To
Cornell University
My Alma Mater
This Book
Is Dedicated

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Chicago

THE BUTTER INDUSTRY

PREPARED FOR THE USE OF

Creameries, Dairy Students and Pure Food Departments

By

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Preface

THE PURPOSE of this book is to acquaint the buttermaker with facts and methods that will assist him in the economical manufacture of butter of attractive flavor, good body, uniform color and superior keeping quality; to place before the teacher and student of buttermaking the newer knowledge of the science and art of butter manufacture; to bring the investigator and research worker in close touch with the real problems of the butter industry; and to point out to those in charge of food control the possibilities and limitations of composition and properties of commercial butter.

This book deals with the several phases of the butter industry, from the care and handling of the milk and cream on the farm to the table of the consumer, with special emphasis of the causes and practical prevention of the multitude of butter defects.

It represents the author's best knowledge on the subject, derived from practical experience in commercial buttermaking, from scientific investigation and research of the problems of economy of manufacture and of production of quality, from the most authentic experimental data of other investigators throughout the dairy world, and from a profound study of the several sciences intimately related to buttermaking.

O. F. HUNZIKER.

Chicago, Feb. 1, 1920.

Acknowledgment

In presenting the information contained in this volume to the Dairy World, the author desires to express his sincere appreciation of the facilities provided and opportunities accorded him by the Blue Valley Creamery Company, which made possible the revelation of new scientific truths of acknowledged value to the butter industry, and which greatly added to the comprehensiveness of this work.

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ERRATA.—Page 301, Footnote, "coal-tar dies" should read "coal-tar dyes." For other typographical errors that may have escaped the proofreader, the reader's kind indulgence is respectfully solicited.

THE BUTTER INDUSTRY

CHAPTER I.

HISTORY AND DEVELOPMENT OF BUTTER INDUSTRY.

Early History.—The art of buttermaking dates back to times immemorial and reference to the use of butter as an article of food and for medical and cosmetic purposes may be found chronicled long before the Christian Era. Benno Martiny,[1] in his treatise "Die Milch" and later in his interesting volume concerning the history of the churn, entitled, "Kirne und Girbe," offers a multitude of quotations on buttermaking by the Ancients as far back as 2000 B. C. He makes reference to the Indians of Asia, the Hebrews, the Arabs, the Egyptians, the Greeks, the Romans, the Teutons, etc., as well as to the history of later centuries.

While the word butter appears in the Scriptures on many occasions and as far back as the book of Genesis 18:8 "And he (Abraham) took butter, and milk and the calf which he had dressed and set it before them" etc., one of the first references to the making of butter is perhaps that by Solomon in Proverbs 30:33, "Surely the churning of milk bringeth forth butter." In the history of Ancient Greece we find that the Greeks knew how to make butter from milk. Herodot and Hippocrates state that the Thracians made butter from cows' milk. Among the Romans who made great strides in agricultural development, cheese appears more popular than butter; however, Plinius refers in several instances to butyrum (butter) as an addition to bread.

The oldest equipment for buttermaking was constructed of earthenware. Originally the milk was placed in earthen vessels and beaten with the hands until the butter granules formed. Later a wooden stirring stick terminating at its lower end in

[1] Benno Martiny, Die Milch, ihr Wesen und ihre Verwertung, Vo. I, 1871.

a butt was used. This arrangement was subsequently changed to a stick carrying a querl consisting of several radial spokes. These were the prototypes of our dash churns in which the dasher terminates in a cross or in a perforated round board or perforated tin cone, fitting closely into the vertical churn. It is evident, therefore, that the two systems of butter-making by stirring or swinging the milk and by beating or dashing it with a dasher, are of very ancient origin.

Concerning the early history of the uses of butter Hayward[1] reports the following:

"In early times butter was employed in many ways. The Hindoos used it for the greatest and holiest sacrifices in their worship. The Greeks and Romans did not use butter as a food, but as the standard remedy for injuries to the skin. The soot of burned butter was regarded as a specific remedy for sore eyes. The Romans also used it as an ointment to enrich the skin and as a dressing for the hair. In the time of Alexander I. certain of the Macedonians annointed themselves with milk oil; and Galen records that in many cold regions people used butter in the bath. Historians speak of butter used as a remedy for wounded elephants, and within a century butter was used in large quantities in Scotland and North England for smearing sheep, also as oil for lamps. Besides being applied externally, it was used internally for various troubles. In Spain, as late as the seventeenth century, butter was to be found in the medicine shops for external use only. In the middle of the previous century "A medicinal and economic treatment of butter" sets forth in detail the value and use of butter as a remedy. In rural districts in Germany at the present time fresh, unsalted butter is much used as a cooling salve for burns.

"Aside from its use as a food, a cosmetic, and a medicine, the use or possession of butter was long regarded as indicating wealth, and so served to distinguish the rich from the common people. Evidences of this still exist. In both Chilas and Darel a practice exists of storing up butter in the ground. Butter so stored is left a number of years, and, to insure its not being

[1] Hayward, Facts Concerning the History, Etc. of Butter, U. S. Dept. Agr., B. A. I. Circular No. 56, 1904.

disturbed, a tree may be planted over it. Under these conditions it turns deep red and is highly prized. The owner's wealth is computed by the quantity of butter he has stored up in this manner.

"Butter was enjoyed as a food by comparatively few people in its early history; those who did so use it seldom ate it fresh. The general practice was to melt it before storing away, and instead of being a spread it was employed to enrich cooked foods. Others, even in comparatively recent times, used the rancid stored butter as an appetizer. In Dardistan peasants are said to highly value salted butter grease that has been kept a long time, and that which is over one hundred years of age is greatly prized.

"Little is known of the part which butter played as an article of commerce in ancient times. However, an early historian states that in the first centuries butter was shipped from India to ports of the Red Sea. In the twelfth century Scandinavian butter was an article of over-sea commerce. The Germans sent ships to Bergen, in Norway, and exchanged their cargoes of wine for butter and dried fish. It is interesting to note that the Scandinavian king considered this practice injurious to his people, and in 1186 compelled the Germans to withdraw their trade. Toward the end of the thirteenth century, among the enumerated wares of commerce imported from thirty-four countries into Belgium, Norway was the only one which included butter. In the fourteenth century butter formed an article of export from Sweden. It may be fairly inferred that butter-making in north and middle Europe, if not indeed in all Europe, was introduced from Scandinavia.

"John Houghton, an Englishman, writing on dairying in 1695, speaks of the Irish as rotting their butter by burying it in bogs. His report was confirmed by the discovery, in 1817 and later, of butter thus buried, packed in firkins. This burying of butter in the peat bogs of Ireland may have been for the purpose of storing against a time of need, or to hide it from invaders, or to ripen it for the purpose of developing flavor in a manner similar to cheese ripening."

Later Development of the Butter Industry.[1]—During the Middle Ages the making and use of butter in the old world gradually increased, but the primitive equipment and methods available and the absence of the helping hand of science precluded rapid strides in the development of this now great industry. At the close of the 18th and beginning of the 19th century, the construction of creaming and buttermaking equipment, other than that made of wood, was beginning to be considered and the barrel churn had made its entrance into the field of buttermaking. And, after the middle of the 19th century, the creaming in ice water or other cold water was strongly advocated.

Up to the middle of the 19th century the factory system of buttermaking was practically unknown and both, in this country and abroad, buttermaking was confined to the farm dairy. From that time on, however, the manner of making butter underwent marked changes, gradually at first, and more rapidly as the advantages of co-operative and community methods of operation became more and more appreciated and the invention of new devices and improved processes were introduced.

In many sections of this country, especially in the Middle West, the "pooling" system of buttermaking became popular. In this system numerous farmers took their milk to a small creamery where it was set in shipping cans, or other deep-setting cans, in cold water and on the following day was skimmed by the operator and made into butter. The returns from the butter, after deducting the cost of making, shipping and selling, were divided among the farmers on the basis of the pounds of milk delivered.

Simultaneous with the advent of this system the gathered cream system also developed and became very popular. The

[1] It is not the purpose of this volume to discuss the history and development of the butter industry in the several butter-producing countries of the world. For detailed historic information the reader is referred to treatise especially devoted to this subject. A very interesting and extensive publication dealing with the world history of Dairying is the publication entitled "Allgemeine Geschichte der Milchwirtschaft, by F. Anderegg, Bern, Switzerland, 1894. The brief references to development of the butter industry given here have for their purpose more especially to point out the leading factors which were instrumental in the direction and extent of development which this important product has attained in the United States, and its possibilities for growth in the future.

farmers skimmed their cream on the farm, usually by the use of shallow pans, but later by setting the milk in deep-setting cans, set in water, and this cream was taken to the creamery.

The Influence of the Centrifugal Cream Separator.—With the advent of the centrifugal separator in the early nineties, originally invented by the German Engineer, Wilhelm Le Feldt, in 1872 and improved and made continuous by the Swedish Engineer, Dr. Gustav De Laval, and others after the year 1878, and first introduced in this country during the years 1885 to 1890, the creameries installed power separators and the creaming on the farm temporarily fell in disfavor. The farmers again hauled their milk to the creamery where it was skimmed by the centrifugal separator and they took back the skimmilk. Many creameries, in order to draw their supply from a larger radius of territory, established skimming stations in various places to which the farmers within hauling distance brought their milk. The milk was skimmed, the cream hauled or shipped to the central creamery and the skimmilk was taken back to the farm. Inasmuch as these skimming stations served exclusively to separate the milk and were not intended for ripening and churning of cream and packing of butter, they required but a small initial investment. Only a small building and only part of the machinery essential for a creamery were needed. The cost of the skimming station was therefore much less than that of a complete creamery. An investment of $250 to $500 for the building and of $600 to $900 for equipment was all that was necessary. Thus the perfection of the centrifugal separator gave birth to the whole milk, creamery system. Under this system the buttermaking industry made rapid progress and the quality of the product showed marked improvement.

In the early nineties of the 19th century the development of the centrifugal separator, first successfully manufactured by Dr. De Laval in 1886, had reached the stage where it could be adapted to practical use on the farm. Dr. De Laval was the first to successfully devise and manufacture hand separators applicable to farm use. Its introduction on the farms was slow at first, but, in the course of a decade, it made rapid progress, especially in the Middle Western States. The advent of the farm separator gradually revolutionized the buttermaking industry.

The farm separator has made it possible for the farmer to skim his milk on the farm efficiently and economically and to ship or haul his cream, instead of his milk, to the creamery.

The dairy farmer readily sees the many advantages and great value of producing and selling cream, over selling milk. The farm separator reduces the volume of his produce, that must be taken care of on the farm and that must be shipped or hauled to the market, to about one-sixth of the volume of the original milk. It means fewer trips to town and less tonnage to the trip, a fact which, especially during the busy season and in the face of the alarming shortage of farm labor constitutes in itself a compelling argument for the farm separator. It means better keeping quality and therefore less difficulty in the care and handling of the product, because for the same reason for which butter keeps better than cream, so does cream keep better than milk. It leaves the farmer in possession of fresh, warm and sweet skimmilk, which he needs for his greatest success in raising his calves, as well as for hog and chicken feeding.

The farm separator is thus rapidly changing the system of selling the product of the dairy cow from a whole-milk business to a cream business and it is transforming the system of creamery operation from the whole-milk creamery of the past to the farm separator creamery of the present and future. This change is taking place throughout the entire dairy belt of the country. Even in the most highly developed dairy sections, the natural home of the whole-milk creamery, the farm separator creamery system is fast replacing the whole-milk creamery system.

But the country's growing demand for butter cannot all be supplied from the limited area of the strict dairy sections where the husbandry of the dairy cow is the principal farming business. Much of the total butter supply of the country must come from the great states and territories where grain-raising is the dominant agricultural pursuit and where the need of the dairy cow for the maintenance of the fertility of the soil is becoming increasingly felt as a dominating factor in the continuance of successful and profitable crop production. Here again the farm separator has come to the rescue. It has enabled the farmer who keeps but a few cows, and who is located in territory with too sparse a cow population, to justify the establishment and operation of local creameries, to find a ready market for his cream by shipping to a distant creamery. And it has thereby produced a vast development of the dairy industry, and a large increase in the annual butter production in the great grain-raising states of the Middle West.

It is the hand separator also that made possible the establishment and operation of the large centralized creameries, which now secure their cream almost entirely from milk separated on the farms and which gather this cream either by means of route wagons, or by the establishment of cream stations to which the farmer himself hauls the cream, or by having it shipped to the creamery by the farmer direct. The rapid development of the creamery business in this country during the last twenty-five years may well be attributed in a large measure to the introduction of the farm separator.

Influence of the Babcock Test.—Aside from the invention of the centrifugal separator the invention and perfection of methods for the rapid and accurate determination of butterfat in milk and cream played a most important role in the development of the butter industry within the last quarter of a century.

With the beginning of the factory system of buttermaking the urgent need of a method to determine the per cent of fat in milk and cream became more and more apparent. in order to enable the factory to pay the farmer on the basis of the butterfat value of his milk or cream. While the chemist was able to accurately estimate the butterfat by the ether fat extraction method, this means was too difficult of operation and too slow of results for use in the creamery. The **creamometer** or **cream gauge,** in which the layer of cream rising on top of the milk was measured, the **churn test,** in which samples of cream from the individual farmers were churned in order to determine the amount of butter that the respective cream would make, and the oil test, in which the butterfat in samples of cream was melted out and measured, were successive steps in the earlier attempts to determine the correct value of the farmers' milk and cream. While they were distinct improvements over the mere weighing and measuring of the cream received, they were slow of operation and often misleading in results and therefore failed to serve as satisfactory methods. Several more or less practical methods devised in Europe did not prove applicable under the American creamery system.

Between the years of 1885 and 1890 chemists at the several American Agricultural Experiment Stations, located within the dairy belt, bent their efforts to devise a method that could be readily used for the rapid and accurate determination of fat in milk and cream. These efforts brought forth several fat tests applicable for the purpose, but the test invented by Dr. S. M. Babcock, Chemist at the Wisconsin Agricultural Experiment Station in 1890, now known as the Babcock test, combining simplicity of apparatus and reagents, practicability of operation by the layman and accuracy of results, is the only method which in this country was adopted for general use. In Europe Dr. N. Gerber, of Switzerland, devised a similar test, the Gerber test, shortly after the introduction of the Babcock test. The Gerber test has never come into general use in this country, but has found wide application in European countries.

The introduction of the Babcock test in American creameries proved of incalculable value to our butter industry, as well as to the dairy industry in general, making it possible for the creamery to pay the farmer on the basis of the butterfat value of his milk and cream, enabling the producer to test the milk of his own cows and thus giving him a practical means to determine the butterfat production of the individual cows in his herd, and assisting the food authorities in protecting the consumer against adulterated milk. Dr. Babcock, with his most valuable invention, has, therefore, been instrumental in placing the dairy industry of this country on a vastly more substantial and permanent basis than it occupied prior to the advent of the Babcock test, lending its development renewed momentum for the inestimable benefit of all branches of the dairy industry and of mankind in general.

Other Inventions Assisting in the Development of the Butter Industry.—The closing years of the nineteenth century and the beginning of this century have witnessed numerous additional inventions and improvements of creamery equipment and methods, which have been of great service to the butter manufacturer.

Some of the more important of these are the introduction of pasteurization and of the use of pure cultures of lactic acid bacteria, first advocated by Storch of Copenhagen, Denmark, and by Weigmann of Kiel, Germany, in 1887, the American invention of combined churns and workers, such as the Disbrow and Simplex in the early nineties, and later the Victor and Perfection and modifications thereof; the invention of artificial refrigeration, improvement of efficient refrigerator service on transportation lines and the rapid development of steam roads and electric interurban lines furnished further important facilities that helped to make possible the rapid growth of the creamery industry.

Cream ripening by the use of pure culture starters of lactic acid bacteria was accepted and taken up rapidly by the American creamerymen, while pasteurization of cream for buttermaking was accepted with considerable reluctance and has become fairly general only within the last decade. Today the great bulk of creamery butter is made from pasteurized cream and in some states legislation has been enacted requiring the pasteurization of all cream for buttermaking.

Influence of Dairy Research, Dairy Instruction and Dairy Control.—In the progress of the butter industry and other lines of dairying the Federal and State Agricultural Experiment Stations, the dairy schools and other educational forces and the law-making and enforcing agencies must be considered as large factors. Much valuable experimental data has been produced in this country and abroad which has greatly assisted the creamerymen in improving their methods, in abandoning faulty processes, in reducing the cost of manufacture, in guarding against costly butter defects and in raising the standard of excellence of the product.

The dairy schools have placed in the field, during the last 25 years, hundreds of trained men annually, whose influence has worked for substantial and permanent improvement of the manufacturing processes and the extension work done by state, government and commercial concerns has been of special service in assisting the producer of cream to produce more economically, to stimulate larger production, and to improve the quality of the raw material.

The organization and activities of local, state, government and international dairy and creamerymen's associations, unions and federations have been important agencies in promoting dairy interest, enthusiasm and progress. They have been instrumental in the formulation and passage of dairy laws fostering the dairy industry, combating disease among dairy stock, prohibiting unsound practices, such as fraudulent testing of milk and cream, damaging schemes of unscrupulous creamery promoters, and adulterations of dairy products, establishing the regulation of transportation rates on milk and cream and controlling creamery competition and the sale of butter substitutes. They have assisted, with competent council, state and government officials in the establishment and enforcement of dairy standards and laws. They have stimulated the consumption of butter and other dairy products by organized campaigns, to acquaint the consuming public with the great food value, unexcelled wholesomeness and true economy of these products as articles of the human diet.

All of these varied agencies of investigation, education and control, which, through liberal state and government subsidies, and through active and generous support of commercial institutions and public-spirited individuals have multiplied speedily, both in numbers and activity, during the last score of years, have served as an additional and mighty impetus in the substantial and rapid development and the permanent prosperity of the butter industry.

Influence of the Creamery Promoter.—Soon after the introduction of the centrifugal separator and up to recent years the creamery industry and with it the entire dairy industry, has suffered great losses and has been delayed in its progress by the activities of the creamery promoter.

Grim monuments to the activities of the creamery promoter, this scavenger of the dairy business, may be found in many parts of the Middle West in the form of defunct creameries. Their history, regardless of location, is much the same, and their careers have had a depressing and retarding influence upon the rational development of the dairy industry. They failed because they lacked the fundamental essentials of the successful creamery.

While organized under the promising name of co-operative creameries, the incentive leading to their creation was not the co-operative spirit of the respective communities, but the greed of unscrupulous promoters, whose alluring promises of exaggerated profits induced dairy communities to buy their ware. In most cases the cow population was entirely inadequate to furnish the necessary raw material to make possible profitable operation, the necessary operating capital was lacking, incompetent buttermakers made an inferior product, inexperienced managers mismanaged the business, the frail tie of co-operation between the stockholders was easily rent by unsatisfactory returns from the market, and the inevitable result was disorganization, dissolution and failure. In a few isolated cases only have these creameries survived these discouraging handicaps, largely on account of exceptionally favorable local conditions, or of the individual and unselfish effort and ability of some one person strong enough to safely guide the ship through the turbulent waters into which the creamery was launched. In some cases these creameries passed into private hands at a great sacrifice to the stockholders. In the great majority of cases, however, the promoters' creameries succumbed, after incurring additional debts, to the natural consequences of the law of the survival of the fittest.

These defunct creameries may be counted by hundreds. They have impoverished the communities in which they are located, they have caused their stockholders the loss of thousands of dollars, they have cast distrust and suspicion on the creamery business and discouraged the business of milking cows and selling cream for buttermaking. They should serve as a warning to all communities contemplating the organization of co-operative creameries and entertaining negotiations with creamery promoters. Fortunately, through the efforts of the United States Dairy Division, the dairy departments and dairy commissioners of many states, the country has been largely cleared of the creamery promoter. Only in isolated cases, do we now hear of his activities and in such cases every effort is made by dairy officials to inform prospective communities of the risk of their contemplated enterprise.

Annual Butter Production in the United States.

Government statistics show that since 1850 there has been a steady and continuous increase in the annual butter output in the United States. From 313,345,506 pounds in 1850 the butter produced in this country increased to 1,619,415,263 pounds in 1910. Up to 1870, when the total butter output amounted to 514,092,683 pounds, practically all the butter was produced on the farm. From that time on the factory system of buttermaking started its development and in 1910 only about 60 per cent of the total butter output was made on the farm. Since 1910 the production of butter has shifted still more rapidly from the farm to the factory. This change has been especially pronounced where the cow population is dense and where the dairy industry is most intensive, but of late years, even in states with a comparatively sparse cow population and where dairying is still in its infancy, owing to the ready markets for cream offered by the large centralized creameries and because of the vastly improved transportation facilities, factory buttermaking has been greatly stimulated, vast quantities of cream are daily shipped from the widely scattered farms to these creameries, causing a gradual abandonment of buttermaking on the farm for commercial purposes and confining farm buttermaking largely to the butter needed for private and neighborhood consumption.

Table 1.[1]—Population, Improved Land, Dairy Cows, and Production of Butter and Cheese, by Geographic Divisions for 1870, 1880, 1890, 1900, and 1910.

Year and geographic division.[1]	Population.	Number of dairy cows.	Improved land.	Production for calendar year preceding date of census. Butter.	Cheese.
1910.			Acres.	Pounds.	Pounds.
New England	6,552,681	841,698	7,254,904	68,699,379	3,676,609
Middle Atlantic	19,315,892	2,597,652	29,320,894	165,392,518	118,339,484
East North Central	18,250,621	4,829,527	88,947,228	424,137,997	180,423,449
West North Central	11,637,921	5,327,606	164,284,862	444,724,204	5,286,968
South Atlantic	12,194,895	1,810,754	48,479,733	125,256,293	514,137
East South Central	8,409,901	1,628,061	43,946,846	136,791,873	93,971
West South Central	8,784,534	2,249,553	58,264,273	134,876,201	441,697
Mountain	2,633,517	514,466	15,915,002	34,756,687	2,546,935
Pacific	4,192,304	826,115	22,038,008	84,780,111	9,208,931
Total, United States	91,972,266	20,625,432	478,451,750	1,619,415,263	320,532,181
1900.					
New England	5,592,017	893,478	8,134,403	92,032,196	6,958,700
Middle Atlantic	15,454,678	2,602,788	30,786,211	233,986,350	141,259,571
East North Central	15,985,581	3,962,481	86,670,271	403,208,930	120,279,089
West North Central	10,347,423	4,527,803	135,643,828	407,632,767	13,667,004
South Atlantic	10,443,480	1,383,319	46,100,226	92,883,312	593,308
East South Central	7,547,757	1,264,282	40,237,337	97,999,645	181,528
West South Central	6,532,290	1,634,954	39,770,530	88,856,542	473,381
Mountain	1,674,657	329,604	8,402,576	20,499,029	4,709,314
Pacific	2,416,692	536,924	18,753,105	54,653,831	10,222,744
Total, United States	75,994,575	17,135,633	414,498,487	1,491,752,602	298,344,639
1890.					
New England	4,700,749	822,001	10,738,930	77,240,024	9,107,032
Middle Atlantic	12,706,220	2,529,060	31,599,094	217,793,692	130,131,662
East North Central	13,478,305	3,752,237	78,774,647	327,051,265	93,779,808
West North Central	8,932,112	4,488,762	105,517,479	323,491,323	16,446,053
South Atlantic	8,857,922	1,369,466	41,677,371	80,401,070	415,291
East South Central	6,429,154	1,312,074	35,729,170	84,955,855	177,070
West South Central	4,740,983	1,517,583	30,559,654	50,347,087	172,597
Mountain	1,213,935	218,689	5,460,739	8,709,349	739,976
Pacific	1,888,334	502,078	17,559,671	35,456,941	5,779,894
Total, United States	62,947,714	16,511,950	357,616,755	1,205,446,606	256,749,383
1880.					
New England	4,010,529	746,656	13,148,466	65,934,782	12,202,042
Middle Atlantic	10,496,878	2,444,089	33,237,166	211,073,290	138,700,187
East North Central	11,206,668	2,990,852	75,589,373	240,351,236	78,950,611
West North Central	6,157,443	2,411,229	61,252,946	143,103,863	7,581,959
South Atlantic	7,597,197	1,280,761	36,170,331	48,703,330	640,065
East South Central	5,585,151	1,145,403	30,820,882	51,603,349	184,538
West South Central	3,334,220	1,002,037	18,985,889	22,605,422	92,385
Mountain	653,119	124,844	2,213,300	3,205,759	606,392
Pacific	1,114,578	297,249	13,352,689	20,091,040	4,199,671
Total, United States	50,155,783	12,443,120	284,771,042	806,672,071	243,157,850
1870.					
New England	3,487,924	642,593	11,997,540	49,662,325	16,316,016
Middle Atlantic	8,810,806	2,190,429	29,119,645	176,248,193	104,047,024
East North Central	9,124,517	2,247,683	54,899,646	156,138,383	35,889,749
West North Central	3,856,594	1,046,324	23,509,863	58,262,042	2,151,998
South Atlantic	5,853,610	1,001,094	30,202,991	28,575,306	252,190
East South Central	4,404,445	835,351	24,218,478	27,273,321	509,290
West South Central	2,029,965	659,083	6,870,297	6,789,083	48,208
Mountain	315,385	83,419	576,200	1,348,607	181,035
Pacific	675,125	229,356	7,526,439	9,795,423	3,531,872
Total, United States	38,558,371	8,935,332	188,921,099	514,092,683	162,927,382

[1] U. S. Dept. of Agriculture, Bureau of Crop Estimates, Bulletin 177, 1915.

Table 1 shows the annual production of butter and cheese, by decades from 1870 to 1910, in the several divisions of the country, as compared with the population, dairy cows and improved acres of land. It emphasizes the fact that the butter industry is by far the most important branch of the manufacture of dairy products in America. Its annual output is about 5 times greater than the output of cheese and its value nearly 10 times the value of the annual cheese output as based on the relative butter and cheese prices in normal times.

It is further interesting to note that while the increase in annual butter production in the United States from 1870 to 1910, amounted to over 300 per cent, the increase in the annual cheese production for the same period was less than 200 per cent, and the increase in population, number of dairy cows and acres of improved land was approximately 238, 231 and 253 per cent, respectively.

During the last decade or more, the center of the butter industry has shown a distinct and continuous movement westward. In the New England and Middle Atlantic States it has gradually declined, while in the central, northern, western and southern states it has increased rapidly. This decline in the East has been due largely to the wide-spread tendency of the energetic eastern farmer to migrate westward in pursuit of greater opportunities, with the resulting decline of the acres of improved land in the East; the rapid increase in the demand for market milk by the growth of the population in the Eastern industrial and trade centers, thus absorbing a large proportion of the raw material, milk and cream, that formerly was made into butter; and the difference in cost of production and manufacture in favor of the western farmer and creamery who can lay down in New England his more staple dairy products, such as butter and cheese, at lower prices than the New England dairyman can produce them.

Number of Creameries in the United States.

According to statistics furnished by the United States Dairy Division there were in operation in the year 1914 5,463 creameries in the United States. These creameries are distributed over the several states as shown in Table 2.

Table 2.—Distribution of Creameries by States in 1914.[1]

Alabama	3	Nebraska	52
Arkansas	4	Nevada	6
Arizona	2	New Hampshire	27
California	152	New Jersey	13
Colorado	41	New Mexico	7
Connecticut	29	New York	576
Delaware	8	North Carolina	5
District of Columbia	1	North Dakota	67
Georgia	1	Ohio	307
Idaho	18	Oklahoma	25
Illinois	216	Oregon	99
Indiana	111	Pennsylvania	445
Iowa	562	Rhode Island	1
Kansas	43	South Carolina	1
Kentucky	5	South Dakota	99
Louisiana	3	Tennessee	9
Maine	26	Texas	95
Maryland	43	Utah	38
Massachusetts	19	Vermont	181
Michigan	273	Virginia	12
Minnesota	848	Washington	96
Mississippi	2	West Virginia	6
Missouri	39	Wisconsin	812
Montana	25	Wyoming	10
Total			5463

The great majority of the creameries in New York, Pennsylvania, Michigan, Ohio, Wisconsin, Minnesota and Iowa are co-operative creameries, while in the Central West and in some of the far western states proprietary creameries and centralized creameries predominate.

[1] By Courtesy of U. S. Dairy Division, U. S. Department of Agriculture.

Table 3.—Production of Butter in Various Countries for the Years Indicated. (From Official Reports, Year Books, Statistical Reports and Consular Reports.)†

Country	Annual butter production			
	1910	1912	1913	1914
	Lbs.	Lbs.	Lbs.	Lbs.
Argentina	16,617,131	20,849,689	22,482,506	....
Australia	193,211,909	187,194,161	....	....
Canada	201,275,297 [2]	....	....	....
Chile	2,564,993	2,767,655	....	1,924,102
Denmark (1905)	209,152,606**	....	....	257,484,052**
Finland	26,226,200**	....	....	....
France (1892).	291,057,156	....	....	....
Netherlands ..	142,430,388	148,166,757	....	222,002,266
Norway	8,174,657	....	....	....
New Zealand..	55,107,360**	58,629,760**	....	70,504,000**
Russia*	275,286,240	306,414,650	326,253,150	....
Sweden	72,616,750	....	....	....
United Kingdom (1905).	359,631,000 [1]	....	....	....
United States.	1,621,796,475 [2]	....	....	786,003,489***
Union of So. Africa	....	....	10,741,000	10,682,000
Italy	....	....	....	112,000,000

Country	1916	1918
	Lbs.	Lbs.
Australia	182,470,778	....
Canada	82,564,130**	(1917) 87,404,366**
Denmark	....	114,400,000**
New Zealand ...	....	(1917-18) 47,494,720 (Consul report)
United States ...	760,030,573**	775000,000**

* Russia including Siberia. ** Butter made only in factories.
*** Bureau of Market reports for factories only.
[1] Estimate of Royal Committee on "Report in Case of War."
[2] Latent census figures which include the "farm" production.
† Courtesy of U. S. Dairy Division. Feb. 18, 1919.

CHAPTER II.

CREAMERY ORGANIZATIONS, CONSTRUCTION AND EQUIPMENT.

Creamery Organizations.—Buttermaking started at the "hub" of the dairy business, the dairy farm, in the days when industrial development was in its infancy and when the farm was not only the source of raw materials, but converted many of its raw materials into finished products of commerce.

The invention and adoption for industrial uses, of power machinery, in the 19th century, made possible economic handling of larger volumes of milk and cream and the manufacture of larger quantities of butter than the product on a single farm represented. The rapidly growing population in our towns and cities demanded larger amounts of butter to be transported to greater distances, than the neighborhood farm supply was capable of adequately taking care of. The butter began to be exposed to more unfavorable conditions, and more time elapsed in its movement from the churn to the table of the consumer, so that the matter of keeping quality required more specialized skill and more elaborate equipment than was available on the general dairy farm. The trend of industrial development and profitable manufacture demanded greater division of labor and occupation, specialization, and centralization of effort. Business enterprise and ingenuity and able financing saw inviting opportunities and unlimited possibilities in butter manufacture on a larger scale.

These and many other results of the economic and industrial evolution of the country were responsible for the gradual development of the factory system of buttermaking, which started after the middle of the last century, and which gave birth to diverse forms of creamery organizations, until today over one half of the butter manufactured in this country is made in creameries, and practically all of the butter that enters interstate commerce and that supplies our large markets is creamery butter. The butter that is still made on the farm is largely confined to that which is consumed on the farm, and by the country store trade.

There are principally four different types of creamery organizations, namely, the mutual co-operative creamery, the joint stock company with co-operative features, the proprietary factory and the creamery corporation.

The Mutual Co-operative Creamery Association.—This is strictly a farmers' co-operative association. Its purpose is to pool the milk or cream of the individual members, the farmers, to manufacture it into butter and to sell the product, by the employment of a butter maker and manager, and in this manner to save equipment and labor needed for manufacture and sale of the product, to secure greater skill for manufacture, to make a better product and to sell it to better advantage.

In the truly mutual co-operative creamery association, every stock holder must be a milk or cream producer, he must be a patron of the creamery, but not every patron need be a stock holder.

In some cases the buttermaker is employed at a stipulated salary, in others the association agrees to pay him a stipulated commission for every pound of butter manufactured, such as, for instance, three cents per pound.

The mutual co-operative creamery association has for its object, not so much the payment of large dividends on the shares of stock, but to profitably manufacture the milk and cream into butter, i. e. to secure the highest possible net returns for the butterfat manufactured into butter.

The amount of money needed and decided upon for building and equipment usually governs the amount of the capital stock to be issued. The shares of stock usually range from $10.00 to $100.00 per share. As it is desirable to have as many patrons as possible that are also stock holders and who are, therefore, interested financially in the creamery, shares of small denominations have their advantage.

The net returns from the business, which represents what is left after deducting from the gross receipts accruing from the sale of butter and other products, all expenses of manufacture, such as labor, supplies, coal, ice, taxes, and insurance, and sales expenses, and after deducting a fixed amount placed in the sinking fund, which is needed to take care of current repairs, etc., and paying a nominal dividend on the shares of stock, as stipulated in the articles of incorporation, may be prorated among all patrons on the basis of the pounds of butterfat each patron delivered at the factory.

Or, the board of directors may pay for the milk and cream on the basis of some market quotation, and after deducting the milk and cream checks and other expenses above enumerated from the gross returns, it may then prorate dividends to all patrons on the basis of the amount of butterfat sold to the factory.

The mutual co-operative creamery association has been a very successful institution, in localities where the cow population is dense and where the farmers are imbued with the co-operative spirit. It has stimulated milk production by making it more profitable, the co-operative service of the association has often extended its useful offices beyond the making and selling of butter, to the co-operative buying of feed, farm supplies and machinery, and it has stimulated community interest and general rural uplift.

This form of creamery is not so well suited, however, in localities where the co-operative spirit is lacking and where the dairy herds are small, few and far between.

The Joint Stock Company with Co-operative Features.— Many, if not most of the so-called co-operative creameries are not purely mutual co-operative creamery associations, but they are joint stock companies with some co-operative features. To this type of creamery companies also belong the promoters' creameries. The joint stock company with co-operative features differs from the mutual co-operative association largely on the following points:

1. A stock holder need not be a patron of the creamery.
2. The capital stock is divided into equal shares.
3. The members of the association usually cast one vote for each share of stock held.

While it is usually intended to have the patrons own the major portion of the stock, so as to have a large number of active patrons financially interested in the creamery, and to thereby make more sure of a constant supply of milk and cream, such is, in fact, very often not the case. Much of the stock is often held by townspeople and others who do not keep cows. This fact has in many cases proven to be a contributing factor, responsible for the failure of the creamery. It has constituted one of the weak links in the fabric of the promoters' creamery, the establishment of which not infrequently was made possible in localities which lacked the fundamentals of successful operation—sufficient cows and farmers imbued with the spirit of co-operation—because a sufficient amount of stock could be sold to persons other than milk producers.

The fitness of a locality for the successful operation of a joint stock company with co-operative features depends on similar conditions as that of the mutual co-operative creamery association.

The Proprietary Creamery.—This form of creamery organization refers to an enterprise owned or operated, or both, by an individual or by several individuals who have formed a partnership. In this case the owner, or owners, usually buy the milk and cream outright at prices generally based on some market quotation, as New York, Chicago, Elgin, San Francisco quotations, and the prices offered are influenced also by competition with other creameries.

The patrons' responsibility and interest in the enterprise are confined to the sale of their milk and cream to the creamery and ceases with the delivery or shipment of the milk or cream and receipt of the creamery's payment for the same on the basis of its own quotation.

The profits and losses on the manufacture and sale of the butter are borne by the creamery, and, in the case of partnership, are shared according to the amount of money invested by each partner.

The proprietary creamery obviously does not depend on the co-operative spirit of the farming community. Its volume is largely a matter of price offered, intensity of competition, cow population, salesmanship, and financial backing. It is in the business to make profit from the investment of capital and its legitimate transactions are unhampered by association articles and by-laws.

Partnership creameries have the disadvantage of all partnership enterprises. Each partner of a firm is individually liable for all debts of the firm, contracted either with, or without his consent.

Creamery Corporations.—The creamery corporation is a joint stock company without co-operative features. It differs from the proprietary creamery in that it is an incorporated organization, hence each stock holder is liable only to the extent of the amount of the money he invested. This limited liability feature of the joint stock company is attractive to investors and renders this type of creamery organization popular. Its relation to the milk and cream producer is similar to that of the proprietary creamery.

Its unlimited possibilities have attracted and invited men of business enterprise and of capital into the creamery business in all parts of the country, and especially into the great stock-raising and grain-growing sections of the Middle West and Far West, where the cow population is not dense enough to make possible the successful operation of co-operative creameries.

This type of creamery organization has lent itself admirably to the establishment and operation of large centralized creameries, who draw their supply of raw material from a vast area. It is furnishing a ready and profitable market for the product of the general farmer who has but a few cows and with whom dairying is a side line rather than the main business. It has opened up, and is developing the husbandry of the dairy cow, in sections where dairying was formerly thought unprofitable, and it thereby has become a mighty factor, not only in increased milk and butter production, but in the re-stocking of the land, improving the fertility of the soil, making farming more profitable, furnishing the means for better education of the farmer's sons and daughters, and dignifying the profession of agricultural pursuits.

CONSTRUCTION OF CREAMERIES

It is not the purpose of this volume to enter into detailed discussion and to give specifications for the construction of creameries. In the case of creameries of limited capacity, such as co-operative creameries, and small proprietary factories, such specifications and plans may be secured gratis upon request from the respective State Dairy Departments, many of whom have published bulletins containing this information in readily available and applicable form. [1], [2], [3]. In the case of creameries intended to do a very large volume of business, the factor of personal ideas and preference on the part of the investor, combined with specialized talent usually employed by him, renders directions in a treatise of this type of little value. This discussion on creamery construction will, therefore, logically be confined to a few general suggestions that may be of value.

Location of Factory: Proximity to cream supply, transportation and marketing facilities.—The small local creamery that depends for its main supply of milk or cream on a very limited localized territory must obviously be located as near that supply as possible. A large centralized plant, whose supply territory covers a wide area, and that receives the great bulk of its raw material by rail, is compelled to give first consideration to suitable railway or other natural transportation facilities, and to close proximity to large consuming centers for the ready marketing of its product.

Water Supply.—The water supply is a most important factor which should be definitely ascertained in the consideration of a suitable site. The creamery, large or small, needs a plentiful supply of clean, pure water, free from pollution with organic matter, and objectionable minerals such as iron and sulphur.

Sewerage Disposal.—The satisfactory disposal of the cream-

[1] Mortenson, and Davidson, Creamery Organization and Construction, Iowa Bulletin 139, 1913.

[2] Farrington and Benkendorf, Organization and Construction of Creameries and Cheese Factories, Wisconsin Bulletin 244, 1915.

[3] Durand and Robotka, Cooperative Creameries and Cheese Factories in Minnesota, Bulletin 166, 1917.

ery waste is exceedingly important. Unless this is provided for by the municipal sewerage system, or a creek or river with running water throughout the year, the creamery is compelled to resort to artificial sewerage disposal in the form of septic tanks, or other contrivances. This is expensive and seldom entirely satisfactory. It is inadvisable to locate the creamery in a place that lacks either natural or municipal facilities for the proper disposal of its waste.

Even in case the creamery is fortunate enough to be able to connect with the town or city sewer, it may be necessary to install a sediment tank or separating cistern, in order to prevent the rapid coating and clogging of the municipal sewer line, whereby the creamery is liable to forfeit its privilege to use the town sewer.

Type of Building.—For small local creameries a one story building is usually the most suitable. For larger plants, the one story building of convenient dimensions generally does not provide for enough storage room to carry the needed stock of supplies. A two-story structure for creameries of over a 500,000 lbs. butter output per year, appears most suitable and most economical. Where it is desired to establish the gravity plan of arrangement and operation throughout the plant it may be advantageous to use a separate story or floor for each department, starting at the top with the receiving and "dumping" department, using the next lower floor for neutralization and pasteurization, the next for holding the cream in the vats before churning and the last and lowest floor for churning.

Material for Construction.—The foundation and floor can only be satisfactory when constructed of substantial, non-rotting material. The material for the superstructure is best chosen according to availability and financial ability. A creamery can be made sanitary without going to the extravagance of costly construction. Show creameries, involving large investment, are often not profitable creameries, nor do they necessarily symbolize superior quality of product. For a small creamery with limited capital a wooden superstructure may be entirely serviceable. If ceiled and plastered on the inside that much the better. For more durable construction, brick, concrete, stone, steel-concrete, etc., according to availability, financial ability and general preference may be used.

Floors.—All floors in the operating rooms should be of concrete with cement surfacing, or similar non-rottable, impervious material. The application of a reliable concrete hardener will greatly help to make the cement more nearly wear-, water-, dust- and crack-proof. On the receiving floor, or platform, where the cream cans are handled, inlaid steel plates, materially protect the floor against excessive wear.

After finishing, the floors should not be used for at least two weeks. This will permit them to thoroughly harden, a condition which means a great deal to the life and serviceability of any cement floor. The short life of the majority of unsatisfactory cement floors in creameries is due to the fact that they were pressed into service before the cement had properly hardened.

The cement should be carried up on the walls and partitions at least two inches or more, forming a sanitary cove. In the case of wooden walls and partitions, it is advisable to lath and plaster the bottom four to five feet.

The floors should slope not less than one eighth of one inch per foot. The slope should be uniform and even throughout, avoiding low places.

Drainage and Drains.—All floors of the manufacturing rooms should slope downward toward the drains, so as to facilitate rapid and complete drainage. Large, water-sealed floor drains should be sufficiently numerous and well placed in all rooms to rapidly carry off the water. The tops of these floor drains should be about one-half inch below the surface of the adjoining floor, so as to catch the water readily. This feature must be personally supervised by the creamery man, as the average contractor is prone to place the drain top a trifle above the surrounding floor, expecting the water to flow "up hill". In the larger rooms and especially immediately under, or behind the churns, one or more open drain ditches in the floor, six to ten inches wide, with their outlet to the sewer trapped, by a large bell-trap or other equally efficient water-sealed drain, is preferable. These drain ditches may be placed along the walls, or platform, or both, in order to least interfere with traffic. If located in places over which there is much traffic they are best covered by heavy, perforated iron plates. These ditches should have a slope of at least one-eighth inch per foot, their depth must necessarily depend somewhat on their length and the depth of the main sewer pipe into which they discharge. It is not advisable to have these ditches more than about 40 feet apart, for rapid drainage of the floor.

The main sewer pipe, catching the drain discharges, should be of large capacity, not less than six inches in diameter for a small creamery and eight to twelve inches for a creamery manufacturing over 500,000 pounds of butter. Where the creamery waste is disposed of through the municipal sewer, there should be installed between the drain and the sewer pipe, outside of the factory, a catch basin, or sediment tank. This is a tight cistern through which all the creamery sewerage must pass and in which the curdy material is given an opportunity to separate out and rise to the surface, forming a dense layer. This curdy material, if allowed to pass off into the municipal sewer, is prone to coat and ultimately clog the town sewer pipe. This is especially prone to happen, where the town sewer line has relatively little fall. This catch basin must be cleaned out, removing the accumulated curdy scum, at reasonable intervals.

In order for this cistern to operate efficiently, it should be large enough to hold the waste of at least one day's run. Its intake from the creamery should terminate above the surface of the accumulating scum in the cistern, and its outlet should extend to near the bottom of the cistern. This arrangement will prevent the outlet from becoming plugged up with scum. The chief solid matter in creamery sewerage floats on the surface. There is very little sediment deposited at the bottom.

Light.—It is advisable to install a reasonable number of properly screened windows, so as to enable the operation of the plant without artificial light, especially in winter, late fall and early spring.

The sanitary value of natural light in the creamery has been, in the past, greatly exaggerated and over-estimated, especially by the average sanitary inspector. The tendency has been toward a hysterical eulogy of the purifying action of the direct rays of the sun. The fact is that even in creameries with a great abundance of windows, direct sun rays do not gain access to the interior very often, and when they do, the windows are usually purposely shaded to keep them out. Excessive exposure of milk, cream and butter to sunlight invites rapid oxidation, and deterioration of the product.

From the sanitary standpoint excessive light is objectionable, because of the difficulty and practical impossibility by any now known and really practicable means of effectively controlling the fly pest in summer. The flies gather where there is light, they shun the dark.

In creameries, the operating rooms of which are not located at a sufficient elevation above ground to place them above the fly-line, which is the case with most creameries, the sanitary condition will average far superior in the absence of natural light. The light attracts the flies, and the pollution of the product in a fly-infested creamery is far more objectionable, more detrimental to quality and more dangerous to health, than the absence of sunlight.

Creameries that have made a real study of fly control, have found and have conclusively demonstrated by practical performance, that the most successful way of keeping their plants free from flies in summer, is to darken the factory, shutting out all direct natural light and operating under diffused or artificial light.

In one story buildings, a well-built skylight, with windows so hung and equipped as to enable the use of the skylight also for ventilating purposes, generally proves a satisfactory arrangement of windows. The skylight has the additional advantage of attracting the flies to the ceiling and keeping them away from equipment and product.

Under any circumstances it is advisable to provide for a satisfactory system of artificial lights for operation when natural light is either not available or not desired.

Ventilation.—A proper and efficient system of ventilation is a very important phase of creamery construction, and sanitary and economical operation. This applies to all parts of the factory where work is being done, and it is especially essential in rooms where much free steam escapes.

The ventilating system should be adequate to afford ready and quick removal of free steam, to efficiently expel foul air, and to facilitate the regulation of temperature. Unless the masses of free steam which befog the atmosphere daily in every creamery, find a ready exit, and are expelled from the factory quickly, they will condense, and cause the walls and ceiling to sweat and drip and rot or corrode, the motors, belts and other equipment to deteriorate, and mold growth to develop on walls and ceilings and supplies. This is especially the case during the winter months. The removal of foul air and the control of the temperature of the air are essential for the comfort, health and maximum efficiency of the employees and for the protection of the product against deteriorating contamination.

The system of ventilation best suited to accomplish this must of necessity vary with the location, type and size of the building and the arrangement of the machinery. In the small, one-story building, with a high roof, a well-made sky-light with a steep slope of the side roofs, toward the sky-light, may prove fairly efficient, especially where an effort is made to place the equipment that gives off the free steam as directly under the sky-light ventilator as possible.

In large creameries with more than one story the sky-light system is seldom feasible. Nor is gravity ventilation, under average conditions, adequate to produce satisfactory results, in creameries where there is bound to be much escape of free steam. In gravity ventilation, the circulation and exchange of air depends exclusively on the difference in temperature between the atmosphere on the inside and outside of the creamery. This fails to produce a sufficiently rapid exchange of air to remove the free steam before it condenses, especially in cold weather.

It is necessary, therefore, to provide for some form of forced ventilation. Under certain conditions the use of the chimney may furnish the needed draft. In this case an outer chimney is built around the smoke stack proper, with an air space between the two stacks, and one or more ventilating flues installed in the creamery and terminating in the jacket between the two chimney shafts, provides the exit for the air in the creamery.

Under many other conditions, however, it becomes necessary to hood that equipment, from which free steam escapes in large volume, such as can washer and steamer, forewarmer, pasteurizer, etc. and to have these hoods connected with flues that are equipped with mechanical fans, preferably of the squirrel-cage type, which expel the air and steam mechanically through the wall or roof of the building.

Hoods without forced draft connections are usually not efficient and prove unsanitary. The steam escaping from the heated cream is always more or less charged with free acids which condense on the sides of the hood and soon render it foul and unsanitary. The forced draft produced by a mechanical fan expels the steam so rapidly that the volatile acids escape to the outside before they have a chance to condense. For satisfactory operation the hood should have as steep a slope as possible, at least 45 degrees, otherwise the friction on the hood retards the escape of the steam too much. The bottom of the hood should terminate in a channel and drip, to collect any condensation that may return from the flue.

Ventilating shafts terminating at their upper extremity in a pent house which is equipped with a fan are very serviceable, provided that the motor which drives the fan is properly protected against the hot steam and free acids that escape, or that the motor is located outside of the penthouse.

In rooms not infested with free steam, but where many people are at work, such as may be the case in the print room, gravity ventilation, usually proves adequate. In the absence of a satisfactory gravity system with air shafts for the automatic intake of fresh air and exit for foul air, the installation of a mechanical fan in the wall or ceiling is recommended.

The Store Room.—A spacious store room should be provided, so as to enable the creamery to carry a plentiful stock of supplies, package, and cans. The size of the store room should offer no obstacle to the creamery's ability to take advantage of rebates and bargains, by purchasing in quantities.

In the case of the one story factory there is seldom enough room provided for a spacious store room and it may be advantageous in such cases to erect or rent the use of a suitable shed, with rain-proof roof, in convenient proximity to the factory. In the case of the two or more story creamery, the second, or upper floor, generally serves as the store or stock room.

The store room should be so located and constructed that it can readily be kept clean and dry. A damp storage room harbors dangers that may prove most disastrous to the creamery. It invites mold growth on tubs, liners, wrappers and other packing material and contributes to the rusting of the cans in stock.

If located on the first floor, as a part of the factory, it should be protected against free steam, and leaky pipes. If a shed is used, the floor should be sufficiently elevated above ground to avoid dampness from below, and the sides and roof should be rain-proof. If located on the second floor above the factory, every effort should be made to keep it closed against the moisture-saturated air in the factory. The elevator shaft should be housed in and the housing should be equipped with self-closing doors in the factory and in the store room. If a portion of the store room is located over the boiler room, care should be taken that the blow-off and pop-off valves discharge, not over the boiler, but through the walls to outside of the room. The store room located over the factory is bound to be penetrated by the factory air to some extent, even in spite of all these precautions. If this store room represents the top floor and the roof is not insulated, this air will condense on the underside of the cold roof in winter, resulting in dampness and dripping, to the serious detriment of the stock stored on this floor. The only permanently satisfactory means of avoiding this dampness is to seal the roof on the under side, either with matched lumber or with some prepared insulation material.

Cold Room.—One or more cold rooms of suitable size, according to the capacity of the creamery, is a necessary feature. Where butter is printed with the Friday printer, or other similar printing equipment, the butter must have a chance to harden, so it can be cut into square-cornered, sharp-edged bricks. This requires storing in a room at a reasonably low temperature. Most churnings of butter, especially during the busy season of the year, must be held for several days before shipment can be made. This holding must be done in a cool or cold atmosphere in order to retard deterioration.

The cold room must be properly insulated, preferably with cork board or similar efficient insulating material, at the bottom under the concrete floor, at the sides and in the ceiling. The floors, walls and ceilings, doors and windows, besides being insulated, must be tight. A poorly insulated cold room, of loose construction and ill-fitting doors, wastes cold and fails to adequately protect the butter.

The cold room must be dry. A damp or wet cold room is a prolific breeding place for molds. In order to insure freedom from dampness, the drips from the melting ice or from the sweating brine pipes, or ammonia coils, must be carried off without leakage, and such circulation of air must be provided as will cause the moisture in the air to condense over the ice or cooling coils.

For this purpose, the ice rack or the cooling coil rack must be located over a water-tight pan which discharges the drips into a suitable receptacle or to the outside of the cold room.

Proper circulation of the air is provided by equipping one side of the ice rack or cooling coil rack with a baffle board that extends from the drip pan to within a short distance from the ceiling. The warm air, which is charged with moisture is lighter than the cold air. The warm air rises to the top of the baffle board and passes over the ice or cooling coils where it condenses its moisture, and the cooled dry air drops down into the cold room from the other side of the drip pan where there is no baffle board. This produces a constant and efficient circulation of the air in the cold room, removing the moist air and replacing it by dry air.

Bath Room.—Every up-to-date creamery should have suitable and adequate toilet and bath room facilities. The necessity of this essential is self-evident.

Heating.—Suitable arrangements should be provided to control the temperature in the factory. In localities with cold winters the heating is usually best done by the use of exhaust steam. Where the machinery is driven by electric power and no steam driven pumps are in operation, and there is therefore no exhaust steam available, a low pressure steam line may be run direct from the boiler to the radiators. It is not advisable to place steam pipes or any other pipe lines in the concrete floor for obvious reasons.

Insulation of Ammonia, Brine Steam and Water Lines.—The matter of insulation of ammonia, brine, steam and water pipes is an important item as related to the economy of fuel. For proper and economical insulation the following types of pipe covering are recommended:

Ammonia and Brine Lines.—

1st layer of tarred felt.

2nd layer of 1″ thick hair felt.

3rd layer of tarred felt.

4th layer of 1″ thick hair felt.

5th layer of tarred felt.

6th layer of wove-felt paper.

7th layer of 8-oz. canvas jacket, sewed on.

8th layer of sizing and one coat of lead and oil paint.

Each layer of hair felt must be securely wound with twine. Each layer of all material should be coated with hot asphalt, applied while hot, excepting layers, 6, 7 and 8.

Special seals must be made at all flanges and fittings, and such flanges and fittings must be insulated independently. This arrangement will prevent damage to adjoining coverings, should fittings spring leaks.

Before applying pitch or asphalt, the necessary precautions must be taken to have the pipes thoroughly dry and the asphalt or pitch must be hot.

Steam Lines.—Air cell asbestos covering, or covering of equal insulating and lasting quality, one inch thick on pipes, and fittings to be built up of asbestos cement to a corresponding thickness; smoothly finished and neatly canvassed, with metal bands at 18″ intervals. Before putting on the metal bands the covering should receive two coats of asbestos cold water paint.

Cold Water Lines.—Covering of wool felt, tar paper lined, sectional, one inch thick on pipes; fittings to be built up to a corresponding thickness with one inch hair felt, the entire line should be neatly finished with a graded mixture of Portland cement and asbestos cement, and canvas-jacketed and equipped with metal bands at 18″ intervals. Before putting on the metal bands, the covering should receive two coats of asbestos cold water paint.

CHAPTER III.

BUYING MILK AND CREAM.

Systems of Securing Milk and Cream.—The economy of the manufacture and sale of butter is greatly dependent on the volume of business done and this in turn is controlled by the amount of butterfat the creamery receives. The creamery must have butterfat to manufacture butter, and the larger the supply of butterfat, other conditions being equal, the more profitable will be its business. Local conditions, the increasing demand for butterfat by manufacturers and dealers of diverse dairy products, and the growing keenness of competition among the creameries for milk and cream, have gradually developed four distinct systems of securing the butterfat from the farmer. These are direct deliveries of milk and cream, milk and cream routes, skimming stations and cream stations, and the direct shipper system.

Direct Deliveries of Milk and Cream.—In this system the milk or cream is hauled by the farmer direct to the creamery. This is the oldest system of getting the butterfat to the creamery. This is the system that first marked the inovation of making butter in the factory instead of on the farm. It started by having the farmers haul their milk to the creamery where it was pooled and separated by gravity. Simultaneously, also, the practise of skimming the milk on the farm by gravity and the hauling of the cream developed. When the centrifugal cream separator for factory use appeared, the skimming on the farm was largely abandoned and the farmer hauled his milk to the creamery where it was separated by the centrifugal separator. But the glory of the whole-milk creamery was comparatively short and the subsequent advent of the farm separator changed the place of skimming back to the farm and again the farmer hauled his cream to the creamery.

This system, whereby the farmer hauls his own cream to the creamery has the advantage that the creamery comes in constant and individual contact with its patrons. Any disputes arising over quality and weights and tests can be readily, quickly and usually satisfactorily settled, misunderstandings are infrequent because the two contracting parties know each other and in case of dissatisfaction, the weighing and testing can be done in the presence of the patron, giving him an opportunity to convince himself of the correctness of the work.

Again, the farmer who hauls his own cream, usually delivers it at reasonably frequent intervals. This enables the creamery to secure a fairly fresh cream of good quality and if the quality is not as it should be, the trouble can be explained and instructions for improvement given at the platform direct to the patron himself.

The greatest drawback to this system lies in the fact that it limits the cream supply territory to a very narrow radius, which does not permit of material extension. The individual patron refuses to haul his cream a long distance. This system is adapted only to sections of the country where the dairy industry has reached a high state of development, where dairying is the principle business, where the herds are of good size and in close proximity, where the cow population is dense. In territories where the dairy industry is as yet in its infancy, where dairying is merely a side issue of beef-, grain-, or fruit-farming, where the herds are small and far apart, and where the cow population is sparse, the creamery could not secure enough raw material to operate on a profitable basis by this system of securing cream.

The Cream Route System.—In this system the creamery establishes routes and the hauling of cream is done by cream haulers engaged by the creamery. The hauler collects the cream at the farmer's door, where he weighs and samples it. The cream route system is the natural outcome of centralization of cream delivery. By it, one man, the cream hauler, with one team or truck, and traveling over the route but once is capable of bringing to the creamery the cream which by the direct delivery system requires the time of a score or more of patrons and the use of as many conveyances and the traveling of hundreds of miles to deliver it. The route can cover a much wider area and it brings the market so close to the door of the patron, that even the farmer who has but a very few cows and can offer only a small amount of cream, can afford to patronize the creamery. The cream route, therefore, is a stimulant to the dairy business, it encourages the milking of cows, it saves the farmer the time and equipment necessary to haul his own cream, it reduces the cost of delivery and increases the cream supply of the creamery.

Its disadvantage lies in the fact that by the route system the creamery operator is no longer in direct touch with the patron. It deals with the patron through the hauler. It must depend on the hauler to take correct weights, and samples of the farmers' cream and to induce the farmer to furnish cream of good quality. The success of this system much depends on the efficiency, conscientiousness and loyalty of the cream hauler. Unfortunately the work of cream hauling, and the compensation for this work, do not always attract men qualified as cream route men. The cream hauler who fails to understand the principle and to appreciate the importance of securing representative samples of cream, or who is so little interested in his business that he permits the patron to become careless in the handling of the cream, resulting in poor quality, or who, for private gain, undermines the faith of the patron in the integrity of the creamery, is obviously a costly liability, rather than a valuable asset to the creamery.

Experience with the route system has demonstrated that the quality of the cream received from the routes is a fairly reliable index to the character and efficiency of the cream hauler. The routes furnishing the best cream are usually found to be manned by the most efficient and reliable haulers. In a similar way the degree to which the route fat checks with the creamery fat reflects fairly accurately the performance of the hauler. Routes operated by efficient and conscientious haulers seldom show serious shortages in fat, the fluctuations are slight and at the end of the month the differences practically balance each other. But not so with the routes covered by an inferior hauler. Here the fat actually received by the creamery is almost invariably less than the fat indicated by the tests of the individual patron's samples and the shortages are often very great. On these routes the creamery is therefore compelled to pay for more butterfat than it receives, the overrun is diminished and profits may turn into losses. It is obvious that, in order to control these losses and to have an accurate check on the work of the route men, the creamery must systematically check up the butterfat of each delivery of each route and impress upon its haulers that repeated serious discrepancies of this nature will not be tolerated.

The haulers either receive a commission of so many cents per pound of butterfat delivered, or they are hired by the day or by the month, or they receive both wages and a commission.

When hauling for a commission, the hauler usually receives from two to four cents per pound of butterfat and he furnishes his own conveyance. The commission basis has the advantage that it furnishes a strong incentive to secure the largest possible volume of cream and to increase the number of patrons. It has the further advantage that the hauler owns the conveyance and the creamery is relieved of the expense of its upkeep. On the other hand, the principle of the commission basis and the type of men who usually insist on hauling for a commission, are not particularly favorable to the stability of the business. On the commission basis the income of the hauler varies very greatly with the seasons of the year. In summer, during the flush of the milk-producing season, he prospers, while in winter milk production is at ebbtide and many patrons drop out entirely, often causing his income to drop below a living wage. This situation causes some of these haulers to quit hauling in winter or to haul elsewhere, where the temporary compensation offered is more attractive. Generally speaking, the hauler who works on a straight commission basis is the most independent and the least controllable hauler. He takes the attitude that he owns the route and is at liberty to do with it what he pleases and since his income depends on volume, he generally pays little or no attention to quality.

When the cream hauler is paid a daily wage he usually receives from two to four dollars per day and the creamery furnishes all or part of the conveyance, or he receives from three to five dollars per day and he furnishes all the conveyance and takes care of its upkeep. As a rule men who are available for employment by the day or month are of somewhat more stable type. They prefer a regular, known income to speculating on the fluctuating fortunes of a commission. They are employees of the creamery in the true sense of the word and as such expect to follow its instructions. Their work, therefore, is more easily controlled by the creamery and is more dependable. The absence of the financial stimulus for results may deprive them of some of the enthusiasm of the commissioned hauler, to secure volume, yet if they are the right type of men this is usually no serious handicap.

Finally, some creameries guarantee a definite wage and then pay, in addition, a small commission of say one-half cent per pound of butterfat for every pound of butterfat received over and above a certain fixed minimum. This double-pay system often works out very satisfactorily, it combines the stability of the daily wage system with the incentive for volume of the commission system, and makes the hauler feel that he is sharing in the profits of the creamery.

The expense of the cream route system varies very considerably with different creameries. It averages from about two to five cents per pound of butterfat. Experience has shown that when the creamery owns the conveyance the expense of hauling is usually greater and frequently very much greater than when the hauler furnishes it. Careless management and neglect of teams and trucks may make the cost of the upkeep very high. It is therefore to the creamery's interest to have the hauler furnish his own conveyance and take care of its upkeep.

The automobile truck has vastly increased the possibilities of the route system, permitting the covering of a much wider area than is possible with a team. For the best team of horses a route with a circuit of twenty-four mlies is the very maximum that can be covered in a day and there is need of frequent days of rest for the horses when the routes cover such wide circuits A good automobile truck can easily make a circuit of fifty miles per day, thereby covering a vastly greater territory and hauling to the creamery a much larger volume of cream. The cost of hauling by truck, when the truck is manned by a competent man, the country is reasonably level and the roads good, is no greater than the cost of hauling by team. In the case of an incompetent driver, however, the repairs may vastly increase the expense of hauling by automobile truck. In a hilly country and in a country with poor roads there usually are times of the year when the truck cannot be used and it is necessary to do the hauling by team.

Not all cream secured by the route system is hauled direct to the creamery. Many routes do not terminate at the creamery but have their circuit at a considerable distance from the creamery and the hauler ships the cream at the conclusion of the day's work to the creamery by rail.

The Skimming Station and Cream Station System.—In the days of the whole-milk creamery and the use of the centrifugal factory separator, the creameries, in an effort to expand their milk supply territory, established skimming stations located at a convenient hauling distance or at a reasonable shipping distance. The farmers brought their milk to these skimming stations, where it was skimmed and tested, and from where the cream was hauled or shipped to the central creamery.

With the advent and use of the farm separator the skimming station gradually disappeared and the cream station took its place. In this case the farmers skim their cream on the farm and haul it to the cream station and the cream station ships it to the creamery. Within recent years the cream station system has developed very rapidly and today tens of thousands of these cream stations are in operation, especially in the central and far west of this continent.

The cream station has been a tremendous factor in developing the business of milking cows, especially in sections of the country with a relatively thin cow population, where herds are too small, the farms too far apart, and the amount of milk produced within the available radius of local creameries is too limited to make possible the profitable operation of such creameries. The cream station brought the market in these undeveloped dairy sections close enough to the farmer to enable him to readily dispose of the product of his cows and to insure him with a permanent market. This naturally encouraged him to keep cows and while milk producing on these general-purpose farms was a side line only, it became a profitable side line that invited attention and development.

Cream stations which are operated by intelligent and competent men who are interested in the development and welfare of the dairy business, have proven successful and beneficial to both the creamery and the farming community. In many localities, however, competition has had a demoralizing effect on the cream station system, as many as half a dozen creamery companies opening up stations at the same shipping point. This has divided and reduced the cream available to each concern, multiplying the expense of handling the cream and increasing the cost of securing the butterfat.

In a great many cases the cream station is merely a corner in the grocery store or country store, largely equipped only with a cream scale and a Babcock tester and lacking proper facilities for the keeping of the cream before shipment and for the proper cleansing and scalding of cans and other utensils. And the station operator in these cases is the storekeeper, or his helper, neither of whom may have any interest in or knowledge of the dairy business. Nor does the storekeeper usually run the cream station for the profit he may make out of it. His chief aim is to attract the farmers, so as to secure and hold their trade on his merchandise. In towns where there are several stores, each store may represent a cream station and the cream received by each station goes to a different central creamery.

It may be readily observed that this type of cream stations is not only of no benefit, but may become a distinct detriment to the dairy industry, causing shortages of butterfat between station and creamery, and encouraging the farmer in the production of cream of poor quality. In the establishment and proper operation of cream stations the following factors are of permanent importance:

Location.—The cream station should be accessible to the farmers who come into town from the various directions. At the same time, a location should be selected which would offer good drainage, freedom from dust, isolation from stables, junk shops and other contaminating surroundings. Open privy vaults and manure piles should be especially guarded against, as they are prolific breeding places of flies which may infect the cream with germs harmful to the quality of the product, and dangerous to the health of the consumer. Bad odors are easily absorbed by cream and in turn are transferred to the butter, thus jeopardizing its market value. The location of the station should, therefore, be selected with due consideration of sanitary surroundings.

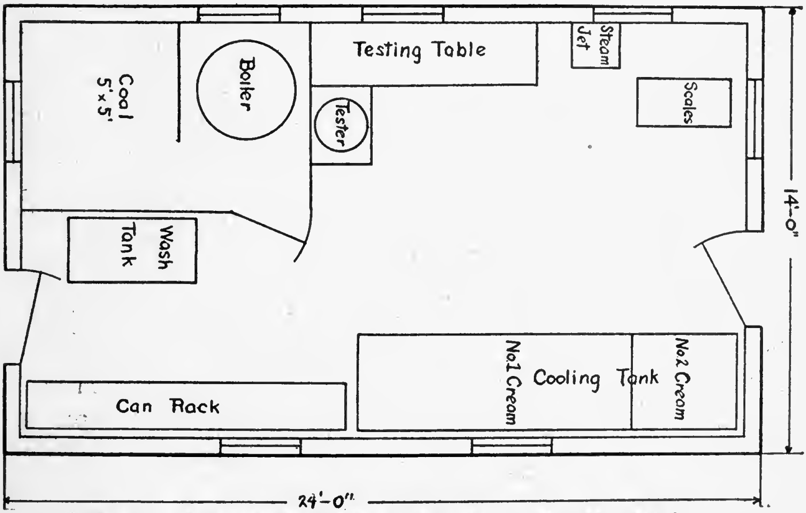

Fig. 1. Arrangement of a properly equipped cream station

Construction.—The materials used for ordinary building purposes are entirely suitable for the cream station. For a permanent cream station, however, the selection of materials of permanent character and not susceptible to decay is a matter of economy. The great majority of the buildings that house cream stations are built and used fundamentally for other purposes, and are selected for the handling of cream after they are built. It is important that at least a separate room be reserved for the purpose of handling the cream. This room should embody the most fundamental sanitary features necessary in the proper handling of perishable food products, such as an impervious floor of sufficient slope to permit good drainage, adequate ventilation and light and proper screening of doors and windows.

Equipment.—The equipment of the cream station should adequately provide for the receiving, weighing, sampling and testing of the cream; for keeping the cream cool and for the washing, scalding and drying of the cans. The chief features of such an equipment are platform scales, sample bottles, samplers, Babcock testing outfits, consisting of standard test-bottles, acid measures, acid, pipettes, cream test scales, centrifugal machine, hot water bath, glymol, facilities for water and steam or hot water, a wash tank, can rack, and a cream cooling tank. There should also be provisions for keeping the first and second grades of cream separately and the places used for the different grades should be so placarded.

The Operator.—The operator is the soul of the station. He is the local representative of his company and should realize his responsibility. He should recognize the fact that he serves as a mirror in which the patrons see the policy and attitude of the creamery. He should give correct and honest weights and tests, and be fair and right in all his dealings with the farmers, so as to gain and maintain their respect and confidence. He should know the problems of the farmer as well as those of the creamery. He should so direct his efforts as to be of service to them with competent advice on better cows, better feeding and the proper care of the cream. He should be familiar with the conditions which cause cream tests to vary so as to satisfy the patrons in the case of controversies arising from such variations; and above all he should appreciate that the most effective means of securing the patrons' co-operation for better cream, lies in his example in grading and caring for the cream properly after it arrives at the station and in returning clean, dry and sweet-smelling cans.

Station Shortages.—One of the biggest problems of the station operator is the shortages which occur between the amount of butterfat paid for by him and the amount received by the creamery. This is usually caused by his failure to remove all of the cream from the patron's can, improper sampling, errors in reading or the reading of unsatisfactory tests, or possibly the loss of cream in transit. The latter can easily be checked by comparing the pounds of cream shipped from the station with the amount received by the creamery. With the exception of the last point, the operator of the station has practically the whole matter in his hands. The very fact that many stations are checking within less than one per cent of the amount of butter fat handled is an encouragement for others to work for a similar standard. Accurate, painstaking work at the creamery and at the station will eliminate excessive losses.

In the majority of the cream stations, the cream is weighed and tested and the station operator pays the farmers direct. In fact one of the advantages of the station system lies in the fact that the farmer can see his cream tested and can get his money upon delivery of the cream. This feature has its disadvantages too, in the fact that it often brings about hasty and inaccurate testing and unreliable tests. In some states (Kansas for instance) the law forbids the testing of the cream on the day it is received, so as to guard against abuses of the station testing.

Some cream stations merely weigh and sample the cream and send the mixed cream and the samples to the central creamery, and the creamery sends the checks to the patrons either direct or through the station operator. Here, as in the route system, the creamery often experiences serious difficulties in making the station fat check with the creamery fat and the shortages are usually against the creamery.

The station operator generally receives a commision of from two to four cents per pound of butterfat handled. This, together with operating expense and railway charges for shipping the cream to the creamery, causes the expense of buying by the station system to amount to about from three to six cents or over per pound of butterfat, not including the usual shortages in the butterfat due to differences between station and creamery tests.

Independent Cream Buyers.—Another phase of the cream station system is that known as the independent cream buyer.

In this case the creamery does not operate a station as such. The independent cream buyer operates a cream station of his own. Here he receives the farmer's cream, weighs and tests it and ships it to the creamery. He sells it to the creamery at a stipulated price based on market quotations. The creamery simply buys the cream from the independent cream buyer and pays him for it, regardless of how he secures it, or what he pays for it. These independent buyers are under no specific obligation to the creamery, they are not employed by the creamery and they sell to the creamery that will pay them the best price.

The independent buyer cannot be considered a stable factor in the creamery business. His investment in the business is negative and his responsibility to the business causes him no worry. His tendencies are nomadic, he exists because he sees, or thinks he sees, an opportunity to make easy money. His plans do not contemplate permanency of business, he goes into it prepared to retire from it the moment conditions are not favorable for immediate profit. In exceptional cases the creamery may advantageously deal with the independent buyer, but more often these business relations are of short duration only, and often cease when the creamery needs cream most. With a few isolated exceptions, the independent buyer cares nothing for quality and furnishes an inferior grade of cream.

Farmers' Co-operative Marketing Association.—Still another type of cream station system is represented by Farmers' Co-operative Marketing Associations, in which the farmers pool their cream and sell it through the medium of the secretary or other representative officer of their association. Such an association has been in operation in the state of Nebraska for several years. While the principle of mutual co-operative organizations of this type is commendable and should be advantageous to the cream producer, the actual results of their operation have not proved very satisfactory from the standpoint of the stability of the creamery industry. This association cream, similar to the independent buyers cream, represents a floating supply. The association sells to the highest bidder and the keen competition among creameries for cream not infrequently causes the prices paid for this cream to be far beyond its market value. This, together with the uncertainty of securing this cream, caused by the fact that the co-operative association may sell to one creamery today and to another creamery tomorrow, tends to have a demoralizing, rather than a stabilizing effect on the creameries concerned.

The Direct-Shipper System.—In this system the patrons ship to the creamery direct. Similar as in the case of the station system the great advantage of the individual-shipper system lies in its practically unlimited supply territory, enabling the creamery to draw on a larger area for its raw material.

This system has the further pronounced advantage of eliminating the middleman and his commission and of doing away with the possibility of discrepancies in pounds of butter-fat between middleman and creamery. The cream reaches the creamery direct from the farmer, where it is weighed, sampled and tested under conditions that facilitate accuracy and minimize errors. It also saves the creamery the expense of shipping cans since the cream is shipped to the creamery in the farmer's own cans and no transfer into creamery cans is required, as is the case with the cream route and with the station systems.

The individual-shipper system combines the simplicity and economy of the direct delivery of the cream by the individual patron at the creamery, with the advantages of securing volume, of the cream-route and cream-station systems.

Its disadvantages are few. In the routine of business personal contact with the farmer is difficult. Except for the holding of occasional dairymen's meetings in which the creamery representative will meet the farmer, the patrons are reached largely by mail only. With a well organized correspondence department, however, it has been found that this manner of contact can be made exceedingly efficient and effective.

Experience has amply demonstrated that the direct-shipper system furnishes a better quality of cream than the usual cream station or the average cream route. The cream is shipped on an average as often as the station or route gets it so that there is not much preference, if any, from the point of view of the age of the cream. The cream coming to the creamery direct and without being held up and transferred in the cream station, where it is often exposed to very unfavorable temperature conditions, and where good cream is frequently mixed with cream of inferior quality, is a strong factor in favor of direct-shipper cream.

Again, the central creamery is better equipped with adequate can washing, rinsing, sterilizing and drying facilities than most of the cream stations. This insures clean cans for the direct-shipper patron while the station patron often gets cans that are in very unsanitary condition. The bad effect on the quality of the cream of an unclean can in itself is serious, but the moral effect such cans have on the patron is of even greater significance. The patron who finds that his can which he takes back from the station is unclean and has a foul odor, loses interest in his own care of the cream. He realizes the hopelessness of his efforts to furnish the station with good cream when he has to store and haul that cream in contaminated cans. And the station operator's gospel of sanitation under such conditions falls on deaf ears.

Concentration Points.—Some creameries receiving their cream by the direct-shipper system establish and operate so-called concentration points, to which the farmers ship their cream and from which it is shipped by the creamery company to the central factory.

These concentration points usually are fully equipped and efficiently manned plants for the grading, weighing, sampling, testing and cooling of the cream, for the washing and sterilizing of the shipping cans and for the soliciting of cream from the farmers. They differ principally from the cream stations, in that the concentration point pays direct-shipper prices for butterfat, and that most of its cream supply arrives by rail.

The concentration point, similar to the cream station, has for its purpose the extension of the cream supply territory, the increase of volume. Its inevitable draw-back is that it tends to jeopardize the quality of the cream. The cream arriving at the concentration point has already been exposed to the trials of rail shipping once, and its delay at this point together with that of reshipping prolongs its journey from farm to factory. The effect of these delays is especially noticeable during hot weather, often resulting in many yeasty and foamy cans. Unless suitable and adequate provision is made for the prompt cooling and keeping cool of the cream at the concentration point, such cream is difficult to handle when it arrives at the creamery and is liable to depreciate the quality of the butter.

The concentration point also has to deal with losses of butterfat due to shortages between its tests and the creamery tests and due to spilling. This, together with the high prices paid for this cream, often renders the cost of the butterfat unduly high and the manufacture of butter from it unprofitable. In short the concentration point, similar to the cream station, tends to increase the cost of the finished butter and to lower its quality.

Management of the Patron.—The patron is the foundation of the creamery business in a similar sense as the cow is the foundation of the dairy business. Without patrons there is no raw material, no milk and cream, and without raw material there can be no butter. The management of the patron in its fullest sense involves the successful solution of the following important problems:

1. The creamery must satisfy the patron with the price he is offered for his butterfat in order to successfully solicit his business.

It is reasonable to predict that the policy which, in the long run will attract and satisfy the largest number of patrons, and that will stand the test of time, is for the creamery to pay the highest price for butterfat possible, consistent with a well managed and legitimately operated business, and allowing for a reasonable creamery profit, together with skill in salesmanship, perseverance and efficiency of service.

2. The creamery must secure the patron's confidence in its honesty and integrity in order to maintain his patronage. This can only be accomplished by honest and accurate weights and tests, and it is greatly facilitated by giving the patron the benefit of the doubt in cases of controversies where there is no indication of intentional dishonesty on the part of the patron.

3. The creamery must interest him in, and enthuse him over, his business in order to induce him to produce more and to improve quality.

4. The creamery must educate the patron in larger and more economical production and in the proper care of his product. The fundamental lesson in better care of cream lies in cream grading and paying on the basis of quality.

CHAPTER IV.

CARE OF MILK AND CREAM ON THE FARM

The cardinal requisites in the production of wholesome and good-flavored milk and cream are:

Healthy cows and attendants.

Wholesome feed and pure water.

Absence of feeds and weeds that produce objectionable flavors and odors.

Reasonable attention to cleanliness.

Prompt cooling.

Frequent deliveries.

Protection in transportation.

Milk from Healthy Cows and Attendants.—Milk from cows suffering from specific bovine diseases, such as tuberculosis, foot and mouth disease, infectious abortion, udder diseases, etc., is unsafe for consumption and manufacture because of its danger of containing the germs of these diseases. Milk or cream from such cows jeopardizes the health and life of the consumer, unless rendered harmless by proper pasteurization.

Cows that suffer from specific disease, and cows that are in poor physical condition such as often is the case with cows, poorly fed, fed unwholesome feed, that receive polluted water, or cows suffering from inclement weather or that are pestered with flies or other insects, or cows that are in feverish condition, may and often do produce milk with abnormal chemical and physiological properties, which in themselves may be harmful to the consumer or which may impair the flavor and marketable properties of the product.

Milk secretion is a physiological function. If this function is abnormal the properties of the resulting product—milk—may also be and often are abnormal. Any condition which materially disturbs the physiological functions of the animal, therefore, is prone also to disturb the healthfulness and the chemical and physiological character of the milk and the products manufactured from it.

It is obvious that, if milk and its products are to be free from germs of infectious, or contagious human disease, the attendants of the cows must be in healthy condition and must not associate with persons suffering from such diseases. The use of water for washing and rinsing milk utensils, that comes from a polluted well, or similar source of infection, further jeopardizes the safety of milk.

Proper Feed and Water.—Outside of the unfavorable effect of moldy and decayed feed on the health of the cows, such feeds are prone to impart to milk and its products undesirable flavors characteristic of these defects. Thus moldy straw and hay, moldy or sour silage and grain, decayed roots, etc., lend milk and its products objectionable flavors which injure their market value.

Certain feeds, when fed in excessive quantities, such as silage, rye pasture, beets, turnips, cabbage, etc., give milk, cream and butter, flavors which are not desired. The danger from these feed flavors may be greatly minimized by feeding such feeds, four to six hours before milking.

Certain weeds, especially wild onions, garlic and leeks, impart to milk, cream and butter a most intense and obnoxious onion flavor, which is very difficult to remove from these products. These flavors usually appear in milk and cream in Spring and Fall, due to the cows having access to pastures which are infested with these weeds, at a time when the pastures are not sufficiently advanced, or have dried up too much, to satisfy the cows, causing them to feed on anything green they can find. The surest way to prevent this flavor in milk, cream and butter is to completely eradicate these weeds from the pastures by burning, plowing up and rotation of crops as recommended by the U. S. Department of Agriculture Farmers' Bulletin 610. When this is not possible the removal of the cows from such pastures either to garlic-free pastures or to the barn-yard, from 4 to 6 hours before milking them, will greatly minimize this objectionable flavor in milk, cream and butter.

Cleanliness.—Filth and manure, when they gain access to milk and cream, pollute these products with their respective odors and flavors. They further contaminate them with diverse species of bacteria, which ferment the product, decomposing one or more of its ingredients, producing objectionable odors and flavors and yielding ferments, such as enzymes, which in turn have the power of decomposing the product and deteriorating it in storage.

In order to avoid unnecessary contamination of milk, cream and butter, these products should be produced and handled under cleanly conditions. The barnyard should be kept dry and free from manure so that the cows are not compelled to wade knee-deep in mud before they enter the stable. The stable must be kept free from abnormal accumulation of dirt, and manure; the manure must be removed at least once daily; the bedding must be clean and the stable must be sufficiently ventilated to eliminate strong animal and manure odors; the floors should be sprinkled with water before sweeping and the sweeping must be done several hours before milking, so as to give the dust in the air a chance to settle before the milk is exposed to the stable air.

The cows must be kept clean, by preventing them from lying down on a filthy floor and their udder and flanks should be wiped off with a clean, damp cloth before milking commences; the currying of the cows should be done after and not before milking.

The milker must be embued with a sufficient sense of cleanliness and decency, to milk with clean, dry hands and to protect the milk from undue contamination with dust, dirt and other impurities.

If machine milking is practised the teat cups and rubber tubes should be thoroughly washed and soaked between milkings in a solution of a suitable disinfectant, and the pulsators, pails and acceessories must be regularly washed and scalded.

The utensils must be clean and as nearly sterile as possible. For this all pails, dippers, strainers, coolers, etc., should be rinsed with cold or luke warm water, washed thoroughly with hot water, containing some washing powder and then scalded with boiling hot water, or steamed if steam is available.

Cleanliness of Separator.—The cream separator is a collector of many of the impurities contained in milk. These impurities are found in the separator slime which deposits on the wall and between the internal contrivances of the bowl. The separator slime consists largely of viscous nitrogenous matter contained in the milk, and a large portion of the dust, dirt and bacteria which may have reached the milk during its process of production. In addition to the separator slime, the bowl, at the end of the separation, contains remnants of milk, skim milk and cream, all of which are prone to decompose and ferment unless removed promptly. If not washed and freed from all these impurities and remnants of milk of the previous separation, the separator bowl becomes a seat of contamination and the source of unclean, unwholesome and filthy cream, the disastrous consequences of which no subsequent care or treatment of the cream can overcome. Not only should the separator bowl be washed after each separation, but the washing must be thorough. The most aggravated cases of unsanitary and unclean cream, result from the use of separators, the bowls of which are never washed entirely clean and, while no large amount of filth is left on them, they contain just enough of old and decomposing matter to expose the cream of each separation to bad odors and to infection with germs capable of producing very undesirable fermentions and flavors, which are responsible for butter of inferior quality.

Fig. 2. This bowl was flushed after use. If not taken apart and washed it will be foul-smelling at the next separation

How to Wash the Separator.—After each separation flush out the bowl, while still running, thoroughly with water until the discharge from the skim milk spout is clear. This removes most of the remnants of milk and cream and loosens the separator slime in the bowl, making subsequent washing easy. Take the bowl apart and wash with brush and hot water containing some good washing powder or other alkali, all parts of the bowl, bowl cover, discharge spouts, float, supply tank and buckets. Rinse them with scalding hot water and steam them if steam is available. Allow them to drain in a clean place, protected from

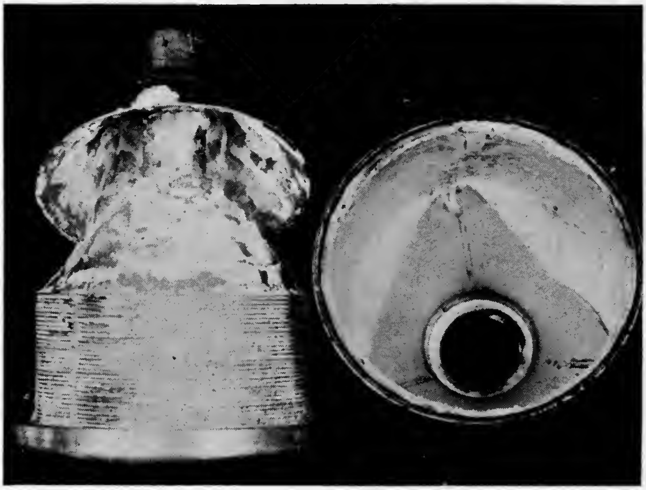

Fig. 3. Bowl immediately after separation

dust and flies. All other milk utensils should receive similar treatment. Do this after each separation.

A clean separator will also skim more closely, as explained in the chapter on the separation of milk, and the separator will last longer, because the acids formed by the decomposing impurities in the bowl tend to corrode the bowl and internal contrivances and to shorten the life of the separator.

Care of Cream After Separation.—The cream should always be cooled immediately as it comes from the separator. The common practise of placing the cream in the cellar for this purpose is undesirable. Cream so stored is prone to contain a so-called cellar odor, which is antagonistic to the flavor of good butter.

Again, by setting the cream can or crock in the cellar, the cooling will be slow and not rapid enough to insure good flavor. The animal heat in it, unless removed by prompt cooling, gives it a peculiar smothered flavor which often follows the cream into the butter.

The warm cream is in ideal condition for bacterial decomposition and spoiling. If promptly and properly cooled the activity of the bacteria and other ferments is retarded, if not entirely checked, and the cream will keep sweet and in good condition for a reasonable length of time. The lower the temperature to which it is cooled, the longer will it keep in normal condition. Cooling to the temperature of the water available on the average farm alone greatly retards bacterial action. The cream should be cooled at once after it leaves the separator. The beneficial effect then is greatest. If the cooling is delayed until fermentations have commenced, the life of the cream is greatly shortened; for once started, fermentations are checked with difficulty.

When promptly cooled and frequently stirred, the cream remains in proper mechanical condition so that it can be readily transferred without excessive loss due to sticking to the can. This also makes possible the taking of representative samples therefrom, which in turn is the foundation for accurate tests. One of the fundamental causes of irregular and incorrect cream tests lies in the poor mechanical condition of the cream when sampled. It is difficult to take a correct sample from cream that has not been cooled promptly and properly, nor stirred frequently, or that is otherwise in poor condition.

How to Cool Cream.—The only practical way to cool cream promptly and to successfully control the temperature under average farm conditions is to set the cream cans in a properly insulated tank filled with cold water. The heat conductivity of water is twenty one times as great as that of air. This means that by setting the cans in water the cream will be cooled twenty one times as fast as by letting them stand in the air at the same temperature. The tank used for cooling the cream should be deep enough to allow the water to cover the cans at least as far up as the cream will reach when the can is full. It should

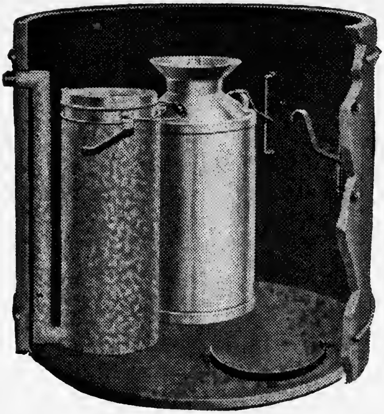

Fig. 4. A practical cream cooling tank
Courtesy of Independent Silo Co.

be large enough to hold a sufficient body of water to avoid too rapid warming up of the water when the tank is opened in hot weather. It should be sufficiently insulated to hold the temperature within a few degrees for eight to twelve hours. It should provide for one can for the warm cream and one can for the cooled cream ;warm cream should never be poured into cold cream. The warm cream should be cooled first before mixing with the cold cream, otherwise the mixture will spoil rapidly. Aside from cooling the cream and keeping it cool, the cream cooling tank furnishes a desirable place for the storage of cream, protecting it against contaminating odors, dust, dirt, flies, gnats and rodents. The cream should be covered so as to prevent these contaminations. Cream stored in the cellar, the dry pit, or other similar places may become infected with insects and other life, that render it unfit for any purpose. The same precautions should be taken in the storage of milk.

There are now available on the market numerous suitable and practical cream cooling tanks for this purpose. The use of these tanks, not only helps to preserve the quality of the cream, but it also simplifies and economizes the labor of handling the cream.

Age of Cream.—Generally speaking, the closer the churn is placed to the cow, the better the prospects of a high quality of butter.

Cream is a highly perishable product. Like other similar food products it is best when fresh and should, therefore, be marketed, or used for manufacture, as early as possible after it escapes from the separator. Age will gradually deteriorate cream under any condition. While proper care retards such deterioration it cannot entirely prevent it, hence, if intended for the sweet-cream trade it should be delivered daily; if butter is made on the farm the churning should be sufficiently frequent to avoid the necessity of using stale cream. If sent to the creamery, deliveries should be made two to three times per week or oftener. Excessive age of cream is one of the arch enemies of the butter industry, because it paralizes largely all other efforts to improve the quality of the butter.

Protection of Cream in Transit.—The cream cans should be kept in the cooling tank until they leave the farm. While on the road they should be properly protected against excessive heat in summer and cold in winter. While hauled to the creamery or station this may be effectively done by covering the cans with a wet blanket in summer and a dry blanket in winter. For shipping long distances the use of insulated cans, or cans over which a jacket has been slipped, is desirable. In the absence of this practise a tank with cool water should be provided at the station in the summer and the cream should be shipped in iced cars during the hot summer months. These precautions are as yet very largely ignored, both by the shipper and by the railway and express companies and it is to be hoped that, with the future development and more intensive practises of cream transportation, this important phase may receive its due share of attention.

Another feature of transportation which has had an unfavorable influence on quality, is the difficulty of insuring a prompt return of the empty cans to the farmer. For reasons which have not as yet been satisfactorily explained, the return of the empties has been consistently neglected by some transportation companies, causing these cans to reach the farmer frequently after weeks of delays and misshipment. The empty can should receive the same attention as the full can. It should be considered perishable merchandise, for if it is not returned to the farmer promptly, he has no means to ship the cream which has been accumulating on the farm, causing this cream to spoil.

CHAPTER V.

THE SEPARATION OF MILK.

Purpose.—The purpose of separating milk is to obtain cream. Cream is that portion of milk which contains a relatively large proportion of its butterfat. In order to comply with the legal Federal standard, cream must contain not less than 18 per cent of butter fat.

The chief objects of using cream for butter making, instead of churning milk, are first to reduce the volume of the fluid to be churned and therefore to increase the capacity of the churn and to reduce the labor and expense of churning; second to facilitate the speed of churning; the richer the fluid is in butter fat, the more readily do the fat globules unite into granules and the shorter the time required for churning; third to increase the exhaustiveness of churning; milk or thin cream do not churn out exhaustively, because the large volume of intervening liquid prevents many of the fat globules, especially the small ones, from uniting, thereby causing a relatively large number of these globules to remain unchurned, to pass into the buttermilk and to result in excessive loss of fat and a correspondingly small churn yield. The churning of milk and thin cream further augments the loss of fat because it yields large volumes of butter milk, thereby increasing the pounds of fat lost.

Aside from the advantages of churning cream instead of milk, large volumes of cream are separated for purposes other than buttermaking, such as for table use, ice cream making, the manufacture of whipped cream, etc.

Principle of Separation.—The separation of cream from milk is based on the principle that the butter fat is lighter than the other constituents of milk. At 60 degrees F. the specific gravity of average milk is about 1.032, that of butterfat about .93 and that of skim milk about 1.037. The fat globules, containing the butterfat, therefore, yield to the gravity force and rise to the surface.

The principal agent retarding or preventing their upward passage is the viscosity of the milk, which is largely due to its albuminoids, the casein, albumin, fibrin, globulin and other similar constituents of a colloid nature inherent in milk and cream, and to the milk sugar. If the viscosity of milk were no greater than that of water, the fat globules would rise to the surface instantaneously in a similar manner as oil poured into water rises to the surface.

In the separation of cream considerable portions of the water and of the non-fatty solids of the milk are carried into the cream. Generally speaking, the relation of solids not fat to water in the cream is approximately the same as it is in milk. The per cent of solids not fat in cream, however, is lower than the per cent of solids not fat in milk, it varies inversely with the per cent of fat. The higher the per cent of fat, the lower the per cent of solids not fat. For further details on the composition of cream see "Composition of Cream," Chapter XVIII.

Methods of Separation.—The separation of milk, as practiced on the farm and in the factory, is accomplished either by gravity or by centrifugal force. In the application of these two fundamental systems of separation the following methods are used:

- Gravity separation
  - shallow pan method
  - deep-setting method
  - water-dilution (or hydraulic) method
- Centrifugal separation
  - farm cream separator
  - power cream separator

Separation by Gravity.—The milk is set at rest in a cool place until most of the fat has risen to the surface forming a layer of cream. The fat globules rise to the surface because of the fact that they are lighter than the other liquid and solid constituents of the milk.

The Shallow Pan Method.—The milk, preferably fresh from the cow, is poured into a shallow pan usually, though not necessarily, 15 to 25 inches in diameter and about 4 inches deep. The pan is placed into a cool place, such as the cellar or it may be set in water. After 36 hours practically all of the fat capable of rising to the surface by this method will have come to the surface and the layer of cream thus formed is then skimmed off with a spoon, ladle or specially constructed skimmer. The skim milk usually contains about .5 to .6 per cent fat.

The Deep-setting Method.—The milk, preferably fresh from the cow, is poured into a can of the "shot-gun" type, about 8 to 10 inches in diameter and 18 to 25 inches deep. This can is placed in cold water and held at as low a temperature as possible. Temperatures between 45 degrees F. and the freezing point of water are preferable. At the end of 24 hours the separation is usually as complete as it is possible to secure by this method of separation. The removal of the cream thus separated is most conveniently accomplished by drawing the skim milk from a faucet at the bottom of the can, leaving about one inch of skim milk in the can. The skim milk should be drawn off slowly in order to avoid currents which cause a portion of the cream to be drawn into the skimmilk. In the case of cans without faucets the cream is removed with a dipper from the top. The skim milk, under proper conditions of creaming, averages about .2 to .3 per cent fat.

The Water-Dilution Method.—The milk is diluted with equal parts of clean water, usually at about 100 degrees F. and set in a cool place for 12 hours, when it is ready to be skimmed. The skim milk is drawn from the bottom of the can. The great rapidity of the separation by this method is due to the lesser viscosity of the diluted milk which permits the fat globules to rise more readily to the surface. The skim milk generally contains from .3 to .4 per cent fat, but since it is diluted to twice its volume with water, the actual loss of fat in the original skim milk is .6 to .8 per cent.

CENTRIFUGAL SEPARATION

Definition.—In centrifugal separation the centrifugal force generated in a rapidly revolving bowl takes the place of the gravity force acting on milk in a vessel at rest. By centrifugal force, in the sense used here, is understood the force which causes a body, revolving around a center point, to fly from the center. As a simple illustration of this may be mentioned the pull which is felt when a weight attached to a string is whirled about the hand. The pull is caused by the tendency of the concentrally moving weight to fly outward and the pull increases in force, the longer the string and the faster the weight is whirled.

The discus throw of the athlete is a concrete example of the cause and effect of the centrifugal force. The centrifugal force acts on liquids as well as on solid bodies.

The Theory of Centrifugal Separation.—The separation of the cream from milk in the centrifugal separator is based on the well known physical law that when liquids of different specific gravities revolve around the same center, at the same distance, and with the same speed, the greater force is generated by the heavier liquid than by the lighter. Milk, as already stated, consists of two liquids of different specific gravities, the fat particles and the milk serum. The milk enters the rapidly revolving bowl either at the top, middle or at the bottom of the bowl. In most separators it runs first through a central tube which carries it to the middle or bottom before it is discharged into the bowl. In the case of a bowl not in motion the milk fills the bowl from the bottom up due to the force of gravity. When the bowl is rapidly revolving the force of gravity is overcome by the centrifugal force which is over a **thousand times** greater than the gravity force. The milk is therefore thrown immediately to the periphery or side of the bowl, filling the bowl from the side to the center.

While both liquids, the fat particles and the milk serum, are forced to the bowl wall, the heavier liquid, which is the skim milk, is driven from the center with greater force than the lighter liquid which is the fat particles. The skim milk thus forms a vertical wall enveloping the side of the bowl. As the result of this separation the fat globules, which are uniformly distributed in the milk before it is subjected to the centrifugal force, separate from the skim milk and, through a recurrent motion, are crowded toward the center of the bowl, where they accumulate in a vertical layer of cream, in a similar way as they gather on the surface of the milk by gravity creaming. It is obvious, therefore, that the least fat is found near the periphery of the bowl and the most fat is found near the center of the bowl.

As more milk flows into the bowl, the vertical wall of skim milk and cream expands in thickness, filling up the larger portion of the bowl. In most types of bowls, operated under normal conditions, the milk never fills the entire bowl, a vacant space being left in the center. The vertical wall of milk in the bowl increases until the discharge from the skim milk outlet and that from the cream outlet equal the rate of inflow of milk to the bowl.

The intensity of the centrifugal force is controlled by three fundamental factors; namely the speed and diameter of the bowl and the weight of the contents. It increases in proportion as the weight of the contents of the bowl and the diameter of the bowl increases, and also with the square of the number of revolutions per minute. Lamson[1] calculated the centrifugal force factor for numerous farm separators as shown in the succeeding table. His calculations are based on the following formula:

$Fc = WD\ (R.\ P.\ M.)^2 .000014208$ in which

Fc=Centrifugal force

W=Weight expressed in pounds

D=Inside diameter of bowl expressed in inches

R. P. M.=Revolutions per minute.

In all of the computations, the weight was figured as one pound, since a comparison only of the centrifugal force factors was desired.

Table 4.—Centrifugal Force Factor when Revolutions per Minute and Diameter of Separator Bowl in Inches are known.

Name of Separator	Revolutions per Minute	Diameter in Inches	Centrifugal Force Factor, Calculated
Galloway	7500.0	4.6780	3738.7
Economy King	8378.0	3.9630	3952.2
Dairy Queen	8160.0	4,2500	4020.7
John M. Smythe	8220.0	4.2500	4080.0
United States	9336.8	3.4500	4273.2
New Butterfly	9145.0	3.7187	4418.7
De Laval	8224.3	4.6325	4451.9
Primrose	8993.0	4.1670	4788.1
Anker-Holth	9200.7	4.0050	4817.0
Renfrew	8980.2	4.5550	5219.1
Empire	10148.4	3.7150	5436.1
Iowa	10449.0	4.1970	6510.6
Sharples	16533.9	2.0000	7768.1

[1] Lamson.—A Study of Farm Separators. M. S. A. Thesis, Purdue University, 1918.

Construction of the Separator.—The centrifugal cream separator consists of three main parts, namely the separator frame, the bowl with internal devices, supply tank and discharge pans, the gear and power attachment.

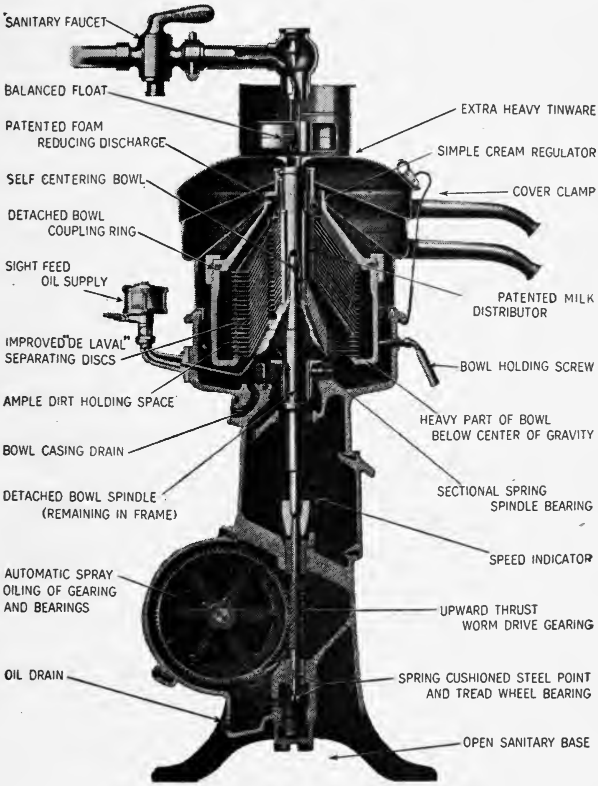

Fig. 5. De Laval cream separator
Courtesy De Laval Separator Co.

The Separator Frame.—The frame of the separator furnishes the foundation and support of all important parts of the machine, it also serves to guide and protect the bowl and its spindle. It is of heavy construction, usually of cast iron and, in order to give the machine greater stability, it often extends at its bottom into a solid platform. The base of the frame carries in the case of most separators the bottom bearing of the spindle which drives the bowl. This bearing is generally equipped with an adjustable screw whereby the bowl may be lowered or raised in its position in the frame. It also carries brass bushings at the bottom and top of the spindle which serve to guide the position of the spindle and to keep the bowl from wobbling. The upper portion of the frame protects the bowl and serves as support for the pans into which the skim milk and cream are discharged. In the case of hand separators the frame is also equipped with supports for the milk supply tank, and for the skim milk and cream cans.

The Separator Bowl and Spindle.—The bowl is the heart of the separator, in it the separation of the milk takes place. In most separators now in use the bowl extends at its lower extremity into the spindle to which is transmitted, either direct or indirect, the motive power which revolves the bowl. In some separators the bowl and the spindle are one piece while in others the spindle is divided into an upper and lower spindle, connected by an offset in the contact end of each, or by a slot in one and a slot and pin in the other. Occasionally the bowl is entirely separated from the spindle, connecting with the top of the spindle. Then, again, there are separators in which the bowl is attached to the spindle by a permanent hinge joint. In still other machines the bowl is suspended, its spindle which in these machines is at the top of the bowl, is coupled to an overhanging spindle head connecting with the seat of power.

The bearing on which the spindle revolves may consist of a stationery but adjustable steel point on which a similar steel point at the termination of the spindle rests; or the spindle may terminate in a tapering disc which rests on a bearing of steel balls or steel rollers. The spindle is guided by an upper and a lower brass bushing. The ease of running and elasticity of the bowl may be enhanced by the use of bushings equipped with springs.

The bowl proper consists in the main of a cylindrical, or cone-shaped vessel. It opens either at the top or at the bottom. It is closed by a coneshaped cover. At the point of contact with the cover the bowl carries a groove or rim which admits a rubber ring. This serves to make an absolutely tight seal between bowl and cover, without which the pressure generated in the revolving bowl causes the milk to leak out. The cover must be firmly screwed to the bowl to prevent leaking. In the case of machines with suspended bowls the cover forms the bottom of the bowl or in some cases, the bowl may consist of two nearly equal halves which screw together, a rubber ring furnishing a tight seal. Most bowls also carry a central tube through which the milk enters, flows to near the bottom and then is released for distribution and separation.

Experience has shown, that the efficiency of separation suffers when the milk is allowed to enter the separating space of the bowl by continuously passing through the innermost layer of milk, which represents the cream layer. This causes a constant mixing of the fresh milk with the cream layer. To avoid this the intake of the milk is so arranged that the inflowing milk passes into the neutral zone of the milk layer outside of the cream layer without passing through the latter. This is accomplished by compelling the milk to flow through an umbella-shaped disc at the bottom of the bowl or through properly located slots in the central tube or other similar devices in the center of the bowl.

The bowls of the earlier separators were hollow in their interior. In order to cause the milk to circulate with the bowl immediately upon its entrance, these bowls were equipped at their periphery with one or more wings extending radially to near the cream layer. In the newer separators most of the bowls carry a series of internal contrivances which not only assist in subjecting the milk promptly to the circular motion, but increase the skimming efficiency of the machine further by exposing the milk over a longer distance to the centrifugal force and by facilitating the return of the fat globules to the cream layer.

Of these internal contrivances the cone-shaped discs of the Alpha separator are the oldest and best known. These tin discs are slipped over the central tube of the bowl and rest on top of one another. They leave a small space open around the central tube for the gathering of the cream. The upper surface of each of these discs is spotted with small projections, for the purpose of keeping the discs at a slight distance from each other. These intervening spaces divide the milk, in its passage from the center to the periphery of the bowl, into very thin layers, augmenting the separating efficiency.

In order to avoid infringement on the Alpha De Laval patent of discs, other manufacturers have constructed a large assortment of different types of somewhat similar internal contrivances, all of which are intended for the same purpose. One distinct deviation from the horizontal or coneshaped disc is the vertical blade arrangement of the Simplex separator in which numerous

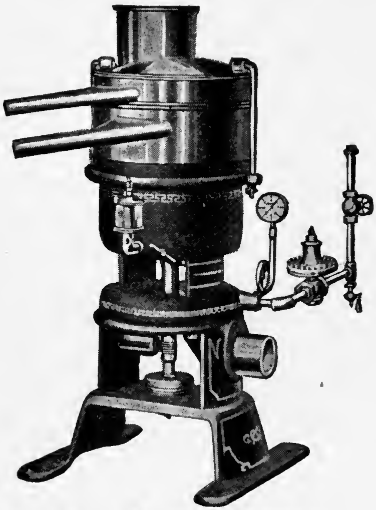

Fig. 6. Simplex separator
Courtesy D. H. Burrell & Co.

Fig. 7. Simplex blades
Courtesy D. H. Burrell & Co.

curved tin blades, attached to a ring around the central tube extend from the central tube to the periphery of the bowl. These wings or blades, similar to the discs, are kept at a slight distance from each other by carrying small projections on their surfaces and in this way divide the milk into a multitude of very thin layers.

The Skim Milk Outlet.—As previously stated, the layer of milk nearest the wall, or periphery of the bowl, contains the least fat and represents the skim milk. The skim milk is discharged either from the top or from the bottom of the bowl. The skim milk flows through small tubes from the extreme periphery to near the center of the bowl where it is discharged. The purpose of carrying the skim milk to near the center before it is permitted to escape is to reduce the force with which it is discharged. By passing toward the center the skim milk has to overcome the centrifugal force.

These skim milk outlet tubes are very small, curved and difficult to thoroughly cleanse, which is an objectionable feature from the sanitary point of view. In the latest improved models of bowls these tubes have therefore been done away with. This has been accomplished by covering the top-most of the internal discs with a special closing disc, the lower edge of which extends to near the wall of the bowl and the upper end of which forms a sleeve extending up into the neck of the bowl cover. This closing disc carries sufficient projections on its upper surface to form a narrow space between it and the cover of the bowl. The skim milk passes through this space in the form of a thin layer and leaves the bowl through a small opening, the skim milk outlet, located at the bottom of the neck of the bowl cover. In some makes of separators the skim milk is discharged through the bottom of the bowl.

The Cream Outlet.—The cream finds its exit from the bowl at, or near the top of the bowl cover. Its entrance to the outlet is located slightly nearer the center than the centermost part of the skim milk outlet. In most separators the cream outlet, or cream screw is adjustable. If the cream screw is located in the top of the bowl cover, it usually carries an eccentric orifice which is the cream outlet. This screw may be turned so as to place the opening or cream outlet nearer to or farther from the center. If the cream screw is located in the side of the bowl neck, the distance from the center at which the cream escapes from the bowl is regulated by turning this screw farther in or out. In the case of some bowls the cream outlet is stationary and the skim milk outlet is adjustable.

Adjustment of Cream Screw to Regulate Proportion of Skim Milk and Cream and to Control Richness of Cream.—As previously stated, the milk in the revolving bowl is forced to the side of the bowl, forming a vertical wall. The inner line of the milk in the bowl and of the skim milk in the skim milk tube, or skim milk space forms a straight vertical line.

As more milk flows into the bowl, the wall of milk extends farther toward the center until the skim milk begins to discharge from the skim milk outlet. As the inflow of milk continues the wall of milk in the bowl increases in thickness until the cream begins to escape through the cream outlet. Simultaneously the

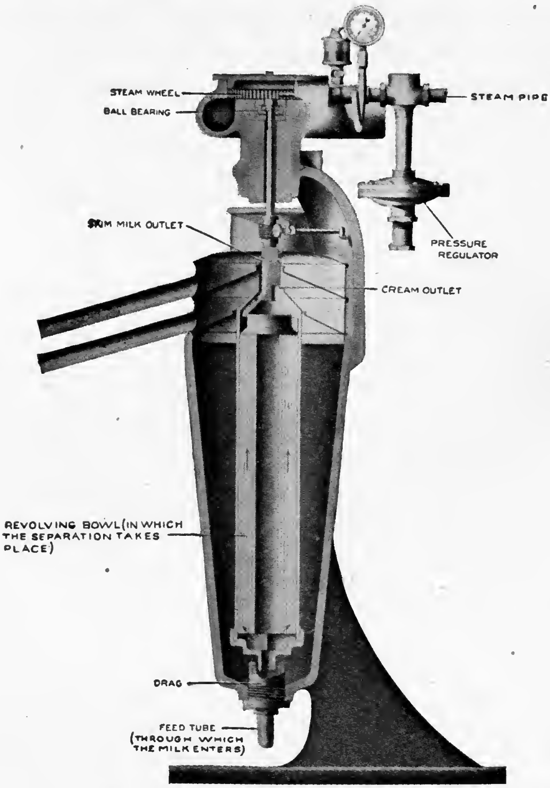

Fig. 8. Sharples cream separator
Courtesy Sharples Separator Co.

discharge of the skim milk increases. When the discharge of the skim milk and cream outlets equal the inflow of the milk, the thickness of the wall of the milk in the bowl becomes constant.

The proportion of cream to skim milk in any given separator is controlled directly and exclusively by the relative distances of the two outlets from the center of the bowl, assuming that the separator is operated under otherwise normal and uniform conditions.

The assertion of some authors that the relative amount of skim milk and cream depends in part on the size of the outlets is erroneous, inasmuch as experimental results by Ecles[1] and Wayman conclusively show that, when the separator is run normally, the volume of the skim milk discharge is not more than half of the capacity of the skim milk outlet.

In order to secure any cream discharge, the cream outlet must be located slightly nearer the axis of the bowl than the outer wall of the skim milk tube. The more nearly alike the distance of the two from the center, the more cream and the less skim milk will there be. The greater the difference between their distance from the center, the less cream and the more skim milk will be discharged. Therefore, the turning of the cream screw toward the center decreases the cream discharge and increases the skim milk discharge and the turning of the cream screw from the center increases the cream discharge and decreases the skim milk discharge.

Simultaneously, with the turning of the cream screw toward the center and thereby decreasing the amount of cream, a richer cream is discharged, because the richest cream is nearest the center of the bowl. The turning out of the cream screw, while increasing the proportionate amount of cream, decreases its richness, because the cream layer farther from the center is thinner.

Supply Tank, Float and Discharge Pans.—As accessories to the bowl may be considered also the milk supply tank, the receiving cup with float and the milk and cream discharge pans.

The milk supply tank rests on an extension of the separator frame. It is used only in the case of hand separators. In factory machines the milk runs into the separator direct from the vat or heater. The receiving cup is a part of the cover of the discharge pans. It accommodates the float, which device consists usually of a sealed, hollow tin bob acting as a regulator of the milk inflow. When the separator is fed too fast it rises on the surface of the milk in the receiving cup and closes a part of milk outlet of the supply tank.

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[1] Eckles and Wayman.—Factors Affecting the Per Cent Fat in Cream from Farm Separators. Missouri Bulletin No. 94, 1911.

Separators with bowls which discharge both, their milk and cream at the top of the bowl, are equipped with a cream and a skim milk catch pan with discharge spouts. These pans lie on the separator bowl frame. The top pan discharges the cream, the bottom pan the skim milk. In the case of separators which discharge their skim milk from the bottom of the bowl, no skim milk discharge pan is needed, the skim milk escaping through a tube in the frame at the bottom of the bowl.

The Driving Mechanism.—The parts of the separator which control the transmission of the motive power, differ with the type of motive power used. The earlier machines were all factory separators which were driven either by belt, or steam turbine and later by electricity.

The mechanism for the transmission of the power which revolves the bowl differs fundamentally between power or factory separators and hand separators and to some extent as to the type of power used. Differences in the details of the arrangement of the transmission further occur between separators of the same type but of different makes.

Power or Factory Separators.—The first centrifugal separators were those used in the factories and which are operated by power. The factory machines, as far as the type and mechanism for the transmission of the motive power is concerned, may be divided into belt machines, turbine machines and electric-driven machines.

In the belt-driven machines the power is generated by a separate engine or motor which is entirely independent of the separator and, as far as the operation of the separator is concerned, is connected with the separator only when the latter is to be operated. In this case the motive power may be generated by a steam engine, a gasoline engine, electric or water motor. In the creamery where the steam engine, or possibly the electric motor, is a necessary part of the equipment for the operation of various lines of power machines, such as churns, pasteurizer, etc., the separator is usually connected by belt with the main shaft or line shaft. In the case of separators of small capacity, not over about 2,000 pounds of milk per hour, the belt from the shaft usually connects direct with the separator. The lower end of the spindle of the separator is geared to a short horizontal shaft which carries a tight and a loose pulley. In order to start the separator slowly and to avoid sudden jars when changing the speed of the engine, the belt is shifted from the loose to the tight pulley very gradually. This type of power transmission is suitable also for large dairy farms where a gasoline engine or similar power is available. It has the advantage of facilitating the maintenance of uniform speed, provided that the belt does not slip, and of utilizing steam or other power and space economically.

For machines of larger capacity, such as are used in the average commercial creamery and which may range as high as 10,000 pounds of milk per hour or higher, indirect transmission of the belt power is used. For this purpose a double transmission in the form of an intermediate, or jack, is installed. The intermediate consists of a tight and loose pulley to which the pulley on the main shaft is belted and a large wheel which transmits the power from the intermediate to the separator by means of an endless separator cord or strap. In order to take up the slack in the cord the intermediate is equipped with a weighted lever which presses against the cord while in operation, tightening the latter and preventing excessive slipping. The intermediate rests on an independent standard, permanently erected and usually at a distance of about 12 feet from the separator. The chief disadvantage of the use of the intermediate is that it takes up considerable space which might be utilized for other purposes. In the latest of models of power separators the intermediate has been dispensed with, removing the above objection.

In the steam turbine-driven separators, in most cases, the lower end of the spindle carries a turbine wheel, which revolves in an inclosed turbine chamber of the separator frame and which contains a reduced steam inlet and a steam exhaust. In separators with pending bowls the turbine is located above the separator bowl. The steam supply pipe is equipped with a valve to regulate the steam inlet and for safety's sake it should carry, between the steam valve and the separator, a steam gauge and a blow-off valve, or safety, properly set to guard against excessive steam pressure. The steam turbine separator has become very popular for both factory and farm machines. Its chief advantages are that the separator can be operated independently of the steam engine or the main shaft. It is compact and does away with the space-wasting objection of the intermediate of the belt-driven machine. On the other hand it involves somewhat less economic use of steam and requires closer attention in order to insure uniform speed. The latter objection has been largely removed, however, in the latest types of steam turbine separators by equipping them with efficient automatic speed governors. The close proximity of the steam chamber to the lower bearing also is prone to augment the tendency of heating the spindle in the absence of adequate lubrication.

The electric-driven separator is a later inovation. It is equipped with an electric motor which is a part of the separator and which requires no power transmission arrangement additional to that which forms a part of the separator. It can be operated independent of all other operations, no steam nor gasoline engine is required, the turning on of the current is all that is necessary. So far these electric-driven separators have not found very extensive use, especially in the case of the larger machines. Their greatest disadvantage so far has been the short life of the motor. Experience has shown that these separator motors are of relatively short usefulness. It seems that the dampness to which they are bound to be exposed in the creamery is injurious to the insulation, necessitating frequent repairs and renewal. This objection is now, however, being rapidly overcome by efforts on the part of the manufacturer to furnish machines with more efficiently protected motors.

Hand Separators.—In the case of the hand separator the power mechanism is a part of the separator proper. It, too, differs in details of arrangement with different makes of machines. The fundamental principle of the mechanism is to produce the relatively high number of revolutions which are required of the bowl,—6,000 to 17,000 revolutions per minute,—

from the limited and relatively small number of turns of the crank shaft—45 to 60 turns per minute—which can be conveniently applied by hand. This is accomplished by transmission of the power by a series of gear wheels located between the crank shaft and the spindle of the bowl. The type of gears varies somewhat with different makes of machines, they may consist of

Fig. 9. De Laval hand separator
Courtesy De Laval Separator Co.

Fig. 10. Sharples hand separator
Courtesy Sharples Separator Co.

cog wheels of various angles, worm wheels, friction wheels, or chain, or belt wheels, or a combination of two or more of these principles.

The transmission by friction wheels has been almost completely abandoned, because they have been found unsatisfactory for this purpose on account of uneven wear of friction surfaces and therefore irregular speed of the bowl.

The chain transmission also is of rare occurrence and the belt transmission is generally installed only on those hand machines which are to be used for power as well as hand operation.

Its chief advantage is that it protects the separator against sudden shock of the spindle and bowl which is practically unavoidable when operated by certain forms of power. This is especially true in the case of gasoline engine explosions. In these belt driven farm separators, the power is transmitted by belt to the tight and loose pulley which is provided with a belt shifter, thence from the short center shaft which is a part of the set drive, by an endless belt to the lower worm wheel shaft of the separator. In the latest type of hand separator the power transmission is further equipped with a coil spring belt tightener over which the belt runs and which automatically absorbs shocks and irregularities in speed.

In the great majority of hand separators which are used for hand power only, the power is transmitted exclusively by cog wheels or by worm wheels or by a combination of both. The transmission mechanism usually consists of one, two or three pairs of wheels. The large cog wheel resting on the crank shaft transmits its power to a small cog wheel, this constitutes the first transmission of power with increased speed. The small cog wheel rests on a second large cog wheel which transmits its power either direct to the worm gear of the lower spindle, or to a third small wheel, to the axis of which is attached a third large wheel which connects direct with the lower spindle.

The successive multiplication in speed resulting from these transmissions depends on the difference in the number of cogs between the large and the small wheels. Assuming for example, that there are three pairs of cog wheels and in each pair the large wheel has 50 cogs and the small wheel has 10 cogs, the speed is increased by each of the three sets of transmissions five times, or 5x5x5=125. In the above case each turn of the crank shaft yields 125 revolutions of the bowl. If the required number of revolutions of the bowl is 6,500 per minute, then the crank shaft must be given $\frac{6500}{125} = 52$ turns per minute.

It is obvious that the smoothness of running, as far as the transmission is concerned, is dependent on the regularity and state of preservation of these cogs. If the cogs are abnormally worn, or if one or more cogs are broken, the machine slips and

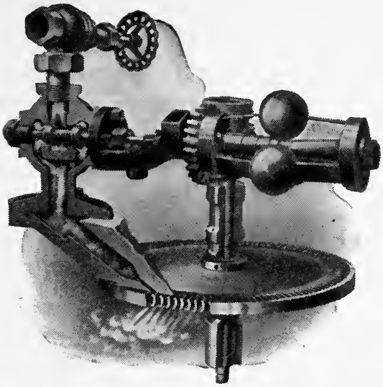

Fig. 11. Steam turbine and speed governor
Courtesy De Laval Separator Co.

jolts, making the proper operation of the separator impossible. Damaged cog wheels or worn wheels therefore should be replaced by new ones at once. These facts further emphasize the importance of care in starting, running and stopping the separator. The machine should be started up slowly and run with a uniform pressure of the hand and should be stopped gradually.

The crank shaft of most hand separators now on the market is provided with a ratchet, which allows the unhindered continuation of the revolution of the bowl when the crank shaft stops, and therefore guards against shocks due to sudden stopping of the crank. However, some machines are equipped with bowl brakes which, if used at all, should be applied gradually, so as to prevent injury and excessive wear on the gearing mechanism.

Another important part of the mechanism efficiency and durability of the separator is the lubricating arrangement and its management.

Systems of Oiling.—The cream separator is a highly specialized piece of farm machinery. Its mechanical parts are comparatively delicate, its bowl revolves at a high speed, and the operation of the machine is usually continuous for at least an hour and often for a much longer period. These facts obviously render the system of oiling a very important part of the machine and its operation. Absence of a proper and adequate system of oiling may cause undue friction on the wearing parts, resulting in misalignment and damage to the separator and unsatisfactory results of its operation.

There are in use principally three systems of oiling, they are the "splash-oiling system," the "sight-feed cup oiling system" and the "open-hole oiling system." They vary in their application with the different makes of separators. Obviously that system is the best which is most nearly automatic, removes the sediment without permitting it to recirculate, and economizes oil.

In "the flash-oiling system" the gears and wearing parts are partly submerged in the oil, the oil usually being splashed by the lowest gear over the others and over the other wearing parts of the separator. In some separators provisions are made in the gear chamber for the draining of the grit and dirt, so that clean oil, only, circulates over the wearing parts. Lamson[1] who made an extensive study of the construction of separators recommends that when this system is used, the gear chamber be frequently drained, using the waste oil for coarser farm machinery and that this chamber be flushed out with kerosene to remove sediment. The "splash-oiling system" is completely automatic in its operation.

The "sight-feed cup oiling system" depends for its efficiency in continuously oiling the friction parts, on being so adjusted as to feed the oil slowly and on being kept filled. In its operation care is required to keep the feed tubes open and free from clogging, which is prone to occur in cold weather when the oil becomes abnormally viscous or congeals entirely. This oiling system may be considered semi-automatic.

The "open-oil-hole system" is obviously the crudest form of oiling the cream separator. It requires constant attention while the separator is used. Its lubrication is not uniform, it wastes oil, is mussy and the holes are prone to become clogged with dirt, waste and other obstructions.

Power Requirements of Cream Separators.—The amount of power required to drive a separator at the requisite speed obviously varies with the capacity of the machine. It also varies with machines of the same capacity but of different makes, and there is a considerable difference between the power required

[1] Lamson.—A Study of Farm Separators. M. S. A. Thesis, Purdue University, 1918.

when empty and when loaded. The state of repair and kind of oil used and efficiency of oiling are further factors which bear on the ease of running.

Factory separators of a capacity about 5000 pounds per hour, when loaded require about 2 H. P. at the start and until full speed is attained. After that, from seven-eighths to one H. P. is sufficient to maintain full speed. Farm separators of the usual capacity of about 350 to 500 pounds per hour require approximately from .063 to .16 H. P. when loaded. Lamson[1] determined the relative Horse power required of twelve different farm separators, when empty and when loaded. He used for his determinations a Torsion dynamometer, designed, built and perfected at Purdue University, but instead of running milk through the separator in his trials with the loaded machine, he used salt brine, having a specific gravity of 1.032 at 60° F. His results are shown in table 5.

Table 5.—Horse Power Required to Drive Empty and Loaded Farm Cream Separators and Ratio of Power Required to Drive Empty to that of Loaded Separators.

Name of Separators	No.	Crank R. P. M. Speed of	Horse Power		Ratio of Power to Drive Empty to Loaded
			Empty	Loaded	
De Laval	12	60	.0362	.0636	1 : 1.757
Economy King ..	4	60	.0335	.0656	1 : 1.958
New Butterfly ..	4½	50	.0365	0.715	1 : 1.959
John M. Smythe.	4	60	.0353	.0726	1 : 2.057
Dairy Queen	5	60	.0366	.0757	1 : 2.068
Primrose	2	60	.0496	.0760	1 : 1.532
Sharples	4	45	.0682	.0880	1 : 1.276
Galloway	7	50	.0373	.0881	1 : 2.362
Renfrew	6	60	.0487	.1015	1 : 2.084
United States ...	16	60	.0538	.1035	1 : 1.924
Anker-Holth	5	60	.0371	.1060	1 : 2.857
Iowa	30	60	.1215	.1624	1 : 1.337
Average		57	.0495	.0895	1 : 1.808

[1] Lamson.—A Study of Farm Separators. M. S. A. Thesis, Purdue University, 1918.

The Capacity of the Cream Separator.—By the capacity of the cream separator is understood the amount of milk the machine will skim per hour. Every cream separator is rated at a definite capacity; that is, it is built to separate a certain specified amount of milk in a given length of time. The farm separators range in capacity from about 150 to 1,200 pounds of milk per hour. For dairies with five to six cows a 350 to 400 pound capacity machine is recommended. The capacity of factory machines ranges from about 1,200 to 10,000 pounds of milk per hour.

The capacity of the separator must have a definite relation to the centrifugal force, if the machine is to do efficient skimming. An increase in the capacity, of any given separator, hastens the passage of the milk through the bowl and shortens the time during which it is subjected to the centrifugal force. The maximum capacity of a separator should, therefore, not exceed the amount of milk which can be efficiently skimmed in an hour. Greater capacity, without also increasing the centrifugal force, overtaxes the separating ability of the machine and causes excessive loss of fat.

Theoretically, the size of the skim milk and cream outlets of the bowl obviously influence the capacity of the separator, for the larger these outlets, the more milk the separator is capable of taking in. If the bowl were not in motion and the discharge of skim milk and cream were depending only on the mechanical overflowing of these parts, this hypothesis would be correct. In this case these parts would be completely filled.

But when the bowl is in motion such is not the case, the increased rapidity of the discharge due to the centrifugal force generated in the revolving bowl, greatly augments the capacity of the discharge parts, so that the skim milk and cream outlets are not completely filled and do at no time discharge skim milk and cream in accordance with their full capacity. This fact has been conclusively demonstrated by Eckles & Wayman,[1] who found that, under normal conditions, the skim milk tube does not run much over one half of its actual capacity.

For this reason it is obvious, also, that a change in the pro-

[1] Eckles & Wayman.—Factors Affecting the Per Cent of Fat in Cream from Farm Separators. Missouri Bull. No. 94, 1911.

portionate amount of skim milk and cream delivered, as caused by a change in the position of the skim milk or cream screw, does not affect the capacity of the separator. The richness of the cream delivered, therefore, has no material effect on the capacity of the separator.

The capacity of the separator is naturally directly affected by the rate of inflow. When the rate of inflow drops below the designated capacity, less milk flows through the separator and more time is required to separate a given amount of milk. When the rate of inflow is increased beyond the designated capacity, more milk flows through the separator than its capacity calls for and less time is required to separate a given amount of milk. This latter fact is possible only because the skim milk and cream outlets are not filled to full capacity when the separator is operated under normal conditions. Hunziker[1] shows that the same volume of milk that under normal inflow required 7 minutes for separation, required 11 minutes in the case of a reduced inflow and 6 minutes in the case of an increased inflow. The reduced inflow did not affect the skimming efficiency, while the excessive inflow caused a greater loss of fat in the skim milk.

The speed of the separator exerts a powerful influence on the capacity of the machine. The speed generates the centrifugal force which expels the skim milk and cream through their respective outlets with great force. The greater the speed and, therefore, the greater the centrifugal force, the more rapid the exit of skim milk and cream and the greater the capacity of the separator. Hunziker[1] shows that, when at normal speed, it required 5 minutes to separate a given volume of milk, the same volume required 9.6 minutes at a speed reduced 25 turns of the crank below normal and it required only 3.3 minutes at a speed increased 15 turns of the crank above normal. The decreased speed lowered the skimming efficiency while the excessive speed very slightly increased it.

The state of cleanliness of the separator may affect the capacity of the machine to a considerable extent and, in the case of extremely bad condition, may clog the machine entirely.

[1] **Hunziker.—Why Cream Tests Vary. Purdue Bulletin No. 150, 1911.**

The formation of a wall of separator slime on the bowl wall reduces the diameter and thereby diminishes the centrifugal force, which, in turn, decreases the rapidity with which the milk passes through and out of the machine. The accumulation of foreign matter and clots also tend to diminish the size of the outlets and partly block the passage of skim milk and cream.

CONDITIONS AFFECTING THE SKIMMING EFFICIENCY OF THE SEPARATOR.

The exclusive purpose for which the cream separator has been devised is to skim milk. In its construction, efficiency to skim close was the dominant aim. This skimming efficiency has been accomplished to a very marked degree, removing from 96 to 98 per cent of the fat of the milk and leaving in the skim milk less than .1 per cent fat under normal conditions. Experiments with the farm separator have shown even greater skimming efficiency when operated under proper conditions.

In order to accomplish high skimming efficiency and to leave the minimum amount of fat in the skim milk, the machine must be operated properly and in accordance with the directions furnished by the manufacturer. The chief factors which control the skimming efficiency of the cream separator are: Speed of machine, rate of milk inflow and temperature of milk. In addition to these fundamental factors, other conditions such as adjustment of cream screw, smoothness of running, cleanliness of separator bowl and condition of milk, may influence to some extent the per cent fat lost in the skim milk.

Effect of Speed of Separator on Skimming Efficiency.—The speed of the revolving bowl generates the centrifugal force which causes the separation of the liquids of different specific gravities, it separates the fat from the skim milk, causing the separator to discharge cream and skim milk.

The higher the speed, the greater is the centrifugal force and, other conditions remaining the same, the more complete is the separation. Every cream separator has a given, rated speed at which it will do its most efficient work. If the speed is reduced below that required, the skimming efficiency will be lessened and more fat is lost in the skim milk. Nothing is gained by running the machine faster than the required speed; excessive speed does not materially increase the skimming efficiency; on the other hand it augments the pressure on the bowl and on other parts of the separator, and beyond certain limits the bowl may collapse, or it may jump the castings, or it may increase the friction sufficiently to cause the spindle and the bearings and bushings to heat and wedge, in which case the bowl may come to a sudden stop warping the spindle. For these reasons each machine is accompanied by directions in which the proper speed of the separator is specifically stated.

The speed of the bowl varies considerably with different makes of separators. Since, at a given speed, the centrifugal force increases with the increase of the diameter of the bowl, separators with wide bowls do not require as high a speed to develop the desired separating efficiency as separators with a narrow bowl. Thus the relatively large-diameter bowls of the De Laval type require only from five to six thousand revolutions per minute, while separators with bowls of the tubular type, long and narrow, must be run at about 17,000 revolutions per minute.

In the case of the hand separator the proper speed is given in terms of number of turns of the crank. This varies with different machines from 45 to 60 turns per minute. The exact number of turns required is usually indicated on the crank of the separator.

When the proper speed has been attained it should be maintained uniformly throughout the separation. Running the separator at uneven speed causes incomplete separation.

Control of Speed of the Separator.—In the case of the hand separator, as used on the farm, the operator can make sure of giving the separator the proper speed by timing himself. All he has to do is to count the turns of the crank per minute, by the watch in his hand. By doing this occasionally he soon learns the necessary rapidity of motion to run the machine at full speed. Unfortunately this is not usually done and experience has amply shown that the general tendency of the operator is to overestimate the amount of work he puts into the machine, causing the separator to be run at too low a speed, thereby not getting out of the milk all the available fat. This is particularly true where different persons operate the same machine, but even the same operator, unless he times himself, may soon get in the habit of running the machine too slowly.

The metronome, which can be set to tick the exact number of turns required per minute is a very useful instrument to keep up the speed of the separator.

Some separators have a bell attachment striking the required number of revolutions per minute when the separator runs full speed.

The gyrometer is another separator speed indicator which is extensively used in European machines. It consists of a graduated glass tube, partly filled with glycerin and closed at both ends. It is either directly or indirectly connected with the spindle of the bowl, so that it revolves with the spindle. When revolving, the glycerin, acted upon by the centrifugal force, recedes from the center, rises along the walls of the tube and forms a funnel of air in the center, the length of which bears a definite relation to the speed of the machine. A graduation on the tube extending from top to bottom, shows the number of revolutions of the bowl at different lenghts of the air funnel.

In more recent years in this country numerous types of speed indicators, attached to the machine and operating on a principle similar to that of the speedometers used on automobiles, have been devised and are in more or less general use. One of the more recent ideas of speed indicator is a combination of speed governor and controller of the rate of inflow of the milk. Its fundamental idea is to reduce the milk inlet as the speed of the machine drops below normal, and thereby automatically maintain the skimming efficiency at a speed below normal, the decreased skimming efficiency of the lower speed being offset by the increased skimming efficiency of the reduced milk inflow.

The principle of regulating the rate of inflow by the speed and thus maintaining the skimming efficiency at a reduced speed has been applied in the case of the Sharples Tubular separator. In the latest models of this machine the rate of inflow is dependent on the suction generated by the revolving bowl. The higher the speed the greater the suction and the larger the milk inflow and vice versa. This principle applies within reasonable limits of speed. When the speed drops below the normal limit the skimming efficiency is jeopardized.

Some of the latest models of steam turbine-driven machines provide for a steam governor, similar to that used on high-class steam engines, insuring an even speed for turbine-driven machines. This principle has been applied in the case of the De Laval Turbine separator.

The automatic speed indicators are particularly valuable in the operation of the hand separator on the farm. Experiments conducted at the Purdue University Agricultural Experiment Station[1] show that the loss of fat in the skim milk, through the failure of the man behind the crank to run the separator at full speed, is often very great.

Table 6.—Effect of Speed on the Skimming Efficiency of the Separator.

Trial No.	Revolutions of Separator Crank							
	10-15 too High		Normal		10-15 too Low		20-30 too Low	
	Per cent of Fat		Per cent of Fat		Per cent of Fat		Per cent of Fat	
	Cream	Skim Milk	Cream	Skim Milk	Cream	Skim Milk	Cream	Skim Milk
1	32.	.02	28.	.02	23.	.095	20.	.135
2	28.	.02	24.5	.02	21.	.14	18.5	.38
3	24.	.03	21.	.04	19.	.115	17.	.15
4	32.	.03	29.	.035	26.	.14	22.	.20
5	28.	.03	26.	.03	24.	.15	20.	.34
6	30.	.04	27.5	.035	24.5	.16	22.	.37
7	48.	.03	42.	.03	36.	.10	34.	.14
8	32.	.03	28.	.025	25.	.11	23.	.14
9	33.	.02	28.	.02	25.	.105	24.	.18
10	33.	.035	28.	.035	27.	.11	23.	.16
11	32.	.03	28.	.03	27.	.11	25.	.155
12	34.	.03	32.	.03	36.	.13	30.	.19
Average..	32.	.029	28.5	.029	26.	.12	23.	.21

[1] Hunziker.—The Hand Separator and the Gravity Systems of Creaming. Purdue Bulletin No. 116, 1906.
Hunziker.—Why Cream Tests Vary. Purdue Bulletin No. 150, 1911.

The accompanying figures show that in the case of a cow producing 6,000 pounds of milk per year and yielding 5,100 pounds of skim milk the loss of butter per cow per year would be 12.85 pounds which at 45 cents per pound would amount to $5.78. This illustration amply demonstrates that the dairy farmer cannot afford to ignore the speed of the separator and should, for his own protection, use some reliable means to insure the proper speed of his machine.

It is obvious that proper attention to the speed of the separator is equally necessary in the factory, particularly when steam turbine separators are used. Especially in small plants with small boiler capacity, the steam pressure is prone to vary and this in turn causes the turbine separator to run irregularly. Excessive speed due to high steam pressure is usually guarded against by the installation of a blow-off valve. In the case of belt-driven machines, the speed is usually more uniform, provided that the engine is equipped with an efficient governor, is running at a uniform stroke and the slipping of belts is avoided.

Effect of Rate of Inflow on Skimming Efficiency of the Separator.—The rate of inflow has a very marked influence on the completeness of the separation. The capacity rated by the manufacturer of the machine is supposed to represent the maximum amount of milk which will insure complete separation. If the rate of inflow is forced beyond the specified capacity of the separator, the skimming efficiency decreases. This is due to the fact that the milk passes through the separator so rapidly that it is not exposed to the centrifugal force long enough to undergo complete separation.

A reduction below capacity of the amount of milk passing through the separator is of no special advantage; it fails to appreciably increase the skimming efficiency and it prolongs the process of separation. These facts were experimentally demonstrated by the Purdue Agricultural Experiment Station,[1] as shown in the following table.

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[1] Hunziker.—The Hand Separator and the Gravity Systems of Creaming. Purdue Bulletin No. 116, 1906.

Table 7.—Effect of the Rate of Inflow on the Per Cent of Fat in Skim Milk.

	Large Inflow		Normal Inflow		Small Inflow	
	Per cent of Fat		Per cent of Fat		Per cent of Fat	
	Cream	Skim Milk	Cream	Skim Milk	Cream	Skim Milk
	22.	.155			30.5	.025
	23.	.165	28.	.025	31.	.02
	22.5	.13	28.	.02	28.	.02
	22.	.14	28.	.035	28.	.03
	24.	.15	28.	.03	31.5	.03
	26.	.13	32.	.03	32.	.035
Average	23.	.145	29.	.028	30.	.027

These facts emphasize the importance of properly controlling the rate of inflow of the cream separator, in order to reduce the amount of fat in the skim milk to the minimum.

Control of Rate of Inflow.—The inflow of milk to the separator may be regulated by various contrivances used with hand and power machines. The most common regulator in use consists of the so-called float which operates in the receiving cup, or milk reservoir, located directly over the bowl. The float is a hollow tin body usually carrying on its upper side a vertical projection. When too much milk flows into the bowl the receiving cup fills up, the float rises and its vertical projection runs into the faucet of the milk supply tank shutting off some of the milk. In the meantime the milk in the reservoir cup recedes, and the float drops back permitting more milk to flow into the bowl. In the Sharples Tubular separator the rate of inflow is regulated, within certain limits, by the speed of the bowl as previously explained.

The rate of inflow is affected to an appreciable extent by the depth of the milk in the supply tank. The fuller the milk supply tank the greater the pressure of the milk on the float and the more milk will flow into the bowl. In the case of the farm separator, properly operated, variations in the rate of inflow caused by variations in the fullness of the supply tank are not sufficient to seriously influence the skimming efficiency, but they may cause an appreciable effect on the richness of the cream. Undue crowding of the machine and of sacrificing skimming efficiency due to the pressure of the milk above the bowl frequently occurs however, when the separator is fed direct from a vat or tank, through a faucet, as is often the case in the factory, when the supply vat may be located at a considerable elevation above the separator, or possibly on the second floor.

Effect of Temperature of Milk on Skimming Efficiency.—Exhaustive skimming requires the temperature of the milk to be near that of the animal body. There is not much difference in the skimming efficiency between 80 and 100 degrees F. but when the temperature drops to 70 degrees F. or lower, there is a decided, excessive loss of butter fat in the skim milk.

This phenomenon is probably largely due to the increase in the viscosity of the milk as the temperature drops. The warmer the milk the more fluid it is and the greater the freedom with which the fat globules can move about. The more fluid the milk the more complete is the separation. With a lowering of the temperature the milk becomes less fluid, its viscosity becomes greater, the fat globules find more resistance and do not respond to the centrifugal force as readily.

Table 8.—Effect of Different Temperatures on the Per Cent of Fat in Skim Milk.

	90 Degrees F.				75 Degrees F.				60 Degrees F.			
	Milk				Milk				Milk			
	Lbs.	% Fat	Cream % Fat	Skim Milk % Fat	Lbs.	% Fat	Cream % Fat	Skim Milk % Fat	Lbs.	% Fat	Cream % Fat	Skim Milk % Fat
1	51	4.1	30.	.02	51	4.1	31.	.04	48	4.1	50.5	.11
2	48	4.4	25.	.02	46	4.4	26.	.05	45	4.4	28.	.10
3	51	3.4	34.	.02	51	3.4	34.	.05	46	3.4	38.	.09
4	50	3.4	24.	.01	50	3.4	25.	.04	50	3.4	38.	.12
5	50	4.2	27.	.03	50	4.2	30.	.05	50	4.2	40.	.20
6	50	4.4	23.5	.04	50	4.4	24.	.07	50	4.4	25.	.12
7	50	4.0	30.	.02	50	4.0	31.	.05	48	4.0	34.	.09
8	50	4.2	25.	.02	51	4.2	27.	.06	48	4.2	40.	.14
Average.				.022				.051				.12

The relative effect of different temperatures of the milk at the time of separation on the per cent of fat left in the skim milk from various makes of hand separators is shown in table 8.

Similar results were obtained by Eckles and Wayman[1] and by Guthrie.[2]

At a temperature below 70 degrees F. most separators began to clog, due to the excessive viscosity and the tendency of the milk and cream to churn.

Control of Temperature of milk.—On the farm the simplest way to have the milk at the right temperature for separation. is to separate immediately after each milking. This practice does away with the bother of artificially heating of the milk before separating, for which the average farm is not properly equipped and which would be necessary, especially in winter, if the milk were held over for separation from the previous milking or previous day.

In the factory, however, where the milk arrives already cooled, special provision is required to heat the milk to the proper temperature (95 to 100 degrees F.) before it passes into the separator. This is most easily accomplished by the use of a continuous milk heater similar to a flash pasteurizer. In some creameries which receive whole milk, the milk is heated to pasteurizing temperature preparatory to separation. This has the advantage of pasteurizing not only the cream but also the skim milk. From the stand point of skimming efficiency, however, nothing is gained by this practice. The fat lost in the skim milk by separating the milk at temperatures of 145 to 185 degrees F. is practically equal to that lost when separating at 95 to 100 degrees F. Experience has further shown that the separator is more prone to clog with milk at pasteurizing temperature and has to be taken apart oftener for cleansing. This hot milk deposits more separator slime. Additional disadvantages of pasteurizing the milk before separation, instead of pasteurizing the cream are, the greater cost of the pasteurizing equipment and the greater expense of heating.

[1] Eckles & Wayman.—Factors Affecting the Per Cent of Fat in Cream from Farm Separators. Missouri Bulletin No. 94, 1911.

[2] Guthrie.—Variations in the Tests for Fat in Cream and in Skimmed Milk. Cornell Bulletin No. 360, 1915.

The skim milk can be pasteurized more economically separately by the use of exhaust steam. In order to accomplish exhaustive skimming of cold milk heated to the desired temperature for separation, the milk must be held at that temperature for a reasonable length of time so as to give the fat globules a chance to warm and expand and thereby to regain their buoyancy.

In some factories the milk is heated without the use of a special heater, but by turning steam direct into the milk. Experience has shown this to be a very undesirable practice. At best, much of the steam used condenses in the milk, diluting the milk and the skim milk. Then, again, the steam is often associated with impurities, such as cylinder oil from the engine, boiler compounds used in the boiler, scales from the inside of the steam pipes, etc. The turning of steam direct into the milk has also been found to be injurious to the quality of the finished product causing both the cream and the butter to take on an oily flavor.

Effect of Position of Cream or Skim Milk Screw on the Skimming Efficiency of the Separator.—As already explained, the purpose of the cream screw, or skim milk screw, is to regulate the ratio of cream to skim milk and to control the richness of the cream. Most makes of separators permit of a rather wide range of fat content in cream, without sacrificing their skimming efficiency. Some machines, however, when they are so adjusted as to produce cream testing below 18 per cent fat or above 50 per cent fat, skim less completely. In the case of some machines, especially those with relatively narrow bowls, there is a tendency for the bowl to clog, when attempts are made to produce cream testing 50 per cent fat or more.

Generally speaking, it is safe to state that the machines now on the market have reached such a degree of perfection that they can be depended on to do close skimming when set to produce cream containing not less than 18 per cent fat, nor more than 50 per cent fat. This range of richness is sufficient to embrace cream of any richness commercially advantageous.

Effect of Smoothness of Running on the Skimming Efficiency of the Separator.—The separator cannot be expected to do efficient work unless it runs smoothly. When the bowl revolves smoothly and without jarring, the skim milk and cream separated by the centrifugal force thus generated, escape from the machine separately. If the machine trembles and jars, a portion of the cream and skim milk may again become mixed by the vibration of the bowl, causing a relatively large amount of fat to escape with the skim milk and thus reducing the skimming efficiency of the separator. This fact is shown in the following table which summarizes the results of experiments conducted by Hunziker, with smoothly running and trembling machines.

Table 9.—Relative Skimming Efficiency of a Balanced and Unbalanced Separator.

Balanced		Unbalanced	
Cream Per cent Fat	Skim Milk Per cent Fat	Cream Per cent Fat	Skim Milk Per cent Fat
42.	.03	25.	.15
28.	.025	30.	.17
28.	.02	31.	.18
28.	.035	28.	.16
28.	.03	28.	.155
32.	.03	30.	.19
Average	.03		.17

The trembling of the bowl may be due to any one or more of the following conditions: Shaky foundation, machine not setting level, spindle sprung, internal contrivances of bowl damaged or not properly placed or incomplete, worn-out bearings, loose bushings, excessive speed.

The separator should rest on a solid foundation. For farm separators a solid plank floor is adequate, for factory machines a concrete, brick or stone base is preferable. The foundation must be level, though the newer machines with self-balancing bowls minimize the undesirable effect of machines not setting quite level. The separator, while it should be fastened securely to its foundation, should not be screwed down too rigidly for smooth running. A certain amount of "give", or "resonance" is necessary in order to insure smooth running. For this purpose it is advisable to place rubber cushions between the separator base and its foundation. The spindle must be true, the bearings and bushings intact and the internal contrivances of the bowl must be undamaged and in their respective places. The bearings must be fed with oil continuously, must be protected against dust and other material increasing friction, and the bowl and internal contrivances must be handled with care, to prevent damage which would cause to throw the machine out of balance.

Effect of Cleanliness of Separator on Skimming Efficiency.—Milk, even in its best condition, contains a certain amount of impurities such as dirt, dust and other foreign matter gaining access to it during its production. This, together with particles of viscous nitrogenous matter naturally present in milk,

Table 10.—Showing the Effect of Clean and Unclean Separators on the Per Cent of Fat in the Skim Milk.

Machines Cleaned After Each Separation Per cent Fat in Skim Milk	Machines Cleaned Once per Day Per cent Fat in Skim Milk
.03	.02
.03	.03
.03	.03
.02	.02
.04	.02
.03	.02
.02	.31
.03	.15
.11	.72
.03	.06
.06	.03
.04	.02
.02	.04
.05	.03
.02	.03
.05	.26
.02	.23
.02	.12
.02	.03
.02	.02
.05	.02
.02	.02
.03	.07
Average ...... .034	.10

collects in the separator bowl, forming the so-called separator slime. It is deposited largely on the walls of the bowl and between the internal contrivances.

This slime also impedes the free passage of the milk and cream within the bowl, thereby reducing the diameter, centrifugal force and capacity of the bowl, lowering its skimming efficiency and causing excessive loss of fat. This loss is greatest with milk in poor physical condition. The results of experiments[1] with clean and unclean separators are shown in Table 10.

Guthrie[2] found that, within reasonable limits, deposits of separator slime in the bowl do not materially interfere with the skimming efficiency of the machine. He concludes that only when the bowl fills up with separator slime to the extent of clogging the passages, does the efficiency of separation suffer.

In his tests, Guthrie used from 240 to 320 pounds of milk only per test. He does not state the rated capacity of the separator. It is probable, therefore, that in these experiments the amount of milk used was too small and the amount of separator slime centrifuged out too limited to materially affect the diameter of the bowl and the centrifugal force.

In commercial separation of the milk, where the separator often is in continuous operation for several hours, the accumulation of separator slime is frequently very great and this in turn is bound to seriously diminish the skimming efficiency of the machine.

Effect of Condition of Milk on Skimming Efficiency of the Separator.—Milk in poor mechanical and physical condition, such as milk containing a relatively large amount of impurities, or milk, which is old and partly sour or curdy, tends to lower the skimming efficiency, largely because it augments the amount of separator slime which collects in the bowl; this in turn impedes the free passage of milk and cream and causes excessive loss of fat.

If the milk is curdy the danger of incomplete separation is augmented by the fact that each particle of curd locks up a small amount of fat, and the curd passing into the skim milk

[1] Hunziker.—The Hand Separator and the Gravity Systems of Creaming. Purdue Bulletin No. 116, 1906.

[2] Guthrie.—Variations in the Tests for Fat in Cream and Skimmed Milk. Cornell Bulletin No. 360, 1915.

on account of its greater specific gravity, carries this fat with it. If it is necessary to run curdy milk through the separator, the milk should be poured from one can to another, or stirred, sufficiently to break up the curd as finely as possible.

Milk in poor condition is very prone to cause the bowl to clog. If such milk must be separated it is advisable to slightly underfeed the separator.

CONDITIONS AFFECTING THE RICHNESS OF CREAM.

It is desirable and important, for more reasons than one, that means and methods be used whereby the per cent of fat in cream can be properly controlled. The creamery, in order to utilize its cream satisfactorily and economically, for sale or for manufacture, requires cream of suitable richness for each specific commercial purpose. For buttermaking, cream testing 30 to 35 per cent fat is most desirable. Such cream makes possible easy handling, it minimizes injury to the fat during pasteurization, and permits of the use of a liberal amount of starter without excessive dilution. Excessively low testing cream sours and spoils more readily than richer cream, so that by the time it reaches the creamery, thin cream is often in a condition unfit to be made into good butter. In this sour and curdy condition accurate sampling and testing is rendered difficult, if it is at all possible. Thin cream is undesirable further, because it diminishes the amount of skim milk available for the feeding of calves and pigs on the farm; it increases the cost of transportation of every pound of butter fat so shipped or hauled; it makes impractical the use of a reasonable amount of starter in the creamery, and starter is essential for the development of a pleasing high flavor of butter; it does not churn out exhaustively and yields an excessive amount of buttermilk, augmenting the loss of fat and thereby reducing the churn yield.

Excessively rich cream, such as cream testing above 45 per cent fat is also undesirable from the farmer's and the creamery's standpoint. Such cream tends to clog the separator; it renders the emptying of the cans exceedingly difficult, especially during cold weather; it makes difficult accurate sampling and thereby tends to yield incorrect tests; and it contains too small an amount of milk solids to properly protect the fat globules against mutilation and injury during pasteurization and churning. It is desirable to produce somewhat richer cream in summer than in winter to prevent excessive fermentation in summer and difficult handling in winter.

When a more exact per cent of fat is desired, as is the case of cream sold as sweet cream direct to the consumer, or used in the manufacture of ice cream, the definite richness is usually most conveniently secured by standardization of the cream after separation.

The knowledge and control of conditions which regulate the richness of the cream produced on the farm, is of unquestionable importance. The cream test reported by the creamery to its patrons is one of the guiding factors which sways the cream producer for or against the reporting creamery. There is no one factor, except possibly open dishonesty, that is so potent of disorganizing and demoralizing the cream supply territory of a creamery, as a repetition of changes in the reported cream tests of successive deliveries of cream from the same patron. This fact is largely due to the usual ignorance on the part of the average cream patron of the numerous conditions under his own control and not under the control of the creamery, which may cause the richness of the cream and, therefore, the test to vary and yet, when the tests do vary the producer is tempted to accuse the creamery of reporting incorrect tests and being unfair in its dealings.

In some cases these accusations are justified, but in the great majority of instances the variations in the tests are due to variations in the richness of the cream caused by irregularities incident to the operation of the farm separator. The following are the chief factors controlling the richness of the cream:

1. Position of cream screw or skim milk screw
2. Richness of milk

3. Speed of separator
4. Rate of inflow
5. Temperature of milk
6. Amount of water or skim milk used to flush the bowl
7. Cleanliness of separator bowl.

Effect of Cream Screw or Skim Milk Screw on Richness of Cream.—The relation of the position of the cream screw and skim milk screw to the proportion of cream to skim milk and to the richness of the cream has been previously discussed.

Fundamentally, any change in the separator which will alter the relative amounts of skim milk and cream will influence the per cent of fat in the cream.

These devices, the skim milk screw and the cream screw are very sensitive adjustments. Only a slight turn ($\frac{1}{4}$ turn) of the screw is sufficient to bring about a very appreciable change in the per cent of fat of the cream.

Effect of Richness of Milk on Richness of Cream.—The richness of the milk separated, directly influences the richness of the cream; in fact the per cent of fat in the cream stands in direct proportion to the per cent of fat in the milk separated.

With the cream screw set to deliver a certain definite richness of cream and all other conditions normal, the separator will deliver a definite ratio of skim milk to cream. This ratio varies with the adjustment of the cream screw or skim milk screw. For illustration, it is assumed that this ratio of skim milk to cream be 85 to 15, that is, that of each 100 pounds of milk separated, the separator discharges 85 pounds of skim milk and 15 pounds of cream. If all conditions are the same this ratio of skim milk to cream remains constant. Changes in the richness of the milk cannot alter it, no matter how rich or how poor the milk, each 100 pounds of milk will yield 85 pounds of skim milk and 15 pounds of cream. But since practically all of the fat goes into the cream, the cream from the separation of rich milk contains more fat than that from poor milk. This fact is graphically illustrated in Fig. 12.

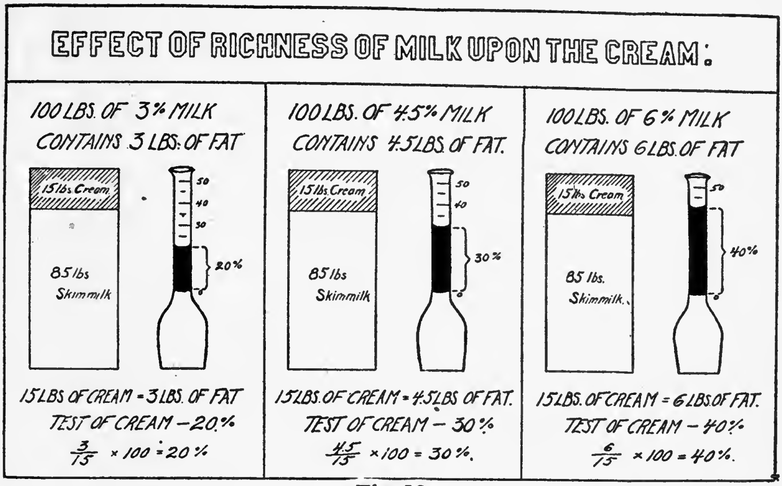

Fig. 12

Table 11.—Showing Effect of Richness of Milk on Richness of Cream.[1]

Experiment No.	Milk Lbs.	Milk Fat %	Milk Fat Lbs.	Time of Separation Min.	Cream Lbs.	Cream **Fat %**	Cream Fat Lbs.	Skim Milk Lbs.	Skim Milk Fat %	Skim Milk Fat Lbs.
				Milk Testing 3% Fat						
I.	50	3	1.5	7	6.25	**19**	1.18	45	.12	.054
II.	50	3	1.5	7	6.5	**20.5**	1.33	46	.03	.013
III. ...	50	3	1.5	7	6.5	**20.5**	1.33	46	.04	.018
Aver. .	50	3	1.5	7	6.42	**20**	1.28	46	.06	.028
				Milk Testing 4.5% Fat						
I.	50	4.5	2.25	7	6.25	**34**	2.12	45.5	.02	.01
II.	50	4.5	2.25	7	6.5	**32**	2.08	44.8	.1	.05
III. ...	50	4.5	2.25	7	6.25	**31.5**	1.96	44.7	.05	.02
Aver. .	50	4.5	2.25	7	6.3	**32.5**	2.05	45	.06	.03
				Milk Testing 6% Fat						
I.	50	6	3	7	6.5	**40.7**	2.65	44	.12	.052
II.	50	6	3	7	6.5	**40**	2.6	44	.10	.044
III. ...	50	6	3	7	6.5	**36**	2.34	44	.2	.088
Aver. .	50	6	3	7	6.5	**39**	2.53	44	.14	.061

The above illustration shows that with a ratio of skim milk to cream of 85 to 15 and all other conditions remaining con-

[1] **Hunziker.—Why Cream Tests Vary. Purdue Bulletin No. 150, 1911 and 1915.**

stant, three per cent milk produces 20 per cent cream, four and one-half per cent milk produces 30 per cent cream and six per cent milk produces 40 per cent cream. The correctness of this rule is further demonstrated by results of separator experiments conducted by the Purdue University Agricultural Experiment Station, as summarized in table 11.

Similar results were also obtained by Eckles and Wayman[1] and by Guthrie.[2]

It is further interesting to note that the difference in the richness of cream from milk of different per cents of fat increases as the ratio of skim milk to cream becomes wider. This rule is shown in the following figures.

Table 12.—Relation of Richness of Cream to Ratio of Skim Milk to Cream.

Ratio of Skim Milk to Cream	Per Cent Fat in Cream from		Difference in Per Cent Fat in Cream
	3 Per Cent Milk	6 Per Cent Milk	
80 to 20	15	30	15
85 to 15	20	40	20
90 to 10	30	60	30

The per cent of fat in the milk separated does not appreciably affect the skimming efficiency, the per cent of fat found in the skim milk from rich and poor milk being practically the same.

Effect of Speed of Separator on Richness of Cream.—The higher the speed of the separator the higher the per cent of fat in the cream. This rule applies in the case of most separators and under most conditions. The influence of the speed on the richness of the cream is largely due to the direct effect of the speed on the ratio of skim milk to cream.

The higher the speed the greater the centrifugal force and the more rapidly will the skim milk leave the bowl. An increase in speed therefore increases the capacity of the skim milk discharge. This means less milk for the cream outlet and consequently richer cream. A decrease in the speed lessens the

[1] Eckles and Wayman.—Factors Affecting the Per Cent of Fat in Cream from Farm Separators. Missouri Bulletin 94, 1911.
[2] Guthrie.—Variations in the Tests for Fat in Cream and in Skimmed Milk. Cornell Bulletin 360, 1915.

centrifugal force, retards the escape of the skim milk, reduces the capacity of the skim milk outlet and more milk has to be discharged through the cream outlet. The cream, therefore, is thinner. In the following table are summarized results of experiments[1] showing the effect of the speed of the separator on the richness of the cream.

Table 13.—Effect of Speed of Separator on Richness of Cream.

Experiment No.	Time of Separation Min.	Cream			Skim Milk		
		Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.
			Low Speed				
I.	9	9.5	11	1.05	40.3	2.8	1.1
II.	9	9.5	10	.95	39.6	2.9	1.15
III.	9	9.7	11.5	1.12	39.8	2.5	1
Average	9	9.6	10.8	1.04	39.9	2.73	1.08
			Normal Speed				
I.	5.5	5.2	41.5	2.17	44.8	.04	.02
II.	7	4.7	45	2.12	44.8	.07	.03
III.	7	5.1	40	2.04	44.5	.07	.03
Average	6.5	5	42.2	2.11	44.7	.06	.03
			High Speed				
I.	6	3.3	65.5	2.1	46.5	.01	
II.	6.5	3.5	59.5	2.08	45.9	.03	.01
III.	6.5	3.1	65	2.02	46.6	.06	.03
Average	6.33	3.3	62.7	2.07	46.3	.03	.01

These facts apply with all separators and under all conditions where the skim milk and cream exits are so adjusted that the skim milk outlet is farther from the center of the bowl than the cream outlet. This is the case with most separators and under most conditions.

Additional factors which may enter into the causes of richer cream, as the result of higher speed, are the reduced relative friction in the skim milk outlet, due to the larger volume of skim milk discharged and the increased relative friction in the cream outlet due to the greater viscosity of the richer cream. Furthermore, the more complete separation in the case of high speed may in part at least be conducive of richer cream.

[1] Hunziker.—Why Cream Tests Vary. Purdue Bulletin No. 150, 1911.

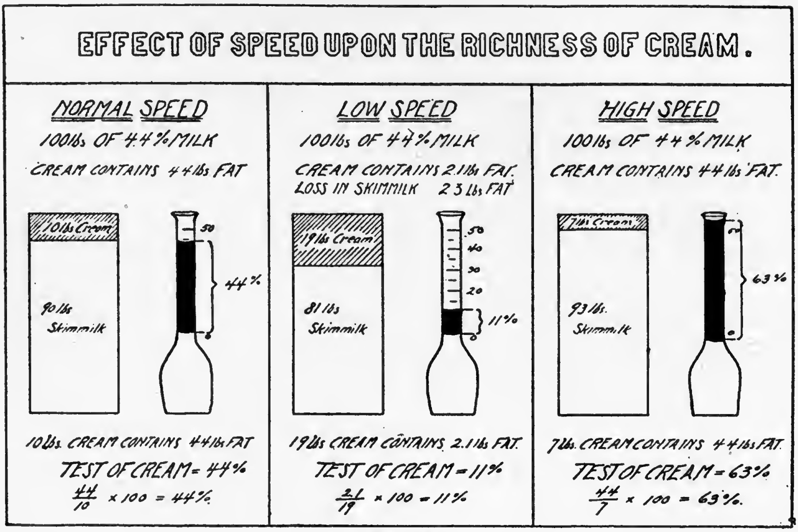

Fig. 13

However, the effect of the speed of the separator varies to some extent with the richness of the cream for which the separator is set. When set for rich cream there is a greater difference in the per cent of fat of the resulting cream between high speed and low speed than when set for thin cream. This is due to the fact that when the machine is adjusted to produce rich cream, the relative difference between the distance of the skim milk and cream outlets from the center of the bowl is proportionately greater, the proportion of skim milk discharged is larger, less milk is left to pass out with the cream, the cream is richer and the influence of the speed is greater than when the separator is set for thin cream. When set for thin cream the relative difference between the distance of the skim milk and cream outlets from the center is smaller, the effect of the speed on the capacity of the skim milk and cream discharge is more nearly equalized, causing less variation in the richness of the cream due to changes in speed.

In separators, or under conditions, causing the cream outlet to be located farther from the center than the skim milk outlet, a high speed will even yield less skim milk, more cream and thinner cream than a low speed. This is the case with the Simplex separator, for instance, when adjusted to produce thin cream, as shown in Table 14, representing results obtained by Eckles and Wayman.[1]

Table 14.—Effect of Speed. Simplex Separator No. 2 (1540).

Full speed ....50 revolutions of crank per minute.
Three-fourths speed ....37 revolutions of crank per minute.
Half speed ....25 revolutions of crank per minute.

Temperature uniformly 90°.

Trial No.	Speed	Kilograms	Kilograms of Skim Milk in 5 Min.	Total Kilograms Separated in 5 Min.	Proportion of Cream to Skim Milk.	Per Cent of Fat in Cream.	Per Cent of Fat in Skim Milk.	Per Cent of Fat in Whole Milk.
	Full Speed	3.126	16.684	19.810	1—5.33	31.3	.02	5.0
						31.3	.03	
17	Three-fourths Speed.	3.200	16.522	19.722	1—5.16	30.2	.06	5.0
						30.1	.06	
	Half Speed	3.128	16.532	19.660	1—5.29	29.0	.31	5.0
						28.9	.32	
	Full Speed	2.448	17.490	19.938	1—7.14	39.6	.03	5.1
						39.8	.03	
18	Three-fourths Speed.	2.708	16.896	19.604	1—6.23	35.4	.06	5.1
						35.6	.05	
	Half Speed	3.052	16.576	19.628	1—5.43	30.0	.20	5.1
						29.8	.23	
	Full Speed	4.238	15.645	19.883	1—3.69	21.4	.03	4.9
						21.4	.03	
19	Three-fourths Speed.	3.863	15.975	19.838	1—4.13	23.2	.07	4.9
						23.1	.07	
	Half Speed	3.206	16.433	19.639	1—5.11	26.8	.25	4.9
						26.8	.25	
	Full Speed	4.365	15.723	20.088	1—3.59	20.6	.03	4.8
						20.6	.03	
20	Three-fourths Speed.	3.975	15.969	19.944	1—4.03	22.2	.05	4.8
						22.2	.06	
	Half Speed	2.868	16.826	19.694	1—5.85	28.0	.36	4.8
						28.2	.36	

The above table shows that, while with rich cream the ratio of skim milk to cream and the per cent of fat in the cream decreased as the speed was reduced, with cream low in fat the

[1] Eckles and Wayman.—Factors Affecting the Per Cent of Fat in Cream from Farm Separators. Missouri Bulletin No. 94, 1911.

reverse was the case. As the speed was reduced the ratio of skim milk to cream and the per cent of fat in cream increased. These differences are due to the relative position of the skim milk and cream outlets.

Effect of Rate of Inflow on the Richness of the Cream.—The rate of inflow exerts a marked influence on the richness of the cream as shown in the table below.

Table 15.—Effect of Rate of Inflow on Richness of Cream.

Experiment No.	Milk			Time of Separation Min.	Cream			Skim Milk		
	Lbs.	Fat %	Fat Lbs.		Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.
Small Inflow										
I.	50	4.3	2.15	**11**	2.86	**70**	2.02	46.7	.05	.02
II.	50	4.4	2.2	**11**	3.12	**68**	2.12	46.4	.12	.06
III. ...	50	4.8	2.4	**12**	3.42	**71.5**	2.44	46.3	.08	.04
Aver. ..	50	4.5	2.25	**11.3**	3.13	**70**	2.19	46.5	.08	.04
Normal Inflow										
I.	50	4.3	2.15	**7**	5.5	**37.5**	2.06	44.2	.1	.04
II.	50	4.4	2.2	**7**	5.37	**40**	2.15	44.1	.05	.02
III. ...	50	3.8	2.4	**7**	4.37	**58.5**	2.55	45.5	.03	.01
Aver. ..	50	4.5	2.25	**7**	5.08	**44.3**	2.25	44.6	.06	.02
Large Inflow										
I.	50	4.3	2.15	**6**	4.5	**23.5**	1.06	45.1	.25	.11
II.	50	4.4	2.2	**6**	7.75	**26.5**	2.05	42.1	.27	.11
III.	50	4.8	2.4	**6**	4.86	**51.7**	2.51	44.7	.05	.02
Aver. ..	50	4.5	2.25	**6**	5.70	**32.8**	1.87	44	.19	.08

The results in table 15 show that the richness of the cream increases as the rate of inflow decreases and vice versa. This is due to the fact that when the rate of inflow increases the capacity of the cream outlet increases proportionately greater than the capacity of the skim milk outlet, while a decrease in the inflow causes a greater decrease in the capacity of the cream outlet than in that of the skim milk outlet. The average results of experiments with a small, normal and large inflow as tabulated above show the following proportion of cream to skim milk, Table 16.

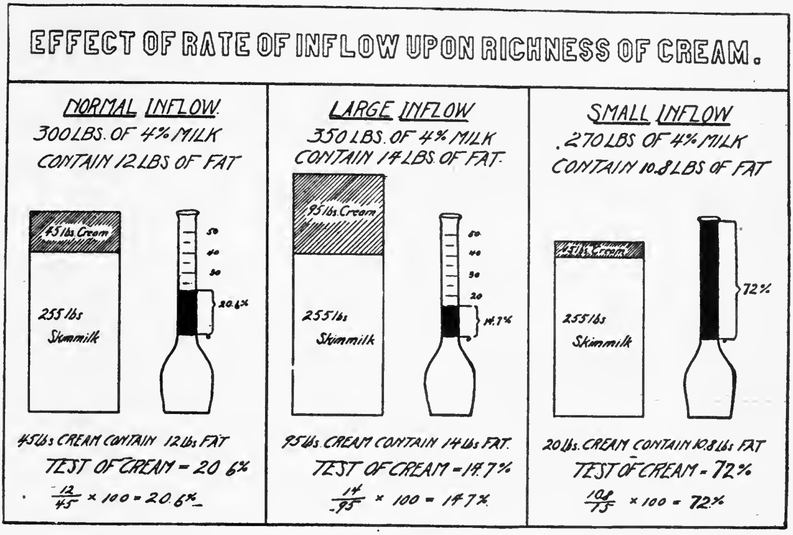

Fig. 14

Table 16.—Effect of Rate of Inflow on Ratio of Skim Milk to Cream.

Rate of Inflow	Cream		Skim Milk		Ratio of Cream to Skim Milk
	Lbs.	%	Lbs.	%	
50 lbs. in 11 Minutes	3.13	6.26	46.5	93	1: 14.86
50 lbs. in 7 Minutes.	5.08	10.16	44.6	89.2	1: 8.78
50 lbs. in 6 Minutes.	5.70	11.40	44.0	88.0	1: 7.72

It was formerly assumed that the skim milk discharge was constant and was not influenced by the rate of inflow and that all the additional milk of an increased inflow would escape through the cream discharge. The above experimental results show this to be erroneous. The skim milk discharge increased very materially with the increase in the rate of inflow as shown in Table 16 and in the following summary:[1]

[1] Hunziker.—Why Cream Tests Vary. Purdue Agr. Expt. Station. Bull. No. 150, 1911.

		Skim milk discharged per minute
Small inflow	$\frac{46.5}{11}$	.... 4.23 pounds
Normal inflow	$\frac{44.6}{7}$	.... 6.37 pounds
Large inflow	$\frac{44.0}{6}$	.... 7.33 pounds

Effect of Temperature of Milk on Richness of Cream.—The temperature of the milk influences the richness of the cream yielded by the separator to a marked degree.

Table 17.—Showing Effect of Temperature of Milk on Richness of Cream.[1]

Experiment No.	Time of Separation Min.	Milk			Cream			Skim Milk		
		Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.
Normal Temperature—90 to 95° F.										
I.	7	50	3.8	1.9	9	17.5	1.58	41	.03	.01
II	5	31.5	4.1	1.29	4.5	28	1.26	27	.03	.01
III.	8	50	4	2	9.7	20.5	2	40.9	.02	.01
IV.	8.5	50	4	2	10.1	20	2.02	39.8	.01	
V.	7.5	50	4	2	10.1	20	2.02	40.3	.01	
Aver. ..	7.2	46.3	3.98	1.84	8.68	21.2	1.78	37.8	.02	.01
Low Temperature—50 to 60° F.										
I.	9	50	3.8	1.9	2	32.5	.65	48	1.50	.72
II.	7	32	4.1	1.31	1.5	43	.65	28.5	2.10	.63
III.	7.5	50	4	2	7.2	27	1.94	43.6	.05	.02
IV.	7.5	50	4	2	7.3	28	2.04	44.3	.03	.01
V.	7.5	50	4	2	7.2	28	2.02	44.1	.05	.02
Aver. ..	7.6	46.4	3.98	1.84	5.04	31.7	1.46	41.7	.75	.28

The experimental results summarized in the above table show that cold milk yields richer cream than warm milk. The cream from the cold milk averaged 31.7 per cent fat, while the cream from milk separated at 90 to 95 degrees F. averaged 21.2 per cent fat. The difference would probably have been considerably greater, had it not been for the excessive loss of fat in the skim milk from the cold milk, which reduced the amount of fat supplying the cream discharge.

The cream from the cold milk is thicker and more viscous than that from the warm milk. This greater viscosity renders

[1] Hunziker, Why Cream Tests Vary, Purdue Bulletin 150, 1911.

it more sluggish in its escape from the bowl, it passes off more slowly, thereby decreasing the capacity of the cream outlet, and more of the milk is forced through the skim milk outlet.

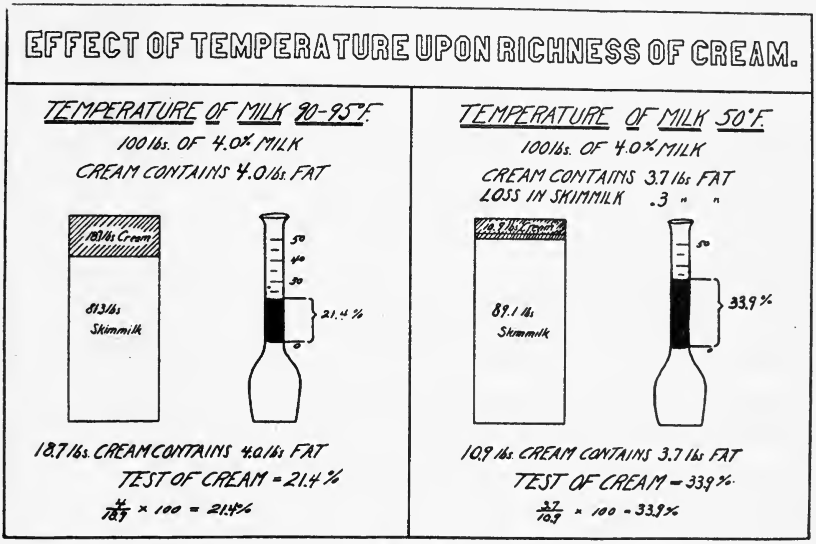

Fig. 15

The fact that the cold milk has a higher specific gravity than the warm milk may cause the skim milk to escape with slightly more force, thus further increasing the capacity of the skim milk outlet. It is not improbable, also, that the warm milk is sufficiently more fluid than the cold milk to increase the rate of inflow and thereby increase the relative volume of the cream discharge in greater proportion than the skim milk discharge. The results above recorded, however, fail to show a uniform increase in the rate of inflow of the warm milk; in fact in two out of five experiments the opposite was the case.

In the case of some separators the bowl commences to clog when cold milk is passed through the machine. When this happens the cream from the cold milk is usually thinner than that from the warm milk. A part of the butterfat in the bowl, churns into a roll of butter and only a small amount of cream is discharged and this cream is very low in butterfat. This phenomenon is shown in table 18.

Table 18.—Effect of Low Temperature of Milk on Richness of Cream when Bowl Clogs.[1]

Temperature	Time of Separation Min.	Milk			Cream			Skim Milk		
		Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.
95° F....	4	32	4.1	1.31	4.5	26	1.17	26	.03	.01
50° F....	7	30	4.1	1.23	1.5	12	.18	25	3.6	.90

As already stated in chapter on "Effect of Temperature of Milk on the Skimming Efficiency of the Separator," as far as the farm separator is concerned, the milk is in the best condition for separation in every respect, immediately after each milking. In the factory, facilities for heating the milk to and holding it at 90 degrees F. or over should be provided.

Effect of Amount of Water or Skim Milk used to Flush the Bowl on Richness of Cream.—While this is strictly a minor factor in the control of the richness of the cream, it should be understood that the indiscriminate flushing of the bowl may dilute the cream unnecessarily.

It is very desirable that the bowl be properly flushed after each separation. This removes most of the remnants of milk and cream, and loosens the separator slime in the bowl, making subsequent washing more easy. In order to accomplish this, all that is necessary is to run water into the bowl until the discharge spout appears watery.

Table 19.—Effect of Amount of Water Used to Flush the Bowl on the Richness of the Cream.[1]

Experiment No.	Amount Water Used to Flush Bowl			
	None	Same as Capacity of Bowl	Till Cream Discharge was Watery	Twice the Amt. Needed for Watery Cream Discharge
	Fat %	Fat %	Fat %	Fat %
I.	32	32	31	29
II.	30	30	29	28
III.	58	56	51	48
IV.	31	31	30	29
Average....	37.8	37.3	35	33.5

[1] Hunziker, Why Cream Tests Vary, Purdue Bulletin 150, 1911.

Effect of Slime in Bowl of Separator on Richness of Cream.—Experiments conducted by Guthrie and Supplee[1] show that deposits of slime in the bowl do not have any appreciable effect on the richness of the cream so long as the slime does not clog the passages.

Advantages of Centrifugal Separator over Gravity Creaming.

The operation of the centrifugal separator has undisputed advantages over the gravity systems of creaming. The chief of these are:

1. Greater skimming efficiency.
2. Richer cream.
3. Better quality of cream and skim milk
4. More uniform richness of cream

Greater Skimming Efficiency.—The centrifugal separator is the most efficient apparatus available for the separation of milk. Below table shows the relative skimming efficiency as secured experimentally.[2]

Table 20.—Per cent of Fat in Cream and Skim Milk of the Four Different Systems of Creaming under Most Favorable Conditions.

Hand Separator			Deep-Setting			Shallow Pan			Water-Dilution		
Milk Lbs.	Cream % Fat	Skim Milk % Fat	Milk Lbs.	Cream % Fat	Skim Milk % Fat	Milk Lbs.	Cream % Fat	Skim Milk % Fat	Milk Lbs.	Cream % Fat	Skim Milk % Fat
31	33.	.01	20	32.	.2	50	30.	.55	64	22.	.70
31	29.	.03	30	29.	.15	50	26.	.40	64	21.5	.68
40	34.	.01	27	27.	.16	52	31.	.38	60	25.	.70
34	30.	.02	30	30.	.18	48	32.	.42	60	26.	.60
35	32.	.02	28	32.	.18	50	26.	.46	56	25.5	.74
34	33.	.03	26	26.	.15	50	27.	.44	56	24.	.68
46	33.	.01	28	24.5	.17	52	25.	.48	60	31.	.72
38	30.	.02	25	28.	.15						
50	32.	.02	30	25.5	.18						
38	30.	.02	30	28.	.18						
38	28.	.02									
38	33.	.02									
Average		.02			.17			.44			.68

A glance at the above table reveals the superiority of the

[1] Guthrie and Supplee, Variations in the Tests for Fat in Cream and Skim Milk, Cornell Bulletin 360, 1915.

[2] Hunziker, The Hand Separator and the Gravity Systems of Creaming, Purdue Bulletin 116, 1906.

centrifugal separator over the gravity systems of creaming Even in the deep-setting system, which causes the least loss of fat in the skim milk of any of the gravity systems, the loss of fat is 8.5 times as great as that incurred with the centrifugal separator; the shallow pan and water dilution system lost 22 and 34 times, respectively, as much fat in the skim milk as the centrifugal separator.

The loss of butter fat with the gravity system of creaming would probably have been even greater, had an attempt been made to secure a richer cream. For buttermaking, cream containing from 30 to 35 per cent fat is most suitable. It is difficult, even under the best conditions, with the gravity systems, to produce cream testing 30 per cent fat, it is practically impossible to do so without a material increase in the per cent of fat lost in the skim milk.

Expressed in pounds of butter lost in the skim milk of one cow in one year, the loss assumes an importance which no progressive dairyman can afford to ignore. It is obvious that even at very moderate butter prices, the centrifugal separator in the skimming of the milk of a herd of 5 to 10 cows would save enough butterfat in less than two years to pay for itself, as shown in table 21. These figures are based on the assumption that each 100 pounds of milk yields 87 pounds of skim milk, that a 20 per cent overrun is secured and that butter sells at 50 cents per pound.

Table 21.—Loss Incurred by the Four Systems of Creaming at 50 Cents per Pound of Butter in One Year.

Cows	Milk	Value of Butter Lost by the Use of Different Methods of Creaming			
No.	Pounds	Hand Separator $	Deep Setting Method $	Shallow Pan Method $	Water Dilution Method $
1	5,000	.52	4.44	11.48	17.75
5	25,000	2.60	22.19	57.40	88.74
10	50,000	5.20	44.37	114.80	177.48

Better Quality and Richer Cream.—The centrifugal separator makes it possible for the creamery and for the dairy farmer to secure a pure, sweet and wholesome cream which can be made into a first class butter. In the whole milk creamery, where the buttermaker has exclusive control over the cream as soon as it leaves the separator, conditions are most ideal and the verdict of the butter markets of this country is proof of the fact that our best butter comes from the whole-milk creameries.

The cream that arrives at our gathered cream plants, as a general rule does not grade high enough to make "Extras." This fact is one of the main drawbacks of the gathered cream plant. While much of this cream is hand separator cream, the fault cannot be attributed to the separator. It is obvious that just as good cream can be produced by the use of the hand separator as with the factory machine. The fault lies not with the use, but with the abuse of the separator. When proper attention is given to cleanliness in the operation of the separator and the handling of the cream, to prompt cooling and to frequent delivery, the resulting cream is bound to be in proper condition to make good butter.

Not so, however, where the cream is separated by gravity. The gravity cream is to-day considered the scum of the raw material which the creameries receive. Creameries which practice systematic grading are generally forced to place gravity cream in their lowest grade and many creameries pay several cents less for such cream than for separator cream.

There are many reasons for the inferiority of gravity cream: It is usually old because time is required for setting. It is always relatively low in butter fat and this, together with its age, causes it under average conditions to be of very poor quality by the time it reaches the creamery. Its dilution deprives the buttermaker of the opportunity to improve it by the addition of starter. This thin cream yields a relatively large amount of buttermilk which in turn means heavy loss of fat. This loss is increased also by the fact that this thin cream, especially when pasteurized, does not churn out exhaustively and finally the cream, owing to its thinness and its usual contamination with undesirable ferments, deteriorates rapidly, yielding a low grade of butter.

CHAPTER VI.

RECEIVING MILK AND CREAM.

When the milk or cream is received by the creamery, or cream station and before it enters the manufacturing process, it is graded, weighed, sampled and "dumped" and the cans are washed, rinsed, steamed and dried and retagged preparatory to returning.

Grading of Cream, Importance.—From the standpoint of improving the quality of cream received by the creamery the use of an efficient system of cream grading is all important. Until recent years the cream grading has received very little attention by our creameries. Little, if any grading was done and the same price was paid for good and poor cream. This has resulted in a general depreciation of the quality of the cream furnished by the farmer, there was no material inducement to the farmer to make a special effort in the care of the cream on the farm. Unless his personal pride and decency prompted him to produce a clean, sanitary and properly cooled cream, he was all too ready to follow the line of the least resistance and pay no attention to the quality of the cream he furnished. In fact, the failure of the creamery to grade cream put a premium on shiftless and careless handling of cream on the farm and on the receipt of poor cream in the factory.

In consequence of this disregard for quality of raw material, much of the butter annually reaching the market was of unsatisfactory quality, the keeping property of much of this butter was inferior, causing it to come out of storage in deteriorated condition, large quantities of butter had to be sold under market quotations, inviting keen competition by foreign butter and butter substitutes and rendering the establishment of a reputation for American butter in foreign countries exceedingly slow and difficult.

Development of Cream Grading.—Within the last five to ten years, the pure food wave that has swept the country awakening the public to a keener appreciation of the value of wholesome food products of good quality, the realization on the part of the creamerymen of the necessity of supplying the market with bettter butter in order to dispose of it at a satisfactory margin, and the efforts of the dairy educational forces to introduce practical methods for the systematic grading of cream, have been mighty factors in focusing the attention of the creamerymen on improving their cream supply by cream grading and quality-paying.

The earlier efforts at cream grading were largely abortive. In isolated cases some concerns had the courage and determination to grade and pay on the basis of grade only. But the great majority of creameries, while acknowledging the fundamental correctness of cream grading, lacked the courage to undertake it. Their intentions foundered on the rock of competition in the cream supply territory. They lacked confidence in each other to stand by mutual agreements to start grading and quality-paying. They were fearful of losing patrons and of working into the hands of their competitors. Gentlemen's agreements, drafted in sectional and national conferences of creamerymen to grade cream proved futile. Attempts to place legislative measures on the statute books, requiring the grading of cream proved unconstitutional, and Government inspection of the creameries for the purpose of compelling nation-wide cream grading did not materialize because of the enormity of the proposed undertaking.

While most of these proposed and apparently ideal plans failed to materialize and were automatically abandoned, one after another, the constant agitation of the subject did not fail to have its good effect. While it became clear to all practical creamerymen that the industry was not ripe as yet for an organized state- or nation-wide plan of cream grading by mutual agreement between creameries, farsighted creamerymen realized that this complex and difficult matter was a problem to be solved independently by each individual creamery and that it was to the unquestioned advantage of each individual concern to introduce cream grading in their own plants.

Today most of the really progressive creameries, large and small, are grading their cream and many of these creameries pay the farmer on the basis of quality. Those who have taken this important step are already convinced of its permanent advantages and it is only a question of time when all creameries, for their own protection, will adopt a rational system of cream grading and paying on the basis of quality. They are bound to come to the inevitable conclusion that, in order to secure satisfactory returns from the market, they must furnish the market with good butter, that they cannot hold the patronage of the cream producer to furnish good cream unless they pay him a differential on the basis of quality, and that the paying of top prices for butterfat of poor quality must ultimately spell financial loss and ruin.

Methods of Grading.—One of the serious obstacles that has been responsible for much delay in the general adoption of grading cream has been the difficulty of doing this work correctly, and the absence of a method practical, rapid and applicable under average creamery conditions. Efforts to use chemical, physical or bacteriological tests that would yield results of specific description and that would make possible the expression of different grades in mathematical figures, have so far failed to solve this difficult problem of cream grading. Such tests as the acid test, the boiling test, the sediment test, the curd test, the fermentation test, the microscopic test, which have been in successful use in market milk plants and milk condenseries for years, were found either mechanically impractical with cream, or their results were unsuited for the proper classification of different grades of cream. The acid test is practically the only test that could be applied under average conditions of cream and creamery management. But its results too, lack conclusiveness, because they fail to furnish a correct index to the relative fitness of cream for buttermaking. While, generally speaking, sweet cream is preferable to sour cream, the acidity in cream is by no means the chief defect of cream of inferior quality. This test has therefore never been adopted for general use in creameries.

The really important characteristics of cream which determine its quality, are its odor and flavor and these can be determined successfully only by the senses of smell and taste. Efficient cream grading, therefore, of necessity resolves itself into the tasting and smelling of the cream and the success of this method is controlled largely by the grader's keenness of these senses and his knowledge and ability to quickly decide on the proper placing of cream so graded.

Grading by the Senses of Taste and Smell.—The earlier attempts to grade cream by this method were crude, unsightly and unsanitary at best. The operator sampled the cream by sticking his fingers into the cream and "licking" them off. Aside from the ethical and sanitary aspect, this practice was objectionable because the results were very crude, did not permit of close grading and often were misleading. By this practice there is always danger of carrying the flavor of one can to the next, considerable cream adhering to the fingers after tasting it. In this way the bad flavor of the first can may also be detected in the tasting of the next can, although the cream in the second can may be entirely free from that flavor. Thus the second can would naturally be erroneously put in the same grade as the first.

The objectionable features of this method have been corrected in many of the more progressive creameries by tasting the cream with a wooden stick, glass rod or spoon, placed in hot water between dippings.

A very satisfactory practice of grading cream is the following:

Apparatus needed:

Two wooden sticks, about the size of an ordinary lead pencil and preferably of maple.

One tin cup about 8 inches deep with handle.

One cream stirring rod with perforated disc at lower end.

One dental spittoon resting on a pipe standard about 3 feet high and with a pipe base sufficiently large to prevent tipping over. This spittoon should be attached to the water line by means of small rubber tubing about 15 feet long.

Operating the Grading Test:

Stir the cream in the can vigorously with the cream stirrer, take its odor by bending over the freshly stirred cream.

From the tin cup filled with hot water take a clean maple wood stick, dip up with it a small amount of cream, taste it, return the stick to the hot water in the tin cup and use the second stick for the next can. By this method the hot water melts the cream off one stick while the other one is used, and thus insures its freedom from cream of the previous can when it is again used. Enough cream adheres to the end of a stick of the size of the average lead pencil for proper tasting. A larger amount of cream is unnecessary as well as objectionable for convenient grading.

The dental spittoon serves to catch the expectorations of the cream by the grader. This is preferable to spitting on the floor, which is unsightly and often unsanitary. The spittoon, being connected with the water line by a long, flexible rubber tubing, can be shifted around at will and it stands high enough to furnish an easy target avoiding splashing over the cans. The expectorations are automatically rinsed out of the spittoon and disappear on the floor through the hollow pipe standard supporting it.

It is advisable to grade closely and to allow to pass as first-grade cream only, cans which are free from specific defects and which are above suspicion and to pull out and place in second grade all cans that do not meet the standard of first grade cream, or cans about which the grader is uncertain. All cans segregated out in this manner should be graded over and this should preferably be done by another man, or the superintendent. Enough time should be given and pains taken to regrade this second grade cream so as to insure accurate work. This will often enable the creamery to return to first grade, cans of cream which at first sight proved uncertain, thus increasing the per cent of grade 1 and decreasing the per cent of grade II. If any cans are found with decayed cream or cream otherwise unfit to be made into butter, their contents should be poured into the sewer and the patron should be so notified. The sanitary laws of some states require such procedure. In case of dispute the co-operation of the local or state pure food or health official should be solicited. If for any reason it is deemed advisable to return to the farm decayed cream, it is advisable to mix into it enough butter color to preclude all temptation on the part of the producer to send it back to the factory with the next shipment, without ready detection by the creamery. When cream is hauled or shipped to the creamery in the farmer's individual can the creamery usually has little difficulty in keeping the several grades separate.

In the station system of cream receiving, the farmers haul their cream to the station, where it can be graded in a similar manner as in the creamery. After grading, it is shipped to the central creamery in completely filled shipping cans. In this case the operator should exercise great care not to pour cream of different grades together in the same can, but to use different cans for different grades and mark the grade on the respective cans. At the creamery the station cream is regraded and if the results of the creamery's grading materially differ from those of the station operator's grading, the operator should be so notified.

In the case of the route system of receiving cream the route man should have on his wagon properly marked cans for each grade. He should grade the cream received from each farmer and pour it into the cans reserved for that grade. When the route cream arrives at the creamery it is regraded and if the results of the grading at the creamery differ from those of the route man or hauler, his attention should be called to the same promptly.

The grader should record all second grade cream with notations of the specific defect, on the shipping tag or other blank which goes to the office, and the office should promptly notify the patron why his cream did not pass grade 1, with suggestions of how to best guard against the recurrence of the defect.

Classification of Grades.—Much has been said and written about specific grades and numerous are the classifications of cream grades on record. After all is said and done, each creamery has to ultimately establish its own individual standard of grades, according to its local conditions of supply and of market requirements. It is a comparatively simple matter to devise an ideal classification of grades, but it is exceedingly difficult to successfully follow such classifications under often very perplexing and frequently unideal commercial conditions of operation. While every effort should be made to work toward a high standard of classification, the commercial practicability of the classification is of the greatest ultimate importance. One of the obstacles in the way of the general adoption of cream grading has been that the classifications of grades have often been far too exacting and complex to make their operation successful. In such cases, after a few abortive attempts at grading the whole principle of grading was declared impracticable and was abandoned. The adoption of a classification that corresponds more nearly with actual commercial conditions, though it may be far from ideal, usually is conducive of better net results, than attempts at the use of a classification that borders perfection, but that is commercially impossible under prevailing conditions. For the great majority of creameries, a classification of two grades is all that may reasonably be expected. Creameries that supply a limited, very critical trade, demanding a superior product may find it advantageous to make three grades. In such cases the following classification may be desirable:

Grade I. Cream that is sweet or practically so and free from all objectionable odors and flavors.

Grade II. Cream that is sour but otherwise free from objectionable odors and flavors.

Grade III. Cream that does not comply with the requirements of Grades I and II but which is free from putrefaction. In this class would fall cream that may have objectionable odors and flavors, such as weedy, garlic, curdy, gassy, yeasty and other off-flavors. All cream containing decaying matter or other substances of putrefaction should be rejected.

For creameries whose trade requirements do not discriminate between extra fine and fair quality and who are not in a position to secure a materially higher price for the superior quality, the following classification of grades is recommended:

Grade I. Cream that is sweet or moderately sour, but free from objectionable flavors and odors.

Grade II. Cream that is free from decaying and putrefactive matter but which may be sour and contain objectionable odors and flavors, such as weedy, garlic, cheesy, gassy, yeasty and other off-flavors. All cream containing decaying matter or substances of putrefaction should be rejected.

Under certain conditions it may be desirable to subdivide grade II, or to make three grades instead of two. Some of the cream may be impregnated with a very intensive flavor, such as intense garlic, yeasty or other similar flavor. In this case it is recommended to place in grade II cream with slight off-flavors only and into grade III the cream with the highly developed off-flavors, always providing, however, that none of this cream shows signs of unfitness for food.

SAMPLING MILK AND CREAM.

Purpose.—In the case of buying milk or cream for buttermaking, the only just and business-like basis of payment is payment on the basis of the pounds of butter fat received and this basis has been adopted by the creameries throughout this country This method of payment necessitates the testing of the milk or cream for butter fat and the correctness of the test depends in the first place on the representativeness of the sample. It is of the greatest importance, if accurate tests are to be made, to secure a sample from the milk or cream of each patron's delivery, or shipment, that is representative of the milk or cream from which it is taken, and this in turn is controlled very largely by the thoroughness of the preparation of the milk or cream before sampling and by the method used for sampling.

Sampling Milk.—The milk arrives at the creamery or skimming station almost without exception in the farmer's individual cans. If one can only is received from one and the same farmer the sample may be taken direct from this can and before the milk is "dumped" into the weigh can. In this case the thorough agitation of the milk with a stout stirring rod is usually sufficient to mix it so that a representative sample can be taken. In the case more than one can is received from one and the same farmer, it is usually most convenient to pour all the milk into the weigh can, and take the sample from the mixed milk.

There are three principal methods of taking milk samples, namely, individual samples of all patrons, that are tested daily, composite samples that are tested at weekly, bi-weekly or monthly intervals, and individual samples of part of the patrons, that are tested daily.

Single Milk Samples for Daily Tests.—In this method the milk of each patron's delivery is sampled and tested. This is the most accurate and reliable method of sampling. The sample is taken either into a glass jar from which later the correct amount is transferred to the test bottle, or the sample may be pipetted from the properly mixed milk in the weigh can direct into the milk test bottle. In this way the extra work of handling sample jars and of preparing the milk in the jar for the test is made unnecessary, and all danger of fat separation before the sample reaches the test bottle is avoided. This is obviously a very accurate method of securing tests, but it involves a very large, and under commercial conditions of operation an almost prohibitive amount of work. On account of this objection this method is not in general use and has been very largely abandoned.

Another practice of taking single samples is to take and test samples from every other or every third delivery of milk. At the end of the month or other period of payment, these individual tests are averaged and the pounds of butter-fat are calculated by multiplying the average test by the total pounds of milk received for that period. This practice is obviously less reliable than where single samples are taken and tested daily. However, experimental results indicate that samples taken as often as every third day give results which compare very closely with those obtained from daily samples, as shown in the next table, illustrating relative accuracy of different methods of sampling milk.

Composite Samples of Milk.—The purpose of taking composite samples is to reduce the labor and expense of testing. The true composite sample consists of aliquot portions of milk of several deliveries from the same patron.

Jars for Composite Sampling.—Composite sample jars must have a tight seal in order to prevent evaporation of moisture.

Fig. 16. Composite sample jar
Courtesy Mojonnier Bros. Co.

Pint jars sealed with glass stoppers, rubber stoppers, cork stoppers, metal caps, or screw tops may be used for this purpose. Bottles with paper caps and jelly glasses with tin lids do not furnish tight seals; they should not be used for this purpose.

A separate jar is used for each patron, and each jar must bear the respective patron's number. The jars should be thoroughly clean and, in order to guard against errors, they should be arranged on convenient shelves near the weigh can in numerical order, grouping the jars of patrons of the same route together.

Taking Composite Samples of Milk.—Correct composite samples may be obtained by the use of a milk thief or a graduated pipette. If the milk thief is used, it is inserted into the weigh can of the entire delivery of one patron. The milk in the tube rises to the level of the milk in the weigh can. The milk thief is then emptied into the sample jar. In case the graduated pipette is used, a certain quantity of milk is taken for every pound of milk delivered by the patron (usually about .1 c.c. for every pound of milk delivered). The milk thief is the handier instrument of the two, but where the amount of milk delivered by different patrons varies considerably, the samples of milk from the larger milk producers are often too large to be practical.

Other so-called composite samples are taken by using the same measure for all milk receipts. In this case a small dipper holding about one ounce is generally used. With this dipper a sample of milk is taken daily from the weigh can of each patron's milk and transferred into the sample jar. This method of composite sampling is not mathematically correct and the results tend to be less reliable, although experimental data by Hunziker show that the results average practically the same as when aliquot portions are taken.

The chief objection to composite samples of milk is that they are usually held too long before testing. This causes more or less complete separation of the butterfat, in the form of a thick and tough layer of cream on the surface of the milk. This cream mixes with difficulty back into the remainder of the sample so that the portion transferred to the bottle is often not representative of the true richness of the milk. This defect is especially pronounced when the samples are not protected against high temperature (summer heat).

Composite samples, if they must be taken, should be kept not over one week and tested at the end of this period. They should be kept in tightly sealed jars and in the cold.

In order to prevent composite samples from souring, fermenting and curdling before they are tested, it is necessary to add a small amount of preservative to the sample jar with the first portion of milk. This is most conveniently done in the form of tablets of corrosive sublimate or bichromate of potassium. One tablet during the winter months will preserve a pint sample for at least two weeks. During the hot weather it is advisable to add two tablets. Liquid preservatives, such as formaldehyde, may also be used in the place of the tablets, but they cause slight dilution of the sample and are not considered quite as convenient as the tablets. After each daily addition of milk to the composite sample jar, its contents should be gently agitated by giving the jar a rotary motion in order to insure a complete mixture of the preservative with the entire contents of the jar. When agitating, care should be taken that the milk does not unnecessarily slobber up along the side of the jar, so as to prevent the coating of the side with cream which subsequently dries and is difficult to mix back into the remainder of the sample at the time of testing. Composite samples should be tightly sealed and should not be held longer than one week. In old composite samples the cream is prone to be so completely separated from the skim milk that it refuses to mix back readily and to form a homogeneous emulsion preparatory to testing.

Individual Samples of Part of the Deliveries only.—In this method, each patron's milk is not sampled daily but only every third, fourth or fifth day. The patrons are divided into groups. Group one is sampled the first day, group two the second day, etc., so that each patron's milk may be sampled say eight to ten times per month. The tests of these samples are averaged at the end of the month and the patron is paid on the basis of this average test. When this is done the time saved in sampling permits the pipetting of the sample direct into the test bottle.

At first glance and from the theoretical point of view this method appears crude and lacking in accuracy. However, an extensive series of comparative tests conducted by the writer in co-operation with the Indiana Condensed Milk Company at Sheridan, Indiana, in which over 5,000 samples were tested, demonstrated very conclusively that the results of this intermittent sampling approached the average of tests of daily samples closer than did the results of composite samples, as shown in the following table:

Table 22.—Comparative Accuracy of Different Methods of Sampling Milk.[1]

Method of Sampling	Average Test Percent Fat	Average of Actual Pounds Fat, as Determined by Actual Pounds Milk Delivered by Each Patron and by Average Fat Test of Each Patron. Pounds Fat	Average Variation from Check Figures Pounds Fat
Single samples, daily (check figures)...	4.95	31.94	..
Single samples, every second day......	4.99	32.04	+.10
Single samples, every third day.........	4.98	31.98	+.04
Single samples, every fourth day........	4.98	31.97	+.03
Single samples, every fifth day..........	4.98	31.90	—.04
Composite samples, aliquot portions....	4.85	31.72	—.22
Composite samples, equal portions......	4.90	31.75	—.19

[1] Hunziker. Experiments conducted at factory of Indiana Condensed Milk Co., Sheridan, Ind., November, 1913. Single samples, composite samples (aliquot portions) and composite samples (equal portions) were taken from each of 300 patrons daily for a period of 14 days. The single samples were tested daily and the composite samples at the end of the 14 day period. The figures in column "Average Test," first column, represent the average of all tests of the samples of each patron for each method of sampling. There were 4,800 (300x14) single sample tests, 300 composite sample (aliquot portion) tests and 300 composite sample (equal portion) tests. The average pounds of fat (second column) were determined by multiplying each single and composite sample test by the respective pounds of milk these samples represented, dividing the product by the number of samples tested. The "Average Variation from Check Figures" (third column) was determined by deducting the average pounds of fat of each method of sampling from the average pounds of fat of all single samples, the average of the single daily tests being accepted as standard and used as check figures.

The reason why sampling every second, third, fourth or fifth day, gave more accurate results than composite sampling must be attributed to the fact that in the intermittent sampling the sample was transferred from the weigh can direct into the test bottle. The portion used for testing, therefore, was bound to be representative of the milk from which it was taken, there could be no question of inaccuracy due to separation of fat. In the composite samples, on the other hand, the cream was separated out and in spite of the most painstaking efforts to thoroughly mix the cream back into the remainder of the composite sample, the portion transferred to the test bottle was of more or less uncertain composition. This was the case with and without heating the sample before the transfer was made. This investigation was made in the month of November under most favorable conditions for preserving composite samples. Had it been made in the month of June, at a time when most of the cows are fresh in milk and the milk contains predominatingly large fat globules and when the temperature on the receiving platform where the samples usually are kept is very high, the separation of cream in the sample jar would have been even more complete, the layer of cream would have been drier and tougher and less miscible and the results of the tests of the composite samples would probably have been still more unfavorable.

Sampling of Cream.—Correct sampling of cream is vastly more difficult than correct sampling of milk. This is largely due to the fact that the cream usually is older and often lumpy and mixes into a homogeneous consistency with difficulty only. It is also due to its richness in butterfat. Average cream contains approximately 10 times as much fat as milk. The possible error caused by lack of uniformity in consistency, therefore, is greatly augmented.

Composite samples of cream representing portions of successive shipments or deliveries from the same patrons are practically out of the question and cannot be too strongly condemned. It is difficult to take small aliquot portions of cream and the tendency of cream samples to lose part of their moisture by evaporation, upon remaining for several days on the shelves of the warm receiving room, causes such samples to yield excessively high and misleading tests.[1] Then again, the established practice among the majority of creameries to pay the farmer for each individual shipment of cream precludes the practicability of holding the samples and makes necessary prompt testing of the daily samples.

In the case of direct deliveries or shipments of cream by the farmer to the creamery or cream station, it is customary to stir the cream with a stout stirring rod previous to sampling. Pouring the cream from one can to another will also insure thorough mixing and should be resorted to especially when the can is too full to be stirred without danger of spilling. Under all ordinary conditions, however, stirring is more practical and consumes less time than pouring. After the cream is properly mixed, a small sample is taken by transferring the cream with a small cone-shaped or cup-shaped dipper into a small sample tube or jar, which is immediately tightly sealed. It is customary to place the dipper into a can containing hot water after each dip, so as to rinse it and facilitate the sliding of the thick cream of the next can into the sample jar. The use of a cold dipper would cause the cream to stick to it and thus delay the work of sampling. These cream sample dippers should have a small hole in their bottom in order to facilitate rapid and complete escape of water when the dipper is removed from the hot water and before it is dipped into the cream. The sampling is best done while the cans are still on the floor and before they are placed on the scales, as the stirring jars the scales and shortens their life.

In the case of the route system, as usually practiced, the sampling has to be done on the route wagon by the hauler. At best the sampling of the farmer's cream on the route, under diverse and often very unfavorable weather conditions is an exacting problem that requires adequate, practical equipment for reliable work. This equipment should consist of a well-made spring scale, capacity 60 pounds, for weighing the cream; a weigh pail in which each farmer's cream is weighed separately, a properly constructed combined stirrer and sampler, consisting of a heavy iron rod which terminates at its

[1] Hunziker, Mills and Spitzer. Testing Cream for Butterfat. Purdue Bulletin No. 145, 1910.

bottom in a securely attached sample disc; a rubber scraper for scraping the remnants of cream from the sides and bottom of the farmer's pail or can and from the weigh pail after each weighing; a set of properly numbered sample bottles with tight stoppers or screw-top lids and arranged in a rack or box in numerical order; two sets of cans, preferably 10 gallon cans, for first-grade and second-grade cream, respectively, into which to empty the weigh pail—each set of these cans should be plainly marked with the grade of cream for which it is intended;—and a cream report book or pad. The cream should be thoroughly stirred, then poured into the weigh pail, weighed and sampled. The scales should not be held up by hand, but should be suspended from a stationary hook, preferably attached to the rear of the wagon. Each sample bottle, after filling, should be sealed tightly and returned to its proper place in the sample box. In case the weigh pail does not hold all the cream of one and the same patron, a separate sample should be taken from each weighing and the corresponding weights recorded. The use of a covered wagon or truck protects the cream against excessive heat in summer and cold in winter.

Creameries that operate routes or cream stations should see to it that their haulers and station agents who do the sampling are honest and conscientious, have the necessary knowledge to do their work right and are supplied with an adequate equipment for sampling and weighing. Men of questionable character and men of careless habits never make reliable agents for securing cream samples.

In all cases of sampling, whether this work be done at the creamery, at the cream station, or on the route, the greatest care should be taken that the cream is mixed very thoroughly before sampling. This requires a stirrer with a good sized disc and a stout rod not less than three feet long and with a hand hold of adequate size. The stirring must be done thoroughly, simply giving the cream a few dips with the sample dipper is not sufficient. The stirrer must be worked to the bottom of the can several times and the entire contents of the can must be thoroughly agitated. Thick, lumpy or icy cream should be warmed until it pours readily and can be mixed properly.

Churned cream cannot be sampled. Its fat content may be calculated by testing the buttermilk and estimating the amount of butter.

In order to guard against serious shortages of butterfat and to protect the creamery against paying for butterfat which it never received, all cream route cream and all cream station cream must be sampled and tested again at the creamery. A composite sample must therefore be taken at the creamery from the cream of the delivery of each route and of each station. This may be done by taking, with a cream thief or dipper, a small portion of cream of each can of the same route or the same station into a pint glass jar, bearing the number of the respective route or station. Or all the cans from the same route or station may first be emptied into the weigh can or vat and a sample taken from the mixed cream after it is thoroughly stirred. The former method has been found by experience to yield more accurate samples because of the difficulty of thorough mixing of different lots of cream of varying richness.

These composite samples should be tested as promptly as possible and the pounds of butterfat calculated. If the amount of butterfat determined from the composite samples does not agree with the amount of butterfat of the route or station men's individual samples of the farmers' cream, the hauler or station man should be promptly notified of the delinquency, in an effort to avoid recurrence of similar shortages in future shipments.

Sampling Frozen Cream.—The sampling of cream that arrives at the creamery in partly or wholly frozen condition as is the case with a good deal of the cream during severe winter weather, is a problem which frequently causes much difficulty. When freezing, the watery portions of the cream usually freeze first. In the case of partly frozen cream, therefore, the frozen portion is poorer in butterfat than the remaining liquid. When this cream is sampled without thawing up the icy portions, the sample is prone to largely contain the liquid part of the cream. This inavoidably causes the tests of such samples to show a higher per cent of butterfat than the mixed cream from which it is taken. This in turn results in a low overrun and loss to the creamery. Cans in which the cream is completely frozen cannot be sampled at all without first thawing the cream.

In order to reduce the frozen cream to a liquid condition most creameries use a wooden, concrete or iron tank partly filled with warm water, into which they set the cans of frozen cream until the cream is melted. The operators are usually instructed to hold the temperature of the water at 110 to 130 degrees F. In order to hasten the work and to avoid delay there is always a strong temptation on the part of the operator to use too hot water or to pull the cans out of the thawing tank before all the cream is melted. Both of these practices are objectionable, because they are prone to yield incorrect samples and they tend to injure the body of the resulting butter.

If too hot water is used, at least a part of the cream is bound to be heated much above the melting point of the butterfat. This causes the fat to "oil off" and run together. When this cream is subsequently cooled, preparatory to churning, this "oiled-off" fat granulates and gives the butter a disagreeable, mealy texture. In this "oiled-off" condition the cream is also very difficult to sample because, in spite of most thorough stirring, the butter oil will rise to the top before the operation of sampling is finished and the sample is very apt to contain a higher per cent of fat than the mixed cream from which it is taken.

If the cans are pulled out of the hot water tank before all the cream is properly melted, much vigorous stirring is necessary in order to reduce it to a homogeneous condition. In the case of sour cream this stirring of the partly melted cream is often sufficient to cause the butter to break, when proper sampling becomes impossible and the remelting of this churned cream in the forewarmer or pasteurizer again gives rise to butter with a mealy texture.

The only reliable way of avoiding these difficulties is to not heat the water to high enough a temperature to cause the butterfat to melt and "oil-off" and to leave the cans in the water long enough to insure complete solution of the cream. This is best done by heating the water in the tank to 95 degrees F.

only and, in order to hasten the melting of the cream, to keep a stream of water at 95 degrees F. flowing through the tank constantly. In this way the cream melts in a natural manner and without "oiling-off" and the continuous removal of the cooled water surrounding the cans by the circulation of the water greatly speeds the work. Cream so treated is in ideal condition for sampling and there is no danger of its producing a mealy-bodied butter.

Amount of Cream for the Sample.—It is the general practice among the creameries to make one test only of each sample. It is often desirable, however, to retest a sample in order to prove the accuracy of the first test, especially when there is an abnormal variation in the tests of successive deliveries or shipments of cream from the same patron. Frequently test bottles break in the tester and a second test is necessary to determine the per cent of fat of the cream which the broken bottle represents. For these reasons it is advisable to take a sample large enough for two tests. Since about 15 to 20 c. c. of cream are sufficient to make one test, the cream sample should contain about 30 to 40 c. c. of cream, or about one and one-half ounces.

Larger samples than this are not only unnecessary, but may cause considerable waste of cream. This latter objection holds true only where preservatives are used as is especially the case with composite samples. When single samples only are taken and these samples are tested on the day received or shortly afterward, the use of preservatives is unnecessary and the unused portion of the sample may be returned to the cream vat or forewarmer to avoid loss.

Care of Cream Samples.—In the larger creameries, especially those operating the cream station system or the individual-shipper system, the farmer's checks are made out daily for each individual delivery or shipment. In these creameries, or their stations, the samples are tested as soon as they are available and their care requires, therefore, no special attention. In a good many of the smaller creameries, however, the samples are not tested on the day they are taken or received, and they are often several days old before they are tested. Few operators realize that, while these samples are waiting for the tester, they are subject to rapid deterioration and to changes in composition due to evaporation of moisture, which has a disturbing influence upon the accuracy of the test. In many creameries the samples are allowed to remain on the shelves of the receiving platform without protection from heat and exposure to air. Careful observations have shown that there is a strong tendency on the part of the cream samples, kept under these conditions, to increase in per cent of fat with age. This is due to the escape of moisture from the cream by evaporation. The rapidity with which this evaporation takes place depends on the tightness or looseness of the seal of the sample bottles and on the temperature of the place where they are stored. This fact was demonstrated in a brief experiment conducted by the writer, in which the daily shipments of cream from six patrons were sampled for single tests and for composite tests. Each patron's sample was divided among nine bottles, three of which were tightly sealed, three loosely sealed and three were left open. One set of these bottles from each patron was placed in the ice box at a temperature of 50 degrees F., one set was left on the receiving platform and one set was placed near the boiler at a temperature of 90 to 110 degrees F. The results are shown in the following table:

Table 23.—Per Cent Fat of Cream Samples Kept in Bottles Sealed Tightly, Loosely and Left Open, at Different Temperatures.

Patrons	Fat Tests of Single Samples, July 13 to 27								Fat Tests of Composite Samples Held Two Weeks								
	July							Average	In Ice Box			On Receiving Platform			Near Boiler		
	13	15	17	20	22	24	27		Tight	Loose	Open	Tight	Loose	Open	Tight	Loose	Open
1	55.	51.	53.	52.	51.	51.	52.	52.1	51.	54.	56.	57.5	59.	65.	58.	58.	70.
2	41.	38.	39.	39.	35.	35.	39.	38.	39.5	40.	42.	44.	45.	50.	51.	59.5	69.
3	28.		27.	29.		25.	30.	27.8	27.5	28.5	30.	34.	35.	37.	31.	34.	68.
4	40.	37.	38.	40.	38.	39.	37.	38.3	37.5	38.5	41.	38.5	39.	48.	41.	41.	65.
5	35.	33.	35.	33.	33.	32.	33.	33.4	33.	34.	37.	34.	37.5	42.	36.	37.	70.
6	48.	48.	48.	48.	47.	47.	49.	47.8	48.	48.	51.	40.	48.	59.	49.	48.	71.
Average - - -								39.5	39.5	40.5	43.	43.	44.	50.	44.5	46.5	69.

The figures in table 23 demonstrate the importance of keeping cream samples that are not promptly tested, in tightly sealed jars and at a low temperature. They further emphasize that creameries keeping their cream samples in loosely sealed bottles on the receiving platform may pay their patrons during the hot summer months for thousands of pounds of butterfat they never received because of the increase in the per cent of fat in such samples with age, due to evaporation of moisture.

Weighing Milk and Cream.—In the case of milk the cans belonging to one and the same patron are usually emptied into the weigh can and the weights are recorded on the milk sheet located in a convenient place on the receiving platform. Where milk is received exclusively or nearly so, the patrons are generally paid weekly, bi-weekly or monthly and it is convenient to have the milk sheet provide for a sufficient number of days to enable the operator to enter all the daily receipts that constitute the period for which the pay check is made out. The days of the months are usually placed on the horizontal line on top and the patrons' names or numbers in the first vertical column at the left of the sheet.

Where cream is received the same method may be used for the individual deliveries and shipments, and the route and station totals are entered in the columns reserved for those routes and stations.

In large creameries and where the individual cream receipts are paid for daily, the milk and cream sheet obviously does not serve the purpose. In these cases the cream is usually weighed in the cans and before it is emptied. The tare weight indicated on the shoulder of the can and the gross weight are recorded on the tag of the can or on a cream record blank, which later goes to the office.

Station and route cream may be poured into the weigh can thus weighing all the cream coming from one and the same route or station together, or each can is set on the scales and weighed separately. This cream has already been weighed in the weigh pail on the route or in the farmer's individual can at the cream station. The creamery weights of the total of each route delivery or cream station shipment should correspond with the total of the weights of the individual farmer's deliveries as recorded on the cream sheet of the respective route man or cream station operator.

In order to insure correct weights the platform scales at the creamery and cream station and the spring scales on the route wagon must be in good operating condition. They should be regularly examined at the beginning of each day. They should be set level, properly balanced, swing freely and indicate the weight correctly. Scales that "stick" or that are otherwise not in satisfactory operating condition should not be used. They should be repaired or replaced with new scales at once. Platform scales should be protected against undue jars and they should be thoroughly cleaned and freed from all remnants of milk and cream at the conclusion of each day's work. On the care of the scales will largely depend their accuracy and their duration of usefulness.

Fig. 17. Platform scales for milk and cream
Courtesy Fairbanks, Morse & Co.

"Dumping" Milk and Cream.—As previously stated the milk cans are most conveniently emptied into the weigh can and after weighing the milk passes into the receiving vat and is heated preparatory to separation in accordance with directions given in Chapter V on the Separation of Milk. All milk should be strained through a wire mesh strainer, 80 to 100 meshes to the inch. This is best done by installing the strainer over the top of the weigh can. The strainer should be rinsed out frequently during the day's work and should receive a special scrubbing with a brush and hot water, and should be steamed, at the end of the day. The use of a drip rack for reclaiming remnants of milk in the cans will assist in avoiding unnecessary losses on the platform.

The cream, after it is weighed, is usually emptied into the forewarmer, which consists of a low vat equipped with a revolving coil for warming the cream. It is desirable to forewarm all cream so as to reduce it to a homogeneous condition and make pasteurization more even and more effective. In the forewarmer the cream is heated to about 90 degrees F. If higher temperatures are used care should be taken that the cream is constantly agitated by keeping the coil revolving, in order to guard against "oiling-off" of the butterfat and consequently a mealy-bodied butter.

The forewarmer should be equipped with a coarse but substantial strainer, about four meshes to the inch, through which all the cream is strained into the forewarmer.

Inasmuch as much of the cream arrives at the creamery in very thick condition, special attention must be given the rinsing of the cans in order to prevent heavy loss of butter fat. After the can is emptied it is best inverted over a steam jet with an opening about $\frac{3}{8}$ inches in diameter where steam is blown into the can until all the cream has run out. A series of two to three such steam jets will allow one can to be steamed while the previous one is taken off and the succeeding one is put on, thus avoiding delay, and increasing the speed of the work of "dumping". If this steam jet arrangement is installed on top of the forewarmer, the remnants of cream run automatically into the forewarmer and no special receptacle is needed to catch and reclaim this cream. Where a mechanical can washer is used it may be convenient to make this cream-reclaiming arrangement a part of the can washer.

Instead of blowing the remnants of cream out of the cans with steam, some factories rinse the cans with hot water, pouring about one half can full of hot water from one can to the next one and finally dumping this milky rinse water into the forewarmer. This method appears somewhat more crude, more sloppy and has the additional disadvantage of diluting the cream with considerable water, which is undesirable, often contributing to the development of costly butter defects.

In the case of very thick and cold cream, it may be necessary to dip the cans into a hot water bath and then invert them over the forewarmer again to facilitate the removal of the remnants of cream. This water bath is best provided in the form of a rectangular tank, 24 inches long, 18 inches wide and 18 inches deep. This dipping of the cans in water is somewhat objectionable because the water adhering to the outside of the cans runs into the cream in the forewarmer upon subsequent "dumping" and, since the cans are often unclean on the outside, this water also is far from being free from impurities and tends to pollute the cream. Where the remnants of cream are blown out of the cans with steam, the dipping of the cans in hot water is largely unnecessary and may, under most conditions, be omitted.

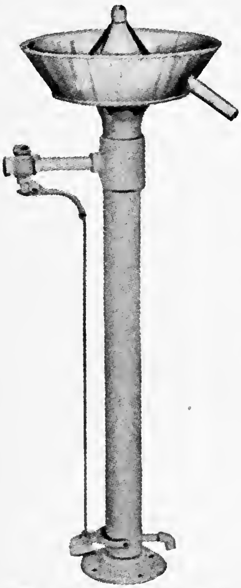

Fig. 18. Can steamer for reclaiming remnants of cream
Courtesy J. G. Cherry Co.

Washing of Milk and Cream Cans.—One of the essential factors in the creamery's successful efforts to improve and uphold the quality of its supply of milk and cream constitutes the returning to the farmer of cans that are clean, dry and smell sweet. It is inconsistent to urge the producer to observe scrupulous precautions of cleanliness and sanitation in the production and handling of his milk and cream, and then furnish him with cans that are not clean and that contain foul odors. Even milk or cream that is sweet and free from objectionable flavors and odors, when poured, stored and shipped in unclean cans, will be of inferior quality by the time it reaches the creamery or cream station. And the psychological effect on the producer who, upon opening the can, detects bad odors and lack of cleanliness, is disadvantageous to the cause of good milk or cream. A clean and sweet-smelling can furnishes an incentive to the production of cream of good quality. An unclean can with objectionable odors discourages the farmer from making the necessary effort to produce good cream because he realizes that if it is exposed to the contaminating influences of such a can, the cream will soon deteriorate anyway, regardless of the care he has exercised in its production. The proper cleaning of the cans at the factory should, therefore, receive most careful attention.

Can Washing Equipment.—Great efforts have been made within recent years by creameries and manufacturers of creamery machinery to devise and construct machines that could be depended upon to cleanse, sterilize and dry the cans. While there is still room for much progress on this point, much improvement in the available can washing equipment has resulted from these efforts.

Washing cans by hand is a laborious and time-consuming work, distasteful to the great majority of creamery employees. On account of its disagreeable features it is difficult to secure men who are dependable to do this work properly and who do not yield to the temptation of slighting it when rushed and in the absence of close supervision.

The earlier attempts at machine washing consisted of the use of mechanical brushes revolving in a can wash trough. The cans were slipped over these brushes, the brushes by the operation of a lever, were then expanded to touch the inside and outside of the cans, cleaning it while revolving. Later steam and hot air jets were attached to the end of these washers for the purpose of sterilizing and drying the washed cans.

The latest designs of can-washing machines consist of so-called hydraulic can washers, in which the cans automatically pass in an inclosed chamber over a series of jets which rinse, wash, steam and dry the cans. These washing machines are made in varying sizes taking care of 100 to 300 cans per hour. Some are of circular type while others are straight-away. The circular washers have the advantage of economizing space and of making it possible for the same person who places the unwashed cans into the machine to also remove the washed cans from the machine. In plants where it is desirable to discharge the clean cans as far away as possible from the intake of the unwashed cans, in order to clear the floor, the straight-away machines are more serviceable.

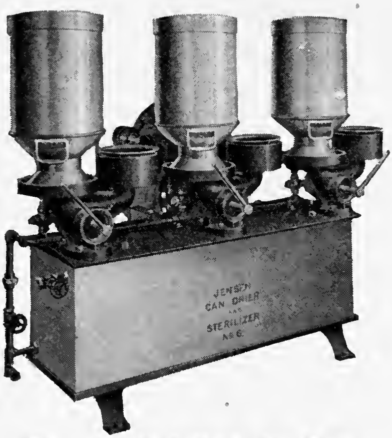

Fig. 19. Can steamer and drier
Courtesy Jensen-Cry Mach. Co.

These hydraulic can washers promise to play an important and useful part in the efficiency of can washing and the improvement of the quality of the cream in the future. Already a great number of these machines are in operation in milk plants and creameries throughout the country. While their high initial cost, their large size, their noise and heat radiation are obstacles which limit their use to the larger factories and make them as yet unsuitable for small creameries, these disadvantages may gradually be overcome and are even now offset in part at least by their greater speed and relative efficiency, their greater economy in the use of alkali

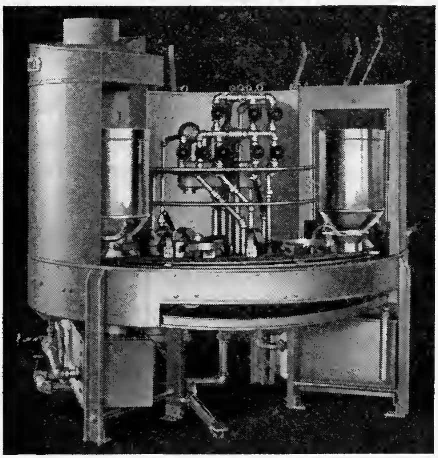

Fig. 19A. Progress circular can washer
Courtesy Davis-Watkins Dairymen's Mfg. Co.

solution, and the fact that the cans require less frequent painting than when washed by hand. While their work of cleansing, sterilizing and drying the cans may fall short of the work of the most expert washing by hand, the machines yield uniformly good results, they can be adjusted to any speed and to any length of exposure of the cans to washing, steaming and drying and their work is far superior to that of the average washing by hand.

Essentials of Efficient Can Washing.—In the proper cleansing of cans there are four essential operations, namely, the washing, rinsing, steaming and drying.

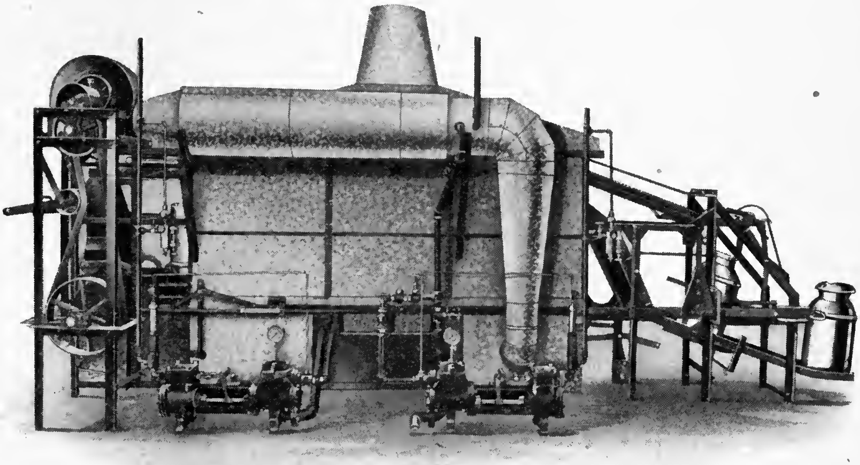

Fig. 20. Mechanical can washer
Courtesy Lathrop-Paulson Co.

The washing of the cans should remove all remnants of milk or cream. In the case of hand washing this is best done by immersing the can in a wash tank of suitable size and containing a solution of washing powder or other alkali in hot water. The cans are washed both inside and out with a stiff bristle brush. In the hydraulic machines the hot alkali water is forced into the cans under pressure and the force of the water is intended to take the place of the brush. In some of these machines clear hot water is used for this purpose without any addition of alkali. Experience has shown that milk cans and cream cans which are not coated with dried cream can be quite successfully cleansed in this way. Old cream cans, however, in which the cream has dried onto the inside of the can need a special hand scrubbing to insure thorough cleansing.

After the cans are freed from the remnants of milk or cream they should be thoroughly rinsed. This is usually done by inverting them over a water jet attached to one end of the wash tank. Or in the case of hydraulic can washers the cans pass from the washing jets to the rinsing jets. In hand washing the rinsing process is too often neglected and remnants of the unclean wash water remain in the cans serving as an active starter to pollute the next batch of cream. The cans should be thoroughly rinsed after they are washed. The rinsing is preferably done with hot water, so as to make more effective the subsequent steaming and drying.

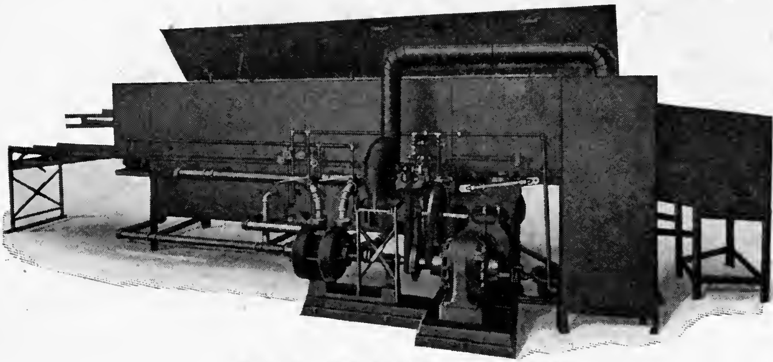

Fig. 21. Mechanical can washer
Courtesy Rice & Adams Corp.

The properly rinsed cans are then ready for the steaming process. This is accomplished by inverting them over a steam jet and blowing steam into them until they are "piping" hot. In the case of hand wash tanks the steam jet is usually installed in close proximity to the water jet so that the cans can be rinsed and steamed in one operation. In the hydraulic can washers the cans pass on automatically from the rinsing jets to the steaming jets. The purpose of steaming is to destroy the germs still contained in the cans and to render the cans as nearly sterile as possible. The length of time required for thorough steaming depends much on the steam pressure, the size of the steam pipe and the distance between the steam jet and the boiler. Under ordinary creamery conditions the steaming should last at least 30 seconds. A shorter time is insufficient to insure effective germ-killing action. Steaming for 5 to 10 seconds, as is all too often the case, does not accomplish the desired purpose. Its sterilizing action is incomplete.

The last but not least important step in the cleansing of the cans is the drying. If the cans are to arrive at the farm in sweet condition and free from objectionable odors, they must be dry when they are sealed with the lid. Water left in the cans is certain to start bacterial action. The drying is best done by inverting the steam cans over a hot air blast. This blast is generated by means of a centrifugal fan blowing atmospheric air through a chamber filled with steam pipes. In the absence of the hydraulic can washer the hot air outlet is located near the steam jet at the end of the wash tank. In the hydraulic can washers the cans automatically pass from the steam jets to the hot air jets. The drying of the cans is indispensable, not only to improve the sanitary condition of the cans but also to prevent rapid rusting and to preserve the life of the cans.

Cleansing the Can Covers.—The can covers should receive the same treatment of washing, rinsing, steaming and drying as the cans themselves. Too often no provision is made to properly treat the covers. They are just washed and possibly rinsed and slightly steamed. When these wet covers, dripping with rinse water, are placed on the clean, dry cans, some water is bound to enter the cans and the good effects of the can drying are largely forfeited. Most of the hydraulic can washers provide for the washing, rinsing, steaming and drying of the covers, too.

Can Washing at the Cream Station.—It is obvious that the limited business and facilities of the cream station preclude the use of mechanical can washing machines and that the cans, if they are washed at all must be washed by hand. But even this process requires the availability of hot water and preferably of steam. The larger and properly-managed cream stations are equipped with a small boiler, a wash tank with steam jet and a rack for drying the cans. Where a steam boiler is not available, the station should use some other simple and inexpensive means for sterilizing the cans and other equipment that comes in direct contact with the cream. For this purpose the steam sterilizer devised by Ayres and Taylor[1] of the United States Dairy Division is recommended.

Size, Quality and Construction of Cans, Rusty and Damaged Cans.—For shipping or hauling milk the 10 gallon can is the most popular can. Most farmers who ship milk have enough of it most of the time to fill a 10 gallon can. This refers largely to creamery patrons. In the case of milk that is intended for city milk consumption, the 8 gallon can predominates in many localities. For shipping cream a smaller can is preferable and the 5 gallon can is recommended. The smaller can is filled in a shorter time and encourages more frequent shipments, thus helping the creamery to secure a fresher cream. The shipping rate on the 5 gallon can also is less than that on the 10 gallon can, so that it is cheaper to ship a 5 gallon can full than a ten gallon can only part full. Again, the purchasing price of the small can is less than that of the large can.

Generally speaking, a well constructed can made of heavy tin plate lasts longer and gives better service than a can of light construction. However, in the case of sour cream, the acid corrodes and rusts even the best cans in time and it is a debatable question whether it is preferable to buy a cheap can that can be replaced with little expense as soon as it shows signs of corrosion, or to buy a more expensive can that will last somewhat longer. Especially when the can is paid for by the producer he often objects to the paying of the price of a high grade can.

All cans, if not made of pressed tin, should have their seams well flushed with solder so as to avoid the lodging of remnants of decaying cream in the seams at the bottom, side or shoulder.

All cans should receive a special inspection at regular intervals and cans which contain more than about 1 square inch of rust spots should be scoured with some good friction material, such as cement or emery powder. Cans that do not respond to this treatment and that show excessive rustiness should be discarded. Also, cans with loose shoulders, if they cannot be mended satisfactorily, should be removed from service.

The fact that the can is rusty indicates that the tin coat-

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[1] Ayres and Taylor, A Simple Steam Sterilizer for Farm Dairy Utensils, U. S. Dept. Agr. B. A. I. Farmers' Bulletin No. 748, 1916.

ing has become defective in spots and that iron is exposed. The exposed iron is chemically acted upon by the acid and some of the other constituents of the cream, causing the formation of metallic salts, which hasten the decomposition of some of the constituents of the cream, either through chemical action, or by accelerating the action of bacteria, or enzymes, or both, and leading to diverse flavor defects in butter, such as metallic flavor, tallowy flavor, fishy flavor, etc.

Rusty cans are objectionable also for sanitary reasons. Rust spots present a rough surface, on which remnants of milk and cream lodge readily and from which they are difficult to remove, and the rust spots harbor and hold moisture to such an extent, that it is very difficult to thoroughly dry the cans by the use of equipment and methods entirely adequate, for the drying of cans free from rust. The tendency of rusty cans to not be perfectly clean and completely dry, causes these cans almost invariably to become foul-smelling, and to pollute the cream and injure the butter made from it.

Replacing Old Cans by New Ones.—An effective means to maintain a satisfactory standard of quality and condition of the cans in use is to adopt a system whereby, at definite intervals, each month or so, a certain per cent, say one per cent, of the cans, those that are in the poorest condition, is discarded. In this manner there is a constant renewal of cans and at a comparatively small cost at any one time.

Retinning Rusty Cans.—Some creameries maintain a tinshop of their own, where defective cans may be repaired and rusty cans retinned. When this can be done at a moderate expense, it is certainly a commendable practice. In many instances, however, experience has shown that the cost of retinning was out of proportion to the value of the can, and was too great to justify it.

There are now in operation several outside concerns, who are specializing in repair work of this type and who dismantle old cans, retin the pieces and reassemble them in a manner that the repaired can is practically as good as new, and at a cost somewhat lower than the price of a new can.

The relation between the condition of the cream can and the quality of the butter is so intimate, and the effect of the use of cans that are in poor condition is so injurious to the quality of the butter, that the matter of proper care and repair of cream cans is a problem that demands most serious attention.

CHAPTER VII.

THE NEUTRALIZATION OF SOUR CREAM.

Definition.—By neutralization of cream for butter making, is understood the reduction of the acid in sour cream. Chemically, neutralization would mean the process of making the cream neutral, removing all the acid. This would be obviously undesirable in the case of cream intended for buttermaking, its injury to the quality of the resulting butter would be far greater than its expected benefits. It would make butter of very inferior flavor and poor keeping quality. In fact it would forfeit the benefits for which cream is neutralized.

In the sense used in the creamery, neutralization refers to the removal of excess acid, reducing the acidity to say .2 to .3 per cent. The term neutralization, therefore, is a misnomer, it is misleading, inasmuch as it misrepresents the intent and practice of the process. A more correct name for this process would be the "Standardization of Cream for Acid." However, neutralization has become an established trade name, it has become an inherent part in the creameryman's vocabulary, so that, in order to avoid confusion and for the sake of clearness, it seems advisable to retain the trade name, "neutralization" in this discussion.

Object of Neutralization.—With the help of proper neutralization, the creamery hopes to and does accomplish the following three principle objects:

1. To avoid excessive loss of fat that results from churning cream that is pasteurized while excessively sour.

2. To guard against the production of undesirable flavors in cream which are prone to result when cream that is high in acid is pasteurized at a high temperature.

3. To improve the keeping quality of butter made from high

acid cream. Butter made from cream which is very sour, does not keep well.

These are the only objects that can be accomplished with neutralization. They all hinge on the reduction of the acid of sour cream before pasteurization.

Improvement of the flavor of butter made from tainted cream, or the removal of rancidity by neutralization, is not possible, notwithstanding many claims to the contrary. These facts have been conclusively established, as may be noted in succeeding paragraphs of this chapter.

Importance of Correct Neutralization.—That neutralization of cream has been a wonderful help to the manufacturer of butter who receives sour cream, is an undisputed fact. Experience has demonstrated beyond all question, that proper neutralization of sour cream improves the keeping quality of butter.

But great as the benefits are that can be derived from proper neutralization, so are also disastrous the results of improper neutralization. Over-neutralization is absolutely ruinous to butter. It is, therefore, of the greatest importance that we practice correct neutralization. That is, a process must be used that will give the full benefits of proper neutralization and that will at the same time protect the butter against the disastrous effect of over-neutralization.

How to Neutralize.—The important requisites of accurate and reliable neutralization may be conveniently grouped as follows:

1. Adoption of a definite standard of acidity.
2. Correct and accurate test for acidity.
3. Choice and use of the right kind of neutralizer.
4. Use of the right strength and amount of neutralizer.
5. Adding the neutralizer to the cream in the right manner.
6. Checking of results by retesting.

Adoption of a Definite Standard of Acidity.—The operator must first of all decide to what point the acidity shall be reduced. If neutralization really means "standardization" of the acid in the cream, it is obvious that there must be a standard of acidity. It is essential then that such a standard be established. Only then is there something definite, something worth while, to work to; and, having established such a standard, it must be abided by.

There are differences of opinion as to the most desirable point, or per cent acid, to neutralize to. However, extensive scientific experiments conducted by the writer and others, as well as practical experience in the manufacture of butter, have conclusively demonstrated that, in order to realize the full benefits of neutralization, the acid content of the cream must be reduced to somewhere near .3 per cent acid, and that we are approaching too near the neutral point and the dangers that accompany it, when the acidity is dropped much below .2 per cent.

Making reasonable allowance for fluctuations and inaccuracies in the results of neutralization, caused by the complexity of the reactions of the neutralizer in cream of varying conditions, and by the naturally crude technique of the process as manipulated by the usually busy and often untrained operator, a standard of acidity should be adopted that will permit of considerable latitude up and down, without, on the one hand forfeiting the benefits of neutralization, and on the other hand jeopardizing the quality of the product.

Neutralization to .25 per cent acid, as indicated by the usual acid test with decinormal sodium hydroxide and phenolphthalein as indicator, has been found to best take care of these fluctuating conditions and errors of operation. A standard of .25 per cent acid, therefore, has been adopted for the purpose of these discussions and is recommended to be adhered to. It is not claimed that this arbitrary standard is necessarily the best under all conditions, but it may well be accepted as the perfect standard for average creamery conditions.

Testing Correctly for Acidity.—It is obvious that the accuracy of neutralization centers fundamentally on the accuracy of the acid test. Reduction of the acidity to a definite standard point need not be expected, unless the operator is able to determine the correct per cent acid contained in the cream before neutralization.

Numerous simple and accurate acid tests are available for the purpose. They all refer to the use of a dilute solution (usually a decinormal solution) of sodium hydroxide. Detailed directions for these tests are recorded in the chapter on "Tests and Analyses," etc., Chapter XXII. If a decinormal solution of sodium hydroxide, and an 18 c.c. pipette are used for measuring the cream, each two-tenths cubic centimeter of alkali solution, as shown on the graduation of the burette, represents .01 per cent acid. Hence the number of c.c. alkali solution divided by 20 gives the correct per cent acid in the cream. Thus, if say 7.4 c.c. alkali solution is required to turn the cream pink the per cent acid is $\frac{7.4}{20} = .37\%$.

Choice of Neutralizer.—There is a variety of neutralizers that have been and are being used for the purpose of reducing the acidity in cream intended for buttermaking.

Neutralizers used for the purpose of reducing acidity, must have alkaline properties, they must be alkalies, or alkaline earths, or their carbonates. An alkali is a substance that neutralizes acids, forming salts, and that saponifies fats. The most common neutralizers that have found application in the creamery are the carbonates of sodium (soda ash), and of calcium (chalk), the bicarbonate of soda (baking soda), the hydrate of soda (soda lye), and of calcium (lime water and milk of lime), and the oxide of calcium and of magnesium (quick lime and magnesia lime).

The chief advantages of carbonate and bicarbonate of soda are that they are readily soluble and, therefore, can be easily made up into solutions of desired strength. This is a distinct advantage. Calcium carbonate, on the other hand, is very insoluble and slow of action, which renders its use unsuitable for this purpose. All carbonates above mentioned liberate carbondioxide gas when they are added to the sour cream. This fact is claimed by some to be greatly in favor of their use, as neutralizers. The claim is that the carbondioxide gas perculating upward in and escaping from the cream, mechanically carries with it volatile gases having undesirable odors and thereby removes from the cream, objectionable odors and flavors.

The extent and value of this expulsion of gases and the consequent improvement of the flavor of the butter, made from cream neutralized with carbonates, are however much overestimated. The expulsion of carbondioxide and other gases that may be present in the cream will occur to a large extent in all cream, whether neutralized or not, during the process of pasteurization. In fact, the flavor-improving effect of carbonate neutralizers is largely imaginary. If these claims were well-founded, it should be possible to make No. 1 butter from Grade 2 cream. This cannot be done. Distinct off-flavors in the cream do not disappear by the use of these neutralizers.

On the other hand, the use of carbonate and bicarbonate neutralizers has the serious disadvantage of robbing the operator of the ability to check the accuracy of his work, because the carbondioxide formed in the cream when these neutralizers are used, reacts acid, causing the test to show a higher acidity than the lactic acid content of the cream represents. These tests could be made to show the correct acidity by boiling the sample of cream to be tested, or by blowing air through it, both of which practices would expel the carbondioxide, but these practices are objectionable in practical creamery operation, because of the delay their application would inevitably cause in the work and also because of the danger of incomplete execution. Methyl orange indicator, which is not affected by the carbondioxide, might be used instead of phenolphthalein, but it is not suitable, because it fails to show a definite, sharp end reaction in weak organic acid such as lactic acid.

Because of their generation of carbonic acid gas in sour cream, the use of carbonates and bicarbonates often presents mechanical difficulties, causing the cream to foam up and over the vat, unless such neutralizers are used with care. This is especially true in the case of high-acid cream and when the temperature of the cream is relatively high at the time the carbonate is added.

Sodium carbonate and sodium bicarbonate are more troublesome in this respect than calcium carbonate, the former being readily soluble and acting quickly, while the calcium carbonate is practically insoluble in water and therefore acts more slowly on the acid, distributing the evolution of carbondioxide gas over a longer period of time and lessening the tendency of the cream to violently foam.

Of the hydrates, lime appears to be the only really suitable alkali to use. It is mild in its action, does not injure the flavor of the butter when used intelligently, does not appreciably attack the metal of the vats and other equipment, tends to form with that portion of the casein with which it reacts, a precipitate of relatively great stability and resistance against bacterial action, and it combines with the curd first, rendering that portion of the curd which enters into the composition of the butter less acid—thereby minimizing the acidity of the butter and its deteriorating power.

Sodium hydrate, the cheapest form of which, for neutralizing purposes, is soda lye, has strong caustic properties. It and the sodium lactate which it forms in the sour cream, readily attack and dissolve metals such as copper and even tin, causing the vat linings and coils and the pasteurizers to turn black and the cream and butter to contain undue quantities of metallic salts which are detrimental to its flavor and keeping quality. Sodium, unlike lime, reacts with the lactic acid of the cream first, and, inasmuch as in the neutralization of cream, acid reduction is not carried to the neutral point, there is but slight action on the casein, leaving the curd in butter made from sodium-neutralized cream, in more acid condition than is the case with butter from lime-neutralized cream. Again, while in lime-neutralized cream the undissolved casein appears in relatively large aggregates of marked firmness and apparent insolubility, in sodium-neutralized cream the insoluble portion of the casein is soft, it suggests greater solubility and less resistence to bacterial action.

The flavor of the butter made from cream neutralized with soda lye, sodium carbonate, or sodium bicarbonate is prone to have a soapy character. This is especially true of cream of high original acidity and cream in which the acid is reduced very close to the neutral point. With lime hydrate, properly prepared and intelligently used and using a sufficient quantity only to reduce the acidity to .25 per cent or thereabout, no objectionable flavor effects occur.

The popular claim that the use of lime conveys to butter a limy flavor does not apply to the proper neutralization with lime hydrate, it is the result of the abuse of lime resulting from inaccurate and faulty methods. Butter made from cream properly neutralized with milk of lime shows no such flavor defect. On the contrary, its flavor is pleasant and its keeping quality, other conditions being the same, is superior. Butter may, however, show a limy flavor when the lime neutralizer is not used properly; if the lime mix is too concentrated and is not adequately diluted before it is added to the cream, or if too much neutralizer is added, as is very often the case with high acid cream when no mathematically correct system of neutralization is used, and when the senses of taste and smell constitute the only means to determine whether the acidity in the cream has been sufficiently reduced.

Another very common cause of limy flavor in butter made from high acid cream due to over-neutralization lies in the fact that where the liming is done by guess only, the cream is usually tested immediately after neutralization and if the acidity at that time is higher than desired, more neutralizer is added. Since the action of the lime is slow and is not completed until after the neutralized cream has been pasteurized, it is obvious that the acid test made immediately after neutralization does not indicate the true acidity of the cream. If more lime is added on the basis of this acid test, there is danger of over-neutralization, resulting in limy-flavored butter and other flavor defects.

In an effort to avoid limy flavor some creameries use both, lime hydrate and sodium carbonate. They reduce the acidity of the cream with lime to say about .35 to .4 per cent acid and then complete the neutralization to the desired point with sodium carbonate. By this method they claim to secure the beneficial action of the escaping carbondioxide, thus combining the advantages of lime hydrate and sodium carbonate without suffering from the disadvantages of either. The lesser amount of lime used minimizes the danger of a limy flavor and the small amount of sodium carbonate required and added to the low-acid cream, prevents excessive foaming and does away with the tendency to produce a soapy flavor.

There is no reason why the double neutralization, when properly done, should not produce very satisfactory results. However, it too largely forfeits the ability of the buttermaker to check his work by determining the per cent acid in the neutralized cream, since the presence of sodium carbonate makes difficult the accurate determination of the end reaction in the acid tests. Moreover, when milk of lime is used correctly and intelligently, double neutralization is unnecessary.

Finally, lime is a natural constituent of milk and butter, it is not only harmless, but represents one of the essential minerals required by the human body for maintenance and especially for growth. If any portion of the neutralizer, no matter how small, does enter into the composition of the butter, it is essential that it add to, rather than detract from the healthfulness and dietetic value of the butter. From the standpoint of the welfare of the consumer, therefore, lime is not only the least harmful but, in fact, the most beneficial and hence the most suitable alkali available for reduction of the acidity in cream.

For the numerous and obvious reasons above discussed, lime hydrate constitutes overwhelmingly the most suitable form of neutralizer available for the reduction of acid in sour cream. All further discussion of, and directions for neutralization in this chapter will, therefore, be confined to the use of lime hydrate.

Strength and Amount of Neutralizers.—Having established a standard acidity to which to neutralize, and knowing the acidity of the cream before neutralization, it is a simple matter to calculate how much lime to use to secure the desired results, but here again accuracy is necessary; for guess work is bound to prove unsatisfactory, misleading and disappointing in the long run.

The most common form of lime used for neutralization of cream is calcium hydrate, or lime hydrate. Lime hydrate may be used in two forms, namely as lime water and as milk of lime.

Lime water consists of the clear water which separates on the surface after the slaked, but undissolved lime has dropped to the bottom. The lime water contains lime hydrate in solution only. From the standpoint of ease of handling, rapidity of action and accuracy of neutralization, this clear lime water would be most suitable. But lime is only very slightly soluble in water. It is soluble to the extent of about .137 per cent in cold water and to the extent of .075 per cent in boiling hot water. The clear lime water is so weak and its neutralizing power so slight that, in order to reduce the acidity in cream from say .85 per cent to .25 per cent, it would require lime water equal in volume to approximately twice the volume of the cream to be neutralized. Clear lime water, therefore, is obviously not a practical neutralizer to use.

A stronger lime hydrate must be used and this consists of milk of lime. Milk of lime is a watery emulsion of lime hydrate which contains, in addition to lime in solution, particles of undissolved lime. The milk of lime is somewhat more difficult to handle and the control of its strength is less easy, because the undissolved particles of lime settle out very readily and quickly. It is difficult to maintain a homogeneous emulsion of it and its neutralizing action is somewhat slow. By proper preparation and intelligent handling, however, the above objections are largely overcome.

In order to consistently reduce the acidity in cream to the standard of .25 per cent acid, and to determine the correct amount of lime emulsion to use, it is necessary to prepare and use a neutralizing emulsion of definite, known strength, and that can be manipulated accurately and conveniently and that lends itself to ready and even distribution and uniform action in the cream.

The mix can be made up direct from the quick lime or calcium oxide, in which case time must be taken to properly slake it. Or it can be made up from hydrated lime which requires no additional slaking. A good quality of hydrated lime gives fully as satisfactory action as unslaked lime, and it requires much less work and trouble to prepare the mix. Slaking lime is a mason's job which is rarely looked upon kindly or done properly by the creamery operator. Improperly and incompletely slaked lime makes an unsatisfactory neutralizer, generally containing much lime carbonate which is coarse, does not strain readily, is insoluble and slow of action in the cream.

A convenient strength and consistency of milk of lime is secured by two pounds of dry hydrated lime in one gallon of lime mix. In other words, add enough water to two pounds of dry hydrated lime to make up one gallon milk of lime. This formula has the further advantage that it is easily remembered by the operator. Since the preparation of the milk of lime is a somewhat unpleasant operation, it is advisable to make it up in sufficiently large quantities to avoid having to repeat the operation at too frequent intervals.

Having adopted this ratio of lime to mix, it is necessary to ascertain how much of this mix it takes to neutralize .01 per cent or .01 pound of lactic acid in 100 pounds of cream. It is necessary here, to remember that the molecular weight of pure lime hydrate is 74, while that of lactic acid is 90, and also that, lime hydrate, being bivalent, its strength is double that of lactic acid. In other words, it takes $\frac{74}{2}$ or 37 pounds of dry lime hydrate to neutralize 90 pounds of lactic acid. Hence, the amount of lime hydrate required to neutralize .01 pounds or .01 per cent lactic in 100 pounds of cream is:

$$90 : 37 = .01 : X;\ X = .00411 \text{ pounds lime hydrate.}$$

But the lime hydrate is not added to the cream in dry form, but in the form of milk of lime consisting of two pounds of dry hydrated lime in one gallon of mix. Hence it is necessary to know how many pints of this mix are required to neutralize .01 pounds or .01 per cent of lactic acid in 100 pounds of cream. Since the lime mix contains 2 pounds of lime hydrate in one gallon, or in 8 pints of mix, this factor is determined as follows:

$$2 : 8 = .00411 : X;\ X = .01644 \text{ pints lime mix.}$$

This then means that for every .01 per cent acid in 100 pounds of cream that is to be reduced, we must add to the cream .01644 pints of lime mix.

Table 24.—Neutralizing Table.—Pints of Lime Mix Required to Reduce Acidity to .25%.
(One gallon lime mix contains two pounds lime hydrate plus water.)

Pounds of Cream	PERCENT ACID IN CREAM																						Pounds of Cream
	.27	.29	.31	.33	.35	.37	.39	.41	.43	.45	.47	.49	.51	.53	.55	.57	.59	.61	.63	.65	.67	.69	
100								.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	100
200				.5	.5	.5	.5	.5	.5	.5	.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	200
300			.5	.5	.5	.5	.5	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	300
400		.5	.5	.5	.5	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	400
500		.5	.5	.5	1.0	1.0	1.0	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.5	3.5	3.5	500
600		.5	.5	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.5	3.5	4.0	4.0	4.0	4.5	600
700		.5	.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.5	3.5	4.0	4.0	4.5	4.5	5.0	5.0	700
800	.5	.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.5	3.5	4.0	4.0	4.5	4.5	5.0	5.5	5.5	6.0	800
900	.5	.5	1.0	1.0	1.5	2.0	2.0	2.5	2.5	3.0	3.5	3.5	4.0	4.0	4.5	4.5	5.0	5.5	5.5	6.0	6.0	6.5	900
1000	.5	.5	1.0	1.5	1.5	2.0	2.5	2.5	3.0	3.5	3.5	4.0	4.5	4.5	5.0	5.5	5.5	6.0	6.5	6.5	7.0	7.0	1000
1100	.5	.5	1.0	1.5	2.0	2.0	2.5	3.0	3.5	3.5	4.0	4.5	4.5	5.0	5.5	6.0	6.0	6.5	7.0	7.0	7.5	8.0	1100
1200	.5	1.0	1.0	1.5	2.0	2.5	3.0	3.0	3.5	4.0	4.5	4.5	5.0	5.5	6.0	6.5	6.5	7.0	7.5	8.0	8.5	8.5	1200
1300	.5	1.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	4.5	5.0	5.5	6.0	6.5	7.0	7.5	7.5	8.0	8.5	9.0	9.5	1300
1400	.5	1.0	1.5	2.0	2.5	3.0	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.0	9.5	10.0	1400
1500	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	1500
1600	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	1600
1700	.5	1.0	1.5	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.5	1700
1800	.5	1.0	2.0	2.5	3.0	3.5	4.0	4.5	5.5	6.0	6.5	7.0	7.5	8.5	9.0	9.5	10.0	10.5	11.5	12.0	12.5	13.0	1800
1900	.5	1.5	2.0	2.5	3.0	4.0	4.5	5.0	5.5	6.5	7.0	7.5	8.0	8.5	9.5	10.0	10.5	11.5	12.0	12.5	13.0	13.5	1900
2000	.5	1.5	2.0	2.5	3.5	4.0	4.5	5.5	6.0	6.5	7.0	8.0	8.5	9.0	10.0	10.5	11.0	12.0	12.5	13.0	14.0	14.5	2000
2100	.5	1.5	2.0	3.0	3.5	4.0	5.0	5.5	6.0	7.0	7.5	8.5	9.0	9.5	10.5	11.0	11.5	12.5	13.0	14.0	14.5	15.0	2100
2200	.5	1.5	2.0	3.0	3.5	4.5	5.0	6.0	6.5	7.0	8.0	8.5	9.5	10.0	11.0	11.5	12.5	13.0	13.5	14.5	15.0	16.0	2200
2300	1.0	1.5	2.5	3.0	4.0	4.5	5.5	6.0	7.0	7.5	8.5	9.0	10.0	10.5	11.5	12.0	13.0	13.5	14.5	15.0	16.0	16.5	2300
2400	1.0	1.5	2.5	3.0	4.0	4.5	5.5	6.5	7.0	8.0	8.5	9.5	10.5	11.0	12.0	12.5	13.5	14.0	15.0	16.0	16.5	17.5	2400
2500	1.0	1.5	2.5	3.5	4.0	5.0	6.0	6.5	7.5	8.0	9.0	10.0	10.5	11.5	12.5	13.0	14.0	15.0	15.5	16.5	17.5	18.0	2500
2600	1.0	1.5	2.5	3.5	4.5	5.0	6.0	7.0	7.5	8.5	9.5	10.5	11.0	12.0	13.0	13.5	14.5	15.5	16.0	17.0	18.0	19.0	2600
2700	1.0	2.0	2.5	3.5	4.5	5.5	6.0	7.0	8.0	9.0	10.0	10.5	11.5	12.5	13.5	14.0	15.0	16.0	17.0	18.0	19.0	20.0	2700
2800	1.0	2.0	3.0	3.5	4.5	5.5	6.5	7.5	8.5	9.0	10.0	11.0	12.0	13.0	14.0	14.5	15.5	16.5	17.5	18.5	19.5	20.5	2800
2900	1.0	2.0	3.0	4.0	5.0	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.0	16.0	17.0	18.0	19.0	20.0	21.0	2900
3000	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	17.5	18.5	19.5	20.5	21.5	3000
3100	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	3100
3200	1.0	2.0	3.0	4.0	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	3200
3300	1.0	2.0	3.5	4.5	5.5	6.5	7.5	8.5	10.0	11.0	12.0	13.0	14.0	15.0	16.5	17.5	18.5	19.5	20.5	22.0	23.0	24.0	3300
3400	1.0	2.0	3.5	4.5	5.5	6.5	8.0	9.0	10.0	11.0	12.5	13.5	14.5	15.5	17.0	18.0	19.0	20.0	21.5	22.5	23.5	24.5	3400
3500	1.0	2.5	3.5	4.5	6.0	7.0	8.0	9.0	10.5	11.5	12.5	14.0	15.0	16.0	17.5	18.5	19.5	20.5	22.0	23.0	24.0	25.5	3500
3600	1.0	2.5	3.5	4.5	6.0	7.0	8.5	9.5	10.5	12.0	13.0	14.0	15.5	16.5	18.0	19.0	20.0	21.5	22.5	23.5	25.0	26.0	3600
3700	1.0	2.5	3.5	5.0	6.0	7.5	8.5	10.0	11.0	12.0	13.5	14.5	16.0	17.0	18.0	19.5	20.5	22.0	23.0	24.5	25.5	27.0	3700
3800	1.5	2.5	4.0	5.0	6.5	7.5	8.5	10.0	11.5	12.5	13.5	15.0	16.0	17.5	18.5	20.0	21.5	22.5	24.0	25.0	26.0	27.5	3800
3900	1.5	2.5	4.0	5.0	6.5	7.5	9.0	10.5	11.5	13.0	14.0	15.5	16.5	18.0	19.0	20.5	22.0	23.0	24.5	25.5	27.0	28.0	3900
4000	1.5	2.5	4.0	5.5	6.5	8.0	9.0	10.5	12.0	13.0	14.5	16.0	17.0	18.5	19.5	21.0	22.5	23.5	25.0	26.5	27.5	29.0	4000
4100	1.5	2.5	4.0	5.5	6.5	8.0	9.5	11.0	12.0	13.5	15.0	16.0	17.5	19.0	20.0	21.5	23.0	24.5	25.5	27.0	28.5	30.0	4100
4200	1.5	3.0	4.0	5.5	7.0	8.5	9.5	11.0	12.5	14.0	15.0	16.5	18.0	19.5	20.5	22.0	23.5	25.0	26.0	27.5	29.0	30.5	4200
4300	1.5	3.0	4.5	5.5	7.0	8.5	10.0	11.5	12.5	14.0	15.5	17.0	18.5	20.0	21.0	22.5	24.0	25.5	27.0	28.5	29.5	31.0	4300
4400	1.5	3.0	4.5	6.0	7.0	8.5	10.0	11.5	13.0	14.5	16.0	17.5	19.0	20.0	21.5	23.0	24.5	26.0	27.5	29.0	30.5	32.0	4400
4500	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	19.5	20.5	22.0	23.5	25.0	26.5	28.0	29.5	31.0	32.5	4500
4600	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	19.5	21.0	22.5	24.0	25.5	27.0	28.5	30.5	32.0	33.5	4600
4700	1.5	3.0	4.5	6.0	7.5	9.5	10.5	12.5	14.0	15.5	17.0	18.5	20.0	21.5	23.0	24.5	26.0	27.5	29.5	31.0	32.5	34.0	4700
4800	1.5	3.0	4.5	6.5	8.0	9.5	11.0	12.5	14.0	16.0	17.5	19.0	20.5	22.0	23.5	25.0	27.0	28.5	30.0	31.5	33.0	35.0	4800
4900	1.5	3.0	5.0	6.5	8.0	9.5	11.5	13.0	14.5	16.0	17.5	19.5	21.0	22.5	24.0	25.5	27.5	29.0	30.5	32.5	34.0	35.5	4900
5000	1.5	3.5	5.0	6.5	8.0	10.0	11.5	13.0	15.0	16.5	18.0	19.5	21.5	23.0	24.5	26.5	28.0	29.5	31.5	33.0	34.5	36.0	5000
	.27	.29	.31	.33	.35	.37	.39	.41	.43	.45	.47	.49	.51	.53	.55	.57	.59	.61	.63	.65	.67	.69	

Pounds of Cream	PERCENT ACID IN CREAM .71	.73	.75	.77	.79	.81	.83	.85	.87	.89	.91	.93	.95	.97	.99	1.01	1.03	1.05	1.07	1.09	1.11	1.13	Pounds of Cream
100	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	100
200	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.0	3.0	3.0	200
300	2.5	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.0	4.0	4.5	300
400	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.5	4.5	4.5	4.5	5.0	5.0	5.0	5.5	5.5	5.5	5.5	6.0	400
500	4.0	4.0	4.0	4.5	4.5	4.5	5.0	5.0	5.0	5.5	5.5	5.5	6.0	6.0	6.0	6.5	6.5	6.5	7.0	7.0	7.0	7.0	500
600	4.5	4.5	5.0	5.0	5.5	5.5	5.5	6.0	6.0	6.5	6.5	6.5	7.0	7.0	7.5	7.5	7.5	8.0	8.0	8.5	8.5	8.5	600
700	5.5	5.5	6.0	6.0	6.0	6.5	6.5	7.0	7.0	7.5	7.5	8.0	8.0	8.5	8.5	9.0	9.0	9.0	9.5	9.5	10.0	10.0	700
800	6.0	6.5	6.5	7.0	7.0	7.5	7.5	8.0	8.0	8.5	8.5	9.0	9.0	9.5	9.5	10.0	10.5	10.5	11.0	11.0	11.5	11.5	800
900	7.0	7.0	7.5	7.5	8.0	8.5	8.5	9.0	9.0	9.5	10.0	10.0	10.5	10.5	11.0	11.5	11.5	12.0	12.0	12.5	13.0	13.0	900
1000	7.5	8.0	8.0	8.5	9.0	9.0	9.5	10.0	10.0	10.5	11.0	11.0	11.5	12.0	12.0	12.5	13.0	13.0	13.5	14.0	14.0	14.5	1000
1100	8.5	8.5	9.0	9.5	10.0	10.0	10.5	11.0	11.0	11.5	12.0	12.5	12.5	13.0	13.5	14.0	14.0	14.5	15.0	15.0	15.5	16.0	1100
1200	9.0	9.5	10.0	10.5	10.5	11.0	11.5	12.0	12.0	12.5	13.0	13.5	14.0	14.0	14.5	15.0	15.5	16.0	16.0	16.5	17.0	17.5	1200
1300	10.0	10.5	10.5	11.0	11.5	12.0	12.5	13.0	13.5	13.5	14.0	14.5	15.0	15.5	16.0	16.5	16.5	17.0	17.5	18.0	18.5	19.0	1300
1400	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	1400
1500	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	17.5	18.5	19.0	19.0	20.0	20.5	20.5	21.0	21.5	1500
1600	12.0	12.5	13.0	13.5	14.0	14.5	15.0	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	1600
1700	13.0	13.5	14.0	14.5	15.0	15.5	16.0	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.5	22.0	22.5	23.0	23.5	24.0	24.5	1700
1800	13.5	14.0	15.0	15.5	16.0	16.5	17.0	18.0	18.5	19.0	19.5	20.0	20.5	21.5	22.0	22.5	23.0	23.5	24.5	25.0	25.5	26.0	1800
1900	14.5	15.0	15.5	16.5	17.0	17.5	18.0	19.0	19.5	20.0	20.5	21.5	22.0	22.5	23.0	24.0	24.5	25.0	25.5	26.0	27.0	27.5	1900
2000	15.0	16.0	16.5	17.0	18.0	18.5	19.0	19.5	20.5	21.0	22.0	22.5	23.0	23.5	24.5	25.0	25.5	26.5	27.0	27.5	28.5	29.0	2000
2100	16.0	16.5	17.0	18.0	18.5	19.5	20.0	20.5	21.5	22.0	23.0	23.5	24.0	25.0	25.5	26.5	27.0	27.5	28.5	29.0	29.5	30.5	2100
2200	16.5	17.5	18.0	19.0	19.5	20.0	21.0	21.5	22.5	23.0	24.0	24.5	25.5	26.0	27.0	27.5	28.0	29.0	29.5	30.5	31.0	32.0	2200
2300	17.5	18.0	19.0	19.5	20.5	21.0	22.0	22.5	23.5	24.0	25.0	26.0	26.5	27.0	28.0	29.0	29.5	30.5	31.0	31.5	32.5	33.5	2300
2400	18.0	19.0	19.5	20.5	21.5	22.0	23.0	23.5	24.5	25.0	26.0	27.0	27.5	28.5	29.5	30.0	30.5	31.5	32.5	33.0	34.0	35.0	2400
2500	19.0	20.0	20.5	21.5	22.0	23.0	24.0	24.5	25.5	26.5	27.0	28.0	29.0	29.5	30.5	31.5	32.0	33.0	34.0	34.5	35.5	36.0	2500
2600	19.5	20.5	21.5	22.0	23.0	24.0	25.0	25.5	26.5	27.5	28.5	29.0	30.0	30.5	31.5	32.5	33.5	34.0	35.0	36.0	37.0	37.5	2600
2700	20.5	21.5	22.0	23.0	24.0	25.0	26.0	26.5	27.5	28.5	29.5	30.0	31.0	32.0	33.0	34.0	34.5	35.5	36.5	37.5	38.0	39.0	2700
2800	21.0	22.0	23.0	24.0	25.0	26.0	26.5	27.5	28.5	29.5	30.5	31.5	32.0	33.0	34.0	35.0	36.0	37.0	38.0	38.5	39.5	40.5	2800
2900	22.0	23.0	24.0	25.0	26.0	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5	34.0	35.5	36.5	37.0	38.0	39.0	40.0	41.0	42.0	2900
3000	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5	42.5	43.5	3000
3100	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	34.0	34.5	35.5	36.5	38.0	39.0	39.5	41.0	42.0	43.0	44.0	45.0	3100
3200	24.0	25.5	26.0	27.0	28.5	29.5	30.5	31.5	32.5	33.5	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.5	3200
3300	25.0	26.0	27.0	28.0	29.5	30.5	31.5	32.5	33.5	34.5	36.0	37.0	38.0	39.0	40.0	41.5	42.5	43.5	44.5	45.5	46.5	48.0	3300
3400	25.5	27.0	28.0	29.0	30.5	31.5	32.5	33.5	34.5	35.5	37.0	38.0	39.0	40.0	41.5	42.5	43.5	45.0	46.0	47.0	48.0	49.5	3400
3500	26.5	27.5	28.5	30.0	31.0	32.0	33.5	34.5	35.5	37.0	38.0	39.0	40.5	41.5	42.5	44.0	45.0	46.0	47.5	48.5	49.5	50.5	3500
3600	27.0	28.5	29.5	30.5	32.0	33.0	34.5	35.5	36.5	38.0	39.0	40.5	41.5	42.5	44.0	45.0	46.0	47.5	48.5	49.5	51.0	52.0	3600
3700	28.0	29.0	30.5	31.5	33.0	34.0	35.5	36.5	37.5	39.0	40.5	41.5	42.5	43.5	45.0	46.5	47.5	48.5	50.0	51.0	52.5	53.5	3700
3800	29.0	30.0	31.0	32.5	34.0	35.0	36.0	37.5	39.0	40.0	41.5	42.5	43.5	45.0	46.5	47.5	48.5	50.0	51.5	52.5	53.5	55.0	3800
3900	29.5	31.0	32.0	33.0	34.5	36.0	37.0	38.5	40.0	41.0	42.5	43.5	45.0	46.0	47.5	49.0	50.0	51.5	52.5	54.0	55.0	56.5	3900
4000	30.0	31.5	33.0	34.0	35.5	37.0	38.0	39.5	41.0	42.0	43.5	45.0	46.0	47.0	49.0	50.0	51.0	52.5	54.0	55.0	56.5	58.0	4000
4100	31.0	32.5	33.5	35.0	36.5	37.5	39.0	40.5	42.0	43.0	44.5	46.0	47.0	48.5	50.0	51.5	52.5	54.0	55.5	56.5	58.0	59.5	4100
4200	32.0	33.0	34.5	36.0	37.5	38.5	40.0	41.5	43.0	44.0	46.0	47.0	48.5	49.5	51.0	52.5	54.0	55.5	56.5	58.0	59.5	61.0	4200
4300	32.5	34.0	35.5	37.0	38.5	39.5	41.0	42.5	44.0	45.0	47.0	48.0	49.5	51.0	52.5	54.0	55.0	56.5	58.0	59.5	60.5	62.5	4300
4400	33.0	35.0	36.0	37.5	39.0	40.5	42.0	43.5	45.0	46.0	48.0	49.5	50.5	52.0	53.5	55.0	56.5	58.0	59.5	60.5	62.0	64.0	4400
4500	34.0	35.5	37.0	38.5	40.0	41.5	43.0	44.5	46.0	47.5	49.0	50.5	52.0	53.0	55.0	56.5	57.5	59.5	61.0	62.0	63.5	65.0	4500
4600	35.0	36.5	38.0	39.5	41.0	42.5	44.0	45.5	47.0	48.5	50.0	51.5	53.0	54.5	56.0	57.5	59.0	60.5	62.0	63.5	65.0	66.5	4600
4700	35.5	37.0	38.5	40.0	42.0	43.0	45.0	46.5	48.0	49.5	51.0	52.5	54.0	55.5	57.5	59.0	60.0	62.0	63.5	65.0	66.5	68.0	4700
4800	36.5	38.0	39.5	41.0	42.5	44.0	45.5	47.5	49.0	50.5	52.5	53.5	55.0	56.5	58.5	60.0	61.5	63.0	65.0	66.0	68.0	69.5	4800
4900	37.0	38.5	40.5	42.0	43.5	45.0	46.5	48.5	50.0	51.5	53.5	55.0	56.5	58.0	60.0	61.5	62.5	64.5	66.0	67.5	69.5	71.0	4900
5000	38.0	40.0	41.0	43.0	44.5	46.0	47.5	49.5	51.0	52.5	54.5	56.0	57.5	59.0	61.0	62.5	64.0	66.0	67.5	69.0	70.5	72.5	5000
	.71	.73	.75	.77	.79	.81	.83	.85	.87	.89	.91	.93	.95	.97	.99	1.01	1.03	1.05	1.07	1.09	1.11	1.13	

The following concrete example of neutralization may serve to illustrate this more clearly: The vat contains 2000 pounds of cream, the cream tests .6 per cent acid. which is to be reduced to .25 per cent acid. How many pints of lime mix must be added?

Answer:

Original acid in cream.............	.6 %
Acid desired.......................	.25%
Acid to be neutralized.............	.35%

Hence the amount of lime mix
required is $.35 \times 2000 \times .01644 = 11.5$ pints.

On the basis of this formula, then, the amount of lime mix required to reduce any per cent of acid in any amount of cream to the desired per cent acid, can readily be calculated, and tables can be assembled whereby the exact amount of lime mix needed can be read off at a glance. For the convenience of the operator tables on pp. 158 and 159 are shown.

If the creamery prefers to make up its milk of lime direct from lime oxide or quick lime, which is unslaked lime, the same formula and the same tables may serve without interfering with their accuracy, provided that the formula used for making up the milk of lime is modified. The unslaked lime or lime oxide is stronger than the hydrated lime, hence the milk of lime used must contain somewhat less lime. The molecular weight of lime oxide is 56, while that of lime hydrate is 74. Hence instead of using enough lime to make each gallon of milk of lime contain two pounds of lime, the amount of lime oxide per gallon of milk of lime must be $74 : 56 = 2 : X$; $X = 1.5135$ pounds lime oxide.

Accuracy of Results of Neutralization Depends on Kind of Lime Used.—The foregoing calculations were made on the assumption that the hydrated lime used contains 100 per cent calcium hydrate or nearly so, and examinations of the hydrated calcium limes of commerce have shown. that many of these limes approach this standard of purity quite closely, so that the above calculations should yield the acid reduction herein indicated.

Furthermore, tests of milk of lime so made, with aqueous solutions of both lactic acid and hydrochloric acid, demonstrated that these limes actually have the power to reduce the acid in the aqueous solutions to the theoretically calculated per cent.

However, neutralization of sour cream and neutralization of aqueous solutions of acid are two vastly different problems, and it has been conclusively demonstrated, by Hunziker and Hosman[1], both by laboratory experiments and by factory tests that, while in aqueous acid solutions the neutralizing action of the lime is complete, in cream not all of the lime added goes to neutralize the lactic acid present. These facts are shown in Table 25.

Table 25.—Fourteen Factory Tests in Which the Cream in the Vats Was Tested for Acidity Before Neutralization, and Three Hours After Neutralization, Showing Per Cent Neutralizer not Reacting.

(Enough lime hydrate was added to theoretically reduce the acid in the cream to .25%.)

Vat No.	Acidity in Cream		Per Cent Neutralizer Not Reacting
	Before Neutralization	After Neutral., Past. and Cooling 3 Hrs. After Neutral.	
1.	.67	33	19.0
2.	.63	.32	18.4
3.	.59	.30	14.7
4.	.75	.30	10.0
5.	.77	.33	15.4
6.	.65	.33	20.0
7.	.69	.32	15.9
8.	.59	.32	20.6
9.	1.00	.35	13.3
10.	.85	.37	20.0
11.	.85	.33	13.3
12.	.75	.35	20.0
13.	.71	.32	15.2
14.	.99	.34	12.0
Average	.75	.33	16.3

[1] Hunziker and Hosman, Investigation of Neutralizing Action of Lime in Different Acid Media, Blue Valley Research Laboratory, 1917. Results not published.

Table 26.—Reduction of Per Cent Acid in Cream and in Aqueous Solution of Lactic Acid and Per cent of Lime not Reacting.

Enough lime was added in each case to theoretically reduce the acidity to .25%.

Laboratory Tests, No.	Original Acid in Cream %	Acid After Neutralization		Difference Between Acid in		Lime Not Reacting	
		In Cream %	In Lactic Acid Sol. %	Cream & Lactic Acid Sol. %	Cream & .25% Acid %	In Cream %	In Lactic Acid Sol. %
1.	..900	.385	.250	.135	.135	21.9	—1.0
2.	.900	.367	.238	.117	.129	20.0	0.0
3.	.891	.346	.255	.091	.096	16.5	+0.6
4.	.900	.390	.261	.129	.140	20.0	—1.1
Average	.898	.372	.251	.118	.125	19.6	—0.38

From the above tables, it is evident that from about 16 to 20 per cent of the theoretically correct amount of lime added, fails to react with the lactic acid of the cream. In the factory tests the lime not so reacting averaged 16.3 per cent of the total lime added, while in the laboratory tests the deficiency in acid reduction averaged the equivalent of 19.6 per cent of the lime added. In the laboratory tests the amount of cream used was relatively very small and the preparation of the correspondingly very small amount of lime mix needed was difficult, obviously inviting relatively large experimental errors. It may be assumed, therefore, with reasonable certainty that for all practical purposes about 16 per cent of the theoretically calculated amount of lime that is required to neutralize the acidity in cream to .25 per cent fails to react on the lactic acid.

In order, therefore, to secure the full neutralizing action desired, that is to reduce the acidity of the cream to .25 per cent by the use of the neutralizing formula and tables given, it is necessary to increase the neutralizing strength of the milk of lime at least 16 per cent. This can readily be done in one or the other of the following ways:

a) By using a correspondingly larger proportion of dry hydrated lime in making up the lime mix. Since the acid-reducing power of the lime mix is approximately 16 per cent less than the theoretical calculations specify, each 100 parts of lime mix has an actual neutralizing strength of only 84 parts.

Hence, in order to secure 100 per cent neutralizing action, as called for in the tables, it is necessary to add enough more dry hydrated lime to the lime mix to make it 119 per cent (84 : 100 = 100 : X) strong. In other words, the amount of dry hydrated lime used to make up 1 gallon of lime mix must be increased by 19, or in round figures by 20 per cent. Instead of using 2 pounds of lime with enough water to make up 1 gallon of mix, use $2 + \frac{2 \times 19}{100} = 2.4$ pound of dry hydrated lime; or

b) By selecting a type of lime, the alkalinity of which is approximately 19 to 20 per cent stronger than the alkalinity of 100 per cent calcium hydrated lime. An extended experimental study of the neutralizing action of different types of hydrated limes by the author showed that these stronger limes are readily available in the form of so-called magnesium limes. The hydrated limes, commercially known as magnesium limes, contain in addition to calcium hydrate, from 35 to 50 per cent of magnesium oxide and their actual neutralizing strength averages from about 16 to 20 per cent greater than hydrated lime containing 100 per cent calcium hydrate. When using a magnesium lime, then, the original formula for making up the lime mix, i. e., two pounds dry lime with enough water to make up one gallon of mix, will reduce the acidity in the cream to the desired .25 per cent when the amounts of lime mix to be added, as indicated in the neutralizing table herein referred to, are used.

That either of the above corrections, as given under (a) and (b), will produce correct results, and will neutralize the cream to .25 per cent acid under practical creamery conditions, may be readily observed in table 27 which shows the averages of 1,545 churnings of cream, each churning representing 250 gallons of cream.

Table 27.—Maximum, Minimum and Average Per Cent Acid in 333 Churnings of Cream Neutralized with Calcium Lime When 20% More Lime was Used Than is Necessary to Theoretically Reduce the Acidity to .25%, and Maximum, Minimum and Average Per Cent Acid in 1212 Churnings of Cream Neutralized with Magnesium (Lime) Which is 16 to 20% Stronger Than Necessary to Theoretically Neutralize to .25% Acid.

Time of Testing for Acid	No. of Churnings	Calcium Lime Using 120% of Lime to Theoretically Neutral. to .25% Acid			No. of Churnings	Magnesium Lime Using 100% of Lime Which Tested 16 to 20% Stronger Than Calcium Lime		
		Max. % Acid	Min. % Acid	Aver. % Acid		Max. % Acid	Min. % Acid	Aver. % Acid
Before neutraliz.	333	.85	.49	.608	1212	.97	.31	.495
After neutraliz.	333	.28	.22	.250	1212	.30	.22	.251

The above table convincingly shows that it is possible to neutralize to exactly .25 per cent acid with lime, provided that the lime not reacting is compensated for by using 20 per cent more lime than is theoretically required in the case of calcium lime, or by using the amount of lime theoretically necessary for calcium lime in the form of magnesium lime which is from 16 to 20 per cent stronger in alkalinity than the calcium lime. In either case the acidity in the neutralized cream averages .25 per cent.

The use of the magnesium lime at the ratio of two pounds of dry lime in one gallon of mix, is preferable to the use of the calcium lime at the ratio of 2.4 pounds of dry lime in one gallon of mix. A lime mix containing 2.4 pounds of dry hydrated lime in one gallon of mix is rather thick and does not yield to agitation as readily as might be desired. Again the 100 per cent calcium lime is seldom as finely pulverized as it ought to be for neutralizing. Its relative coarseness renders it somewhat sluggish in its neutralizing action and unless intelligently and carefully prepared and handled, it tends to excessively combine mechanically with the curd of the cream, causing lumps.

Magnesium limes, which contain 35 to 50 per cent **MgO** have an alkalinity equal to 115 to 120 per cent of pure calcium hydrate. Their use requires only 2 pounds of the lime in one gallon of mix, to reduce the acidity to .25 per cent by the use of the neutralizing tables, appended. This lime mix is lighter and thinner, more easily agitated and made uniform in strength when used. The magnesium lime is perfectly white and very finely pulverized, it distributes more readily in the cream and acts very satisfactorily. It does not convey to the cream any objectionable flavor. Lime stone, as a rule, contains either a large percentage of magnesium (35 to 50 per cent) or a very small percentage of magnesium, less than 5 per cent, though there are exceptions. If magnesium lime is purchased, therefore, with the intention of securing a lime with relatively high neutralizing power, it should be ascertained that the lime contains 35 or more per cent of magnesium.

Analyses[1] show that the hydrated limes containing magnesium contain only enough water to satisfy the calcium. These limes, therefore, are a mixture of calcium hydrate and magnesium oxide.

Incomplete Reaction of Lime in Cream Due to Affinity of Lime for Curd.—In previous paragraphs it was shown that while the lime is capable of, and does exert its full neutralizing strength in aqueous solutions of lactic acid, a portion of the lime, about 16 to 20 per cent, when added to sour cream, fails to so act. It remains now to explain why all of the lime does not react in the cream and what becomes of that portion which fails to react with the acid in the cream.

It is well known that the casein has a marked affinity for calcium. In raw, sweet milk and cream the casein is present as a calcium salt. When cream becomes sour, the lactic acid thus formed removes calcium from the casein. This leaves a part of the casein as free casein which is a solid, and a part occurs as casein lactate which is in a colloidal state. The casein lactate, however, is readily hydrolized; upon neutralization it is precipitated, becoming solid, so that from the

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[1] Brigham, S. T. Engineering news, Vol. 50.

standpoint of neutralization of cream, it may be considered equivalent to free casein.

When lime is added to the sour cream the concentration of the acid is very greatly reduced and the concentration of the calcium is increased to excess. In the presence of free casein, these conditions are most favorable to the formation of calcium caseinate.

Since both the lime, in the form of milk of lime, and the casein are in a similar physical state and have a specific chemical attraction for each other, it appears unnecessary for the calcium to go into solution in order to react on the casein.

That such action takes place is indicated by the fact that when cream is poured over dry hydrated lime, the lime gradually becomes coated with a layer of casein-like material that adheres to the particles of lime with which it comes in immediate contact. This is especially noticeable on heating. A similar action seems to take place when the lime is added to the cream in the vat, in concentrated form, either due to inadequate dilution of the lime mix or lack of proper distribution. Large lumps and masses form, the solid constituents of which consist largely of curd, with a very high lime content, and in which is locked up a good deal of fat, as shown in Table 28.

Table 28.—Composition of Lumps in Cream Caused by the Use of Too Coarse or Too Concentrated Lime, or By Incomplete Distribution of the Lime Mix.

Sample No.	Water %	Fat %	Curd %	Ash Expressed as CaO %	Ash Expressed in $Ca(OH)_2$ %
1.	59.06	22.07	6.13	3.99	5.27
2.	57.96	19.29	8.73	3.82	5.05
3.	58.56	19.44	7.84	5.59	7.38

The greater affinity of the lime for the casein than for the lactic acid in the cream is proven by analysis of the serum and the curd, respectively, of cream that was neutralized to .26% acid with milk of lime of the standard strength of two pounds of dry hydrated lime made up with water to one gallon of mix, as shown in Table 29.

Table 29.—Relative Action of Lime on Serum and on Curd in Cream When Neutralized.

Components of Cream	Per Cent Calcium in Cream			
	Before Neutralization	After Neutr. to .26% Acidity	Increase of Calcium	Per Cent Increase of Calcium
Serum	.049	.074	.025	51.0
Curd	.105	.405	.300	285.7

The above figures show that while the serum of the neutralized cream contained 51% more calcium, the curd contained 285.7% more calcium than was contained in the serum and curd before neutralization of the cream. This evidence can leave no doubt regarding the fact that the lime reacts with the casein and that this action exceeds the action of the lime on the lactic acid in the cream.

Since casein is an acid body, it must follow that the readiness with which it enters into combination with the lime also causes it to surrender its acidity in excess of the action of the lime on the lactic acid. Table 30 shows that such is, in fact, the case.

Table 30.—Relative Action of Lime on the Acid of the Curd and on the Lactic Acid in the Cream, Serum and Fat.

No. of Samples	Per Cent Acid in											
	Cream			Serum			Curd			Fat		
	Un-Neutral. %	Neutral. %	Reduction %	Un-Neutral. %	Neutral. %	Reduction %	Un-Neutral. %	Neutral. %	Reduction %	Un-Neutral. %	Neutral. %	Reduction %
1......	.553	.261	52.8	.369	.161	56.4	.124	.043	65.3	.046	.044	4.3
2......	.531	.265	50.1	.373	.174	53.3	.120	.045	62.5	.036	.036	0.0
3......	.560	.193	65.5	.375	.117	68.8	.123	.034	72.4	.052	.041	21.0
Aver. Reduction of Acid			56.1			59.5			66.7			8.4

Table 30, unmistakably shows that the acid in the curd is reduced to a greater extent than the lactic acid in the serum.

It should be understood that the lower the point to which neutralization of the cream is carried, the greater is naturally, the relative reduction of the lactic acid in the serum. But even in sample No 3, where the acidity in the cream was reduced to

.193 per cent, the per cent reduction of acid in the curd still exceeded that in the serum, though to a lesser extent than when neutralization was carried only to .26% acid in the cream. The same tendency would obviously occur in the case of cream of very high acidity. It can readily be seen that while the lactic acid in the cream can be increased very greatly, the per cent curd and therefore, the amount of acid it contains is quite constant and remains practically the same. Hence in the neutralization of high-acid cream, the per cent reduction of the lactic acid in the serum might be greater than that in the curd. In very high acid cream, it might be possible for the acid in the curd to be reduced to the neutral point. This is improbable, however, because in such cream the stronger acid (the lactic acid of the serum) would claim more of the alkalinity of the lime.

It should be noted also in Table 30, that the per cent reduction of the acid in the fat is very slight. This may be explained by the probability that the fat becomes saturated with lactic acid from the acid serum and the acid so held is not redistributed in the serum, unless the serum is reduced to a low percentage of acid. This assumption is borne out in the case of Sample No. 3, representing cream neutralized to .193 per cent acid and in which the acid reduction in the fat was abnormally great.

Ability of Acid Test with Sodium Hydroxide to Show Total Acidity in Cream.—It has been shown that the lime has a great affinity for the casein, that the curd of neutralized cream absorbs over five times as much calcium as the serum and that the action of the lime on the acid in the curd is in excess of that on the lactic acid in the serum. The question then arises, does Sodium which is used in testing the cream for acid, and in the use of which the titration is carried to the neutral point, show a similar preference for the acid in the curd as the lime? In other words, does the acid test show the total acid in the cream, including both the lactic acid and the casein acid, or does it indicate the lactic acid only?

This question is important, because if the acid test represented the determination of the lactic acid only, then it would not be a true index of the acidity of the cream and it would also furnish a very logical explanation of why a portion of the lime added to the cream shows no reduction in the acidity as determined by Mann's acid test.

Table 31 demonstrates that sodium hydroxide, such as is used in the acid tests, does indicate the total acid in the cream, including the lactic acid, curd acid and fat acid. Its action is very nearly equal to that of lime. The figures in this table were analyzed, for percentage of acidity, separately. The table shows that the sum of the acid in the components—the serum, curd and fat—of the cream is practically equal to the acid in the original cream.

Table 31.—Per Cent Acid in Unneutralized Cream and Its Components.

Components of Cream	Per Cent Acid in Cream and Its Components				
	Lot 1.	Lot 2.	Lot 3.	Lot 4.	Aver.
Cream	.560	.531	.553	.461	
Serum	.375	.373	.369	.335	
Curd	.123	.120	.124	.108	
Fat	.052	.036	.046	.039	
Total components	.550	.529	.539	.482	
Difference between cream and total components	.01—	.002—	.014—	.021+	.001—

"–" acidity in total components less than acidity in cream.

"+" acidity in total components more than acidity in cream.

Further evidence of the fact that sodium shows similar preference for curd as lime does may be found in Table 32. In this experiment the neutralizing action of the lime water (lime hydrate in solution) and sodium hydrate is shown. Here neutralization was carried to the neutral point. The action of the two alkalies was very similar.

Table 32.—Showing Neutralizing Action of Lime Water and Sodium Hydroxide.

Neutralized with	Original Acid %	Acidity Reduced %	Acidity Remaining After Heating to 145° F. %	Total Acidity Reduced to Reach Neutral Point %
Sodium hydrate, N/10	.639	.393	.246	.624
Calcium hydrate, N/20 in solution	.659	.448	.221	.625

The neutralizers were added in two installments. After the first addition the cream was heated to 145° F. for one hour, then enough more neutralizer was added to reduce the cream to the neutral point.

The lesser total acidity which was required for complete neutralization, was undoubtedly due to the expulsion of carbon dioxide, during the heating process. The slight decrease in the acidity due to pasteurization is a matter of common experience. These figures show a slight difference in the total neutralizing effect between the sodium hydroxide and the lime water. This is probably caused by the difference in dilution of the neutralized cream, the greater dilution due to the lime water facilitating the recognition of the end point in the titration.

When neutralization is not carried to the end point, or neutral point, the distribution of the Sodium hydroxide and the calcium hydrate in solution differs somewhat; a slightly smaller proportion of the remaining acid is lactic acid, when sodium hydroxide is used, than in the case of lime water.

This difference in the action of the two alkalies is materially augmented when milk of lime (lime hydrate not in solution) is used in the place of lime water. This is shown in Table 33.

Table 33.—Showing Relative Action of Sodium Hydrate, Lime Water and Milk of Lime on Acidity in Serum of Cream.

Character of Neutralizer	Original Acidity %	Acidity of Cream After Neutralization %	Acidity of Serum After Neutralization %	Reduction of Acidity in Serum %
Sodium hydroxide	.637	.250	.028x50%	.323
	.637	.250	.028	.323
Lime water...	.637	.250	.034	.317
	.637	.250	.037	.314
Milk of lime..	.637	.250	.044	.307
	.637	.250	.044	.307

The figures in Table 33 show that when neutralization is not carried to the neutral point, adding neutralizer sufficient only to reduce the acidity to .25% acid, the lime water (lime in solution) shows somewhat greater preference for the casein than for the serum and that this preference for the casein is greatly augmented in the case of milk of lime. Both the lime water and the milk of lime showed greater preference for the casein than did the sodium hydroxide, hence the lime neutralizers had less alkalinity left to act on the lactic acid in the serum, and reduced the acidity in the serum to a lesser extent than did the sodium neutralizer. It should be clearly understood here that this difference of distribution of the neutralizing action between sodium hydrate and calcium hydrate occurs only when the neutralization is not carried to the neutral point. Tables 31 and 32 show that when neutralization is carried to the neutral point, the sodium hydrate fully neutralizes both the lactic acid in the serum and the acid in the casein. This fact furnishes reliable proof that the acid test with sodium hydroxide shows the total acidity in cream. Its results are, therefore, correct, and they demonstrate that the incomplete acid reduction of the lime is not due to any shortcomings of the acid test of the cream, but must be due to the great affinity of the lime for the casein which causes the mechanical combination of particles of undissolved lime with particles of solid casein, thereby mechanically tying up a portion of the lime and making the alkalinity of the portion of the lime, so fixed, unavailable for acid reduction.

Summary of Action of Lime in Sour Cream.—Summing up the foregoing discussion concerning the action of lime hydrate when used as a neutralizer in sour cream, the following points are of importance:

(1) When a sufficient amount of lime is added to sour cream to theoretically reduce the acidity in the cream to .25% acid, the lime fails to accomplish the full extent of this acid reduction. About 16 to 20% of the lime does not react.

(2) This delinquency may be corrected by using approximately 20% more lime hydrate, thus making the lime mix about 16% stronger than required theoretically, or by using instead of calcium lime, magnesium lime. Magnesium lime containing from 35 to 50% magnesium oxide has an alkalinity equivalent in strength to approximately 116 to 120% of pure calcium lime.

(3) Lime has a marked affinity for casein. The absorption of lime by the casein and the reduction of the casein acid are greater than the absorption of lime by the serum and the reduction of the lactic acid.

(4) When neutralization is carried to the neutral point, the distribution of the neutralizing action in the components of cream —the serum, curd and fat—is similar with sodium hydrate as it is with lime water.

(5) The acid test of the cream determines the total acidity of the cream, including both the casein acid and the lactic acid, It yields, therefore, the correct per cent of acid.

(6) The deficiency of the neutralizing action of the lime is due to physical and mechanical combination between portions of insoluble lime and the curd. The fact that from 16 to 20% of the lime does not react in the cream must be attributed to the great affinity of the lime for casein, particles of lime adhering and becoming permanently attached to particles of free casein. In this condition the lime so held is unable to exert its full neutralizing action.

Adding Lime Mix in Proper Manner.—It is not enough to use the right strength and amount of lime. The lime mix must be handled in the proper manner, after it is made up and before it is added, otherwise it cannot accomplish that for which it is used. Lime settles to the bottom quickly, hence it must be stirred thoroughly before use. It must be strained and diluted with an equal volume of water before it is poured into the cream and it must be sprinkled over the entire surface of the cream while the cream is in agitation. Sediment of limy curd in the bottom of the forewarmer or vat is a fairly conclusive proof that the lime mix was not added as it should have been.

In order to secure maximum reaction between the alkalinity of the lime and the acid in the cream, the neutralizer must be distributed thinly and uniformly throughout the entire batch of cream. This is possible only when the lime mix is reasonably diluted before it is poured into the vat, and when it is added, not in one place, but over the entire vat, in the form of a small stream, or a spray, and while the cream in the vat is vigorously agitated.

If the full strength of undiluted lime mix is "dumped" into the vat all in one place, there is very intense action on the curd, a portion of the lime mechanically combines with the curd and fat, and will drop to the bottom of the vat in the form of lumps. In this case the lime so fixed, fails to yield its full alkalinity to the serum of the cream and the acid reduction falls short of that calculated even when an excess of 16 to 20% of lime is used, and accurate results from such procedure need not be expected. This lack of proper distribution of the neutralizer in the cream has the further disadvantage of causing excessive loss of fat, the lumps of limy curd in the bottom of the vat being high in fat content.

To avoid this, the lime mix should be diluted with an equal volume of water and its uniform distribution is facilitated by spraying it over the vigorously agitated cream, from a flower sprinkling can.

Checking Results by Retesting.—Finally, if the operator is to do continuously accurate and reliable work, he must check his work by retesting the cream for acid, after he has given the neutralizer the proper time and condition for full action.

Other Factors That Cause Irregularities of Results of Neutralization.—The complexity of the physical and chemical make-up of cream, its susceptibility to a variety of changes in composition, which are largely beyond the control of the creamery, together with irregularities in the preparation and use of the neutralizer which are largely due to the personal factor of the operator, naturally invite frequent fluctuations in the results of neutralization, and interfere more or less with the desired uniformity and accuracy of the results. Notwithstanding these facts, the use of a systematic process of neutralization makes possible the removal of excess acid and the reduction of the acidity to the desired point, within the limits of not to exceed .05 per cent acid above or below that desired. It enables the creamery to secure the full benefit of neutralization without danger of overneutralization and its detrimental effect on the quality of the finished product.

The dominating factors which cause fluctuations in the reduction of the acidity of the cream by neutralization are the original per cent acid in the cream before neutralization, the per cent casein in the cream, the amount of carbondioxide in the cream, the strength, dilution and distribution of the lime mix when added, the temperature of the cream and the time allowed for neutralization.

Effect of Original Per Cent Acid in Cream Before Neutralization on Accuracy of Acid Reduction.—It has been shown that in the neutralization of cream of average acidity (testing about .60 to .80 per cent acid), a portion of the lime (from about 16 to 20 per cent) does not react and that, therefore, lime sufficient in amount, or in strength to be equivalent in alkalinity to 16 to 20 per cent in excess of that required to theoretically reduce the acidity to the desired point must be added. It was further shown that this loss of reaction of a portion of the lime is due to the fact that a part of the solid particles of lime mechanically combines with the solid particles of casein, rendering the alkalinity of the lime so held inaccessible to the acid in the cream.

The amount of lime not reacting is, therefore, fairly constant and does not vary greatly with the acidity of the cream. It is not proportional with the original per cent acid present in the cream. Hence in very high-acid cream, the 16 to 20 per cent excess lime added will tend to reduce the acidity of the cream slightly below the calculated point, while in cream of relatively low original acidity, the point to which the acidity drops will tend to be slightly above the calculated point.

Effect of Per Cent Casein in Cream on Accuracy of Acid Reduction.—Since the fact, that a portion of the lime does not react, is due to the mechanical tying-up of a portion of the lime with the casein, the amount of lime not reacting must of necessity vary with the per cent casein in the cream, and this in turn is largely controlled by the fat content of the cream. Generally speaking, the ratio of solids not fat to water in cream is the same as that in milk, hence the more fat, and therefore, the less water cream contains, the lower is the per cent of solids not fat in cream, and the per cent curd, being a non-fatty constituent is also reduced correspondingly. The following Analysis of Cream, by Richmond,[1] illustrates this point clearly.

Table 34.—Composition of Cream.

	Thick Cream %	Thin Cream %
Water	39.37	63.94
Fat	56.09	29.29
Sugar	2.29	3.47
Protein	1.57	2.76
Ash	.38	.54
	99.70	100.00

The above analysis shows that cream testing 56. per cent fat contained only 1.57 per cent protein, while cream testing 30. per cent fat contained 2.76 per cent protein.

The smaller curd content of rich cream, therefore, ties up less lime than the larger curd content of thin cream. In the case of rich cream, the proportion of lime not reacting with the lactic acid is less than in thin cream. Hence the acidity in rich cream is reduced to a slightly lower point than that in thin cream, when the calculated amount of lime used is the same for both, rich and thin cream.

[1] Richmond Dairy Chemistry, Second Edition, 1914, p. 266.

Effect of Amount of Carbondioxide in Cream, on Accuracy of Acid Reduction.—When determining the acidity present in cream before neutralization by titration with sodium hydroxide, the results show not only the lactic acid and the casein acid present, but also the carbondioxide that cream may contain. But the carbondioxide escapes during pasteurization, being expelled by heat; it, therefore, does not claim the alkalinity of the lime added, and allows this alkalinity to further reduce the lactic acid and casein acid of the cream.

The carbondioxide content of cream is very variable. It is largely the result of fermentation. In fresh and only moderately sour cream it is very slight, while in highly acid cream and especially in yeasty cream, it may be relatively great. Hence, the addition of the amount of lime calculated to reduce the acidity to a given point when based on the original acid test of the cream before neutralization will, in the case of high acid and fermented cream, drop the acidity to a sligthly lower point than that calculated. This irregularity is somewhat minimized by the heating of the cream in the forewarmer, which expels a portion of the carbondioxide present before the cream is tested for its original acidity, and the higher the temperature to which the cream is heated in the forewarmer, the more of the carbondioxide is liberated. This fact, however, should not be interpreted to mean that it is desirable to heat the sour cream excessively before neutralization. Such a practice would in part forfeit the benefits of neutralization, causing, especially in the case of thin, sour cream, the formation of an abnormal curd, with excessive loss of fat and the danger of white specks in the butter. The temperature of the cream before neutralization, either in the forewarmer or in the pasteurizing vat, should not be raised above 90 degrees F., if these defects are to be avoided in a dependable manner by neutralization.

Effect of Time and Temperature on Accuracy of Acid Reduction.—The neutralizing action of the lime is comparatively slow, it is not instantaneous. The acid test of the cream, made immediately after neutralization, does not show the full neutralizing power of the lime. The per cent acid found in the cream at that time is higher than the calculated per cent acid to which the cream is to be reduced. Time is required for complete action. Creameries that add their neutralizer by guess and then calculate from the per cent acid found in the cream immediately after neutralization the additional amount of lime needed to reduce the acidity to the desired point, will fail to secure uniform results and may, under certain conditions, unknowingly overneutralize the cream.

Proper dilution and distribution of the lime greatly hasten the action of the lime and the heat of pasteurization assists in completing it. The following table may serve to show the rate at which neutralization progresses from the time the lime mix, properly diluted, is added to the cream, when the temperature of the cream at the time of neutralization averages about 90 degrees F.

Table 35.—Showing Progressive Reduction of Acidity in Cream After the Addition of the Neutralizer.

Number of Batches of Cream	Per Cent Acid in Cream		
	Before Neutralization	Immediately After Neutralization	After Pasteurization and Cooling; 2 to 3 Hrs. After Neutralization
Averages of 139 batches..	.658	.295	.251
Averages of 114 batches..	.755	.291	.243
Averages of 175 batches..	.729	.369	.270
Averages of 181 batches..	.740	.362	.275
Averages of 97 batches..	.553	.303	.256
Averages of 133 batches..	.653	.363	.256
Averages of 96 batches..	.485	.300	.244
Averages of 228 batches..	.517	.281	.247
Averages of 76 batches..	.524	.298	.268
Averages of 93 batches..	.594	.335	.271
Averages of 140 batches..	.611	.343	.249
Averages of 1472 batches.	.620	.322	.257

Effect of Neutralization on the Composition of Butter.—The composition of butter made from neutralized cream does not appreciably differ from that made of unneutralized cream. The curd content of butter tends to be slightly reduced as the result of neutralization. Ramsay[1] found the following differences in curd content.

Butter Made From	Per cent Curd
Unneutralized Cream	1.28
Cream treated with Sodium Bicarbonates	.87
Cream treated with Calcium Carbonate	.72

The above analyses show a rather unusually high per cent of curd in butter made from both, neutralized and unneutralized cream. When butter is washed properly the curd content generally averages several tenths per cent lower. However, they are valuable because they show the relative reduction of curd content due to neutralization.

The decrease in the curd content may be explained by the fact that the neutralizer causes the precipitated curd to be firmer, more grainy and to separate more completely from the serum. This is especially the case with lime-neutralized cream, but even sodium-neutralized cream has a firmer curd than unneutralized cream. In this firmer condition more of the curd passes into the buttermilk and less is taken up by the butter. A similar difference is noted between butter made from sour and sweet cream. In sweet cream, the curd is present in a more colloid condition which sticks to the butter particles and causes such butter to have a higher curd content than sour cream butter.

The butter made from lime-neutralized cream contains slightly more calcium than butter made from untreated cream. Wichmann[1] found a slight increase in the calcium oxide of the salt-free ash of neutralized cream butter, as well as in the butter itself, and he claims that when the calcium oxide content of butter exceeds .025 per cent, there is strong indication that such butter was made from limed cream, provided that the salt added to the butter did not contain calcium salts. The slight increase in the calcium oxide of lime-neutralized butter is in all probability due to the calcium attached to the curd. As shown in previous paragraphs, the calcium content of the curd increased

[1] Ramsay. Note on Neutralization of Cream in Butter Manufacture and the Effect on the Butter Produced. New South Wales Dept. Agr., Science Bulletin No. 16, 1915.

about fivefold when lime was added to the cream. Wichmann's results, however, are marred by the fact that his experiments seem to have lacked a systematic and accurate method of neutralizing. The lime was apparently added by guess and the acid test was taken immediately after neutralization, so that the full neutralizing action was not determined. It is doubtful that butter made from lime-neutralized cream contains enough more calcium oxide to reliably detect neutralization by chemical analysis. In fact such butter might, under certain conditions, contain no more or even less lime oxide than butter made from untreated cream, depending on the completeness of the removal of the buttermilk, which in turn largely depends on the size of the butter granules when the churn is stopped and on the thoroughness of washing the butter.

SPECIFIC DIRECTIONS FOR NEUTRALIZING CREAM WITH LIME HYDRATE.

1. Secure hydrated lime that is relatively free from carbonates.

If the hydrated lime is a calcium lime (containing but little, not over five per cent magnesium oxide), make up a lime mix or milk of lime by using 2.4 pounds of the dry hydrated lime for every gallon of mix.

2. If the hydrated lime is a magnesium lime, containing not less than 30 to 35 per cent magnesium oxide, make up a lime mix or milk of lime by using 2 pounds of the dry hydrated lime for every gallon of mix.

3. Magnesium lime is more satisfactory than calcium lime.

4. For making up lime mix in small quantities use a ten-gallon can, add 24 pounds of calcium lime or preferably 20 pounds of magnesium lime, fill half full of water, stir until the emulsion is complete, then fill the can full with water and stir again. This now represents the milk of lime, or lime mix, or lime neutralizer. Use the neutralizing tables for determining the correct quantity of this neutralizer required to reduce the acidity in the cream to .25 per cent.

5. For making up larger quantities of lime neutralizer, use a circular tank with agitator, similar to a starter can. A tank with an operating capacity of say 100 gallons may be found most convenient. Mark the level at which the tank contains 100 gallons. This is readily done by pouring ten 10-gallon cans full of water into it and punching a small hole into the side of the tank at a point level with the surface of the water.

6. Withdraw half of the water and weigh into the tank 200 pounds of dry hydrated magnesium lime or 240 pounds of dry hydrated calcium lime, revolve the agitator until all lumps have disappeared and a homogeneous emulsion is secured. Fill up the tank with water to the 100 gallon mark and stir again.

A lime mix tank equipped with mechanical agitator which is operated by belt or motor power is much preferable to one with a hand agitator, as it obviates the laborious work of hand stirring and insures more complete homogenousness of the mix.

7. Now mix the milk of lime in the lime tank thoroughly, giving the agitator at least 15 vigorous turns in the case a hand agitator is used. Then measure out with a gallon measure graduated to half pints the required amount of neutralizer, as indicated in the neutralizing table.

8. Strain it through a cheese cloth into a garden sprinkling pot, add an equal amount of water and sprinkle the neutralizer over the cream in all parts of the vat.

9. Keep the cream agitated while the neutralizer is being added.

10. Always make sure that the quantity of cream and the test of the original acid present are correct, that the milk of lime has been properly mixed before removing the required amount from the lime mix tank and that the neutralizer is properly diluted before it is added to the cream.

11. It is advisable to not heat the cream much above 90 degrees F. before the neutralizer is added.

CHAPTER VIII.

PASTEURIZATION.

Definition.—As applied to buttermaking, pasteurization may be defined as the process of heating milk or cream to a temperature capable of destroying the great majority of bacteria and other ferments contained therein and of cooling quickly to the ripening or churning temperature.

In proper pasteurization the milk or cream is heated to 145 degrees F. and held at that temperature for at least twenty minutes or it is heated to from 176 to 185 degrees F. and cooled without holding. Proper pasteurization may also embrace any modification of the above relations of temperature to time of exposure that is equivalent in germ-killing efficiency to the above processes and has otherwise no injurious effect on the flavor and texture of butter. If the cream is to be ripened subsequently, it is cooled after pasteurization to about 65 degrees F. If the ripening process is dispensed with the cream is cooled after pasteurization to the churning temperature which will generally vary from 45 degrees F. to 60 degrees F., according to locality and season of year.

Objects of Pasteurization.—Pasteurization does not make possible the manufacture of fancy butter from a poor grade of cream, but it does help the creamery to minimize the injurious effect of contamination of milk and cream with diverse types of germ life and ferments injurious to the quality of the butter and possibly dangerous to the health and life of the consumer. Proper pasteurization, therefore, improves the quality, and keeping properties of butter and makes the product safe for consumption. Briefly, the chief objects of pasteurization of cream for buttermaking are: Improvement of flavor of butter, better keeping quality, more uniform flavor and quality, destruction of germs of human and animal diseases, increase of economic efficiency of dairy industry.

Improvement of Flavor.—Proper pasteurization improves the flavor of butter, partly, because it destroys the great majority of ferments present in the cream, some of which are prone to decompose one or more of the ingredients of butter, producing objectionable flavors and odors and partly, because the pasteurizing heat removes from the cream gases and volatile and soluble substances which possess undesirable odors.

Experimental results conducted at various experiment stations in this country and abroad have conclusively demonstrated that efficient pasteurization destroys over 99 per cent of the micro-organisms present in the cream. The type of micro-organism most damaging to the quality of butter is the liquefying bacteria—those which attack the proteins and fat,—and certain species of yeast and molds. Bacteriological analyses of cream before and after pasteurization show that the per cent decrease of these undesirable germs is practically the same as that of the lactic acid bacteria.

Pasteurization expels from the cream, vapors and gases, especially carbondioxide gas, which carry with them objectionable volatile substances which may have been absorbed mechanically or which have developed in the cream due to bacterial action. This expulsion is further facilitated by the reduced viscosity of the hot pasteurized cream. Gases are less soluble and more volatile at high temperatures, therefore they escape more readily from pasteurized cream. In raw cream they tend to go in solution, they remain in the cream and may be carried into the butter.

Soluble decomposition products, such as may be present in cream that has yielded to fermentation, are more easily expelled from the cream and butter made from pasteurized cream than from raw cream. The clusters of fat globules break up, and offer a greater surface for the liberation of these biproducts. Some of these products as well as the curd, that harbor faulty odors, are precipitated more completely by pasteurization and in this condition pass off in the buttermilk. The curd contracts and squeezes out soluble substances, so that part of the curd which subsequently does become a part of the butter is freer from these undesirable, soluble bi-products.

Improves Keeping Quality.—Since certain species of bacteria, yeast and molds that may be present in the cream, cause deterioration of the butter in storage, the elimination of these micro-organisms retards such deterioration and improves the keeping quality of the butter. High temperature pasteurization also destroys the activity of enzymes, some of which are capable of decomposing one or more of the constituents of butter, shortening its life. The destruction of their activity, therefore, furnishes additional protection against deterioration of butter with age.

At best the great bulk of butter is several weeks old before it reaches the pantry of the consumer, and during this time it is often exposed to unfavorable temperature conditions which stimulate bacterial and enzyme action. Large quantities of butter are also stored for a considerable length of time for the purpose of holding it over from summer, the time of surplus, till winter, the period of usual shortage. It is, therefore, of great economic importance that the butter have sufficient keeping properties to successfully withstand the deteriorating influences of age.

Produces Greater Uniformity of Quality.—Uniformity of flavor and quality are essential requisites for the successful marketing of butter. The consumer demands that the butter on his table be of uniform quality. With intelligent pasteurization the fermentations in the cream and butter can be more readily controlled, thus insuring greater uniformity of the resulting flavor of the butter of different churnings. Instead of being constantly and entirely at the mercy of the conditions to which the cream is exposed on the farm and in transportation, the buttermaker, by means of efficient pasteurization, is able to modify the variable bacterial flora in cream, eliminating undesirable ferments and thereby producing a butter of greater uniformity in flavor and quality.

Where it is desired to ripen the cream, pasteurization assists in confining the ripening process to the fermentations which are desired and to the exclusion of fermentations of known injurious effect.

Destroys Disease Germs.—Pasteurization, when properly executed, also frees the cream, buttermilk and butter from germs of human and animal diseases, thus making the butter safer for human consumption, raising the standard of safety and wholesomeness of the product in the eyes of the public and protecting the livestock interests of the country against the spread of infectious diseases among young stock and hogs fed on skim milk and buttermilk returned to the farm.

Increases Economic Efficiency of Dairy Industry.—For the reasons above indicated, pasteurization has distinct economic value. Through improving the flavor and keeping quality of butter, pasteurization stimulates the appetite and demand for butter; it assists the creamery in securing a satisfactory price for its product and protects it against heavy losses caused by the development of costly defects of butter made from contaminated raw cream. The increased demand for the improved product, accompanied by better prices, and the elimination of serious loss due to specific butter defects, in turn, enable the creamery to offer to the farmer maximum prices for his butter fat, to increase his profits and thereby to stimulate the production of milk and cream, and indirectly to improve the fertility of the soil.

Through destruction of disease germs pasteurization safeguards the physical welfare of the consumer and minimizes the danger of heavy losses of livestock due to epizoötics resulting from the feeding of infected creamery bi-products to farm animals.

The improved quality of butter made from pasteurized cream and the guarantee which such butter offers the consumer, as a product wholesome and free from germs of disease, are the most forceful weapons the dairy industry possesses in its never-ending struggle against competition with foreign butter and butter substitutes at home, and in its efforts to establish permanent and satisfactory markets abroad.

Essential Conditions for Successful Pasteurization.—Many butter buyers are looking upon butter made from pasteurized cream with disfavor, claiming that such butter lacks the desired flavor, open grain and "live" body of raw cream butter. And it is a fact that some butter made from pasteurized cream has marked defects in flavor and in body. In the great majority of these cases the cause, however, lies in the improper and faulty application of pasteurization. These criticisms should not be interpretated as a condemnation of the principle of pasteurization, they refer only to the faulty use of a beneficial process. Butter made from properly pasteurized cream does not harbor these defects and is not subject to these criticisms.

In order to apply the process of pasteurization so as to accomplish its helpful objects and to guard against undesirable results, the creamery must use efficient equipment of adequate capacity and kept in sanitary condition, it must have a sufficient and constant supply of heating and cooling media for rapid heating and cooling and for effective temperature control and, above all, the process must be supervised by a competent operator whose experience, knowledge and judgment enable him to properly prepare the cream for, and to conduct, the process in an intelligent and efficient manner.

Methods of Pasteurization.—There are in use at the present time fundamentally three methods of pasteurizing cream for buttermaking. These are the flash or continuous method, the vat or holding method and the combined flash and holding method.

In the flash or continuous process of pasteurization the cream flows through the pasteurizer in a continuous stream, is heated from 176 to 185 degrees F. and then immediately cooled to the ripening temperature, or the churning temperature.

In the vat or holding method of pasteurization the cream is heated in a vat with agitator to a temperature of about 145 degrees F., then held at that temperature for twenty to thirty minutes and cooled to the ripening or churning temperature.

In the combined flash and holding method of pasteurization the cream flows through a continuous pasteurizer, is heated to a temperature ranging from about 150 to 170 degrees F. and is held in a vat at the above or at lower temperatures for from ten to thirty minutes, after which it is cooled to the ripening or churning temperature.

FLASH OR CONTINUOUS METHOD OF PASTEURIZATION.

Flash Pasteurizers.—The following is a list of some of the more popular flash or continuous pasteurizers and coolers now in use in American creameries:

- Continuous pasteurizers
  - Stationary jacketed drum with revolving agitator
    - Jensen old style
    - Jensen sanitary
    - Reed
    - Peerless
    - Simplex centrifugal
    - Eclipse
  - Regenerative with revolving drum
    - Jensen sanitary pasteurizer, regenerator and cooler
    - Progress regenerative
    - Simplex regenerative
  - Revolving discs
    - Farrington
    - Farrington Jr.
    - Miller Tyson

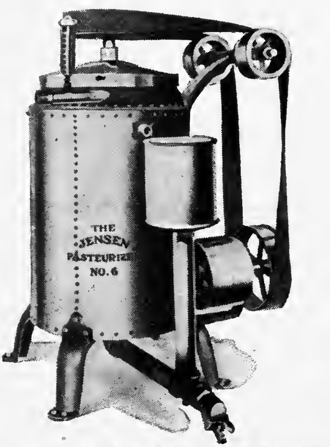

Fig. 22. Jensen flash pasteurizer
Courtesy J. G. Cherry Co.

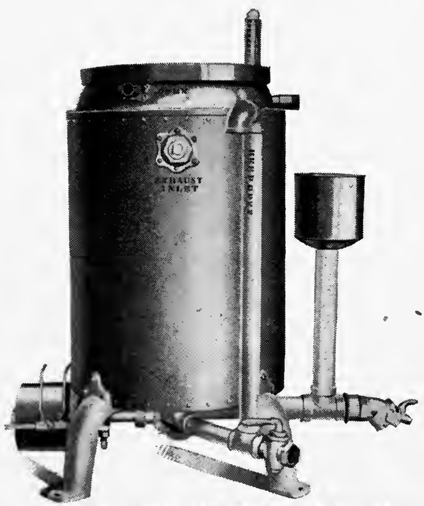

Fig. 23. Peerless flash pasteurizer
Courtesy J. G. Cherry Co.

Principal Features of Diferent Types of Flash Pasteurizers.—The flash, or continuous pasteurizers are principally of three types. 1. Those consisting of a hollow drum, equipped with a revolving agitator and surrounded by a heating jacket. 2. Those consisting of two hollow drums, the smaller rotating inside the larger one and with the heating or cooling medium circulating in the inner drum and in the jacket surrounding the outer drum, while the cream passes in a thin film between the heating surfaces of the two drums. The latter are frequently of the regenerative type. 3. Those consisting of compartments equipped with revolving discs which heat the cream while it flows through the compartment. This type of pasteurizers usually, though not always, contains also compartments for cooling the heated cream.

Some creameries use two flash pasteurizers, connected tandem fashion, in the place of one. The machines are frequently installed at different elevations. In the lower machine the cream is heated to about 135 degrees F. and in the upper machine to about 180 degrees F. The cream flows from the lower to the upper machine and these pasteurizers may be so connected that the first or lower machine is heated by the exhaust steam of the upper or second machine, or each machine may be heated with direct steam in which case they are generally installed side by side on the same level. This double system of flash pasteurization, when properly operated, helps to insure thoroughness of heating.

All of the flash pasteurizers with closed drums have the power of elevating the cream, making unnecessary the use of pumps to convey the pasteurized cream over the coolers or into the vats.

Some of the flash pasteurizers do part cooling of the heated cream, while the remainder are heaters only and require separate coolers. For this purpose surface coil coolers are most generally installed. Frequently the surface cooler is done away with and internal tube coolers or other coolers are used, or the heated cream may flow direct from the flash pasteurizer into the ripening vat where it is cooled by the revolving coil.

Regenerative Heaters and Coolers.—Some of the heaters and coolers are arranged on what is known as the regenerative principle. The inflowing cold cream is heated by the hot cream passing from the pasteurizer, and the outflowing hot cream is cooled by the cold cream flowing to the pasteurizer. The hot and cold cream tend to equalize their respective temperatures by passing in countercurrent directions. Manufacturers of these coolers claim that the regenerative principle effects a saving of heat and cold amounting to 25 to 35 per cent of the fuel needed.

Fig. 24. Simplex regeneration pasteurizer
Courtesy D. H. Burrell & Co.

Construction of Flash Pasteurizers.—Most of the continuous pasteurizers are constructed of copper with heavily tinned heating surface. Some of these pasteurizers are lined with German silver. From the standpoint of heat conductivity there is little choice between the two metals. Their efficiency is practically equally high. The German silver has the advantage of preserving the brightness of its surface. In the copper-lined machine the tin coating soon wears off. This, however, is no serious objection as long as the copper surface is kept bright and no verdigris is permitted to form.

The details of construction and of power transmission vary somewhat with the different types and makes of flash pasteurizers. Their descriptions are usually furnished by the respective manufacturers of the machines.

In the installation of flash pasteurizers the directions for the same, which accompany the machines, should be carefully followed. The cream connections, especially those for the heated cream, should be of such type as to reduce the friction of the cream and consequently the mutilation of the fat globules, to the minimum. Sharp bends should be eliminated as much as possible, and where they are unavoidable, they should be equipped with rounded sanitary couplings in preference to T's

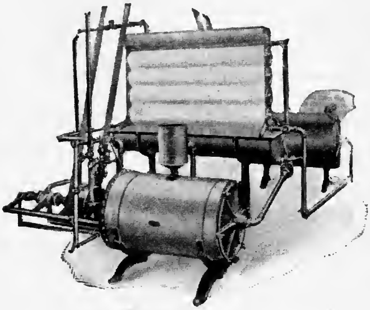

Fig. 25

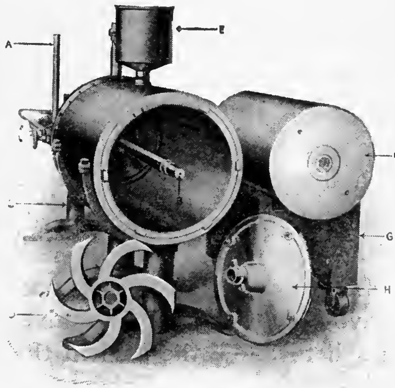

Fig. 26

Jensen universal pasteurizer

Courtesy Jensen Creamery Machinery Co.

and crosses. The entire system should be composed of standard sanitary pipes, valves and fittings. The straight pipes should be equipped with sanitary unions at intervals of 6 to 8 feet, so as to facilitate their dissembling, cleaning and reassembling.

Operation of Flash Pasteurizers.—In the case of sweet cream, such as is available in wholemilk creameries, the cream needs no special preparation for pasteurization. It is run through the pasteurizer direct from the receiving vat.

When cream arrives at the creamery in thick, lumpy or sour condition or is otherwise in unsatisfactory physical condition, as is the case in many of the gathered cream creameries, it is not only desirable but very necessary to warm it to about 90 degrees F. and agitate it until it is uniform in consistency and reasonably smooth. This is best done by the use of a forewarmer. The usual type of forewarmer is a plain, tinned galvanized iron or tinned copper vat equipped with a revolving copper coil or disc, through which hot water is circulated to raise the temperature of the cream. The forewarmer should be preferably of "low-down" construction so as to facilitate the "dumping" of the cans.

If the cream consists of part sweet and part sour cream or if the acidity of different lots of cream in the forewarmer differs materially, it is advisable to hold it in the forewarmer for about thirty minutes or longer, to make the entire batch uniform in acidity. If this is not done a tough, rubbery curd is prone to form in the pasteurizer, which clogs the machine and the strainers and causes excessive loss of fat in the buttermilk.

The formation of this curd is due to the fact that the acid in the sour cream acts intensely on the curd in the less sour or sweet cream in the presence of pasteurizing heat. This can be avoided by holding the mixed cream in the forewarmer long enough to allow the acid in the sour cream to act on the curd in the sweet cream at about 90 degrees F. At this temperature this action is less intense and the curd precipitates in the usual and normal way.

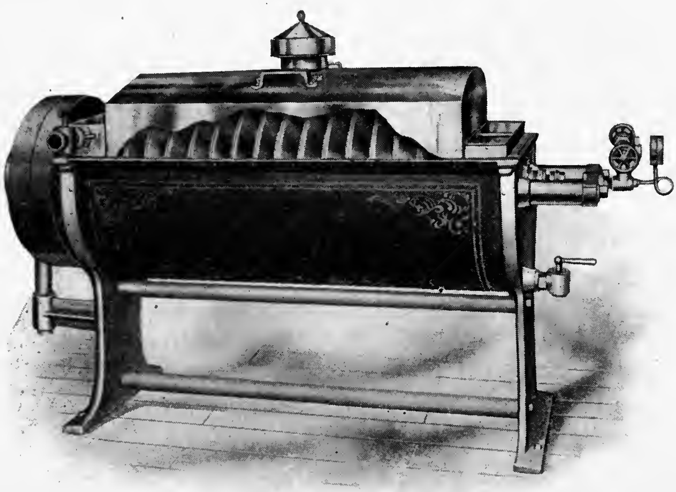

Fig. 27. Farrington Junior pasteurizer
Courtesy Creamery Package Mfg. Co.

If the mixed cream is neutralized in the forewarmer, as is done in most creameries receiving sour cream, the danger of abnormal curd formation is removed, and it is not necessary to hold the cream in the forewarmer after neutralization. In case the cream is neutralized it is desirable to use two or more forewarmers of suitable capacity, usually holding 250 to 300 gallons, so that, while one forewarmer is being filled, the cream in the other may be neutralized and passed through the pasteurizer. The use of numerous forewarmers has the advantage of speeding up the work, increasing the capacity of the plant and assisting the continuity of operation of the pasteurizer.

Thin, sour cream is prone to suffer more intense curdling action, to cause more difficulty in the pasteurizer and to produce greater loss of fat in the buttermilk, than cream of reasonable richness, testing 30 to 35 per cent fat, and averaging about 33 per cent fat. Excessively rich cream, while desirable from the standpoint of economizing vat and churn space, is objectionable, because it is deficient in milk solids not fat, which are necessary to protect the fat globules against mutilation in the pasteurizer. Such cream, when pasteurized is apt to yield butter with a greasy or salvy body and an oily flavor, which may later develop into other and more damaging off-flavors, such as metallic and fishy flavor.

It is advisable to standardize all cream in the forewarmer for fat to about 33 per cent fat, and for acid to about .25 per cent acid. Dilution of the cream with water, such as occurs when the cream cans and the vats are rinsed with water, or when the standardizing of rich cream is done with water, should be avoided, because such dilution lowers the per cent of non-fatty constituents in the cream. The cans should be freed from the remnants of cream by inverting them over a steam jet, (see paragraph on Can Washing, Chapter IV,) and the standardizing of rich cream for fat should be done with sweet milk or skim milk or redissolved skim milk powder. For standardizing the acidity, see Chapter VII on Neutralization of Sour Cream.

The flash pasteurizer should be set high enough to make unnecessary excessive elevation of the cream by the pasteurizer. The greater the elevation to which the pasteurizer must raise the cream, the faster must be the speed of the pasteurizer. This high speed tends to cause the liquid fat globules at the high pasteurizing temperature to become distorted, disturbing the thin surface layer of adsorbed concentrated serum, which protects them, and exposing a larger surface of the fat to objectionable influences, such as the oxidizing action of light, air, heat and metals. Excessive speed therefore may, under certain conditions, result in serious butter defects.

For the same reason it is undesirable also to try to force more cream through the pasteurizer than its rated capacity. The amount of cream the pasteurizer is capable of taking care of depends on the speed of the agitator. The higher the speed of the agitator the more cream can be made to pass through the machine in a given length of time. The flash pasteurizers are usually furnished with specific directions as to capacity per hour and speed of agitator or revolving drum, needed to yield the rated capacity. It is unwise to force more cream through the machine than the rated capacity and speed call for, by speeding up the agitator. If faster work is desired, the installation of a larger machine, or an additional machine, will accomplish the purpose without injury to the butter fat. Forcing the machine, aside from its unfavorable effect on the fat globules, also usually diminishes the pasteurizing efficiency.

Temperature Control.—In all flash or continuous pasteurizers the regulation of the temperature needs constant attention in order to make possible uniform heating of all the cream that flows through the pasteurizer. Unless the operator supervises the operation of the pasteurizer from start to finish, reliable results need not and should not be expected. The ease of temperature control varies widely with different makes of machines, as well as with such ever-varying factors as temperature of the cream in the forewarmer, mechanical condition of the cream, uniformity of cream inflow, uniformity of steam supply and uniformity of speed of cream pump and pasteurizer.

In order to make possible and to facilitate temperature control, the cream in the forewarmer must have a constant temperature, preferably about 90 degrees F., the cream pump feeding the pasteurizer must run at a uniform speed, the cream supply pipe must be equipped with a suitable valve regulating the inflow, preferably an automatic regulator such as a floating ball device, the steam pressure must be uniform and the pasteurizer must run at a uniform speed. In order to make possible a uniform supply of cream, the cream must also be in satisfactory mechanical condition, it must have a smooth body.

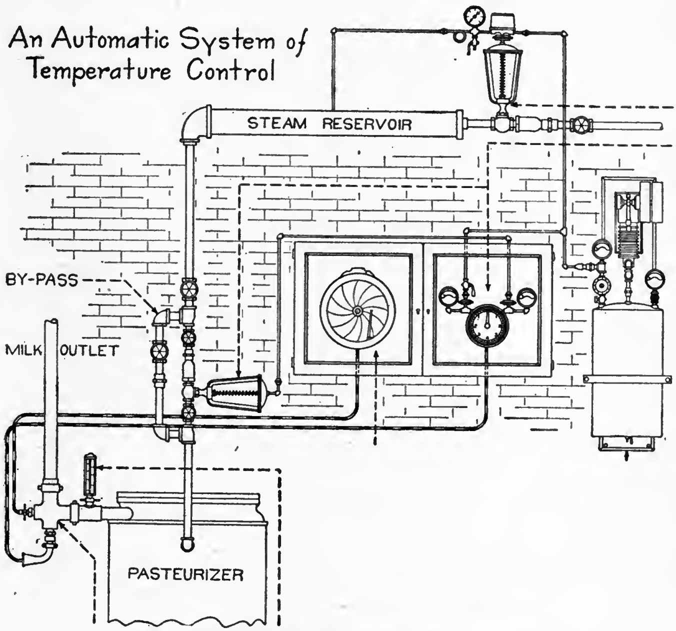

Fig. 28. Automatic temperature control
Courtesy C. J. Tagliabue Mfg. Co.

Lumpy cream makes the flow irregular, tending to clog the valve at times.

The installation and use of a properly operating thermostat or heat controller is a great help in, and is practically indispensable for regulating the steam pressure and thereby controlling the temperature of the cream. All pasteurizers should be equipped with a high-grade steam gauge, installed between the steam valve and the pasteurizer, and in the absence of a thermostat, a pop-off valve, set for the steam pressure desired, should be fitted in the steam pipe, between the valve and the pasteurizer. This will guard against excessive heating and excessive steam pressure, which might jeopardize the machine.

At the beginning of the pasteurizing process some cream is almost sure to pass through the pasteurizer at a temperature lower than that required. If the system of pasteurization practiced, involves the running of the hot cream direct into the vat where it is held for some time, before it is cooled, all the cream has a chance to become heated to the proper temperature and no material decline in the germ-killing efficiency of such pasteurization is likely to occur, even if a small portion of the cream did pass through the pasteurizer at too low a temperature.

But if, as is usually the case, the cream passes from the pasteurizer over an instantaneous cooler and reaches the vat cool, then the escape from the pasteurizer of incompletely heated cream becomes a serious menace to the quality of the resulting butter. This danger can readily be avoided by installing, between the pasteurizer and the cooler, a by-pass, through which the first cream pasteurized and any other portion of the cream that fails to be heated to the desired temperature, can be automatically returned to the pasteurizer and run through again. When the pasteurizer is first started up, therefore, all cream should be by-passed until the desired temperature is reached and is permanently maintained.

Automatic Temperature Recorders.—The installation and use of an automatic temperature recorder is of additional, valuable help to insure reliable temperature control. By its use a permanent record is produced which shows the exact temperature of pasteurization during the entire process. The superintendent in charge should examine these records daily, and caution the operator when the records disclose irregularities. The knowledge on the part of the operator that his work is thus permanently recorded and the records checked daily, exerts a good moral effect on the operator. He realizes, that unless he performs his duty properly, the record is unsatisfactory and that carelessness is thus immediately detected.

Cooling Cream from Flash Pasteurizer.—The hot cream flowing from the pasteurizer is either passed over a surface coil cooler, regenerative or otherwise, or through an internal tube cooler, a disc continuous cooler, an inclosed drum cooler, or a combination of two or more of these devices, or it flows direct into a ripening vat where the cooling is done with a revolving coil or disc. It is advisable to cool

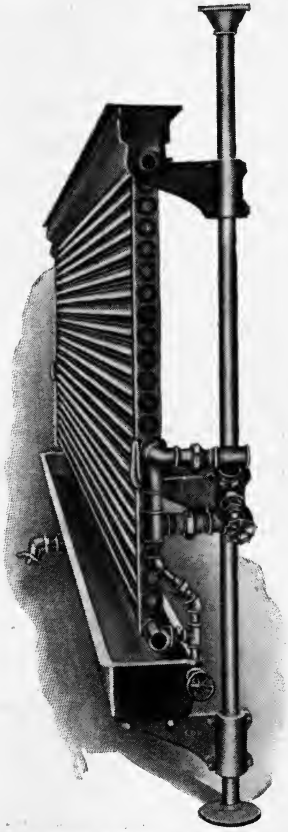

Fig. 29. Surface coil cooler
Courtesy J. G. Cherry Co.

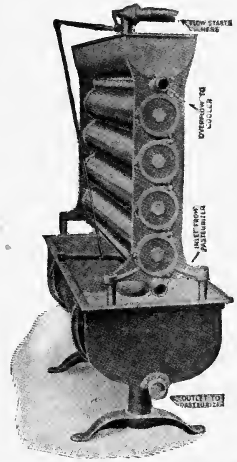

Fig. 30. Jensen regenerative cooler
Courtesy Jensen Cry. Mach. Co.

the cream as quickly as possible to about 70 degrees F. or below. In most creameries this can be accomplished by the use of the available water and further cooling to the churning temperature is done with brine.

Surface coolers have the advantage of speed in reducing the temperature and of freely permitting the gases in the cream to escape. This is especially desirable in the case of cream tainted with objectionable flavors and odors, such as may be derived from weeds, wild onions, etc., or from undesirable fermentations of the cream prior to pasteurization.

On the other hand, there are some serious objections to the use of surface coolers. There is a tendency to recontaminate the cream. This is especially the case in an ill-ventilated factory where the air is teeming with undesirable germ life and odors. Again the exposure of the hot cream to air and light, while running over the copper surface cooler, invites oxidation of some of the components of the cream which may lead to serious butter defects, such as tallowy, metallic or fishy flavor, etc. For this reason this type of cooler cannot be recommended; coolers which do not expose the hot cream excessively to air and light are preferable.

VAT PASTEURIZATION

Vat Pasteurizers.—The vat pasteurizers on the market are of two general types, namely jacketed vats with plain agitators and non-jacketed vats with hollow disc or coil agitators. In the jacketed vats and tanks, with plain agitators the inside wall of the jacket surrounding the vat furnishes the heating surface. The jacket is charged with a continuous flow of the heating or cooling medium, or the heating or cooling medium is sprayed against the outside of the heating surface. The cream

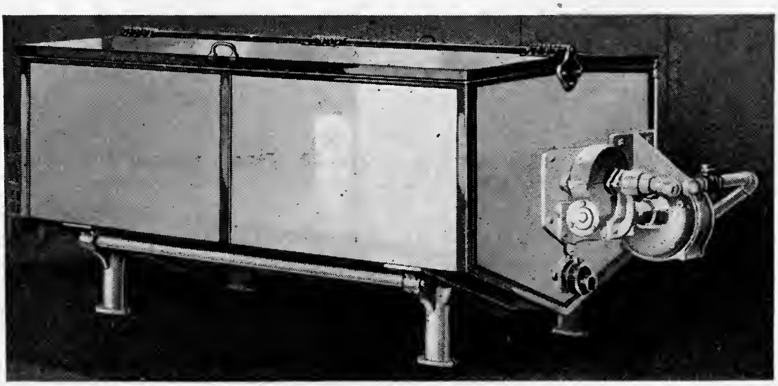

Fig. 31. Progress vat pasteurizer

Courtesy Davis-Watkins Dairymen's Mfg. Co.

is agitated by means of a series of blades moving lengthwise back and forth, or in the case of round tanks by a vertical, rotating agitator.

The other type of vat pasteurizers consists of the most modern types of cream ripeners equipped with horizontal or vertical revolving discs or coils which carry both the heating and the cooling medium. This is the most widely used type of vat pasteurizer. The revolving discs have now been largely replaced by the revolving coils, as the strain of steam, water and brine pressure and the wide range of temperature proved too great a tax on the discs.

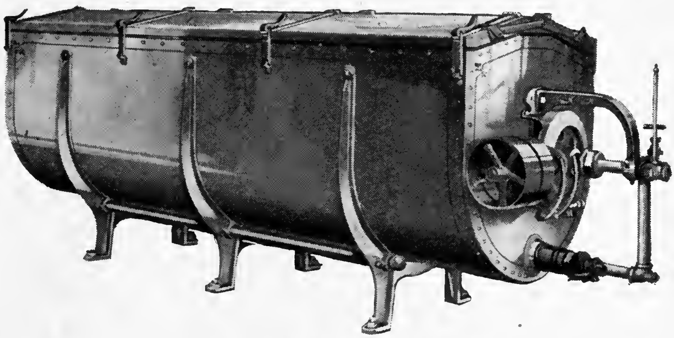

Fig. 32. Jensen vat pasteurizer
Courtesy J. G. Cherry Co.

The coils in the vat pasteurizers vary somewhat in construction, principle of feed and size, with different makes of manufacture.

In some vats of large size there are two coils side by side. This makes possible the placing of the coils low down without curtailing heating surface. This principle has the advantage of keeping the coils submerged in the cream, which is desirable, because it minimizes the beating of air into the cream, thereby avoiding foaming and the tendency of oxidation of some of the constituents of the cream, while the cream is hot.

Most of the coils have a tube diameter of from two to two and one-half inches and the diameter of the spiral ranges from twenty-four to twenty-nine inches.

The amount of heating and cooling surface per gallon of cream varies with different makes and sizes of vats. In many cases the heating and cooling surface of a 300-gallon vat is practically the same as that of a 600-gallon vat, because the same size coil is used in different size vats. Generally speaking, large vats have less heating surface per gallon of cream than small vats. For efficient and reasonably rapid heating and cooling a vat should have not less than about twenty square inches of heating surface per gallon of cream.

The great majority of the coils and outer shafts are constructed of copper, tinned over and the lining of the vats is of the same construction. In some rare cases vat pasteurizers have been equipped with German silver coils.

The inner shafts in the older vats were made of iron. This caused them to corrode rapidly and give much annoyance due to electrolytic action of two metals in brine. This objection has now been largely removed by either doing away with the inner shaft entirely or lining it with copper.

The exposure of the coils and vat linings to heat, cold, acid, and neutralizers is exceedingly hard on the tin coating. The tin coating soon yields to these corrosive agents and wears off. This is especially true where the vats are not thoroughly cleaned and freed from lime, cream and alkali washing powder, or when wire dish cloths or other similar scouring equipment is used for cleaning. Caustic alkalies should not be used for washing the vats and the vats should be thoroughly rinsed out with water after cleaning, and drained and steamed so that they dry quickly. If alkaline washing powder is used, it should not be sprinkled over coil, vat lining and cover lining and allowed to remain there dry. Even the smallest specks of dry and moist washing powders quickly attack the tinned copper surface, causing the surface to become covered with black spots and blotches. And any alkali deposited in the bottom of the vats will inevitably tarnish the lining, and expose the copper. The washing powder should be placed into the water in the vat where it dissolves quickly and completely and in which form it can be removed completely at the conclusion of the cleansing operation.

The copper lining of the pasteurizing vats and covers is objectionable at best, for the reasons discussed under construction of cream ripening vats, and here, too, the use of glass-enameled equipment, instead of copper-lined vats, would greatly reduce the effect of agencies that make for butter deterioration. As long as copper-lined pasteurizing vats are and must be used, the danger of the injurious effect of the copper and its salts, on the quality of cream and butter, may be materially minimized by holding the cream in these vats for the shortest possible time only, consistent with adequate chilling of the fat preparatory

Fig. 33

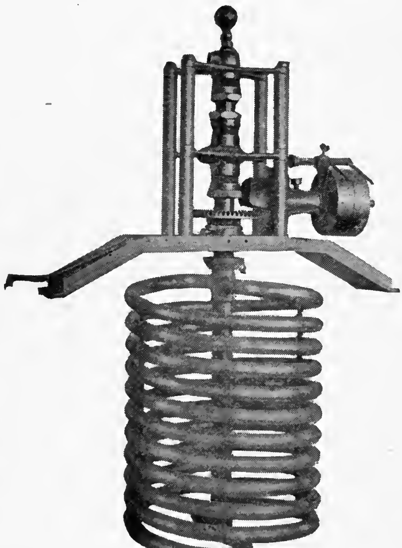

Fig. 34

Jensen circular vat pasteurizer with suspended coil

Courtesy Jensen Cry. Mach. Co.

to churning. The holding of cream in these vats over night cannot be recommended. At certain seasons of the year it is almost sure to cause metallic and other off-flavors in butter. If the cream cannot be churned the same day it is "dumped" and pasteurized, it would be preferable, from the standpoint of quality, to hold it over night in the cans set in the cooler.

Construction of Covers.—The construction of the covers of these vats is also of great importance. The covers should be lined with tinned copper on the under side and the lining should lap over and up on the upper side of the cover so as to avoid cream from seeping in between the liner and the wood of the cover, causing the latter to become a serious source of contamination of the cream. Some of the most modern vat covers are enveloped entirely in tinned copper and are proving highly satisfactory from the sanitary standpoint.

Connections for and the Circulation of the Heating and Cooling Medium.—There are two principle systems which serve to circulate the heating and cooling medium, the hot and cold water and the brine, through the revolving coils in the pasteurizing vats, namely the self-circulating system and the positive circulating system.

The self-circulating system operates on the principle that air is lighter than water. It consists of admitting to the coil, a small amount of air through an automatic air vent, installed at the head of the coil shaft. As the air and water, or brine, enter the coil, the air rises to the surface in the coil. If enough air enters so that the surface of the water in the coil is below the under side of the coil wall at its highest point, the air in the top portion of the coil forms a solid plug, or partition, between the water columns in the left and right side of the coil. When the coil revolves, this partition of air prevents the water in the coil from staying or flowing back. The coil being a spiral, causes the air plug to push the water column forward with each revolution of the coil. This inevitably produces a vacuum and suction behind the air plug and this suction draws in more water and air, the operation thus repeating itself with every turn of the coil.

In the positive system of circulation the heating and cooling medium are forced through the revolving coil by a pump. In this system there is no air in the coil, the water fills the entire coil.

For heating, the coils should be fed with hot water only. They should not be charged with steam, as the agitation of the cream in the vat, is not sufficient to prevent excessive burning of the cream on the surface of the steam heating coil, and direct steam is also exceedingly destructive to the packing in the glands, if not to the bearings themselves. In the case of the self-circulating system the water is heated in one of the following three ways:

Steam is blown into the water entering the shaft, through a steam jet located at the front end of the vat. This is the most objectionable manner of heating, usually causing the coil to become excessively coated with burnt cream and making it exceedingly hard to clean. In this method free steam is bound to occasionally blow into and through the coil.

Again, the water in some of the vats is heated by means of a water heater of the McDaniels or Penberthy type, installed at the back end of the pipe which returns the exhaust of the coil to the head of the coil. This method gives the steam a somewhat better opportunity to be completely absorbed by the water, but even in this case there is a spasmodic blowing of the steam through the coil at times.

In the third method of heating, a water heater is installed in the ice-box at the rear end of the vat, all the water is heated in the ice-box and from here, the hot water returns to the head of the coil through the return pipe located under the vat. This method precludes the blowing of steam through the coil and is, from this point of view, the most satisfactory manner of heating the water with the self-circulating system. By this method, however, the cream is not heated quite as rapidly as when the steam is injected into the water in the return pipe or at the head of the coil.

In the positive circulating system, a separate tank is provided in which the water is heated with direct steam to the desired temperature, from which it is pumped with a centrifugal pump, attached to the tank, through the coil, and to which the exhaust water of the coil returns. In this method the coil is completely filled with the hot water. It is obviously a very reliable and rapid method of heating, but necessitates extra equipment and additional space.

The cooling is done in a similar manner as the heating, the same system serving both. It is customary to use water for the first cooling, lowering the temperature to about 70° F. and then finish the cooling with brine or ice water. If ice water is used, the ice box in the rear of the vat, or the separate tank of the positive system, serves to dissolve the ice and the ice water is circulated in a similar manner as the hot water. Water and brine usually enter the coil under pressure, in which case they circulate on the principle of the positive circulating system. The water exhausts into the sewer and the brine is pumped back into brine tank above or returns to the brine tank by gravity if the latter is located in the basement. In order to avoid excessive weakening of the brine by the water remaining in the coil, it is advisable to not only give the coil as many turns as there are rungs in the spiral after the water is shut off, and before the brine is turned on, but to allow the exhaust of the coil to run off, after the brine has been turned on until the exhaust begins to taste briny.

Steam, water und brine connections should be at least of equal size as the inlet to the vat. If they have to be brought from a considerable distance it is recommended that they be at least one pipe-size larger than the vat inlet. The pressure on the disc machines should not exceed 5 to 10 lbs. and that on the coil machines about 35 pounds per square inch.

Operation of Vat Pasteurizer.—The use of a forewarmer before the cream reaches the vat pasteurizer is not so essential in the holding process of pasteurization as in the flash process. The standardization of cream for acid and for fat may be, and is often done in the pasteurizing vat. However, the forewarmer is a convenient dumping vat and is used in most creameries in connection with either vat or flash pasteurization.

If the cream is sour, or part sweet and part sour, it is advisable to raise the temperature in the vat pasteurizer slowly to about 115 degrees F. and then rapidly to 145 degrees F. in order to avoid abnormal curdling. In extreme cases of curdling difficulties it may even be necessary to hold the cream at about 115 degrees F. for a while. This slow heating below 125 degrees F. gives the curd an opportunity to contract and harden in the usual way, so that when the higher temperature is reached, the formation of a rubbery and sticky curd and loss of fat as the result of intense action of heat and acid on the soft casein, is avoided. The tendency of abnormal curdling is especially pronounced in the case of cream very low in butterfat.

In the case of sweet cream, or sour cream neutralized to about .25 per cent acid, there is no danger of the formation of an abnormal curd. The neutralizer should be added after all the cream of one batch is in the vat pasteurizer and before the heat is turned on. The neutralizer should be distributed uniformly throughout the cream in the vat while the coil is revolving. If sweet milk is added to the cream it should be added immediately after neutralization and before pasteurization.

Speed of Revolving Coil.—The coil in the vat pasteurizer should be run at the speed indicated in the directions furnished by the manufacturer of the vat. The exact speed desired varies with the size of the vat and the size of the coil, ranging from about 25 to 40 revolutions per minute. The higher speed applies to the smaller coils and the lower speed to the larger coils. A coil with a 24 inch diameter should revolve about 35 to 40 revolutions per minute, while a coil with a 29 inch diameter should make about 28 to 30 revolutions per minute.

Insufficient speed of the coil fails to produce adequate agitation which in turn makes the control of the temperature difficult, retards the heating and cooling and may augment the coating of the coil with cooked cream.

Too high a speed of the coil causes excessive foaming of the cream and the beating of air into it. The foaming is objectionable because it renders difficult the emptying of the vat without the use of excessive volumes of water and usually incurs excessive loss of fat. The beating of air into the cream is undesirable because the incorporated air invites oxidation which later may lead to butter defects.

Fullness of Vat Pasteurizer.—The best results are obtained when the vat is full enough to completely submerge the revolving coil in the cream. The heating and cooling proceeds faster when the coil is submerged than when part of it projects above the cream, because with a submerged coil the entire coil is active at all times while, in the case of an exposed coil only part of the coil does duty. The portion of the coil that is exposed to the air is more apt to become coated with cooked cream than the submerged coil. A submerged coil precludes all danger of excessive foaming and of whipping air into the cream, while an exposed coil is bound to incorporate air in the cream and the more the coil projects above the cream the more pronounced is this objection. An exposed coil also invariably causes much splashing of the cream, which is objectionable.

Because of the objection of operating the vat with the coil projecting above the cream, vat pasteurizers in which the coils are set low are preferable to those in which the coils extend to the top of the vat.

For this same reason vat pasteurizers of cylindrical shape and with a vertical, suspended coil are superior to vats with horizontal coils. In the cylindrical vat the motion of the coil spiral is upward, and out of the cream, making impossible the mixing of air with the cream, while in the vat with the horizontal coil the spiral of the coil moves downward into the cream.

Temperature and Time of Exposure.—The heating should be done as rapidly as the supply of steam, the available heating surface and the circulating system permit. The cream should be heated to 145 degrees F., and held at that temperature at least twenty and preferably thirty minutes.

Slow heating and prolonged holding at 145 degrees F. are prone to produce cream and butter with a mealy body. Under proper conditions the heating of the cream to 145 degrees F. should not occupy more than about fifteen to twenty minutes.

Experimental[1] results have shown that when holding the cream at 145 degrees F. for a shorter time than twenty minutes, the germ-killing efficiency suffers. This is clearly demonstrated in Table 36.

As soon as the temperature has reached 145 degrees F. a pail full of the hot cream should be drawn from the gate of the vat and poured back into the vat. The nipple at the gate con-

[1] Hunziker, Mills and Spitzer, Pasteurization of Cream for Buttermaking, Purdue Bulletin, No. 203, 1917.

Table 36.—Per Cent Micro-Organisms destroyed when Heated to 145° F. for 10, 15, 20, 30 and 40 Minutes, Respectively.

(Averages of 21 churnings.)

Time Held at 145° F.	Per Cent Decrease of Germs Due to Pasteurization			
	Total Bacteria	Acid-ifiers	Lique-fiers	Yeast and Molds
10 minutes.......	99.39	99.29	98.79	87.50
15 minutes.......	99.89	99.94	99.72	99.18
20 minutes.......	99.98	99.98	99.95	99.93
30 minutes.......	99.99	99.999	99.98	99.94
40 minutes.......	99.999	99.999	99.99	99.98

tains a plug of raw cream which fails to be heated properly and which tends to recontaminate the cream in the churn.

Blowing air into the cream, during the process of heating is not recommended, except in the case of very poor cream tainted with objectionable strong odors and flavors. This kind of cream is often considerably improved by blowing, eliminating some of the objectionable odors, but butter from such cream will at best be of low grade.

Blowing air into cream of fair or good quality is objectionable because the air, in the presence of heat invites oxidation and jeopardizes the keeping quality of the resulting butter. The blowing of the cream during pasteurization is undesirable also because butter made from such cream is prone to have a mealy body. This is largely due to the fact that the blowing retards and prolongs the heating process, hardening the curd particles to such an extent as to render them mealy. The prolongation of the heating process as the result of blowing air into the cream is due to the cooling effect of air on the cream and the increased evaporation of moisture which absorbs additional heat units.

It is advisable to revolve the coil while the cream is being held at 145 degrees F. in order to guard against the tendency of the hot cream to "oil off," causing the fat to become granular during subsequent cooling and giving the butter a mealy body similar to that of renovated butter.

In order to avoid appreciable lowering of the temperature of the cream, with the coil revolving during the holding process, the covers should be down. It is customary to empty the coil as soon as the temperature has risen to 145 degrees F. in order to avoid overheating and mealiness. When conditions are prone to produce mealiness, a rise of a very few degrees above 145 degrees F. may cause this defect. Under such conditions it may even be advisable to turn the steam off when a temperature of 140 degrees F. has been reached, then pull the cover down and hold for 32 minutes, leaving the hot water in the revolving coil. Experience has shown that with the hot water in the coil at the usual temperature at this stage of the process, there is sufficient heat present to raise the temperature of the cream to 145 degrees F. in one or two minutes, but not enough heat to cause the temperature to rise above 145 degrees F. during the holding process.

Cooling the Cream in the Vat Pasteurizer.—After the cream has been held at 145 degrees F. for 20 to 30 minutes, it should be cooled as promptly as facilities permit. In order to economize cold, the cream is best cooled with water to about 70 degrees F. and then with brine or ice water to the churning temperature. If starter is used it may be added when the temperature has reached about 70 degrees F. For butter that is not consumed promptly it is recommended to not add the starter until about five minutes before churning. If it is not intended to ripen the cream, it should at once be cooled to the churning temperature and held there for not less than two to three hours. During the cooling process the cover of the vat should be down. When emptying the vat it should be rinsed down to reclaim the butter-fat contained in the cream that does not automatically run out. This rinsing should be done with the minimum amount of water that will do the work, or preferably with skim milk. The excessive dilution of the cream with water is very objectionable because it diminishes the power of the milk solids to protect the fat globules against mutilation during the churning process and tends to give the butter a poor body, susceptible to the development of serious butter defects.

Temperature Control in Vat Pasteurization.—Vat pasteurization offers greater facilities for temperature control, because of the larger volume of cream simultaneously heated than is the case with flash pasteurization. Nevertheless the process, if it is to be dependable and successful, requires the constant attention of the operator. The installation and use of a temperature recorder in this process, too, is a great help in order to insure accurate work.

Flash and Holding Pasteurization Combined.—In some instances the two systems of pasteurization are combined, the cream being heated in the flash pasteurizer and held in the vat. For this purpose anyone of the flash pasteurizers above referred to may be used. The cream is run through the flash pasteurizer at 150 degrees to 170 degrees F. From the flash machine it is allowed to flow into the vat or retainer where it is held for from 10 to 30 minutes at the desired temperature and then cooled. This method is more generally used in milk plants. Very few creameries have adopted it.

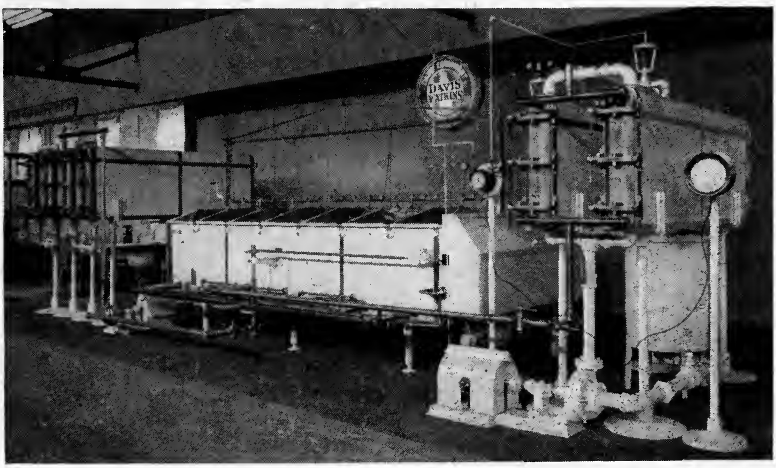

Fig. 35. Progress internal tube pasteurizer, holder and cooler
Courtesy Davis-Watkins Dairymen's Mfg. Co.

With equipment of average capacity, there is no very great saving in time by this combination pasteurizing process. It requires about as much time to run the cream through the flash machine as it does to heat the cream to the desired temperature in the vat. The extra time needed to fill the vat, however, is eliminated, inasmuch as with this system the heating of the cream and the filling of the vat are done in one operation.

The chief advantage of this system lies in the preservation of the vat. The cream being neutralized before it reaches the vat avoids the corrosive action of the acid on the vat, and the heating in the vat being eliminated minimizes further corrosion and wear of the tin coating on coil and vat liner; thereby rendering the cleaning of the vat easier. The bearings and stuffing boxes in the vat are also saved from heavy wear caused by expansion incident to heating in the vat.

In some cases where the combined flash and holding pasteurization is in operation, the holding of the hot cream is done in a compartment retarder in which it is held for the desired length of time and from which it finally reaches the vat where it is cooled. One objection to this system lies in the obvious danger of recontamination of the cream by flowing into two containers after pasteurization. When this system of pasteurizing is used, special attention should be given to the proper cleaning and steaming of all containers used after pasteurization.

Cleaning and General Care of Pasteurizers.—On the proper cleaning and care of the pasteurizer depend very largely its efficiency and its period of usefulness. Remnants of cream, neutralizer or wash-water containing alkali, have a corrosive action on the tin coating and cause this coating to wear off rapidly. The use of tools that scratch the metal, such as wire dish cloths, sand and emery paper, metal bristle brushes, etc., cannot be too strongly condemned. Washing powders containing free caustic substances, such as soda or potash lye, attack the metal and should not be used. Dry or concentrated alkali of any kind should not be allowed to remain on the tinned surface of coils and vat. It is best to use only dilute solutions and rinse off all traces of alkali after washing.

If the pasteurizer is in poor condition, rusty, or with the tin worn off and the exposed copper unclean and coated with verdigris, etc., the damage done to the cream and butter may be far greater than the possible benefits of pasteurization. The direct exposure of the cream to iron and copper and their salts tends to give the finished product a disagreeable metallic flavor. The acid in the cream enters into chemical combination with such metals as iron and copper, forming metallic salts, such as iron lactate and copper lactate. These salts have the power to accelerate bacterial action in butter and also to stimulate oxidation and decomposition of its ingredients. In the presence of pasteurizing heat this chemical action is intensified. The action of these metallic salts is made more damaging by the fact that they possess catalytic properties, that is they continue to act, changing the substances (fats, curd, etc.) with which they come in contact, without they, themselves, (the salts) being changed or weakened. Metallic salts have been found to constitute important members of the combination of conditions that produce butter with metallic, tallowy, fishy, and other flavor defects.

Immediately after use the pasteurizer should be rinsed out with water. In the case of the flash machine the water can be pumped through the pasteurizer immediately following the cream. The machine is then opened, the agitator or drum carefully removed and all parts are scrubbed with brush and hot water containing non-caustic washing powder. Some operators prefer to fill the flash pasteurizer with alkali solution, allow it to soak over night and then complete the cleansing the following morning. It has also been found that the coating on the heating surface of flash machines can be readily removed by charging the jacket with steam, after the pasteurizer has first been rinsed with water. This heating causes the coating to dry, contract and peal off, facilitating its removal.

The vats are best filled one-third to one-half full with hot water containing non-caustic washing powder and the sides, bottom, coil, shaft and gate are scrubbed with a good brush until all remnants of cream are removed. If the vat pasteurizer has been operated in the proper manner, avoiding the blowing of steam direct into the coil, there is little danger of a coating of burnt cream on the coil. If the coil has become so coated it is very difficult to thoroughly cleanse it at best. The secret of easy and proper cleaning therefore lies in the proper operation of the pasteurizing process.

After the remnants of cream are removed, the pasteurizer should be rinsed out thoroughly with hot water, freeing it from all traces of alkali. Then it should be thoroughly steamed until "piping" hot, leaving the gate open to allow the condensed steam to pass off. After steaming, the vat cover should be raised so as to insure prompt drying of all parts of the machine. If the vat is so installed as to cause its bottom to slope about $1\frac{3}{4}$ inches to 2 inches for every ten feet, the water will drain out readily and there is no danger of water remaining in the trough of the vat. Immediately before use the next day the pasteurizer should again be flushed and steamed out before the cream enters it.

Stuffing boxes should not be allowed to leak cream, water, brine, or steam. Glands should be carefully tightened until leaks are stopped. Packing should be renewed as often as is necessary to keep the glands from leaking. Avoid the use of impure calcium brine. Calcium brine containing magnesium chloride causes rapid corrosion of the iron parts of the circulating system, which intensifies the danger of generating electrolysis. This is damaging to the machine and injurious to the cream.

All pumps, cream conduits and strainers should receive daily cleaning and steaming so as to prevent them from becoming dangerous sources of contamination.

Advantages and Disadvantages of Continuous and Vat Pasteurization.

General Practicability.—Taking into consideration all conditions, such as irregularities of delivery of cream, condition of cream, average intelligence of operator and simplicity of operation, the vat method of pasteurization appears the most practical. This applies especially to conditions as they prevail in the average small creamery. When the daily cream receipts are limited and the shipments or deliveries happen to arrive at irregular times of the day, it is difficult to use the continuous pasteurizer to advantage. When this machine is once started it is desirable to continue its operation. In the case of vat pasteurization this objection is largely eliminated. The usually limited knowledge of the preparation of cream for pasteurization on the part of the average operator in the small, local creamery renders the successful operation of the continuous machine often difficult. The high temperatures employed in flash pasteurization intensify the usual difficulties, such as abnormal curdling, etc., which are encountered with cream of varying quality, acidity and richness. The vat pasteurizer with its lower temperature facilitates the handling of cream in this respect. The simplicity of the vat pasteurizer and the ease of operation are in its favor under the conditions of the small creamery.

Capacity.—For heavy duty and maximum capacity the flash or continuous process excels. In the flash process the heating and cooling is practically instantaneous and requires little time additional to that needed for filling the vat with the cream, while in the vat process, after the vat is filled, the heating, holding and cooling require from one and one-half to two hours for each vat full of cream. When a small amount of cream is handled this delay may not be so great a factor. But in a creamery manufacturing large quantities of butter daily, the speed of operation is an essential factor. In fact, the limited capacity of the plant may demand this extra speed in order to increase the working capacity of the plant and make possible the handling of all the cream received during the flush of the season.

Durability of Equipment.—Originally the vat with agitating coil was intended only for control of the temperature of the cream during ripening and cooling. It was not intended for pasteurization of the cream. The wide range of temperature between the heating and cooling medium and the operation of the heating and cooling itself places an extremely heavy tax on the vat pasteurizer, and the exposure of the coil and liner to high acid in the cream and to the neutralizer, augment the wear and corrosion of the machine.

Especially where used for heavy duty, as is the case in many creameries during the flush of the season, when the vats are refilled with batch after batch of cream, practically day and night, the wear and tear on the vats, is very great and their life is comparatively short. In order to keep them in acceptable condition, frequent retinning and other repairs are necessary and even then the vats have to be replaced by new ones every five to six years.

The flash pasteurizer, on the other hand, is built to withstand the heat of pasteurization, it is made, intended and used for heating only, and one flash machine performs the heating of all the cream received, as against an entire row of vats in the case of vat pasteurization in a large creamery. Being constructed and operated for but one purpose, that of heating the cream, the flash pasteurizer is capable of serving that purpose without undue wear and damage. Its chief wear is on the tin coating of the heating surface. This heating surface can readily be retinned when desired, or it can be used with the copper exposed without serious danger of damage to the cream, as the exposure of the cream to it is of very short duration only, provided that the copper surface is kept clean and bright and free from verdigris. Since the heating surface in the flash machine is a simple plain surface, easily accessible, it can be kept in proper condition without difficulty.

In the case of the vat pasteurizer, both the coil and the vat liner are difficult to clean, some portions are almost inaccessible. Hence, when the tin coating is worn off it is very difficult to keep the vat in proper sanitary condition and the objectionable effect of this condition is greatly intensified by the fact that the cream often remains in the vat for several hours. If the agitator of the flash machine becomes worn, the defective parts can be replaced readily and at small cost, while the expense of removing and retinning the coil and liner in the vat is relatively great.

The labor required for cleaning the flash machine is comparatively small. The proper cleaning of vats in which the cream was pasteurized requires much time and hard labor.

Expense of Equipment and Operation.—The initial expense of the equipment is decidedly in favor of the vat pasteurizer. Since the vat is doing both the heating and the cooling, the equipment for vat pasteurization is confined exclusively to the vat with revolving coil. In the case of the flash process the same type of vat is needed to hold, ripen and cool the cream, but in addition to this there must be installed the flash pasteurizer and the cooler (unless all the cooling is done in the vat) and there is further need of at least two forewarmers. This extra equipment is partly offset by the fact that the flash pasteurizer increases the vat capacity, hence fewer vats are needed by this system of pasteurization. The upkeep of the vats used for pasteurizing is much greater than the upkeep of the flash machine as already explained under "Durability." The labor needed for operation is very similar with both systems except that of cleaning which is greater in the case of vat pasteurizers.

The cost of fuel for heating and cooling is somewhat higher in the case of flash pasteurization than in the case of vat pasteurization. More heat is required to raise the temperature of the cream to 180 degrees F. of flash pasteurization than to 145 degrees F. of vat pasteurization, and the cooling of the hotter, flash-heated cream involves the use of correspondingly more cooling medium than the cooling of the less hot cream of the holding process.

EFFECT OF PASTEURIZATION ON QUALITY OF BUTTER

Germ-Killing Efficiency.—The germ-killing efficiency of vat pasteurization at 145 degrees F. and holding for thirty minutes, and flash pasteurization at 180 degrees F. is practically the same. When properly operated the two processes destroy over 99 per cent of the bacteria, yeast and molds, present in the cream. From the standpoint of prevention of bacterial action in butter it would seem, therefore, that both processes are equally efficient.

Effect on Enzymes.—The effect of the two processes of pasteurization on enzymes present in the cream, both, those which are inherent in milk and those which may have developed as the result of bacterial action before pasteurization, must of necessity be quite dissimilar. Exposure to a temperature of 176 degrees F. or over is destructive to the activity of most of the enzymes naturally present, while at 145 degrees F. enzyme action is not destroyed.

The presence of enzymes in butter capable of splitting butter fat and of attacking the curd is most probable, especially in the case of butter made from an inferior quality of cream that is contaminated with diverse species of bacteria and that is several days old. It is reasonable to assume, therefore, that the presence of these enzymes in butter, plays an important role in the deterioration of butter with age.

Since vat pasteurization is incapable of destroying the activity of these enzymes, this process fails to preserve the butter from the point of view of enzyme action. The flash process at 180 degrees F., on the other hand, is destructive to the activity of these enzymes and therefore assists in preserving the butter. This assumption is supported by experimental results conducted at the Purdue Experiment Station,[1] which show that there is a greater increase in the acid value, soluble proteids and amino acids in storage butter made from cream pasteurized by vat pasteurization at 145 degrees F. than by flash pasteurization at 180 degrees F.

Effect on Score of Butter.—The same experiments also demonstrated that, while the fresh butter made from cream pasteurized by the flash process at 180 degrees F. scored no higher than, and in the case of sour, unneutralized cream not as high as, butter made from cream pasteurized with the vat process, the scores of the same butter when 30, 60 and 90 days old showed less deterioration in the case of the flash process than the vat process of pasteurization. In the case of sour cream that was not neutralized, however, the fresh butter of the flash process had a very disagreeable, oily flavor, while that of the vat process was free from oiliness. For further details on the causes of oily flavor, see Chapter XVII on Butter Defects.

The condition and quality of the cream at the time of pasteurization are important factors in the determination of the benefits of pasteurization, to the quality of the resulting butter. The better the flavor and the lower the acidity of the cream before pasteurization, the better will be the flavor of the butter when fresh and after storage. However, experimental results have amply demonstrated, that the butter from both, good and

[1] Hunziker, Mills and Spitzer, Pasteurization of Cream for Buttermaking, Purdue Bulletin No. 203, 1917.

poor quality cream, is of better quality and keeps better when made from properly pasteurized cream, than when made from raw cream.

Effect on Texture and Body of Butter—Butter properly made from raw cream has a more crisp, live body and open texture than butter made from pasteurized cream. The latter is usually more compact and tends more towards a salvy consistency. Much of the pasteurized-cream butter also has a duller appearance and is more or less mealy in texture. This difference in the body and texture was somewhat objected to by the trade in the earlier days of pasteurization, but the market has gradually become accustomed to the characteristic body of butter made from properly pasteurized cream. The extent to which pasteurization modifies the body and texture of the butter depends materially on the method of pasteurization and of cooling and on the condition, per cent of fat and acidity in the cream.

Flash pasteurization has less effect on the life, clearness and smoothness of the body than the holding process. This is especially noticeable in the case of butter made from farm-skimmed cream that arrives at the creamery in sour condition, even if the cream is neutralized before pasteurization.

The prolonged exposure to heat in the holding process appears to precipitate the casein into very fine and firm particles of curd, which seem to rob the butter of its bright lustre and which tend to give it a more or less mealy texture. These changes are not so pronounced in the case of the flash process because the cream is exposed to the heat for a very short time only and then is cooled rapidly. Slow heating, prolonged holding at 145 degrees F. and slow cooling almost invariably produce mealiness in butter. Mealiness is also often caused when the cream is allowed to "oil off", either before pasteurization, due to improper thawing up of frozen cream, or during the pasteurizing process due to allowing the heated cream to lay in the vats undisturbed for any considerable length of time. Mealiness of this type is caused by the running together of the globules while in melted condition and their granulation during subsequent cooling. See also Chapter XVII on Mealy Butter.

The difference in the method of cooling between flash and holding pasteurization is a further reason for the greater tendency toward mealiness in the case of vat pasteurization. Slow cooling, especially below the melting point of butterfat, invites crystallization or granulation of the butterfat. And crystallized butterfat means mealy butter. Slow cooling is often characteristic of vat pasteurization. Rapid cooling, such as is usually accomplished in flash pasteurization, is antagonistic to crystallization. There is solidification but not crystallization of the fat. Hence flash-pasteurized cream butter is seldom mealy and usually has a more waxy body than much of the vat-pasteurized cream butter.

In the case of rich cream, cream testing over 35 per cent fat, pasteurization tends to produce a salvy butter. This is especially prone to happen with flash pasteurizers in which the cream is violently agitated at a high speed, as is the case with machines that are equipped with a rapidly revolving dasher. In rich cream the milk solids which protect the fat globules against mutilation are diminished, and in this very fluid and expanded condition due to the high heat, the fat globules are more sensitive to the excessive friction that results from violent agitation. Flash machines in which the cream flows gently and in a thin layer between two heated surfaces, and vat pasteurizers, are less prone to mutilate the fat globules and therefore are less objectionable on this point. However, all pasteurizers tend to produce a salvy butter when operated with excessively rich cream. The salviness of butter made from rich cream is further intensified during the churning process. With cream testing from 28 to 33 per cent fat the danger of salviness in butter is greatly minimized.

Effect of Season of Year on Germ-Killing Efficiency of Pasteurization.—The resistence of micro-organisms to heat varies with the species and types of germs present. The bacterial flora in milk and cream varies considerably with the season of the year. As a rule the predominating species in fall and winter cream are more resistant to heat than those in summer cream. This fact is brought out in the following table[1] which shows the per cent reduction of germs due to pasteurization of summer cream and of winter cream:

[1] Hunziker, Spitzer and Mills.—The Pasteurization of Cream for Buttermaking, Purdue Bulletin, No. 203, 1917.

Table 37.—Average Per Cent Decrease of Micro-Organisms in Summer and in Winter Cream Due to Pasteurization at 145° F. Holding Process, and at 165° F. and 185° F. Flash Process.

Method of Pasteurization	Total Count Per Cent Decrease		Acidifiers Per Cent Decrease		Liquefiers Per Cent Decrease		Yeast and Molds Per Cent Decrease	
	Summer Months	Winter Months	Summer Months	Winter Months	Summer Months	Winter Months	Summer Months	Winter Months
145° F. holding ..	99.72	99.91	99.97	99.96	99.98	99.97	99.78	99.96
165° F. flash	93.73	88.25	94.32	86.42	94.61	86.29	92.02	76.63
185° F. flash	99.82	98.15	99.76	97.97	99.94	99.29	99.16	97.17

The figures in table 37 show that when cream is pasteurized at 145 degrees F. and held at that temperature for at least twenty minutes, over 99 per cent of the germs contained therein are destroyed regardless of season of year. The flash process at 185 degrees F. was slightly less efficient in winter than in summer. The flash process at 165 degrees F. was efficient neither in summer nor in winter, but its germ-killing efficiency was pronouncedly lower in winter than in summer, especially as regards the germs known to be most harmful to the quality of butter, the liquefying bacteria and the yeast and molds.

These findings demonstrate anew the inadequacy of the flash process at 165 degrees F., as a means to free the cream and butter from undesirable germs. It further emphasizes the need of using either the holding process, or the flash process at 180 degrees to 185 degreees F., especially during the winter months, in order to insure maximum germ-killing efficiency.

The phenomenon that fall and winter cream is freed from its germ content less readily than summer cream must be attributed to the fact that in fall the crops are harvested and are brought into the barn. These crops, especially corn silage and grain crops, are teeming with various types of resistant micro-organisms and when handled in the barn, the dust incident to unloading and feeding is charged with these germs, causing the milk and cream to become profusely contaminated with them through diverse channels, such as the air, the coating of the cows, the bedding, the utensils, the milker.

Additional contamination and possible spore formation results from storing the cream in places where these undesirable germs are prone to abide, such as poorly ventilated cellars, etc., and where the cream is held long before it goes to the creamery, as is often the case during the winter season.

Effect of Pasteurization on Per Cent Fat Lost in Buttermilk.—It is the general opinion that sour pasteurized cream does not churn out as exhaustively as raw cream, and that buttermilk from sour pasteurized cream churnings tends to show a relatively high butterfat test. The average per cent fat in the buttermilk of 104 churnings made from raw and pasteurized, sour cream is shown below.[1]

Table 38.—Per Cent Fat in Buttermilk from Raw Cream and from Pasteurized Cream Churnings.

Number of Churnings	Range of Acidity in Cream %	Per Cent Fat in Buttermilk			
		From Raw Cream	From Pasteurized Cream		
			145° F. 20 M.	165° F. Flash	185° F. Flash
104	.37 to .62	.101	.137	.120	.120

The above figures do not show an appreciable difference in the exhaustiveness of churning between raw and pasteurized cream. While the raw cream buttermilk contained the least amount of fat, the pasteurized cream buttermilk contained but very little more fat. The difference in the fat content of the buttermilk between the three different processes of pasteurization used, also is very slight.

In order to detect the effect of acidity of the cream on the per cent fat in the buttermilk the 104 churnings were grouped into churnings which at the time of pasteurization contained .5 per cent acid and above, and churnings which at the time of pasteurization contained less than .5 per cent acid. These results are averaged in the following table.

[1] Hunziker, Spitzer and Mills.—The Pasteurization of Sour, Farm-Skimmed Cream for Buttermaking, Purdue Bulletin, No. 203, 1917.

Table 39.—Showing Effect of Acid in Cream before Pasteurization on Per Cent Fat in Buttermilk.

Number of Churnings	Per Cent Acid in Cream Before Pasteurization	Per Cent Fat in Buttermilk			
		From Raw Cream	From Pasteurized Cream		
			145° F. 20 M.	165° F. Flash	185° F. Flash
44	less than .5%	.100	.123	.116	.104
60	.5% or above	.093	.160	.127	.136

The figures in Table 39 show that the high-acid cream produced a somewhat larger loss of fat in the buttermilk from the pasteurized cream, than the low-acid cream. The difference might have been considerably greater had the range of acidity in the different lots of cream been wider. As it was, the cream with the least acid, tested .376 per cent acid and the sourest cream tested .621 per cent acid.

The pasteurization of sour cream has a tendency to produce a firm, contracted and dry curd. The particles of curd lock up a small amount of fat. In this contracted condition they fail to surrender the imprisoned fat and carry it into the butter milk. This automatically results in a slightly increased fat content of the buttermilk. Under normal conditions of properly mixed cream of uniform acidity the extra loss of fat due to pasteurization is small.

However, if sweet and sour cream are pasteurized together and without proper mixing and holding before pasteurization, the loss of fat may be very great. In this case the acid in the sour cream acts intensely on the curd in the sweet cream, in the presence of the pasteurizing heat. This often causes the formation of large lumps of a tough, rubbery and sticky curd. This curd locks up relatively large amounts of fat, and, since the curd passes into the buttermilk, the loss of fat in the buttermilk is excessive.

This loss can best be avoided by pasteurizing sweet and sour cream separately. If sweet cream and sour cream must be pasteurized together they should be thoroughly mixed and the mixed cream should be given some time before heating to pasteurizing temperature. The heating should be done slowly below 125 degrees F. and from thereon rapidly. This gives the curd in the sweet cream an opportunity to be acted upon in a normal way by the acid of the sour cream, so that the effect of the subsequent high heat is minimized.

The pasteurization of very thin sour cream usually causes excessive loss of fat, unless such cream is churned at an excessively low temperature.

Not infrequently, excessive losses of fat in buttermilk from pasteurized cream, while attributed to pasteurization, are due largely to churning factors, such as churning the pasteurized cream at too high a temperature, or to not holding the cream at the churning temperature long enough. For most exhaustive churning the cream should be held at the churning temperature not less than two hours and preferably three hours. Attempts to crowd the churns with too large churnings, which are prone to occur during the flush of the season in summer, are a further common cause of excessive loss of fat in the buttermilk.

Chemical Composition of Butter made from Raw and from Pasteurized Cream.—The following table[1] contains averages of the per cent moisture, salt, curd and acid in 76 churnings of fresh butter.

Table 40.—Averages of Composition of 76 Churnings of Butter Made from Raw and Pasteurized Cream.

Composition Per Cent	Raw Cream Butter	Butter Made From Pasteurized Cream		
		145° F. 20 Min.	165° F. Flash	185° F. Flash
Moisture	14.57	14.14	14.19	13.76
Salt	2.05	2.42	2.40	2.24
Curd	.51	.50	.48	.45
Acid	.11	.09	.08	.08

As indicated in the above figures, there is very little difference in composition between butter made from raw and from pasteurized cream. The slight differences agree, in direction, with the great bulk of data available on this subject and with the general conception of the effect of pasteurization on the composition of the butter. Thus the moisture, curd and acid are somewhat lower in the pasteurized cream butter than in the raw cream butter and the highest temperature used for pasteurization shows the greatest difference.

The decrease in moisture is in all probability due to the more contracted and dry condition of constituents, which in this condition tend to diminish their power to hold water.

The difference in curd content between the raw cream and the pasteurized cream butter is very slight. The curd content of butter made from sour pasteurized cream is usually from .1 to .5 per cent lower than in raw cream butter. The very slight difference shown in the table is in all probability due to the fact that all the butter was washed thoroughly with two washings of water and that the removal of the buttermilk was facilitated by the relatively small churnings.

The acid content of the butter in above table is unusually low and this again suggests that the butter was washed thoroughly. Generally butter contains from about .1 to .3 per cent acid, as shown in the averages of 44 churnings of sour cream tabulated below.

Table 41.—Acidity of Butter Made from Raw and Pasteurized Cream. Averages of 44 Churnings.

Raw and Pasteurized Cream	Per Cent Acid in Butter
Raw cream	.3073
Cream pasteurized at 145° F. (20 minutes)	.2565
Cream pasteurized at 165° F. flash	.2295
Cream pasteurized at 185° F. flash	.2093

Pasteurization tends to lower the acidity of the cream and butter. The decrease usually averages about .05 per cent, but may be greater. It is greater in the flash process than in the holding process of pasteurization. The lowering of the acidity due to pasteurization may be explained to be caused by the expulsion by heat of carbon dioxide and other volatile acids which may be present in the cream, and the higher the temperature of pasteurization, the more complete is this expulsion and therefore the greater the decrease of the per cent acid in pasteurized cream butter.

The influence of pasteurization to reduce the acidity in cream and butter must of necessity largely depend on the condition of the cream. The carbon dioxide and other volatile acids present are, in the main, products of fermentation. They are, therefore, present to a greater extent in intensely fermented and sour cream than in cream of good quality and with low acidity. Hence the reduction of the acidity due to pasteurization must be greater in cream of poor quality, and especially in yeasty cream, than in cream of good quality and cream that comes fresh and sweet from the separator.

AERATING OR BLOWING CREAM.

Purpose.—By aeration of cream is understood the intentional and systematic exposure of the cream to air. The purpose of such aeration is to facilitate the escape from the cream of objectionable volatile substances, gases, that harbor undesirable odors and flavors. In short, the object of aeration is to improve the flavor of cream and butter.

Methods.—The aeration may be accomplished in three different manners, i. e. 1. By exposing the cream in a thin layer to the atmospheric air. 2. By blowing air through the cream. 3. By drawing the air and gases out of the cream by suction.

The first method usually consists of running the hot cream from the pasteurizer over a surface-coil cooler. The cream flowing over the cooler in a very thin film, comes in contact with a relatively large amount of air, facilitating the escape of gases and objectionable odors. The heat of the pasteurized cream further enhances the expulsion of these gases. The removal of the escaping gases may be further hastened by the installation of a ventilator over the aerator-cooler and the efficiency of the ventilator may be augmented by equipping it with a mechanical fan. In this form of aeration, it is important that the atmosphere in which the cream is aerated and to which it is exposed, be free from foul odors and bacterial pollution, otherwise the cream will absorb these odors and become recontaminated with germ life.

The second method of aeration, the blowing of air through the cream, is an intensified form of aeration. Its purpose is to not only bring the cream in contact with the maximum amount of air, but to cause this air to blow through the cream and thereby mechanically force the gases out of the cream. The blowing is accomplished by the use of a centrifugal fan.

This fan draws the air from the outside of the factory and pumps it through the cream. In order to insure pure air for this purpose, the air is drawn through absorbent cotton, canvas or other filtering material, usually placed in a funnel at the suction end of the air pipe on top of the roof. This filter removes the dust, soot, flies and other impurities in the air. From this funnel the air is generally drawn through a water bath, preferably lime water, for additional cleansing. The lime water not only removes dirt, etc., but also absorbs carbon dioxide and other gases, some of which may contain objectionable odors.

From the lime water bath the air is blown through the cream in the vat, or forewarmer, or both, through perforated pipes installed in the bottom of the vat. In some of these blowing systems, the vat is closed during the blowing operation and a second pump or fan draws the air escaping from the cream to the outside. The blowing generally occupies from 20 to 30 minutes. In some creameries the cold cream is blown, in others the air is blown through the hot cream.

In the third method of aeration the cream is enclosed in a nearly air-tight chamber, to which suction is applied, sucking the air and gases present in the cream out of it. This method represents a partial evacuation of the air in the cream.

Effect of Aeration on Flavor of Cream and Butter.—There can be no question that any form of aeration, assists in removing objectionable gases, odors and flavors, that may be present, and therefore, improves the flavor of the cream and butter to that extent. The more intimate the contact of the cream with the air, the more complete is the removal of odors. In this respect, therefore, the blowing of cream is a more effective method of aeration than the mere surface exposure of the cream to the air.

Effect of Aeration on the Keeping Quality of Butter.—From the standpoint of the keeping quality of the butter, any method of aeration, that mixes air into the cream, is positively objectionable. The newer knowledge of butter deterioration is demonstrating conclusively, that the fundamental agencies that shorten the life of butter, that cause it to deteriorate and to develop flavor defects with age, are intimately associated with the oxidation of one or more of the constituents of cream and butter. Atmospheric air is an active oxidizing agent. Its presence in cream and in butter, hastens deterioration, and the greater the amount of air present, the more rapid and the more intense the destructive action.

To run the hot cream over a surface coil cooler, where it is freely exposed to the air, is detrimental to the keeping quality of the resulting butter. The damaging action of the air in this case is greatly intensified by the heat of the cream, and the copper of the aerator over which the cream flows. Heat alone enhances all forms of oxidation. The heat and acid of the cream act on the copper and copper is a most active oxidizer and catalizer. Even very minute quantities of copper salts in butter, resulting from the action of hot, slightly sour cream in the presence of air, have a very intense deteriorating effect on the butter.

To blow air into and through the cream obviously influences the keeping quality in a similar unfavorable manner, and if the cream is blown while hot, the action is correspondingly greater. The blowing of cream, therefore, is a very questionable expedient, as a means to improve the permanent flavor of the butter.

These facts can leave but little doubt that, while surface aeration and blowing do temporarily improve the flavor of cream and of butter, they are positively dangerous to the keeping quality of butter, and since keeping quality is the crucial and final criterion of butter acceptable to the trade, these forms of aeration cannot be recommended as beneficial processes in the manufacture of butter.

The drawing of air out of the cream, on the other hand, has distinct merits, as far as it is practicable. It not only improves its flavor, but it assists in removing from cream one of the destructive agents—air—and thereby tends to enhance the stability of the finished product.

If it were mechanically and economically feasible to handle the cream and to manufacture the butter under reduced pressure, in a partial vacuum, the keeping quality of butter would be greatly benefitted and such a process of so-called aeration might logically be looked upon as the last word on ideal butter manufacture.

CHAPTER IX.

CREAM RIPENING AND STARTER MAKING.

THE RIPENING OF CREAM.

Definition.—By cream ripening is generally understood the treatment the cream receives and the changes which it undergoes in flavor, aroma and texture from the time it leaves the separator until it reaches the churn. These changes largely control the quality of the resulting butter, with reference to flavor, aroma and texture. Under present conditions and taking into consideration the several processes to which cream is subjected in the modern creamery, this broad definition is somewhat misleading and should be modified. Cream ripening, strictly speaking, refers to the souring and chilling of the cream preparatory to churning.

Contrary to popular impression the practice of ripening cream is the result of economic expediency, rather than of a specific discovery or invention, or of careful and systematic planning and experimenting for the attainment of an important purpose. Cream ripening began in the early days of butter manufacture on the farm. In order to save time and labor the dairy farmer dispensed with the task of churning his cream daily and adopted the practice of churning the cream of several days' production together. In those days the creaming was done exclusively by the gravity system, using in most cases the shallow-pan method. When the cream was skimmed off it was already slightly sour and its additional holding at temperatures not low enough to check bacterial action till churning day, caused it usually to be quite sour and ripe by the time it reached the churn. A further reason for allowing the cream to sour was that this sour cream churned more readily and more exhaustively than sweet cream. It churned quicker and produced more butter.

Some of the butter made by this natural ripening process was of the very best quality. This was true especially where proper attention was given in the production and handling of the milk and cream, to cleanliness, and when the butter was thoroughly washed and properly worked. Much of the butter, however, was made on farms where these precautions were not regularly observed, resulting in butter of poor flavor and of inferior keeping quality. But this butter made from sour cream showed a high aroma and flavor which sweet cream butter did not possess. The consumer became accustomed to this high flavor, learned to like it and gradually demanded it.

In order to satisfy this demand the souring or ripening of cream was gradually adopted even in dairies and later in creameries where the cream was available in sweet condition and where it was churned daily. As the fundamental principles of cream ripening became better understood, and with the helping hand of science, the process of cream ripening was gradually perfected, eliminating as far as possible some of the agencies detrimental to good butter, and intensifying those agencies which became known to produce the best results. In this evolution the most prominent factors that assisted in the improvement of the process of cream ripening and of the quality of the resulting butter were, the advent of the centrifugal separator, which gradually replaced the gravity can; the introduction of pasteurization of milk or cream, which removed the great majority of undesirable bacteria and other forms of germ life, and the adoption of pure culture starters which made possible the almost exclusive development of ferments producing the desired flavor and aroma.

Purpose.—The principal objects of cream ripening as now practiced are: 1. To give the butter the desired flavor, aroma and texture; 2. to produce uniformity of quality and 3. to increase the exhaustiveness of churning.

1. To Produce Flavor and Aroma.—The exact and specific agents which are responsible for the characteristic and desired butter flavor and aroma during the ripening process, have not as yet been conclusively determined. The fact that milk and cream, when souring in the natural way, contain very greatly predominating numbers of lactic acid bacteria, especially Streptococcus lacticus and Bacterium lactis acidi, has led to the assumption that these species of lactic acid bacteria play an essential part in the production of the characteristic flavor and aroma in butter. This has been further borne out by the fact that when inoculated into sweet cream these micro-organisms do, under proper conditions of ripening, produce a butter of a cleaner flavor and aroma and of better keeping quality, than when cream is permitted to sour in the ordinary way and without the addition of a pure culture of these organisms.

On the other hand, it is generally conceded that butter from cream in which the promiscuous assortment of organisms of its natural bacterial flora has been largely destroyed by pasteurization, and which has been ripened with a pure culture starter of these lactic acid bacteria, has a milder and less pronounced flavor than butter made from cream ripened in the natural way. Conn, Weigmann, Freudenreich, Ademetz, Marshall, Bosworth and other investigators have succeeded in isolating species of bacteria, yeast and molds, capable of producing the characteristic and desired butter flavors to a very marked degree. Among these flavor- and aroma-microbes were bacteria of the coli and aerogenes group, also peptonizing yeast and molds. Some of these specific butterflavor-producing organisms were recommended to be used jointly with the real lactic acid milk bacteria in the ripening of cream. These findings suggest that possibly the associative action of one or more of these specific aroma-producing organisms with one or both of the lactic acid bacteria, streptococcus lacticus and Bacterium lactis acidi, is needed to produce a high butter flavor.

Furthermore, it is by no means established that the butter flavors are exclusively of bacterial origin. Experience has amply demonstrated that the feed which the cows consume may directly or indirectly affect the flavor of the butter. Some of the aromatic substances coming from the feed may pass into the milk direct, through the udder, the excreta, or the air, as completely developed substances from the feed. But it is equally probable that they are separated from the feed and reach the udder as complex and but slightly aromatic products from which volatile and aromatic products are formed in the ripening process by bacterial decomposition. In this latter case the micro-organisms which bring about these decompositions are therefore aroma-producing only in the milk and cream which contain these specific materials, but not in all milk and cream.

The period of lactation of the cows also has a very pronounced effect on the presence and intensity of the desirable aroma and flavor of butter. Thus butter from cows during the first two to three months of lactation invariably shows the desirable flavor and aroma, characteristic of good butter, very decidedly, while butter from cows which approach the latter stage of the period of lactation lacks this characteristic butter flavor and is prone to have a somewhat stale and lifeless taste. This fact is explained to be due to the relatively high per cent of volatile and soluble fats in milk from fresh cows and the relatively low per cent of these same fats toward the end of the period of lactation.

Inasmuch as the lactic acid bacteria which have been found to produce a clean acid, and which are being used in the manufacture of pure starter cultures for cream ripening, produce only a mild butter flavor and aroma, it might be of much importance to the butter industry to find a butter-aroma organism capable through joint action with the lactic acid bacteria, to produce a butter with a high characteristic butter flavor and aroma.

So far, all known attempts in the manufacture of butter on a commercial scale, of developing starters and ripening cream through associative bacterial action have failed to produce the desired object. The differences in temperature and other requirements between different groups of micro-organisms have made difficult the joint development of these organisms in their proper proportion and have made unsuitable this method of cream ripening on a commercial scale. Experience has also demonstrated that butter with a high aroma and flavor is generally of relatively low keeping quality. Such butter tends to "go off" in flavor comparatively rapidly and is particularly unsuited for storage purposes.

These reasons largely explain why we recognize today only certain lactic acid bacteria which may be used to advantage in cream ripening. The most prominent of these are Streptococcus lacticus and Bacterium lactis acidi.

2. To Produce Uniform Quality.—It is obvious from the discussion of the effect of cream ripening on the flavor of the butter that in the absence of a systematic method of ripening the cream, the production of a uniform flavor from day to day and season to season is difficult. If the fermentation of the cream during the ripening process is at all responsible for the flavor of the resulting butter, the systematic use of specific bacteria in the cream ripening process is bound to greatly assist in securing a uniform flavor in the butter. If, on the other hand, no attempt is made to control the bacterial flora of the cream and its development, either by pasteurization which destroys most of the organisms present, or by ripening with pure cultures of lactic acid bacteria, or by both, the butter maker is powerless to regulate the flavor in the finished product and the flavor of the butter will largely vary with the character of the cream that he receives.

3. **To Increase the Exhaustiveness of Churning.**—Other conditions being the same, the churn yield from a given quantity of butter fat depends on the exhaustiveness of the churning. The more exhaustive the churning, the less of the butter fat will be lost in the buttermilk and the larger will be the amount of butter made.

Experience has amply demonstrated that sour or ripened cream will churn out more readily and more exhaustively than sweet cream. This means less labor and time required to complete the churning and more butter made from sour cream than from the same amount of butter fat in sweet cream. This fact is due to the difference in the viscosity between sweet and sour cream. Sweet cream is of relatively viscous consistency due to the colloid condition of the casein. The viscosity minimizes the concussion to which the fat globules are exposed during the churning process, and therefore delays the formation of butter granules. For the same reason, also, a relatively large proportion of the small fat globules is not churned out at the time the churn is stopped and there is excessive loss of fat in the buttermilk.

In the ripened cream the viscosity is very materially reduced. The acid alters the physical condition of the casein, and other nitrogenous bodies precipitating them into finely divided particles. This changes the mechanical condition of the cream from a viscous body to a granular, friable body. In this sour cream the fat globules encounter less resistance and have greater freedom to respond to the agitation caused by the revolving churn. They strike each other and the sides of the churn oftener and with greater force. Their equilibrium is disturbed more readily and the formation of butter granules is facilitated, shortening the time required for churning, churning out more completely, and avoiding excessive loss of fat in the buttermilk.

The excessive loss of fat incurred by churning sweet cream may be avoided by lowering the churning temperature. The lower temperature retards the churning and gives the smaller fat globules which are slow in uniting, a better opportunity to churn out before the churn is stopped.

Effect of Cream Ripening on the Keeping Quality of Butter.—The relation of ripening of cream to the keeping quality of butter has not been clearly understood for many years and even to this day the general impression prevails that cream ripening improves the keeping quality of the butter. Thus McKay and Larsen,[1] Meyer,[2] and Michels[3] emphasize the improvement of the keeping quality of butter as one of the objects of cream ripening.

There are no experimental data on record that show that the ripening of cream ever improved the keeping quality of butter, but there is plenty of evidence, both experimental and commercial, that the ripening of cream is a distinct detriment to the keeping quality of butter.

The "theory" that cream ripening improves the keeping quality of butter originated with the advent of the use of pure culture starters. Lactic acid bacteria which produced the desired flavor and did not noticeably decompose the protein of cream, were thought to be favorable to keeping quality. Their predominance in ripened cream, retarding or inhibiting the development of micro-organisms of the liquefying and putrefactive species, was considered a partial protection against undesirable changes and fermentations which give rise to objectionable flavors, and the lactic acid thus produced in itself was thought to have a sufficient antiseptic effect to control, if not inhibit, the growth of the bacteria known to produce objectionable flavors and odors.

[1] McKay and Larsen, Principles and Practices of Buttermaking, 1915, p. 192.
[2] Martin H. Meyer, Modern Buttermaking, 1910, p. 74.
[3] John Michels, Creamery Buttermaking, 1914, p. 46.

This was the bacteriologists' theory. Within its own limitations it was perfectly natural and reasonable, but as far as its relation to the keeping quality of butter is concerned, it was utterly erroneous. He considered good flavor of fresh butter and keeping quality synonymous.

High flavor and keeping quality are not synonymous, but they are positively antagonistic to one another. One and the same churning of butter may have either, high flavor or keeping quality, but it cannot have both. Cream ripening means fermentation. High flavor, which is produced by cream ripening, then, is the result of a partial decomposition of one or more of the constituents of cream and which subsequently, become constituents of the butter. The deterioration of butter with age also is the result of decomposition of one or more of its constituents.

Cream ripening, therefore, represents the first stages of the decomposition of one or more of the constituents which subsequently make up the composition of butter. It so happens that the changes resulting from this early and partial decomposition, caused by the ripening of cream, yield flavors that are desired. But when this decomposition goes beyond a certain stage, flavors are produced that are objectionable and which are recognized as a deterioration of the butter.

Cream that is ripened sufficiently to give butter a very pronounced, high flavor, produces butter that, when taken from the churn, represents a product in which the flavor-producing decomposition has been carried to the very limit of changes that are capable of producing good flavor. But this decomposition does not stop at the churn, it continues, only instead of going on producing desired flavors, these further changes yield now objectionable flavors, the butter deteriorates. Hence butter so made, has reached the peak of quality at the churn, it has attained the very top of desired flavor and any further changes which even a few weeks of age are bound to bring about, place it on the tobbogan, it cannot change further without deteriorating, it will not stay inert, because the changes once started must go on. Cream ripening, therefore, not only does not improve the keeping quality of butter, it actually tends to destroy it.

On the other hand, if butter is made from sweet or only slightly ripened cream, its flavor is mild, the decomposition has been only slight. When this butter is taken from the churn, the changes which are capable of developing good flavor have not reached the limit. Further changes do not produce immediate deterioration, the top has not been reached, and the development of good flavor can continue through a considerable distance of changes and for a considerable length of time, before the desired flavor yields to objectionable flavor and deterioration. Therefore, butter made from sweet or only slightly ripened cream, has relatively good keeping quality, other details of the process of manufacture and quality of the original cream being the same.

Again, the theory that the lactic acid produced during the process of cream ripening exerts a favorable influence on the keeping quality of butter is not well founded. It has gained considerable credence because of the fact that high acid, such as is found in ripened cream, produces an unfavorable medium for many of the objectionable bacteria present in the cream, and therefore retards or inhibits their destructive action. This argument permits of consideration only when confined to the cream. In the finished butter, made from ripened cream, the percent acid is too low, ranging usually between .15 and .35 percent, to exert any appreciable retarding action on germ life. From the standpoint of the biological effect of the lactic acid resulting from cream ripening, therefore, it is highly improbable that the ripening of cream is capable of benefitting the keeping quality of butter.

On the other hand, even the slight increase in the acidity of butter made from ripened cream, through chemical action, has a very marked detrimental effect on the keeping quality of the butter. It appears that acid is one of the essential agents, in the combination of conditions that reduce the resistance of butter against the deteriorating influence of age, and that causes the development of such off-flavors as storage flavor, oily flavor, metallic flavor, fishy flavor, etc., as discussed in Chapter XVII on "Butter Defects."

The fact that the changes brought about in sour cream, whether souring be due to natural causes or to artificial ripening, for the development of flavor, are detrimental to the keeping quality of the butter has been conclusively established, both experimentally and in practical buttermaking, although the teaching and practice of churning cream at a low acidity are far from being generally accepted as yet in the creamery world.

H. J. Credicott[1], proprietor of the Freeport Creamery, Freeport, Ill., and formerly buttermaker in Minnesota, and later butter expert for the U. S. Department of Agriculture, was the first exponent of sweet-cream churning, who successfully manufactured butter from sweet cream without ripening, after the practice of ripening cream had been generally adopted in this country. McKay[2] and Hunziker[3] first demonstrated methods and the advantages of reducing the acidity in sour cream for buttermaking.

Rogers[4] as the result of an extensive investigation of the causes of fishy flavor in butter, states that "in all cases in which the records were complete, it was found that those experimental butters which became fishy were made from high-acid cream, though cream with high acidity did not uniformly develop fishiness. Rogers and Gray[5] found more rapid deterioration of butter made from high-acid cream than from sweet cream, and they conclude that the acid developed normally in the cream by the action of lactic acid bacteria, or added directly to the cream in the form of pure acid, brings about, or assists in bringing about, a slow decomposition of one or more of the labile compounds of which butter is largely composed; and Dyer[6] demonstrated that "the production of off-flavors, so commonly met with in cold storage butter, is attributed to a chemical change expressed through a slow oxidation, progressing in some one or more of the non-fatty substances occurring in buttermilk,

[1] Credicott, Address at First National Dairy Show, Chicago, 1906.
[2] McKay, Experiments in Neutralizing Sour Cream for Buttermaking, at Iowa Dairy School, 1906, Results not published.
[3] Hunziker, Experiments and Commercial Practice, at Purdue University Creamery, 1906—1916, Results not published.
Hunziker, Address at National Conference of Allied Dairy Interests, Washington, D. C. 1916.
Hunziker, Spitzer & Mills, Pasteurization of Sour, Farm-Skimmed Cream for Buttermaking, Purdue Bulletin 203, 1917.
Hunziker, The Neutralization of Cream, Address American Association of Creamery Butter Manufacturers, Chicago, 1918.
[4] Rogers, Fishy Flavor in Butter, U. S. Dept. of Agr. B.A.I. Circular 146, 1909.
[5] Rogers and Gray, The Influence of Acid of Cream on the Flavor of Butter, U. S. Dept. of Agr. B.A.I. Bulletin 114, 1909.
[6] Dyer, Progressive Oxidation of Cold Storage Butter, Journal Agr. Research, Vol. VI. No. 24, 1916.

and that the extent of this chemical change is directly proportional to the quantity of acid present in the cream from which the butter was made."

In the presence of the above facts it appears safe to conclude that the ripening of cream does not enhance the keeping quality of butter, that the churning of sour cream is distinctly injurious to keeping quality, that butter that is not consumed soon after it is manufactured, or butter intended for storage purposes, should be made from unripened cream or from cream in which the acidity is low, and that cream ripening is justifiable only in the case of butter that is intended for immediate consumption.

Natural Ripening of Cream.—The natural ripening of cream consists of allowing the cream to sour without the addition of a starter. This is the oldest method of cream ripening, the cream is held at a temperature favorable for bacterial action until it is sour. The character of fermentation which occurs and the quality of the resulting butter depend largely on the bacterial flora of the cream after it leaves the separator, or after it arrives at the creamery and this in turn will depend on the sanitary care which the milk and cream receive on the farm, on the age of the cream and on the particular types of bacteria which may predominate in any given locality and at any given season of the year. With cream that is clean and that has been produced under highly sanitary conditions, natural ripening may produce very good butter. Where little or no attention is given to cleanliness, contamination of the cream with relatively large numbers of undesirable species of micro-organisms is unavoidable. When such cream is allowed to ripen in the natural way, undesirable fermentations are prone to gain the ascendency, resulting in butter of inferior flavor and low keeping properties.

Inasmuch as the natural ripening process affords no facilities for controlling fermentations, the product usually also lacks in uniformity of quality. The bacterial flora of the cream varies not only with the individual care which each lot of cream receives on the farm, but also with the season of the year. Thus in early summer when the cows are on pasture, conditions are favorable to a preponderance of lactic acid bacteria to the partial exclusion of peptonizing and putrefactive germs, while in late fall, winter and early spring, when the cows in the central and northern dairy belt are confined to the stable and receive dry feed, there is a marked increase in the group of putrefactive microbes which tend to impair the flavor and shorten the life of the butter, unless their action is retarded by pasteurization or possibly by the addition of lactic acid bacteria to the cream.

At best, the results from the natural ripening process are uncertain. Where butter of uniformly high quality is desired the natural ripening cannot be recommended and it is justifiable only, if at all, when butter is made on too small a scale to warrant the extra labor and expense of handling pure culture starters, as is the case on the majority of farms making farm dairy butter and where the milk and cream are produced under highly sanitary conditions.

While, under favorable conditions, natural ripening may give butter a flavor more attractive to the palate of the consumer than butter made from sweet cream, the keeping quality of such butter is prone to be low and would be materially improved by not ripening such cream at all.

Artificial Ripening of Cream.—By artificial cream ripening is understood the souring of the cream with the aid of a starter. The term starter includes a variety of materials, such as buttermilk, sour cream from the previous churning, sour milk and skim milk ripened by spontaneous souring and sour milk, cream, diluted condensed milk, or redissolved skim milk powder, ripened by the addition of a pure culture of lactic acid bacteria.

The desirability of the use of buttermilk and sour cream for starter, depends very largely on the degree of purity of the previous batch of cream. If the cream shows a pure, mild acid, the resulting buttermilk may be reasonably safe to use as starter, provided that the cream was not overripe and the churn at the time of churning was in good sanitary condition. Buttermilk from overripe cream and from cream lacking in clean acid flavor is unsafe. Its use is likely to propagate, in the next lot of cream, the very fermentations which are to be avoided.

Sour cream, if of a clean acid may prove beneficial in the absence of a better starter. In most cases, however, its use is not to be recommended, it has the same objections as the use of buttermilk. Then, again, the butterfat as well as the non-fatty constituents in this sour cream are thus exposed to a double ripening period; this is considered undesirable because of the possible action of the acid on these cream constituents, lowering their resistance to oxidation, if not actually starting oxidation, or cleavage by hydrolysis, thereby jeopardizing the quality of the butter.

Spontaneously soured milk or skim milk starter is preferable to either buttermilk or sour cream, provided that in its preparation a high sanitary quality of raw material, milk or skim milk, has been selected. Otherwise, the ripening of cream by the use of such starters may be no better than the natural ripening of cream.

Milk or skim milk starters and possibly starters made from condensed and powdered milk, soured with pure cultures of lactic acid bacteria, are the only really dependable starters and it is the use of this group of starters which will be exclusively considered in the discussion of artificial cream ripening.

The ripening of cream by means of pure culture starters is a practice which has come into more general use in this country only within the last score of years. Its application is largely the result of investigations of Storch.[1]

Artificial cream ripening may be divided into two classes, namely, ripening by the addition of a sufficient amount of starter to raw cream to control fermentations, and 2. ripening of cream in which the majority of bacteria and other ferments have been destroyed by pasteurization and which, after cooling has been inoculated with a lactic acid starter.

Either of these methods is preferable to the natural ripening process, inasmuch as they both assist in regulating fermentation by accelerating the development of desirable lactic bacteria to the partial exclusion of other organisms. In the case of artificial ripening of raw cream, the control of the fermentations may, however, be less complete and the final results less certain than when the cream is first pasteurized. The raw cream has a mixed flora which may consist of both desirable and un-

[1] Storch, Eighteenth Annual Report of Danish Experiment Station, 1890.

desirable bacteria. Unless the starter added is an active one, and the cream is of relatively good quality the benefits of artificial ripening are prone to be very diminutive. In the case of sour gathered cream, nothing is gained by further ripening unless possibly here neutralization is resorted to. In this kind of cream the fats and the curd have already been exposed to acid for an excessive length of time and further ripening will tend to weaken their resistance just that much more, inviting with greater certainty their partial decomposition.

If the cream is properly pasteurized before the starter is added the fermentations that occur during the cream ripening period can be controlled most readily, provided, of course, that the operator understands the fundamental requirements for relative optimum development of the lactic acid organisms and has proper facilities in the way of temperature control. The artificial ripening of pasteurized cream is, from the bacteriological point of view, the most nearly ideal method of cream ripening. In pasteurized cream the bacterial count of all bacteria has been reduced to a relatively low figure, approximately to one-tenth of one per cent of their original number. The cream furnishes therefore an ideal seed bed for the lactic acid starter, and the desirable bacteria, added in the form of a pure culture starter, have a free and unhindered field for rapid development.

Here again it should be understood that the better the quality of the cream, the better and the more uniform will be the results of the ripening process. The ordinary run of gathered cream, such as is received at the centralized creamery, averages possibly about from 50,000,000 to 500,000,000 bacteria per cubic centimeter. Assuming that the pasteurization efficiency, or germ-killing efficiency be 99.9 per cent, which is very good under average commercial conditions, there would still be left in the cream 50,000 to 500,000 bacteria per cubic centimeter. Since a considerable proportion of the micro-organisms which survive belong to the group of undesirable or harmful types, it is obvious that the development of undesirable fermentations during the ripening process is by no means entirely eliminated, in spite of pasteurization, and that the otherwise beneficial results of artificial ripening are prone to be partly paralyzed.

Temperature of the Cream for Ripening.—Bacteriologically, the best temperature for ripening cream is that at which the desirable lactic acid bacteria develop more readily than any other type or species of micro-organisms. The optimum temperature for lactic acid bacteria lies within the range of 90 to 100° F. This temperature, however, is most favorable also to the growth of many species of organisms harmful to the quality of butter, such as those belonging to the Bacillus coli group, the aerogenes group, and certain species of yeast and molds, etc. For this reason these high temperatures, 90 to 100° F., are unsuitable for the ripening of cream.

On the other hand, experience has shown that a temperature of from 60 to 70° F. permits of reasonably rapid development of the lactic acid bacteria while such temperatures are too low to give most of the harmful species an opportunity to gain the ascendency. Hence this lower range of temperatures, 60 to 70° F., has been generally adopted as the proper ripening temperature. In summer when the atmospheric temperature is relatively high and other conditions are comparatively favorable for rapid acid development, the cream is preferably ripened at 60 to 65° F. In winter when the atmospheric temperature is relatively low and other conditions present tend to retard lactic acid fermentation, the cream is preferably ripened at 65 to 70° F.

Aside from the fact that relatively high ripening temperatures invite the development and domination of undesirable bacteria, such as the species of the Bacillus coli and the aerogenes group, etc., at the expense of the pure lactic acid ferments, they may also prove harmful to the texture and body of the butter, causing the butter to be soft and weak in body and of a salvy texture. All of these phenomena indicate unmistakably the danger of ripening the cream at high temperatures. The unfavorable effect of high ripening temperature is more pronounced in the case of cream of a poor quality than with cream of a high degree of purity.

In more recent years many of the most observant butter makers are leaning towards low-temperature ripening and many creameries have adopted the practice of ripening their cream at temperatures ranging from 48 to 55° F. This practice is recommended especially where a rather sour cream is received, such as is the case in gathered cream creameries all over the country, if such cream must be ripened. Its advantages are, that most of the undesirable fermentations are held in check and that the resulting body of the butter is firm and free from weakness. The retardation of the acid development at these low temperatures may be materially overcome by the use of a larger amount of starter (See Amount of Starter to Add to Cream, page 242.)

Control of Ripening temperature.—If the process of cream ripening is to be successful it is essential that the operator have as complete control over the temperature of the cream as possible. This is necessary, not only in order to maintain a uniform temperature during the ripening process proper, but especially also in order to cool the cream promptly and properly as soon as the desired degree of acidity has been reached. The absence of such facilities may cause exposure of the cream to too high ripening temperature and the over-ripening of the cream, both of which jeopardize the flavor and body of the butter.

Ripening Vats.—The essentials for adequate facilities for regulating the temperature of the cream are equipment to permit exposure of the cream over a relatively large area of heating and cooling surface and an adequate supply of an efficient cooling medium, such as cold water, ice water or brine.

In order to increase the tempering capacity of the cream ripening vat, the vat must be equipped with an agitator that brings large volumes of the cream in direct contact with the heating or cooling surface. For this purpose there are now in use cream ripening vats with coil or disc agitators, the heating or cooling medium passing through the revolving agitator. These agitator vats are a great improvement over the old jacketed ripening vat without agitator, from the standpoint of heat control. One seriously objectionable feature of most of these ripening vats with disc or coil agitators is that the bearings and stuffing boxes of their axis are submerged in the cream and some cream is bound to enter these glands, where it is ground to grease. The mechanical effect of this alone is undesirable and the lodging of the cream in these friction places is highly unsanitary and conducive to contaminating the cream with undesirable ferments. In this respect, vats equipped with agitators of horizontal or vertical motion are preferable to the rotary agitators, such as the discs and horizontal coil, but the former are slower in their tempering action than the latter. There are some coil vats on the market now in which the coil is vertically suspended, removing the glands and bearings entirely from contact with the cream.

Effect of Copperlined Vats on Quality of Butter.—From the standpoint of material of construction it should be thoroughly understood, that the cream ripening vats, now in general use in this country, are unsuitable and highly objectionable, because the metal, copper, with which they are lined, constitutes one of the most active agencies that invites chemical decomposition of one or more of the constituents of cream and butter and thereby impairs the flavor and deteriorates the keeping quality of butter, as has been conclusively shown by Hunziker and Hosman[1] who demonstrated that copper, alloys of copper such as brass and german silver, and copper salts, acting as powerful-oxygen-carriers and catalizers, are capable of introducing oxidation in butter that is most disastrous to its flavor and keeping quality. Iron also has a specific catalytic action which aids the oxidation process, but in the case of iron bases and salts this action is relatively slight. Tin and nickel are practically inert, exerting no appreciable oxidizing influence.

In the earlier days of butter manufacture, the lining of the cream ripening vats consisted of tinned sheet iron. The tin coating on the iron lining is relatively permanent. It stays bright as long as the vat lasts. These vats, however, were jacketed vats and the lining was prone to rust. The rusting did not usually occur on the inside of the vat lining that was exposed to the cream. The lining rusted on the jacket side, because of the continued exposure of the lining to the dampness in the jacket.

From the standpoint of their effect on the quality of the cream these old-fashion, iron-lined, tinned, jacketed ripening vats were not objectionable. So long as the lining did not rust through from the outside, the tin coating remained on the sheet iron and was bright. But these vats were of comparatively short

[1] Hunziker and Hosman, Tallowy Butter—Its Causes and Prevention, Journal of Dairy Science, Vol. I., No. 4, 1917.

life, because they rapidly rusted through from the outside and sprung leaks. Manufacturers of cream vats, therefore, endeavored to construct and place on the market, vats of a more durable metal and they naturally chose copper for the lining. This step seemed necessary also as the result of the introduction of brine as the cooling medium and its well-known corrosive action on iron.

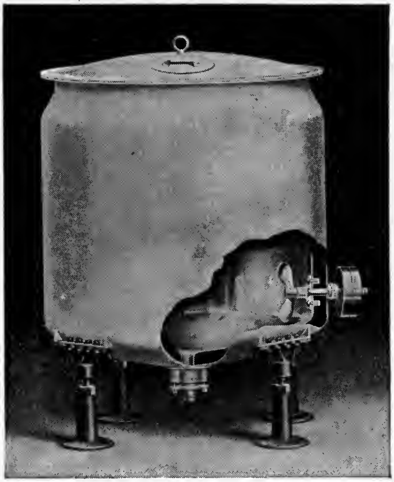

Fig. 36. Enameled cream ripening tank
Courtesy The Pfaudler Co.

But all efforts, so far, to cover the copper surface with a satisfactory and permanent coating of tin, have been abortive. The exposure of the tinned copper surface of the ripening vat to the sour cream, causes the surface to soon turn black and the copper to be exposed, jeopardizing the quality of both cream and butter and giving rise to the most disastrous flavor deteriorations in butter. Hence the copper-lined, tin-coated ripening vats are highly unsatisfactory and their annual retinning involves a very considerable expense.

Advantages of Glass-Enameled Vats.—Because of the general use in the creamery of brine for cooling the cream it is not feasible to return to the iron-lined, tinned cream ripening vats. But the perfection attained within recent years in the manufacture of glass-enameled vats, now makes possible their use for cream ripening equipment, These vats, from the standpoint of their protection of the cream and butter against the oxidizing influence of exposed metals such as iron and copper, and the damaging effect of such chemical action to the quality of the butter, are as nearly ideal as can be desired and this desirability, and the absence of the necessity of frequent recoating are additional factors in their favor.

In the presence of these facts it appears reasonable to believe that as soon as the commercial butter manufacturers fully realize this disastrous influence of copper and copper salts on cream and butter, and learn to appreciate the feasibility of using glass-enameled vats in the creamery, glass-enameled vats will commence to take the place of copper-lined vats in a similar way as has been the case for years in the brewery and the condensed milk factory, and is now the case in oleomargarine factories, market milk and ice cream plants. This change will result in a marked improvement of the quality of butter, and especially of butter for storage purposes.

Amount of Starter to Add to Cream.—The amount of starter to add to the cream depends on such factors as the temperature at which the cream is to be ripened, season of the year, the length of time during which the cream is to be ripened, the richness of the cream and the availability of the starter. The amount of starter that is used under normal conditions ranges from 5 per cent to 20 per cent, though larger amounts may be used to good advantage under certain conditions.

At low ripening temperatures more starter is needed to ripen the cream than at high temperatures. When ripening around 50° F., 20 per cent starter is desirable, while at 65° F. 10 to 15 per cent starter should be quite sufficient.

If the time during which cream must be ripened is short, a relatively larger amount of starter is needed. Where conditions necessitate the prolonging of the ripening process, a less amount of starter should be used in order to guard against the danger of over-ripening.

More starter is usually needed to ripen the cream in winter than in summer, because both, atmospheric conditions and the bacterial flora of winter cream, tend to delay the souring, while in summer they are favorable to rapid souring.

Cream rich in fat will take care of a relatively large amount of starter to good advantage, while the addition of large quantities of starter to thin cream would be a distinct disadvantage, the resulting dilution reducing the readiness and exhaustiveness of the churning and decreasing the churn yield.

Finally, the amount of starter used is controlled in a great many creameries by the availability and expense of milk and skim milk and other materials for starter making. Especially in the smaller gathered cream creameries the scarcity of a good quality of skim milk and the high price of other starter media, such as condensed milk and milk powder are a serious obstacle in the way of the use of a large amount of starter.

Time Required for Ripening.—The time required for the ripening of cream depends on a variety of factors, some of which are ever changing. Generally speaking, quick ripening, if not done at too high temperatures, insures a purer lactic acid fermentation, greater freedom from the development of injurious fermentations and undesirable flavors than slow ripening. Unusually quick ripening is the result of the use of a large percent of active starter while slow ripening, other conditions being the same, is caused by the use of a small amount of starter, or starter that has lost some of its vitality and has become sluggish. The longer the ripening period, the greater is the danger of the development of undesirable fermentations and flavors at the expense of the pure lactic acid fermentations. Slow ripening further jeopardizes the quality and especially the keeping quality of butter due to excessive exposure of the fat and curd to the acid, inviting partial decomposition of one or both of these ingredients.

Sweet cream will generally require a longer ripening period than sour cream, in order to secure the desired degree of acidity and it will stand the longer ripening without danger of injury to the keeping quality of the butter better than sour cream. In the case of cream that is sweet and of good quality and relatively rich in butter fat, such as cream testing 35 per cent fat or over, the addition of a heavy starter, cooling immediately to the churning temperature and holding it at that temperature about twelve hours (over night) has been found to produce a butter of exceptionally fine quality. This practice is locked upon with favor by many creameries. Sour, gathered cream is rarely, if ever, benefitted by further ripening. It usually has a high degree of acidity when it reaches the factory and it is contaminated with a variety of detrimental organisms. If warmed to and held at the ripening temperature for any length of time, undesirable fermentations are prone to gain the upper hand, hastening objectionable decompositions and injuring the flavor and keeping quality of the butter, in spite of the addition of a pure culture lactic acid starter. For this reason sour gathered cream is best cooled to the churning temperature at once, or if pasteurized, immediately after pasteurization, and churned after holding it at that temperature for about three hours. The addition of starter to this type of cream either immediately after cooling or just before churning usually freshens up its flavor to some extent and improves the flavor of the resulting butter, though it may not benefit its keeping quality appreciably.

The Proper Degree of Acidity in Cream at the Churn.—The per cent acid in cream at the churn that produces the most desirable result depends on such factors as disposition of butter, whether it is intended for immediate consumption or for storage, quality of cream and richness of cream.

That the addition of starter to cream and the proper ripening of cream assist in developing flavor in butter is an established fact. Good starter improves the flavor of butter and the ripening of the cream produces the high flavor desired by the American consumer. If butter is intended for immediate consumption, therefore, the use of starter in all cream, and the ripening of cream that arrives at the creamery in sweet condition, are desirable and assist in best meeting the demands of the market. Under these conditions cream may be ripened with starter to an acidity of .50 to .60 per cent, the exact acidity varying with the fat of the cream.

On the other hand, it should be clearly understood that acidity in cream is harmful to the keeping quality of the butter, assisting in the decomposition of the non-fatty constituents in cream and butter. Hence, if butter remains on the market for several weeks before it reaches the consumer, or if it is intended for storage purposes, the ripening of the cream is not beneficial and may prove exceedingly harmful to the quality of the butter at the time it reaches the consumer. If starter is used at all in the manufacture of this butter, it should be added to the cream after the cream has been cooled to the churning temperature, or preferably immediately before the cream is drawn into the churn. This will lend the cream and butter the beneficial and freshening flavor effect of the starter and at the same time, it will prevent the acidity from rising to a point harmful to the keeping quality of butter.

The desirability and extent of the use of starter and of cream ripening further depends on the quality of the cream. In the case of cream of good quality and that arrives at the creamery in sweet condition, the addition of starter and the ripening of the cream, do not jeopardize the keeping quality of the resulting butter nearly as much as in the case of cream of inferior quality, or cream that is already highly acid when it reaches the creamery. In this type of cream the fermentations and the acidity produced may and usually have already started the formation of cleavage products and the further ripening hastens decomposition and shortens the life of the butter. This holds true of all sour cream, whether neutralized or not. If starter is used at all in cream that arrives at the creamery sour, it should be added only just before churning time. In most cases it would be preferable to use sweet milk or sweet skim milk, in the place of sour starter when butter made from this sour cream is held for any length of time before it is consumed. Or if the consumption of the butter is fairly rapid the milk originally intended for starter, may be divided into two equal portions, one half to be added as sweet milk, immediately after neutralization and before pasteurization, and the remainder as ripened starter, just before churning. Such cream should have an acidity of less than .3 per cent at the time of churning.

In the case of sweet cream, it is obvious that butter made without the use of starter and without cream ripening, has a milder flavor than the public desires. Butter made in this manner is therefore, less suitable for immediate consumption, but for storage purposes, such butter will show a better flavor when it comes out of storage, than butter made from ripened cream.

The per cent acid to which cream may be ripened in case cream ripening is practiced, should be governed also by the richness of the cream. The development of lactic acid is the result of the action of the lactic acid bacteria on the milk sugar. The milk sugar is present only in the serum of the cream. The acid, therefore, also is confined to the serum, the fat being practically neutral. The relative amount of serum varies with the per cent of fat in the cream. The higher the per cent of fat, the smaller the proportion of the serum and the lower the per cent af acid required in the cream. The proper per cent of acid in the ripened cream therefore varies with, and should be adjusted in accordance with the fat content of the cream. It is obvious that, if uniformity of results is to be secured, there must be uniformity of the per cent of acid in the serum.

Authorities are at variance as to the exact per cent of acid which cream of a given richness should contain. A few years past the general tendency was to favor a rather high acidity while more recently the danger of the detrimental effect of high acidity on the keeping quality of the butter has become more thoroughly appreciated, and those who have given this subject most careful study practically agree that an acidity of about .6 per cent for cream of good quality and testing 25 per cent fat is sufficiently high to meet the demand of the public for flavor and is less apt to jeopardize the keeping quality of the butter than a higher degree of ripeness. It should be understood that these figures refer only to cream of good quality and that reaches the creamery in sweet or nearly sweet condition. Ripening to this acidity is justifiable only when butter is intended for immediate consumption and the trade demands a high flavored butter. Accepting .6 per cent acid as the proper acidity for 25 per cent cream, it is a simple matter to calculate the per cent acid of the serum, which may be adopted as the standard.

The per cent serum in cream is determined by deducting the per cent fat from 100. Cream testing 25 per cent fat therefore contains $100 - 25 = 75$ per cent serum. When the per cent acid in the cream is known, the per cent acid in the serum is calculated by dividing it by the per cent serum and multiplying the quotient by 100. The per cent acid in the serum, of cream testing 25 per cent fat and .6 per cent acid is as follows: $\frac{.6}{75} \times 100 = .8$ per cent acid. The above calculation shows that the standard amount of acid in the serum should be .8 per cent. On the above basis the standard per cent acid for cream of any richness may readily be calculated, by deducting the per cent fat in the cream from 100, multiplying the difference by .8 and dividing the product by 100.

Example: Cream tests 33% fat. To what per cent acid should it be ripened?

$$100 - 33 = 67; \quad \frac{67 \times .8}{100} = .536 \text{ per cent acid.}$$

For the convenience of the operator Table 42 has been devised which shows the desired degree of ripeness in per cent acidity, number of cubic centimeters of one-tenth normal alkali solution required as per Mann's test and degree acidity as per Soxhlet-Henkel method.

In using this table the butter maker and student should bear in mind that it was devised only as a guide applicable and convenient under fairly normal conditions. Its value is limited by the fact that its figures need modification and readjustment under a great variety of conditions, and at best should be applied only to cream that is of good quality and sweet when it reaches the creamery and to butter intended for immediate consumption.

Overripened Cream.—The overripening of cream is detrimental to the flavor, texture and keeping quality of butter. In overripened cream the most favorable acid bacteria have gone beyond their maximum stage of activity, the excessive degree of acidity, their own product, is detrimental to their further development, they become weakened, degenerate and give way to other fermentations, less desirable and usually harmful to the flavor of the butter.

Table 42.—Standard Per Cent Acid in Cream of Varying Richness, Number Cubic Centimeters of N/10 Normal Alkali Solution Needed When 50 c.c. and 18 c.c. of Cream Are Used, and Acidity in Terms of Degrees.

Per Cent Fat in Cream	Standard Per Cent Acid in Cream	Mann's Test. C. C. Decinormal Sodium Hydroxide Required to Neutralize Acid in		Degrees of Acid Soxhlet Henkel Method	
		50 c. c. Cream	18 c. c. Cream	50 c. c. Cream	100 c. c. Cream
20	.640	35.6	11.26	14.2	28.4
21	.632	35.1	11.12	14.0	28.1
22	.624	34.7	10.98	13.9	27.7
23	.616	34.2	10.84	13.7	27.4
24	.608	33.8	10.70	13.5	27.0
25	.600	33.3	10.56	13.3	26.7
26	.592	32.9	10.42	13.2	26.3
27	.584	32.4	10.28	13.0	26.0
28	.576	32.0	10.14	12.8	25.6
29	.568	31.6	10.00	12.6	25.2
30	.560	31.1	9.86	12.4	24.9
31	.552	30.7	9.72	12.3	24.5
32	.544	30.2	9.57	12.1	24.2
33	.536	29.8	9.43	11.9	23.8
34	528	29.3	9.29	11.7	23.5
35	.520	28.8	9.15	11.6	23.1
36	.512	28.4	9.01	11.4	22.8
37	.504	28.0	8.87	11.2	22.4
38	.496	27.6	8.73	11.0	22.0
39	.488	27.1	8.59	10.8	21.7
40	.480	26.7	8.45	10.7	21.3

The true lactic acid bacteria of cream ripening require the presence of oxygen for their development, they are aerobes. During the process of ripening, or of changing a portion of the milk sugar to lactic acid, they use up most of the free oxygen in cream. Overripened cream is a medium practically devoid of free oxygen and favorable particularly to anaerobes, those species of bacteria, which thrive best in the absence of oxygen, and also to yeast and molds. Some of the most common of these anaerobic species of bacteria belong to the putrefactive type, decomposing the proteids and possibly splitting the fats, and generally producing odors and flavors detrimental to the quality of good butter and shortening its life. The high acid in overripened cream in itself accelerates the development of certain other classes of micro-organisms, such as the molds which demand an acid medium for maximum growth, and whose presence in butter is exceedingly objectionable. From the bacteriological point of view, therefore, the overripening of cream is highly undesirable, it deteriorates the flavor and keeping quality of the butter.

Overripening does prove harmful to butter also from the chemical standpoint. The proteids of cream and butter are prone to undergo chemical changes which invite further decomposition, giving the butter off-flavors tending towards metallic and fishy flavor defects and hastening its deterioration in storage.

For these reasons great care should be exercised in stopping the ripening process before it has developed too far, by promptly cooling the cream to 50 degrees F. or below. When facilities for prompt cooling are lacking, the cooling of the cream should be started before the desired degree of acidity is reached, making due allowance for additional acid development during the cooling process and until the cream has reached a low enough temperature to completely check further fermentation.

Where cream is churned only once or twice per week, as is often the case in small creameries and during the months of small supply, it is advisable to keep all cream at a low temperature until twenty-four hours before churning time and then raise the temperature for the ripening process sufficiently to complete the ripening, if the cream "must" be ripened, until about three hours before churning when it should be cooled to the churning temperature and held there.

Methods to Determine the Desired Degree of Acidity.— When the cream has reached the proper degree of acidity it usually has a clean, mild acid flavor, pleasant to the palate. The viscosity of sweet cream has disappeared and the cream has a granular body and glistening luster. The creamy yellowish color has changed to a whitish tinge. These changes in body and color are due to the precipitation of the casein into a granular form.

The experienced operator can usually detect the proper degree of ripeness by the taste and appearance of the cream. In order to assist him in detecting the proper degree of ripeness he should use a convenient and accurate test to determine the per cent of acid, such as the Farrington Alkaline tablet test, the Mann's acid test or the Marshall acid test. These tests are based on the principle that normal solutions of alkalies neutralize equal portions of normal solutions of acids. The alkali usually used is sodium hydroxide with phenolphthalein as an indicator, which turns pink in an alkaline solution and remains colorless in an acid solution. For detailed directions of testing cream for acid see Chapter XXII on Chemical Tests and Analyses.

Starter Ripening Instead of Cream Ripening.—As previously stated, the species of lactic acid bacteria, which have been found the most suitable ferments and which can be used to advantage in cream ripening, attack exclusively the non-fatty constituents of cream and particularly the lactose, breaking it down into lactic acid. The most prominent of these species are Streptococcus lacticus and Bacterium lactis acidi. Since the non-fatty serum of the cream is very largely all washed out of the butter it would seem that the flavor and aroma developed in the serum and exclusively outside of the fat globules would also be washed out of the butter. This, however, is not the case. The highly aromatic Isigny[1] butter for instance is washed exceptionally thoroughly. The reason for this lies in the fact that butterfat possesses the property of absorbing flavors and aromas from volatile oils and other substances. This property has long been recognized and is extensively made use of in the manufacture of perfumes. This shows that the flavor and aroma developed in the serum are taken up by the fat globules.

From the above facts it may reasonably be assumed that the desired butter flavor and aroma can be acquired by their addition to the cream or butter, in the form of a properly ripened starter, in the place of the process of cream ripening. Instead of developing these flavors in the cream by means of the cream

[1] Isigny butter is made on the dairy farms, in the vicinity of Isigny, Normandy, France. This butter has established an enviable reputation for fine flavor, and keeping quality, on the continent of Europe.

ripening process, they may be developed in the starter and added to the cream shortly before churning or to the butter before working.

This assumption has been amply borne out in creamery practice. This practice has the further advantage that it shortens the time between receiving the cream and churning, and it minimizes the danger of chemical action of the acid on the less staple constituents of the cream, which action may jeopardize the flavor and is known to injure the keeping quality of the butter. This is especially true in the case of cream that is old, relatively sour and of poor quality. This type of cream needs no further ripening, it is usually overripe at best but it is materially improved by the addition of a good starter shortly before churning and without further ripening. The starter serves to bring back and freshen up its flavor. If added to the cream, both the cream and starter should be cooled to near the churning temperature before mixing. Otherwise bacterial action will continue and there is danger of overripening. If added to the butter the starter should be poured on the butter after washing, after which the butter is salted and worked. The addition and working into the butter of the starter after churning, is not recommended however, because it tends to increase the curd content of the butter, and curd is an undesirable constituent from the standpoint of keeping quality. Its decomposition- or cleavage products are injurious to the flavor of the butter.

STARTERS

Definition.—As applied to buttermaking, starter is a clean-flavored batch of medium, usually milk or skim milk, teeming with lactic acid bacteria favorable for the development of a clean acid and an agreeable flavor.

Purpose.—The purpose of using starter is to insure the flavor and aroma in butter which the market demands. As previously stated the American consumer has become accustomed to, and desires a rather high flavored butter. Sweet cream butter is considered flat and lacking in flavor and is not highly relished. In order to overcome this absence of flavor, the flavor may be developed in the cream by ripening or souring it, which is best done with the help of a pure culture starter, or the flavor may be added to the cream by adding a considerable amount of properly ripened lactic acid starter to the cream, shortly before churning and without further ripening of the cream, or the flavor may be added by pouring over and working into the butter a considerable amount of lactic acid starter in the churn.

Kinds of Starters.—The starters in use in butter making may be conveniently classified into two groups, namely:

Natural starter	Spontaneously soured whole milk Spontaneously soured skim milk Sour cream from previous churning Sour buttermilk from previous churning Sour whey	
Commercial or artificial starter	Whole milk Skim milk Condensed skim milk rediluted Skim milk powder redissolved	Soured by use of commercial culture of lactic acid bacteria

Natural Starters.—Under favorable conditions, starters belonging to this group may be used to good advantage, but as a whole they cannot be consistently recommended, as their source usually is uncertain and their purity questionable. They cannot be depended on for uniformly satisfactory results. This is especially true of sour cream, buttermilk and sour whey. If the cream of the previous churning was at all contaminated with undesirable micro-organisms, the use of such cream or of the buttermilk thereof, might easily become the very cause of the propagation of harmful germ life and the development of flavors injurious to the quality and market value of butter, and this defect would be propagated from one churning to another.

In a similar manner the use of spontaneously soured whole milk or skim milk might also prove detrimental, rather than beneficial, in most cases where the source of the raw material is unknown.

Commercial or Artificial Starters.—Commercial starters are those, in the preparation of which a commercial, so-called pure culture of lactic acid bacteria is used. The application of pure cultures of lactic acid bacteria for the ripening of cream is the result of extensive research by the eminent Danish investigator, Dr. Storch who demonstrated its value as early as 1890,[1] and later by Dr. Weigmann of Kiel, Germany.

While these commercial lactic acid cultures are frequently spoken of as pure cultures, they are generally not pure cultures; they consist more often of mixed cultures of several different species of desirable lactic acid bacteria and particularly of Streptococcus lacticus and Bacterium lactis acidi, occasionally they also contain species of yeast.

Some of the commercial lactic acid cultures are put on the market in liquid form, usually in a medium of nutrient bouillon (beef broth), whey bouillon, or sterilized milk. Others are prepared in the form of a dry powder which consists of liquid cultures to which has been added some powder, such as ground milk sugar, starch, chalk, etc., in sufficient quantities to absorb the excess moisture.

The liquid cultures have the advantage of greater purity, but must be used within a few days of their preparation. Old liquid cultures have usually lost their virulence and are worthless.

The dry or powdered cultures are commercially more practical, inasmuch as the bacteria they contain, retain their virulence for a reasonable period of time. They are therefore adapted to transportation to distant destinations. Their keeping quality is by no means unlimited, however, they cannot be held over from one season to another, but should be used within a few weeks of their preparation. They are somewhat slower in regaining their activity, than the liquid cultures and require several propagations before they can be depended on to produce a usable starter. One of the most serious disadvantages of the dry starter cultures lies in the fact that they are seldom really pure, and quite often they are seriously contaminated with other and frequently undesirable micro-organisms. The contamination is due, in part, to the bacterial impurities in their absorptive medium and partly to the often

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[1] **Eighteenth Annual Report, Danish Experiment Station, 1890.**

very careless handling in their preparation and packing at the hands of employees who fail to realize the full significance of aseptic conditions. Owing to the prevalence of these sources of contamination the use of these dry cultures occasionally becomes the cause of serious butter defects.

Classification of Commercial Starter Cultures.

Commercial starter cultures	Liquid cultures	O. Douglass, Boston, Mass.	Boston butter culture Duplex culture Lactic acid culture
		Keith, Boston, Mass.	Boston butter culture
		Elov Ericsson, St. Paul, Minn.	Ericsson's butter culture
	Dry cultures	Chris. Hansen, Little Falls, N. Y.	Lactic ferment
		Elov Ericsson, St. Paul, Minn.	Ericsson's butter culture
		Park Davis & Co., Detroit, Mich.	Flavorone
		Eli Lilly, Indianapolis, Ind.	Lactic acid culture

Mother Starter or Startoline.—In order to revive the desirable germs in the commercial starter culture and to avoid the addition of the often malodorous and stale medium of the commercial culture direct to the milk which becomes the starter, it has been found necessary to inoculate the commercial culture into a small amount of milk and make several propagations (usually two to three) before the culture is transferred to the regular starter milk. This is called the startoline or mother starter.

In order to keep the starter in uniformly active and pure condition it is necessary to propagate several jars (4 to 6) of mother starter continuously from day to day, as the conditions which are essential to preserve the starter can be more readily controlled in the case of the mother starter in small jars than in the "big" starter in the vat or starter can.

In the successful propagation of startoline, cleanliness in all operations, good quality of properly pasteurized milk or skim milk, protection from contamination after inoculation, and proper control of temperature are of the greatest importance.

Use the best milk or skim milk available; be sure that it has been thoroughly heated to at least 180 degrees F. or higher and held at that temperature at least thirty minutes. Use only jars and other apparatus such as thermometers, spoons, dippers, etc. that are perfectly clean and as nearly sterile as is possible to make and keep them under reasonably sanitary factory conditions. Do not touch with the fingers the commercial culture nor the startoline but transfer it direct from the original bottle into the jar containing the pasteurized and cooled milk. Keep the startoline jars closed, so as to guard against contamination from the dust in the air. Maintain a uniform temperature of about 65 to 75 degrees F. according to season of year. During the hot season use the lower and during the cold season the higher temperature.

Good mother starter demands systematic work and scrupulous attention to details and in order to make this possible and to economize time, some suitable equipment should be provided which is available and used for this purpose only. The following simple and inexpensive equipment has been found most serviceable for the preparation of mother starter:

Equipment for Preparation of Mother Starter.

1. One galvanized iron box for sterilizing quart jars, dippers, thermometers, spoons, etc., size preferably 13 inches long, 8½ inches wide, 8½ inches deep.

2. Twelve, one quart fruit jars with lids.

3. One insulated box, metal lined, with drain hole and insulated cover, size preferably 15 inches long, 10 in. wide, 10 in. deep.

4. One dairy thermometer with holder.

5. One dessert spoon.

6. One long handled one pint dipper with lip.

Fig. 36. Electric incubator for the preparation of startoline
Courtesy Mojonnier Bros. Co.

For creameries operating on a large scale, special incubators and other equipment, manufactured and placed on the market, with detailed directions for installation and use by reliable milk products equipment manufacturing firms greatly facilitate the work and enhance uniformity of results.

First Propagation.—Fill a clean and properly scalded quart jar two-thirds full of milk or skim milk. Pasteurize at 180° F. or above and hold for not less than 30 minutes. Time may be saved by heating the milk before the jar is filled, then fill the jar with the hot milk and set it in hot water at 180° F. for 30 minutes.

Or the startoline milk may be taken from the milk pasteurizer, held and cooled in the starter vat or starter can. Cool to 70° F. and pour the contents of the bottle containing the commercial starter culture into it, stir thoroughly and let stand at a temperature of 80° F., or according to special directions furnished by the manufacturer of the starter culture, until sour and curdled. This usually requires about 24 hours. The seal of the bottle containing the starter culture should not be broken until just before the culture is used.

Second Propagation.—Wash six one-quart fruit jars and lids thoroughly clean, rinse them and submerge them in boiling hot water, temperature 200° F. or above, in the galvanized iron box.

Pull the six quart jars out of the hot water box, scald the clean dipper by dipping it into the hot water in the galvanized iron box and fill the still hot fruit jars two-thirds full with pasteurized milk from the starter vat, and cool to 75° F. or lower according to season. Take the lids out of the hot water box and place them on the jars.

Now open the jar containing the first propagation. With the dessert spoon skim off the top inch, having first dipped the spoon into the boiling-hot water. Place the lid on this jar again and shake thoroughly to break up the curd and until the contents are smooth. Again scald the spoon in the hot water and transfer one spoonful of the startoline of the first propagation into each of the six quart jars containing the pasteurized and cooled milk for the second propagation. Seal these jars, and hold them in the insulated box at about 75° F. until sour and curdled.

Third Propagation.—The next day again prepare and scald six one-quart jars as directed under the "second propagation." Fill them with freshly pasteurized milk from the starter vat; cool to about 75° F. or below, according to season. Take their lids out of the hot water box and place them on the filled jars.

Now line up the six mother starter jars of the second propagation. Open one at a time, dip the spoon in scalding-hot water and remove the top inch of milk from each jar, dipping the spoon into hot water after skimming each jar. Seal these jars again with their respective covers and shake each jar until contents are smooth. Then taste the mother starter of each jar, using the spoon and always dipping the spoon in hot water for each jar.

Select the jar the contents of which have the cleanest and best flavor and transfer with the scalded spoon, one spoonful of its contents into each of the six jars containing the freshly pasteurized startoline milk. Seal the jars of the third propagation and place them in the insulated box. In hot weather it may be advisable to pour enough tap water (temperature 50 to 60° F.) into the insulated box to have the jars stand in about two inches, of water. This will help to control the temperature. Close the insulated box.

The next morning, examine the jars without removing their lids. If the milk in them is coagulated, place the jars immediately into the cold room, or preferably into ice water until ready to use. If the milk shows no signs of coagulation, raise the temperature to at least 75° F. and hold until coagulated; then set in cold water until ready to use. If after a few hours at 75° a satisfactory coagulum does not form, reject the contents of the jar.

Succeeding Propagations.—The succeeding propagations are made in exactly the same manner as directed for the third propagation. All the mother starter that is of good quality and that is not used for inoculation into jars is then utilized for the inoculation of the "big" starter in the starter vat or starter can.

The amount of mother starter used to inoculate fresh mother starter milk in the jars, and the temperature at which the mother starter is held, should be such that in 12 to 18 hours a nice, smooth and soft coagulum forms on the jars, without the appearance of wheyed-off water. The better, purer and more active the startoline, the less startoline need be used. One dessert spoonful per jar is ample in the case of good startoline. If the holding of the jars at 75° F. causes the curd the next morning to be too firm and possibly to whey-off and to be too high in acid, the temperature should be lowered until a temperature is found that will control the fermentation sufficiently to prevent over-ripening and yet to produce the desired coagulum. The acid in good active startoline usually is .8 to .9 per cent. It is not practical, nor feasible, to prescribe an exact temperature that would apply everywhere, and at all times of the year. The operator must use his own judgment and be guided by his results from day to day.

The directions above given for the preparation and propagation of mother starter, accompanied by proper modifications of temperature at which the jars are incubated, according to weather and factory conditions, will yield a uniformly good quality of startoline and the results can be depended on from day to day. By the above method, propagations from one and the same culture can be carried on almost indefinitely and the startoline often improves in quality and activity as the number of transfers increases. If the directions on sterilizing all apparatus are conscientiously followed, the startoline will have no gas holes. If the temperature is adjusted and controlled properly, there will always be active acid production and good body. Without these precautions, neither the startoline nor the starter can be depended on to be of good quality from day to day, and the startoline has to be renewed often by a new commercial culture.

Directions for Making Commercial Starter.

Good quality of milk, sterility of all utensils and proper temperature control are all important The absence of any one of these essentials ultimately means poor starter.

Good Quality of Milk.—Good quality of milk is all essential for good starter of a sharp, clean acid, such as is desired for the best results, although efficient pasteurization will assist in minimizing defects of the raw material. However, a really good starter cannot be made unless the milk which is used is clean and fresh. Fresh, sweet whole milk purchased direct from dairy farms on which a high standard of sanitary production prevails, generally yields the most satisfactory starter, both as to quality and economy of manufacture. Skim milk, if of good quality, is also suitable for this purpose, but often proves somewhat more expensive. Condensed milk and milk powder, though serviceable in the absence of whole milk and skim milk, are not as satisfactory media for starter making. Under favorable conditions they may yield reasonably satisfactory results, but quite often their use conveys to butter a distinct off-flavor. Skim milk powder deteriorates with age, it should therefore, be reasonably fresh when used.

Whole Milk from Farmers.—The best quality of starter milk is usually secured where the milk is delivered or shipped direct by the farmer to the factory. Every effort should be made to arrange for such milk supply direct from the farmer.

Upon arrival the milk should be graded for quality and tested for fat and with the lactometer. Milk that has an unclean flavor, or that tests more than .2% acid, or that shows a lactometer reading of less than 29 points at 60° F. should not be accepted for starter milk.

Special attention should be given the cans returned to the farmers. These cans must be free from rust. They must be washed, rinsed, steamed and dried properly, so that they are perfectly clean, dry and sweet-smelling. The farmer should not be allowed to take back buttermilk in the cans in which he furnishes the milk for starter making. If he wants buttermilk, he should use a separate set of cans for it. The cans for the sweet milk must be returned to him empty, clean and dry.

Skim Milk or Whole Milk from Milk Products Factories.—Milk or skim milk purchased from ice cream plants or other milk products factories is usually of poor quality, it is often high in acid and frequently contains undesirable off-flavors. If secured from these sources, each can should be carefully inspected and it should be clearly understood by the party selling, that milk that is stale, high in acid, off in flavor, or contains preservatives, or extraneous water, will be rejected.

The milk must be delivered in cans that are free from rust and clean. If the factory from which this milk is purchased furnishes the cans, the plant should be visited to make sure that the cans are in satisfactory condition when they are filled with the milk or skim milk.

Milk, and skim milk purchased in this manner, should be tested with the lactometer. At 60° F. normal whole milk varies between 29 and 35 lactometer degrees, and normal skim milk varies between 36 and 38 lactometer degrees. If whole milk drops below 29 and skim milk drops below 36 lactometer degrees it may reasonably be suspected that they have been watered. If whole milk rises above 35 lactometer degrees it has been skimmed. If skim milk rises above 38 lactometer degrees it has been adulterated with some foreign substance, other than water.

Condensed Milk.—If condensed milk is to be used, purchase plain condensed bulk milk, skimmed. Ask for a concentration of four to one. Dilute with three gallons of water for each gallon of condensed milk. Pour the water into the starter vat first, start the coils without heat and add the condensed milk. Mix well, and pasteurize as usual. If the condensery is not in position to furnish condensed milk with a concentration of 4:1, secure what they can furnish, and ask them for the ratio of concentration and dilute as follows for milk with different concentrations:

Concentration	Gallons Water	Gallons Condensed Milk
4 :1	3	1
$3\frac{3}{4}$:1	$2\frac{3}{4}$	1
$3\frac{1}{2}$:1	$2\frac{1}{2}$	1
$3\frac{1}{4}$:1	$2\frac{1}{4}$	1
3 :1	2	1

Skim Milk Powder.—Dissolve at the rate of one pound of powder to nine pounds of water.

Attach two small wooden slats, similar to lath, to the coil on its periphery on opposite sides. The slats should be long enough to reach from one end of the coil to the other. They will help to beat up the lumps and to mix and dissolve the powder. These slats are best fastened to the coil by means of "U" bolts. There are some vats on the market, originally intended for use in preparing the mix in ice cream factories, the coil of which is equipped with metal slats, running lengthwise. These vats are ideal for this purpose. Then pour the water, cold or luke warm, into the vat, and add the skim milk powder. Avoid pouring the powder over the sides of the vat and on the coil as it tends to stick and cake upon heating. Start revolving the coil and turn the heat on. Pasteurize as usual.

Preparation of Starter Milk.—Heat the milk, skim milk, or the diluted condensed milk, or the dissolved skim milk powder to 180° F. or higher, hold for one hour and cool to 75° F. or lower, according to season. Keep covers down while cooling. Now add the startoline. Two quarts of good startoline is sufficient for 200 gallons of milk. If the startoline is not in good active condition, larger quantities are necessary. Agitate with coil, cover down, for ten minutes. In hot weather, it may be advisable to allow a small stream of water to run through the coil in the vat or through the jacket in the starter can, over night, in order to prevent the temperature from rising too high. In this case the valve in the water pipe should be open just a "crack."

The next morning, examine the starter. With a properly scalded dipper, dip out some and test for acidity. If a nice smooth coagulum has formed and the acidity is about .8% or slightly over, cool at once to 50° F. or below and draw the starter off, adding it to the cream as needed. If the starter is not needed for several hours, but the starter vat or can must be vacated for the preparation of the next batch, draw the starter off into clean, steamed and dried shipping cans and set them in the cooler, so as to avoid further fermentation.

When the vat is empty, rinse it, wash it clean with washing powder and hot water, rinse, and steam thoroughly with cover down. Fill with new batch of starter milk, pasteurize at 180° F. or above, hold for one hour, cool to about 75° F. or lower, according to season and add startoline as directed for previous day. A good starter has an acidity of about .8 to .9%, it is clean, fairly sharp and has a smooth, soft curd that shakes down readily and that is free from gas holes.

Equipment for Making Commercial Starter:

Where only a small amount of starter is needed, the milk may be heated in ten gallon milk cans by setting the cans in a vat containing boiling hot water. For larger quantities of starter milk special equipment is desirable. The circular starter can, with the insulated water jacket on the outside and the revolving agitator on the inside, has been found very convenient for this purpose and is in general use in many creameries. The chief objection to these starter cans is that the agitation of the relatively great volume of milk is not sufficient at the periphery to keep the milk from baking onto the heating surface. This makes thorough cleaning exceedingly difficult and laborious and it invites the application of agents which remove the tin as well as the remnants of milk from the copper lining.

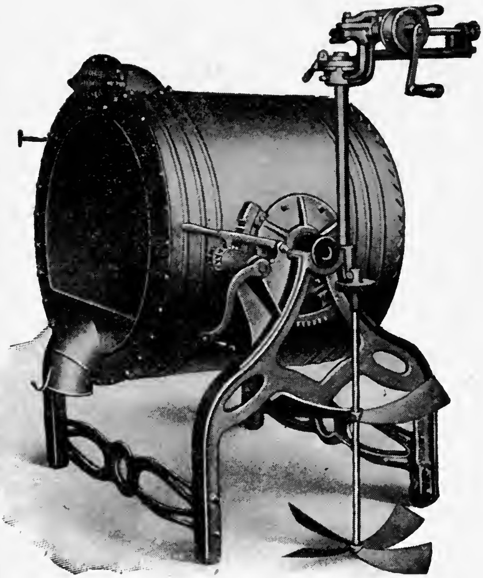

Fig. 37. Trunion starter can
Courtesy Creamery Package Mfg. Co.

For creameries with a large make the circular starter can is too small. They generally use standard cream ripening vats with disc or coil agitator and with cover, as their receptacle for starter making. Easy control of temperature is essential.

As a whole, copper-lined starter cans or starter-vats are objectionable. The tin coating on the copper soon wears off, exposing the copper surface This invites action of the acid in the starter on the copper, yielding metallic salts which are distinctly injurious to the quality of the cream and butter, enhancing decomposition which jeeopardizes the flavor and keeping quality of the butter, and leading to the development of such butter defects as metallic flavor, tallowy flavor, fishy flavor, etc. If tinned, copper-lined starter cans and vats are used, they should be retinned as soon as they show any considerable area of exposed copper. The use of glass-enameled starter vats cannot be too highly recommended as the most suitable equipment for starter making.

Fig. 38. Glass-enameled starter tank
Courtesy Elyria Enameled Products Co.

The Proper Degree of Ripeness.—At the time when the starter milk begins to be sour to the taste, but has not reached the coagulating point, it usually has a peculiarly disagreeable odor and flavor. This is explained to be due to the activity of other micro-organisms aside from the lactic acid species inoculated. Later, when the acid is more pronounced and the milk is at the point of curdling, this disagreeable flavor and aroma generally disappear, the lactic acid species of bacteria having gained the ascendancy, holding the other species in check.

If the starter were therefore used in the early stage of acid development and before the battle of species for the survival of the fittest had been decided in favor of the lactic acid organisms, the starter would fail to lend to the cream and the resulting butter the flavor for which it is used. It is important, therefore, to permit the starter to develop until the maximum number and activity of lactic acid bacteria are secured, which is the case usually at the point when the milk commences to curdle.

On the other hand, it is equally undesirable to carry the souring process too far. After the casein is coagulated the lactic acid bacteria seem to lose their maximum efficiency as acid producers, they weaken, become inactive or degenerate and permit other species to gain the ascendancy. The starter loses its fine flavor and its snap, yeasty fermentations and casein-digesting changes set in, which make the starter unfit and unsafe for use. It is generally conceded that .80 to .90 per cent acid represents the maximum acidity to which it is safe to allow starter to ripen when ordinary commercial cultures of lactic acid bacteria are used. This does not necessarily hold good with cultures of Bacillus bulgaricus. This organism is capable of developing a much higher acid without degenerating and without depreciating the aroma and flavor of the cream. Bacillus bulgaricus has not as yet been thoroughly tried out in connection with cream ripening and its desirability as a starter organism is as yet undetermined.

Amount of Starter to Use.—For directions concerning the proper amount of starter to add to cream the reader is referred to the chapter on Cream Ripening.

Scoring the Starter.—In order to express the quality of the starter, aside from the per cent of acid it contains, in more concrete terms, it is desirable to use a figure scale, or score card. This is especially desirable for the use of the student and for experimental data. The following score card is recommended for this purpose:

STARTER SCORE CARD

Name........................ Date........................

	Score		Description
	Perfect	Actual	
Aroma	20		Clean, pronounced, pleasant, no taints
Flavor	40		Clean, pronounced, snappy, free from yeasty, cheesy, curdy and other off-flavors
Body	20		Smooth, soft, creamy, no gas holes, no whey
Acid	20		.8 to .9% acid
Total	100		

CHAPTER X.

CHURNING.

Object of Churning.—The object of churning is to separate the butterfat from the caseous and serous parts of the milk or cream, to make butter. This is accomplished by the formation of butter granules.

Philosophy of Churning.—The formation of butter granules is brought about by the crystallization or solidification of the fat in the fat globules and by coalescence of the wholly or partly solidified fat globules into butter granules.

Milk and Cream an Emulsion.—In freshly drawn milk the fat is present in the form of minute globules of liquid fat. These fat globules are emulsified in a watery mixture of hydrated colloid—the skim milk. An emulsion, in this case, is a mixture of two liquids which are insoluble in each other, where one is suspended in the other in the form of minute globules. Milk then represents an emulsion of fat-in-skim milk, the fat representing the divided or dispersed phase, and the skim milk the continuous or dispersing phase of the emulsion. As long as this emulsion remains intact, there can be no formation of butter granules. Butter does not form.

The establishment of this emulsion of fat-in-skim milk is the direct result of the process of milk secretion. When milk is secreted, nature places the fat, which is liberated by the metabolic activity of the cells which line the alveoli, into the skim milk in the form of very finely divided particles.

Fischer and Hooker[1] who made an extensive study of fatty secretions and fatty emulsions, considering the phenomena of milk secretion from the standpoint of the pathologist, speak of the secretion of butterfat as a fatty degeneration of the cells in the alveoli. "The originally cubical cells which make up the alveoli of an active mammary gland become richer in water and filled with granules (cloudy swelling), while the fat in the cells runs together into more readily visible droplets (fatty degeneration). When this process of cloudy swelling with fat

[1] Martin H. Fischer and Marion O. Hooker, Fats and Fatty Degeneration, 1917.

Fat Globules in Milk, Cream, Skimmilk and Buttermilk
Magnification 740.

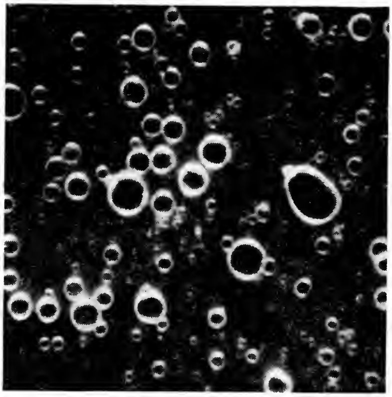

Fig. 39. Milk

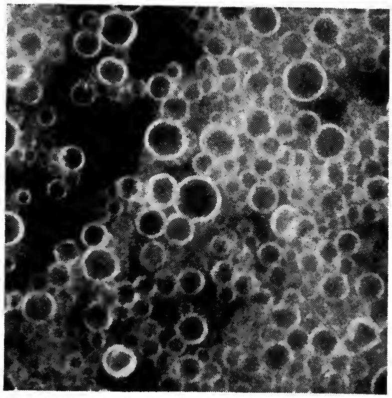

Fig. 40. Cream

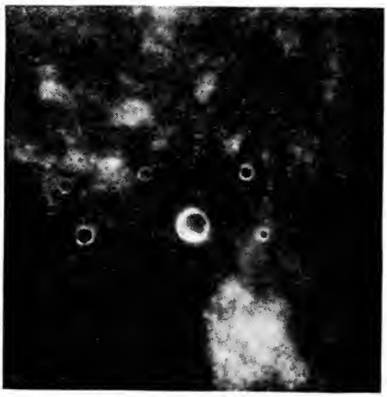

Fig. 41. Skim milk

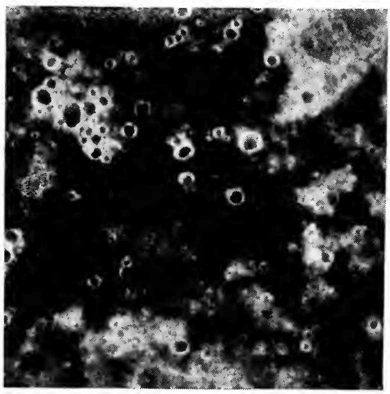

Fig. 42. Buttermilk

coalescence becomes sufficiently great, the cell bursts and a fluid mixture of hydrated colloid (meaning the skim milk), containing the fat globules, results. This is milk."

It is obvious from the above discussion that the fine division and uniform distribution of the fat in the milk, or the fat-in-skim milk emulsion, is the handiwork of nature. In this finely divided state the fat is most accessible to the digestive juices, facilitating digestion by the young, who depend on milk as their exclusive food and whose delicate digestive organs are not prepared to deal with solid masses of fat.

Permanency of Fat-in-Skimmilk Emulsion.—This emulsion, established by the secretion of the milk, is fairly permanent. The question here consistently arises: What causes these fat globules to remain divided, what hinders them from running together like oil?

Earlier investigators claimed that each fat globule was surrounded by a definite membrane. This was a mere assumption which proved erroneous. The presence of such a membrane has never been satisfactorily established. Later study failed to demonstrate its existence and yielded substantial evidence that such a membrane does not exist. The only envelope that surrounds the fat globules in milk is the skim milk in which they are suspended.

The forces that make it possible for the minute fat globules to retain their identity as single units and that prevent them from running together, are the difference in the surface tension between the fat globules and the skim milk, adsorption and the viscosity of the milk.

Surface Tension.—The fat globules stay apart, they retain their individuality, they do not run together, primarily because of the law of surface tension. By surface tension is understood the attraction which the molecules of one and the same substance have for each other. The molecules which are located in the surface of a liquid, are attracted toward the interior of the liquid by the molecules situated there, but there is no similar attraction towards the exterior, because the molecules in the interior of a liquid are subject to attraction from all sides. The tension thus produced on the surface by this molecular attraction towards the interior is called the surface tension. It obviously conveys to the surface the tendency to become reduced to the smallest possible dimensions. Hence, if a liquid is placed in a position, where it is not affected by gravity, the form of the liquid changes until it assumes the smallest possible surface for a given volume. And this is the sphere.

In the case of milk, in the secretion of which nature has placed the fat in finely divided particles, the fat possesses a greater surface tension than the surrounding skim milk. The minute units of fat, therefore, retain their identity and individuality and, because of the surface tension, they are present in the form of round globules.

Adsorption and Viscosity.—The ability of the fat globules in milk and cream, to retain their individuality is further assisted by the law of adsorption and by the viscosity of the milk.

By adsorption, in the sense here used, is meant the somewhat greater concentration in the surface layer of the fat globules of the skim milk, than the concentration of the remainder of the surrounding skim milk. This concentration of the skim milk on the surface layer of the fat globules assists in maintaining their internal cohesion and in diminishing the power of adhesion between fat globules. It tends to convey to the individual fat globules greater stability.

Finally, the permanency of the emulsion of the fat globules in milk is enhanced by the natural viscosity of the skim milk, caused by the presence of such colloids as albumen and casein, and of milk sugar.

Effect of Cream Separation.—When cream is separated these phenomena do not materially change, they remain fundamentally the same. Cream still represents an emulsion of fat-in-skim milk. The composition of the non-fatty serum in cream is similar to that of milk and the difference in the surface tension between the fat globules and the cream serum remains the same. There is merely a larger aggregation of fat globules in a smaller volume of skim milk.

Effect of Cooling of Cream.—When cream is cooled, preparatory to churning, the fat in the fat globules wholly or partly solidifies. This enhances the internal power of cohesion in the fat globules and increases the power of adhesion between fat globules, offsetting and completely overcoming the effect of the surface tension of the fat globules. If cream were not cooled sufficiently to partly or wholly solidify the fat, the churning would result in a finer division of the fat globules.

Effect of Agitation in Churn.—When this cooled cream, with the partly, or wholly solidified fat globules is subsequently subjected to the agitation and concussion generated in the revolving churn, the increased power of adhesion enables the partly or wholly solidified fat globules to unite, forming butter granules.

Increase in Size of Butter Granules.—This union of fat globules and formation of butter granules proceeds in geometric progression. While it commences as soon as the churn starts revolving, the process of uniting at first is slow and the change is imperceptible. The minute size of the fat globules retards their opportunity for collision with and adhesion to one-another and the butter granules resulting from these early adhesions are microscopic in size. The average fat globule measures about 3/1000 of one millimeter or about 1/10,000 of one inch in diameter. The sum of two fat globules forming one butter granule, therefore, also is extremely small. But, as the churning process progresses, the butter granules form more rapidly and grow in size more rapidly. The larger they grow the more rapidly they increase in size with each successive adhesion.

Why Cream Thickens in the Churn.—As the churning process proceeds, the cream begins to thicken and continues to thicken, until it assumes marked rigidity, practically assuming maintenance of form. This thickening is due in part to the increased size of the still microscopic or semi-microscopic butter granules. These larger granules offer more internal friction and hold the serum in a mash-like emulsion. Up to a certain point, the larger these microscopic granules the thicker and more rigid the cream.

The thickening of the cream during the early part of the churning process is also due, in a large measure, to the profuse incorporation of air in this viscous, cold cream. The cream whips. The air so incorporated and the rigid character of the cream which the minutely divided air helps to bring about, have a very marked retarding effect on the churning process, greatly minimizing the concussion to which the fat globules are subjected, and making it difficult for them to find each other and to strike each other with sufficient force to coalesce to one another. If it were not for the obstructing presence in the cream of this air, cream would churn more rapidly. It is obvious that in a vacuum, or under reduced pressure, the churning process would occupy much less time.

Since it is during the churning process and not during the working process, that the bulk of the air found in the finished butter, is incorporated, and since the presence of air in butter represents an active agent of butter-deterioration, churning in vacuo, aside from grealy reducing the churning period and increasing the capacity of the creamery, would tend to exert a markedly favorable effect on the keeping quality of the butter.

Under certain conditions, which render cream excessively viscous, such as is the case in cream from stripper cows, or very cold cream, or cream that has undergone ropy-milk fermentation, the churning process is very much prolonged and frequently it does not reach the breaking point at all, because of the air-holding and whipping properties of the abnormal viscosity of such cream. For this same reason, any agency, or condition that reduces the viscosity, hastens the churning process. Thus, sour cream churns more quickly than sweet cream, the acid destroying the viscosity and the whipping power of the cream. Cream from cows which have been in milk for a short time only churns more rapidly than cream from stripper cows, because the former is more fluid and less viscous. At a high churning temperature, provided that the temperature remains below the melting point of fat, cream churns quicker than at a low temperature, because a rise in the temperature increases the fluidity of the cream.

In this stiff and rigid cream the emulsion of fat-in-skim milk is still intact.

Why Butter "Breaks" Suddenly.—As the butter granules become larger in size in the thickened cream, a point is reached, where the surface of the butter granules becomes so small in proportion to their cubic contents, that the fat-in-skim milk emulsion can no longer be sustained, the emulsion is broken.

The skim milk (now called buttermilk), in excess of that portion that is incorporated in, or adheres to, the surface of the butter granules, recedes and "wheys off," the butter granules separate out, and the butter "breaks." This point is reached after the majority of the butter granules have outgrown their original microscopic size and have become large enough to be readily visible to the naked eye.

Fig. 43. Water droplets in butter, magnification 740

With the "breaking" of the butter, the emulsion changes from a fat-in-skim milk emulsion as represented by the cream, to a buttermilk-in-fat emulsion, as is represented by the butter. The fat globules cease to exist as units. Butter is a mass of butterfat into which have been emulsified small divided units, or droplets, of buttermilk. Butter represents an emulsion in which the fat is the continuous phase and the hydrated colloid or buttermilk the divided or dispersed phase.

While, under normal conditions of churning, the churning process occupies from about 40 to 60 minutes, the actual "breaking" of butter happens with almost instantaneous suddenness.

The reason for this is obvious. As previously explained, the increase in the size of the butter granules during the early stages of the churning process is slow, due to the small initial size of the fat globules and to the obstructing foam. Numerous progressive steps of adhesion between fat globules and later between butter granules are necessary before the breaking point is reached. This requires time, and yet, during all this time there is no visible sign of butter formation.

Just before the breaking point the contents of the churn are still cream. But the butter granules, though still invisible to the naked eye, have reached the maximum size at which their reduced surfaces are still capable of sustaining their emulsion with the skim milk in the form of cream. One more union between each two of these relatively large butter granules, causing the granules to be twice of this already relatively large size, may break the emulsion, the resulting granules being too large and their surfaces too small to still sustain their emulsion in the skim milk of the cream. The result is that the skim milk immediately breaks away from the butter granules and the butter "breaks," and we have masses of butter granules on the one hand and buttermilk on the other.

The suddenness of the "breaking of the butter is further intensified by the fact, that the relatively large size of the still emulsified butter granules in the cream just before the breaking point, facilitates the coalescence, or adhesion, of these granules in the cream. The larger the granules before the breaking point, the more easily they find each other, the more readily they collide, and the accelerated force of impact between these larger granules increases their power of adhesion. When they collide they stick together. Simultaneous with the break of the tension of the fat-in-skim milk emulsion, much of the incorporated air also is liberated, further quickening the breaking of the emulsion. Hence, when this critical point is reached, one or a few more revolutions of the churn suddenly transforms the emulsion of cream into solid butter and fluid buttermilk. The butter "breaks" abruptly.

The foregoing discussion makes it clear that the churning process resolves itself into a change from a fat-in-skim milk emulsion, such as exists in milk and cream, into a buttermilk-in-fat emulsion, such as exists in butter. This transformation of emulsions, or of cream into butter, is brought about fundamentally by solidification of the fat globules and by subsequent coalescence of the solidified fat globules, forming butter granules, and by progresive adhesion or uniting of the butter granules.

Solidification.—The solidification of the fat globules is caused by low temperature and concussion.

The solidifying point of butterfat, like the melting point, is not constant. It varies particularly with the chemical composition of the butterfat. Thus the fats of the harder glycerides, such as the myristin, stearin and palmitin, have a higher solidifying point than the fats of the softer glycerides, such as the fats of the volatile fatty acids and the olein. Hence the solidifying point fluctuates according to the relative proportion of these several fats in the mixed fat.

At the temperature of the animal body, 98° to 100° F., butterfat is liquid. At ordinary temperatures (room temperature) butterfat contains both solid and liquid elements. By lowering the temperature, fractional crystallization of the butterfat is effected, the harder glycerides crystallizing first. As the temperature drops, more of the softer glycerides begin to crystallize. The extreme range of the solidifying point of the mixed butterfat lies between about 15.5 degrees C. to 30 degrees C. (60 to 80 degrees F.) Under normal conditions the range of temperature is confined to much narrower limits, not falling below about 18 degrees C. nor exceeding 24 degrees C. (65 to 75 degrees F.) and averaging about 21 degrees C. (70 degrees F.).

In order for the fat globules to form butter granules, it is necessary therefore, to lower the temperature of the cream sufficiently to insure solidification of the fat in the fat globules. The reason why the churning temperature of the cream must be dropped below the minimum temperature at which the mixed fat solidifies, must be attributed in part at least to the fact, that mere solidification, while it causes the cream to churn, does not necessarily give the butter granules the desired firmness. Lower temperatures are needed to render the butter granules sufficiently firm to insure exhaustive churning and to produce butter with good body, and free from leakiness and excessive moisture.

Recent experiments by Hunziker and Hosman have revealed the fact that mixed butterfat has more than one solidifying point. It appears that even in the cooling of the cream the mixed butterfat does not solidify all at one temperature, but that fractional solidification takes place, the high melting-point fats solidifying first. These findings further explain why it is necessary to cool the cream to a temperature materially below that of the solidifying point of the mixed butterfat, if a firm bodied butter is to be secured. The temperature must be low enough to also cause the solidification of the lower-melting point fats, particularly the olein. In fact it is at this point, it is in the cream vat, that the body of the butter is determined. If the cream has never been exposed to a temperature low enough to solidify all the butterfat, the butter tends to have a weak and slushy body that does not stand up well under unfavorable temperature conditions. In a warm room it is prone to soften quickly, because some of its fat constituents have not been properly solidified, they still are in fluid, or semi-fluid, condition and cause the butter to become soft and lose its shape even at temperatures below the melting-point of butter. On the other hand, if the cream, at least once between the processes of pasteurization and of churning, has been cooled sufficiently to completely solidify all the butterfat, the butter made from such cream will have a good body that will hold up well, even under unfavorable temperature conditions. In this case the butter has to be warmed to near the melting point, before it will show signs of appreciable softening. And even a considerable rise in the churning temperature of such cream above that desired will not materially reduce the firmness and standing-up properties of the butter made therefrom.

Aside from the churning temperature the solidification of the fat globules is enhanced by subjecting them to vigorous concussion. The agitation which the cream receives in the churn, furnishes this concussion and therefore further hastens the solidification of the fat globules.

Coalescence.—Coalescence is the second necessary factor for the formation of butter granules By coalescence is meant the uniting and adhering together of the fat globules and butter granules. The power of the fat globules to coalesce is largely determined by the extent of solidification and the amount of concussion. It is also affected by the size of the fat globules, by adsorption and by the viscosity of the cream.

In liquid form the fat globules cannot coalesce to the extent of forming butter granules. In warm cream set at rest they may run together, "oiling off" and forming a continuous layer of oil. In cream at any temperature not low enough to cause solidification or partial solidification of the fat, when subjected to agitation such as is produced in the revolving churn, the fat globules, instead of coalescing tend to diminish in size, due to the effect of their surface tension, adsorption and the viscosity of the cream. For this reason cream does not churn out, and butter granules do not form when the temperature is too high to effect at least partial solidification.

On the other hand, coalescence and the formation of butter granules is greatly delayed, if not made impossible, when the degree of solidification has been carried so far, as to cause the fat globules and the small butter granules to be very hard. In this case the adhesive property, or stickiness, of the fat globules and of the initial butter granules is greatly reduced, the impression which they suffer when they collide is very slight, the surface of contact is therefore too small and the individual globules and granules are too firm to readily adhere to each other when they collide. For this reason, cream that is churned at an extremely low temperature, or that has been held at a very low temperature for a long time before churning, or the fat of which has a relatively high melting point, churns with great difficulty.

In order to give the fat globules an opportunity to coalesce they must be subjected to concussion. This is obviously produced by the operation of the churn. The more vigorous the concussion, other things being equal, the greater their power to coalesce and the more rapidly is the churning completed.

Other conditions being the same, the time required for the butter granules to form is determined by the size of the fat globules and by the viscosity of the cream. The larger the fat globules the more rapid the formation of the butter granules[1]. The effect of the concussion and the ease of coalescence are intensified in the case of the large globules, because they strike each other and the sides of the churn oftener and with greater force than do the small globules.

The viscosity of the cream diminishes the force of the concussion. It obstructs the frequency of the collisions between globules and detracts from the force of the impact when they do collide, lessening their power of adhesion.

Conditions which Affect the Churnability of Cream and the Mechanical Firmness of Butter.—The ease with which cream churns is dependent on many and varying factors, some of these factors have to do with the initial character of the cream as it arrives at the factory, while others refer to conditions of the process of manufacture. To the former group may be classed the size of the fat globules, the chemical composition of the butterfat and the viscosity of the cream. The second group includes such factors as temperature of cream, degree of ripeness, richness of cream, nature of agitation, fullness of churn, speed of churn.

The following schematic classification may serve to illustrate the numerous factors which enter into the churnability of cream, and to clarify their logical relation to each other:

[1] Hunziker, Mills and Spitzer, Purdue Bulletin No. 159, 1912, p. 325.

Classification of Essential Conditions Influencing the Churnability of Cream

The churning process, or the formation of butter granules, depends on

- Solidification of fat. This is influenced by
  - Melting point of butterfat
    - Chemical composition of butterfat
      - Breed
      - Period of lactation
      - Feed
  - Temperature of butterfat
    - Churning temperature
    - Time held at churning temperature
  - Size of fat globules
    - Breed
    - Period of lactation
      - Locality
      - Season of year
  - Concussion of cream
    - Agitation
      - Fullness of churn
      - Speed of churn
    - Viscosity of cream
      - Period of lactation
      - Acidity
    - Richness of cream
- Coalescence of fat globules. This is influenced by
  - Mechanical firmness of fat
    - Melting point
      - Chemical composition of butterfat
    - Size of fat globules
      - Breed
      - Period of lactation
  - Size of fat globules
    - Breed
    - Period of lactation
      - Locality
      - Season of year
  - Concussion of cream
    - Agitation
      - Fullness of churn
      - Speed of churn
    - Viscosity of cream
      - Period of lactation
      - Acidity
    - Richness of cream

Size of Fat Globules.—Cream in which the small fat globules greatly predominate churns with difficulty while cream with large average globules churns quickly. As previously stated the formation of butter granules is dependent in part on the coalescence of the fat globules. In order for the fat globules to coalesce, the fat must be partly or wholly solidified. For the solidification of the fat it is necessary that the physical equilibrium of the fat globules be disturbed and partly destroyed. Other things being the same, the chief factor keeping the fat globules intact is the surface tension. The forces which overcome and partly destroy the effect of the surface tension are greater in their effect on the large globules than on the small globules, the equilibrium of the large globules is more easily disturbed. Therefore they solidify more readily and coalesce more quickly. Again, the effect of the concussion in the churn, and the ease of coalescence are intensified in the case of the large globules, because they strike each other and the sides of the churn oftener and with greater force than do the small globules.

This is one of the reasons why milk from stripper cows in which the fat globules are usually relatively small, often churns with great difficulty. And since, in winter, the great majority of the cows supplying the creamery are well advanced in their period of lactation, it is in winter that the majority of the churning difficulties occur. The diameter of the fat globules in stripper milk averages about one-third of that of the fat globules of milk from cows during the first two to three months of lactation.

The size of the fat globules is also very materially affected by breed, the fat globules in milk of the Channel Island cows averaging much larger than those of the Holsteins and Ayrshires. This explains in part, why cream churned on the farm and produced exclusively from Holsteins and Ayrshires, at a time when the cows approach the end of their period of lactation, often churns with great difficulty. In the creamery the factor of breed of cows is of much less importance. As the cream supply territory of most creameries embraces a varied mixture of the several breeds and grades of dairy cattle, the danger of churning difficulties due to effect of breed on the size of the fat globules, is a negative quantity.

Chemical Properties of the Butterfat.—The chemical make-up of the butterfat influences its churnability largely through its effect on the melting point and mechanical firmness of the fat. While the desired degree of solidification of the fat globules is chiefly a matter of temperature adjustment of the cream before churning, it is very materially influenced by the chemical composition of the fat. Butterfat is a mixture of fats with different melting points, different solidifying points and of varying mechanical firmness.

Experimental results by the author[1] and others show that, while there appears to be no definite relation between the per cent of volatile acids, as arbitrarily expressed by the Reichert-Meissl number, and the per cent of oleic acid, as expressed by the Iodine number, and the melting point, and while the relative proportion of soluble acids exclusive of butyric and that of insoluble acids exclusive of oleic acid is evidently an important factor related to the melting point, it appears reasonable to conclude, that the volatile acids and the oleic acid do influence the melting point to a very marked degree and that there is a strong tendency for the melting point to follow, inversely, changes in the per cent oleic acid and volatile fatty acids.

Since the volatile fatty acids have a much lower melting point than the oleic acid, it is obvious that variations in the amount of the former, present in the butterfat, exert the greater influence on the melting-point of the fat. However, the volatile fatty acids are present in relatively small amounts and their changes, expressed in percentage of the total fat, are usually slight. Oleic acid, on the other hand, constitutes a large portion of the total butterfat and it often varies between wide limits (35 to 50%). Hence the fluctuations in the amount of oleic acid present are looked upon as, and have been found to be, responsible for, in a large measure, variations in the melting point.

Butterfat in which the fats with high melting points and great firmness are present in excess and at the expense of the fats with low melting points and soft texture, churns relatively slowly. The fat globules solidify at a relatively high temperature, and unless the churning temperature has been correspondingly raised, they are prone to become excessively firm, their

[1] Hunziker, Spitzer and Mills, Purdue Bulletin No. 159, 1912.

power of coalescence is greatly reduced and the formation of butter granules is retarded. When cream containing butterfat of this character is held at a low temperature for a considerable length of time and is churned at that low temperature, the difficulty of churning becomes very marked and the churning process may require several hours. On the other hand, in the case of cream containing butterfat which is made up of a relatively large portion of fats with a low melting point and has a soft texture, the cream will churn quickly because the coalescence of the soft fat globules is facilitated.

Individuality, breed, age and length of milking period exert some influence on the melting point and mechanical texture of the fat. Thus the Channel Island cows produce butterfat with a higher melting point and of firmer texture than the Holsteins and Ayrshires. Quite often cows which have been in milk for an abnormal length of time produce a very firm butterfat that churns with great difficulty. But these factors must be considered rather incidental and of material influence only in the case of butter that is made on the farm and from a small number of cows.

The most important and decisive factor affecting the chemical composition, melting point and mechanical texture of the fat and the churnability of the cream is the feed. Experimental investigations[1] have conclusively brought out the following facts with reference to the influence of different feeds on the melting point and mechanical firmness of the butterfat:

Feeds which increase the per cent of olein usually tend to make a soft butter. To these belong feeds rich in vegetable oils, such as germ oil, corn oil, linseed oil, linseed meal rich in fat, cottonseed oil, soya bean oil, soya bean meal, gluten feeds rich in fat when fed in large quantities and blue grass pasture.

Feeds which decrease the per cent of olein, such as feeds low in vegetable oils, and rich in carbohydrates and sugars, tend to make a firm butter. To these belong potatoes, corn meal, corn silage, sweet corn fodder, wheat bran, sugar beets, etc. Cottonseed meal also tends to make a firm and crumbly butter.

It is obvious from the above results, that in winter, when the cows are on dry feed and especially if the grain ration con-

[1] Hunziker, Spitzer and Mills. Purdue Bulletin No. 159, 1912.

tains bran and cottonseed meal, the butterfat is prone to be relatively firm and the fat globules are slow in uniting into butter granules. This condition is further intensified by the fact that the fat globules in winter cream are relatively small and the cream is often of viscous nature due to the advanced state of the period of lactation of the majority of the cows. Where butter is made on the farm and the buttermaker therefore has the feeding under his control, the addition to the ration of some concentrate rich in vegetable oil, such as linseed meal, or gluten feed, will help to overcome churning difficulties. In summer when the cows are on succulent pasture, which tends to lower the melting point of the fat and frequently causes the butter to come too quickly and in soft and slushy condition, the difficulty may be avoided by feeding a small amount of dry hay if available, or cottonseed meal, or other feed producing hard fat. In the creamery, where the buttermaker has no control of the feeding, the difficulty can best be overcome by adjusting the churning temperature so as to make the butter come moderately firm. In summer the chief remedy against too rapid formation of the butter granules and the production of an excessively soft and slushy butter lies in the proper lowering of the churning temperature.

Viscosity of Cream.—The more viscous the cream the more time is required to complete the churning. The viscosity of the cream counteracts to a considerable extent the concussion to which the fat globules must be subjected, in order to make possible their coalescence. In very viscous cream the fat globules strike each other less readily and with less force than in cream free from abnormal viscosity. The churning difficulty is further greatly intensified by the obstructing effect of the great volume of air which is beaten into and held by this viscous cream.

Abnormal viscosity of cream is often due to its peculiar chemical properties. Cream from stripper cows and cows which have been in milk for a prolonged period is prone to show pronounced viscosity and often churns with great difficulty. This is especially true with certain individual cows. Such cream usually contains a relatively high per cent of solids not fat, and these solids, especially the proteids, may be of abnormally viscous character.

The viscosity is frequently also brought about, or intensified, by abnormal fermentations which break down a portion of the proteids. Excessively low temperature and churning the cream sweet, are additional conditions which tend toward churning difficulties by intensifying the viscosity and the resulting frothing in the churn.

The viscosity may be materially reduced by properly ripening the cream and by raising the churning temperature, also by adding a small amount of salt to the cream.

Churning Temperature.—The churning temperature is one of the most important factors governing the churnability of the cream. Other conditions being the same, and within reasonable limits, the higher the churning temperature, the more rapidly do the butter granules form and the shorter is the churning process; the lower the temperature the more time is required to complete the churning.

Excessively high churning temperatures are very undesirable, because they are injurious to the texture and quality of the butter. Butter made under such conditions is prone to have a greasy texture and a poor, weak, slushy and leaky body. Such butter does not stand up well on the market and readily develops off-flavors. This is especially true with cream with a relatively high per cent of fat. Cream with a low fat content can be churned at relatively higher temperatures without danger of serious injury to the body of the butter. High churning temperatures are also prone to cause overchurning. The fat globules unite so rapidly that the churn usually is not stopped soon enough, so that the coalescence has gone far beyond the granular stage, large lumps of butter having been formed. Churning at too high temperatures further causes excessive loss of fat in the buttermilk. This is due to the great rapidity with which the large globules coalesce and the shortness of the churning period, giving the small globules insufficient opportunity to become properly incorporated in the butter granules.

High churning temperatures in early summer, when the butterfat naturally has a low melting point, and is relatively soft because of access of the cows to green pasture, tends to produce butter high in moisture and there is danger of violating the 16 per cent moisture limit. When butter contains too much moisture as the result of churning at too high a temperature, it is often difficult to correct the error. The fat in this condition is so soft that it is exceedingly miscible with water and the water is very finely distributed throughout the butter and thoroughly incorporated. For correction of this defect see chapter on Moisture Control.

High churning temperatures under certain conditions are also prone to produce a slushy and very leaky butter. This is especially the case in fall, winter and early spring, when the melting point of the butterfat is relatively high and the higher churning temperature does not very greatly increase the miscibility of the butterfat, but reduces the emulsifying power of the protein substances in butter.

Too low a churning temperature is undesirable because it greatly prolongs the churning process. This is due partly to excessive solidification of the fat in the fat globules. The fat globules become so firm that their power to coalesce and to form butter granules is greatly reduced. The difficulty of churning is further augmented by the increase of the viscosity of this cold cream, which lessens the concussion, and by the churning of cream with a very low butterfat content which hinders the fat globules from uniting into granules, because of the large amount of intervening serum. When churned at abnormally low temperatures the butter appears in the form of very firm, small, round granules which make the proper and uniform incorporation of the salt difficult and which hinder the control of moisture and overrun. Such butter is prone to be low in moisture and to cause a correspondingly low overrun. In order to get the salt properly incorporated there is danger of overworking it and of giving the butter a salvy body. Of the two extremes, too high and too low temperatures, the former, too high a temperature, however, is the most harmful to the quality of the butter.

As previously shown, the churning temperature must be governed by and adjusted according to the degree of firmness of the fat in the cream and this in turn will vary with locality and season of year.

The locality largely determines the breed of dairy cows and the feed; while the season has to do with the period of lactation and feed.

Table 43.—Showing Effect of Breed on Mechanical Firmness of Butter and Relation of Mechanical Firmness to Butter Fat Constants.[1]

Breed	No. of Cows	Reichert-Meissl No.	Iodine Number	Melting Point	Depression mm.
Ayrshire ..	3	27.84	35.64	34.1	16.83
Holstein ..	3	27.56	37.10	34.3	4.88
Jersey	18	31.12	29.10	34.5	1.83

The above table shows that the fat from Holsteins and Ayrshires contains a greater proportion of the softer fats (olein) as expressed by the Iodine number and makes a much softer butter than the fat from the Jerseys. In localities, therefore, where the Holsteins and Ayrshires predominate, lower churning temperatures should be used than in exclusive Jersey territory

In the southern states where, because of the great availability and cheapness, cottonseed meal is fed in relatively large quantities, higher churning temperatures must be used than in the northern sections where gluten feed and linseed meal are a prominent part of the grain ration. In fact, in certain sections of the South it is necessary to raise the churning temperature to as high as 72° F. in order to complete the churning process in a reasonable length of time and to secure butter with a body sufficiently soft for proper handling.

With reference to the season of the year the fact is well known that in winter higher churning temperatures must be used than in summer, in order to complete the churning process without undue delay and to produce a butter that is not too firm. The fat in winter milk is usually of a firmer character than that of summer milk.

That this condition is largely due to the change of the chemical properties of the butterfat with the change of the season, is shown in the following table which represents analyses

[1] Hunziker, Mills and Spitzer, Purdue Bulletin No. 159, 1912.

Table 44.—Effect of the Season of the Year on the Composition of Butter Fat of Creamery Butter.[1]

	Reichert-Meissl Number	Iodine Number	Melting Point ° C.
January	30.03	31.20	33.4 ° C.
February	30.58	31.97	33.5 ° C.
March	31.30	31.94	33.5 ° C.
April	29.35	35.83	33.3 ° C.
May	29.55	36.48	32.5 ° C.
June	29.56	38.23	32.45° C.
July	28.90	37.10	31.9 ° C.
August	27.13	38.99	32.1 ° C.
September	27.19	35.36	33.0 ° C.
October	26.54	34.27	33.2 ° C.
November	28.36	30.65	33.4 ° C.
December	29.62	30.30	33.6 ° C.

of butterfat of butter made in the Purdue University Creamery during the twelve months of the year.

The above table shows that during the winter months the melting point of the butterfat is highest, causing a relatively firm butter while in summer it is lowest causing a soft butter. The reason for the higher melting point in winter and the lower melting point in summer is obviously largely due to the decrease in winter and increase in summer, of the per cent of olein as expressed by the Iodine number and of the volatile fatty acids expressed by the Reichert Meissl number. The greater firmness of the winter butter has been attributed by some writers to the effect of the period of lactation. Since the majority of the cows approach the end of their lactation period in winter it was assumed that stripper cows produce fat with less olein, a higher melting point and a higher degree of hardness than fresh cows. This is erroneous and not substantiated by facts as shown in below experimental results. In the experiment referred to in table on next page the cows received the same feed ration throughout the year.

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[1] Hunziker, Mills and Spitzer, Moisture Control, Factors not under Control of the Buttermaker, Purdue Bulletin 159, 1912.

Table 45.—Effect of Period of Lactation on Butter Fat Constants.[1]

Period	Reichert-Meissl No.	Soluble Acids Per Cent	Insoluble Acids Per Cent	Iodine Number	Melting Point
1st month.	34.55	7.80	87.01	32.08	35.2
2nd month.	32.62	7.50	87.37	32.15	35.2
3rd month.	31.57	7.34	87.45	31.67	35.4
4th month.	31.89	7.34	87.34	32.00	35.2
5th month.	31.59	7.24	87.41	32.30	34.7
6th month.	31.39	7.19	87.57	32.78	34.1
7th month.	30.39	6.97	87.70	34.74	34.5
8th month.	28.48	6.55	88.00	35.90	34.7
9th month.	28.72	6.56	88.00	35.23	34.7
10th month	29.72	6.69	87.78	33.72	34.0

The above figures clearly indicate that, while the volatile fats as expressed by the Reichert-Meissl number, decrease, the olein as expressed by the Iodine number increases and the melting point drops, reducing the degree of firmness of the fat as the period of lactation advances. This condition may, however, in part, be offset by the reduction of the size of the fat globules with the advancement of the period of lactation as shown in the following table:

Effect of Breed and Period of Lactation on the Size of the Globules.[1]

Month of Period of Lactation	Breeds of Dairy Cows					
	Jersey 25 Cows	Guernsey 20 Cows	Holstein 9 Cows	Ayrshire 33 Cows	Holderness 20 Cows	Devon 16 Cows
1st month......	1104	928		687		546
2nd month.....	1098	1063	640	580	661	585
3rd month......	1228	954	576	624	607	450
4th month......	1097	659	256	426	501	547
5th month......	1149	839	396	384	397	319
6th month......	846	737	595	399	324	355
7th month......	1017	584	340	322	329	270
8th month......	733	568	310	298	379	200
9th month......	715	408	384	241	315	250
10th month.....	571	426	284	248	336	228
Ave. for year..	955.8	716.6	420.1	420.9	427.6	375

[1] Hunziker, Mills and Spitzer, Moisture Control, Factors not under Control of the Buttermaker, Purdue Bulletin 159, 1912.

The chief cause of the change from the relatively soft butter in summer to firm butter in winter is unmistakeably the change from green pasture to dry feed. This is most conclusively brought out in the following table:

Table 47.—Effect of Dry Feed versus Blue Grass Pasture on Mechanical Firmness of Butter and Its Relation to the Butter Fat Constants.[1]

May	Reichert-Meissl Number	Iodine Number	Melting Point	Average Volume Fat Globules	Depression mm.
8-14 Dry feed	30.24	29.97	34.5	39.48	.655
	30.47	29.51	34.5	40.00	.500
	30.56	29.34	34.3	45.11	.540
	30.40	29.11	34.5	48.44	.580
	30.14	28.67	34.3	61.49	.580
	30.15	29.50	34.4	49.31	1.040
	30.00	29.00	34.3	51.01	1.000
Average	30.28	29.30	34.4	47.83	.701
15-21 Dry feed plus one to two hours pasture daily	30.85	29.11	34.3	52.02	1.000
	30.77	29.33	34.4	51.92	1.080
	31.03	29.55	34.2	50.59	.955
	30.86	30.05	34.4	54.93	1.580
	31.20	30.36	34.3	75.62	1.665
	30.62	31.84	34.2	70.64	1.415
	30.93	33.12	33.8	76.01	3.080
Average	30.89	30.48	34.2	61.68	1.539
22-28 Pasture exclusively	29.96	33.51	33.5	76.04	4.165
	28.83	36.43	33.5	82.87	8.580
	28.66	38.06	33.4	93.83	3.915
	28.87	38.86	33.6	67.32	5.915
	27.57	38.97	33.2	60.60	6.832
	29.65	38.92	32.9	55.55	7.705
	28.59	39.36	33.1	62.12	5.830
Average	28.87	37.73	33.3	71.19	6.135

In Table 47 is shown the relation of the mechanical firmness to the moisture content of butter, average volume of fat globules and butter fat constants, as affected by the change from dry feed to blue grass pasture.

[1] Hunziker, Mills and Spitzer, Moisture Control of Butter, Factors not under Control of the Buttermaker, Purdue Bulletin 159, 1912.

The increase of the depression was accompanied by an increase of the moisture content of the butter, of the average volume of the fat globules and of the per cent. olein and by a decrease of the volatile acids and a drop of the melting point. The effect of the decrease of the volatile acids was again off-set and overcome by the marked increase of the per cent. olein. This in turn lowered the melting point 1.1 degrees and yielded the softer butter. The increase in the depression of butter may also have been accelerated by the decided increase of the average size of the fat globules.

The depression in millimeters indicates the mechanical firmness of the butter. The mechanical firmness of butter was determined by measuring the degree of depression under a given weight for a given time. The mechanical firmness is expressed in millimeter depression.

On the basis of these facts the churning temperature may vary within wide limits, possibly from 42 to 75 degrees F. In the northern and central tier of the dairy belt and under fairly normal conditions the variations of the proper churning temperature are confined to within much narrower limits, ranging in summer between about 48 and 53 degrees F. and in winter between about 55 and 60 degrees F.

In order to use the proper churning temperature it is necessary for the buttermaker to familiarize himself with the conditions which influence and alter the mechanical firmness of the butterfat he receives, to study the changes of these conditions and the character of the cream as it comes to the factory, and then adjust the churning temperature of his cream accordingly. This is especially important in the spring of the year when the pasture season opens up and in the fall of the year when the cows are stabled.

The appearance of any conditions which tend to produce firmer fat should be followed by a corresponding rise in the churning temperature and any conditions tending to render the butterfat softer should be followed by a corresponding drop in the churning temperature.

Since the firmness of the butterfat directly governs the time necessary to complete the churning, the buttermaker may use as a convenient guide for the desired temperature of the cream of the next churning, the time required to churn the previous batch of cream. Under otherwise normally controlled conditions, when the churning process occupies from 40 to 50 minutes, the butter usually has a body and texture of good firmness. The churning temperature should therefore be so adjusted as to complete the churning process in about 40 to 50 minutes.

For the production of butter of superior body and texture, it is necessary to use a churning temperature low enough to yield a firm butter. This will also facilitate moisture control and the production of uniformity in color, as such butter will stand a sufficient amount of working to regulate the per cent moisture as desired and to effect a most complete fusion between the brine and water, without danger of injuring its body. Of the two evils, too low and too high a churning temperature the former is by far preferable, while the latter may cause real damage to the market value of the butter.

Aside from the physical and chemical properties of the butterfat and the viscosity of the cream, the factors of length of time held at churning temperature, richness of cream, age of cream, acidity of cream and fullness and speed of churn, should be carefully considered by the buttermaker in his adjustment and choice of the churning temperature. The relation of these factors to the churning is discussed in detail in the following paragraphs.

Time of Holding Cream at Churning Temperature.—The cream should be held at the churning temperature for not less than two hours prior to churning. As previously explained the chief purpose of churning the cream at a temperature lower than that at which it is ripened is to secure butter of satisfactory firmness of body and to avoid excessive loss of fat in the buttermilk. Cream would churn much more rapidly at a somewhat higher temperature, but under most conditions the injury to the body of the butter and the abnormal loss of fat make such practice prohibitive.

In order to secure the full benefit of cooling the cream to the churning temperature, the cream must be held at the churning temperature for at least two hours. Butter fat is an exceedingly poor conductor of heat. It gives off its heat slowly and only upon prolonged exposure to cold. If cooled to the churning temperature immediately before churning, the thermometer, while registering the correct temperature, indicates the temperature of the serum only. If such cream is churned at once the temperature during the churning will rise rapidly and the resulting butter will have a weak, slushy and leaky body. This danger is avoided by cooling the cream to the churning temperature several hours before churning and holding it at that temperature. This gives the fat globules an opportunity to give up their heat and to become thoroughly chilled and hardened. If the buttermaker is so situated that he has to churn without holding the cream at the churning temperature for the necessary length of time before churning, he should cool the cream to a much lower temperature than would otherwise be required, or he may have to add crushed ice to the churn in order to avoid injury to the body of the butter and heavy loss of fat.

Richness of Cream.—Cream low in butterfat requires more time to complete the churning than cream rich in fat. In the thin cream the fat globules do not coalesce as readily as in the rich cream. They find each other with more difficulty on account of the intervening serum, and the butter granules are slow in gathering enough fat globules to assume sufficient size to complete the churning. This greatly prolongs the churning process. In winter when there is no opportunity for the cream to warm up during the prolonged churning process, the butter granules formed in the thin cream are subjected to excessive concussion, becoming round and very compact. This condition is prone to produce butter with a low moisture content. Thin cream, owing to the large amount of intervening and interfering serum, generally does not churn out exhaustively, excessive fat is lost in the buttermilk, and the loss of fat is further augmented by the relatively large amount of buttermilk.

In the rich cream there is less intervening serum, the fat globules are closer together, they find each other readily and they churn out more rapidly. Since the richer cream churns more rapidly, the butter granules are subjected to less grinding against each other. They retain their original shape more completely, are irregular in shape, flaky and less compact. In this condition they do not drain as readily and lose less moisture during the process of working. There being less buttermilk from rich cream, there is less loss of fat than from thin cream. The above advantages hold good only with cream of reasonable richness. Cream excessively high in butterfat, such as cream testing 35 per cent and over, may stick to the sides of the churn and fail to be agitated when the churn revolves. Such cream, espe-

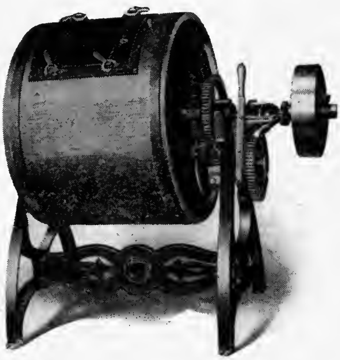

Fig. 44. Dairy size Victor combined churn and worker
Courtesy Creamery Package Mfg. Co.

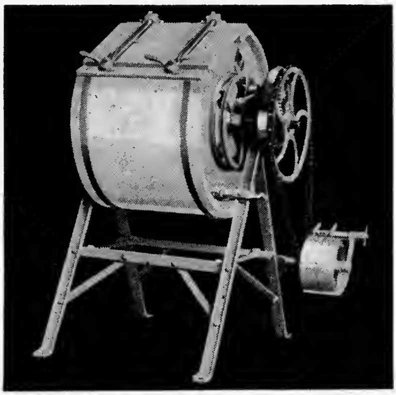

Fig. 45. Minnetonna Home butter maker
Courtesy Davis-Watkins Dairymen's Mfg. Co.

cially when churned at a relatively high temperature, is prone to produce butter with a greasy body and containing excessive buttermilk, which it is difficult to remove. Cream with a low fat content can be churned at a higher temperature without injury to the quality of the butter than cream rich in fat. The most suitable richness of cream for churning lies within the range of 30 to 33 per cent fat.

Acidity of Cream.—Sour cream churns more rapidly and more exhaustively than sweet cream. This is chiefly due to the reduced viscosity in the sour cream. Sweet cream is naturally viscous and this viscosity lessens the concussion to which the fat globules are subjected and hinders the globules from striking each other with sufficient force to coalesce. Sour cream has lost much of its viscosity and is granular in body, the acid having changed the physical make-up of the proteids and the mechanical properties of the cream. Excessive loss of fat by sweet-cream churning may be avoided by lowering the churning temperature.

Nature and Amount of Agitation.—In order to facilitate the bringing together and adhering to each other of the fat globules, they must be subjected to agitation and concussion. This is accomplished in the churn. While there is a great variety of churns on the market, the entire assortment of churns may be grouped into two principal classes, namely churns in

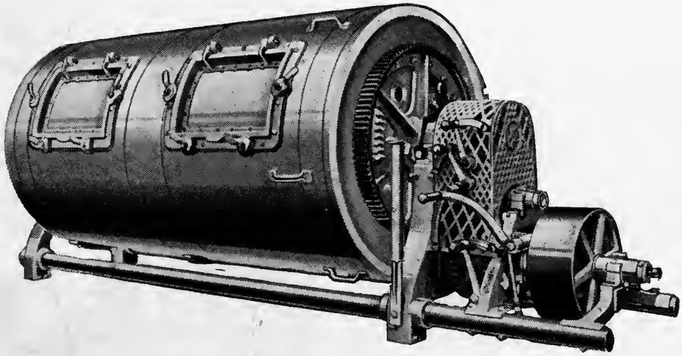

Fig. 46. Perfection Dreadnaught
Courtesy of J. G. Cherry Co.

which the cream is agitated by means of an internal agitator, and churns in which the agitation is brought about by the motion of the churn itself.

The first class, the churns with agitators, represents the older styles of churns. The old dash churn is a typical representative of this principle. The agitator may have an up-and-down motion or it may revolve in the churn like a paddle wheel. Churning by the use of the dash churn is a laborious task, the amount of concussion produced for the energy expended is comparatively low. Another objection to this type of churn is that all the butterfat does not churn out simultaneously, considerable time elapses between the first appearance of the butter granules and the completion of the churning, and the stirring motion of the agitator or paddles has a tendency to partly destroy the grain of the first granules formed, making butter of a poor texture. Furthermore, the dash churns are not conducive to maximum exhaustiveness of churning and usually cause a relatively great loss of fat in the buttermilk.

The second group of churns, the churns in which the agitation is brought about by the motion of the churn itself, represents the type of churns now almost exclusively in use in this country. Some of these churns have a swinging motion, but the majority are revolving or rotating barrels or boxes. From the point of view of efficiency of agitation the hollow barrel or box churn is the most desirable. The rotating motion of the churn causes the fat globules to strike the sides of the churn and the concussion thus produced hastens the formation of the butter granules. The churns of small capacity such as are used on the farm are usually, though not necessarily, entirely hollow,

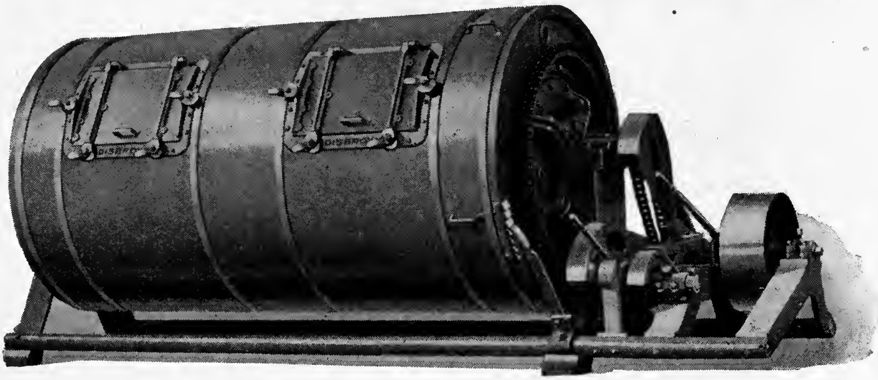

Fig. 47. Giant Dibrow churn
Courtesy Davis-Watkins Dairymen's Mfg. Co.

turning end over end, while the great majority of the factory churns are equipped in their interior with rollers and workers, and with shelves attached to the sides of the churn, raising the butter and dropping it on the rollers at least once with every revolution of the churn.

Speed of Churn.—Aside from the style or construction of churn, the amount of agitation and concussion materially depends on the speed of the churn. The speed which produces the maximum agitation and at which the churning is completed in the shortest time is that which will subject the particles of cream to the most rapid motion upon one another. Up to a certain point an increase in the speed of the churn increases the concussion of the particles of the cream. But when the speed is carried to the point where the centrifugal force causes the cream to partake of the motion of the churn, the motion of the particles of cream upon one-another is diminished, the concussion of the fat globules is lessened, and the churning process is retarded. For maximum concussion, therefore, the churn should revolve at the highest speed consistent with the absence of centrifugal motion of the cream and that permits the cream to fall from side to side of the churn. The exact speed which accomplishes this condition varies somewhat with make of churn, the fullness of the churn and the richness of the cream. Under average normal conditions it has been found that the churn should revolve at a maximum speed of about thirty revolutions per minute.

Amount of Cream in the Churn.—Other conditions being the same, when the churn is about one-third to one-half full the cream is subjected to the maximum concussion. The amount of cream in the churn bears a direct relation to the agitation of the cream. The fuller the churn the more difficult it is to produce thorough agitation and the more time is required for the formation of the butter granules. When the churn is too full the cream is also more prone to foam and swell, which makes the completion of the churning next to impossible, without first removing some of the cream. Under such conditions there usually is also excessive loss of fat in the buttermilk.

With too little cream in the churn, the cream, if it is rich in butterfat and thick, is prone to adhere to the sides of the churn, it will then either revolve with the churn or slide back along the side of the churn. In either case the process of churning is delayed. If the cream is thin, the granules are difficult to gather. Too little cream in the churn has the additional disadvantage that the control of the temperature is difficult, and in case of a warm churn room, the cream may warm up considerably and the butter is apt to be excessively soft. In the case of thin or medium rich cream and at a low temperature the butter granules of small churnings in a large churn are subjected to excessive agitation, striking against the sides of the churn with much force. This makes them very compact, intensifying the expulsion of water, thus tending to reduce the overrun.

From the above discussion it should be clear that, for quickest and best results, the size of the churning should be adjusted to the size of the churn and that a churn about one-third to one-half full will do most satisfactory work. The crowding of the churn, in order to make one churning out of two, is usually poor economy of time. More time is required to churn out the butter from an overfilled churn than by dividing the cream into two batches and churning each separately.

Preparation of the Churn.—Before the cream is transferred to the churn, the churn should be properly prepared as to

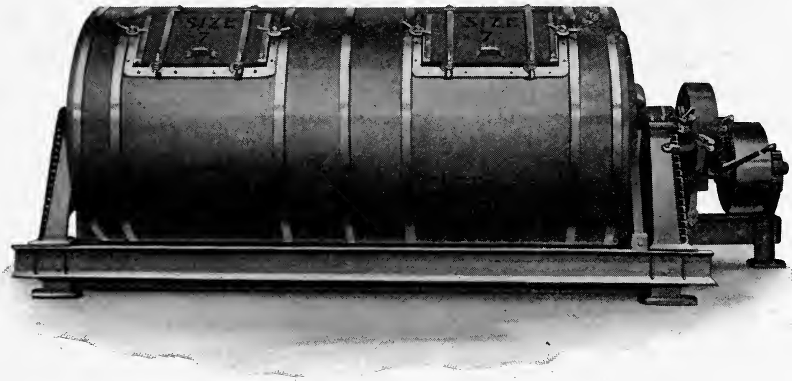

Fig. 48. Heavy Duty Dual churn
Courtesy Creamery Package Mfg. Co.

cleanliness and temperature. New churns generally have a pronounced woody odor which is prone to be absorbed by the butter unless the churn is previously treated to remove this odor. If the churn is a new one that has never been used, or an old one that has been laying idle for some time, it should be soaked with a solution of milk of lime or other alkali solution for several days before it is used. Milk of lime is preferable because it helps in hardening and closing the pores of the wood, thus assisting in excluding grease, curd and other impurities which are prone to lodge and which sooner or later become the cause of a foul smelling churn. Other alkali solutions, such as washing powders, sal soda, etc., while effective as purifiers, tend to soften the wood and to leave its pores open. Lime has the further advantage of absorbing and removing from the churn woody and other undesirable odors. Brine or buttermilk are frequently used for removing the woody odor. While these remedies may help to remove the woody odor, they are less satisfactory for other reasons. Brine, though it has limited antiseptic properties, with age becomes stale and sometimes foul unless it is more concentrated than is generally the case, and buttermilk has elements of decomposition, such as curd and a variety of germ life with which it is undesirable to fill the open pores of the new churn.

The churn containing the milk of lime should be revolved frequently so as to expose all parts of the churn to the lime

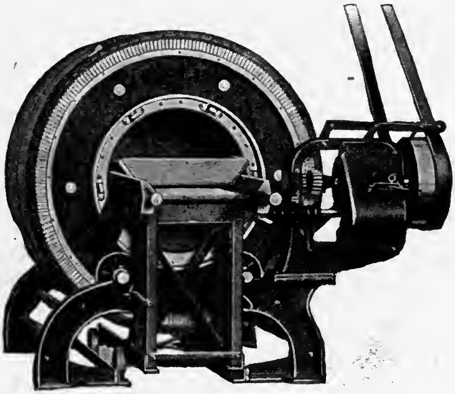

Fig. 49. Simplex churn
Courtesy D. H. Burrell & Co.

emulsion. When the soaking has been completed—after not less than three days—the milk of lime is drawn off and the churn is washed out thoroughly and with several washings of water, the last of which should be boiling hot. Care should be taken that all particles of undissolved lime are completely removed, otherwise the butter will pick up this insoluble grit and incorporate it.

Churns that are not in constant use should be kept filled with milk of lime while not in use. This will prevent them from becoming leaky, due to drying out and shrinking of the staves. It also prevents the churn from becoming foul-smelling which is so often the case with idle churns, due to the presence in the cracks and pores of the wood of decomposing remnants of cream, butter and buttermilk. These fermenting impurities and germs tend to imbed themselves in the wood in an inactive churn until it is almost impossible to dislodge them. The milk of lime soaking into the wood inhibits their growth, both because of the purifying action of the lime and because of the exclusion of air. Even churns which are in daily use are benefitted by a weekly treatment with milk of lime.

Immediately after the butter is removed from the churn, the churn should be rinsed out with two rinsings of boiling-hot water. The first rinsing should contain some good washing powder, the second rinsing should be done with clear, pure hot water. It is advisable to revolve the churn for several minutes on high gear while rinsing. The churn should not be rinsed with cold water for the last rinsing, because cold water will not

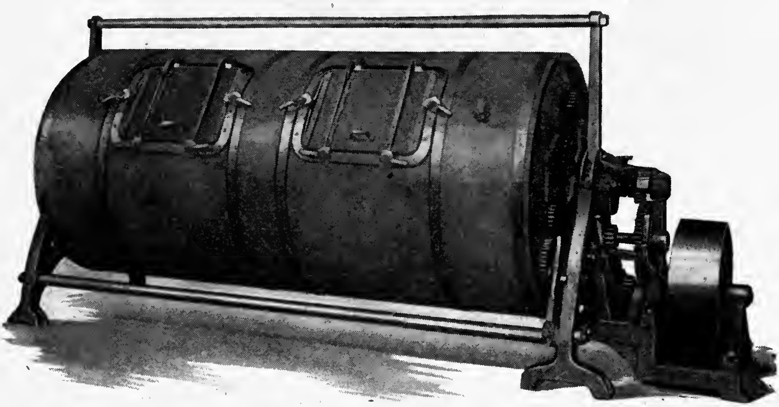

Fig. 50. Heavy Duty Victor churn
Courtesy Creamery Package Mfg. Co.

evaporate, causing the churn to become watersoaked and musty. On the next day, immediately before filling the churn with the cream, it should be thoroughly steamed, and then rinsed with clean, cold water so as to thoroughly chill it.

Most churns in use are constructed of wood, usually of cypress. Cypress is most resistent to the swelling action of water and to fungus attacks. The temperature control is easier in wooden churns than in metal churns. Some farm churns are made of iron, tinned on the inside. These churns are easily kept sweet and clean, but they are objectionable when used in a warm room because the cream is prone to warm up during the churning process, causing the butter to become soft.

The churn should be kept clean on the outside as well as on the inside. This is best accomplished by washing it often with hot water and soap or washing powder. It should be painted at least once per year. Two coats of white lead followed by a coat of enamel paint give the churn a sanitary appearance and a smooth surface that is easy to keep clean. Before the paint is applied all loose paint, rust, remnants of cream and alkali should be removed.

The churn door openings should be equipped, when the churn is not in use, with frames covered with cheese cloth or fine wire mesh netting to keep out flies, dust and other impurities. The churn door frames and the doors themselves should be kept in good repair to avoid loss of cream by leaking. Old and worn-out cork packing can easily be replaced by new, and broken door catches should be promptly replaced by new ones.

If the churn does not drain properly a one-inch hole may be bored in the side of the churn at its lowest place. The churn should be so located that the operator has easy access to the gear end for repairs and for frequent oiling. The churn should be oiled daily. The condition of clutches and rollers should receive constant attention and the starting of the churn should be done with care and not too suddenly, in order to save clutches and cogs. At best the life of the churn is short, but its period of usefulness is much shortened by careless handling and neglect. It is a good plan to take the churn apart in winter when the buttermaker has time and to make such repairs and order such new parts as may be necessary in order to forestall serious trouble and delay during the heavy season.

Sticky Churns.—Occasionally great difficulty is experienced to keep the butter from sticking to sides, ends and rollers of the churns. In many cases this trouble is caused solely by not having the churn properly chilled, before it is filled with cream, the butter sticking to the warm wood surface. In such cases the recurrence of the difficulty may readily be avoided by thoroughly chilling the churn with cold water or with ice water before filling it with cream.

In many other instances, however, the churn does not respond to this treatment and the butter continues to stick, due to the fact that, owing to improper care, the wood of the churn has become loaded with grease and alkali. The most effective remedy against stickiness then, is to treat the churn with a chemical that will free the pores of the wood from the grease and alkali, and that is to rinse out the churn with a dilute solution of sulphuric acid, using one quart of commercial sulphuric acid in 100 gallons of water and running the churn with this acid solution for about an hour. The churn must then be rinsed thoroughly with several washings of hot water.

Straining the Cream.—The cream should be strained into the churn. This is best done by inserting a strainer with fine perforations into the churn door opening. These strainers can be obtained from any one of the reliable creamery supply houses. The straining is necessary in order to break up and keep out of the churn, lumps of curd which might otherwise be incorporated in the butter and give rise to white specks and other irregularities in color. The proper straining of the cream will also avoid insoluble foreign matter, impurities flies, etc., from being churned into the butter. In farm buttermaking on a small scale the use of a strainer dipper is a very convenient way whereby the cream may be strained as it enters the churn.

Addition of Butter Color.—The market demands that butter be uniform in color, and the successful manufacturer must supply that which the consumer wants. The natural color of butter is that which is naturally yielded by cows feeding upon green pasture. This color is of a bright golden yellow. According to Palmer[1] this yellow color is due to the yellow pigment carotin and xanthophyll, found in fresh green feeds and which accompany, and are hidden by, the chlorophyll. During the flush of the milk producing season the great majority of the cows are on green pasture, therefore the great bulk of butter has this golden yellow color as a natural ingredient. Towards fall when the pastures begin to dry up, the natural color of the butter becomes lighter and in winter, when the cows are on dry feed, butter is only faintly yellow, the exact shade of color

[1] Palmer, "The Yellow Color in Cream and Butter," Missouri Circular 74, 1915.

varying considerably with the kind of feed, the breed of cows and the period of lactation. The Channel Island breeds produce a more highly yellow butter than the Holsteins and Ayrshires, and at the beginning of the period of lactation the cream and butter have a deeper shade of yellow than after the cows have been in milk for some months. All green feeds and yellow roots intensify the yellow color of butter while most dry roughage, grains and mill by-products tend to diminish the yellow color of milk and dairy products. (See also "Color Defects of Butter," Chapter XVII.)

In order to maintain uniformity of color, or the color of summer butter, throughout the year, in fall, winter, early spring and in times of drought during the summer, butter is artificially colored. For this purpose a variety of butter colors is used.

A suitable butter color must be free from ingredients injurious to the health of the consumer, it should have such strength of coloring that only a very small quantity need be added to cream in order to give the butter the desired shade of yellow, and it must be free from undesirable odors and flavors so as to not impair the quality and market value of the butter.

Aniline colors which formerly were used extensively for this purpose possess very intensive coloring properties, but their use is prohibited by the Federal Pure Food Act which went in force in 1907.[1] While extracts from various plants may serve as butter colors, the bulk of butter color of commerce today is the coloring substance extracted from the seed of the Annatto plant, Bixa oreltana, by means of some neutral oil, such as cottonseed oil, or corn oil.

The extract of butter color is made by boiling the annatto seed in the oil for several hours. During the latter period of the process the heat is raised to a very high temperature, about 240 degrees F., for the purpose of effecting a permanent solution of the annatto coloring principle in the oil. The mixture is then filtered through heavy canvas, either by gravity or un-

[1] On January 9, 1920, the U. S. Department of Agriculture, Bureau of Chemistry, S.R.A.-Chem. 24, announced the certification, subject to the provisions of Food Inspection Decisions 76, 117 and 129, the following oil-soluble coal-tar dies: Yellow A.B. (Benzeneazo—B—naphthylamine), and Yellow O.B. (Ortho-Tolueneazo—B—naphthylamine). These two coal-tar dies can now be legitimately used as butter colors.

der pressure. The filtered oil constitutes the butter color of commerce. It is perfectly clear to the eye, but under magnification shows to contain a very fine precipitation of suspended matter.

Good grades of annatto butter color, purchased from reliable manufacturers, are made from high grade annatto seed and oil. Such butter color is free from objectionable flavor and odor and from sediment, and it does not deteriorate readily in flavor. It is not advisable, however, to purchase more than can be used in one season, nor to buy it from supply houses or stores where it may have been on hand for years. It should be purchased fresh, from a reliable firm and it should not be carried over summer. Old, stale butter color may deteriorate and lend butter objectionable flavors.

It is not necessary, nor desirable, to keep butter color in the cold. If made from pure, neutral oil and sound seed, butter color does not deteriorate when kept at warm temperature, if not more than one season old. Annatto, similar to other vegetable colors, is a fugitive color. While the butter color prepared from it, is not known to bleach under conditions to which it is exposed in the creamery, it may precipitate and settle out some of its coloring principle, so that different portions of color, drawn from the same package, may not produce the same shade of yellow in butter, causing dissatisfaction when the butter reaches the market. Low temperature, abrupt changes of temperature, exposure to air and agitation accelerate the precipitation of butter color.

The drums, cans or other containers of butter color should, therefore, be stored in a place where the temperature is fairly uniform, and preferably at room temperature, and their contents should be protected against excessive agitation and exposure to air. The practice of pumping the butter color out of the drum when it is needed, tends to incorporate considerable air in it and to produce excessive and repeated agitation, both of which conditions invite precipitation. It is preferable to lay the drum on a sleeper and attach a spigot to one end of the drum from which the butter color can readily be drawn when needed.

The amount of butter color to be used varies greatly with locality, season of year and markets. In localities where the Channel Island breeds greatly predominate, less artificial coloring is needed than where the cream comes largely from Holstein and Ayrshire cows, the latter naturally producing a butter with a much lighter shade of yellow.

During the summer months and as long as the cows are on succulent pasture the natural shade of yellow is quite sufficient for the bulk of the trade and no artificial butter color is needed. Towards fall the natural color of butter becomes lighter, necessitating the addition of small amounts of artificial color in order to suit the trade. As the intensity of the natural color diminishes, in late fall and winter, more artificial color is needed to maintain a uniform shade of yellow. This is due to the cows being on dry feed and to the advanced stage of the period of lactation of the majority of cows.

The demand of the market is an important factor determining the amount of color to be added. American markets demand a higher shade of yellow than European markets. The southern markets require a deep yellow butter, the eastern and northern markets a straw color. The Jewish trade demands uncolored butter.

The amount of artificial butter color that must be added, then, varies greatly under these diverse conditions and it ranges from none to about 4 ounces for every 100 pounds of fat in the churn.

One ounce of butter color for every hundred pounds of butter fat in the churn is a fair average amount. For the convenience of the farm buttermaker the following equivalents of one ounce per 100 pounds of fat are given:

For 100 pounds fat use 1 ounce color
For 1 pound fat use 5 drops color
For 1 gallon 30% cream use 12 drops color
For 5 gallons 30% cream use 1 teaspoonful color.

The above figures should be considered only as very approximate averages, which it may be necessary to modify in order to make them suitable to prevailing conditions of breed, season of year, feed and market demands. These figures may prove serviceable, however, to the beginner.

Analine butter colors are much more intensive in their coloring properties than annatto butter color. Hence when using the now certified and permissible analine colors, the amount required is very much less than above indicated in the case of annatto color.

As a matter of principle the use of artificial butter color, though sanctioned by tradition and by law, should be limited to the minimum needed to satisfy the trade. The demand of the trade for a highly colored butter is overestimated by the average buttermaker and much butter is colored to a deeper shade than necessary or desirable. The present tendency of the butter trade is for a lighter colored butter.

The best time to add the butter color is after the cream has been transferred to the churn and before the churn is closed. If this has not been done, as is frequently the case due to an oversight, it may be added to and mixed with the salt just before working. It is then worked into the butter and distributed when the salt is worked in. This practice cannot be recommended for general use, owing to the difficulty of working the butter sufficiently to effect a complete and uniform distribution of the color without overworking the butter. It should be resorted to only in emergencies. The butter color when added in this way should be mixed with the dry salt; being an oily emulsion it does not mix well with water or wet salt.

Gas in the Churn.—During the first five minutes of churning considerable pressure develops in the churn. This is caused by the expulsion of gases from the cream and the consequent expansion of the air. This pressure has a slight tendency to minimize the agitation of the cream and to cause excessive leakage of cream. It is advisable, therefore, to open the vent of the churn once or twice during the first five minutes of churning to release this pressure.

Stopping the Churn.—Under normal conditions the churning is completed and the churn is stopped, when the butter has gathered in granules of the size of wheat or corn kernels. While the size of the granules is only one of the many indications of the completion of the churning process, and while it is not necessarily an infallibly sure sign, it furnishes the most practical index for the buttermaker to tell when to stop the churning process.

When the butter first breaks, the butter granules formed are very small and the buttermilk still has a rich, creamy, opaque appearance. From this point on, under normal conditions, the formation of additional butter granules, the coalescence of the small granules into larger ones and the completion of the churning take place rapidly. When the churning is completed the buttermilk should have lost its creamy consistency and opaqueness and should have a thin, bluish, watery appearance and should be free from butter. If the churning comes from different lots of cream of different degrees of ripeness, or of different ages, the completion of the churning requires more time and it is necessary to churn to larger granules. The butter from the sour and older cream breaks first. If the churn is stopped when the butter granules are no larger than small corn kernels, the chances are that the fat of the sweeter or fresher cream is not completely churned out yet and there is much loss of fat in the buttermilk.

The underchurning or stopping of the churn when the butter granules are very small, always tends to cause excessive loss of fat. The smaller fat globules churn out more slowly than the larger ones, and at this stage a large number of the smaller globules need further agitation to coalesce into butter granules of sufficient size to stay in the churn or strainer when the buttermilk is drawn off. If these small granules are very hard, either on account of the natural firmness of the fat or churning at a low temperature, the formation of larger granules and the completion of the churning will occupy considerable time. If the butter granules are soft, the granules increase in size very rapidly. These phenomena are further intensified by the richness of the cream. Thin cream delays, while rich cream hastens, the coalescence of the granules. If the churning process must be stopped when the butter-granules are still very small, excessive loss of fat may be avoided by allowing the churning to rest undisturbed for about ten minutes. This gives the smaller granules an opportunity to rise to the surface and adhere to the butter.

Overchurning, that is, the formation of large granules or lumps, is objectionable, because of the excessive incorporation of buttermilk which may prove injurious to the keeping quality of the butter. In the case of churning cream of a poor quality, this incorporation of buttermilk is especially objectionable, because of its tendency to give the butter an unclean, coarse and rank flavor and to hasten fermentations in the butter detrimental to its quality. In the case of poor cream, therefore, it is important to stop the churn when the granules are still small, consistent with reasonable exhaustiveness of churning. In this case the buttermilk will drain off readily and can be washed out thoroughly. Butter from poor cream should be drained well and washed in several lots of water. Overchurning may also cause injury to the body of the butter. If the butter granules are very soft, overchurning is difficult to avoid, because of the very rapid coalescence and lumping together of the granules after the breaking point has been reached.

Some buttermakers practice overchurning for the purpose of incorporating moisture in the butter. The popular conception, that overchurning causes the finished butter to be high in moisture, is not well founded and would hold good only in the case of very soft butter. When the churning temperature is at all normal and the butter granules are reasonably firm, as they should be, there is no tangible reason why large granules should make butter containing more moisture than small granules. The supposition is that the large granules lock up a great deal of moisture. Experimental data do not bear this out. On the contrary, they suggest that overchurning, if it has any effect at all on the moisture content of the finished product, tends to pound the moisture out of the butter.

The frequent occurrence of overchurned butter with an abnormally high moisture content is not the result of overchurning, but is usually due to the weak body of the butter for which other conditions, such as soft butter fat, high churning temperature, or cream that was not held at the churning temperature long enough, are responsible and which conditions are also responsible for the overchurning. It is difficult to stop the churn before the butter is overchurned in the case of cream that is not cooled sufficiently to make the butter come reasonably firm.

Overchurning has a tendency to injure the grain of the butter. Danger of this type is especially great when the butter granules are small and firm, like shot, and when an effort is made to secure larger granules by a prolonged continuation of the churning process. This condition occurs generally when the cream is very thin and cold. Additional churning causes excessive friction between these granules and often results in a salvy butter. This may be avoided to some extent by drawing off a part of the buttermilk, The greater density of the butterfat in the churn thus produced, hastens the completion of the churning and avoids unnecessary injury to the grain of the butter.

In order to secure butter of a good body the individuality of the butter granules should be preserved. Injury to the granules, as the result of overchurning, causes injury to the body of the butter, usually making it salvy or greasy.

Churning Difficulties.—Churning difficulties are occasionally experienced. In the majority of cases when the butter granules are exceptionally slow in gathering, and when the churning process is greatly prolonged, the cause lies in the peculiar character of the butterfat and the great viscosity of the cream. These abnormal conditions are chiefly due to certain individual cows. They therefore are encountered largely only where butter is made on the farm and from the cream of one or a few cows only. In the creamery the cream supply is derived from a comparatively large number of cows, which differ in breed, lactation and feed, so that abnormal cream

Table 48.—Showing Effect of Size of Butter Granules on Moisture Content of Butter.[1]

Date	Experiment Number	Churning Temperature Degrees F.	Approx. Size of Granules, Diam. Inches	Buttermilk		Wash Water Temperature Degrees F.	Revolutions		Moisture, %		
				Fat Per Cent	Temperature Degrees F.		Washed	Worked	After Drawing Buttermilk	After Washing	Finished Butter
1908											
August 18 ...	1	49	1/8	.75	56	54	10	12			14.69
		49	3/8	.75	56	55	10	12			13.90
August 22 ...	2	48	1/8	.42	56	55	10	12			14.62
		48	3/8	.09	56	56	10	12			14.47
August 25 ...	3	48	1/8	.60	55	55	10	12			14.57
		48	3/8	.40	54	54	10	12			14.46
August 29 ...	4	50	1/8	.42	56	56	10	12			13.71
		50	5/8	.39	56	56	10	12			13.30
1912											
March 26 ...	5	56	1/8		58	58	10	20	23.64	19.87	15.48
		56	2½		57	57	10	20	15.57	14.04	15.00
April 13	6	57	1/8	.70	59	55	10	20	30.66	26.66	13.12
		57	1½	.55	59	55	10	20	17.47	15.63	14.44
April 16	7	56	1/8	.30	57	55	10	20	25.53		14.68
		56	1½	.27	57	55	10	20	14.70	13.42	13.54
April 17	8	49	1/8	.20	55	56	10	20	23.70		14.13
		49	3/4	.25	55	56	10	20	15.84	13.47	13.38
April 18	9	51	1/8	.20	55	56	10	20	21.77	19.20	14.45
		51	3/4	.15	55	56	10	20	14.35	12.77	12.70
April 20	10	49½	1/8	.10	53	56	10	20	25.00	19.66	14.59
		49	3/4	.10	53	56	10	20	14.07	13.46	13.92
April 23	11	50	1/8	.20	53	54	10	16	19.83	19.07	13.84
		50	8	.17	53	54	10	16	15.64	13.61	13.84
April 24	12	50	1/3	.15	54	55	10	20	21.28	19.57	13.86
		50	1	.25	54	55	10	20	15.61	14.00	14.27
April 25	13	50	1/8	.10	54	55	10	20	24.04	18.58	14.15
		50	3/4	.10	54	55	10	20	13.37	13.32	13.21
April 27	14	50	1/8	.25	54	56	10	20	22.55	18.63	14.78
		50	8	.30	54	54	10	20	15.50	14.63	15.00
April 30	15	49	1/8	.17	54	56	10	20	22.33	17.65	15.00
		49	1	.15	54	56	10	20	16.24	12.88	13.01
Average for small granules..........................									23.66	19.87	14.38
Average for large granules and lumps..............									15.30	13.74	13.89

[1] The churnings of the different experiments ranged from 319 to 1420 pounds and the per cent of fat varied from 21 to 35. In all churnings of the same experiment the amount and richness of the cream were the same.

[1] Hunziker, Mills and Spitzer, Moisture Control of Butter, Purdue Bulletin No. 160, 1912, page 387.

of this type becomes greatly diluted with cream that is normal in its churnability and causes no material disturbance in the churnability of the whole churning.

Certain cows when they have been in milk five to six months persist in yielding cream which churns with great difficulty, and the butter granules of which are exceedingly slow in gathering. The difficulty is usually accompanied by very great loss of fat in the buttermilk.

The same difficulty is experienced frequently with cream from old cows and from cows which have not been with calf for a long time. This condition is usually intensified by the feeding of dry roughage and certain kinds of grain. Examination of such cream invariably shows that it either is abnormally viscous, or contains unusually small fat globules, or that its butterfat is unusually hard, containing a low per cent of olein, or a combination of two or all of these conditions. As explained under "Conditions Affecting the Churnability of Cream," all of these conditions make the formation of butter granules difficult and therefore retard the churning process.

These conditions occur usually in the fall and early winter when the cows are on dry feed and are well advanced in their lactation. In some cases the abnormal condition of the milk can be minimized by the addition to the feed ration of some succulent feed, such as corn silage or roots, or some grain rich in vegetable oil, such as linseed meal. The succulence increases the milk flow and tends to reduce the viscosity. The grain rich in vegetable oil increases the per cent of olein causing the butterfat to be of softer character. In the majority of cases, however, the cow refuses to respond to a change of feed at the end of her period of lactation. After parturition the milk usually is normal again and the cream churns readily.

In numerous cases the churning difficulties reported are not due to any abnormal condition of the cream as produced by the cow, but to faulty methods of manufacture. The cream has undergone peculiar fermentations which cause it to become abnormally viscous, a cream very low in butterfat is produced, the churn is filled too full, or the churn revolves too fast or too slow.

In the majority of cases the churning difficulties will yield wholly or to some extent at least, to proper treatment of the cream. A reasonably rich cream containing about 30 per cent fat, ripened to about .6 per cent acid, churned at the proper temperature and in a churn not more than one-third to one-half full, seldom refuses to churn out. If it foams and swells in the churn, further agitation is useless until the foam has subsided. If the frothing is due to too much cream in the churn, the quickest way to churn the cream is to remove a portion of the cream from the churn and make two churnings. If the swelling is due to churning at too low a temperature, the difficulty may be overcome by adding a small amount of warm water. The same treatment will often also increase the churnability of cream which is abnormally viscous as above described. If warm water is added to the cream the amount of water used should be small, otherwise churning difficulties may arise as the result of too great dilution of the cream.

Churning difficulties, not due to overloading the churn may also be remedied by the addition to the churn of some dry salt. The salt has a greater affinity for water than the casein has. The salt helps to precipitate or to "salt out" the curd due to dehydration or withdrawal of water from the casein. This causes the casein to contract and the cream to become less viscous.

In most cases of churning difficulties not due to an overloaded churn, the turning of the hot water hose over the outside of the revolving churn will hasten the "breaking" of the butter. The resulting slight warming of the churnbarrel breaks the adhesion of the cream to the sides of the churn, the cream drops and concussion is resumed.

CHAPTER XI.

WASHING, SALTING AND WORKING THE BUTTER.

Washing the Butter.

Purpose.—The chief purpose of washing the butter is to free the butter granules, after the buttermilk has been drawn from the churn, from such remnants of buttermilk as may adhere to them. Other objects may be to harden the butter, in case the butter shows a weak body, and to remove undesirable flavors in case the original cream was of poor quality.

Drawing off Buttermilk.—When the churning process is complete, the buttermilk is drawn from the bottom of the churn and the butter should be allowed to drain thoroughly. If the butter granules are very small their separation from the buttermilk and their rising to the surface, may be facilitated by the addition to the churn of a little cold water. When the buttermilk has considerable commercial value and a steady trade has been established for it, the practice of pouring water into the churn before the buttermilk is removed is obviously objectionable. In this case excessive loss of fat may be avoided by leaving the churning at rest for about 10 minutes before drawing off the buttermilk. This gives the smaller granules an opportunity to rise to the surface and to attach themselves to the mass of butter.

In order to avoid the escape of butter granules the buttermilk should be strained. In farm buttermaking the use of a fine hair sieve or of a dipper strainer is convenient for this purpose. For creamery buttermaking a cone-shape or cylindrical tin or wire mesh strainer is inserted in the buttermilk outlet of the churn. These strainers can be purchased from creamery supply houses.

Addition of Water.—After the buttermilk is removed, the butter should be allowed to drain thoroughly. Then the wash water is added, using about as much water as there was buttermilk. The churn is then given a few revolutions to agitate the contents gently and to facilitate the washing of the granules. The wash water is then withdrawn, the butter again allowed to drain and the washing is repeated by the addition of a second batch of water. Under normal conditions this second washing should be practically clear. If it shows milkiness the butter should be washed a third time. The butter should be washed until the wash water runs off clear. Usually two washings are sufficient.

If the butter comes from cream of good quality the least amount of washing consistent, with the complete removal of the free buttermilk, is preferable. Excessive exposure of the butter to the cold wash water tends to rob the butter of its fine, delicate flavor and to cause such butter to assume a more or less flat taste. The loss of the fine flavor is due to the power of the cold water to absorb some of the aromatic, volatile and soluble substances characteristic of good butter. Sweet cream and cream only slightly soured requires comparatively little washing for the removal of the buttermilk, because the solids in such buttermilk are largely in solution or in very fine suspension similar as the solids in milk. In this fluid condition the solids of the buttermilk are removed readily.

In the case of cream of poor quality, and of highly acid cream, it is advisable to wash the butter very thoroughly, to increase the number of washings and, if the butter shows very pronounced off-flavors, to hold the wash water in the churn for a while (10 to 20 minutes). This gives the volatile substances and free acids of old and overripe cream an opportunity to pass off into the wash water, liberating the butter made from such cream from some of its undesirable flavors and odors. An additional washing with sweet skim milk may greatly help to improve the flavor of such butter.

Butter in the form of very small granules, washes more readily and more quickly than butter in the form of large granules and lumps, less water and less manipulation of the butter is required. The finer the granules the more surface is exposed to the wash water and the more facile the removal of the buttermilk. The removal of the buttermilk requires more washing in the case of large granules of butter. Other things being the same, excessive washing of very fine granules of butter is objectionable because of excessive loss of the delicate flavoring principles which are partly soluble in the cold water, making the butter flat in flavor. When butter is churned into large lumps there is not so much danger from this source. Small granules are also more sensitive to variations in temperature. All of these conditions point to the desirability of washing small granules of butter more rapidly and less extensively than butter in the form of lumps.

In the case of churns which tend to unduly mass the butter during the washing process, thorough removal of the buttermilk is difficult. In such cases it is advisable to spray the first washing over the butter granules from the hose or by other means, with the buttermilk gate open, until the drain loses its milky appearance and then add the second washing in the usual way.

Where the subsequent working of the butter is done in the churn, as is now the case in most American creameries, the washing is best done in the churn also, by giving the churn a few revolutions after each addition of wash water. Where the butter is taken out of the churn for subsequent working, as is usually the case in farm buttermaking on a small scale, the butter may be washed in the churn before it is placed on the worker, or the water may be poured over the butter on the worker.

As a whole, defects in the body of the butter cannot be overcome by any particular method of washing or temperature of wash water, though they may be somewhat minimized. The character of the body of the butter is determined prior to, and during the churning process, incident to the formation of the butter granules. If a good, solid, compact body, free from slushiness, leakiness and weakness is desired, the cream must have been cooled to the proper churning temperature and held there long enough to yield firm granules of butter. It is at this point that the stability of the emulsion of water-in-fat is determined. If it is not accomplished then, the butter is prone to have a defective body regardless of the process of washing and working.

Temperature of the Wash Water.—The temperature of the wash water should be regulated according to the firmness or softness of the butter. Inasmuch as the mechanical firmness of the butter is a somewhat fluctuating factor and is difficult of definite description, it is not feasible to lay down all-embracing directions.

Under all normal conditions, however, and with butter of reasonable firmness, wash water with a temperature of a few degrees (2 to 4 degrees) below the temperature of the buttermilk is usually advisable. Wash water much warmer, or much colder than this tends to have an unsatisfactory effect on the body and texture of the butter and may indirectly disturb the uniformity of the color. To a limited extent it also interferes with the control of moisture.

Such wash water, coming in direct contact with the exterior of the butter granules only, causes uneven temperature and firmness of different parts of the butter. The outside of the granules changes in firmness according to the temperature of the wash water, while their interior retains the original temperature of the butter. In this condition the distribution of the salt and brine and the fusion of brine and water is made difficult and lacks uniformity throughout the body of the butter. This uneven distribution of the salt and incomplete fusion of brine and water invites excessive migration of brine and water after the butter is placed at rest (in the cold room) resulting in mottles or streaks in color, and particularly in the case of excessively warm washwater the butter is prone to show a leaky body.

If the butter is very soft and of weak body, however, it may be necessary to use wash water of a temperature 5 to 10 degrees or more lower than that of the buttermilk, and to allow the butter to rest in the cold water for some time to give it a chance to harden. In extreme cases it may be desirable to put ice into the churn in order to temporarily improve the body of the butter so it can be handled. It should be understood that when the cream has been properly handled before churning, especially as to churning temperature and holding at that temperature before churning, there is little danger of a weak-bodied and leaky butter and these special precautions are unnecessary. These precautions refer only to churnings where the cream was either churned at too high a temperature or was not held long enough at the churning temperature, conditions which produce a soft, weak, slushy and leaky body. In such cases they will help to minimize the defect, but an ideal body of butter under these conditions should not be expected, and excessively soft butter so exposed to very cold water will be prone to be flat and possibly tallowy in flavor. It also will not stand up well on the market.

Effect of Wash Water Temperature on Moisture Content of Butter.—High temperatures of wash water tend toward a slight increase in moisture content of the butter. However, this effect on the per cent water in butter is not as marked as is generally believed. The butter fat is a poor conductor of heat and the short time during which the butter is ordinarily exposed to the wash water is not sufficient to materially affect its mechanical firmness, provided, of course, that the butter is in fairly normal condition. It should be borne in mind, however, that the washing of the butter in warm wash water does tend towards a softening of the butter. Though this influence seems to be very slight, it may be sufficient to modify the effect of the subsequent working. If this butter is worked with the churn doors closed and consequently in the presence of water it may take up slighly more water. When worked with the churn doors ajar this butter cannot take up appreciably more moisture. Butter washed with cold water tends to be somewhat firmer and in this condition it may lose somewhat more moisture when worked with the churn doors ajar. If the temperature of the wash water does influence the moisture content of butter at all, the effect is indirect rather than direct and depends largely on the extent to which the butter is drained and worked subsequently. These facts are clearly demonstrated in Table 49.

Overchurning Butter in Wash Water.—Buttermakers frequently churn their butter in the wash water for the purpose of moisture incorporation.

When butter is churned in the wash water at normal temperature the butter granules gather into larger granules and finally into masses. If the original granules are round, smooth and firm, they do not readily lose their identity but remain largely intact. Under these conditions the churning in the wash water has no marked effect on the moisture content of the

Table 49.—Effect of Temperature of Wash Water on Moisture Content of Butter.

(Experiments conducted in Purdue University Creamery, Lafayette, Ind.)[1]

Date	Experiment Number	Per Cent Fat	Churning Temperature Degrees F.	Approx. Size of Granules, Diam. Inches	Buttermilk Temperature Degrees F.	Wash Water Temperature Degrees F.	Revolutions, Washed	Revolutions, Worked	Moisture Per Cent
1911									
April 4..	1	32.0	56	⅛ to ¼ angular	58	54	10	18	13.64
		32.0	56	⅛ to ¼ angular	60	64	10	18	14.24
April 5..	2	33.5	56	⅛ to ¼ angular	60	54	15	16	15.45
		35.0	56	⅛ to ¼ angular	60	64	15	16	15.95
April 7..	3	29.5	56	⅛ to ¼ angular	60	54	15	16	16.31
		31.0	56	⅛ to ¼ angular	60	64	15	16	14.75
April 11.	4	32.0	56	1/16 to ¼ angular	60	54	15	20	15.38
		32.0	56	⅛ to ¼ angular	60	64	15	12	14.99
April 12.	5	31.0	56	⅛ to ¼ angular	60	54	15	12	15.07
		31.0	56	⅛ to ¼ angular	60	64	15	12	15.79
April 12.	6	30.5	56	⅛ to ¼ angular	58	54	10	18	13.22
		31.0	56	⅛ to ¼ angular	58	64	10	18	13.52
April 18.	7	29.5	53	¼ to ⅜ angular	55	54	15	18	13.30
		29.5	52	¼ to ⅜ angular	53	65	15	18	13.91
April 18.	8	29.5	55	⅛ to ¼ angular	57	54	15	14	14.64
		29.5	54	⅛ to ¼ angular	54	65	15	14	14.54
Average at 54 degrees F.									14.62
Average at 64 degrees to 65 degrees F.									14.71

[1] Experiments 1, 6 and 7 were made with the Disbrow churn. Experiments 2, 3, 4, 5 and 8 were made with the Simplex churn. All cream was pasteurized at 170 degrees to 180 degrees F. The cream for each churning of the same experiment was taken from the same vat. The amount of cream used in the churnings of the different experiments varied from 250 to 2000 pounds. The same amount of cream was used for each churning of the same experiment. In each churning the butter was salted dry and worked with the churn gates open.

Hunziker, Mills and Spitzer, Moisture Control of Butter, Purdue Bulletin 160, 1912.

finished butter. If the original butter granules are irregular in shape, flaky and soft, they mass together very readily and largely lose their identity, forming solid lumps and masses. The pounding of the butter into compact masses tends to expel moisture rather than incorporate it, causing a decrease in the moisture content of the finished butter, unless this butter is later worked in the presence of water for the purpose of incorporating more moisture.

The above facts are conclusively borne out by experimental results as shown in the following tables:

Table 50.—Showing Effect of Over-Churning Butter in Wash Water on the Moisture Content of Butter.[1]

DATE	Experiment Number	Cream Per Cent Fat	Churning Temperature Degrees F.	Approx. Size of Granules, Diam. Inches	Buttermilk Temperature Degrees F.	Wash Water Temperature Degrees F.	Revolutions Washed	Approx. Size of Granules, Diam. Inches	Revolutions Worked	Moisture Per Cent
1910										
November 10...	1	24	52	1/4	56	56	15	3/8	18	15.01
		24	52	1/4	56	56	50	3½	18	15.74
		24	52	1/4	56	56	225	8	18	16.48
November 14...	2	23	54	1/4	58	54	10	1/4	13	15.52
		23	54	1/4	58	54	150	1	13	15.78
		23	54	1/4	59	54	225	3½	13	14.89
November 15...	3	26	47	1/4	57	52	10	1/4	13	15.35
		26	47	1/4	56	52	150	3½	13	15.35
		26	47	1/4	56	52	225	8	13	14.31
Average for 10 to 15 revolutions										15.29
Average for 50 to 150 revolutions										15.62
Average for 225 revolutions										15.22

[1] Hunziker, Mills & Spitzer. Moisture Control of Butter, Purdue Bulletin 160, pp. 394 and 395.

Twenty-four hundred pounds of cream were used for each individual churning. All cream was pasteurized at 175 degrees F. The butter in Experiment 1 was salted wet and worked with the churn gate open; the butter in experiments 2 and 3 was dry-salted, worked one revolution with the churn gate closed, then finished with the churn gate open. The Victor churn, size 1, was used in these experiments.

Twenty-four hundred and seventy-seven pounds of cream were used for each individual churning. The cream was pasteurized at 150 degrees

F. In Experiments 1 and 3 the butter was salted dry and worked with the churn gates open; in Experiment 2 the butter was salted dry and worked seven revolutions with the gates closed, then finished with the churn gates open. The Simplex churn No. 9 was used in these experiments.

DATE	Experiment Number	Cream Per Cent Fat	Churning Temperature Degrees F.	Approx. Size of Granules, Diam. Inches	Buttermilk Temperature Degrees F.	Wash Water Temperature Degrees F.	Revolutions Washed	Approx. Size of Granules, Diam. Inches	Revolutions Worked	Moisture Per Cent
1910										
November 29...	1	28.5	54	1/4	57	57	6	3/8	18	15.64
		28.5	54	1/4	59	57	50	8	18	14.51
November 30...	2	31.0	52	3/8	58	58	6	3/7	19	15.51
		31.0	52	3/8	59	58	50	3½	19	13.28
December 1....	3	28.0	58	1/4	60	58	6	3/8	19	14.80
		28.0	59	1/4	60	58	50	8	19	13.65
Average of 6 revolutions washed										15.31
Average of 50 revolutions washed										13.81

How to Regulate the Wash Water Temperature.—In localities where the available water is naturally cool (50° F. or below), such as is the case in the northern states and in the mountainous regions with running springs, as well as in most localities within the dairy belt in winter, the matter of regulating the temperature of the wash water resolves itself merely into a proper arrangement for heating. In such cases the installation of a noiseless water heater or similar home-made device and with an outlet directly over the churn, furnishes the usual equipment to temper the wash water to the desired temperature. In the summer season, however, the water supply of a great many creameries is too warm. This is true especially in the central and southern tier of the dairy belt. Under such conditions it is necessary to provide for some simple and practical system of cooling the water. In small creameries which have no artificial refrigerating plant this is conveniently accomplished by placing a vat on a platform high enough for the water to run into the churn by gravity. The temperature of the water in this vat is lowered by the addition to it of ice. In the absence of a stationary platform the vat may be placed on a truck which can be moved up to the churn when the wash water is needed. In creameries operating an artificial refrigerating machine, a large stationary vat may be installed at some elevation or on the second floor. This vat should be properly insulated on the sides, bottom and top and equipped with a brine coil or ammonia coil whereby the water may be cooled to any temperature. The water is piped from this vat to the churn where it is connected with the steam line. This arrangement furnishes a practical and reasonably efficient means to regulate the temperature of the wash water as desired for the one-churn creamery.

For larger creameries which operate numerous churns, greater uniformity of temperature is assured and less time is consumed for temperature control, where the wash water equipment is so arranged as to have the cold water from the brine-cooled sweet water tank on the second floor, discharge into a tempering tank elevated in the creamery and equipped with large thermometer gauge and steam supply. Then have from the bottom of this tempering tank a two-inch water line extend over the entire row of churns with a lateral and valve over each churn.

In this manner the wash water for numerous churnings can be tempered to the desired temperature simultaneously and when the churnman is ready for the wash water, all he has to do is to open the valve over any one of the churns where it is needed.

The same equipment can also serve for the hotwater supply for rinsing and washing the churns after use.

In other factories, portable tempering tanks are used. In this case, the tap water, cold water and steam line outlets are generally located at some distance from the churns, in a convenient and readily accessible place and at a sufficient height so that a portable wash water tank on a truck can be backed under these outlets and filled. The use of a suitably constructed tank on wheels, holding about 100 to 150 gallons and standing high enough so that the gate of the tank clears the bottom of the door frame of the churn, when the churn is in position to receive the wash water, has been found serviceable and convenient for this purpose.

The same arrangement is useful also for transferring the hot water to the empty churn, for washing and rinsing at the close of the day's work and for rinsing the churn with cold water preparatory to filling it with cream.

Purity of Wash Water.—It is obvious that the water used for washing the butter should be pure. It should be free from excessive organic and mineral matter, from undesirable bacteria, yeast and mold and from grit or sand. Water from shallow wells, ponds, creeks, lakes and similar sources is unsafe on account of the danger of contamination with organic and biological impurities which may prove detrimental to the quality of butter. Such water should be pasteurized or filtered, or both, in order to render it harmless. In rare cases spring and deep well water may contain an excess of mineral constituents. such as compounds of iron, sulphur, etc., which, if used for washing the butter may greatly impair its flavor; such water is unsuitable for use in the creamery. Frequently the water contains sand and grit which, when used for washing butter, is incorporated in it and offends the good humor of the consumer. Sand may get into the water where a new well is used, or where the water supply line is being repaired, or in the case of leaky underground conduits during heavy rains, or from roily river water during times of freshets. In most of these cases the presence of sand is temporary only and, while it lasts, it may be kept away from the butter by either permitting it to settle out in a storage tank, or by attaching a fine mesh strainer, or tying several thicknesses of cheesecloth over the end of the pipe, that discharges into the churn, or by filtration.

Wherever the purity of the wash water is uncertain, it is advisable to permanently install some form of water purifier. For the removal of organic matter and grit, water filters should be used. When used properly, a cotton filter may serve the purpose well. Filters of the type of the "International Filter," in which the water is forced under pressure through a thick layer of Cotton batten, with a heavy sheet of muslin at top and bottom, have been found very useful. The renewal of these filters is simple and inexpensive. The muslin is laundried and used over again while the soiled cotton, charged with impurities, is replaced by a new layer. These filters have the additional advantage of taking up very little space.

If the creamery is troubled with roily water, these cotton filters are not practical, because they clog rapidly. In such cases sand, gravel and coke filters are preferable. Home-made filters of this type have been found somewhat cumbersome, owing to the attention and extra work which their care involves. There are on the market, however, very compact and practical specimens of these sand, gravel and coke filters which require but little attention and which are capable of freeing the water from its grit and probably from much of its organic matter. They consist of a closed iron drum which contains the filtering material and through which the water is forced, and are equipped with a rotary agitator. For cleaning, the current of water through the filter is reversed and the agitator is rotated. The operation of cleaning the filtering material requires but very little time (about 10 minutes) and if this is done daily, and in accordance with directions furnished by the manufacturer, these filters can be depended upon to do the work expected of them very efficiently.

For the effective removal of micro-organisms from the water, the efficiency of any of these filters is somewhat questionable. Bacteriological analyses of the filtered water show variable results, probably depending on the condition and care of the filter. Under ordinary creamery conditions they can hardly be considered a reliable means to free the water from objectionable germ life.

In order to render water sterile or nearly so, high temperature pasteurization of the water may be practiced, but it requires considerable equipment, time and fuel, for heating and cooling. Of late years, for the sterilization of drinking water, water for swimming pools, etc, the ultra violet ray process has been found very suitable and its use is rapidly gaining. Its efficiency has been established by Government tests.[1] At the present writing there are no creameries as yet which are using

[1] Public Health Report, Vol. 31, No. 41, Oct., 1916. U. S. Public Health Service.

this method of water purification, but the increasing adaptation of electric power to creamery purposes, together with the efficiency of the process, suggests the possibilities of this method of purifying the water used for washing butter. The initial expense of an equipment of suitable capacity is somewhat high and therefore probably beyond the reach of the small creamery. The operating expense on the basis of 5 cents per K. W. is about one quarter of one cent per gallon of water. Inasmuch as this process is effective only with perfectly clear water and does not sterilize water that is roily, its use would necessitate preparatory filtration of the water in the case of water that is not naturally clear.

Wherever the water intended for washing the butter is stored in a tank reserved for this purpose, great care should be taken, that this sweet water tank is kept clean, and free from accumulations of organic matter. It should be completely emptied and cleaned out, if necessary, with the use of odorless disinfectants, at regular intervals. The brine or ammonia coils in these tanks should be painted with suitable paint, so as to avoid rusting and the consequent pollution of the water with rust.

Creameries located in large towns or cities usually have access to the water supply of municipal corporations. This often solves for them the problem of pure water, but the use of a good filter is recommended even in these cases.

SALTING THE BUTTER.

Purpose.—The fundamental object for which salt is added to butter is to lend it the flavor desired by the consumer—to season it. Formerly it was believed that salted butter kept better in storage, but experimental data, as well as experience, have demonstrated that while salt has undisputed antiseptic properties, it has no material effect on the keeping quality of butter. The addition of salt to butter is of importance to the creamery also, because with salted butter a larger overrun is secured than with unsalted butter. This is due to the fact that the salt replaces a portion of the butterfat.

Amount of Salt.—The amount of salt that should be added to butter should depend primarily on the market for which the butter is intended. The salt requirements of different markets vary somewhat. American markets demand a relatively highly salted butter, with the exception of the Jewish trade which requires unsalted butter. The English markets call for a butter that is lightly salted, while continental Europe, especially France, Southern Germany, Switzerland, etc., demand unsalted butter. Thus the salt content of butter, as regulated by different markets, may vary from no salt to about four per cent of salt.

In reality, however, the salt requirements of different markets where salted butter is wanted, are salt tolerances rather than requirements; i. e. there is not really a very marked difference in the amount of salt which the salted butter trade demands, but it is rather a question of how much salt the trade will stand for or tolerate. The manufacturer of butter naturally aims to salt his butter heavily, because salt is cheaper than butterfat. He will furnish the trade just as highly salted butter, within the limitations regulated by effect on quality, as the trade will accept and tolerate. Some markets are more critical and quicker to resent the imposition than others, but none really demand a very highly salted butter.

The salt content of butter intended for one and the same market should be uniform. Variations in the salt content of butter are detected by the consumer more easily than similar variations of any other ingredient of butter. Uniformity of salt content is, therefore, important in order to satisfy the trade. In order to accomplish this, the amount of salt to be added to any given churning should be based on the most constant factor. On farm dairies and in whole milk creameries the amount of salt is frequently calculated per hundred weight of milk. In this case from three to four ounces of salt per 100 pounds of milk would produce a moderately salted butter. This method gives fairly uniform results. Others are determining the amount of salt needed on the basis of the amount of cream in the churn. With the greater variability of the richness of the cream, this method obviously may frequently lack in uniformity of results. In the case of cream testing about 30 per cent fat, for instance, from one and three-quarter to two and one-half ounces of salt per gallon of cream would yield a butter with a moderate salt content. On farm dairies and in creameries where the butter is taken out of the churn and placed on a separate worker, the required amount of salt is usually determined by the weight of the butter, using from one-half to three-quarters of one ounce of salt for every pound of butter for medium salted butter. Where the butter is worked and salted in the churn this method is not practical. Today the great majority of creameries are basing the amount of salt to be used, on the pounds of butterfat in the churn, as calculated by the weight and test of the cream. This is by far the most accurate and most satisfactory method. Experience has shown that the proper amount of salt for the average American market is about three-quarter to one and one-half ounces of salt per pound of butterfat. These figures are based on a desired salt content of from 2.5 to 3.5 per cent under average conditions and methods of salt incorporation, the latter being relatively crude from the point of view of economy of salt. For salt tests see "Determination of Salt in Butter," Chapter XXII.

Where the method of manufacture and other conditions are fairly constant from day to day, this ratio makes it possible to produce butter with a reasonably uniform salt content. However, the portion of salt that remains in the butter depends, aside from the amount added, on such factors as size and condition of butter granules, amount of working which the butter receives before and after salting, the condition and amount of moisture in butter at the time the salt is added, the method of salting, whether the salt is added in dry form, in wet form, or in the form of brine, and the type of salt crystals.

Size and Condition of Butter Granules.—If the butter consists of small, round and very firm granules the salt is dissolved, distributed and held by the butter with difficulty, and much of the salt is lost in the expelled brine. If the butter is reasonably firm and the granules large and irregular, or if the butter granules have united into large lumps, the salt can be worked into the butter more readily, there is less expulsion of brine and therefore a relatively large proportion of the salt added is absorbed by the butter. For this reason the trench system of salting assists in the economic use of the salt.

If part of the working is done before salting, or if the butter has been allowed to drain thoroughly before salting and the churn gates are closed after the salt is added there is relatively little loss of salt. In this case the loss of salt may not exceed .5 per cent under favorable conditions.

Amount and Condition of Moisture.—Butterfat is no solvent of salt. In order for the salt to dissolve in the butter there must be moisture present. The more moisture butter contains the more salt it is capable of holding in solution. Butter with a low moisture content cannot hold much salt in solution. Efforts to incorporate a high per cent of salt in dry butter usually result in overworking and in gritty butter.

If the moisture is properly incorporated in the butter, the slat will also remain there, and butter containing a large amount of properly incorporated moisture is therefore capable of retaining a relatively high per cent of salt. If the moisture is incorporated loosely, resulting in leaky butter, the escape of moisture in the working and packing is great, and there is a relatively large loss of salt, which causes the salt content of the finished butter to be low, although, owing to the presence of free brine such butter usually tastes very briny. (See also Chapter XVIII on Composition of Butter.)

Method of Salting.—The salt is added to the butter either in dry form, as a wet mash, or in the form of brine.

Dry Salting Method.—This is the most common method used. The salt is sprinkled over the butter in the churn, in the trench, or on the workers and then worked into the butter until it is dissolved and evenly distributed. When the butter is of medium firmness this method works satisfactorily and there is little danger from grittiness and mottles. In the case of very firm and hard butter the distribution and solution of the dry salt, is more difficult and requires often excessive working, which in turn tends to make an inferior texture of butter. More often, however, the working is stopped before the salt is thoroughly dissolved and the butter remains gritty and may become mottled. In the case of very soft and slushy butter the dry salt kernels become coated with a film of fat before they have an opportunity to take up enough moisture to insure complete solution. Such butter renders the complete solution of the salt difficult, and is almost invariably gritty.

Wet Salting Method.—In this method the salt is moistened either by pouring water over the dry salt already sprinkled over the butter, or placed into the trench and before working, or enough water is added to the salt in a tub or pail before the salt is put into the churn, to make a salt mash. In order to secure a satisfactory mash slightly less than one half as much water as there is salt, by weight, should be mixed with the salt. This mash is then distributed over the butter, or placed into the trench, then the trench is closed and the butter is worked. This method of wet salting is very satisfactory and preferable under many conditions to the dry salting method. There is less danger of a coarse, briny flavor, gritty butter and mottles, because the salt is given more favorable conditions for complete solution and the brine formed has a chance to completely fuse with the finely divided water in the butter. This largely removes the difficulties above cited when salting very firm and very soft and slushy butter.

In churns in which the reduction of moisture is not accomplished readily, as is frequently the case with certain makes of churns, wet salting slightly increases the tendency toward excessive moisture. This can be readily avoided, however, by draining the butter more competely before salting. If the bottom of the buttermilk gate happens to be located considerably above the bottom of the churn, so that it is impossible to drain all the free water from the churn, the butter should be drained through the churn doors.

It is frequently claimed that salting lowers the per cent salt retained in the finished butter. This is not borne out in practice. In fact the salt crystals in the mash, because of their ability to go into complete solution quickly do not draw the water droplets of the butter out as much as the dry crystals and therefore are more readily permanently incorporated in the form of brine.

Brine Salting.—In this method the salt is previously dissolved in water, making a saturated salt solution. In order to secure a brine of maximum saturation and to hasten the solution of the salt, the salt may be dissolved in hot water and the brine is then cooled to the proper temperature suitable for addition to the butter. This is the ideal way of salting from the point of view of completeness of solution, uniform distribution of salt, and absence of a coarse, briny flavor and grittiness. However this method is practical only where a very light salt in butter is desired. It is impossible to incorporate a high salt content with this method. Brine-salted butter contains only from one to two per cent salt. And even in order to incorporate the maximum of two per cent salt by this method it is necessary to use two separate batches of brine. One batch may be used in the place of the second washing and the butter has to be churned considerably in this. The brine left in the butter after this brine washing is naturally very dilute. After the first batch of brine has been drawn off the second batch is added. This is left with the butter for five to fifteen minutes. Care should be taken not to work the butter in the brine excessively in the case of soft butter, in order not to incorporate excessive moisture. After the second batch of brine is drawn off the working is completed. The butter should be worked only enough to properly distribute the brine and to bring the butter together in a compact mass for easy handling.

Butter with so low a salt content does not meet the requirements of the majority of American markets for salted butter, hence this method is not commonly used in our creameries. The brine-salting method has the further disadvantages of being excessively laborious and wasteful of salt and the low salt content of the finished product obviously results in a relatively low overrun. In the spring of the year there is always more or less danger of excessive moisture where the brine-salting method is practiced.

Type of Salt Crystals.—The ease with which salt dissolves and is incorporated in butter is also influenced by the type of crystals of the salt. Cube crystals which have the smallest relative surface in proportion to their cubic content absorb water and dissolve, more slowly than flake crystals, unless the size of the cube crystals is reduced to the point where their relation of

Type of Salt Crystals of Buttersalts

Magnified 20 times

Fig. 51. Colonial Salt

Fig. 52. Diamond Crystal Salt

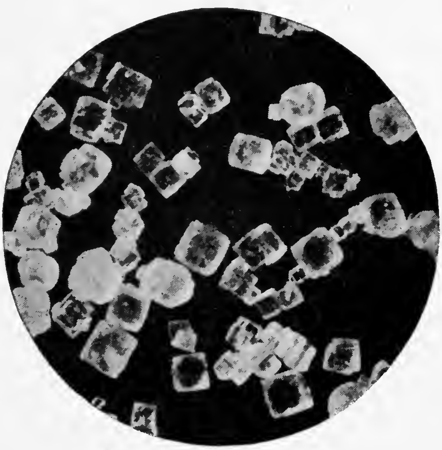

Fig. 53. Worcester Salt

surface to cubic content is similar to that of the coarser flake crystals.

Quality of Salt.—It is important that the salt used for buttermaking be of the very best quality. It should have a high degree of purity both bacteriologically and chemically, it should be of the proper physical consistency and should be protected from influences that jeopardize its bacteriological, chemical and physical fitness for use in the creamery.

Bacteriological Purity of Butter Salt.—It is obvious that the salt should be as free as possible from germ life, lest it become a source of contamination of the butter. The better brands of butter salt on the market come from the salines in practically sterile condition. The latest improved processes through which the brine passes from the time it is pumped from a depth of several thousand feet in the ground, till it is sealed in the paper-lined barrels are such, as largely to eleminate any micro-organisms originally present in the brine, and the handling of the finished salt occurs under conditions highly sanitary and reduces the danger of contamination of the finished product to the minimum. The increasing concentration of the brine during the process and the practically complete absence of moisture in the salt when packed, in themselves, are conditions antagonistic to the life of germs. The heat to which the brine and salt are subjected before and incident to the evaporation and again in the final dryers, is destructive to all germ life and the packing of the salt is done exclusively by machinery and while still hot, thus removing the possibility of recontamination practically entirely.

Bacteriological analyses of the salt in the sealed barrels have shown such salt to be either entirely sterile or to contain less than 10 germs per gram. When barrels are opened in the creamery, however, and are left uncovered and exposed to dampness and impure air, for a prolonged period of time, as is the case in a great many creameries, the salt becomes damp and often contains large numbers of bacteria, particularly the types of micro-organisms which render the butter rancid and cheesy and possibly moldy. Weigmann[1] reports cases where the up-

[1] Weigmann, Versuche zur Bereitung von Dauerbutter, Milchwirtschaftliches Zentralblatt, Vol. 44, No. 23, p. 364, 1915.

per layers of salt in an open receptacle contained as high as 32,000 germs per gram, consisting largely of liquefying and non-liquefying micrococci, alkali bacilli, lactic acid bacteria, yeast, Bacterium mycoides, Mucor, Penicillium Actinomyces and other spore forms. These facts obviously show that butter salt exposed to the atmosphere may become contaminated with many species of micro-organisms, some of which are of the type dangerous to the flavor and keeping quality of butter. They emphasize the importance of keeping the salt well covered after the barrel is once opened. In a properly managed creamery there should be provided proper covers for the barrels that have been opened and not completely emptied, in order to avoid this unnecessary source of contamination of the butter.

Some creameries are equipped with a salt chest, or bin, or box, into which they empty and in which they store the salt. These boxes are more conveniently accessible than the barrels. They should be equipped with a well fitting cover and located away from excessive dampness. It is advisable to not fill them with more than one barrel of salt at a time, as the original seal of the unopened barrel furnishes better protection than the creamery salt chest.

Chemical Purity of Butter Salt.—The best buttersalts contain from 98 to over 99 per cent pure sodium chloride. The salts of commerce contain besides sodium chloride, small but varying amounts of gypsum, calcium chloride and magnesium chloride. All of these impurities, when present in considerable quantities, are undesirable from the standpoint of the quality of butter. The gypsum reduces the solubility of the salt and the magnesium chloride tends to give butter a distinct bitter flavor. The salts of magnesium also are very strongly hydroscopic, augmenting the tendency of the butter salt in storage when exposed to the air, to absorb moisture and to become damp and lumpy. The butter salt should also be free from mechanical impurities such as dust, dirt and other organic matter.

The chemical purity of the salt is determined largely by the purity of the brine and the process of manufacture used for the elimination of the natural impurities contained in the brine. The purity of the brine varies very considerably with the locality, in some localities the wells yield a brine of a relatively high degree of chemical purity, while in other localities the admixture of undesirable minerals and mineral salts, such as gypsum and magnesium chloride, iron, etc. is very marked. For this reason there is a wide difference in the need of purifying processes used in the different salines, in order to attain purity.

The brine from which the butter salt is manufactured in this country is secured from wells which reach salt deposits which lie anywhere from 1500 to 3000 feet below the surface. When the salt stratum is to be penetrated a double pipe is put down. The outer one, which represents the diameter of the well, about 6½ inches, reaches the top of the salt bed, while the inner tube which measures from 3¼ to 4½ inches in diameter, goes clear through to the bottom of the salt deposit. Fresh water is pumped down the outer tube. This dissolves the rock salt, and the brine thus formed under continued pressure, rises to the surface through the inner tube and is conveyed to large tanks, the settling tanks, where it is allowed to settle and clarify. From this point on the brine is passed through one of three processes, the grainer process, the vacuum process, or the Ahlsberg process. These processes largely determine the degree of purity of the salt and the shape of the salt crystals.

The Grainer Process is the oldest process. It simply consists of pumping the brine from the storage or settling tanks into large evaporating vats equipped with steam coils which are charged with exhaust steam. In these vats the brine is heated to the boiling point under atmospheric pressure. As the water evaporates, crystals form on the surface where evaporation is most rapid. These crystals unite into larger aggregates, which gradually drop to the bottom and are drawn out of these vats by mechanical, slowly-moving rakes. These salt crystals are piled on a platform where they are allowed to drain or they are centrifuged to remove the bulk of the water and are then subsequently dried and run through sieves. No attempt is made in this process to purify the brine from mineral impurities, except possibly to bleach it by addition of small quantities of lime. The chemical purity of the salt made from this brine will therefore almost wholly depend on the natural purity of the brine. The slow evaporation at a relatively high heat causes the salt crystals to be relatively large and flaky, the individual crystals appear to have rhomboid shape, they gather into clusters forming large crystals, of the shape of hollow pyramids.

In the Vacuum Process the brine is conveyed from the storage tanks to large heating tanks, where its temperature is raised so that as soon as it enters the vacuum pan evaporation commences. In the vacuum pans, which are huge iron retorts, the brine is evaporated at relatively low temperatures under reduced pressure. The evaporation is very rapid. From the vacuum pan the crystals are conveyed to centrifuges, where they are freed from about 95 per cent of their water. From here on the process of drying and sifting is similar to that of the Grainer process. In the vacuum process in some factories mineral impurities are removed, in part at least, through a discharge chamber in the bottom of the pan in which the "bitter water," being heavier than brine and remaining in solution longer, collects. The crystals produced by this process, as the result of rapid evaporation at low temperature, are cube shape, they are very small and remarkably uniform in size.

In the Ahlsberg Process the brine is pumped through heaters where it is subjected to very high temperature (about 280° F.) under pressure. These heaters resemble water-tube boilers, the brine flowing through the tubes and the spaces between the tubes being charged with steam. In these heaters the brine deposites its gypsum and other impurities forming a coating on the tubes, which is daily removed by steel drills. From these heaters the brine passes through gravel filters which furnish an additional means to deposit the gypsum. From here the brine enters large circular evaporating vats. As soon as its pressure is released and the brine passes into these vats, crystallization sets in. From these crystallizing vats the wet salt passes through centrifuges for the removal of the bulk of the water, and the dryers and sieves as described in the Grainer and Vacuum process. The Ahlsberg process is particularly adapted for salines whose brine supply contains considerable mineral impurities, such as gypsum and which it is capable of very efficiently removing. Crystallization takes place very rapidly and at high temperature and the crystals are flaky and of rhomboid shape.

Table 51.—Chemical Analyses of Butter Salts.

These analyses refer to butter salts only.

Brand of Butter Salt	Analyses Made By	Sodium Chloride Per Cent	Calcium Sulphate Per Cent	Calcium Chloride Per Cent	Magnesium Chloride Per Cent	Insoluble Matter Per Cent	Moisture Per Cent
Anchor	Wisconsin[1]	97.79	1.48	.28	.08	.06	.31
Ashton	Wisconsin[1]	98.01	1.47	.20	.16	.03	.18
Australian Dairy	Canada[2]	97.90	1.03	.39	.02	.38	.28
Canfield and Wheeler	Wisconsin[1]	98.18	1.21	.22	.12	.04	.23
Chippewa	Connecticut[3]	98.79	1.01	.00	.03	.05	.12
Colonial	Cornell[4]	99.53	.29	.09	.02	.03	.06
DiamondCrystal	Wisconsin[1]	99.18	.54	.19	.05	.03	.01
DiamondCrystal	Connecticut[3]	99.50	.45	.00	.04	.01	.00
DiamondCrystal	Connecticut[3]	99.54	.30	.00	.07	.01	.08
DiamondCrystal	Maine[5]	99.71	.23	.00	.06	.00	.00
Dominion Dairy	Canada[2]	96.04	1.44	.92	.00	.00	1.60
Eagle	Canada[2]	98.98	.47	.41	.00	.00	.14
English Dairy	Canada[2]	97.90	1.57	.18	.00	.00	.35
Extra Dairy	Canada[2]	96.15	.91	.84	.00	1.90	.20
Genesee	Wisconsin[1]	98.27	1.11	.24	.07	.04	.16
Le Roy	Canada[2]	96.88	1.40	.10	.07	1.05	.50
Le Roy	Wisconsin[1]	98.15	1.31	.39	.08	.01	.06
Imperial	Maine[5]	98.02	1.23	.29	.04	.15	.27
Peerless	Maine[5]	98.12	1.14	.21	.13	.00	.40
Port Huron	Canada[2]	97.31	1.66	.23	.00	.00	.80
Purity	Connecticut[3]	98.53	1.01	.00	.11	.02	.33
Warsaw	Wisconsin[1]	98.57	.92	.25	.07	.02	.17
Windsor	Canada[2]	98.08	1.16	.00	.36	.00	.40
Worcester	Wisconsin[1]	98.57	.92	.25	.07	.02	.17
Worcester	Connecticut[3]	98.94	.59	.19	.07	.01	.20
Worcester	Maine[5]	98.53	.82	.07	.13	.10	.35

[1] Wisconsin Agricultural Experiment Station, Bulletin 74, 1889.
[2] Canada Internal Revenue Department, Bulletin 128, 1906.
[3] Connecticut Agricultural Experiment Station Report, 1907-1908.
[4] Cornell University, Analysis by Prof. H. C. Troy, Chemist, 1919.
[5] Maine Agricultural Experiment Station Annual Report, 1910.

The final drying process of all butter salt is the same. The driers are huge, cylindrical, revolving drums, 32 to 35 feet in length, and six feet in diameter and set at an incline so that the salt may travel slowly from one end of the drier to the other. Heat is supplied by means of steam pipes which pass through the driers. The temperature in these driers is about 280° F. The hot salt coming from the driers is then sifted. For butter salt, wire sieves with 25 to 30 meshes to the inch are used. After sifting, the salt is ready to be packed.

Most of the better butter salts contain these chemical impurities in exceedingly small amounts only, are practically entirely free from insoluble matter and contain less than .5 per cent of moisture. The foregoing table shows analyses of diverse salts and indicates their relative freedom from chemical impurities.

In the consideration of the chemical analyses of butter salts, as shown in table 51, it should be understood that the composition of different lots of one and the same brand not infrequently varies quite considerably, so that an unbiased and fair conclusion concerning the relative merits of the several salts, based on their standard of chemical purity is possible only, when the respective analyses represent averages of a large number of samples of each brand in question.

Many of the analyses shown in table 51 represent but one sample of the respective brands and even in the case of figures which do represent averages, only a comparatively few samples of the respective brands served to make up these averages. For these reasons it is obvious that the figures in table 51 should be accepted only as a general guide and should not be looked upon as a guarantee of the standard of chemical purity of the brands involved.

Physical Condition of the Salt.—It is very important that the salt be present in the form of crystals of the proper form and size. This factor controls its readiness to dissolve and its ease of being retained in the butter. The crystals must be of medium coarseness. When the crystals are excessively large they dissolve with comparative difficulty, tending toward gritty butter, or necessitating the overworking of the butter. Their distribution also tends to be less uniform, the individual crystals are farther apart so that their action on the casein and the expulsion of buttermilk are uneven, and the fusion of brine and water in the butter is slow and relatively incomplete. This in turn tends to cause an uneven color in butter.

When the salt crystals are too fine, the salt is prone to be pasty, which renders its uniform distribution difficult. Excessively small crystals hinder the expulsion of buttermilk because the drops of buttermilk which each crystal is capable of taking up are so small, that their complete and ready expulsion is hampered.

Salt crystals of medium size, and which will pass through a screen having 25 to 30 meshes to the inch, are best suited for butter salt.

With reference to the shape or form of the salt crystals, the butter salts are divided into two classes, the flake crystal salt and the cube crystal salt. The flake grain represents a thin and flat crystal usually of rhomboid or pyramid form, while the cube crystal grain appears in the form of regular-shaped solid cubes. Since the flake grain, with the flat thin crystal, exposes more surface in proportion to its cubic contents, than the cube crystal with its cube shape, it is obvious that the flake grain salt dissolves somewhat more readily and is therefore better suited for butter salt than the cube crystal grain, unless the cube salt is of sufficiently smaller grain to reduce the cubic contents of the cube crystals in proportion to their surfaces to that of the coarser crystals of the flake salt. The difference in the shape of the crystals is due to the temperature at which the brine is evaporated. The flake grains are the product of evaporation at a high temperature (under atmospheric pressure) while the cube crystal grains result from evaporation at a relatively low temperature (in partial vacuum).

Solubility of Buttersalts.—The solubility and rapidity of solution of Colonial, Diamond Crystal and Worcester butter salts, representing the Grainer, the Ahlsberg and the Vacuum process, respectively, were tested by Hunziker and Hosman.[1] In the case of butter containing 16% water, and assuming that all the water in the butter were accessible to the salt, these results would indicate the following:

With a 2 per cent salt content in the butter the brine would contain 11.11 per cent salt. This concentration was reached in 5 seconds with the Colonial and the Diamond Crystal salts, and in 5½ seconds in the case of the Worcester salt.

With a 3 per cent salt content in the butter the brine would contain 15.78 per cent salt. This concentration was reached in 6½ seconds with the Colonial and Diamond Crystal salts, and in 7 seconds with the Worcester salt.

With a 4 per cent salt content in the butter the brine would contain 20 per cent salt. This concentration was reached in 8 seconds with the Colonial and Diamond Crystal salts, and in 9 seconds with the Worcester salt.

With a 5 per cent salt content in the butter the brine would contain 23.8 per cent salt. This concentration was reached in 10 seconds with the Colonial salt, in 13 seconds with the Diamond Crystal salt, and in 21 seconds with the Worcester salt.

With a 5.5 per cent salt content in the butter the brine would contain 25.58 per cent salt. This concentration was reached in 25 seconds with the Colonial salt, in 35 seconds with the Diamond Crystal salt, and in 41 seconds with the Worcester salt.

Inasmuch as the point of saturation of pure salt is reached with brine containing 26.41 per cent salt, salts showing a brine

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[1] Hunziker and Hosman. Determination of Solubility of Buttersalts. Blue Valley Research Laboratory, 1919.

In this experiment the samples of the three buttersalts were taken from the interior of the barrel, after removing about 30 pounds from the top. Three hundred and seventy grams of salt were added to 1,000 c.c. of water which was being violently agitated by means of a mechanical stirrer. It required from two to three seconds to add the salt. At definite intervals, after adding the salt, a sample was removed by means of a pipette, the suction end of which was covered with silk cloth. The mesh in this silk was from .05 mm. to .10 mm. in cross section and there were from 140 to 160 meshes per linear inch. All samples of brine were filtered through a double layer of this finely woven silk. Samples were removed after 10, 30, 45, 60, 57, 90, 105, 120, 180, 210 and 300 seconds, respectively. About 20 c.c. of brine was taken for each sample. The samples were kept in glass stoppered bottles until weighed. The determination of salt was made by weighing into a watch crystal about 6 grams of the brine and evaporating at 135° to 140° C. to constant weight. The apparatus and speed of agitation used were such as to preclude the possibility of any settling of the salt while the samples were taken. The amount, nature and speed of the agitation were uniform in each test.

concentration beyond this point suggest the presence of impurities.

These conclusions are purely arbitrary and relative. As stated elsewhere in this volume, the fine division and emulsion of the water in butter greatly diminishes the availability of a portion of it to the salt. It is not mechanically possible to completely dissolve a sufficient amount of salt in butter to reach the saturation point of all the water present. If salt is added to butter at the ratio of 26.41 parts of salt for every 100 parts of water present, and which ratio represents the maximum concentration possible of salt brine, all of this salt will not dissolve and the butter is bound to be gritty.

These figures, however, do show the relative solubility and the speed of solution of different buttersalts, and they may serve to suggest in a general way the limitations of satisfactory salt in corporation.

The Condition of the Salt as Affected by Storage.—It has already been stated under the paragraph on "Bacteriological Purity" that the salt should be kept tightly covered in order to avoid bacterial contamination which may prove disastrous to the quality of the butter.

The buttermaker should also exercise due care to protect the salt against a damp atmosphere, because of the great affinity of the salt for moisture from the air, causing it to become lumpy and musty.

It is frequently claimed that, when the salt is stored in barrels for an excessively long period of time, the salt is capable of absorbing a woody odor and flavor from the barrel, which may be imparted to the butter. It is doubtful that salt packed in sound barrels, kept dry, ever absorbs woody flavor. Experts on butter salt testify that this is impossible. However, instances are on record where salt stored in barrels made of poorly seasoned wood, or wood derived from trees which were felled while the sap was still running, or from lumber which was allowed to soak in stagnant ponds, gave butter a pronounced woody and moldy odor. The storing of the salt barrels in damp places where the barrel becomes wet may also be responsible for this defect.

If stored in a very cold place and not given a chance to warm up by being taken into the creamery long enough before use, the salt chills the butter with which it comes in immediate contact and thereby hinders ready solution and uniform distribution of the brine. Where the storage place of the salt is very cold, as is often the case in creameries in winter where the salt is stored in a shed, the salt needed for the next day should be brought into the creamery the previous day, or long enough before use, to allow it to temper, in order to avoid the undesirable consequences of the use of very cold salt.

Effect of Salt on the Keeping Quality of Butter.—The antiseptic properties of salt are generally recognized. Salt has the power of inhibiting bacteriological growth. It would seem, therefore, that salted butter should possess greater keeping quality than unsalted butter and that the more salt butter contains the better it should keep.

Jensen[1] reports that all micro-organisms grow better and faster in unsalted butter than in salted butter. The growth of the water bacteria is retarted most by the salt. Klein[2] says that although butter is primarily salted to improve its flavor, its keeping quality is also materially improved. Weigman[3] found that salt has a conserving action, that unsalted butter generally contains more microorganisms than salted butter and that in unsalted butter the multiplication of bacteria lasts longer than in salted butter. His experimental results show that in unsalted butter the multiplication lasted 106 days as against 62 days in salted butter. McKay and Larsen's[4] experiments show that salt improves the keeping quality of butter. Rahn, Brown and Smith[5] who stored salted and unsalted butter at —6° C. and +6° C. state that there is no hope of keeping unsalted butter longer than salted butter. Fettig,[6] in experiments in which butter was stored at similar temperatures as above, concluded, that salted butter keeps better, both above and below the freezing point, than unsalted butter.

[1] Jensen, Die Bakteriologie der Milchwirtschaft, 1913, p. 124.
[2] Klein, Milchwirtschaft, 1914, p. 218.
[3] Weigmann, Mykologie der Milch, 1911, p. 210.
[4] McKay and Larsen, The Keeping Quality of Butter, Iowa Bulletin 71, 1903.
[5] Rahn, Brown and Smith, Keeping Quality of Butter, Michigan Technical Bulletin 2, 1909.
[6] Fettig, Centralblatt für Bakt. II. Band 22, No. 32, 1909.

While the results above quoted all point toward improved keeping quality of salted butter, both experimental results and the experience of the butter manufacturer have demonstrated that the beneficial influence of salt on the keeping quality of butter, depends to a very considerable extent on a variety of factors incident to the making and storing of butter and the amount of salt, butter contains.

Again, all micro-organisms present in butter do not take part in the decomposition of the ingredients of the buttermilk and therefore do not affect its keeping quality and some species are considered capable to actually prolong the life of butter. On the other hand, the inhibiting action of salt varies greatly with different micro-organisms and with the concentration of the brine present. In slightly salted butter, i. e., butter containing not to exceed about two per cent salt, the liquid parts of the butter contain only about thirteen per cent salt, which is insufficient to retard the growth of most micro-organisms. Weigmann found that 2.5 per cent salt in butter, or about sixteen per cent in the brine of butter, inhibits the growth of some species of germs and that the molds are affected by this salt more than the bacteria and yeast. When, however, the salt is increased to 4 and 5 per cent, or approximately 21 to 25 per cent in the brine, the keeping quality is not only not improved, but it suffers. In this case the lactic acid bacteria which improve the keeping quality are affected unfavorably, their growth is inhibited, while other bacteria which give the butter undesirable flavors, such as those of the coli and aerogenes groups, Bacillus subtilis, Bacillus putrificus and several molds, are more resistant to salt. These results are corroborated by experiments by Gray and McKay[1] who show that in the case of butter stored at temperatures varying from —10° F. to +32° F., lightly salted butter averaged 2.16 points higher in score than heavily salted butter. These investigators therefore concluded that butter containing low percentages of salt, keeps better than butter containing a high per cent of salt. Fettig also found that if the salt concentration is so high as to stop the activity of lactic acid bacteria, some of the more resistant

[1] Gray and McKay, Investigations in the Manufacture and Storage of Butter. U. S. B. A. I. Bulletin 84, 1906, p. 17.

organisms have a chance to grow and to decompose butter. He adds that the coli group of bacteria thrives in butter containing 6 per cent salt and B. prodigiosus thrives in butter containing four per cent salt. Hunziker, Mills and Spitzer found that unsalted and lightly salted butter had a better flavor and kept better in storage at —6° F. than heavily salted butter, as shown in the following table.

Table 52.—Showing Scores of Butter with Varying Amounts of Salt Before and After Storage.[1]

Lot No.	Salt Per Cent	Revolutions Worked	Scores Before Storage		Average	Scores After Storage			
			Credicott	Mittlested		Credicott	Keist	Mittlested	
1	none	12	93	93	93	93½	93½	93½	93½
2	2.20	12	93	93	93	93	93	94	93⅓
3	4.44	12	92	92	92	91	91	91	91
4	6.66	12	88½	88½	88½	88⅓	88	87	87¾
5	7.17	12	87½	87½	87½	89	89	88½	88¾
6	none	30	94½	94½	94½	94	94	94	94
7	2.92	30	91	90½	90¾	91	90½	90½	90⅔
8	6.13	30	89	91	90	90	90	90½	90¼
9	7.81	30	89	90½	89¾	88	88	87	87⅔
10	8.57	30	89½	89½	89½	85	85	84	84⅔

The above ten lots of butter were made from the same churning. Lots 1 to 5 were worked 12 revolutions, lots 6 to 10, inclusive, were worked 30 revolutions.

These findings, then, give evidence of the fact that while a small amount of salt may and does retard the action of some undesirable microbes, such as certain molds and yeast, and at the same time permit the activity of desirable bacteria, such as the lactic acid species and, therefore, has a tendency to improve the keeping quality of butter, the opposite effect may be expected with heavily salted butter.

But the effect of salt on the keeping quality of butter, is also governed and modified to a very appreciable extent, by the temperature at which butter is stored. Bacteria, in order to thrive on the food they find in butter, must have that food in liquid form. When the serum of butter, containing the curd

[1] Hunziker, Mills and Spitzer, Moisture Control of Butter. Purdue Bulletin 160, 1912.

and sugar, is frozen, bacteria cease to be able to utilize it and their activity stops. When butter is stored at or above the freezing point of water the liquid portion in both salted and unsalted butter is in solution. In salted butter liquid brine has a retarding influence on some of them, while in unsalted butter their development is unhindered. It is obvious therefore that at ordinary temperatures the unsalted butter will spoil more readily than the salted butter, a fact which is amply borne out in the commercial manufacture and handling of butter.

But not so when butter is stored at the cold storage temperature generally used in this country, i. e. —6 to —10° F. At such low temperatures the moisture in unsalted butter is frozen solid, a fact which makes further bacterial development impossible. In heavily salted butter on the other hand, the freezing point of the brine is very near the storage temperature. The brine therefore remains in solution for a relatively long period of time and the micro-organisms which are capable to resist the concentrated brine are able to continue their work. That the brine in heavily salted butter remains in solution for some time, if it freezes at all after the butter has been placed in cold storage, is clearly shown in the paragraph relating to "The Effect of Salt on the Moisture Content of Butter." Unsalted and lightly salted butter lost practically no moisture in cold storage, while heavily salted butter lost from one to three and one-half per cent moisture. Similar results are reported by Washburn.[1] These findings are in no way contradictory to those obtained by the investigators previously quoted who reported that salted butter kept better than unsalted butter, because of the differences in the temperature at which their butter was stored.

The earlier impression among buttermakers and also quoted in some of the text books was that salt covers up the bad flavors in butter, and it used to be recommended that butter of inferior quality should be salted heavily in order to hide the undesirable flavors. Our latest findings on this point do not bear out this assumption. On the contrary, experience has

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[1] Washburn. Influence of Salt on Storage Butter, Journal of Dairy Science, Vol 1, No. 2, 1917.

shown, that heavy salting rather intensifies than minimizes the effect of poor quality. Such butter usually takes on a disagreeable, coarse flavor particularly objectionable to the consumer. In fact the bulk of evidence goes to show that butter made from second grade cream is of better flavor and sells to better advantage when it is not salted at all. For this reason many of the most progressive creameries, whose daily make is sufficiently large to justify them to churn the different grades of cream separately, put their second grade cream into unsalted butter, for which they can realize a better price than if they salted it, and frequently their second grade unsalted butter brings as good a price as their first grade salted butter.

Leaving out of consideration the preference of the consuming public, one of the most important disadvantages of unsalted butter, as related to quality, lies in the fact that unsalted butter molds very much more readily than salted butter. Mold development usually makes its appearance within less than two weeks of manufacture. Since this is the period before the butter reaches cold storage, and during which the temperature to which the butter is exposed, is generally considerably above 32° F., mold growth makes rapid progress. In the absence of salt there is nothing to inhibit it, and if the unsalted butter happens to be made from cream that is high in acid when churned, the moldiness is further intensified. Molds flourish in an acid medium. Salt brine, on the other hand, retards mold growth. Salted butter, therefore, is not so prone to arrive on the market in moldy condition.

Effect of Salt on Possible Germs of Disease That May be Found in Butter.—This applies only to butter made from raw cream, as it is generally conceded that proper pasteurization of the cream eliminates the germs of infectious diseases from butter. Data on the effect of salt on the virulence of pathogenic bacteria, are not numerous and such data as are available are confined to the bacillus of tuberculosis. Schroeder and Cotton,[1] as the result of experiments with infected butter, conclude that living bacilli of tuberculosis will retain their infectious properties for at least 160 days in salted butter when

[1] Schroeder and Cotton, The Relation of the Tubercle Bacillus to Public Health, U. S. Dept. Agr., B. A. I. Circular 153, p. 38.

kept without ice in cellar. Mohler, Washburn and Doane[1] report as follows: "No dependence should be placed upon the action of the salt that is added to butter as an agent in the destruction of Bacillus tuberculosis. It has been shown that the effect of salt as commonly used in the manufacture of butter, is very slight at best. Most of the samples used were salted with the usual amount. Yet the butter contained its virulence for 6 months."

These facts emphasize that the heavy salting of butter, as usually practiced on the dairy farm where butter is made, is not an adequate substitute for pasteurization and that pasteurization is indispensible as a guarantee of freedom from disease germs.

Effect of Salt on Moisture Content of Butter.—Before the salt is added to butter, butter represents an emulsion of water-in-fat, in which the water is present in very small droplets, of relatively uniform size and even distribution.

The addition of salt causes this emulsion to be disturbed. The salt, owing to its great affinity for water, draws many of the water droplets together into larger droplets and drops and even larger aggregates. There is a marked decrease in the number of small droplets and an increase in the number of large droplets. And there is an unmistakable tendency for water to run out of the butter, causing a decrease in the percentage of moisture.

In butter made from cream that was not sufficiently cooled, nor held at the low temperature long enough to thoroughly chill and harden the fat before churning, the salting invariably produces a leaky body. In this case the mechanical condition of the fat is such that the formation of the water-in-fat emulsion, resulting during the churning process, is incomplete. While it is sufficiently complete to prevent unsalted butter from being leaky (unsalted butter never is really leaky) it is not sufficiently complete to withstand the emulsion-disturbing influence of the salt. It yields to the salting-out process and becomes leaky.

At best the salt tends to decrease the moisture content of

[1] Mohler, Washburn and Doane. Virility of Bacillus Tuberculosis, U. S. A. I. 26, Annual Report, 1909.

butter to some extent, and in the case of butter made from insufficiently chilled cream this decrease may be very great. This does not necessarily mean, however, that the finished product is lower in moisture in the case of salted butter than in the case of unsalted butter. The expulsion of moisture by the salt occurs during the first few revolutions of the workers. As the working continues, especially with the churn doors closed, brine is reincorporated and the moisture content again increases. Salted butter, at the conclusion of the working process may, therefore, contain as much water as unsalted butter, the salt replacing a corresponding portion of the fat and not of the water, causing salted butter to be lower in butterfat than unsalted butter. This fact is demonstrated in the following table:[1]

Table 53.—Showing Effect of Amount of Salt on Moisture and Fat Content of Butter When the Butter is Worked With the Churn Gates Closed.

Lot No.	Ounces of Salt per Lb. Fat	Revolutions Worked	Chemical Composition of Butter in Per Cent				
			Salt	Fat	Moisture	Curd	Ash
April, 1907 (before storage) worked 12 revolutions							
1	none	12	.02	84.58	14.05	.63	.20
2	⅔	12	2.20	83.00	14.07	.60	.19
3	1½	12	4.44	81.22	14.00	.60	.19
4	2¼	12	6.66	77.70	14.78	.61	.18
5	3¼	12	7.17	77.31	14.75	.60	.20
Average			4.10	80.76	14.33	.61	.19

When butter is placed i ncold storage the loss of moisture in salted butter is very much greater than that in unsalted butter, as shown in experimental data[1] in Table 54.

As shown in Table 54, the loss of moisture of butter in cold storage is greatest in heavily salted butter, while it is very slight in lightly salted butter. While unsalted butter lost no moisture in eight months storage at —6° F., lightly salted butter lost .42 per cent and heavily salted butter as high as 3.08 per cent. Similar results were obtained in exper-

[1] Hunziker, Mills and Spitzer, Moisture Control of Butter, Purdue Bulletin 160, 1912, p. 399.

iments conducted by Rahn, Brown and Smith.[1] This loss of moisture in storage was formerly attributed to evaporation, and such is in fact the case to a limited extent with butter stored at ordinary temperature. In commercial cold storage, however, moisture does not evaporate to any noticeable extent.

Table 54.—Showing Loss of Moisture in Butter in Cold Storage.

Per Cent Salt	Per Cent Moisture		
	Fresh	Stored 8 Months at -6° F.	Decrease of Per Cent Salt
none	14.05	14.20	....
2.20	14.07	13.65	.42
4.48	14.00	13.01	.99
6.66	14.78	11.70	3.08
7.17	14.75	11.83	2.92

If here the loss of moisture were due to evaporation, this decrease of moisture would necessarily have to be accompanied by a material increase in the per cent of salt. This is not the case, as shown in the results of Hunziker, Mills and Spitzer in table 55.

The loss of moisture in butter in storage is apparently due to leakage, caused partly by the precipitation and contraction of the casein, rendering the buttermilk less viscous and giving the butter a more open texture, and partly to the fact that in heavily salted butter the brine is so concentrated that its freezing point is near that of the cold storage temperature. This leaves the moisture in butter in liquid form during a considerable part of its storage period and gives it an opportunity to leak out. In the case of unsalted and lightly salted butter the moisture freezes at the usual cold storage temperature, preventing further leakage. In butter stored at ordinary temperatures and not far below the freezing point of water, the leakage of moisture in both salted and unsalted butter would be more nearly the same.

[1] Rahn, Brown and Smith, Keeping Qualities of Butter, Michigan Technical Bulletin 2, 1909.

Table 55.—Salt Content in Fresh and Stored Butter.[1]

Lot No.	Ounces of Salt Added per Pound of Fat	Fresh Butter		After 8 Months Cold Storage	
		Per Cent Moisture	Per Cent Salt	Per Cent Moisture	Per Cent Salt
1	none	14.05	.02	14.20	.02
2	⅔	14.07	2.20	13.65	2.01
3	1½	14.00	4.44	13.01	4.48
4	2¼	14.78	6.66	11.70	5.57
5	3¼	14.75	7.17	11.83	7.07
Average per cent salt.......			4.10		3.83

WORKING THE BUTTER

Purpose.—The fundamental purpose of working the butter is to completely dissolve, uniformly distribute and properly incorporate the salt, to accomplish as complete as possible a fusion between brine and water in butter, and to bring the granules of butter together into a compact mass for convenient handling and packing. Incidentally the working process further serves to expel buttermilk and to control the moisture content of butter. The working is an important part of butter manufacture, it is a science which requires knowledge, and it is above all an art that demands experience and judgment on the part of the operator, if uniformly satisfactory results are to be obtained.

Butter Workers.—There is a great variety of butter workers on the market, in principle they are conveniently divided into two classes, namely those which are independent of the churn, and in the use of which the butter is taken out of the churn, and those which are a part of the churn, known as the combined churns and workers.

To the first group belong all the handworkers such as are generally used in farm buttermaking and the mechanical table workers which were formerly used in American creameries and are still used to a considerable extent in European creameries. These independent butter workers consist of a bowl, tray or table on which the butter is placed and where it is worked with ladles, or with a lever, or by one or more revolving cor-

[1] Hunziker, Mills and Spitzer, Moisture Control of Butter, Purdue Bulletin 160, 1912.

rugated rollers. In the case of the large table workers, both the table and rollers revolve. When only small quantities of butter are handled, these workers may serve the purpose fairly well, but at best they are a very crude apparatus, their operation requires much labor, is time consuming, lacks uniformity of results as to distribution of salt and moisture, makes the control of temperature of the butter impossible, renders the protection of the butter from flies in summer and diverse impurities difficult, and exposes the butter excessively to light. Even for the farm dairy the combined churn and worker is greatly preferable and such workers are now available, adapted for use in dairies with a small make.

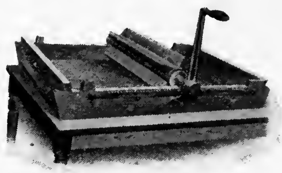

Fig. 55. Hand butter worker
Courtesy Creamery Package Mfg. Co.

For creamery use, the independent worker is practically out of the question and the combined churn and worker is the only really satisfactory equipment. The combined churn and workers are of two types. In one type the butterworkers, consisting of one, two or four rollers, according to the make of the churn, are permanently installed in the churn, running lengthwise, either near the periphery of the churn barrel or through the center of the churn. The workers revolve on steel shafts with bearings in each end of the churn, and with the gear attachment at one end on the outside of the churn. To this type of combined churns and workers belong the Disbrow, Dual, Perfection, Victor, Wizard, etc. In the other type of combined churns and workers one end of the churn is open and the butter workers are on a separate truck outside of the churn. When ready for working, the truck is moved up to the open end of the churn, the workers are pushed into the churn, and the driving gear located outside of the churn is slipped in place. The Simplex churn is a representative of this type of churn, On the interior of the combined churns and workers one or more shelves are fastened to the sides of the churn; as the churn revolves these shelves carry the butter and some of the water up and drop them over the workers.

In churns containing one worker only, as is the case with the Perfection churn, the roller works against a shelf, the butter being worked while passing between the roller and shelf.

Fig. 56. One-roll workers perfection churn
Courtesy J. G. Cherry Co.

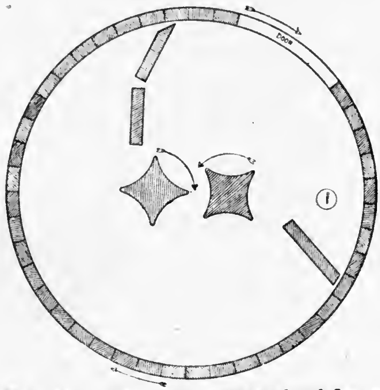

Fig. 57. Two-roll workers' Disbrow churn
Courtesy Davis-Watkins Dairymen's Mfg. Co.

In churns containing one or more sets of two rollers each, roller works against roller, the butter being worked while passing between the rollers. To churns of this arrangement belong the Disbrow, Dual, Simplex, Victor (4 rollers) and Wizard. The Dual churn is equipped with an idler, a small, loose roller on each side of the main workers. These idler rollers assist in guiding the butter towards the workers and prevent it from dropping down outside of the workers. In some churns (Disbrow and Victor) the workers travel with the drum of the churn, while in other churns (Dual, Perfection, Simplex and Wizard) the worker or workers are stationary and revolve only on their own axis. In all churns excepting the Wizard, the churn revolves while the workers are rotating. In the Wizard the churn makes one turn, dropping the butter on the workers, then it automatically stops and the workers start rotating. When the butter has gone through the workers, the churn again revolves and the operation is repeated.

In order for the churn workers and shelves to perform their work properly, to work all the butter alike, to distribute the moisture and salt evenly and produce uniformity of color in the butter, they must be correctly set, must be taut and free from excessive slack. The distance between workers and between worker and shelf must be the same over their entire

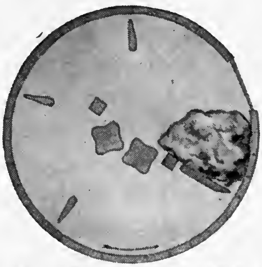

Fig. 58. Two-roll workers with idlers, Dual churn
Courtesy Creamery Package Mfg. Co.

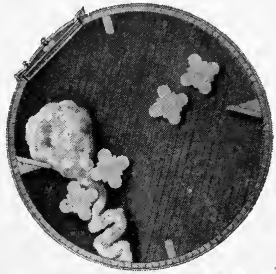

Fig. 59. Four-roll workers Victor churn
Courtesy Creamery Package Mfg. Co.

length, the workers must be so set that, when in operation, the ridges of one worker meet the grooves of the opposite worker, and there must be sufficient freedom from slack or looseness to insure permanency of this correct position of the workers while in operation. Improperly set, maladjusted, loose and slipping workers cause uneven working and this in turn almost invariably causes mottles.

Looseness or slipping of the workers is always due to a faulty mechanical condition of the churn. It is caused either by the rollershaft having worked loose in the end of the worker, or by the rollershaft slipping in the gear wheel due to a worn key, or to an excessively worn condition of the cogs in the gear wheels. It is a part of the buttermaker's duty to see to it that the churn and workers are constantly kept in proper mechanical repair.

Overloading the Churn.—The author's observation among creameries has been that it is one of the common tendencies of the buttermaker to overload the churn. Similar experience is related by Professor F. W. Bouska,[1] butter expert for the American Association of Creamery Butter Manufacturers. The

[1] Bouska, Elgin Dairy Report, 1914.

amount of butter which any given churn will properly work, is dependent on a variety of factors:

Churns in which the butter is brought up on the workers in several installments (Simplex) with each revolution of the churn, can take care of more butter, without overloading the workers, than churns in which the butter is deposited on the workers in one mass. Workers that are deeply corrugated and are placed a considerable distance apart, will work more butter than workers with shallow corrugations and which are set close together. In the case of too great a space between workers, however, it is difficult to work small churnings satisfactorily. High-speed workers will handle more butter than low-speed workers. Too low a speed of the workers makes moisture control difficult and tends toward leaky butter. In the case of hard butter, a slow speed causes excessive expulsion of water. Excessive speed of the workers causes rapid incorporation of moisture and makes expulsion of water more difficult. Wide workers can take care of more butter than narrow workers, in the latter case the butter is prone to fall over the workers and to miss being worked. Soft butter increases, while hard butter decreases, the capacity of the workers.

Overloading the churn often causes the butter to be crowded toward the ends of the churn. More butter being loaded on the workers than they are able to work through, causes the butter to pile up; it presses against the ends of the churn. The uneven surface of the ends, magnified by the projecting bolt heads and the sunk-in spy glasses, makes part of the butter stick to the ends and to be carried around by the revolving drum without going through the workers, all the butter does not get the same amount of working, there is uneveness of moisture, salt and brine distribution, and the butter usually becomes mottled.

In order to avoid the objectionable consequences of this condition, the buttermaker may stop the churn and turn the butter which piled up at the ends toward the center. This practice minimizes the resulting defects, but it is laborious, time-consuming and fails to remove the cause of the trouble.

The tendency of the butter to crowd toward the ends of the churn is not always due to there being more butter in the churn than its rated capacity under normal conditions can properly take care of. Frequently it is caused by the fact that, when renewing the workers, a larger diameter worker is furnished and installed. Since the distance between the centers of the worker shafts remains the same, regardless of size of worker, the installation of the larger diameter workers leaves less space between workers, so that the butter of a churning of normal size cannot all go through the workers and the effect is obviously the same as if the churn with workers of proper size had been overloaded. When replacing old churn rollers by new ones, great care should, therefore, be taken that the new workers are of the proper size.

Of late years manufacturers of churns that contain more than one worker, have endeavored to overcome the tendency of the butter to crowd toward the ends, by installing at the top and bottom in the center of the churn, a so-called "centerboard." The centerboard is a heavy cypress board, about 24 to 36 inches long, running lengthwise, with one edge lying against the churn drum and the other edge pointing radially toward the center. This board is braced on its sides by heavy wooden braces.

The evident purpose of these centerboards is to give the butter more contact and therefore more stability to stay in the center (between churn ends) and thereby offset the adhesion at the ends which otherwise pulls the butter away from the center. The center board also helps to hold the butter over the workers and to prevent it from dropping over the outside of the workers without being worked. Practical experience shows that the centerboards do effectively help to prevent the crowding of the butter toward the ends. But, if the churn is really overloaded, so that the butter cannot all pass through the workers, a portion of it is bound to escape the workers and if it cannot crowd toward the ends it must inevitably fall off the workers over their whole length.

One of the most fundamental causes of the tendency in American creameries to overload the workers, lies in the fact that the listed working capacity of the majority of combined churns and workers on the market and in use is greatly over-rated. The working capacity of these churns is far below their churning capacity. The reason for this absence of proper proportion between churning and working capacity is obvious. Most of these churns were designed some twenty to thirty years ago and the design, from the standpoint of working capacity, is the same now as it was then. But in those early and formative days of the creamery industry the creameries received and churned a much thinner cream than they do now. Twenty or more years ago the cream separated on the farm averaged around 20 to 25 per cent fat. During the last score of years the creameries, the dairy schools and the dairy press, all have pointed out to the farmer the advantages of separating a richer cream and urged him relentlessly to produce and ship cream with a high per cent of fat. This campaign for richer cream, together with the abandonment of gravity creaming and the universal adoption of the farm cream separator, had their desired effect. Today many creameries receive cream testing as high as 50 per cent fat and the average cream when churned probably contains not less than 33 per cent fat.

It is obvious that combined churns and workers, designed for a working capacity of 20 to 25 per cent cream, have their workers overloaded when operated to the limit of their rated churning capacity, with cream that tests 33 per cent fat.

The overloading of the workers, whatever its cause may be, is bound to result in incomplete and uneven working, lack of uniformity of salt and moisture, inadequate fusion of brine and water and consequent streakiness and mottles.

Manner and Amount of Working.—After the washwater is drained from the churn, the churn is given one revolution to bring the butter on top, in front of the churn doors. A deep trench is then dug in the butter, running the entire length of the churn. The salt is placed into this trench, care being taken that the salt is distributed uniformly in all parts of the trench, otherwise there is prone to be a variation in color in butter from different parts of the churn. After salting, the trench is closed and the worker started. Some butter makers prefer to work the butter a few revolutions (3 to 6) before salting, either in the presence or absence of extraneous water, claiming that they can more readily control the moisture. Each individual butter maker has his own method which he believes to operate most satisfactorily. The amount of draining which the butter receives before salting, the method of salting and the draining incident to the working process, largely regulate the per cent of moisture which the finished product of one and the same churning will contain. The extent of draining and working that will yield the desired result as to per cent of moisture and body of butter, must be governed by type of churn and by the mechanical character of the butter in the churn.

Inasmuch as the mechanical character of the butter must determine how much working any given churning in any given churn requires and can stand, and since the mechanical character of the butter varies with many conditions, (such as locality, season of year, richness, acidity and temperature of cream, size of butter granules, fullness of churn, etc.) it is impossible to prescribe any set method that would prove satisfactory under all conditions.

The working should be continued until the butter has a compact, tough and waxy body, consistent with the desired moisture content. Butter has been worked enough when it breaks with a ragged edge upon passing a laddle through it quickly. Butter not worked sufficiently usually has a loose body, with the grain not packed together properly. Such butter is often leaky and lacks compactness. Butter overworked shows a tallowy or salvy texture in the case of very firm butter and a greasy texture in the case of very soft butter. See also "Moisture Control."

Effect of Working on Body and Color of Butter.—Properly worked butter has a tough, waxy body, is free from leakiness, greasiness and tallowiness and has a live, bright color, which is uniform throughout the package. When a plug of such butter is pulled out of the tub and is broken, the break presents an uneven surface similar to that of a piece of iron, showing that the grain is still intact.

Working has the effect of whitening the color of the salted butter. This is due to the reduction of the size of the water droplets in butter during progressive working. In unsalted butter the water droplets are present in the form of innumerable

Size of Water Droplets in Unsalted Butter During Working Process

Magnified 740 times

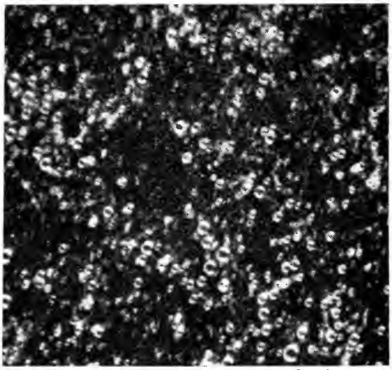

Fig. 60. Worked six revolutions, no mottles

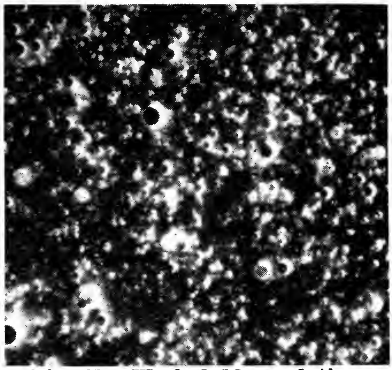

Fig. 61. Worked 12 revolutions, no mottles

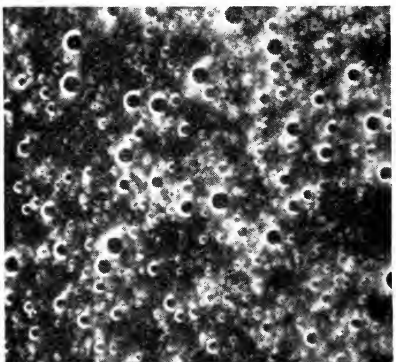

Fig. 62. Worked 18 revolutions, no mottles

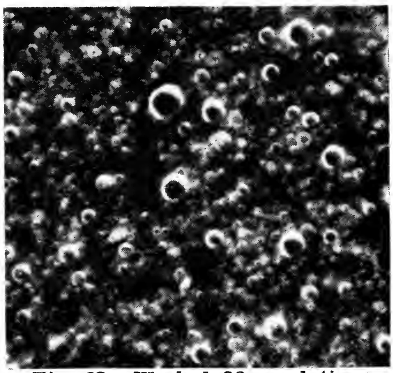

Fig. 63. Worked 26 revolutions, no mottles

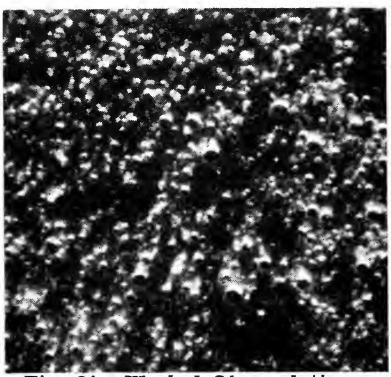

Fig. 64. Worked 34 revolutions, no mottles

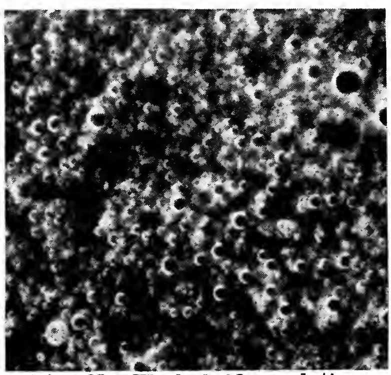

Fig. 65. Worked 66 revolutions, no mottles

Size of Water Droplets in Salted Butter During Working Process
Magnified 740 times

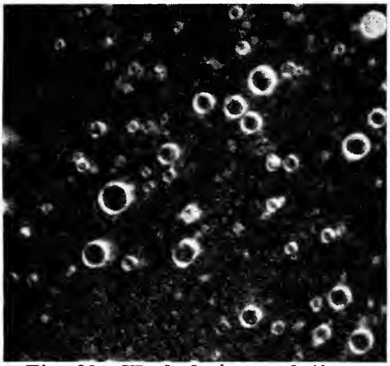

Fig. 66. Worked six revolutions, mottled

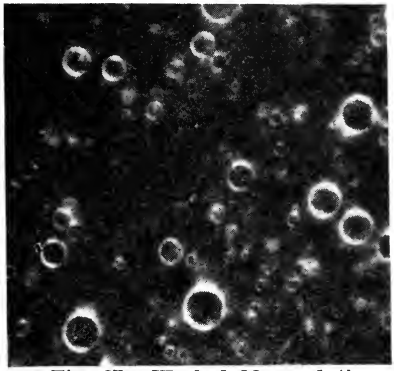

Fig. 67. Worked 12 revolutions, mottled

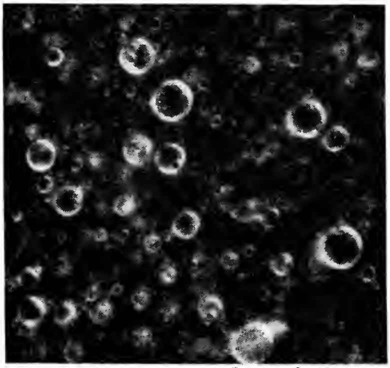

Fig. 68. Worked 18 revolutions, mottled

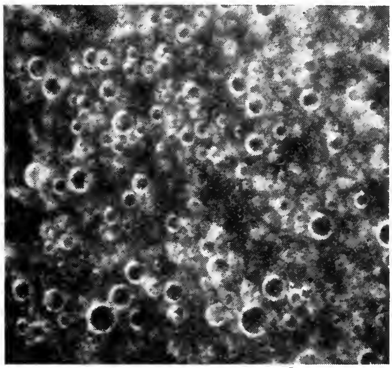

Fig. 69. Worked 26 revolutions, slightly mottled

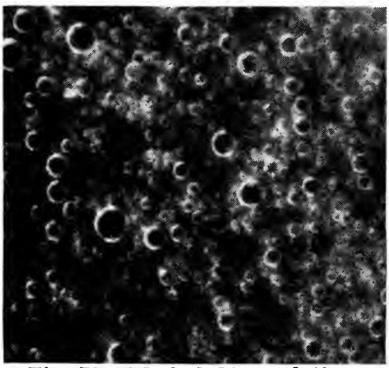

Fig. 70. Worked 34 revolutions, no mottles

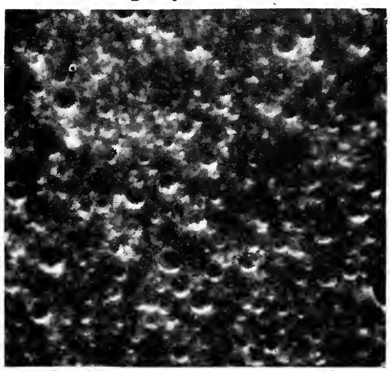

Fig. 71. Worked 66 revolutions, no mottles

and exceedingly small units which give the butter an opaque whitish color. These droplets remain in this condition during the process of working. Working therefore has no noticeable effect on the color of unsalted butter.

But not so in the case of salted butter. When butter is salted many of these small water droplets run together, forming fewer but larger units or drops. This causes the opaque whitish appearance to vanish and to be replaced by a clear, more translucent and more deeply yellow color, approaching more nearly the natural color of pure butterfat. As the working process proceeds these large droplets are gradually divided again into smaller droplets and as this division and increase of number of small water droplets progresses, the color of the butter begins to lose some of its clear, translucent, bright yellowness. By continuing the working process to the point where the water droplets are reduced to their original very small size which they presented before salting, the color of the butter can be returned to the opaque whiteness of the unsalted butter. This can only be done, however, by greatly overworking the butter.

The above phenomenon also explains why different portions of butter from one and the same churning show different shades of yellow, when all the butter in the churn does not receive an equal amount of working, as may be the case when the workers slip or are overloaded.

Insufficiently worked butter has a loose, open and often a leaky body. A plug of such butter drawn from the tub or cube usually shows lack of compactness and sometimes marked crumbliness. In the case of salted butter, such butter is often gritty, due to the presence of undissolved salt and it usually is streaked or mottled in color, due to the incomplete fusion of brine and water and the consequent uneven size and distribution of the water and brine droplets. While still in the churn, such butter generally has a loose body, being profusely perforated with water pockets which are plainly visible when the butter is cut with the ladle. Unsalted butter, while it may be crumbly and may lack the plasticity of properly worked butter, is compact and free from excessive leakiness, even when very insufficiently worked, and such butter does not become streaky nor mottled in color, because the water droplets which it contains are very minute and there is a permanent absence of large droplets.

Overworked butter usually has a poor body and defective grain, severely criticized on the market. Overworking injures the grain of the butter. If butter is overworked while soft, the body is prone to be greasy; if overworked when hard it tends to be salvy in texture. A plug of such butter pulled from the tub breaks with a smooth surface, similar as if it were cut with a knife and showing that the grain has lost its identity. Overworked butter also has a dull, lifeless color, similar to oleomargarine and which is not attractive to the buyer. Such butter seldom stands up well on the market under unfavorable temperature conditions and its flavor and keeping quality may be impaired. Frequently butter of this description contains excessive moisture. Butter with a firm body will stand much more working without injury to its body than butter that is soft.

Effect of Working on Moisture Control of Butter under diverse Conditions.—The working is an important part of the process of buttermaking as a means to regulate the moisture content of butter. In fact, the expulsion or retainance of moisture largely depends on the method employed for working.

The smaller the granules when the churn is stopped, the larger the amount of moisture they hold. Churning butter to large granules or lumps tends to expel moisture, unless such overchurning is due to very soft butter, in which case the butter may hold abnormally much moisture. If the churning process is stopped at the proper time, that is when the butter has gathered in the form of granules of the size of small corn kernels, butter contains more than sixteen per cent moisture immediately after the buttermilk has been drawn off, and immediately after washing it still contains an excess of moisture. The subsequent salting and working removes this excess moisture. If the butter granules are round, smooth and firm as is usually the case in fall, winter and early spring, and especially in the case of thin cream, the excess of moisture escapes very rapidly and there is a strong tendency toward too great escape of moisture, a low moisture in the finished butter and a correspondingly low overrun. The excessive expulsion of moisture can be minimized by draining less thoroughly and working with the churn gates closed, and it can be entirely prevented by working the butter in the presence of a small amount of water. The water so used should be of practically the same temperature as the butter.

Table 56.—Showing Amount of Moisture in Butter After Drawing-off Buttermilk, After Washing and in Finished Butter When Butter Granules Are of the Size of Wheat Kernels.[1]

No. of Churning	Size of Granules Inches	Per Cent Moisture		
		After Drawing Buttermilk	After Drawing Washwater	Finished Butter
1	⅛	23.64	19.87	15.48
2	⅛	30.66	26.66	13.12
3	⅛	21.77	19.20	14.45
4	⅛	25.00	19.66	14.59
5	⅛	19.83	19.07	13.84
6	⅛	21.28	19.57	13.86
7	⅛	24.04	18.58	14.15
8	⅛	22.55	18.63	14.78
9	⅛	22.33	17.65	15.00
10	⅛	21.70	16.94	15.80
Averages ...	⅛	23.28	19.58	14.51

When the butter granules are very hard, so that considerable working may be necessary in order to bring the moisture content up to the maximum allowed by law (less than sixteen per cent), there is always more or less danger of injury to the grain of butter.

If the butter granules are soft, flaky, irregular and have a ragged surface, as is usually the case in late spring and early summer, when most of the cows have freshened and have access to abundance of succulent pasture, which conditions yield fat globules of large average size, and butterfat with a relatively low melting point, the excess moisture does not escape so readily, and there is danger of excessive moisture in the finished butter. This is due to the fact that cream with predominatingly large fat globules and butterfat with a low melting point, produce a soft butter. This soft butter is more miscible with water

[1] Hunziker, Mills and Spitzer, Moisture Control of Butter, Purdue Bulletin 160, 1912.

than hard butter and when the churn is stopped, the moisture is incorporated in the butter granules in the form of very fine drops which are expelled with difficulty. Whenever the butter maker has difficulty to keep the moisture down, the butter should be drained very thoroughly before working and should be worked with the churn doors ajar. It is then advisable to work the butter four to five revolutions before the salt is added and to drain again. During the working the churn should be stopped after every two to three revolutions, allowing it to swing freely, with the churn doors ajar and down, permitting the free moisture to escape readily. In cases of extreme difficulty of keeping the moisture within the limits of the law, it may be necessary to delay the working after the salt has been added, for a considerable time. This gives the salt an opportunity to assist in the expulsion of moisture. Owing to its great affinity for water it draws the minute drops of water out of the butter and gathers them in larger drops which, upon subsequent working, are more easily expelled.

It occasionally happens that, owing to the extreme natural softness of the butterfat, or to faulty handling of the cream before churning, or to too high a churning temperature, no amount of working will reduce the moisture content to or below the maximum legal limit. In such butter the moisture has formed so intimate a mixture with the fat, and moisture incorporation is so complete, that additional working, even to the extent of injuring the grain of the butter, fails to expel water. The only practical way to bring the moisture content of such butter within the limits of the law, is to set the butter in the cold room and allow it to harden over night. The next day it is then cut up into small pieces and worked again with the churn doors ajar and in a similar manner as above described. Unless its moisture content is very greatly in excess and the incorporated moisture is present in the form of abnormally fine drops, this second working will remove sufficient moisture to meet the requirements of the law. If it still contains over sixteen per cent moisture, more moisture may be expelled by putting the butter back into the cold room and working it again the next day. The hardening of the butter in the cold changes its mechanical make-up and makes it more granular. Some of the minute water particles gather into large drops which can be expelled when the butter is worked again. It is obvious that this repeated working does not improve the body of the butter and should be avoided as much as possible.

The buttermaker should bear in mind that when the butter has been washed, it contains excessive moisture, part of which must be expelled, and that moisture control is not so much a matter of incorporating additional moisture into butter, as it is a matter of properly regulating the expulsion of moisture. The control of the expulsion of moisture can be greatly facilitated by proper handling of the cream as to churning temperature, according to the character of the butterfat and this in turn is a problem which requires constant observation and intelligent adjustment of the process in accordance with prevailing conditions. See also "Moisture Control."

Effect of Working on the Flavor and Keeping Quality of Butter.—Generally speaking, the less the butter is worked and the more nearly the grain of the butter is preserved, the better will be the flavor and keeping quality of the finished product. There is an unmistakable tendency in American creameries to work their butter too much and thereby to impair its body, and possibly its flavor and keeping quality. This tendency is chiefly the result of one or both of the following two practices:

In order to hasten the process of manufacture the butter is worked immediately after the salt has been added. The salt is given no time to dissolve before working. This requires considerable working, especially when the usually large amount of salt is incorporated, in order to insure complete solution of the salt and to avoid grittiness and in order to distribute the salt evenly and to fuse the water and brine completely so as to avoid waviness and mottles. For this reason some of the very badly mottled butter has an exceptionally good flavor. This is not due to the presence of the mottles, but it is the result of the same condition which tends to bring about the mottles, usually underworking, or the absence of overworking. In some European creameries where a special effort is made to produce quality, the butter is not worked for several hours after the salt has been added. The salt thus has an opportunity to largely go in solution before working and but little working is needed to complete the solution and distribution of the salt. The same reason, why underworked butter is of better quality than much-worked butter, also accounts in part for the fact that unsalted butter is often of better quality and keeps better than salted butter. Such butter does not require working in order to insure solution of the salt and to avoid mottles. It therefore is often not worked as much as salted butter and has a better body and better grain.

The second reason for the tendency of overworking butter is the common practice of trying to incorporate the maximum amount of moisture which the law permits. In late spring and early summer, when the butter is relatively soft and naturally takes up water readily, there usually is no need of excessive working in order to incorporate moisture, and if the buttermaker understands his business, he need not overwork the butter to the extent of injuring its body or flavor. But not so when the butter comes firm and tends to be low in moisture as is the case in fall, winter and early spring. Under these conditions the butter often requires a comparatively large amount of working in order to contain the maximum amount of moisture allowed by law. This is true especially in the states where much cottonseed meal and similar fodder producing hard and crumbly butter, are fed. Butter made from such cream, when worked in the usual way, and just enough to insure proper compactness, usually does not contain much over 13.5 per cent moisture and the additional moisture can only be incorporated by additional working and this is often done at the expense of body, flavor and keeping quality. From the point of view of the quality of American butter this additional working or overworking is objectionable and it is a debatable question if, in the long run, the loss in price and prestige due to sacrifice in quality, is not greater than the increased returns due to larger overrun. If in winter, when butter naturally comes in the form of smooth, round and firm granules, the creamery insists on incorporating the maximum amount of moisture permitted by law, it would seem preferable to churn at a sufficiently higher temperature to make the butter come somewhat less firm, thereby increasing its ability to naturally hold moisture and making unnecessary excessive working. In this case great care should be exercised to chill the cream sufficiently long so as to guard against a slushy and leaky body of the butter.

The exact channels through which overworking of butter deteriorates its flavor and tends to cause such off-flavors as oily, metallic and fishy flavors, are not as yet well understood. Rogers[1] shows experimentally that overworking increases the amount of air present in butter and that the presence of air, in combination with other influences, enhances oxidation of the non-fatty constituents of butter. He further states that the development of a fishy flavor is hastened and made more certain by overworking, which increases the air and the oxidizing surface and that fishy flavor may be produced with reasonable certainty by overworking the butter made from sour cream.

Rogers' conclusions on this point have not been fully borne out by the work of Hunziker. While overworking certainly does not improve the quality of butter, it fails to produce the distinct defects indicated by Rogers with any degree of regularity. Nor does it necessarily increase the air content of butter. The incorporation of air in butter begins as soon as the cream is subjected to agitation in the churn and up to a certain point it increases, greatly retarding the completion of the churning process. In fact the amount of air incorporated in the interior and on the surface of the still microscopic butter granules is so great, that it is difficult to make satisfactory microscopic examinations of these granules. After the granules have reached a sufficient size to "break" the fat-in-skimmilk emulsion and to establish a buttermilk-in-fat emulsion which is butter, much of this air is released and the completion of the churning process is facilitated. And from this point on, any further churning and subsequent working appears to effect an expulsion of a portion of the air locked up in the butter, rather than an incorporation of additional air.

There is a vast difference between the overworking of butter that results from manipulating it with a spatula in small amounts as described by Rogers, and by working it in the combined churn and worker. While it is quite conceivable how, by special effort, air may be beaten into soft butter with a spatula, it is much less obvious that the squeezing which the butter

[1] Rogers, Fishy Flavor in Butter, U. S. Dept. Agr., B.A.I. Circular 146, 1909.

receives in the commercial combined churn and worker incorporates air and the probability of actual air expulsion in this case is by no means remote.

However, it is unquestionably a fact, that any air permanently present in the butter, becomes very finely divided and emulsified by overworking and in this form a much larger area of the butter becomes exposed to this air, so that, even without the actual incorporation of additional air, the injurious effect of the air present is greatly magnified.

The fact that overworking gives the butter a whiter color is not necessarily due to the incorporation of additional air as Rogers concluded, but it is invariably caused by the reduction of the size of the water droplets as shown by Hunziker and Hosman. Unsalted butter is always whiter than salted butter, both, before working and during any part of the working process. Microscopic examinations of butter during all stages of the working process, by Hunziker and Hosman, conclusively show, that in unsalted butter the water droplets are exceedingly minute while in salted butter they are relatively large, especially during the early stages of the working process. And, again, the whitening effect due to working takes place even when the butter is submerged in water during the working process, eliminating any possibility of incorporation of additional air.

It is also not improbable, though not experimentally proven, that the destruction of the grain of the butter, as is the case in overworking, tends to lessen the resistance of the fat to such oxidizing agencies as air, metallic salts, etc. and therefore hastens its deterioration.

When the butter has been worked enough, the workers are stopped and the churn is given another revolution or two in order to deposit the butter on top of the workers from where it can be easily removed and transferred to the tubs or cubes, or other receptacles.

Before removing the butter from the churn it should be accurately tested for moisture content, so that if the moisture is excessive, or deficient, it may be corrected by further working. For directions on controlling moisture see also chapter on Composition of Butter—Moisture Control—Chapter XVIII., and for directions on moisture tests see Chapter XXII.

Chapter XII.

PACKING BUTTER.

Variety of Packages.—Butter is packed and placed upon the market in a great variety of receptacles and forms, varying widely in shape, style and material, such as tubs, boxes, cubes, firkins, tin cans, crocks, pails, prints, rolls and individual molds, and varying in weight from one-fourth pound bars up to 110 pound firkins. The standard Danish firkin weighs 50 kilograms, or 110.23 pounds net. The great bulk of the American butter that is put up for the wholesale produce trade in the large markets is packed in tubs, boxes and cubes, while the local trade and retail stores prefer much of their butter in the finished package, the print. Export butter is put up in tubs and cubes, and butter intended for the tropics and much of the butter furnished the United States Navy, is packed in hermetically sealed tin cans. Farm butter is packed in crocks, small fibre boxes, small tubs and pails, rolls, special molds and prints. In many foreign countries the firkin is the predominating package, though much foreign butter is also packed in boxes and prints.

Tubs.—Butter tubs are usually constructed of spruce or white ash. They range in size from ten pounds to 63 pounds net. While no particular size has been adopted officially as the standard size tub, the 60 to 63 pound tub is by far the most popular and is used for the great bulk of American tub butter.

The war situation threatened a shortage of white ash and especially of spruce. For a time the creameries had difficulty in locating and contracting for a sufficient supply of tubs and prices soared to an unprecedented level. A campaign was started to invite and urge the creamerymen to break away from the butter tub and use boxes or cubes instead. The effort failed and the tub prevailed in spite of all handicaps. The reason for this persistence and tenacity with which creameries stick to the tub is not limited by mere custom and usage. There is no question that, all things considered, the 60 to 63 pound tub is the most satisfactory form of package in which to handle butter in bulk. The mechanical handling at the creamery, in transit, at the market end and in cold storage is by far easier and more practical than any other package of butter of equal capacity. With the possible exception of the firkin, which is not used in this country, and of the tin can which is too expensive a package for domestic use, the butter tub withstands better the abuse and rough handling it is necessarily subjected to in its journey from the creamery to the market, and arrives at its destination in better condition than other butter receptacles. Unlike cubes and boxes it has no nailed sides, ends, bottoms and tops to tear loose, the butter in it does not become soiled, because the tub is tight and dust-proof, which is often not the case with the boxes used for bulk butter.

The tub strips easily and quickly, the package does not have to be destroyed in order to get the butter out. Its disadvantages are that it does not pack quite as closely as square boxes, requiring somewhat more space in transit and in storage, and that tubbed butter does not cut as satisfactorily for putting up prints as does cube butter.

Smaller size tubs are used upon special request, to fill special orders and for special occasions, such as for scoring contest butter, etc. Butter tubs are lined with parchment liners and circles which protect the butter from woody odor, impurities, and contamination with mold and prevent it from sticking to the wood, so that the butter slips out of the inverted tub readily when "stripped."

Butter tubs should be constructed of the best quality of sound wood, and they should be stored in a dry, clean place in the creamery. They should be well put together, tight, and free from cracked staves. Tubs made from lumber that was felled while the sap was still running, or that has been lying in stagnant ponds, tend to give rise to woody odor and molds in butter. Their wood is prone to give butter an objectionable woody flavor. Often it is partly decayed and porous, in which condition it may harbor mold spores which contaminate the butter. Exposure of the tubs to dampness and to unclean surroundings in the creamery is an additional source of moldy butter. When stored in a damp room the tubs frequently become spotted inside and out with mold growth. The liners also may become the source of moldy butter, unless made of a good quality of parchment, kept in a clean, dry place and properly treated before use.

Preparation of Tubs and Liners.—All butter tubs should be properly treated before being packed, in order to remove the woody odor which is prone to be absorbed by the butter, to free them from mold spores with which they are always more or less contaminated, to make them airtight to hinder the growth of molds after packing, and to prevent excessive loss of weight due to leakage of brine. Moldy butter in the great majority of cases is the direct result of lack of attention to the proper treatment of tubs and liners.

Since salt has properties antagonistic to the growth of molds, the soaking of the tubs in a saturated solution of hot salt brine is a very common and fairly effective method of treatment. This is best done by immersing the tubs in a long vat containing the hot brine. The tubs should be nested so as to retain their shape, otherwise they are prone to warp out of shape. The tubs should be set to soak on the day before they are needed. If they are not clean or show signs of mold spots, they should be thoroughly scrubbed with a brush and hot water containing some alkali, before soaking. Steaming for 5 to 10 minutes is an additional safeguard against mold. The addition to the water or brine in which the tubs are soaked, of formaldehyde, sodium hypochlorite, boric acid and other disinfectants has also been recommended to guard against mold.

Formaldehyde lends the butter an objectionable flavor and odor, if used in other than exceedingly dilute solutions. A safe proportion that still is antagonistic to mold growth is a dilution of 1 part of formaldehyde in 400 parts of water, or about ¼ ounce formaldehyde in one gallon of water.

Hypochlorite of soda also should be used with caution, because of its tendency to bleach butter. It may be used at the rate of two tablespoons hypochlorite in four gallons of water.

Boric acid has no known injurious effect on butter. It is best used in the form of a .5 per cent solution or about 2/3 ounce in one gallon of water.

It should be clearly understood that all these disinfectants and antiseptics are injurious to health when consumed with food, and their presence in butter is in violation of the Federal Pure Food Act of 1906. Their use for treatment of tubs and liners may be justifiable as a means to stamp out an epidemic of mold in butter, but their continued use cannot be recommended and in any event the tubs after treatment should be rinsed with clean water or distilled water before packing.

Within the past decade the practice of brine-soaking the tubs has been superseded in a great many creameries by the more efficient treatment of paraffining them. The tubs should be paraffined whenever facilities permit. Proper paraffining obviates the temptation of using antiseptics as far as the tub as a source of mold in butter is concerned.

When butter is packed in paraffined tubs, it is unnecessary to soak the tubs in water or brine, in fact it is preferable not to, because the unsoaked tubs present a much more attractive appearance. The old practice of soaking butter tubs in water prior to packing had for its purpose to load the wood with sufficient water to minimize the absorption by the tub of moisture contained in the butter, which caused a considerable shrinkage in net weight. A properly paraffined tub is impervious to water and therefore is incapable of taking up moisture from the butter. If the tubs are not soaked in water the creamery should always put the tare on the tub. The unsoaked tub weighs from 1 to 2 pounds less than the soaked tub. Without determination of the tare weight, this difference will be lost to the creamery.

Soaking in water or brine before paraffining is desirable, however, in the case of tubs the staves and bottoms of which have shrunk to the point where a tight tub can not be secured and in order to hold the tub together.

Before paraffining, the tubs should be steamed out thoroughly until they are hot and dry. This opens the pores and permits the hot paraffine to penetrate. If they are paraffined while wet the paraffine will not penetrate, it merely sticks to the surface and is prone to peel off. If they are cold the paraffine cools before it has an opportunity to fill the pores, it fails to spread, in a thin, smooth and uniform layer and tends to crack.

The paraffine should be applied in such a way that it will coat the inside of the tub in the form of a thin film, filling the pores and cracks. The paraffine may be applied with a brush or by pouring a small amount into the tub and rotating the tub until the entire surface is covered, or it may be sprayed into the tub under pressure. The brush method is somewhat crude and tends to produce an uneven coating owing to rapid cooling of the paraffine.

In order to secure satisfactory results and avoid a rough and uneven coating of paraffine, the paraffine must be heated to the proper temperature. Rogers[1] found that at a temperature of 250 to 260 degrees F. the paraffine can be applied most satisfactorily. The paraffine may be heated over an oil stove or gas burner, but a more convenient arrangement, devised by Rogers, consists of a large pail or small tank equipped with a steam coil connected with the steam line of the creamery, and a drip is provided extending through the bottom of the tank and permitting the condensed steam in the coil to escape. A small amount of the hot paraffine is dipped from the tank into the tub, the tub is rotated so that the paraffine covers its entire inside surface. Then the tub is inverted on a galvanized iron drip tray in order to pour out, and reclaim any excess paraffine in the tub. Such an outfit can be constructed at small cost and is very serviceable, especially in small creameries.

There are now on the market also patented paraffiners which both steam and paraffine the tub. The paraffine is heated by a steam heated jacket. The tub is inverted over the paraffiner and steamed and sprayed with paraffine under pressure. These machines operate very fast, coating the tub with a smooth layer of uniform thickness and economizing the paraffine. These paraffiners are rapidly replacing the dipper and brush method.

Aside from protecting butter against mold contamination and mold growth the paraffining of tubs is advisable in order to minimize loss in weight due to leakage of moisture and to give the tub a neater appearance. Rogers[1] found the following loss of moisture in 12 paraffined and 12 unparaffined tubs of butter on the eighth day after packing:

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[1] Rogers, Prevention of Molds in Butter Tubs, U. S. Dept. Agr. B. A. I. Bull. 89. 1906.

	Paraffined tubs Pounds of butter	Unparaffined tubs Pounds of butter
When packed	757¼	766¼
8 days later	756	759
Shrinkage	1¼	7¼

When paraffine of the proper temperature is used, from two to three ounces are required per tub. The labor cost of paraffining is no greater than that of preparing a saturated brine solution.

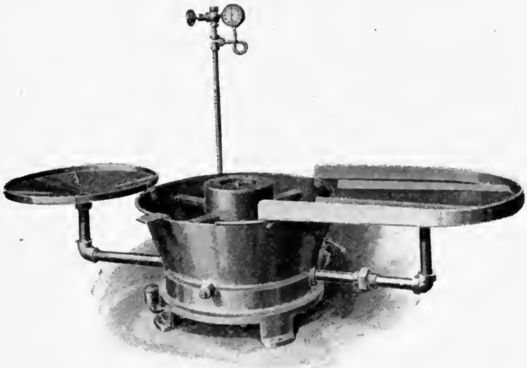

Fig. 72. Tub Paraffiner
Courtesy Creamery Package Mfg. Co.

It is advisable to paraffine tubs and to clean covers as shortly before they are needed as the routine of the factory permits, and to stack them, inverted, in a clean place, so as to prevent unnecessary soiling and recontamination.

Paraffined tubs should always be lined with parchment liners and circles, the same as the tubs prepared in the ordinary way. Unlined paraffined tubs strip with difficulty, the butter sticks to the comparatively rough surface of the paraffine. This is a serious objection at the market end.

Preparation of Parchment Liners and Circles.—The best quality of parchment liners only should be purchased. Inferior parchment invites excessive leakage of moisture and may injure the flavor of the butter. In the summer season, when the butter is often exposed to temperature conditions that cause it to be soft and therefore to yield readily to the knocks to which the tub is subjected in transit, there is always a tendency for moisture to be pounded out. Evaporation at the higher temperature is also most rapid. It is advisable, therefore, to use extra heavy liners in summer.

The liners should be of ample size so they will abundantly lap on the side, fold under at the bottom and lap over at the top. The circles should be large enough to cover the entire bottom of the tub. There is a tendency on the part of supply houses to furnish liners and circles that are of inadequate dimensions, unless the desired dimensions are specifically demanded.

The stock of parchment liners and circles should be kept in a clean, dry room, protected against dust, dirt and dampness. They should not be stored in the creamery cold room which is almost always damp.

Immediately before use they should be thoroughly soaked in hot saturated brine. The brine should be of such strength that a deposit of undissolved salt forms in the receptacle, it should be supersaturated, and its temperature should be raised to the boiling point. The circles and liners should be soaked in this hot brine for at least 5 minutes. Such treatment is a three-fold protection against mold development. The heat destroys mold spores that may adhere to the parchment, the soaking frees the parchment from much of its glucose content and glucose is an ideal food for bacteria, and the brine adhering to the parchment helps to inhibit the growth of mold germs that may be in or on the butter.

This treatment should be given parchment liners and circles used for packing unsalted butter as well as salted butter. The unsalted butter, because of the readiness with which it becomes moldy, needs these precautions more urgently than the salted butter. The fact that the brine-treated liner conveys some salt to the surface of the butter needs no serious consideration. The very small amount of salt thus imparted to butter is not noticeable and does not remove such butter from the class of unsalted butter.

The lining of the tubs should be done with care. The bottom circle should be so placed as to cover the entire bottom of the tub, and the line should be strung around the periphery of the tub uniformly and neatly, and in such a manner as to cause one inch of the liner to project above the top of the tub.

The tub covers should also receive some attention. They often contain cinders, soot and dust, which they usually gather in transit to the creamery and in the creamery stock room. These impurities, when the cover is fastened to the packed tub, drop on the salt which is generally sprinkled on the top circle and they soil both the salt and the circle, give the package, when opened by the prospective buyer, an unsightly appearance and convey an unfavorable impression. If the tub happens to be subjected to very rough handling, they even may work into the butter. It is important, therefore, that the tub covers be thoroughly cleaned before they are fastened to the tub. This can readily be done by turning them bottomside up and turning the water hose on them until they are freed from all foreign matter.

Boxes and Cubes.—Some of the Eastern markets require the butter to be packed in square wooden boxes, holding about 50 pounds of butter. These boxes should be constructed of good sound wood, with bottoms, sides and tops at least one-half inch, and ends at least ⅞ inch thick, properly assembled and nailed with 4 penny cement-coated wire nails. They should be paraffined and otherwise treated in the same manner as the tubs and carefully lined with parchment paper.

In the Pacific Coast markets, both for domestic and for export trade, the cube is the standard butter package. The San Francisco Wholesale Dairy Produce Exchange issued official regulations concerning the size, shape and preparation of the cube, which went in force Feb. 1, 1916, as follows:

"In order to grade as 'extras' butter must be packed in cubes as follows: The materials of the sides, tops and bottoms shall be one-half inch in thickness and the ends ⅞ inch in thickness. Lumber to be surfaced on both sides, and corners of cubes nosed and rounded. Inside dimensions shall be 12¼x12¼x13½ inches and the cubes shall be packed to a uniform weight of 69 pounds net at churn and marked 68 pounds on each end of each cube, as the shrinkage from creamery to market is about one pound. The cubes shall be paraffined on the inside and lined with parchment paper."

Firkins.—Firkins are not used in this country for packing butter except on very rare occasions. They are a popular butter package in European countries especially for export and storage butter (Dauerbutter). Firkins (Drittel) hold 50 kilograms or 110.23 pounds of butter. These barrels are 55 cm. (22 inches) in height and their diameter in the center and at the ends is 34 and 41 cm. (13.6 and 16.4 inches) respectively. Before packing they are steamed, soaked in cold water, brine or sal soda solution, for one day, then rinsed out with hot water and again with cold water after which salt is rubbed into the staves on the inside. The bottom is then covered with a thin layer of salt, and the firkin is lined with parchment. After packing, the top of the butter is beveled off toward the sides and covered with a layer of salt. The object of having the surface of the butter highest in the center and tapering toward the sides is to permit the brine to run into the space between the butter and the side of the barrel when the butter, upon standing, has receded from the sides of the barrel; this shuts out the air and assists in protecting the butter against mold, etc.

Tin Cans.—Butter intended for the tropics and South America and some butter supplied the U. S. Government is packed in hermetically sealed tin cans. Exporting houses buying their butter from American creameries and supplying the tropics buy the butter in tubs and repack it into tin cans, which are subsequently hermetically sealed. These cans hold from ¼ to 5 kilograms, the metric system being used as the basis of weights. They are packed into cases and in order to prevent shaking and damage to the cans, the interstices between the cans and the sides of the case are filled in with some cheap, light packing material such as rice hulls, shavings, excelsior, corrugated paper, etc.

The object of the use of a non-absorptive and hermetically sealed package is to prevent leakage of water and oil and to improve the keeping quality of the butter, exposed to unfavorable temperature conditions, by excluding the air. Experiments conducted by Rogers[1] show that sterile butter so packed and

[1] Rogers, "Canned Butter." U. S. Dept. of Agriculture, B. A. I. Bulletin 57, 1904.

held for one hundred days at 23° C. showed no increase in acidity. From these results Rogers concludes that the causal relation of physical agents such as heat and moisture to changes of the butter is excluded. In the case of non-sterile canned butter examination showed a marked change in the texture and flavor. The changes were gradual; when about 25 days old, a distinct off-flavor was noticed which increased in intensity, until, at two hundred and ninety-seven days in one case and at two hundred and fifty-one days in another, there was a disagreeable, fishy flavor and a strong penetrating odor. There was also a correspondingly slow increase in the acidity. Micro-organisms which consisted almost entirely of lactic acid bacteria, a comparatively small number of Torula yeasts and a few liquefying bacteria decreased rapidly until there were present only a few spore-forming liquefying bacteria. Owing to this marked decrease in germ life, Rogers attributes the increase in acidity and the off-flavor to the probable action of fat-splitting enzymes.

Weigmann[1] in a very extensive investigation studied the keeping quality of butter made by different processes and sealed in tin cans, samples of which were placed on board of German men-of-war and which were returned and examined at intervals of six, twelve and eighteen months. These results demonstrated that there is a great variation in the keeping quality of different lots of butter and that while prolonged storage under unfavorable temperature conditions tended to intensify the deterioration of the butter, a few of the samples packed in tin cans returned in excellent condition even after eighteen months' travel. While Weigmann's results were not conclusive and while his fundamental aim was to determine that process of manufacture which would produce the best keeping butter, the data secured demonstrated that under certain ideal conditions of manufacture, butter packed in tin cans has remarkable keeping quality.

In the canning of butter the tin plate used should be coated with shellac or enamel to protect the can against the action of the acids and the brine of the butter and to guard the butter against rapid deterioration as the result of such action. While tin itself is an inert metal that does not yield to the action of

[1] Weigmann, "Versuche zur Bereitung von Dauerbutter" Milchwirtschaftliches Zentralblatt, Vol. 44. Nos. 23 and 24, 1915.

acids and brine, iron is quickly corroded by these agents. The tin plate of the butter cans is sheet iron with a thin coating of tin. This tin coating is not always entirely impervious and sooner or later the acids and the brine will attack the iron underneath, unless the tin plate is heavily shellaced. Iron salts thus formed are disastrous to the quality of the butter. Of late years, and particularly as the result of the shortage of tin plate, cans constructed of aluminum are also being used for packing butter.

Packing tubs, boxes, cubes and tins.—After the packages have been properly treated and lined, they are ready for the butter. They are now conveniently arranged in a row in front of the churn and the butter is transferred into them from the churn. Since the distribution of salt and moisture in the butter is seldom entirely uniform in all parts of the churn, butter from the same part of the churn should be distributed into the different tubs, boxes or cubes, so that all packages receive butter from all parts of the churn. The butter should not be transferred with the naked hand. The skin of the perspiring operator should not touch the butter, he should either wear cotton gloves or rubber gloves, or use ladles, or both. Before using the ladles and packers they should be thoroughly washed and steamed in order to prevent unnecessary contamination of the butter with germ life, then they should be soaked in cold water to prevent the butter from sticking to them. The gloves should be clean and sweet-smelling, and when taken off they should be placed in brine.

It is important that the butter in the tub be packed very solidly, avoiding air pockets, especially between the butter and the sides of the package, which admit air and favor mold growth. Pockets in the body of the butter are undesirable also because these pockets collect the brine, cause uneven distribution of the moisture, uneven color, and give the butter a leaky appearance. The package should be filled completely full and finished neatly on the surface. This is best done by filling the tub or box above the edge of the wood, tamping thoroughly with the packer and cutting off the surplus with a taut wire or a sharp piece of wood—wood is preferable. The border of the liner, which should project about one inch, is then neatly folded over toward the center and the butter is covered with the top circle, preferably of cloth, on which is strewn a handful of clean, dry salt. The tub cover is then fastened down with 3 to 5 tin fasteners, or in case of the box the lid is nailed down firmly. The package is weighed and marked with the net, tare and gross weight and the churning number, and is placed in the refrigerator until ready for shipment. The cold room should be clean, dry, and cold enough to chill and harden the butter before shipping. When ready to ship, the address of the consignee is stencilled or plainly written on the tub cover.

The numbering of each churning and the placing of the churning number on the tub, is an important precautionary measure. It tells the receiver which tubs belong to the same churning and therefore contain the same kind of butter. The receiver is able thereby to supply his customers with butter of uniform quality, salt and color. In case the butter develops defects the receiver, when reporting to the creamery, is in a position to refer to the respective churning number as marked on the tub and the creamery then is able to investigate the conditions under which that particular churning was made. If the buttermaker keeps a full and systematic churn record, as he should, the numbering of the churnings gives him an opportunity to prevent recurrence of the reported defect.

Butter Prints.—Formerly butter was retailed direct in bulk packages, such as tubs, boxes and cubes. At the present time the trend is toward individual or consumer's packages in the form of one, two and five pound rolls, and one-quarter, one-half, one, two and five pound prints. Much of the butter that goes to the wholesale trade in bulk packages, is printed by the wholesale receiver, commission man, jobber, or butter cutter before it reaches the retail store. In most of these cases the wholesale dealer packs the butter under his own brand, for which he establishes a special trade. In other cases the retailer uses his own special brand and furnishes the wrappers and cartons to the creamery. Some wholesalers handle prints put up by the creamery under the creamery's brand, in which case they pay about one cent more per pound than in bulk. Most of the butter which the creamery sells direct to the retail store is sold in prints. During the fall and winter, when the output is at ebbtide, many creameries print all their butter.

The individual or consumer's packages are two pound prints or rolls, one pound prints, one-half pound prints and bars and one-quarter pound prints. The predominating consumer's pack-

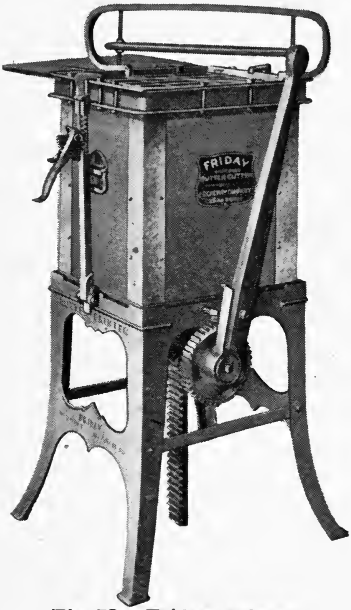

Fig. 73. Friday Printer

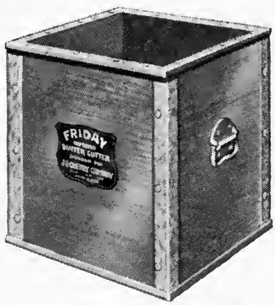

Fig. 74. Friday Box

Courtesy J. G. Cherry Co.

age is the one pound print of the following standard dimensions: 2½ x 2½ x 4⅝ inches, wrapped in parchment, or wax paper, or both and slipped into a carton. Some creameries wrap an additional paper around the carton and seal it at both ends. Considerable quantities of butter are sold in one-half pound and one-quarter pound prints wrapped in the same manner as the one pound prints and varying in shape from a flat slab to a so-called hotel bar. In New England, efforts are made to establish a one pound print having twice the width, half the depth and the same length as the standard one pound print. Within the last few years the practice of putting the one pound prints up in the form of four one-quarter pound bars, each wrapped separately in parchment paper, has found much favor as a means to accommodate the consumer and increase sales.

In accordance with the Federal Pure Food laws all individual or consumer's packages must be marked in plain and legible letters with the net weight of the contents. Packages weighing one pound or over must have the net weight indicated in terms of pounds, packages weighing less than one pound must have their net weight indicated in terms of ounces.

A law passed by the New York State Legislature in 1912 provides for the following tolerances in the weight of print butter:

"The maximum variation allowed on a pound print to be three-eighths of an ounce on an individual print, provided that the average error of twelve prints, taken at random, shall not be over one-fourth of an ounce per pound. The maximum variation allowed on two-pound prints to be one-half ounce, provided that the shortage on twelve prints, taken at random, be not more than three-eighths of an ounce for two pounds.

"Prints that are not of one pound or two pounds must be marked in letters at least three-eighths of an inch in height, giving the correct weight in terms of ounces, or pounds and ounces."

Methods of Printing.—The printing of butter is done in various ways. Some creameries transfer their butter from the churn to a table from which it is printed while soft, by the use of one-pound hand molds, or by the use of a mold sunk into the table and worked with a hand lever. In some European creameries the soft butter, coming from the churn or worker, is placed on an automatic, revolving printing table. This table is equipped with several molds. The butter is piled into these molds, which pass under a mechanical plunger that tamps it into the mold, then under a stationary knife that removes the surplus butter, after which the finished print is released. Most of the American creameries pack the butter from the churn into specially made crates, boxes or cubes, set it in the cooler over night to permit the butter to harden and then cut it into prints by means of wire cutters. To this type of printers belong the

Friday, the Low, the Simpson, the Miller printers, and others. For cutting tub butter a machine that utilizes all the culls is most practical. For this purpose the American Butter Cutter is used very generally.

When printers of the type of the Friday printers are used, it is advisable to line the boxes with parchment before packing. This keeps the surface of the butter cleaner, it protects it against the injurious effect of contact with the iron parts of the cubes, it minimizes the amount of scraps that have to be disposed of at a loss. It is desirable also to cover each Friday cube, after packing, with a properly fitting cover.

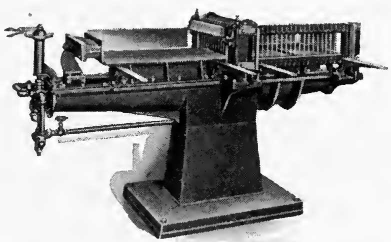

Fig. 75. C. F. Miller Hydraulic Cutter for Frozen or Otherwise Very Firm Butter
Courtesy L. C. Sharp Mfg. Co.

The cutting of the butter should be done with clean taut wires, free from rust. Piano steel wire is used for this purpose. For the good of the flavor of the prints, tinned wire only should be used. Any butter adhering to the bare steel wire soon causes it to rust and the action on the metal gives the butter a very disagreeable, puckery, metallic flavor.

The mechanical operation of the butter printer should be performed in such a manner as to insure prints with square corners and straight, sharp edges. The handling of the prints should not be done with bare hands. It can readily be done with ladles or sticks. The operator who cuts the butter and places it on the wrapping table, and the person who puts the first wrapper around the print, should wear clean gloves, preferably freshly laundered, white cotton gloves. The printing should be done in a clean, cool room, screened from flies, and properly ventilated.

In order to insure correct weights, each print should be passed over an accurate scale. No matter how accurately the wires of the cutter are set, they yield to the resistance of the butter and are apt to stretch. The weighing of each print is the only reliable guarantee against short weights and overweights. Unsalted butter is slightly lighter than salted butter, so that prints of unsalted butter must be very slightly larger than those of salted butter in order to weigh the same.

The wrapping is done either by cheap help, boys or girls, or by wrapping machines, which wrap the butter, place it in cartons, and wrap and seal the cartons with great rapidity and precision. The first wrapper should be a parchment wrapper. This should be treated in a similar manner as the tub liners. For maximum convenience a wooden box about 20 inches long and with an inside width slightly greater than the width of the one pound parchment wrapper may be used. This box may be installed in a convenient place in the print room, it should have an overflow and be connected with the steam and water line. While the print room is in operation this box is kept full of boiling hot brine, containing enough salt, so that there is always a visible deposit of undissolved salt in the bottom. A little steam should run into this brine continually, so as to keep the brine at boiling heat.

For suspending the parchment wrappers in the brine, wooden clamps of sufficient length may be used. A bunch of wrappers is fastened into the clamps, the clamps are placed across the box and the wrappers swing and soak in the brine. In this manner all but the top inch of the wrappers is soaked. It is not desirable to wet the entire wrapper because the sheets then stick to one another and delay the work of wrapping. The wrappers should be soaked in the boiling hot brine for at least 5 minutes and the brine should be renewed at least once each day. The same treatment may be given wrappers used for unsalted butter.

High grade parchment wrappers, properly parchmented and free from all kinds of specks, are the most economical. Parchment wrappers frequently contain very minute specks of metallic lustre. Microchemical examination of these specks shows that they consist of copper or of some alloy containing copper such as brass or german silver. These metal specks are acted upon by the salt and acid in the butter. Gradually a green spot or circle forms on the wrapper and on the butter at the point of contact, showing verdigris, giving the butter an unsightly and suspicious appearance, and actually rendering it unwholesome.

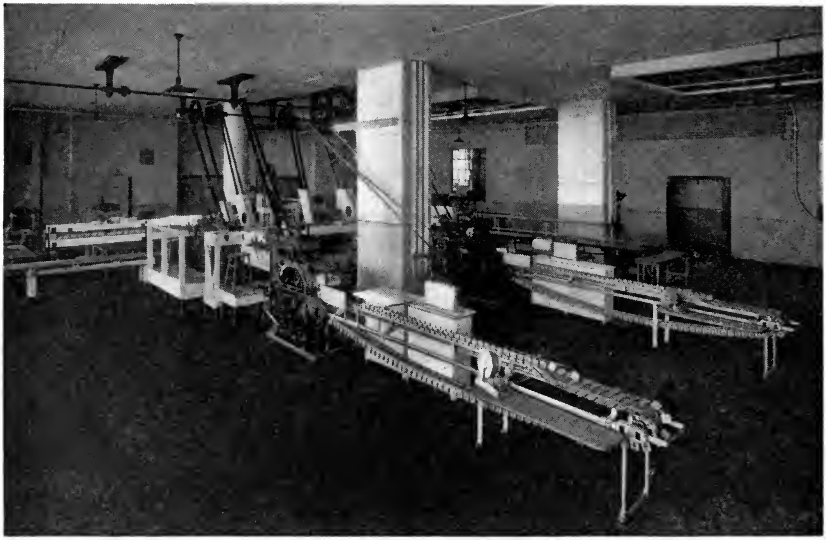

Fig. 76. Unit of Peters Package Machinery

This machine forms and lines the carton, folds the wrapper and closes the carton, and wraps and labels the carton. Courtesy Peters Machinery Co.

Such butter is usually rejected by the consumer. With prolonged age the action of these metallic specks bleaches the entire print and gives it a rank tallowy flavor and odor. Parchment wrappers used for butter should be free from these metallic impurities.

The second wrapper is a wax paper. It consists of paper coated on both sides with a thin film of paraffine, the paper having been passed through a paraffine bath. The wax paper wrapper furnishes additional protection against evaporation and against the deteriorating action of air. Experimental trials and commercial experience have demonstrated that butter actually does keep better, especially is the flavor on the outside of the print preserved, by the double wrapper.

The wrapped print is slipped into a carton. If the carton is the final enclosure, it is usually of high quality stock, paraffined, and bears the name and trade mark of the creamery. Creameries placing a special wrapper on the outside of the carton, generally use a cheaper grade, plain carton, and have their name and trade mark placed on this outside wrapper. Occasionally also printed matter with information for the consumer concerning the quality of the butter, also premium labels, etc., are slipped into the carton.

Packing in Boxes.—The prints, wrapped and placed in cartons, are packed into wooden or fibre boxes, usually holding from 10 to 50 one pound prints. Some of the larger creameries have their name and trade mark stencilled or burnt onto the ends of the box. This adds to the attractiveness of the package and advertises the brand. Of recent years, carton or fibre boxes have come into extensive use for packing and shipping prints.

The chief virtue of the fibre boxes lies in their relative cheapness, averaging at least five cents less per box. They are used to good advantage for local shipments of print butter and especially during the cold season. For long distance shipments of print butter and particularly during the hot summer season, corrugated fibre boxes and similar paper boxes are less suitable. Under these conditions the boxes often become soaked with the brine of the butter and thus suffer seriously in transit. The reason for this is that corrugated fibre boxes are not as rigid as wooden boxes; in summer, due to the heat, the butter is soft and the rough handling to which these boxes are subjected, causes this soft butter to become mutilated; this in turn results in the expulsion of a portion of the brine of the butter, which soaks through the carton of these boxes. Grocery stores often also object to the fibre boxes, because these boxes are not as serviceable and convenient to use in the store and on the delivery wagon as wooden boxes.

Most of the wooden boxes for print butter are made of poplar, hemlock or spruce. The majority of these are bought in the knock-down shape and are made up in the creamery. Four-penny cement-coated wire nails are best suited for assembling the sides, ends, bottom and top. The most perfect boxes are tongued and grooved, but their greater expense causes their use to be limited. The usual weight of the lumber used for wooden boxes is one-half inch for the sides, top and bottom and three-fourths inch for the ends. For large creameries the assembling of the boxes by the use of nailing machines is most economical. Of late, wire-bound boxes have come into use for packing and shipping prints. These boxes, while they are light, are stronger than the nailed boxes, their initial cost is slightly lower and the expense of assembling them is smaller, requiring less labor and fewer and smaller nails. Wire-bound boxes have the further advantage that they are practically burglar proof, avoiding loss of prints due to removal in transit. The correct size of boxes for standard size one pound prints is 13 x 13 x 10 inches for 50 pound boxes.

Too little attention has been paid by many creameries to the quality and neatness of these shipping boxes and to the manner of packing itself. Poor material, shiftless nailing and the use of second hand boxes should be avoided. The boxes should be of the proper size, so that they can be filled full with prints. The packing of 10 prints into a thirty pound box and filling in with diverse refuse material, such as paper, straw, etc., is a poor policy which often results in mutilation of the prints and unsightly appearance. Too large boxes also involve excessive expense of transportation. Most boxes see rough handling in transit and unless they are strongly constructed and properly packed they are apt to reach their destination in damaged condition. This is especially the case with long-distance shipments and with export shipments.

Advantage of Selling in Consumer's Packages.—It is obvious that the expense of the package and of packing is greater in the case of prints than in the case of tubs, boxes or cubes. The difference in cost, including package and labor, averages from one-half to one and one-half cent. This extra expense is borne by the consumer; print butter averages usually about one cent more than tub butter, at the sales end. The consumer's package has several distinct advantages. The butter when sealed in the consumer's package at the creamery or in the wholesale dealer's establishment, is effectively protected against further agencies of contamination and deterioration. The package is opened only by the consumer; and usually reaches him therefore in more satisfactory condition. The individual package is the most convenient form for distribution through the retailer's stores and for use by the consumer. The butter is protected against agencies of deterioration such as light, air and rapid changes in temperature, after it reaches the consumer. Butter bearing the trade mark of the manufacturer or dealer, as is the case with butter sold in the individual package, serves as an effective advertising means. If the butter is of uniformly acceptable quality, the consumer soon becomes familiar with that particular brand and will assume the habit of calling for that brand. In the case of occasional batches of low grade butter it is advisable to use either a plain wrapper or a special brand reserved for second grade butter only, in order not to jeopardize the reputation of the established brand.

Packing Farm Butter.—Butter made on the farm is put on the market in diverse packages. Butter that goes to the country store is usually packed in crocks, but considerable butter reaches the store also in the form of rolls. Crocks have the advantage that they protect the butter against abrupt temperature changes. If the crock is well glazed on the inside, it is fairly sanitary. Poorly glazed crocks are porous. The pores fill with grease and curd which are not removed by ordinary methods of washing and which cause the crock to become foul-smelling and to serve as a constant source of contamination with agencies detrimental to the quality of the butter. The crock is objectionable also because of its weight and its frailty.

Some farm butter is put up in rolls weighing 1, 2 or 5 pounds and usually wrapped in parchment. Fancy or individual molds are also quite popular. The tendency, however, is to print the butter into standard size one pound prints and put them on the market wrapped in parchment and packed in cartons. The standard size print is, all things considered, probably the most desirable type of package for farm butter, especially when sold direct to residences, etc. The farmer who sells butter, in prints, wrapped in parchments and cartons bearing his name and trade mark is in a position to create a permanent call for it, provided that the butter is of good quality and uniform flavor, salt, and color, while butter sold in crocks, carton boxes, pails, etc., loses its identity when it leaves the farm and before it reaches the consumer. In the choice of cartons for the prints, paper cartons should be given preference over wooden cartons. Wooden cartons such as are frequently used, lend the butter a woody flavor which is objectionable.

Packing for Parcel Post Shipments.—Farm butter or creamery butter, to be shipped by parcel post, is best put up in pound prints, wrapped in water-proof parchment and sealed in paraffined cartons. The cartons are best inserted into corrugated pasteboard containers suitable for accommodating the different amounts to be shipped, and wrapped with good wrapping paper. Brand[1] of the U. S. Department of Agriculture, Office of Markets, conducted an extensive study of the possibilities and limitations of shipping butter by parcel post. This investigation showed that under ordinary weather conditions practically no difficulty was experienced. The chief problem in shipping butter by parcel post is to prevent the butter from melting, mere softening did not prove injurious. While the difficulty is somewhat greater in summer than in winter, the fact that mail cars must be heated in winter, does not entirely remove the danger of overheating the butter during cold weather. Brand points out, however, that the regulations of the Post Office Department on this subject are of such a nature that it is possible to obviate this trouble to a considerable extent in cold weather by marking butter parcels as follows: "Perishable—Keep away from heating apparatus."

He further offers the suggestions that over ordinary distances and under average conditions butter wrapped as above directed, can be shipped without deterioration; that it should always be chilled before shipment and chilled again immediately upon receipt by the consumer; that it should be dispatched with attention to the mail schedule so that it will be on the road as short a time as possible, and that shipments preferably should be timed to make the greater part of their journey at night, when temperatures are materially lower than during the day.

One of the obstacles that has retarded the development of

[1] Brand, "Marketing by Parcel Post." U. S. Dept. of Agriculture, Farmers' Bulletin 611, 1914, pp. 16 to 21.

parcel post shipment of farm butter and similar farm produce has been the unfortunate tendency of some farmers to ask prices far above those current in their own rural localities and higher than those charged by fancy retail stores of the cities for butter of the same grade. It is obvious that the consumer will refuse to look to the parcel post service as a practical and desirable means to secure his butter, as long as he is unable to buy it through this channel at prices that are no higher than those which he is charged at the store.

Packing Butter for Exhibits and Scoring Contests.—When preparing butter for exhibits and scoring contests neatness, attractiveness and protection against high temperature are of chief importance. For exhibits proper, butter may be used for diverse designs, representing certain objects, or it may be put up in neat commercial packages, attractively grouped and arranged. For scoring contests, where the chief object is score on the quality basis, the twenty pound white ash tub is the most suitable package. It is large enough for all practical purposes of scoring and sampling for analysis, and it is small enough to avoid unnecessary sacrifice of butter and excessive transportation charges. Scoring contest butter is usually not returned to the maker after the contest. In most cases it is sold and the returns are used towards defraying the expense of the scoring, in which case the entire package is lost to the creamery. In other instances the returns are pro-rated among the contestants according to the pounds of butter entered, in many cases the creamery gets something back for its butter, though the price received for the butter after scoring, is usually very low, due to the damaged condition of the goods. The twenty pound tub is desirable also because it can be conveniently packed into a sixty pound tub for shipment.

In putting up the scoring contest butter a perfect tub should be selected. This should be treated in the usual way, steamed, paraffined and neatly lined with brine-soaked parchment circles and liners. The butter should be packed into it very firmly with sterile and cooled ladles and packers and in a clean, cool room. The packing should be finished in the neatest possible way. After cutting the surplus butter off the top so as to leave a perfectly level and smooth surface, the liner extending one inch above the edge of the tub is carefully folded over the butter with clean hands, a clean cloth circle is placed on top and on this is sprinkled a little clean dry salt, evenly distributed. After the lid is put on the tub, the outside of the tub should be sandpapered until it is perfectly smooth and clean. Then the lid is neatly fastened down to the tub with three to five standard fasteners.

The twenty pound tub is then dropped into a sixty pound tub and clean paper, clean shavings, excelsior, sawdust or other insulating material, is solidly packed between the inside and outside tub, bottom, sides and top. It is advisable to place the 60 pound tub and the packing material into the creamery cold room several days before use, so as to thoroughly chill them. The lid is then fastened to the sixty pound tub, it is tagged with the name and address of the maker and the addressee. Then it is best set into the cold room for twenty-four hours before shipping, in order to harden the butter.

Butter put up as above directed will reach its destination at any reasonable distance in good and attractive condition. The cold packing around the inside tub furnishes a splendid insulation, guarding against rapid warming up, which would prove detrimental to the delicate flavor of the butter and disadvantageous to the buttermaker's chances of success in the contest. Some buttermakers fill the space between the two tubs with crushed ice. This is unsatisfactory because it detracts from the neatness of the exhibition tub. Also the ice generally melts in transit and if the tub is put in cold storage before scoring, as is usually the case, the water between the two tubs will freeze into a solid mass, converting the entire package into one inseparable unit. The only means to get the inside tub out in such a case is to chop off the staves of the outside tub with an ax. If the butter judge has to attend to the unpacking himself these difficulties may have an unfavorable, though entirely unconscious, effect on the score of the troublesome tub. Aside from these objections melted ice is a good conductor of heat and therefore makes very poor insulation, while sawdust, paper, wood shavings, etc., hold cold very efficiently.

Loss of Moisture in Packing.—When butter is packed into tubs and boxes some moisture is lost, as a certain amount of water is thereby pounded out of the butter. A small additional loss of moisture further occurs in the cutting and printing of the butter. The average loss of moisture due to packing of 619 different churnings of butter at the Purdue University Creamery is shown in the following table:

[1] **Table 58.—Showing Difference of Moisture Content Between Churn and Box Samples—Averages Grouped According to Season of Year.**

Year	Loss of Moisture Due to Packing from Churn to Friday Box			
	April, May and June % Moisture	July, August and September % Moisture	October, November and December % Moisture	January, February and March % Moisture
1907–8	.27	.57	.40	1.45
1908–9	.50	.89	1.04	.82
1909–10	.52	.61	.61	.90
1910–11	.49	.44	1.04	1.58
Averages	.44	.63	.77	1.18

The least difference between the churn and box samples was shown in April, May and June. The difference increased gradually and was highest in January, February and March, when it averaged over 1 per cent.

This gradual increase of the loss of moisture, due to packing, from early summer to spring is interesting. It suggests that it is the result of the increasing firmness of the butter during the same time. The winter butter is firmer than the summer butter, more pounding is required in packing firm butter than in the case of soft butter.

The loss of moisture by packing varies considerably with individual churnings. It depends on how well the moisture is incorporated. Leaky butter may lose several per cent. of mois-

[1] These figures represent the differences between the churn samples and the tub or box samples. In every case the churn samples contained more moisture than the tub or box samples.

[1] Hunziker, Mills & Spitzer, Moisture Control of Butter, Purdue Bulletin, 160, 1912.

ture during packing. Under all normal conditions the butter-maker may expect a loss of at least ½ per cent moisture due to packing from the churn into the tub or box.

Table 59.—Moisture Content of Butter Before and After Printing with Friday Printer. The Samples Were Taken from Friday Cubes in the Cooler and Again from Prints of the Same Cubes after Wrapping. The Weight of All Prints Was One Pound, Each. Each Lot of Butter Represents a Different Churning.

Lots of Butter	Percent Moisture						
	Before Printing			After Printing			Average Loss
	A	B	Average	A	B	Average	
1	15.8	15.9	15.85	15.4	15.9	15.65	.20
2	15.3	15.3	15.30	14.8	14.8	14.80	.50
3	15.8	15.9	15.85	15.9	15.9	15.90	+.05
4	15.4	15.1	15.25	15.4	15.4	15.40	+.15
5	15.6	15.7	15.65	15.7	15.5	15.60	.05
6	15.1	15.1	15.10	15.4	15.2	15.30	+.20
7	15.9	15.9	15.90	15.8	15.9	15.85	.05
8	15.7	15.8	15.75	15.7	15.7	15.70	.05
9	15.7	15.9	15.80	15.6	15.7	15.65	.15
10	15.3	15.3	15.30	15.3	15.1	15.20	.10
Average			15.58			15.51	.07

The loss of moisture that occurs during the process of printing obviously depends, aside from the completeness of moisture incorporation, on the method of printing employed and the firmness of the butter. Butter that is printed direct from the churn with the hand mold, while it is still soft, is not prone to lose much moisture. Butter that is packed in cubes or crates, which are subsequently placed in the cold room over night and then printed by simply cutting it with wires, as is the case with the Friday printer, also suffers but very little loss of moisture. This is readily shown by the following analyses of butter before and after printing:

In the case of tub butter that has been allowed to harden and is subsequently stripped and printed by the use of the American Butter Cutter, the loss is obviously considerably greater, amounting to several tenths per cent. In this case the butter is not only cut, but considerably mutilated while it passes through the cutter, as shown in the following table which represents eighteen different lots of tub butter bought on the open market:

Table 60.—Moisture Content of Butter Before and After Running it Through the American Printer. The Samples Were Taken from the Stripped Tubs Before Cutting and Again from the Prints Made from the Butter.

Tub Numbers	Percent Moisture		
	From Tubs	From Prints	Loss
1	15.3	15.2	.10
2	14.3	14.0	.30
3	14.9	14.8	.10
4	16.1	15.9	.20
5	16.0	15.6	.40
6	16.0	15.6	.40
7	14.9	14.6	.30
8	15.2	14.7	.50
9	14.6	14.5	.10
10	16.2	15.9	.30
11	15.9	15.9	.00
12	15.8	15.4	.40
13	15.4	15.3	.10
14	15.4	15.2	.20
15	15.3	15.0	.30
16	15.4	15.1	.30
17	15.9	15.6	.30
18	15.1	14.9	.20
Average	15.43	15.18	.25

Cost of Packing.—The cost of packing butter varies largely with the cost of the package and the expense of labor. Prints are a more expensive package than tubs, boxes and cubes. The quality of wrappers, cartons and shipping boxes used and the elaborateness of the design on them further influence the expense of the package. The quantity in which the package is bought also affects its cost. In car load lots larger rebates, both in the price of the package and in the freight rates, may be secured.

This difference naturally operates in favor of the large creamery and against the small creamery with limited operating capital. The use of machines for printing, wrapping and sealing the butter and for mailing the boxes reduces the help needed for labor. In the large creamery this work can be done by the cheapest kind of help, by young boys and girls, for there is enough work to be done to furnish steady employment for this kind of help. In the small creamery where the printing and wrapping occupies only a part of one person's time, the creamery usually cannot secure special cheap help for this work and it is done by the more high-priced help, the buttermaker or his helper.

The cost of putting up one-half pound prints in separate cartons is about one-third higher per pound and the cost of putting up one-quarter pound prints in separate cartons is about twice as high per pound of butter as the cost of putting up one pound prints. The cost of putting up one-half pound prints and one-quarter pound prints in one pound cartons is about one-fifth and one-fourth, respectively, higher than the cost of putting up one pound prints.

Cost of Packing Butter in Tins.—Two sizes of tins for packing butter are accepted as standard tins by the United States Navy, the net 5 pound tin and the net 6 pound 6 ounce tin. The 5 pound tins are packed in boxes holding 16 tins, the 6 pound 6 ounce tins are packed in boxes holding 12 tins. In May, 1918, the cost of the package (5 pound tins), including tins, boxes, corrugated paper liners and strap iron, was about $2.44 per 1000 tins or about 3 cents per pound of butter. To this should be added the cost of nails and labels which amounts to less than .05 of one cent. The labor, when large quantities of butter are tinned, is but very slightly more than that of printing and wrapping butter, but for average conditions it should be placed at one-half to three-quarters of one cent per pound. This then, would make the total cost of packing butter in tins about 3½ cents per pound.

It is customary for the manufacturers of tin cans to loan to the creamery a sealing machine, for closing the cans after they are packed. The rental basis is usually about $25 per year plus the freight on the machine both ways and plus an insurance premium of about $3.50 per year on the value of the machine.

These prices and terms are naturally subject to changes. They prevailed in the spring of 1918.

GENERAL DIRECTIONS FOR PACKING BUTTER FOR THE UNITED STATES NAVY.

Tinned and Tub or Cube Butter—Quality.

"Shall be fresh butter, made from fresh pasteurized cream (held at a temperature of 145° F. for 25 minutes, or at 176° F. for an instant), none of which shall at any time contain more than 0.27 per cent of acid, calculated as lactic acid, for butter scoring 94, or 0.234 per cent for butter scoring 95 (or more acid in 50 c. c. of cream than will be neutralized by 15 c. c. of N/10 alkali solution for butter scoring 94, or 13 c. c. for butter scoring 95); nor shall the cream contain more than 35 per cent butter fat.

"Shall be strictly of the highest grade of creamery butter, at least two-thirds of which must score not less than 95 and the rest not less than 94 when made.

"Moisture in the finished product at time of packing must not exceed 13½ per cent for tinned butter and 14 per cent for tub or cube butter. There must be no preservative used other than common salt, and that shall be at a rate giving not less than 2½ per cent or more than 3¼ per cent salt in the finished product at time of packing.

Inspection and Tests.

"The ingredients, manufacture, sanitation, packing, boxing, marking, and shipping of the butter shall be subject to inspection by Government inspectors, who shall have full authority to reject any package or lot of milk, cream, or finished butter, and to enforce compliance with the requirements of these specifications as well as to demand first-class work in every particular.

"The Government inspector shall make all the necessary tests to determine that the acid in the milk or cream and the salt and moisture contents in the butter are within the limits specified.

"At the option of the Bureau of Supplies and Accounts, the contractor or his agents may, however, be required to make all the tests necessary to determine that the acid in the milk or cream and the salt and water contents of the butter are within the limits specified, and all such tests made by the contractor or his agents shall be subject to supervision, verification, and approval by Government inspectors.

Containers—Tinned Butter.

"**Tins.**—Tins to be made of prime coke plate weighing not less than 90 pounds per box of 112 sheets, size 14 inches by 20 inches. Side seams to be of either lock or lap type and soldered on outside only. Top and bottom ends to be lined with sanitary lining compound of suitable gasket before being double-seamed on.

"Tops and bottoms to be completely covered on the inside and outside with processed lacquer so that there will be no untinned edges exposed on the inside of the can. Inside and outside of cans, tops, bottoms and sides, except necessary margin for soldering side seams, to be lacquered before plate is manufactured into the finished container, with processed lacquer, which is to be baked on at a temperature of approximately 380° F. The unlacquered margin of side seam to be covered with air-drying lacquer after can is finished.

"Two sizes of tins will be acceptable, viz., tins containing 5 pounds net weight, as used heretofore, and standard No. 10 sanitary type tins containing approximately 6 pounds 6 ounces.

"The tins must be packed completely full, leaving no air space. Net weight only to be paid for.

"**Packing.**—The butter must be packed in thoroughly clean tins, and the tins fully sealed and marked immediately as directed, the creamery where the butter is made, the butter to be packed within two hours after the time of churning.

"**Sealing.**—Each tin must be hermetically sealed by mechanical process, without the use of solder.

"**Cases.**—The cases shall be made of well-seasoned lumber, planed on outside; tops, bottoms, and sides to be not less than full ½ inch and ends not less than full $\frac{13}{16}$ inch thick when finished. To be securely nailed and strapped with ½-inch flat iron. On each case shall be plainly stenciled or stamped the actual net weight of butter contained therein, the score, name of contractor, brand (optional with contractor), number of contract, and date of packing; cases shall be free from all other marks, except such as may be placed thereon by the Government inspector. Five-pound tins are to be packed 16 to the case, and No. 10 tins 12 to the case. Each tin must be plainly marked "...... pounds net .... butter," name of contractor, and date of packing, and shall be carefully wrapped in paper and packed in sawdust; the cases shall be completely filled with sawdust. Suitable corrugated paper liners and paper fillers may be used in lieu of sawdust, in which case it will not be necessary to wrap each tin in paper, but all motion of tins must be prevented if this style of packing is used.

Containers—Tub Butter.

"**Tubs.**—The butter must be put up in regular, sound, first quality white-ash tubs, provided with sound covers and five sound hoops, two at the bottom, one at the center, and two near the top; tubs to hold from 60 to 65 pounds net weight each. The tubs must be soaked in the usual manner, properly steamed, and immediately coated on the inside with paraffine having a temperature of not less than 240° F. when applied. They must then be lined with parchment paper (side lining, bottom and top circles), which must first have been sterilized and then soaked in a clean brine solution for at least 30 minutes immediately preceding the time at which they are used.

"**Packing.**—The parchment lining must overlap the bottom and the top edges of the butter at least half an inch. The butter must be packed immediately after it is made, and each tub must be packed solid throughout and completely filled. A cloth circle must be placed on top of the parchment circle of each tub and covered with a thin layer of salt. The tub covers must be securely fastened by two strips of substantial flat iron not less than ½ inch in width securely fastened to the sides of the tub and brought over the cover at right angles.

"By means of a suitable rubber stamp and stamp ink each tub must be plainly marked on the cover and side with the net weight of the butter it contains, the name of the contractor, with or without brand, number of contract, and the date of packing, and shall be free from all other marks, except such as may be placed thereon by the Government inspector. Net weight only to be paid for.

"The letters in the rubber stamp must not be less than 3/8 inch square. Marking by means of stencil and blacking will not be permitted.

Containers—Cube Butter.

"**Cases.**—Cases to be cubical or rectangular in shape and to have a capacity of from 56 to 66 pounds; to be made of first quality white spruce or Pacific coast spruce or clear poplar lumber, cut true to gauge and planed on both sides; tops, bottoms, and sides to be not less than 1/2 inch thick, and ends not less than 7/8 inch thick when finished; to be well nailed with cement-coated nails, and strapped with 1/2-inch flat iron or strong wire; otherwise to conform to all applicable requirements of the specifications for containers for tub butter above, which include paraffin coating and parchment paper lining."

CHAPTER. XIII.

THE OVERRUN.

Definition.—By the overrun is understood the difference between the pounds of butterfat churned and the pounds of butter made. The overrun is made possible by the fact that, in addition to butterfat, butter contains non-fatty constituents, such as moisture, salt, curd and small amounts of lactose, acid and ash.

Importance.—The overrun is the financial "vitamine" of the creamery business. Under the present system of creamery operation there is no margin left between the purchase price of the butterfat and the sales price of the butter, on which the creamery can do business. In fact, in a great many instances the cost per pound of butterfat is greater than the price received per pound of butter. The creamery must, therefore, depend on the overrun to pay for the cost of manufacture and sale of the butter and to make a reasonable profit. If it were not for the overrun the creamery could not do business on the present method of paying the patrons for butterfat. The overrun, therefore, logically and rightfully belongs to the creamery.

If the dairy farmer makes butter on the farm, the overrun he makes compensates him for his trouble, time, labor and expense involved in making and selling the butter.

The Theoretical Overrun.—The theoretical overrun is a "pencil" overrun. It aims to indicate the maximum amount of butter that could be legitimately made from a given amount of butterfat, if all conditions of butter manufacture could be controlled with mathematical accuracy.

The theoretical overrun shows, for example that, if there were no mechanical losses and if butter contained exactly 80 per cent of fat, the maximum amount of butter that could be made from 100 pounds of fat would be $\frac{100}{80} \times 100 = 125$ pounds and that, therefore, the maximum legitimate overrun is limited to $125 - 100 = 25$ per cent.

In the commercial operation of the cream, however, it is a mechanical impossibility to establish the degree of accuracy that is assumed in the calculation of the theoretical overrun. No such standard of accuracy can be attained. For this reason the figures resulting from calculation of the theoretical overrun cannot serve as an acceptable standard for overrun. They fail to take into consideration the true possibilities and limitations of the overrun and they are prone to prove confusing and misleading. At best they can serve only as an approximate and arbitrary illustration for the elementary information of the layman.

The Actual Overrun.—The actual overrun shows the difference between the actual amount of butter churned out and the amount of butterfat bought and paid for. It is affected by a multitude of factors, which control, directly or indirectly. the determination of the amount of butterfat bought and churned and the amount of butter made.

Conditions Influencing the Overrun.—As previously stated, the overrun is made possible by the fact that butter contains, in addition to the butterfat, water, curd, salt and ash. The larger the sum total of these non-fatty constituents, the smaller the amount of fat that is required to make one pound of butter, the more butter can be made from a given amount of fat, and the larger, therefore, will be the overrun.. Consequently, the composition of the butter is the fundamental factor that controls the overrun. Other factors which influence the overrun are the accuracy of weights and tests of cream, butterfat shortages of cream routes and cream stations, the number and amount of mechanical losses of butterfat, such as loss of fat in the skim milk, in the buttermilk and through factory leaks, and accuracy of weights and tests of butter.

Effect of Composition of Butter on Overrun.—Of the non-fatty constituents of butter, that control the overrun, the moisture, salt and curd are the only ingredients that need be considered and the relative amount of which is large enough and is sufficiently variable to materially affect the overrun. The other non-fatty constituents, the ash, milk sugar and acid, all together total less than .5 of one per cent, they are practically constant and are not materially affected by the process of manufacture under all normal conditions.

Moisture.—The moisture exerts the greatest influence of the non-fatty constituents, on the overrun. It is present in larger amounts than all the other non-fatty constituents combined and it is the most variable. Its maximum limit in the United States is fixed by a ruling of the Internal Revenue Department below 16 per cent. According to this ruling butter containing 16 per cent moisture or over is no longer legal butter, but is classed as adulterated butter.

Under all reasonable conditions of manufacture and of raw material, the moisture content of butter will not exceed 16 per cent. There are times and conditions, however, when butter has an inherent tendency to naturally hold more moisture. This is especially the case in early summer when the cows are turned from dry feed to succulent pasture, and on account of their ravenous appetite for green feed they consume a great abundance of it. This causes the butterfat to have a low melting point and to be abnormally soft. In this soft condition it mixes readily with water and has the power to retain relatively large quantities of it. With intelligent control of the churning temperature and careful adjustment of the process of working, the buttermaker can, without much difficulty, hold the moisture content of his butter below the maximum limit of 16 per cent, even under these abnormal conditions of raw material.

There are other times and conditions when the butter has properties that cause it to take up and hold much less moisture than 16 per cent. This is usually the case in winter, when the cows are well advanced in their period of lactation and receive largely only dry feed. These conditions are conducive of relatively small size fat globules and fat of a relatively high melting point, causing the fat to be very firm, in which condition it refuses to readily mix with and hold water. The tendency then is for butter to be low in moisture and the overrun to be correspondingly low. But here again, with the proper adjustment of the churning temperature and with the intelligent manipulation of the butter in the churn, the buttermaker can, without great difficulty, hold the moisture content of his butter close to the 16 per cent limit and thereby maintain a satisfactory overrun.

These facts also explain why the buttermaker on the farm and the buttermakers in many small local creameries, who lack the knowledge, skill and equipment necessary to regulate the per cent moisture in butter, and who often pay no attention at all to moisture content, are unable to secure a satisfactory overrun in winter, and frequently exceed the 16 per cent moisture limit in summer.

Since the overrun represents one of the all-essential factors in successful butter manufacture, and since, in the face of the keen competition and of the narrow margin of profit, the very life of the creamery depends on the overrun, it is the buttermaker's undisputed duty to hold the moisture content of his butter as close to the maximum limit permitted by law as possible, consistent with maintenance of quality and making due allowance always for unavoidable variations. If the buttermaker adjusts his process in such a manner as to work to a moisture content of 15.5 per cent, he should experience no serious difficulty to stay within the requirements of the law, and at the same time to secure the maximum overrun that may be expected of him, other factors being under control.

Salt.—The salt represents the next largest non-fatty constituent of butter. The salt content of butter ranges from no salt to about 4.5 per cent salt, averaging about 3 per cent.

It is obvious that the more salt butter contains, other factors being equal, the larger will be the overrun. Unsalted butter, therefore, yields a much lower overrun than salted butter, unless the legal moisture limit is exceeded or an abnormal amount of curd is incorporated in the unsalted butter, both of which practices are unlawful and would unfavorably affect the keeping quality of the resulting butter.

The difference in overrun between unsalted butter and butter containing about 3 per cent salt is approximately 4.5 per cent. With the price of butter at 40 cents, the sale of unsalted butter at the same price would cause the creamery to sacrifice 1.8 cents on every pound of butter manufactured. In other words, unsalted butter would have to be sold at a price approximately 1.8 cents higher than salted butter in order to secure the same returns for butterfat sold in the form of unsalted butter as that sold in the form of salted butter.

Curd.—The curd content of butter is not generally considered a factor of consequence from the standpoint of overrun. In properly made butter the curd content is small, averaging about .7 of one per cent, and it is fairly constant. If butter were not washed at all it would not exceed 1.5 per cent curd and would average around 1 to 1.25 per cent. In properly washed butter it is practically always below 1 per cent. In calculating the overrun, the curd is usually figured to be 1 per cent, allowing it to also represent the remaining traces of other non-fatty constituents, the ash, milk sugar and acid.

Efforts are made occasionally, however, to increase the overrun by incorporating in butter, extraneous additional curd, in the form of wet or dry casein, or skim milk powder. In such cases the extraneous curd is added to the butter in the churn with the salt and it is worked in during the regular process of working.

If the curd is so added, in form of starter, the increase of the curd content in the butter is very slight and barely perceptible by analysis, and there is no appreciable increase in the overrun.

If the curd is added to the butter in the form of dry casein, or skim milk powder, then the increase of the per cent curd found in such butter is very marked and is limited only by the amount of these products added. The curd content of the butter thus may be from 5 to 10 per cent or more and the increase in the overrun may amount as high as 15 per cent or more. In the case of skim milk powder a considerable amount of milk sugar is also retained in butter with the added curd, making the overrun still higher. Furthermore, the increased curd content of such butter augments the moisture-holding properties of the butter and unless efforts are made to hold the per cent moisture in such butter to or below 16 per cent, the moisture content may far exceed this limit, causing a still greater overrun.

The practice of working extraneous curd into butter in any manner is a pernicious practice. It is in violation of the law which forbids the incorporation in butter of any substance other than the fat of milk or cream and small portions of such other milk constituents as naturally enter into butter in the process of manufacture, with or without salt and with or without harmless coloring matter. Extraneous curd incorporation further is a positive detriment to the butter industry, because it causes rapid deterioration, injures the keeping quality and thereby displeases the consumer, reduces sales, depresses the price and invites the consumption of butter substitutes.

Accuracy of Weights and Tests of Cream.—Since the overrun is calculated on the basis of butterfat actually bought and paid for, it is necessarily immediately influenced by the accuracy of the weights and tests of milk and cream, upon the basis of which the amount of the butterfat is calculated. The overrun cannot be correct, be it high or low, if the weights and tests are not correct. Weights of milk or cream that are in excess of the correct weights received and tests higher than the correct tests, are bound to lower the overrun and if the error is considerable and continuous, it spells ruin to the creamery.

Where the milk or cream is sampled, weighed and tested at the creamery, as is the case with most cooperative creameries and with creameries operating on the direct shipper system, inaccuracies of this sort are not very frequent and their recurrence can be readily avoided. But when the cream is weighed and sampled on the route wagon, as is the case with the cream route system, or where the cream is weighed, sampled and tested at the cream station, or where the creamery accepts the weights and tests of the independent cream buyer, control is far more difficult and the creamery often suffers great losses of butterfat, which compel it to pay for more butterfat than it actually received and this in turn is bound to greatly depress the overrun.

If the error in weights and tests is in the other direction, if the weights are short of the actual amount of milk or cream received and if the recorded tests are lower than correct tests would be, then the creamery is receiving more butterfat than it is paying for and the overrun is correspondingly high. Abnormally high overruns, therefore, are not infrequently due to low weights or low tests, or both.

Occasional accidental errors in weights and tests may reasonably be expected. They generally work no great hardship, neither on the creamery nor on the farmer, and in the long run usually balance each other.

Persistent and continued inaccuracies, all in one direction, on the other hand, suggest either systematic carelessness and inefficiency, or intentional wrongdoing. If due to inefficiency, then the equipment or the method is at fault, and the overrun can only be made to return to what it should be by a systematic effort to locate the trouble.

The route, station or platform scales should be examined to make sure that they swing freely, operate correctly, and weigh accurately. Scales that "stick" or do not "break" sharply are very often the cause of a low overrun, registering more milk or cream than the creamery actually received. The milk or cream, and especially the cream on the route wagon and at the cream station, must be thoroughly mixed before the sample is taken. Sudden drops in the overrun in winter are not infrequently due to an unsatisfactory mechanical condition of the cream at the time the sample is taken. Frozen cream should be treated in accordance with directions given in chapter IV, and the cream, after the treatment, should be stirred very thoroughly. Under any condition the cream sampler should understand that the top layer in the cans or in other cream containers, is usually richer in butterfat than any other portion of the contents. If the sample is simply taken from the top, it cannot help containing a higher per cent of fat than the remainder of the cream, and tests made from such samples are bound to be too high and the overrun low.

In the testing of the milk or cream it should be definitely ascertained that the glassware used is correct, that the cream test balance has the necessary sensibility and is in satisfactory operating condition, and that the weighing, testing and reading is done with care and according to standard methods.

Cream route and cream station shortages of butterfat are most always due to improper and careless sampling, causing the individual samples to be richer in butterfat than the cream from which they are taken. Whether this be due to mere carelessness on the part of the operator, or willful deception, makes little difference. Creameries who fail to systematically check up the work of their routes and stations, and to hold their operators to account for their delinquencies, are doomed to a disastrously low overrun.

Buying cream on the weights and tests of the independent buyer is a practice fundamentally wrong. The independent buyer is largely interested in selling to the creamery the greatest amount of butterfat possible. Therein lies his livelihood and his profit. He cannot afford to sell more butterfat than he gets paid for and he is usually looking out for that. Unless he masters a strength of character far above the average of his profession, he may yield to temptation to the detriment of the overrun of the creamery that accepts his weights and tests. The creamery cannot afford to buy butterfat on any basis other than that of its own weights and tests.

High tests and low overrun are likely to occur also in creameries that hold their samples for several days before testing. This is especially the case when the samples are kept in loosely sealed jars, or in a warm room, or both. In this case the incorrectly high tests are due to evaporation of part of the moisture in the cream sample, increasing the per cent of fat and causing a low overrun. It is advisable to test all cream samples on the day they are taken or received. All samples should be taken and kept in tightly sealed jars, and if they cannot be tested promptly, they should be placed in the cold room until needed.

Mechanical Losses of Fat.—Of the mechanical losses of fat in the creamery which materially affect the overrun, the fat lost in the skim milk and the fat lost in the buttermilk are the most important.

Skim Milk.—On the basis of average milk, testing about 4 per cent fat and of butter containing 80 per cent fat, every one-tenth per cent fat lost in the skim milk reduces the overrun by about 2.2 per cent. It is obvious, therefore, that whole milk creameries cannot hope to secure as large an overrun as gathered cream creameries. The very marked effect of the small amount of fat lost in the skim milk, on the overrun, emphasizes the importance of securing the greatest possible skimming efficiency in the operation of the factory cream separator, so as to reduce the resulting loss to the very minimum. For detailed directions on the factors which influence the skimming efficiency of the cream separator the reader is referred to Chapter V on the "Separation of Milk."

Buttermilk.—The exhaustiveness of the churning does not have so great an effect on the overrun as does the exhaustiveness of skimming, yet it is a factor that must be reckoned with in order to secure maximum overrun. With cream testing about 33 per cent fat and using 10 per cent starter, and with butter containing 80 per cent fat, each one-tenth per cent fat lost in the buttermilk lowers the overrun approximately .23 per cent. It is generally considered that an average buttermilk test of not to exceed .2 per cent fat is not excessive on this basis; the sacrifice in overrun that may be expected under fairly normal conditions, due to the fat lost in the buttermilk, is about .5 per cent.

In a properly operated creamery where the conditions relating to exhaustiveness of churning are carefully watched, the buttermilk seldom exceeds .2 per cent, and frequently drops below .1 per cent. In plants which ignore the importance of the exhaustiveness of churning and which do not systematically check it up by testing the buttermilk, it is not uncommon to find the buttermilk to test very high, amounting to from .5 to 1 per cent or more, and causing a reduction of the overrun of from 1 to 3 per cent or more.

As it is difficult to correctly determine the per cent fat in the buttermilk by the ordinary Babcock test, the results of the test often do not show all the fat present in the buttermilk, so that the operator may think that he is churning exhaustively when in reality he loses much fat. For directions of testing buttermilk see Chapter XXII.

Some of the most important factors which control the exhaustiveness of churning are: Churning temperature, time held at churning temperature, richness of cream, condition of cream, fulness and speed of churn, size of butter granules when churn is stopped, etc. For detailed discussion of these factors the reader is referred to Chapter X on "Conditions Influencing the Churnability of Cream," also Chapter VII on "Neutralization" and Chapter VIII on "Pasteurization."

Other Mechanical Losses Which Tend to Reduce the Overrun.—Frequently the low overrun is found to be due to excessive foaming of the cream in the vats. The cream foam usually contains a high per cent of fat. It is flushed out of the vats with difficulty only, and often much of it goes into the sewer. Efforts to thoroughly flush this foam out of the vats into the churn require excessive amounts of water, usually warm water. This in turn dilutes the cream and increases the amount of buttermilk, thus augmenting the volume of buttermilk and with it the amount of fat lost. The thinning of the cream in itself causes a higher per cent of fat in the buttermilk. Furthermore, the cream in the churn is thus warmed above the intended churning temperature, by the copious rinsing down of the foam with warm water, which makes for less exhaustive churning.

In most cases the excessive foaming of the cream in the vats is due to too high a speed of the coils, whipping air into the cream. This is especially the case when the vat is not full and the coil is only partly covered with the cream. Reducing the speed of the coil generally diminishes and often stops the foaming entirely. The larger the coil the slower should be its speed. The proper speed for a 24-inch coil is about 35 to 40 revolutions per minute, for a 29-inch coil 28 to 30 revolutions per minute.

Filling the vat full, so as to submerge the coil, will lessen the foaming. Running the coil with the vat cover down minimizes the foaming, the slight pressure thus produced in the closed vat helps to keep the foam down. If the cream splashes into the vat from a great height, there is more or less foaming. A large vat gate assists in carrying off the foam with the cream, when the vat is being emptied.

Additional mechanical losses occur now and then by accidental spilling of milk and cream, leaks in pumps, pipe lines, cream troughs and churn doors, incomplete draining of milk and cream cans, pipes and troughs. These losses will greatly vary with the degree of carefulness or carelessness of the creamery personnel. They represent a useless waste, benefitting no one and reducing the overrun. They are avoidable in most cases and can be guarded against by efficient supervision. All of these precautions play an integral part in the systematic maintenance of a satisfactory overrun.

Accuracy of Moisture Tests.—Since the per cent of moisture is a fundamental factor determining the overrun, it is important that its determination be correct and reliable. This means careful sampling of the butter, a sensitive balance and conscientious operation of the test. For details of testing butter for moisture see Chapter XXII.

The butter should be tested at the churn and again the next morning from the cooler. The churn tests are necessary as a guide for the buttermaker, the cooler tests serve as a check of the churn tests. The cooler tests are final and become a matter of record.

Accuracy at this point enables the creamery to approach the moisture limit permitted, with reasonable certainty of not violating the 16 per cent ruling, and thereby to secure the maximum overrun possible.

Accuracy of Weights of Butter.—Finally the overrun may be very materially affected by the accuracy of the weights of butter. In the case of the factory overrun the cubes and tubs are weighed prior to packing and again after packing, the difference between the tare and the gross weights gives the net weight of the butter. Accuracy of weighing is necessary in order to insure the correct calculation of the overrun.

In the case of packing 63-pound tubs, it is customary to allow from 4 to 12 ounces for shrinkage. If the net weight of the butter is say 62 pounds 10 ounces the weight put on the tub is 62 pounds. Instead of weighing the filled tub, the butter may be weighed before it reaches the tub and the weighed butter is then packed into the tub. In this case only the net weight is placed on the tub. The San Francisco Wholesale Dairy Produce Exchange issued regulations demanding that standard cubes be filled with 69 pounds of butter net and that the cubes be marked 68 pounds.

If the butter is printed at the creamery, the accuracy of the net weight put into each print is reflected in the office overrun. Accuracy here is best secured by passing each print over a sensitive butter balance and correcting the weights, if short, or over.

Example of Overrun in Whole-Milk Creamery.

10,000 lbs. of 4% milk are received.
32% cream is separated.
Skim milk tests .1% fat.
10% starter is added.
Buttermilk tests .2% fat.
Butter contains 80% fat.
How much butter is made?
What is the overrun? What is the per cent overrun?

Answer.—

Butterfat contained in milk, $\frac{4 \times 10000}{100} = 400$ lbs. fat.

Cream separated from milk, $\frac{4 \times 10000}{32} = 1250$ lbs. cream.

Skim milk separated from milk, $10000 - 1250 = 8750$ lbs. skim milk.

Fat lost in skim milk, $\frac{.1 \times 8750}{100} = 8.75$ lbs. fat.

Fat remaining in cream, $400 - 8.75 = 391.25$ lbs. fat.

Starter added to cream, $\frac{10 \times 1250}{100} = 125$ lbs. starter.

Total pounds of cream churned, $1250 + 125 = 1375$ lbs. cream.

Approximate pounds of buttermilk made, $1375 - 391 = 984$ lbs. buttermilk.

Fat lost in buttermilk, $\frac{.2 \times 984}{100} = 1.97$ lbs. fat.

Fat left for butter, $391.25 - 1.97 = 389.28$ lbs. fat.

Butter made, $\frac{100 \times 389.28}{80} = 486.6$ lbs. butter.

Overrun, $486.6 - 400 = 86.6$ lbs. overrun.

Per cent overrun, $\frac{86.6 \times 100}{400} = 21.65\%$ overrun.

In the above example the mechanical losses on the 400 lbs. of fat were $8.75 + 1.97 = 10.72$ lbs. of fat, the per cent loss was $\frac{10.72 \times 100}{400} = 2.68$ per cent of the total fat received. Adding to these losses, the probable fat lost in the form of milk and cream spilled and retained in the pipes, etc., the total mechanical loss of fat may be placed at from 3 to 3.5 per cent of the total fat received. In whole milk creameries a loss of 3 to 3.5 per cent of the total fat received is generally accepted as a fair average loss under normal conditions of operation, though this loss can be considerably reduced by better organization and greater efficiency of operation.

If there were no compensating factors, such as undeterminable unrecognized fractions of weights and tests of milk, which, in an efficiently operated creamery are bound to function in favor of the creamery, the per cent overrun would be as follows:

Loss of 3% of total fat received $= 25 - \frac{125 \times 3}{100} = 21.25\%$ overrun.

Loss of 3.5% of total fat received $= 25 - \frac{125 \times 3.5}{100} = 20.625\%$ overrun.

Example of Overrun in Farm Separator Cream Creamery.

2000 lbs. of 33% cream are received.
10% starter are added.
Buttermilk tests .2 per cent fat.
Butter contains 80 per cent fat.
How much butter is made?
What is the overrun? What is the per cent overrun?

Answer.—

Fat in 2000 lbs. of cream, $\frac{2000 \times 33}{100} = 660$ lbs. fat.

Starter added to cream, $\frac{2000 \times 10}{100} = 200$ lbs. starter.

Total pounds of cream churned, $2000 + 200 = 2200$ lbs. cream.

Buttermilk produced, $2200 - 660 = 1540$ lbs. buttermilk.

Fat in buttermilk, $\frac{.2 \times 1540}{100} = 3.08$ lbs. fat.

Fat left for butter, $660 - 3.08 = 656.92$ lbs. fat.

Butter made, $\frac{100 \times 656.92}{80} = 821.1$ lbs. butter.

Overrun made, $821.1 - 660 = 161.1$ lbs. overrun.

Per cent overrun, $\frac{161.1 \times 100}{660} = 24.41\%$ overrun.

Per cent loss of total fat, $\frac{3.08 \times 100}{660} = .467\%$ fat.

Adding to this loss, the probable fat lost in the form of cream spilled and retained in the pipes, etc., the total mechanical loss of fat may be placed at approximately 1 per cent of the total fat received. In farm separator cream creameries a loss of 1 per cent of the total fat purchased is generally accepted as a fair average loss under normal conditions of operation, though this loss can be considerably reduced by improved organization and greater efficiency of operation.

If there were no compensating factors, such as undeterminable and unrecognized fractions of weights and tests of cream, which, in an efficiently operated creamery are bound to function in favor of the creamery, the per cent overrun would be as follows:

Loss of 1% of total fat received yields $25 - \frac{125 \times 1}{100} =$ 23.75% overrun.

Unavoidable Discrepancies in Weights and Tests that affect the Overrun.—The foregoing examples of actual overrun differ from the calculations of the theoretical overrun, in that they make allowance for the mechanical losses of fat in the process of manufacture. But, similar as in the case of the theoretical overrun they are based on the assumption that the pounds of fat received and paid for, are determined with mathematical accuracy that yields absolutely correct results. They make no allowance in the weighing of milk and cream for the fractions of pounds that fall between the smallest graduations on the beam of the scales; they provide no tolerance in the testing of milk and cream for fractions of the per cent of fat that fall between the smallest graduations on the neck of the test bottle; and furthermore, they assume, in the calculation of the money due the farmer, that all fractions of pounds of butterfat, even those of the last decimal are included, making no allowance for the dropping of any fractions.

But in practical operation these details do exist, and contrary to the general impression, their occurrence very vitally affects the actual overrun.

It is not often that either the empty or the full can weighs exactly to whole or half pounds. In the majority of cases the exact weight is somewhere between the whole and half pound and the operator has to choose between dropping the undeterminable and unrecognized fraction or calling that fraction one whole or one-half pound.

Similar limitations of accuracy occur in the testing of milk and cream, and particularly in the case of cream. The smallest division marks on the neck of the standard cream test bottle record one-half per cent and the distance between the graduation marks is very minute, about one thirty-seventh of one inch, making it impracticable, if not impossible, to determine and record fractions of less than one-half per cent, and occasionally difficult to even distinguish one-half per cent.

But quite often the length of the fat column fails to exactly coincide with the whole per cent or the half per cent marks and the tester has to choose between dropping the uncertain, undeterminable and unrecognized fraction, reading to the next lower line, or calling that fraction a whole or a half per cent.

Finally, the pounds of butterfat, as calculated from the pounds of cream and the fat test, often represent an amount with three to four decimals, rendering the computation of the money due the farmer complicated, time-consuming, uneconomical and inviting errors in the results. This has led to the practice on the part of the creameries, of dropping some of these fractions, usually including those of the second decimal.

These unreadable and unrecognized fractions in the weights and tests of cream have, in the past, failed to be considered in the treatment of the subject of the overrun. They are a fact, however, which the creamery has to deal with. It has no choice in the matter, and collectively they do affect the overrun to a very marked degree in one direction or the other, and to a degree that has not been fully recognized by the industry in the past.

Since business cannot be conducted successfully by paying for more than is actually received, the creamery cannot pay for butter-fat it does not receive and no efficiently operated creamery would tolerate such transactions. Every loyal creamery operator will record only as much weight of cream and as much fat in the test as the cream scales and the Babcock Test actually show. And if the exact weight and the exact test involve fractions which cannot be determined by the standard equipment, and which are not recognized, he ignores these fractions.

A similar practice is in vogue the country over in the purchase of butter and other farm produce. When butter is sold to the produce trade on the open market, the buyer makes remittance for whole pounds only. The butter buyer does not recognize fractions of pounds, nor even half pounds, and he often insists on the scale beam touching the top when weighing. If a tub of butter weighs 63 pounds and 15 ounces, the creamery selling this butter would be entitled to and would receive pay for 63 pounds only. This is an established custom, recognized and accepted by the industry, notwithstanding the objections which have been raised against it recently.

When the creamery recognizes, records and pays for half pounds of cream and half per cents of the test, and this should be the practice in every creamery, it is paying the farmer more nearly for the exact amount of the product it receives than is the established custom of buying butter and other farm produce. It cannot, as an efficiently conducted business, pay for more than it actually receives, hence it must receive the benefit of the doubt in all cases of unavoidable and unreadable fractions of pounds of cream and of per cent fat in the test.

It may be argued that equity demands the payment for butterfat on the basis of a "give and take" system as far as these unreadable fractions of weights and tests is concerned, in which case fractions of over one-fourth pound and over three-fourths pound of cream would be recorded as half pounds and whole pounds respectively, and all fractions of over one-quarter and three-quarters per cent in the test would be recorded as half per cents and as whole per cents respectively, while all fractions below the quarter and below the three-quarter pounds and per cents would be ignored. By this system of "give and take," it is claimed by some, these unreadable fractions would be taken care of equitably, both to the farmer and to the creamery.

From the standpoint of absolute correctness, this system would be more nearly ideal, but it is impracticable in commercial operation. It is too complicated and confusing to be adaptable to the routine of creamery operation; in fact, it is not done. The unreadable fractions are either not recognized, or they are recorded as half or whole pounds and per cents respectively. There can be no double method, and since long established custom of the industry accepts, and business competition demands, the ignoring of the unreadable fractions, these fractions are, in fact, ignored.

The gains in overrun which these unreadable and unrecognized fractions effect will naturally vary. Under average conditions they may amount to about 2 to 4%. In creameries in which the general standard of efficiency is low, these gains are more than offset by the mechanical losses. In creameries which maintain a high standard of efficiency, reducing the mechanical losses to the minimum, these gains very appreciably exceed the mechanical losses and result in the production of an overrun slightly higher than the maximum overrun possible on the basis of the calculations of the theoretical overrun.

Other conditions being the same, the increase in the overrun due to the unrecognized fractions varies largely with the amount and richness of each individual shipment of cream; the smaller the amount of fat contained in each individual shipment of cream, the greater must necessarily be the effect of the undeterminable and unrecognized fractions on the overrun. Hence these gains actually amount to more in the case of creameries whose individual shippers, ship largely only in 5-gallon cans than in the case of creameries that receive most of their shipments in 8 and 10-gallon cans.

The following arbitrary example may serve to illustrate the influence of the unrecognized fractions of weights and tests of cream and of the resulting fat calculations on the overrun:

Example.—

Gains, in weighing empty cans and full cans.

5-gallon empty can weighs 12.75 lbs., marked 13 lbs.; gain is .... .25 lbs.

5-gallon full can weighs 51.75 lbs., marked 51.5 lbs.; gain is .... .25 lbs.

Gain of cream.. .50 lbs.

Net weight of cream recorded is, 51.5 — 13 = 38.5 lbs.

Cream tests 33 per cent fat.

Fat in 38.5 lbs. of 33% cream, $\frac{33 \times 38.5}{100}$ 12.705 lbs. fat.

Fat in .5 lbs. of 33% cream, $\frac{33 \times .5}{100} = .16$ lbs. fat.

For each 100 lbs. fat, gain in fat is, $\frac{.16}{12.705} \times 100 = 1.259$ lbs. fat.

Gain in testing cream.

Assuming that the fat column measures between 33 and 33.5%, say 33.25%, the test is read at 33% mark.

For each 100 lbs. of cream the gain is .25 lbs. fat.

For 38.5 lbs. of cream the gain is, $\frac{.25 \times 38.5}{100} = .09625$ lbs. fat.

For each 100 lbs. of fat the gain is, $\frac{.09625 \times 100}{12.705} = .758$ lbs. fat.

Gain in calculation of butterfat.

Second decimal is dropped.

In case of 12.705 lbs. of fat .005 lbs. fat are gained.

For each 100 lbs. of fat the gain is, $\frac{.005 \times 100}{12.705} = .0394$ lbs. fat.

Summary of Gains.

Gains on weights of cream........................1.259 lbs. fat
Gains on tests of cream............................ .758 lbs. fat
Gains on calculations of fat....................... .039 lbs. fat
Total gains per 100 lbs. fat received..........2.056 lbs. fat
Total losses (see example of actual overrun in farm separator cream creamery)............................1.000 lbs. fat
Net gains ....1.056 lbs. fat

Possible overrun.

Butter contains .... 80% fat

100 lbs. fat make, $\frac{100}{80} \times 100$..................125 lbs. butter

Less fat ....100 lbs.

Overrun 25%

Gain in overrun due to losses & gains, $\frac{125 \times 1.056}{100} = 1.32\%$

Total possible overrun.....................26.32%

The above example is suggestive of the possibilities and limitations of the actual overrun. Its purpose is not, to indicate what the overrun should be, but to invite the consideration of the overrun from every angle that influences it. This example does not represent any specific case, nor do the gains shown represent maximum possible gains. On the contrary, the unrecognized fractions recorded here are small, they might in actual operation at times be considerably larger, in which case the increase in the overrun would be correspondingly greater. But this example does show that, provided that the creamery operates on a high standard of efficiency, it is quite possible for the overrun to be slightly above the maximum of the theoretical overrun which, with butter containing 80% fat, is 25%.

In short, the subject of overrun can be consistently considered only in terms of efficiency and it is through efficiency only that any creamery can hope to regulate the overrun. The creamery that expects to reliably regulate its overrun must aim at maximum efficiency in those many details that so vitally affect the overrun; efficiency that makes for exhaustiveness of churning and minimum mechanical losses on the one hand, and correct weighing and testing of cream and butter on the other; efficiency that means the recording of every fraction of a pound of cream and every fraction of a per cent of fat in the test, that the standard equipment for weighing and testing enables the operator to determine. This, practical experience and careful experimental study have shown to result in an overrun, in which the unavoidable mechanical losses are largely, or wholly, or occasionally even slightly more than wholly offset by such gains as may accumulate from the undeterminable and unrecognized fractions in weights and tests.

CHAPTER XIV.

MARKETS AND MARKETING OF BUTTER

Importance.—At best the success of all business ultimately depends on its ability to dispose of its products at a satisfactory margin. Successful marketing is an open secret in all lines of business success and the butter business is no exception to this rule. Notwithstanding this fact, the market end of the butter business is a department not infrequently much neglected and often least understood by many producers and manufacturers of butter and causing annually vast sacrifices in the form of unsatisfactory returns to the farmers and creameries of this country.

Essentials in Successful Marketing of Butter. Quality.—Quality is the first and all fundamental requisite for successful marketing. Butter must be of such quality that there is a demand for it. The consumer is the final judge of quality. The importance of quality is summarized most admirably in an address on Butter Markets by Mr. N. J. Eschenbrenner[1] of the firm of Gude Bros. & Kieffer of New York City before the Dairy students of Cornell University April, 1916, as follows: "In summing up the whole proposition of marketing butter, **it is wholly a matter of quality.** When good butter is competing against poorer grades, when high flavored, clean butter is competing against unclean flavors, when solid, waxy-bodied butter is competing against weak-bodied, when desirable color, salt and style is competing against undesirable color, salt and style and general workmanship, on a basis of price and distribution, the better grades get the preference over the poorer grades and the poorer grades are absorbed only after satisfactory concession has been made in price."

While it is true that at times of butter shortage, when the demand exceeds the supply and the market is very brisk, the difference in price between different grades of butter is relatively small, because the average consumer is willing to "put-up" temporarily with lower grades in preference to going without butter, in the long run quality asserts itself. Under normal market conditions and when the supply is equal to, or greater than the demand, it is the lower grades that suffer. On quality depends the stability and permanency of our butter markets, quality controls the consumptive demand of the public, quality determines our ability to successfully meet competition with butter substitutes from within, and with imported butter from without our country, quality is the key to the establishment of satisfactory export markets abroad that will take care of our surplus at home, quality decides our ability to pay the farmer, on whose success the prosperity of the entire dairy industry depends, prices sufficiently attractive to induce him to keep on feeding

[1] Eschenbrenner—Address on Butter-Markets, New York Produce Review & Am. Creamery, April, 1916.

and milking the dairy cow, and to interest himself in better cows, better methods, larger production and greater returns that make for increased prosperity of the producer and his family and better education for his children.

Knowledge of Requirements of Different Markets.—The average consumer wants good butter, not always fancy butter, but butter of clean flavor, firm body, even color and medium salt. While butter of the best quality brings the highest price in most markets, there is a vast difference in the demands of the consumers in different markets of the country and in different sections of the same market. Hence all wholesalers, commission men and jobbers do not cater to the same class of trade.

There is a class of consumers who demand extra fine butter and are willing to pay a premium for it. The trade in many sections of the eastern markets is particularly critical. With this class of trade nothing but the best quality will do and lower grades are not desired.

But there is also another class which considers price rather than quality and which is satisfied with butter that is of fair quality. While the creamery should concentrate its efforts on securing the best possible quality of cream, and on making the best quality of butter from it, under the now prevailing system of receiving cream in many sections of the country and particularly in the central west, it is impossible for many creameries to economically produce butter that grades above "extras," and extreme efforts to improve the quality in order to satisfy the most critical trade under such conditions would tend to prove disadvantageous to the financial success of the creamery, the difference in price received for the butter not being sufficient to offset the increased expense of operation and the possible falling-off of the cream supply. The quality of the butter which the creamery can afford to produce under these and similar circumstances will depend upon the class of trade it must supply.

The creamery that has developed a local trade, that is able to sell its butter 24 to 48 hours after manufacture and that distributes it in small quantities, so that the butter is consumed within one week or less of the time of manufacture, may secure top prices for an 89 to 91 point butter by selecting those stores that do not supply a highly critical trade. In trade of this kind many of the customers buy butter largely by the brand, they believe in the brand and if the butter is fairly uniform in quality they are satisfied. Similar markets may be located in the wholesale trade of the large consuming centers for the surplus butter. There are wholesale dealers in these markets whose specialty lies in catering to the less critical trade and who therefore are in a position to dispose of the creamery shipments of butter of only fair quality to good advantage. It is to the creamery's interest to study the different channels through which the grade of butter which it produces will net the highest price.

There are times when it is exceedingly difficult for the creamery to secure a satisfactory price on the wholesale market. During the early summer months when the principal demand in the larger markets is for butter for storage purposes, butter is bought strictly on the quality basis and sour-cream butter is not in demand, except that from creameries which have established a reputation of knowing how to handle such cream and how to manufacture from it a product of dependable keeping quality. Then again, in August and September, when the jobbers are loaded with May and June butter of good quality, and which they bought at low prices, the fresh midsummer butter is usually of poorer quality than the May and June butter placed in storage, the demand for it is very limited and its sales are often possible only by offering it at prices below those paid for the early summer butter. At the same time midsummer prices of butterfat paid by the creamery are generally higher than prices paid to the farmers for May and June butterfat. This combination of conditions therefore is prone to yield returns unsatisfactory to the creamery. The advantage to the creamery of having direct connection with consumptive channels of distribution, such as local and neighborhood retail stores, is obvious, and the creamery should aim, during unfavorable periods of the wholesale trade in the larger markets, to move its lower grades through these local channels.

The creamery which grades its cream and churns the grades separately may succeed in satisfying its more critical trade with the butter from the first grade cream. The butter from the second grade cream may be sold to bakeries and confectioners but it is often preferable to sell the second grade butter under a special brand reserved for that class of butter only; frequently it is possible to establish a satisfactory trade with acceptable returns with this special brand. Another, often very desirable outlet for the second grade cream is to manufacture it into unsalted butter and sell it to the Jewish trade, ice cream factories and bakeries.

It is obvious from the above discussion that, while quality is supreme, the sucessful marketing of butter requires careful investigation and study on the part of the creamery, of the various market demands, and of the channels of trade by which these demands may best be supplied. The creamery must find and supply that class of trade which has the greatest demand for its butter.

Uniformity of Quality.—Having succeeded in finding the most advantageous channels into which to divert the butter, it is very important that the creamery be able to hold these markets, and success at this point in turn will largely depend on the maintenance of uniformity of quantity and quality. The problem of maintaining the quantity of the supply will be discussed under the heading of "Selling Creamery Butter Locally."

Uniformity of quality is an inevitable demand which the consumer exacts. In fact it is paramount in importance to quality itself. The public demands butter that is uniform in flavor, salt, color and workmanship. Lack of uniformity makes the consumer suspicious and dissatisfied. He feels that he cannot depend on the product. Large creameries, who are in a position to grade their butter closely, whose churnings do not vary in size and whose process of manufacture is carefully standardized, find little difficulty to supply the class of trade which they cater to, with butter of fairly constant uniformity. Small creameries. with their irregular churnings and often inadequate equipment and system of manufacture, are not so fortunate in this respect. This handicap is responsible for the frequent loss of an otherwise satisfactory local trade and for their difficulty in securing satisfactory returns from the wholesale and commission markets.

Standardizing Quality, Transportation and Distribution.—In an effort to overcome this handicap, creameries located in certain sections of the country have united into county and district associations. The purpose of these cooperative organizations is to improve and standardize the quality and uniformity of their product. They employ a competent inspector whose duty it is to standardize their methods of manufacture and to inspect and grade their butter.

Some creameries have gone one step farther in their cooperative effort, shipping cooperatively in carload lots and standardizing their methods of selling and marketing their product through the same distributing agency.

The output of the individual small creamery is too small to ship in carload lots. The average small creamery has to hold its butter for a week or longer before it can ship to advantage and even then it is often difficult for the small creamery to secure refrigerator service. The holding of the butter at the creamery with the usual inadequate facilities for keeping it cool, and the lack of refrigeration in transit, often cause the butter to arrive at the market in deteriorated condition resulting in low returns. Through intelligent cooperation numerous small creameries located in fairly close proximity and situated on the same railway line are often able to fill a car once or twice per week and thus are in a position to secure prompt refrigerator service and at reasonably low cost, so that at a reduced expense they are in a position to place their butter on the market fresher and in better condition.

The standardization of methods of selling, is another step in the right direction, which is entirely practical with proper cooperation of a sufficient number of creameries and efficient leadership. In some instances these cooperative efforts have resulted in the establishment and adoption of an association stamp or trade mark. In some states, viz., Michigan, Minnesota, Iowa and Wisconsin, with the assistance of their respective State dairy commissioners, the creameries have established State brands.

Marketing Dairy Butter.—Dairy butter, or butter made on the farm, is sold either direct to the consumer, to private residences, hotels, restaurants, boarding houses, clubs, etc., who pay for it in weekly or monthly cash payments, or it is sold to the local country store which generally pays the farmer in trade and not in cash. The great bulk of dairy butter goes to the country store. This is a most primitive method of marketing butter which results, in the great majority of cases, to the disadvantage of the dairyman.

Selling Creamery Butter Locally.—Generally speaking the best markets are those nearest home. Selling butter locally, either to the direct consumer at the door of the creamery, by going direct to residences, through public or municipal markets, by parcel post, or selling to local stores, or shipping direct to retail stores in neighboring towns and cities, has many and distinct advantages. It enables the creamery to reduce the number of middlemen to the minimum or to do without them entirely, thereby netting the creamery the consumer's or retailer's price. It saves transportation charges to distant points, which may amount to from 1 to 2 cents or more per pound of butter. It protects the butter against conditions unfavorable to its quality in transit and reduces the interval between manufacture and consumption, thereby enabling the creamery to supply the consumer with butter of better quality and demanding a better price. It gives the creamery a better opportunity to put up its butter in the final package, the print, and under its own brand, thereby establishing a constant trade for its own butter and usually at satisfactory prices. It protects the creamery against loss by shrinkage.

In some instances creameries have succeeded in disposing of part of their regular output through what is known as the club-buying system. Clubs whose members are consumers are organized by a local individual in his community. He buys butter regularly and usually in sufficiently large quantity per shipment, to supply all the members of his club. This is a very effective system of reaching the consumer in distant markets direct, but the amount of butter that the creamery can dispose of through this channel is naturally limited.

The chief difficulty encountered by the average small creamery in establishing and holding local markets lies in the irregularity of the amount of its output throughout the year and the fluctuations in the demand and supply of local markets.

If the creamery establishes a local market for all of its output during the flush of the season, it invariably is confronted with the difficulty of supplying that market during the time of shortage, or if the local market takes care only of the output during the time of shortage, then in summer, during the heavy make, there is a surplus of butter which must be disposed of on the open market. This surplus is usually increased by the fact that during the early summer months, when butter fat prices are relatively low, considerable cream is churned on the farms and the creamery has to compete against country butter, which is usually offered for sale at prices below creamery butter. At the same time also the consumption of butter in the local markets generally reaches ebb-tide, partly because of a reduction of butter consumption per capita during the hot weather and partly because many of the consumers leave for cooler climes.

In order to equalize these fluctuating conditions of supply and demand some creameries are buying butter on the open market during the time of shortage to take care of their trade, while others store some of their surplus during the time of flush. In the buying of butter to offset the shortage of output, the greatest care should be exercised that the quality of the butter purchased is equal to that of the regular make. The creamery should also make sure that it complies with the laws of the state concerning the labeling of such butter. In many states the law prohibits the sale of butter under the creamery's private brand, unless the brand plainly indicates that the butter was not made by that creamery. Instead of stating that the butter is made by the respective creamery, the wrapper should state that the butter is packed and distributed by the respective creamery.

The storing of butter in the creamery, in order to take care of its surplus and to hold it over for the time of shortage, is usually not a practical proposition in the case of the small creamery with limited cold storage facilities. Unless butter can be kept at a uniform temperature of Zero degrees Fahrenheit or below it will, under average conditions, depreciate in value to the extent to where it can no longer be sold to the regular trade. If the butter is made from a good quality of cream it is best stored in a commercial cold storage plant. If it is made from a poor quality of cream, its storage is a risky adventure under any condition. Furthermore, the storing of butter involves the "tying-up" of operating capital which is often beyond the financial resources of the small creamery.

Experience has shown that under average conditions of the small creamery, it is safer to dispose of its surplus as soon as possible after making. If the creamery exercises due caution and foresight in making the proper arrangements for the disposition of its surplus on the open market, there is no need of serious loss and it should at least break even with its surplus, provided that the butter is of a quality acceptable to the market where it is sold.

Furthermore, November 1, 1917, by Proclamation of the President of the United States, Federal Rules and Regulations went into effect providing that butter, and other food products held in cold storage longer than 30 days shall be marked, either on the butter itself, or on the container, with the words "Cold Storage" and shall be sold as cold storage goods. Similar regulations have also become state laws in several of the States. While this ruling, which is a War measure, remains in effect, the creamery may find considerable difficulty to satisfy its trade during the period of shortage with butter placed into cold storage during the time of flush. June butter, made from butterfat that is produced by the cows during the prime of their lactation period and that are feeding on nature's choicest feed, succulent pasture grass, is acknowledged to be superior in flavor. If manufactured in the proper manner, it generally is of fully as good quality when it comes out of storage as fresh winter butter which is made largely from the milk of stripper cows and cows receiving dry feed. In fact, it often is of a quality distinctly superior to the fresh winter butter. From the standpoint of quality, therefore, cold storage butter may be fully as desirable and appetizing as fresh winter butter, but the fact that the package bears the words cold storage, makes it less attractive to the average consumer, it arouses his suspicion that he is getting an inferior article. For this reason, under the cold storage ruling, the creamery may experience serious obstacles in its efforts to take care of its regular trade during the time of shortage of fresh butter, by offering it cold storage goods in the place of fresh butter.

The large centralized creameries obviously have the advantage in disposing of their output direct to the retailer. Their output is large enough, so that they can afford to establish distributing offices in the large markets. Through these distributing offices they are able to reach the retailer in distant consuming centers in a similar way as in the local and home markets. These distributing offices also serve as a channel through which the trend of the market may be accurately followed, and through which that class of trade may be located that has the greatest demand for the quality of butter the creamery produces.

Selling butter to the wholesale produce trade.—The distribution of vast quantities of the butter made, is taken care of by an organization of middlemen intermediary between the shipper and the city retail stores. This organization is known as the wholesale trade. The wholesale produce trade occupies an important position in supplying the shipper with a market for his product and in regulating the quantity and quality of the supply of the retail store, in reducing the cost of transportation by making possible shipments in large units, in maintaining the necessary business relations with the retail stores for or in the place of the shipper, and in making possible prompt payments so as to enable the shipper to pay the farmer for his cream without delay. In other words, the wholesale produce trade performs that function which the shipper—the creamery—without branch offices in the distant city markets, is unable to accomplish. It acts as a clearing house for the shipper and retailer alike. Its proximity to the distributing channels enables it to feel the pulse of the market in its and other cities and to regulate the influx and movement of the various grades of butter and other commodities on the market.

The organization of the wholesale produce trade is established in all cities of appreciable size. According to Weld,[1] "a city is large enough to require a separate wholesale trade organization when it can handle goods in car lots for consumption in the city

[1] Weld, The Marketing of Farm Products, p. 67, 1916.

or for redistribution in nearby towns." The wholesale produce trade is always localized in a certain district of the city. Thus in Chicago, South Water Street represents the wholesale produce district for that city.

The wholesale dealers may be divided into two classes, to each of which are attributed certain, more or less definitely defined functions, namely the middlemen who receive goods direct from the shipper and the middlemen who buy direct from the receivers and sell to the retail stores or other outlets.

To the first class belong the wholesale receiver, the commission man and the broker. The wholesale receiver buys the butter outright and pays the shipper for it upon receipt. He sells the butter to the retail store and also to the jobber. The commission man does not buy the butter, he does not become owner of it, but acts as an agent for the shipper, selling it for him to retail stores, hotels, restaurants, and other outlets and deducting from the gross receipts a commission for his services, together with freight and cartage charges. The rate of commission usually charged to the butter shipper is 5 per cent of the gross receipts. The broker operates on a similar plan as the commission man, but he usually handles goods in larger quantities and charges a lower rate of commission.

To the second class, the middleman who buys from the wholesale receiver and not direct from the shipper, belongs the jobber. He also sells to the retail trade.

These middlemen have their organization of solicitors who look after the retail trade and other outlets in their city as well as in other cities.

Most of the butter shipped to the wholesale trade is desired in bulk packages, usually 60 pound tubs or 50 pound boxes for Eastern markets and 68 pound cubes for the Pacific coast markets. In exceptional cases the shippers put their butter up in the finished package, the print. Most of the wholesale receivers have a brand of their own, on which they have established some fancy trade, and for which they print fancy butter and sell it under their own carton.

Methods of Sales.—Butter shipped to the wholesale trade is sold according to any one of the following four methods:

1. **Track Sales.**—By track sale is understood F. O. B. (free on board) shipping point. By this method the responsibility of the shipper ceases when the butter is placed on the car, or on ship board, at the shipping point. The buyer pays the freight, cartage, assumes the risk of transportation and the price is definitely fixed. From the shipper's, or creamery's point of view this is the most advantageous method of selling butter to the wholesale trade. In order to sell butter under this agreement the creamery must previously satisfy the receiver of the uniformity of quality, workmanship, composition and color of butter the creamery is capable of supplying. This is usually done by trial shipments. The receiver agrees to pay a definite price, based on market quotations of the leading markets F. O. B. track. The creamery knows exactly what it is going to get for its butter at the time the butter is shipped and payments are made upon arrival of the goods at the market.

2. **Delivered Sales, or F. O. B. Market.**—In this method of sale the shipper's responsibility ceases when the butter has reached the market of the buyer. The shipper pays the freight, cartage, and assumes the risk of transportation. The price depends on market prices on the date of arrival of the goods at the market. Agreements to buy butter on the above basis are usually also entered into upon receipt of trial shipments representative of the quality of the average run of butter manufactured by the contracting creamery. While not as advantageous to the creamery as method No. 1, because the price is determined at the market end and because the shipper has to pay the freight and assumes the risk of transportation, this method is by far preferable to the commission sales. Both, in method 1 and in method 2, the butter sells at prices based on market quotations. It is important that prices should not be based on the score of the butter. According to methods 1 and 2 the buyer agrees to pay the price stipulated on the basis of market quotations, as long as he is willing to accept the butter. Should the butter of some shipments not measure up in quality to the trial samples, the buyer will still pay the price agreed upon, but will notify the creamery of the defect, so it may be remedied promptly. In case the quality continues to be inferior

to that of the trial shipments, the buyer may ask the creamery to find another outlet for its butter, or else negotiate another agreement satisfactory to both parties.

3. **Commission Sales.**—The shipper pays the freight and cartage, assumes the risk of transportation and the commission man acts as an agent to sell the butter for which service he charges the shipper a commission, usually of 5 per cent. of the gross receipts. This method places the shipper at the mercy of the commission man, it deprives him of all control over the returns from his butter and it is a method which generally proves very unsatisfactory and costly to the creamery.

While there are many reliable and trustworthy men in the commission business, the temptations which surround the commission man to abuse his power at the expense of the shipper are very great, and are finding many a vulnerable spot among their members. Most commission men not only act as agents for the shippers, but usually do also a receiver's business. On an advancing market they are encouraged to buy outright, while on a declining market they are prone to adhere to the commission business exclusively. Not infrequently they charge the shipper a commission on goods they purchase outright and thus receive a commission on their own purchase. The creamery has no guarantee that the returns reported represent the price at which the butter actually sold. A business that offers such unlimited opportunities for illegitimate gain at the expense of the powerless shipper, naturally attracts an element that is no credit to the profession and that jeopardizes the welfare of the shipper.

4. **Contract Sales.**—By contract sales is meant the method whereby the shipper enters into a contract with the dealer agreeing to deliver a certain number of pounds of butter per week at a price based on market quotations. The contracts are usually short-term agreements and are largely, though not always, confined to the storage season. Contract sales are usually taken advantage of by large creameries. Small creameries with a limited and often uncertain output are seldom in a position to negotiate such sales and, when consummating them, they are liable to find serious difficulty in fulfilling their agreement.

Speculating in Futures.—Buying or selling for future delivery is not as common in the butter business as on the grain market, though it is participated in to a limited extent by the speculative element in most markets. The purpose of buying for future delivery is based on the hope of the buyer to sell at a higher price at the time of delivery, thereby making a profit. The object of selling for future delivery lies in the assumption of the seller that he may be able to buy at a reduced price and thereby reap a profit. It is obvious that buying and selling for future delivery is purely a speculative transaction which may yield profitable returns, but which involves the usually high risks characteristic of all speculation.

Methods of Payment.—As previously stated, dairy butter sold direct to customers or by parcel post, is usually paid for by cash on delivery. In the case of hotels, restaurants, etc., the dairy farmer usually collects weekly or monthly and sometimes at the end of the season. Dairy butter sold to the country store is generally paid for in trade.

Creameries selling direct to retail stores make their collections weekly or monthly. In the case of doubtful customers it is advisable to demand remittance with the order or to deliver the butter C. O. D.

Payments for shipments to the wholesale trade in distant markets involve more or less delay. If butter is sold on commission, usually several weeks elapse before the returns arrive and even in the case of "track sales" and "delivered sales" several days and often one to two weeks are required for the payments to arrive. In the meantime the farmers have to be paid and the supplies and package have to be purchased. This is often too great a financial strain on the creamery whose operating capital is generally exceedingly limited.

This difficulty is most commonly taken care of by permission, on the part of the wholesale receiver or the commission man, to allow the shipper to draw on him to the extent of a large portion of the shipment of butter at the time of shipment. The creamery attaches a draft to the bill of lading and the receiver or commission man settles for the balance upon arrival of the goods or upon their sale, respectively. Banks that pay interest on the balance of the creamery account, invariably discount these drafts. Banks that pay no interest on the creamery balance, frequently accept the drafts without discounting.

Butter Exchanges.—The butter exchange is a voluntary trade organization of wholesale dealers in butter. In many cases the exchange is not confined to butter alone, but includes other allied commodities, such as cheese, eggs, poultry, etc. Specific examples of produce exchanges of dealers in butter or butter and allied commodities, whose operations are recognized as having the greatest influence upon the marketing of butter in this country, are:

The New York Mercantile Exchange, New York City, N. Y.

The Chicago Butter and Egg Board, Chicago, Illinois.

The San Francisco Wholesale Dairy Produce Exchange, San Francisco, California.

The Elgin Board of Trade, Elgin, Illinois.

The Boston Chamber of Commerce, Boston, Massachusetts.

These produce exchanges are generally incorporated associations. Weld[1] enumerates the primary functions of the produce exchange as follows:

"1. To provide a convenient market or trading place.

2. To regulate business dealings of members.

3. To provide a system to facilitate the settlement of trade disputes.

4. To establish uniform grades and a system of inspection.

5. To acquire and to disseminate market information."

The specific objects and functions of the different exchanges cover a varying range. The charter of the New York Mercantile Exchange, for instance, records the following objects of the Association: "To provide and regulate a suitable room or rooms for an exchange in the City of New York; to foster trade; to protect it against unjust or unlawful exactions; to reform abuses; to diffuse accurate and reliable information; to settle differences between members; to promote among them good fellowship and a more enlarged and friendly intercourse; and to make provision for the widows and families of deceased members."

The realization of its objects and the safeguarding of its policies is accomplished by the careful supervision of admission of new members.

[1] Weld, The Marketing of Farm Products, 1916.

The "Call."—One of the important features of the butter exchange is the "Call." Weld defines the "Call" as "a device for making bids and offers, partly to establish market prices or quotations and partly to bring about actual sales."

In the larger markets, such as New York, Chicago, etc., the traders assemble each day at a fixed hour (at 10 a. m. in New York and Chicago) for the "Call." The "Call" is usually conducted in a room with a raised platform at one end for the chairman, and a blackboard at the back, on which are recorded receipts of the day, general market conditions and the bids and offers made under the call. After the offers for sale made by the traders, including quantity, quality and price, are posted on the blackboard, bids are called for. The bids are also posted. The members of the Exchange appear on the floor and buyers and sellers make public bids on the offers of butter. Often these bids and offers result in sales and these sales show in a public manner the prices at which receivers are willing to sell their butter and the prices at which buyers are willing to purchase it.

The bidding under the "Call" affords competitive sellers an opportunity to sell butter against each other according to the supply. Should there be more demand for butter on any one day at a price above the quotation of the previous day, the quotation will be advanced to such a point as buyers are paying for the butter, for the buyers will not stand for any quotation that is lower than the price they are actually paying for butter. The same principle applies to the sellers. Should the sellers be loaded down with butter, it is their privilege to offer it at such prices at which and until the buyers will take hold, and oftentimes with the market stocked with butter, it is necessary to sell it at prices where the retailers will be able to reduce their selling price to the consumer. In this way the consumer becomes interested in consuming more butter and the surplus stock becomes disposed of.

The actual sales and purchases made under the "Call" are few. According to Eschenbrenner[1] they sometimes do not exceed 5 per cent of the daily receipts of butter, the primary object of the "Call" being to feel market conditions rather than make specific sales. The present tendency of the butter trade

[1] Eschenbrenner, New York Produce Review, April, 1916.

is toward conducting its transactions through the medium of private sales. The great bulk of butter handled by members of the Exchange is not sold under the "Call," but by private deals between buyers and sellers. This situation is largely the result of the increasing differentials of grades and the development of special markets for special grades, for which butter from special creameries is demanded. The "Call," however, serves in many instances as a convenient means for the seller who has a surplus, to find a buyer and for the buyer in case of shortage of any particular grade of butter to locate a seller of that grade. Considerable trading is also usually done privately between members at the conclusion of the "Call" and before the meeting adjourns.

Butter Quotations.—The problem of determining butter quotations is a subject of the greatest importance to the entire butter industry. Butter quotations, in order to be correct, should coincide with the actual market value of the butter. They should therefore be determined by the supply and demand of butter, otherwise they may be conducive of serious disturbances in the normal movement of butter on the market, which disturbances are bound to operate against the best interests of the butter business.

Limited space does not permit here a detailed discussion of the multitude of agencies through which price quotations are established, but the importance of the subject justifies a brief reference to the prevailing systems of determining butter quotations in a few of the leading butter markets of the country. These references are confined here to the New York, Chicago and Elgin quotations.

Formerly the New York and Chicago quotations were determined by a committee of the New York Mercantile Exchange and the Chicago Butter Board, respectively. These committees, consisting of dealers, being in most intimate touch with the market and with the actual market value of the butter, were assumed to be admirably qualified to arrive at just and correct quotations. They met each day at the conclusion of the "Call" behind closed doors.

"This same practice obtained abroad and even in Denmark butter quotations decided upon by the Copenhagen merchants are still largely used as a basis of settlement with creameries. But in this country quotations made by price committees of merchants have not been looked upon with favor by government officials, especially when they did not accurately represent prevailing values, and it was usually found that the tendency of most price committees of merchants was to keep the official quotations below prevailing selling values. Several of our trade organizations were thus forced by the government to discontinue the so-called official quotations, but some still continue the practice."[1]

In 1907 the Mercantile Exchange of New York was sued by the Government on the ground of fraudulent manipulation of quotations, with the result of prohibiting the Exchange from issuing quotations not representing the value of butter based on actual sales by first hand receivers. In a decision rendered by the Supreme Court it was decided that this quotation committee was a combination in restraint of trade and the practice was decided to be illegal. Realizing that the actual sales under the "Call" of the Exchange were too small to justify the basing of quotations on these sales, the Exchange discontinued the issuance of official quotations and the determination of price quotations was assumed by outside market reporters.

Since then the firm of Urner-Barry Company, with the help of a most efficient force of trained market reporters, has assumed the responsibility of establishing daily price quotations in New York. After the "Call" each day, having taken into consideration the bids and offers under the "Call," the market reporter makes a canvass of the market, calling on the buyers and sellers and ascertaining the prices at which they are doing business through private negotiations; then, at about noon each day he announces the quotations he will publish in his paper for the various grades of butter. These quotations are accepted as the settling basis for the day and these are the quotations that are sent broadcast throughout the country.

In Chicago the quotation committee met a similar fate, the courts prohibiting its functions, unless quotations were made on the basis of actual sales, and the making of butter quotations passed into the hands of outside market reporters.

[1] Making Quotations—Comments, The Buttermakers' Discussion Club, New York Produce Review, July 12, 1916.

The Elgin Board also changed its method of determining quotations to issuing them on the basis of actual sales made at weekly meetings of the board. In some markets, however, the committee system of issuing quotations still prevails.

The chief reason why quotation committees proved unsatisfactory and which led finally to their discontinuation in Chicago and New York was the fact that these committees represented largely only the wholesale receivers. The receiver naturally is interested in buying as cheaply as possible and this created a tendency for the establishment of quotations lower than the actual sales value of the butter, with its undesirable results on the market, such as dissatisfaction among retailers who could not understand the great difference between the prices they had to pay and the butter quotations of the committee, it also invited the practice of paying premiums to the shipper, etc.

The exceedingly small sales on the floor of the Exchange did not justify the price determinations on the basis of the actual sales of the Exchange, hence the only logical alternative appeared to be for the Exchange to turn the responsibility of making price quotations over to independent market reporters. In the case of the Elgin quotations the discontinuation of the Elgin board would have meant the discontinuation of Elgin quotations, because the Elgin market itself is a negligible quantity, so the only means to save the Elgin quotation was to comply with the order of the courts and issue quotations on actual sales by the board, in order not to deprive the large sections of the country doing business on the Elgin basis, of the Elgin market to which they have become accustomed as a trading basis.

It is obvious that the market reporter, assuming the responsibility of making price quotations, is thus vested with vast powers, the abuse of which for his own interests, or through incompetence, would throw the market into a most chaotic condition. In the first place, the market reporter must be a man of ability, experience and judgment. He gets his information by going around among the trade and must be able to distinguish between gossip and facts and between fiction and the truth. Aside from the condition of supply and demand he must cope with the difficulties of the influence on the demand for and supply of storage butter, on the market value of fresh goods, and he must above all be a man of superior integrity, honesty and disinterestedness.

Inspection and Grading.—Upon its arrival in the wholesale receiver's hands the butter is inspected and graded. Butter dealers have agreed to a standard score card with 100 points as the basis for perfection, and giving certain values to flavor and odor, body and texture, color, salt, and package.

Most butter exchanges in the larger markets have an official inspector of butter, whose services are available to the members of the exchange, for compensation. Butter so inspected is branded with the official stamp of the exchange. The inspector of the New York Mercantile Exchange has a stamp of different shape for each main grade, so as to facilitate the recognition of the grade by the stamp. The great bulk of the butter received by the wholesale distributors of the larger markets is not subjected to an official inspection by the inspector employed by the wholesale trade organization. Sales, on the negotiation of which official inspection is not requested, are commonly spoken of as being "over-the-trier." The inspection service maintained by the Exchange is largely, if not entirely, for the purpose of inspecting those lots of butter of which inspection is requested by the butter, when purchased under the "Call," as for instance in the case of dispute between the seller and buyer as to grade, or in the case of butter sold to the Government.

When, in the opinion or judgment of the buyer the butter he receives does not conform in quality with the grade he purchased under the "Call," he has the privilege to apply for the services of the official inspector. If the decision of the inspector is not acceptable to either or both of the contracting parties, an appeal may be made from the decision of the inspector, to the chairman of the Butter Committee, who then appoints three members from that committee to inspect the butter in dispute. They report their results to the Superintendent of the Exchange. The decision of this subcommittee is final.

While there are minor variations in the grades and grading of butter on the different markets, as a whole the classification of grades is very similar in the principal markets throughout the country.

BUTTER RULES OF THE NEW YORK MERCANTILE EXCHANGE.[1]

Classifications—Grades and Scores.

1. Butter shall be classified as Creamery, Renovated, Ladles, Packing Stock and Grease Butter.

Definitions.—2. Creamery.—Butter offered under this classification shall have been made in a creamery from cream separated at the creamery or gathered from farmers.

3. Renovated.—Butter offered under this classification shall be such as is made by melting butter, clarifying the fat therefrom and rechurning the same with fresh milk, cream or skim-milk, or other similar process.

4. Ladles.—Butter offered under this classification shall be such as is collected in rolls, lumps, or in whole packages and reworked by the dealer or shipper.

5. Packing Stock.—Butter offered under this classification shall be original farm-made butter in rolls, lumps or otherwise, without additional moisture or salt.

6. Grease Butter shall comprise all classes of butter grading below thirds. or of packing stock grading below No. 3, as hereinafter specified, free from adulteration.

Grades.—7. Creamery. Renovated and Ladles, shall be graded as Extras, Firsts, Seconds and Thirds; and Packing Stock shall be graded as No. 1, No. 2 and No. 3.

Definition of Grades.—8. Grades of Butter must conform to the following requirements.

Extras.—9. Shall be a standard grade of average fancy quality in the season when offered under the various classifications. Ninety per cent. shall conform to the following standard; the balance shall not grade below Firsts:

Flavor.—Must be sweet, fresh and clean for the season when offered if Creamery, or sweet, fresh and reasonably clean if Renovated or Ladles.

Body.—Must be firm and uniform.

Color.—Not higher than natural grass, nor lighter than light straw. but should not be streaked or mottled.

Salt.—Medium salted.

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[1] Secured through courtesy of New York Produce Review and Am. Creamery, April, 1919.

Package.—Sound, good, uniform and clean.

Firsts.—10. Shall be a grade next below Extras and must be good butter for the season when made and offered, under the various classifications. Ninety per cent. shall conform to the following standard; the balance shall not grade below Seconds:

Flavor.—Must be reasonably sweet, reasonably clean and fresh if Creamery or Renovated. and reasonably sweet if Ladles.

Body.—Must be firm and fairly uniform.

Color.—Reasonably uniform, neither very high nor very light.

Salt.—May be reasonably high, light or medium.

Package.—Sound, good, uniform and clean.

Seconds.—11. Shall be a grade next below Firsts.

Flavor.—Must be reasonably good.

Body.—If Creamery, must be solid boring. If Ladles or Renovated, must be ninety per cent. solid boring.

Color.—Fairly uniform, but may be mottled.

Salt.—May be high, medium or light.

Package.—Good and uniform.

Thirds.—12. Shall be a grade below Seconds and may consist of promiscuous lots.

Flavor.—May be off-flavored and strong on tops and sides.

Body.—Not required to draw a full trier.

Color.—May be irregular or mottled.

Salt.—High, light or irregular.

Package.—Any kind of package mentioned at time of sale.

13. (For grades higher than Extras see paragraph No. 25.)

No. 1 Packing Stock.—14. Shall be sweet and sound, packed in large, new, or good uniform second-hand barrels, having a wooden head in each end, or in new tubs, either to be parchment paper-lined. Barrels and tubs to be packed full.

No. 2 Packing Stock.—15. Shall be reasonably sweet and sound, and may be packed in promiscuous or different kinds of barrels, tubs or tierces, without being parchment paper lined, and may be packed in either two-headed or cloth-covered barrels.

No. 3 Packing Stock.—16. Shall be a grade below No. 2, and may be off-flavored, or strong; may be packed in any kind or kinds of packages.

17. Charges for inspection of Packing Stock shall be the same as the rules call for on other grades.

18. Mold.—There shall be no grade for butter that shows mold.

Known Marks.—19. Known marks shall comprise such butter as is known to the trade under some particular mark or designation and must grade as Extras or better if Creamery or Renovated, and as Firsts or better if Ladles in the season when offered unless otherwise specified. Known marks to be offered under the call must previously have been registered in a book kept by the Superintendent for that purpose. If Renovated, the factory district number and statement be registered.

Scoring.—20. The standard official score shall be as follows and shall apply to Creamery Butter only:

Flavor	45 points
Body	25 points
Color	15 points
Salt	10 points
Style	5 points
	100 points

21. Extra Creamery may score either 91, 92 or 93 points at the discretion of the Butter Committee, who shall determine the required score from time to time in such manner that it shall represent an average fancy quality in the season when offered. But butter scoring more than required for Extras shall be deliverable on a contract for Extras, and may be branded as such at the request of seller, or buyer. Any change in the Standard score required for Extras shall, after authorization by the Butter Committee, be announced by the caller at the opening of the next regular call and posted upon the bulletin board of the Exchange and be effective 24 hours later.

22. The minimum score of Firsts shall, at all times, be 4 points below the score required for Extras.

23. The minimum score of Seconds shall be 5 points below the minimum score required for Firsts.

24. The minimum score of Thirds shall be 7 points below the minimum score required for Seconds.

BUTTER RULES OF THE CHICAGO BUTTER AND EGG BOARD.[1]

Packages to be Used.

Creamery, Centralized Creamery or Held Butter:—

Tubs—hardwood about sixty (60) pounds standard, White Ash with wood—or satisfactory metal hoops, or boxes of satisfactory material; thickness of material shall not be less than 9/16″ for sides and ends and 5/16″ for tops and bottoms; boxes shall have net capacity of not over seventy (70) pounds or less than sixty (60) pounds. All tubs or boxes should be paraffined and lined with parchment paper.

Ladles	Tubs or boxes.
Renovated	Tubs or boxes.
Packing Stock	Any size or style of package.
Grease Butter	Any size or style of package.

Classifications, Grades and Scores.

1. Butter shall be classified as Creamery, Centralized Creamery, Held Butter, Renovated, Ladles, Packing Stock and Grease Butter.

Definitions.

2. **Creamery.** Butter offered under this classification must be made in a creamery. The cream shall either be separated at the creamery or hauled direct to the factory from the farms.
3. **Centralized Creamery.** Butter offered under this classification must be made in a creamery. Cream used in the manufacture of this butter may be gathered direct from the farmers or shipped in from cream stations.
4. **Held Butter.** Butter offered under this classification shall be butter that has become Cold Storage Butter by virtue of the laws of the United States or of the State in which such butter is sold.
5. **Renovated.** Butter offered under this classification shall be such as is made by melting butter, clarifying the fat therefrom and re-churning the same with fresh milk, cream, or skimmilk, or other similar process.

[1] Secured through courtesy of Chicago Dairy Produce, April, 1919.

6. **Ladles.** Butter offered under this classification shall be such as is collected in rolls, lumps, or in whole packages and re-worked by the dealer or shipper.

7. **Packing Stock.** Butter offered under this classification shall be original butter without additional moisture or salt, from creamery or dairy (but may be from miscellaneous sources), which has been collected in any quantity and packed in barrels, tubs or other containers. It must be of quality fit for human consumption as food and free from adulteration.

8. **Grease Butter.** Butter offered under this classification shall consist of all grades of butter below thirds. If Packing Stock, below No. 3, free from adulteration.

Grades.

9. Creamery, Centralized Creamery and Held Creamery shall be graded **Extras, Standard, First, Seconds, and Thirds**; Renovated and Ladles as **Firsts** and **Seconds**; and Packing Stock as **Number 1, Number 2.** and **Number 3.**

10. Grades of butter must conform to the following requirements:

Extras.

11. Shall be a grade of creamery of average fancy quality in the season when offered under the classifications. Ninety per cent shall conform to the following standard, the balance shall not grade below ninety points:

    Flavor: Must be sweet, fresh and clean for the season when offered in Creamery, and sweet and clean in Held.

    Body: Must be firm and uniform. **Color:** Must be either light straw color, medium or high, but must be uniform and neither streaked, or mottled. **Salt:** May be defined as light, medium or high, but must not be gritty. **Package:** New, sound, good, uniform and clean.

Standards.

12. Shall be a grade of centralized creamery of average fancy quality in the season when offered. Ninety per cent shall conform to the following standard and the balance shall not grade below eighty-nine points:

Flavor: Must be sweet, fresh and clean, and sweet and clean if Held.
Body: Must be firm and uniform. **Color**: Must be either light straw color, medium, or high, but must be uniform, and neither streaked nor mottled. **Salt**: May be defined as light, medium or high, but must not be gritty. **Package**: New, sound, good, uniform and clean.

Firsts.

13. Shall be a grade below Extras and must be good butter for the season when made and offered under the classifications. Ninety per cent shall conform to the following standard, the balance shall not grade below eighty-seven score:
Flavor: Must be reasonably sweet, reasonably clean, and fresh if Creamery, Centralized Creamery, Renovated, and reasonably sweet and clean if Held. **Body**: Must be firm and fairly uniform. **Color**: Reasonably uniform, neither very high nor very light. **Salt**: May be light, medium or high. **Package**: New, sound, good, uniform and clean. If Ladles, must be ninety per cent solid boring, color reasonably uniform and package sound and clean.

Seconds.

14. Shall be a grade below Firsts. **Flavor**: Must be reasonably good. **Body**: If Creamery, Centralized Creamery, or Held must be solid boring. If Renovated or Ladles, must be ninety per cent solid boring. **Color**: Fairly uniform, but may be mottled. **Salt**: May be light, medium or high. **Package**: Good and uniform.

Thirds.

15. Shall be a grade below seconds and may consist of promiscuous lots. **Flavor**: May be off flavored and strong on tops and sides but not rancid. **Body**: Not required to draw a full trier. **Color**: May be irregular or mottled. **Salt**: High, light or irregular. **Package**: Any kind of package mentioned at the time of sale.

No. 1 Packing Stock.

16. Shall be original butter without additional moisture or salt, sweet and sound, packed in barrels, or in tubs or boxes, to be parchment paper-lined; packages to be packed full.

No. 2 Packing Stock.

17. Shall be original butter without additional moisture or salt, sweet and sound, may be packed in different kinds of barrels, tierces, pails, tubs or boxes; may be without paper lining.

No. 3 Packing Stock.

18. Shall be a grade or quality above Grease butter and packed in any kind or all kinds of packages.

Scoring.

19. The standard official score for salted butter shall be as follows:

Flavor	45 points
Body	25 points
Color	15 points
Salt	10 points
Style	5 points

20. The standard official score for unsalted creamery butter shall be as follows:

Flavor	45 points
Body	30 points
Color	15 points
Style	10 points

Extras.

21. Shall consist of a grade of butter scoring ninety-two points or better.

Standards.

22. Standards shall consist of the highest grade of Centralized Creamery made during the season when offered and shall score ninety points or better.

Firsts.

23. The minimum score of Creamery Firsts shall at all times be four points below the score required for Extras.

Seconds.

24. The minimum score of Creamery Seconds shall be four points below the minimum score required for Firsts.

Thirds.

25. The minimum score of Creamery Thirds shall be five points below the minimum score for Seconds.

Distribution.—The distribution of butter to the retail trade on the large markets is a class of work which is the business of the jobber. The jobber buys from the wholesale receiver, commission merchant or broker and sells to retail stores, hotels, restaurants, steamship companies, Pullman car companies and other retail outlets. The jobbers are also frequently termed retailers because they sell to the retail stores. Jobbers who have no established place of business but load the goods they buy from the wholesale receivers on their wagons and peddle them among the retail stores, are called "wagon men."

In reality the jobbers are not the only middlemen who distribute the butter to the retail men. Many of the wholesale receivers and of the commission men also sell to the retail trade.

While some of the butter is sold from the wagon direct to the hotel and restaurant trade, and through other similar direct outlets, the great bulk of the butter reaches the consumer through the medium of the grocery store.

The houses selling to the retail trade have in their employ a force of salesmen canvassing the city. They call on the grocery trade at regular intervals, such as once per week, soliciting their business. The houses selling to the retail stores are very numerous in the large markets and competition is usually very keen, so that constant soliciting is indispensable in order to hold the trade.

As previously stated, the butter passes through the hands of several middlemen, first the railroad, then the wholesale receiver, or the commission man, then the jobber and finally the retail store. When the wholesaler sells direct to the retailer the jobber drops out of the chain of steps through which the butter moves in its passage from the creamery to the consumer. Occasionally the broker also enters into the chain of agencies through which butter passes. The broker handles large quantities only, he does not take possession of the goods but acts in a similar capacity as the commission man, and his overhead expense is very low. He is therefore able to handle butter at a very low rate of commission, usually not over $\frac{1}{4}$ of 1 cent per pound. He may represent the buyer or the seller. His services are engaged most often when the buyer or seller is located at a great distance from the place where the butter is to be bought or sold, and the party who is trying to buy or sell is not familiar with prospective customers in the distant market.

Frequently the wholesale receivers or the commission men have their butter printed by the so-called "butter cutters." These men have the equipment for printing butter and receive a small commission for their services. Again, there are firms with chain stores, whose buyers may purchase their entire supply of butter from the wholesale receiver, or the commission man.

Finally, there is the speculative buyer of butter. He may be a part of the butter business, the creamery, the wholesale receiver, the commission man, the jobber, etc. But quite often he belongs to a class generally not handling butter as a main business, but largely or wholly only for speculation on the side. Thus, especially during the storage season, when butter prices are at ebbtide, individuals in diverse walks of life, buy butter and put it in storage with the hope of reaping a profit when butter prices are high. This type of speculative buyer represents an element that does not usually add stability to the butter business. He is interested largely only in temporary private gain, in making a little "easy money." When the market unexpectedly weakens, he generally becomes panicky and pours his holdings out on the market, causing a further weakening of prices, which in some cases may result in a slump of the market to the temporary detriment of the butter industry This in turn usually discourages this class of butter buyers and often rids the business of much of the speculative element for several years.

Consumption of Butter in the United States and in Other Countries.—According to T. R. Pirtle,[1] Statistician United States Dairy Division, there was prior to the World war, a steady increase in the consumption of butter throughout the world, and the countries of small butter production had been importing increasing amounts of butter year by year.

Exceptions to this general statement are the United States which has shown a decrease in consumption since 1900, the Netherlands since 1903 and the United Kingdom since 1906.

The following figures, secured from Mr. Pirtle's article show the per capita butter consumption by years in the United States and in other countries.

[1] Pirtle—The Consumption of Butter in the U. S. and in Other Countries, The Milk Magazine, Vol. II, No. 6, 1919.

Table 61.—Per Capita Annual Consumption of Butter in the United States by Years.

All Butter		Creamery Butter	
Year	Pounds per Capita	Year	Pounds per Capita
1850	12.9	1890	2.4
1860	14.5	1900	5.3
1870	13.3	1904	6.3
1880	15.2	1909	6.8
1890	18.8	1914	8.0
1900	19.6	1916	7.3
1909	17.5	1917	6.9
1914	16.5	1918	7.6
1918	14.0		

Table 62.—Per Capita Annual Consumption of Butter by Countries.

Country	Date	Pounds per Capita
Australia	1913	25.6
New Zealand	1914	21.7
Denmark	1914	19.0
United Kingdom	1906	19.0
United States	1909	17.5
Canada	1911	16.3
Norway	1906	14.0
Netherlands	1912	11.3
Switzerland	1906	11.0
France	1906	8.0
Italy	1913	2.5
Argentina	1913	1.7 (1)
Union of South Africa	1916	2.0 (2)
Germany	....	(3)
Austria	....	(4)
Egypt	....	(5)
Hawaii	....	(6)
Japan	....	(7)
China	....	(8)

[1] Represents consumption of factory butter only.
[2] Estimated.
[3] It is generally understood that consumption of dairy products in Germany is large. Imports of butter in 1911 exceeded 120,000,000 pounds, but no records are available to establish per capita consumption.
[4] No record available of total production. Imports in 1913 were 14,000,000 pounds and exports 2,000,000 pounds.
[5] Consumption very small.
[6] 1900 record suggests less than one pound per capita. This was improved to about five pounds in 1918.
[7] Very little butter is consumed except by the foreign population; however, use is increasing and becoming more general.
[8] Butter not used by Chinese except by a small but growing number of wealthier classes. Normal consumption of butter estimated at 2,000,000 pounds per annum.

EXPORTS AND IMPORTS.

The following table shows the pounds of butter exported from and the pounds of butter imported into the United States from 1852 to 1918, inclusive:

Table 63.—Exports and Imports of Butter for the United States 1852-1918[1]

Year ending June 30,	Exports pounds.	Imports pounds.
1852-1856	2,781,510	1,612,671
1857-1861	6,793,614	2,484,819
1862-1866	21,625,165	2,978,951
1867-1871	2,858,578	5,257,975
1872-1876	5,527,762	D
1877-1881	39,481,907	D
1882-1886	17,681,492	246,631
1887-1891	16,685,391	202,883
1892-1896	12,150,434	91,224
1897-1901	23,758,629	47,421
1902-1906	14,609,637	321,038
1907-1911	6,601,489	847,351
1912-1916	7,341,923	2,914,234
By years:		
1907	12,544,777	441,755
1908	6,463,061	780,608
1909	5,981,265	646,320
1910	3,140,545	1,360,245
1911	4,877,797	1,007,826
1912	6,092,235	1,025,668
1913	3,585,600	1,162,253
1914	3,693,597	7,842,022
1915	9,850,704	3,828,227
1916	13,487,481	712,998
1917	26,835,092	523,573
1918	26,194,415[2]	1,655,467[2]

Exports.—The butter export trade of the United States has so far been very limited in amount and value of butter, considering the vast expanse of this country and the great development of our dairy industry. The annual butter exports within the last 60 years have varied from two million pounds to thirty-nine million pounds, as compared with over two hundred mil-

[1] Annual Report, U. S. Department of Commerce and Labor. These figures represent twelve months, ending June 30.

D. Included in other Packing House Products.

[2] These figures represent twelve months, ending December 31.

lion pounds exported by the little country of Denmark with an area of less than 16,000 square miles and a population of only two and one-half million people.

During and since the World war there has been a marked and growing increase in the amount of butter exported by the United States, and the great shortage of butter and other fats in Europe suggests that this increase may continue until the depleted stocks of butter on the European continent are again replenished. In considering the immediate future of the butter-export trade the fact should not be lost sight of that the neutral dairy countries, such as Denmark, Holland, Sweden and Norway, whose decrease in dairy products during the war was due not so much to decrease in cow population, but to diminished production per cow because of shortage of dairy feed, are now rapidly approaching normal production again, and are in a position to export to the butter-poor countries of the European continent.

Prior to the war our butter exports to countries of the North American continent went largely to Canada, considerable portions were also shipped to the Central American countries, Bermuda, British Honduras, Mexico, Newfoundland and Labrador. Of the European countries England received the lion's share, while minor portions went also to Scotland, Germany, Denmark, Belgium, the Netherlands, Spain, the Azores and Turkey in Europe. The chief exports to Oceania went to Australia and the Philippine Islands. Of the South American countries Venezuela received the largest portion, while British and French Guiana, Colombia, Chile, Peru, Brazil, Bolivia, Argentine and Ecuador were recipients of smaller amounts. In Asia our export trade was confined largely to China, Hongkong and Japan. In Africa, American butter went largely to the Belgian Congo and British West and South Africa. During and since the war large shipments of butter have been consigned to the countries of the European continents.

Table 64.—Exports to Foreign Countries of Butter and Butter Substitutes.

Exported To	1911		1912		1913		1914		1915	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
No. America	3,239,788	762,555	3,822,734	992,295	2,687,035	694,818	2,356,501	613,156	4,671,914	1,178,981
Europe.....	848,171	157,518	1,452,457	313,226	890	329	737,381	150,504	3,339,512	748,312
Oceania....	16,509	3,857	17,408	4,426	10,582	3,512	55,320	15,254	1 257,108	345,158
So. America.	769,389	134,214	797,169	157,702	885,575	173,600	537,960	96,900	404,732	80,170
Asia.......	3,115	961	2,247	732	1,118	445	5,775	1,383	47,037	12,711
Africa......	825	327	220	51	400	100	600	256	130,401	27,148
Total......	4,877,797	1,059,432	6,092,235	1,468,432	3,585,600	872,804	3,693,597	877,804	9,850,704	2,392,480

Table 65.—Imports of Foreign Butter and Butter Substitutes by Continents for the years 1911 to 1915 Inclusive.

Imported From	1911		1912		1913		1914		1915	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Europe.....	443,233	131,956	269,593	94,086	577,214	170,687	3,793,698	783,029	1,739,367	520,517
No. America	145,533	82,255	629,220	109,235	351,428	75,318	722,426	146,170	1,277,962	263,909
So. America.	....	....	....	....	....	....	280,585	68,892	351,233	87,295
Asia.......	79,805	16,236	59,152	15,541	128,277	30,001	128,516	28,479	26,579	6,013
Oceania....	69,228	17,505	67,703	18,292	100,449	26,846	2,916,108	726,728	433,086	99,528
Africa......	27	9	....	....	4,885	1,238	689	163	....	....
Total......	1.007,826	247,961	1,025,668	237,154	1,162,253	304,090	7,842,022	1,753,461	3,828,227	977,962

Quality of Butter Exported.[1]—Prior to the European war the great bulk of butter exported by the United States has been of the lower grades. This is due in part to the fact that the surplus butter available for export has consisted of the poorer grades, partly because there is always a large demand in our home markets for our better grades and a disposition of our high class trade to pay higher prices for the best butter than can be obtained in foreign markets, and partly because many foreign markets, including the English markets, do not demand our highest grades, as the poorer classes in many of the larger foreign cities cannot afford to purchase our best grades. For this class of trade, therefore, an inferior quality of butter is exported. The quality of butter for export, therefore, is largely dependent upon the class of trade and the purpose for which the butter is to be used.

The fact is that before the war the export business was almost wholly on Renovated and Baking butter. Since the beginning of the war, however, the export business has been largely on butter scoring 90 to 92 points.

While the difference in price for butter between foreign and domestic markets will always remain the governing factor in the quality and quantity of butter exported, it is to be hoped that, with the systematic improvement in the quality of American butter, the development of foreign markets for our highest quality of butter may grow more rapidly in the future than it has in the past and that our total exports may assume proportions consistent with the vastness of the butter industry at home.

Imports.—The annual imports into the United States of foreign butter have averaged very materially less than the exports. The extreme variations of annual imports ranged between 6,821,696 pounds of butter in 1868 and 23,700 pounds in 1899. Since the year 1884 and up to 1909 they amounted to less than one million pounds annually. Beginning with the year 1910 the annual imports exceeded one million pounds.

The imports fluctuated largely with the domestic butter quotations and the rate of tariff on foreign butter. During the

[1] Information furnished by Prof. R. C. Potts, Specialist in Marketing Dairy Products, U. S. Dept. of Agriculture, 1916.

years immediately following the Civil War, when domestic butter production was at ebbtide and prices soared high, 40 cents and over, butter imports reached their maximum. From 1885 to 1900 when domestic quotations for butter were relatively low, averaging 23 cents, butter imports reached their minimum figure. After the year 1900 butter quotations steadily rose and the amount of imported butter increased. After the tariff revision which went into effect in November, 1913, and which lowered the tariff on foreign butter from 6 to 2½ cents per pound, foreign shipments of butter arriving at the Atlantic and Pacific seaports increased very rapidly. This increase would undoubtedly have continued had it not been for the advent of the European War which diminished the surplus of foreign butter and increased the home demand for butter in the warring and neutral countries abroad, causing an immediate and rapid decline of butter imported into the United States from foreign countries.

Source of Butter Imports.—The amount and value of butter and butter substitutes imported from foreign countries during the years 1911 to 1915 inclusive is shown in Table 63.

Prior to the war and immediately after the tariff revision the chief importing European nations were England and Denmark. Small consignments also came from Belgium, France, Germany, Greece, Italy, the Netherlands, Norway, Russia in Europe, Spain, and Turkey in Europe. Since the beginning of the war the imports from the warring and neutral nations have become insignificant, Denmark remaining the principal shipper.

Imports from countries of the North American continent are largely confined to Canada. The South American butter comes largely from Argentine. In Asia, Turkey is the principal country from which butter reached our ports. From Oceania, Australia and New Zealand were the chief shippers of imported butter and the small amounts of butter imported from Africa came largely from Egypt, Tripoli and Italian Africa. At the close of the year 1916 importation of foreign butter had ceased almost entirely.

Quality and Effect of Imported Butter on Domestic Butter Markets.—The quality of foreign butter imported into the United States before the war varied naturally with the source of the butter, the grades ranging from 85 to 93 points. Butter from Denmark and from the Argentine Republic usually scored 92 or better. Butter from Siberia was more or less irregular in quality, some of it was very poor. New Zealand and Australian butter also came irregular in quality, some of it however being very fine.[1]

The tariff reduction and the subsequent large influx of foreign butter depressed price quotations in American markets to a very marked degree. Thus in March, 1914, Elgin quotations dropped to 24 cents, which is an abnormally low figure for March. This price depression on domestic goods was felt most in the Pacific Coast states in 1914, at which time large shipments of butter were received from Australia and New Zealand. Prices at that time were depressed from 3 to 5 cents, presumably as the result of the influx of foreign butter. Potts[2] offers the opinion, however, that the sudden depression in prices was largely for the purpose of curtailing further imports, as thereby the market prices here would be lower than those abroad and therefore discouraging exportation from foreign countries. He further states that prior to the beginning of the European war several New York butter firms were arranging for contracts to receive butter from Europe.

CHAPTER XV.

BUTTER STORAGE.

Time and Duration of Storage.—The great bulk of butter goes into storage in May, June and early part of July, though butter may be, and is, stored at any time of the year when the supply and butter prices appear favorable for storage. May, June and the first half of July are the natural storage months of butter in the northern hemisphere, because the freshening of the majority of the cows and succulent condition of the pastures

[1] Information furnished by S. C. Thompson, U. S. Dairy Division, August, 1916.

[2] Potts, Specialist in Marketing Dairy Products, U. S. Dept. of Agriculture, 1916.

during these months provide a natural surplus of butter and cause butter prices to be at ebbtide.

In times of early draught which causes a shrinkage of the surplus output and a rise in butter prices, the storage season is usually cut short. When the season is blessed with plenty of rainfall, keeping pastures green until late into fall and continuing a large make, the storage season is usually greatly extended beyond the months of May, June and July.

Under normal conditions the great bulk of butter in storage is taken out of storage within nine months of the time it went in. Only in exceptional cases is butter held in storage over one year, and when this is done it is usually accompanied by a great sacrifice in quality and in price. Not all butter that goes into storage is held till late winter. Considerable quantities of butter are "short held," that is, they are put on the market after one or but a few months of storage. As early as August some of the May or June butter may be sold. Especially in times of early draught and consequent early falling off of the summer make and rapid rise of butter prices, and when the quality of the fresh butter is poor, due to the hot weather, butter dealers often find it advantageous to supply their trade from their May or June butter in storage, which is usually of better quality and which was purchased at a considerably lower price than they would have to pay for the midsummer butter. In the case of an open summer and fall with a continuous large make and only very gradual rise in prices, the tendency is to hold the butter in storage until such time as the demand necessitates and prices warrant its movement. It is obvious that aside from the output of fresh butter, the condition of the market, butter prices and consequently the duration of storage and the amount of the storage holdings, are influenced by the general industrial conditions of the country, exports and imports, and to some extent the sale of butter substitutes.

Since the advent of the Federal Storage Ruling.[1] [2] in November, 1917, and January, 1918, and rescinded March, 1919, requiring all butter that is held in cold storage over thirty days to

[1] Rules and Regulations, Governing the Importation, Manufacture, Storage and Distribution of Food Commodities for Domestic Trade, by Act of Congress, approved August 10, 1917, and effective November 1, 1917.

[2] Amendments and Additions to the above, Series B, Supplement, effective January 28, 1918.

be marked on each package with the words "Cold Storage," the volume of butter that is "Short Held" or stored not in excess of thirty days has increased greatly and the practice of "rotating" the butter stored, on a 30 day rotation basis, has become quite prevalent. This does by no means take the place of the "long held" cold storage of butter, but in a limited way it helps the creamery and dealer to bridge over and take care of temporary surplus and shortages and to thus avoid sudden embarrassing extremes of supply and demand.

Distribution of Commercial Stocks of Butter.—During the major portion of the "long held" storage season the butter held in cold storage represents close to 50 per cent of the commercial stocks of butter in the country. The remaining stocks of butter are divided between the wholesale dealers, creameries, retail dealers and meat packers. According to statistics furnished by the United States Bureau of Markets,[1] the distribution of commercial butter stocks July 1, 1918 and July 1, 1917 was as follows:

Table 67.—Stocks of Butter on Hand July 1, 1918, with Comparative Figures for July 1, 1917, by Classes of Business.

Class of Business	Total stocks reported as on hand July 1, 1918	Comparative Figures—From Firms Reporting for Both 1918 and 1917			Quantity reported as in transit on July 1, 1918
		1918 stocks		1917 stocks	
		Quantity	Per cent of 1917		
	Pounds	*Pounds*		*Pounds*	*Pounds*
Total	**76,143,419**	**71,645,214**	**102.7**	**69,756,707**	**11,785,536**
Creameries	13,526,964	12,349,457	108.7	11,363,204	8,986,444
Cold storages	38,558,001	37,623,380	101.7	37,011,569	367,537
Meat Packers	5,895,423	5,860,935	133.5	4,389,469	320,550
Wholesale dealers	16,188,809	14,236,457	93.0	15,302,442	1,843,813
Wholesale dealers in butter, eggs, and cheese	*13,630,918*	*12,057,916*	*93.3*	*12,921,408*	*1,787,546*
Other wholesale dealers	*2,557,891*	*2,178,541*	*91.5*	*2,381,034*	*56,267*
Miscellaneous	1,974,222	1,574,985	93.2	1,690,023	267,192
Bakers	*505,988*	*478,959*	*91.2*	*525,305*	*605*
Oleomargarine manufacturers	*370,196*	*251,732*	*59.1*	*425,869*	....
Cheese factories	*295,905*	*255,679*	*124.2*	*205,849*	*200,180*
Other miscellaneous	*802,133*	*588,615*	*110.4*	*533,000*	*66,407*

[1] Food Surveys, Bureau of Markets, U. S. Department of Agriculture, Special Issue, Vol. II, No. 3, August 31, 1918.

Amount of Butter Held in Cold Storage.—The amount of butter held in cold storage varies largely with the supply and demand of fresh butter, length of storage season, market prices of fresh butter, etc. It is naturally greatest during the storage season proper, and lowest just before the storage season opens up again. The peak of storage holdings is generally reached

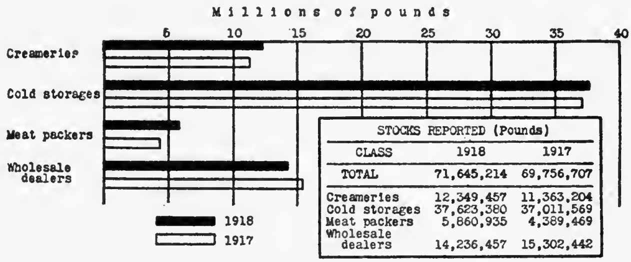


Fig. 77. Stocks of Butter Reported for July 1, 1918, and July 1, 1917, by Important Classes of Business

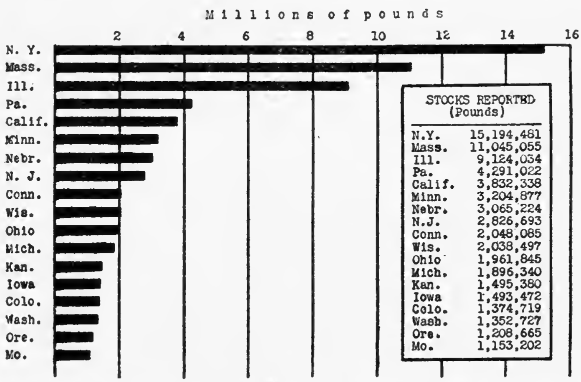
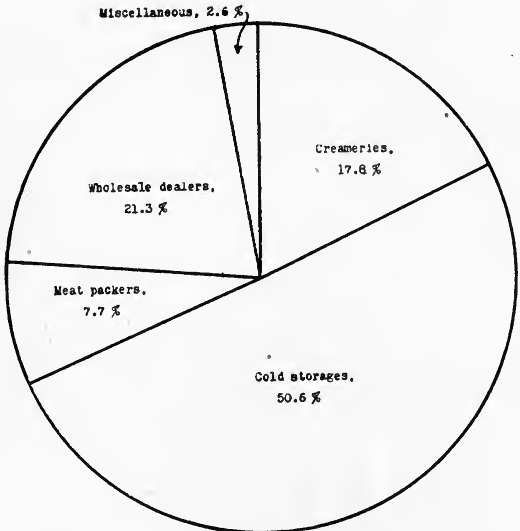


Fig. 78. Stocks of Butter Reported for the Eighteen Most Important States.

by September and the bottom early in May. During the years from 1907 to 1916 the percentage of storage holdings of butter reported by the Associated Warehouses averaged six and nine-tenths on May 1, and 100 on September 1, as shown in graphic illustration, Fig. 80.

The average holdings on the first of September, for the entire period of 10 years amounted to 64,378,898 pounds. This diagram further shows that more than three-quarters of the holdings in these warehouses are stored during the months of June and July, while most of the distribution is within the months of October and March, inclusive. The fact that, according to these figures, an average of 6.9 per cent of the holdings remain at the opening of the new storage season, suggests that this proportion of holdings is carried over into the next season.



STOCKS REPORTED (Pounds)	
TOTAL	76,143,419
Creameries	13,526,964
Cold storages	38,558,001
Meat packers	5,895,423
Wholesale dealers	16,188,809
Miscellaneous	1,974,222

Fig. 79. Distribution of Stocks by Important Classes July 1, 1918

The cold storage holdings of creamery butter by months reported to the United States Bureau of Markets by the great majority of warehouses and including all of the more important warehouses in this country, are issued by this bureau for the benefit of the dealers, free, in the form of monthly reports. The cold storage holdings covering the period of October 1, 1916 to December 1, 1919 are recorded in Table 68.

Storage Conditions.—In order to justify storage and to have the storing of butter fulfill the purpose for which it is intended,

COLD STORAGE HOLDINGS
OF
CREAMERY BUTTER

Compiled from the reports of the associated warehouses.
Based on the average holdings of the years
1907 to 1916 inclusive.

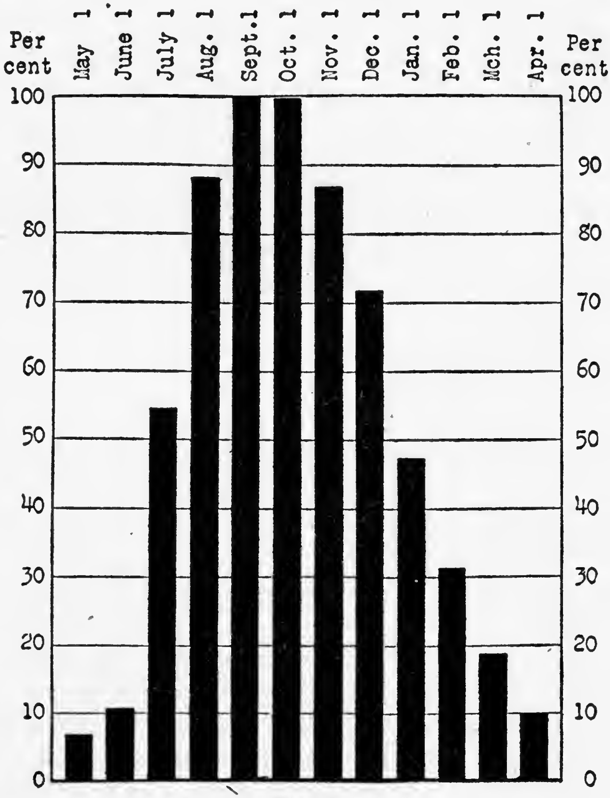


Fig. 80

Table 68.—Cold Storage Holdings of Creamery Butter in the United States, Oct. 1, 1916, to Dec. 1, 1919.[1]

Months	Total Holdings: Storages Reported	Total Holdings: Butter, Pounds	Comparison of Holdings: Storages Reported	Comparison of Holdings: Butter, Pounds	Comparison of Holdings: Butter, Pounds	Increase or Decrease Percent
1916		1916		1915	1916	1915–1916
Oct. 1....	165	91,728,394	133	99,449,607	88,909,646	−10.6
Nov. 1....	179	82,269,098	142	92,718,649	79,294,074	−14.6
Dec. 1....	239	60,774,859	189	71,848,767	58,627,236	−18.4
1917		1917		1916	1917	1916–1917
Jan. 1....	268	45,996,514	227	48,977,322	44,673,639	− 8.8
Feb. 1....	273	30,281,472	211	31,139,173	29,250,641	− 6.1
Mar. 1....	286	15,542,532	215	15,032,769	14,582,975	− 3.0
Apr. 1....	275	6,239,268	214	3,345,717	6,022,216	+80.0
May 1....	281	2,586,593	211	1,081,913	2,433,144	+124.9
June 1....	292	8,942,120	217	7,016,731	8,431,140	+20.2
July 1....	289	47,612,460	217	53,863,278	44,633,595	−17.1
Aug. 1....	310	85,540,972	257	102,537,337	81,502,751	−20.5
Sept. 1....	335	99,225,394	268	105,836,003	94,644,780	−10.6
Oct. 1....	380	104,293,375	332	100,521,573	97,456,876	− 3.0
Nov. 1....	396	100,114,760	345	85,260,302	93,209,717	+ 9.3
Dec. 1....	385	77,463,551	340	67,291,844	73,133,855	+ 8.7
1918		1918		1917	1918	1917–1918
Jan. 1....	373	47,069,946	324	41,686,684	43,311,258	+ 3.9
Feb. 1....	372	24,780,358	325	30,473,709	23,542,245	−22.7
Mar. 1....	386	18,808,303	333	16,952,367	18,168,209	+ 7.2
Apr. 1....	381	14,607,017	345	6,805,476	14,177,901	+108.3
May 1....	375	10,245,288	341	3,607,119	10,100,054	+180.0
June 1....	383	13,017,143	353	9,953,184	12,752,296	+28.1
July 1....	419	49,389,491	386	49,981,732	47,436,912	− 5.1
Aug. 1....	421	87,382,926	380	79,203,492	81,384,643	+ 2.8
Sept. 1....	420	101,838,897	390	107,776,392	100,503,488	− 6.7
Oct. 1....	408	87,105,801	390	104,926,813	86,253,033	−17.8
Nov. 1....	409	80,595,375	389	96,663,946	79,670,291	−17.6
Dec. 1....	397	65,577,900	372	78,733,939	65,380,993	−17.0
1919		1919		1918	1919	1918–1919
Jan. 1....	377	43,210,770	......	50,725,766	43,140,260	−15.0
Feb. 1....	364	36,815,793	353	25,964,218	36,563,442	+40.8
Mar. 1....	349	24,436,630	338	18,658,019	24,414,104	+30.9
Apr. 1....	333	12,233,700	327	14,628,544	12,226,929	−16.4
May 1....	330	9,661,244	323	10,157,399	9,634,690	− 5.1
June 1....	344	29,285,220	333	12,749,056	29,190,222	+129.0
July 1....	342	87,851,371	325	47,919,035	87,720,486	+83.1
Aug. 1....	334	122,771,843	[2]	89,157,820	123,545,670	+40.6
Sept. 1....	289	129,251,064	[2]	99,334,448	131,710,210	+32.6
Oct. 1....	284	121,674,977	[2]	87,924,232	121,834,544	+38.6
Nov. 1....	270	100,285,328	[2]	80,816,681	100,851,405	+24.8
Dec. 1....	268	73,440,191	[2]	65,110,521	73,676,233	+13.2

[1] Monthly Reports of Cold Storage Holdings of Butter, Bureau of Markets, U. S. Department of Agriculture, 1916-1919.
[2] Comparison of total holdings.

the butter must be protected against agents and conditions which cause it to deteriorate in quality. The chief of the conditions injurious to the quality of butter in storage are air, light, heat and moisture.

Air, Light and Heat.—Excessive exposure to air causes deterioration of butter through oxidation, or through bacterial action, or both. This oxidation is greatly intensified in the presence of light, or heat, or both, and bacterial action is enhanced in the presence of heat. Exposure to air is minimized by the use of packages of comparatively large size and by packing in wrappers and containers that have previously been made as near impervious to air as possible. Butter is best stored in packages of the largest possible size consistent with convenient handling. The larger the cubic content of the package, the smaller, relatively, is its surface and the smaller is, therefore, the area of butter which is exposed to the air. For this reason the firkin used in Europe, the 63 pound tub which predominates in the central and eastern United States and the 56 to 68 pound cube used in the Pacific Coast states, furnish more suitable forms of packages, than smaller packages such as one, two, or five pound prints, slabs or rolls. The firkins, tubs and cubes should be properly paraffined and lined with heavy, brine-soaked parchment paper, so as to furnish as nearly hermetical a seal as possible. These same conditions, large size and imperviousness of package to air, also protect the butter against light. In full containers butter keeps better than in containers only partly filled. This was experimentally demonstrated by Gray and McKay,[1] who stored butter in cans and in tubs completely filled and similar containers only partly full. At —10 degrees F. to +10 degrees F. there was practically no difference in the keeping quality of butter packed in full cans and full tubs, but at 32 degrees F. there was a slight difference in favor of the cans.

Humidity of Storage Rooms.—Aside from the oxidizing effect of air, light and heat on the constituents of butter, the deterioration of butter in storage results from the decomposition or cleavage of the non-fatty constituents, especially the proteins

[1] Gray and McKay, Investigations in the Manufacture and Storage of Butter, U. S. Dept. of Agriculture, B. A. I. Bulletin 84, 1906.

or curd of butter, as caused by bacterial, enzymic or chemical action hastened in the presence of air, heat and moisture. A damp storage is prone to cause the development of mold. The storage room therefore should be dry.

Temperature of Storage.—Heat intensifies every type of butter deterioration in storage. It hastens oxidation, it enhances the action of bacteria and enzymes, it accelerates chemical action and it favors mold development. Butter that is intended for prolonged storage must be stored at temperatures of zero degrees Fahrenheit or below. At higher temperatures its keeping quality is invariably jeopardized and the poorer the quality, the more rapid will be the deterioration with age.

Gray and McKay,[1] in a series of experiments, studying the effect of storage temperature on keeping quality of butter, found that at —10 degrees F. the butter kept better, both while in cold storage and after removal from cold storage, than when stored at higher temperatures. The butter in these experiments was stored at these temperatures for 5 to 8 months. Similar results were obtained by Rogers, Thompson and Keithley,[2] who show the following scores of butter stored at temperatures ranging from zero degrees F. to 20 degrees F.:

Kinds of Butter	Points Lost After Storage		
	Stored at 0° F. Points	Stored at 10° F. Points	Stored at 20° F. Points
Raw cream butter, Cry. A.............	5.0	5.3	5.8
Raw cream butter, Cry. D..............	1.7	4.1	3.3
Raw cream butter, all samples...........	3.2	4.6	4.8
Pasteurized ripened cream, Cry. B.......	2.2	3.0	5.1
Pasteurized ripened cream, Cry. E.......	1.7	3.6	4.0
Pasteurized ripened cream, all samples...	2.0	3.3	4.6
Pasteurized unripened cream, Cry. C.....	.6	1.0	1.5
Pasteurized unripened cream, Cry. D.....	.4	1.0	1.6
Pasteurized unripened cream, all samples.	.5	1.0	1.6

From the above results Rogers and his co-workers conclude that the difference between zero degrees F. and 10 degrees F.

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[1] Gray and McKay, Investigations in the Manufacture and Storage of Butter, U. S. Dept. of Agriculture, B. A. I. Bulletin 84, 1906.
[2] Rogers, Thompson and Keithley, The Manufacture of Butter for Storage, U. S. Dept. of Agriculture, B. A. I. Bulletin 148, 1912.

is sufficient to warrant the use of the lower temperature, even for butter of the best keeping quality. The author's own experience, both in experimental and commercial storage of butter, is entirely in accord with the above findings and conclusions; in order to insure the best keeping quality for storage butter of any quality, the butter must be kept at a temperature of zero degrees F. or below.

In isolated cases creameries have their own cold storage. This is true of many of the larger creameries. The great majority of the creameries of the country, however, lack the necessary equipment and facilities for prolonged cold storage and their attempt to use their own facilities in a great many cases proves disappointing in its results. By far the largest portion of the storage butter is stored in the cold rooms of large commercial cold storage houses, whose exclusive business is the storage of perishable goods.

Shrinkage of Butter in Cold Storage.—Under normal conditions the shrinkage in the weight of butter put in cold storage in tubs or cubes is not very great. The main shrinkage usually takes place before the butter reaches the cold storage, while the butter is held in the creamery cool room and in transportation, and after storage when the butter is put up in prints. The loss in weight between the package at the churn and the arrival at the cold storage, varies considerably with the workmanship of the butter, the completeness of moisture incorporation, the treatment of tubs and liners, the time that elapses between packing and storing and the amount of salt butter contains.

Butter that has a leaky body, as is usually the case with butter that is churned at too high a churning temperature, or that is made from cream that was not held long enough at the churning temperature, or butter that is not worked sufficiently to close up the water pockets, is prone to show maximum shrinkage due to loss of water or brine. Butter packed in unparaffined tubs will shrink more than butter packed in paraffined tubs. A thin, poor liner permits of greater shrinkage of butter than a heavy liner of good quality. The longer the butter is held at ordinary cool room temperature and the greater the distance of transportation before the butter reaches cold storage, the more it will sacrifice in weight. Salted butter will lose more weight than unsalted butter and heavily salted butter will shrink more than lightly salted butter. Even after the butter is in cold storage this shrinkage in the case of heavily salted butter will continue, resulting in very appreciable loss of weight by the end of the storage period. Light salted and unsalted butter, on the other hand, do not suffer material loss in cold storage.

Deterioration of Quality of Butter in Storage.—Butter of good quality, intelligently manufactured and properly packed, will generally withstand noticeable deterioration under ordinary commercial conditions and without regular cold storage for about a month. After that time it tends to depreciate, and unless of exceptional keeping quality, it will gradually develop specific defects, such as rancidity, fishy flavor, etc. In regular cold storage good butter may retain the character of fresh butter for several months. However, age is the arch enemy of quality, and prolonged storage even at commercial cold storage temperatures, gradually develops in the great bulk of butter so stored the characteristic storage flavor.

The changes and the causes of these changes which take place in butter in storage are exceedingly complex and as yet far from being thoroughly understood. These changes affect both the flavor and the texture of butter, varying in kind and extent with the character and quality of the butter while fresh and the temperature and period of storage.

The flavor changes often are very marked, the butter loses the characteristic flavors and aroma of fresh butter and develops a variety of off-flavors, the specific flavor and its intensity in each particular case depending probably on specific combinations of conditions. Only in rare cases can the flavor defect be traced direct to one specific cause. A certain combination of factors may yield a specific flavor defect, the absence from this combination of one factor may fail to produce the same defect and may cause an entirely different defect, although all other factors and conditions responsible for the original defect may be present. Thus butter may develop a fishy flavor under certain apparent conditions. Yet when an effort is made to produce fishy butter by subjecting butter to these conditions, fishiness often fails to result and in its place usually some other flavor develops, such as oily flavor or metallic flavor, etc.

These facts emphasize the probability that there are many factors which are instrumental in the production of a specific flavor defect through their joint action, while each separate factor, though necessary for the combination that produces the defect, is by itself alone incapable of so doing. As a concrete example of this may be quoted the case of tallowy butter the specific causes of which have been determined with certainty.[1] Oxygen carriers and catalizing agents, such as certain metals and their salts, especially copper and copper salts, are capable of making butter tallowy. These agents are present in average butter to a very small extent and in butter containing a normal per cent acid and kept in cold storage they fail to produce the tallowy flavor. If this butter is made from over-neutralized cream, or is wrapped in parchment which was not entirely freed from the ammonia used for the neutralizing of the sulphuric acid used in the parchmenting process, the butter so wrapped may become tallowy very rapidly, especially when it is exposed to room temperature. In this case the alkali, which alone does not make butter tallowy, is a necessary part of the combination, in which copper may be the fundamental cause of the tallowy flavor.

The texture of the butter usually shows marked changes only after prolonged cold storage. The grain of the butter gradually breaks down giving such butter a more or less crumbly and pasty consistency.

Summary of the Effect of Cold Storage on the Quality of Butter.

Summing up the most important phases of our present knowledge of the effect of storage of butter on its quality the following points are emphasized:

1. Age tends to deteriorate the flavor of butter. The rapidity and intensity of this deterioration, other factors being the same, is influenced largely by the temperature of storage. At the usual temperature of commercial cold storage, —6 to —10° F. the changes in flavor are usually very gradual.

2. The most predominating flavor defect which butter develops in cold storage is the flavor known as cold storage flavor. In the case of butter that was of good quality when it went

[1] Hunziker and Hosman, Tallowy Butter, Its Causes and Prevention, Journal of Dairy Science, Vol. I., No. 4, 1917.

into storage, the development of the storage flavors may be very slight. Butter of poor quality usually shows very great deterioration in storage, the flavor defects may be numerous and often one flavor may succeed another as storage progresses. An oily flavor may develop into a metallic flavor and this in turn may give way to fishy flavor, etc.

3. The quality of the cream from which the butter is made, largely governs the keeping quality of the butter in storage. Butter made from a poor quality of cream cannot be expected to withstand rapid and intense deterioration in storage.

4. The analysable chemical changes which butter undergoes in storage, are very slight, even in butter which has yielded to most pronounced flavor changes. The exact changes, and the constituents of the butter which are changed, that are responsible for the development of specific flavor defects have not been determined in the great majority of cases. It is assumed with reasonable certainty however, that rancidity and tallowiness are due to cleavage of the butterfat, rancidity through bacterial or enzymic action or both, and tallowiness through chemical action. The characteristic flavor of cold storage butter and its derivations such as oily, metallic and fishy flavors, are generally assumed to result from the decomposition of the non-fatty constituents of butter.

5. The most active agents bringing about deterioration of butter in cold storage appear to be cream with a high acid content, the presence in cream and butter of metals, such as copper and iron, and their salts, the air incorporated in the butter and bacteria and enzymes; though the influence of microorganisms is considered of indirect rather than of direct nature.

6. In order to insure, with reasonable certainty, butter of good keeping quality, and minimum deterioration in commercial cold storage, the butter should be made from cream of good quality and low acidity, transported in cans that are free from rust, and handled in vats, pasteurizers and conduits properly tinned and the surfaces of which are kept bright and free from accumulations of oxidized or dissolved metal, the pasteurization should be thorough and preferably by the flash process at 176° F. or over, or the holding process at 145° F. for 30 minutes, the

butter should be worked in the normal way, avoiding overchurning and overworking and excessive incorporation of air, all equipment and rooms in the factory in which the cream and butter is handled and exposed should be kept clean, the butter should be packed and stored under approved conditions and should reach the cold storage with the least possible delay after manufacture.

CHAPTER XVI.

BUTTER SCORING.

Definition.—The scoring or judging of butter refers to the examination of butter for flavor and aroma, body and texture, color, salt and package.

Purpose.—The primary object of scoring butter is to determine its quality and market value. The bulk of the butter that reaches the wholesale receivers, jobbers and commission men is scored and most of this butter is sold "over the trier" and paid for on the basis of the grade to which its score entitles it.

Butter intended for storage usually is, and always should be, most carefully scored in order to ascertain its fitness for storage. Butter showing a weak body and tendency toward an oily, metallic or fishy flavor is unsafe to go into storage. Such butter is prone to become fishy or develop other storage flavors with age. Careful scoring before permitting its entrance into cold storage may save the owner from heavy loss at the end of the storage period.

At butter scoring contests such as are held at County, State and National fairs and shows, the careful scoring of the butter judges and their criticisms and instructions, are often of great help to the buttermaker in his efforts to eliminate butter defects and to improve upon his methods of manufacture.

The butter should be scored not only by the buyer and the educational judge but by the buttermaker himself. He should have accurate knowledge of the quality of butter that leaves his factory and he can secure this knowledge only by carefully scoring each churning. This scoring should not be done at the churn, however, for the quality of the fresh butter at the churn is seldom a reliable index to the quality of the butter when it is one or two weeks old. Most butter when perfectly fresh is palatable. Serious defects generally develop and "show up" with age.

The Score Card.—The national score card adopted and used by the officials and butter men in all parts of the country is that contained in the rulings of the New York Mercantile Exchange and quoted in the chapter on "Markets and Marketing."

Valuation of Butter Defects.—The prices paid for butter sold on the open market, are based fundamentally on the established classes of market grades, the chief of which are: "Extras," "Firsts," "Seconds" and "Thirds," and in commercial scoring the deductions for defects are generally so made as to place the butter into its respective grade. The exact scores for each grade vary somewhat with the condition of the market and the season of the year as determined by the Butter Committee of the Exchange. Thus the New York Mercantile Exchange rules provide that extras may score either 91, 92 or 93 points, as the minimum, at the discretion of the Butter Committee, who shall determine the required score from time to time in such manner that it shall represent an average fancy quality in the season when offered. But butter scoring more than required for "Extras" shall be deliverable on a contract for "Extras," etc. See rules of New York Mercantile Exchange.

The minimum scores, for the several grades are as follows, with Extras at 91, 92 or 93 points:

Extras at	91	92	93
Firsts	87	88	89
Seconds	82	83	84
Thirds	75	76	77

In discussing the figure valuation of butter defects it will be assumed here that "Extras" require a minimum score of 92 points.

"Extras."—In order for butter to score "Extras," it must have a clean and pleasant flavor and aroma and it must be free from any undesirable off-flavors. Its color, salt and body must be perfect. Such butter would merit a flavor score of 37 and a total score of 92. Butter with a specially delicate flavor and creamy texture, showing excellent quality of cream, may be given a flavor score of 38, 39, 40 or 41 points, or higher, or a total of 93, 94, 95 or 96 or higher, according to the pronouncedness of these desirable qualities.

"Firsts."—Butter which is of clean flavor but lacks the characteristic delicacy of aroma, and is perfect in body, color and salt, is considered a good "Firsts," meriting a flavor score of 35 to 36 points, or a total score of about 90 to 91 points.

Butter with a slightly acid flavor and aroma, or that shows traces of weedy flavor or other slight flavor defects might still be classed as a "Firsts," with a flavor score of 33 to 34 points and a total score of 88 to 89 points, provided that it is perfect in body, color and salt.

"Seconds."—Butter that shows slight rancidity, fishiness, oily or metallic flavor, garlic flavor, or yeasty flavor, is classed as a "Seconds," with a flavor score of 28 to 32 inclusive, and a total score of 83 to 87 inclusive, the exact score varying with the intensity of the defect.

"Thirds."—Butter with a strongly rancid, tallowy, fishy, or other intense off-flavor is scored as "Thirds."

Butter with a leaky texture or leaky or crumbly body would not be accepted as an "Extras." These defects would cut its score on body such texture from 1 to 3 points. If of clean flavor and perfect color, such butter might score a good "Firsts."

Butter that is pronouncedly mottled is cut from 3 to 5 points on color. If otherwise of good quality and clean flavor it would be classed as a "Firsts."

Butter that is gritty and excessively salty may be cut from ½ to 2 points on salt according to the intensity of the defect. Such butter usually has a coarse flavor. If it shows no distinct off-flavor, it may be classed as a "Firsts."

In rare cases only is butter scored down on package, but it should be understood that the neatness and cleanliness of the package makes a favorable impression on the judge, while an untidy and soiled package tends to condemn the goods.

Method of Scoring.—The scoring of butter is most conveniently done by the use of a butter trier. A plug of butter is removed from the package by boring from top to bottom of the tub or cube, or from end to end in the case of the print. First the aroma is observed by passing the trier under the nose. Then the butter is tasted for flavor and salt by cutting with a clean knife or spatula, a small piece off the plug. Then the plug is examined for uniformity of color. The texture and body are examined for leakiness, crumbliness, stickiness and weak body. In the case of crumbly and sticky butter it is difficult to secure a solid plug, the plug is ragged and irregular and butter sticks to the back of the trier. In the case of leaky butter the brine runs freely, and in large drops, from the butter. A weak body refers to butter with a poor grain; when the plug is broken the surface at the break resembles that of a tallow candle and the butter gives the impression of salviness. The color of such butter generally lacks brightness and life, it is dull.

The Ethics of Butter Scoring.—It must be obvious to all who are interested in the dignity and standard of excellence of the butter industry that the sanitary and ethical aspect of butter scoring demands, that this work be done in a neat, cleanly and careful manner, and yet so many so-called butter judges ignore the most primitive dictates of decency in the scoring of butter. They do this work in slovenly manner, they pay no attention to the cleanliness of their hands, they fail to wipe the trier clean before it is inserted in the butter, they try to ascertain the aroma by rubbing their nose into and wiping it on the butter, they determine the flavor by digging their teeth into a plug, and then replace this mutilated and desecrated butter into the package which is later offered for sale and consumption. Such performances are an insult to the dignity of the butter industry and a depredation to this most valuable and wholesome of food, butter. Nor do such practices denote expertness on the part of the judge. The flavor and aroma of butter are of delicate nature, their correct impression on the senses demands subtle and delicate handling. Pressing one's nose into the butter destroys the delicacy of flavor and aroma and dulls the senses. There is room for much improvement, especially in the cellars of the wholesale produce, in the ethics of butter scoring as now done, and this improvement will assist in convincing the laymen of the wholesomeness and superior virtues of butter as a food which the dairy interests claim for their product.

The necessary equipment for performing the examination and scoring of butter in an approved manner, consists of a nickel-, tin- or silver-plated butter trier, a knife or spatula and clean cheese cloth or clean soft paper, such as tissue paper.

Before commencing the work of examining the butter, the scorer should thoroughly wash his hands with soap and water. The trier should be wiped dry and clean. When the plug on the trier is examined for aroma, it should be passed under the nose without touching the nose. For tasting the butter a small piece of butter is removed from the plug with the knife or spatula. The uniformity or color can be seen without mutilation of the plug. Examination for leakiness and body and texture is best made by pressing the plug with clean thumb.

When the examination is completed, the plug is neatly replaced in the bore of the package by carefully returning the trier in the bore and withdrawing the empty trier. The surface of the package at the place of the returned plug is then evened up and smoothed over, not with the fingers, but with the trier, and the circle or wrapper is again replaced neatly. The trier and spatula are then wiped clean, not with the bare hands, but with the cheese cloth or paper, before the next package is examined.

Accuracy of Butter Scoring.—It is said that expert butter judges are born and not made. This is true to a limited extent. Expertness requires, above all things, a keen sense of taste and smell. Individuals deprived of an accurate sense of taste and smell lack the fundamental attributes that make for expertness in butter scoring. However, most persons possess these senses to a sufficient degree to be able to distinguish good butter from bad butter, and with a little practice they soon acquire the power to differentiate between the more pronounced flavors and odors. Aside from the natural and acquired ability to detect flavor and aroma, the butter judge needs knowledge, experience and judgment in determining and deciding on the correct valuation in terms of figure scores, of the flavors found in the butter, and these attributes are largely a matter of practice. Finally the butter judge must be a man of character, not given to superficial work and "bluff verdicts," he must be conscientious, careful and able to decide for himself and, after deciding, to stand by his convictions.

When more than one judge does the scoring, as is generally the case at educational butter scoring contests and county, state and national fairs, also in scoring experimental butter, each judge should work entirely independent of the other judges, there should be no expression of opinion, no comparison of notes, while the scoring is in progress and until each of the judges has completed his work, otherwise the personal judgment of the individual judge is jeopardized and is liable to be materially, though unknowingly, influenced, and this occurs usually to the detriment of the accuracy and fairness of the final score. After each judge has completed his scoring, then the judges may compare notes and rescore, for their own satisfaction, packages on which the scores of the different judges show considerable diversion. The average of the individually determined scores of the several judges promises results of maximum accuracy, and freedom from disturbing influences, of the final score awarded to each package.

The Value of Educational Butter Scoring Contests.—With due allowance to the actual service these contests are often capable of rendering, the judge through his criticisms giving the buttermaker valuable information that makes for improvement, it must be admitted that the lasting results of educational butter-scoring contests and the concrete usable information they offer, are often very meager and in a great many cases they do not justify the expense incurred. There are many reasons for this.

The average butter judge is not a practical buttermaker. He lacks the full knowledge of the real problems which confront the buttermaker and he therefore falls short in his appreciation of the significance of these problems. In fact, even assuming that he is a capable judge of butter, which is by no means always the case, he has very little to offer to and a great deal to learn from the man whose butter he is scoring. Some of the information which he endeavors to convey to the buttermaker through his letter of criticisms is either not well founded or does not apply, and much of the remainder of the information given has long been a part of the buttermaker's knowledge, but local conditions, lack of sufficient energy, or other conditions, have hindered him from putting this knowledge "across" in his factory.

Again, the basis upon which the butter is scored at most of the scoring contests puts a premium on a very mistaken standard of excellence, that not only has no real commercial value, but is a positive detriment to the success of the butter industry.

The ideal used as the basis for scoring has been that of butter with a highly developed butter flavor, and in their efforts to successfully compete, the buttermakers so ripened their cream and handled their butter as to cause it to possess as high a flavor as possible on the day of the contest.

Elsewhere in this volume it is conclusively shown that butter so made has very poor keeping quality. It has reached the very limit of changes it is capable of undergoing, without actually deteriorating in flavor and any further changes, which it is bound to suffer with age, will cause it to develop off-flavors. The butter with high flavor which wins top scores and honors at these contests, therefore, has the ear-marks of butter that does not keep well and that, by the time it reaches the table of the consumer, may be anything but "prize butter."

Since the consumer is the final judge of the value of butter, the butter must have such keeping property that it is able to withstand agencies of deterioration until it is consumed, and it is essential to the success of the butter industry that the buttermaker concentrate his knowledge and energy in this direction, rather than to manufacture butter that is a prize winner tomorrow and that "goes to pieces" thereafter.

In some of the states the management of scoring contests, appreciating the significance of these facts, is effectively correcting this weakness, by either holding all contest butter for several weeks before the contest, or by rescoring a second time after an interval of several weeks. The results of scoring contests following this practice are bound to be fruitful of much real good, from the standpoint of assisting the buttermaker in his efforts to improve the commercial value of his butter.

Finally, the conducting of educational butter scoring contests has much educational value in an indirect way. It is an effective means to bring the buttermakers together, where they can discuss their problems and difficulties, where they have an opportunity to hear lectures and see demonstrations that give them new information, and where they can come in close touch with the dairy schools and their staffs.

CHAPTER XVII.

BUTTER DEFECTS.
THEIR CAUSES AND PREVENTION.

Classification of Defects.—This discussion is confined to the most important butter defects which are considered individually under the following few headings: flavor and aroma, body and texture, color and appearance.

DEFECTS IN FLAVOR AND AROMA.

Flat Flavor.—Butter termed flat in flavor lacks the delicate flavor and aroma characteristic of "Extras" and fancy butter. Its flavor lacks life. Such butter usually sells as "Firsts" on the market, provided that it has no serious defect otherwise.

The flat flavor is usually due to washing excessively in cold water. Cold wash water has the power to absorb the flavor-producing volatile oils of the butter when in granular form. Excessive washing and prolonged exposure of the butter to the cold wash water, therefore, tend to leave the butter without much flavor, or flat.

Occasionally butter is criticised as being flat in flavor simply because it is low in salt. The use of more salt brings out the flavor more pronouncedly.

Butter made from sweet cream which was not subjected to the ripening process and to which no starter was added, is generally very mild in flavor and may be termed flat by those who desire a high-flavored butter.

Stale Flavor.—The staleness and lifelessness of butter, termed stale, is usually due to the advanced state of the period of lactation. It is an off-flavor which is characteristic of butter made in winter when the cows are approaching the end of their lactation period. The cause here, as in flat-flavored butter, lies in the partial absence of the flavor-producing volatile and soluble fats, oils and acids. As the period of lactation advances, the per cent of the flavor-producing elements decreases and is lowest at the time the cows are ready to go dry. Observant butter-makers know from experience that, when all their cream comes from stripper cows, their butter always has more or less of this stale flavor, and that the addition of but a few cans of cream or milk from fresh cows will make a wonderful improvement in the flavor of their butter. At the beginning of the period of lactation when the cows are fresh, as is generally the case in early summer, the milk contains the maximum per cent of volatile and soluble fats and acids and the stale flavor is entirely absent in butter made from such milk or cream.

While the use of a good active starter generally assists in minimizing the stale flavor, it seldom will overcome it entirely, because the natural flavoring principles in the milk and cream which are necessary in order to secure the full benefit of the starter, are lacking or are present in insufficient quantities in cream from stripper cows. Stale butter seldom grades "Extras."

The stale flavor is frequently attributed also to old cream, or cream having been held too long before churning. In most cases of cream that has been held for a long time, however, the staleness is expressed by more specific off-flavors, resulting from fermentation, or absorption of odors from environment, and it is doubtful if the so-called stale flavor of butter can conclusively be traced to old cream.

Sour, Curdy and Cheesy Flavor and Aroma.—This defect is characteristic of much of the butter that is made from high-acid cream, such as gathered cream and cream shipped long distances. The sourness is noticeable particularly in the odor or aroma of the butter. If otherwise perfect such butter usually scores a poor "Firsts" or a good "Seconds." It is rejected by the critical trade and is unfit for storage as it tends to deteriorate rapidly.

The sour flavor and aroma are usually largely due to cream that arrives at the creamery in very sour condition. It may be avoided by neutralizing the cream and thorough washing out of the buttermilk. Frequently sour butter is the direct result of overripening the cream, or starter, or both, and of leaving too much buttermilk in the butter. Attempts to produce high-flavored butter by only slightly washing the butter and causing it to have a milky brine tend toward the development of a sour flavor and aroma.

High buttermilk content, overripe cream and starter and similar agencies are responsible also for curdy and cheesy flavors which often accompany the sour flavor, or take its place. They are due directly to the curd content of the butter. This class of flavor defects is characteristic of hot weather butter and especially of butter made from sour, farm separator cream during the summer season. It will appear as long as the creamery accepts a poor quality of cream, but may be minimized by neutralization, pasteurization, the use of a good quality of starter and expulsion of buttermilk by thorough washing.

Unclean Flavor.—This is a rather general term and yet it represents, in the vocabulary of the butter judge, a definite flavor condition of the butter. Butter with an unclean flavor lacks the clean, delicate, pleasant, aromatic butter flavor. Its taste suggests the use of unsanitary utensils and methods of handling the cream, such as unclean strainers, especially cloth strainers; foul smelling cans, especially cans that are not washed clean, or that contain dirty wash water due to incomplete rinsing, or that were not thoroughly steamed and dried after washing and rinsing; unclean farm separators, as the result of not removing all remnants of milk, cream and separator slime after each separation, or not washing the separator after each separation; unclean and leaky vats, pipes and conveyors, churns and packers; and unclean milk and cream and polluted wash water.

The unclean flavor is imparted to butter in two ways, by direct incorporation in milk, cream and butter, of decayed remnants of milk with foul smelling odors and indirectly by the contamination of the product, through these channels, with putrefactive bacteria, yeast and molds, thriving in decaying remnants of milk and developing products of putrefaction in the cream and butter.

Unclean flavor in butter can be prevented by using clean utensils for the production and handling of milk and cream on the farm, returning to the farmer clean, sterile and dry cream cans, and keeping the equipment in the creamery in sanitary condition.

Cowy and Barny Flavor.—Butter with a cowy flavor suggests contamination with manure and stable air. This flavor occasionally is very pronounced, especially in some species of dairy butter, in which case the butter usually scores a poor "Seconds." The cowy flavor may be due to milking cows whose udders and flanks are plastered with manure, the handling and exposure of milk and cream in unventilated stables, and not removing the animal heat from the milk or cream promptly.

The milk and cream which produce butter with a cowy or barny flavor are generally contaminated with large numbers of Bacillus côli communis and Bacillus coli aerogenes. These organisms are the natural inhabitants of the colon, or large intestine of the animal, and are therefore found abundantly in the manure. The abundant presence of these bacilli in milk and cream is rather conclusive evidence of the pollution of milk and cream with excreta from the cow. When milk and cream so contaminated are not promptly cooled these germs multiply rapidly and intensify the barny odors in the butter. For details see Chapter IV on Care of Milk and Cream on the Farm.

Musty and Smothered Flavor.—This butter defect is generally caused by lack of prompt cooling and aeration of the cream on the farm. The sealing up of the warm cream in the shipping can without giving it any opportunity to give off its animal heat is generally believed to cause a musty, smothered flavor. The storing of the cream in damp and poorly ventilated cellars with a stagnant atmosphere is another probable cause of musty flavored butter. The cause of musty flavor frequently also lies in the feeding of moldy, musty and decayed foods, such as moldy hay, moldy silage and musty grain.

Feed and Weed Flavors.—To this group of butter flavors belong a variety of flavors characteristic of the feeds to which the cows have access. Many of these flavors are not very pronounced and therefore not seriously objectionable, but others are very marked and in some instances greatly depreciate the market value of butter.

Since the feed flavors are usually traceable direct to the characteristic feeds producing them, or to excessive feeding of certain types of feeds, or to microorganisms with which certain feeds are associated, their prevention must of necessity lie with the producer of milk and cream. The flavors due to weeds such as garlic, rag weed, etc., can be guarded against only by eradication of these weeds from the pasture. See "Garlic Flavor."

Roots, such as turnips, are best fed after milking in order to give the feed time to pass through and out of the cow several hours before the succeeding milking.

Feed flavors caused by frozen, decayed and moldy feed are prevented by eliminating from the ration all feed not in good, sound condition. Sour, moldy silage, frozen and decayed roots and tops of roots, damp, moldy and poorly cured hay, damp and musty straw, etc., should not be fed to dairy cows.

While most of the feed flavors are inherent in the milk and cream which contain them and therefore follow these products into the butter and while their appearance in the butter is beyond the control of the great majority of creameries, many of these flavors, not including the garlic flavor, and rag weed flavor, are greatly minimized by pasteurization and aeration of the cream. Pasteurization assists in driving and expelling from the product volatile flavors, odors, and gases and thus helps to lessen the intensity of these flavors in the finished butter.

Garlic or Wild Onion Flavor.—When the wild onion flavor has once impregnated the milk or cream, it is very difficult to keep this objectionable flavor out of the butter, and butter made from such milk or cream usually grades a poor "Seconds." It may be improved materially, however, by blowing air through the milk or cream while hot and by prolonged pasteurization at a high temperature. Ayres and Johnson[1] demonstrated that milk and cream can be freed from the wild onion flavor entirely by adequate blowing, while these raw materials are hot. These investigators contrived a blowing equipment for blowing milk and cream on a small scale, with which they were able to entirely remove the onion flavor from milk heated to 145° F for five minutes. For cream they recommend a somewhat longer period of blowing and a temperature of 160° F. Their work was done with sweet cream testing 30% fat. It is probable that for richer cream and for cream that is sour, the apparatus devised would have to be modi-

[1] Ayres and Johnson, Removal of Garlic Flavor from Milk and Cream. U. S. Dept. of Agr., B. A. I. Farmers' Bulletin 608, 1914.

fied somewhat to prevent clogging and to insure more complete aeration. The usual equipment and method employed for this purpose in the creamery are quite inadequate for complete removal of garlic flavor in sour cream. They fail to furnish the volume of air necessary for successful results.

Because of the difficulty of even minimizing the garlic flavor in butter made from garlic-flavored milk or cream, and the impossibility, under practical commercial conditions, of removing this flavor from the once tainted product, entirely, every effort should be made to keep this flavor out of the milk on the farm. There are two ways to accomplish this, namely, to prevent the cows, so far as possible, from obtaining garlic and secondly to manage the herd on garlic pasture in such a manner as to have it suffer the least harmful effect.[1]

Garlic makes a growth much earlier in the spring than pasture grasses, and therefore is usually most troublesome when cows are first turned to pasture and when grass is not plentiful. In many cases garlic is localized in the pasture and these places should be fenced off and used for pasturing stock other than milk producing cows. When the garlic is scattered about the fields it is impossible to do so, and the dairyman who would not have the flavor of the milk of his cows impaired must so manage his herd as to overcome the difficulty. The unpleasant odor and flavor are strongest in milk from cows that have just eaten the garlic. If, three or four hours before milking, the cows are placed in a garlic-free field, the trouble will be reduced to a minimum. If such a field is not available, they may be brought to the stable yard and fed on silage or hay and allowed to remain out of doors until the regular milking time. This practice the dairyman can usually follow without serious inconvenience.

The trouble caused by garlic is not liable to last long, as the weed is usually cropped off by the cows within a few days after they are turned to pasture, and as soon as the grass becomes plentiful they will eat that in preference.

However in years when the season opens slowly so that the pastures fail to satisfy the cows with an abundance of grass for a considerable period of time, garlic-flavored cream may occur for

[1] Hoard's Dairyman, November 18, 1918.

many weeks. In the fall also there is a tendency in some sections for this flavor again to appear.

The complete eradication of the garlic plant is the most satisfactory method of avoiding trouble and is practicable on the ordinary dairy farm. Those interested in such eradication should write to the Department of Agriculture, Washington, D. C., for Farmers' Bulletin 610, entitled, "Wild Onion; Methods of Eradication", and Farmers' Bulletin 608, which gives directions for removing the garlic flavor of milk.

MOLDY BUTTER

The genuine moldy flavor of butter is usually due to the presence and growth in cream and butter of certain species of molds. Frequently storage butter, that has reached an advanced stage of deterioration, develops a very marked disagreeable moldy odor and flavor.

Causes of Mold Spots on Butter.—The greatest objection of moldy butter, however, does not lie in its objectionable flavor, but rather in the appearance on and in the butter of mold specks and spots which render it unsightly and cause much loss to the creamery and the butter dealer.

This butter fault is especially prevalent in summer and usually shows up in the course of a few days after manufacture. Wholesale receivers practically every summer complain of moldy butter. They find the butter to be spotted with mold specks of a greenish-brown to black color. These specks are located largely on the surface of the butter, especially in the lower sections of the butter tub. In aggravated cases the mold specks penetrate the butter to a considerable depth and frequently they permeate the entire tub. Even if butter scored an "Extras" in all other points, moldy butter would be classed as a "Seconds" and would be sold by the dealers as such at a great sacrifice in price. The difficulty and trouble of removing all traces of mold from moldy butter is great and expensive. Much butter is wasted, new tubs and liners have to be supplied, and much labor is required. Upon storage at not very low temperature butter occasionally becomes completely coated with a matting of molds. The filaments often grow so long that the surface is actually bearded.

Unsalted butter is much more prone to become moldy than salted butter, the salt exerting a considerable retarding, if not inhibiting, effect on mold growth. In fact, it is frequently very difficult to prevent unsalted butter from showing moldiness, in spite of the observance of otherwise successful and effective precautions.

There are numerous classes and species of molds that are capable of developing mold spots on butter, such as Penicilium, Trichosporium, Streptothrix, Cladosporium oidium. Griepenberg[1] who examined storage butter, found that most of the molds in butter belonged to the genera Penicilium and Trichosporium and that of these, Penicilium cruslaceum and Trichosporium collae were the most common species. Penicilium glaucum and oidium lactis are also known to be very common molds of butter. Most of these organisms thrive on the caseous matter of the butter and some are also capable of splitting the butterfat.

According to Thom and Shaw,[2] mold in butter usually takes three forms:

"1. Orange-yellow (red) areas with a submerged growth of mycelium, which are produced by Oidium lactis. Cannot develop in butter containing 2.5% of salt.

2. Smudged or dirty-green areas, either entirely submerged or with some surface growth. These are produced by species Alternaria and Cladosporium. Cannot develop in butter containing 2.5% salt.

3. Green surface colonies, which are produced by Penicilium, or more rarely, Aspergillus, either upon the butter, causing decomposition, or upon the container or wrapping, injuring the appearance of the sample in the market."

The natural channels through which butter becomes contaminated are infection of milk and cream on the farm, and contamination of cream or butter in the factory, from the air in ill-ventilated plants, from unclean vats, pipes, churns and packing equipment, from impure starters and impure washwater, and from mold-infected material used for packing, such as parchment wrappers and liners, and butter tubs and boxes.

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[1] Griepenberg, Fleischmann, Lehrbuch der Milchwirtschaft, p. 324, 1915.
[2] Thom and Shaw. Moldiness in Butter. Jour. Agr. Research, Vol. III, No. 4, 1915.

Proper pasteurization materially minimizes the tendency of butter to become moldy. It is destructive to the majority of the species of molds usually found in the cream.[1] Pasteurization therefore limits the problem of preventing moldy butter very largely to precautions against recontamination of cream and butter after the cream leaves the pasteurizer and confines it to the sanitary condition of the air, vats, pipes, pumps, churns, wash-water and packing equipment and material.

Moldy butter has in some instances also been traced to contaminated salt.

The most probable cause of the salt as a source of moldy butter lies in the contamination of the salt in the creamery after the barrel is opened. In many creameries the salt is kept in a room none too clean and in an atmosphere none too pure. If the barrel is left open the surface of the salt is prone to become contaminated with germ life of the air and may become the carrier of mold. The salt barrels should be stored in a clean place and a properly fitting cover should be provided for remnant barrels. Such barrels should be covered immediately after each removal of salt.

Prevention of Mold in Butter.—Moldiness in butter may best be prevented by observing the following precautions:

1. Pasteurize all cream, skimmilk and starter used. In vat pasteurization heat to at least 145° F. and hold not less than 30 minutes. In flash pasteurization heat to 180 to 185° F. When using the holding process draw a pailful of cream from the gate of the vat as soon as the temperature of the cream reaches 145° F. and pour it back into the vat. This will insure proper heating of the cream located in the gate and nipple.

2. Use pure starter only. If the starter is contaminated reject it.

3. Thoroughly wash, flush and steam all vats, pipes, conduits and pumps daily.

4. Rinse the churns daily with one batch of hot water containing some good washing powder and then with clean hot water. The water must have a temperature of 180° F. or over. Use thermometer to make sure. Lime the churns at regular

[1] Thom and Ayres—Effect of Pasteurization on Mold Spores. Jour. Agr. Research, Vol. VI, No. 4, 1916.

intervals, preferably once per week, or whenever they show signs of staleness. Churns that have been lying idle should always be limed and receive a special cleaning and scalding before they are pressed into service again. The churn is the most difficult piece of equipment to keep clean and sweet, and it represents one of the most dangerous sources of moldy butter.

5. Do not wash packing equipment, such as packers, ladles, cubes and tubs, in dirty water. Rinse them thoroughly with scalding hot water after washing and store them in a clean, dry atmosphere.

6. Wash the butter thoroughly to remove as much as possible of the curd of the buttermilk. Curd is a necessary food for molds to grow on. Use pure wash water. Have the wash water tested bacteriologically at reasonable intervals and if it contains molds pasteurize or filter it. If a wash water storage tank is used it should be kept clean and free from slimy material by frequent scrubbing out.

7. Keep the salt in a clean, dry place. Do not break the seal of the barrels until necessary. Keep remnant barrels covered.

8. Do not store cubes, tubs and parchment liners and wrappers in a damp room. Keep them in a clean, dry atmosphere and keep the parchment wrappers and liners in their original package until used.

9. Properly paraffin all tubs and boxes. Heat them over the steam jet until they are "piping" hot before paraffining and use boiling paraffin only. Do the paraffining as short a time as possible before the tubs are used and keep them inverted in a clean place after paraffining and before use.

10. Soak parchment wrappers, liners and circles from 5 to 10 minutes in boiling hot saturated brine before use, both for salted and for unsalted butter.

11. Incorporate the moisture in the butter properly. Wet, leaky butter assists in the spread of mold colonies.

12. Pack the butter solidly, avoiding air pockets, especially between the butter and the sides of the tub. Air favors mold growth.

13. Store the butter in a clean, dry room and keep the temperature as low as possible. Molds grow best in a moist atmosphere and at a temperature around 50 to 60° F.

14. Make the butter from cream of low acidity (.3% acid or below). Molds prefer an acid medium for growth.

15. Keep the air in the creamery well ventilated and the sewers and floors well scrubbed. A stagnant, impure atmosphere is often pregnant with mold spores.

16. Spray the walls, ceilings and floors of butter storage rooms with formaldehyde, at reasonable intervals. Do not permit the appearance of mold specks on walls and ceilings.

For additional directions for the treatment of liners and wrappers see Chapter XII on "Packing Butter."

Yeasty Flavor and Foamy Cream.—This flavor is the result of a yeast fermentation of the cream. It is most prevalent in summer, particularly during the hottest summer weather, when both, the days and the nights are hot and when the cream is exposed to the summer heat for a considerable length of time. Yeasty flavored butter seldom scores better than a "Second." It represents a very objectionable flavor defect which no now-known process of manufacture is capable of entirely removing. Nor does it disappear while the butter is held in cold storage. This flavor stays in butter until the butter is consumed.

Yeasty cream, therefore, should be culled out at the creamery by rigid grading, and churned separately, if it is accepted at all. The adoption and practice of an efficient system of cream grading and paying on the basis of quality is the creamery's most effective immediate weapon to minimize receipts of yeasty cream, accompanied by a systematic effort to acquaint the farmer with the fact that the reason why he received a lower price was that the cream was yeasty, and by instructions of how to best avoid the recurrence of this defect.

The fundamental cause of yeasty and foamy cream lies in the presence in cream of yeast cells. Most, if not all, cream contains some yeast cells, but at moderate or low temperatures they fail to gain the ascendency and therefore do not develop a yeasty flavor in the cream nor cause the cream to foam.

Yeast cells require a relatively high temperature, approaching that of the animal body, for their greatest development. When on the farm, or in transit, or both, the cream is exposed sufficiently long to summer heat, so that the cream itself becomes warm, the development of the yeast cells becomes very pronounced and very intense. Often it is accompanied by violent gas production, frequently causing the lids of the cans to blow off and the cream to foam over. In this condition the cream gives off a very decided and objectionable yeasty flavor similar to baker's yeast, that follows the product into the finished butter.

If the cream is cooled promptly and properly on the farm when it leaves the separator and is kept cool until shipped, it usually reaches the creamery before it has a chance to become yeasty and foamy. On the other hand, if the cream is not cooled on the farm, the yeast cells become active at once and when this fermentation has once commenced, it goes on rapidly and is stopped with difficulty only.

It is obvious also that the number of yeast cells present in the cream to start with, has a great deal to do with the rapidity and extent to which this defect develops. Contamination of the cream through such channels as impure water, unclean utensils, unclean separators and cans, should be avoided as much as possible, and the cream producer should be instructed to pay close attention to the following precautions:

Prevention of Yeasty and Foamy Cream.

1. Wash and scald all milk utensils, such as strainers, pails, dippers, cans, etc., after each use.
2. Wash and scald all parts of the cream separator that come in contact with milk and cream, after each use.
3. Cool the cream as soon as it leaves the separator to as low a temperature as possible, preferably below 60° F.
4. Use a cream cooling tank and keep the cream in cold water until it leaves the farm.
5. Protect the cream cans in transit from summer heat by covering them with wet blankets.
6. Do not allow the cans to stand on the station platform exposed to the sun in hot weather.

7. Deliver or ship the cream often.

In the case of the cream station system of receiving cream, cream that may have arrived at the cream station in good condition, frequently is yeasty and foams over by the time it reaches the central creamery. In this case the yeasty defect is largely due to faulty handling of the cream at the cream station.

In order to avoid this the cream, after it has been transferred to the shipping cans, should be set in cold water or in a cold room and held there until shipping time.

If, during hot weather, cream arrives at the creamery at a time too late for "dumping" on the same day, the cans should be rolled into the cooler, in order to prevent the development of foamy cream over night.

Bitter Flavor.—The bitter flavor of butter is a defect, which is confined largely to dairy butter. Its occurrence in creamery butter is comparatively rare. The bitter flavor is either present in the milk at the time it is drawn or it develops in the milk or cream after milking. In either case it passes also into the butter.

There are individual cows when in poor physical condition, or when they have reached an advanced state of their period of lactation, usually after the sixth month, that yield milk that has a bitter taste. In many of these cases of bitter milk, the milk is abnormal also in other respects. Often the milk is very viscous and produces cream that refuses to churn out; the butter usually has a poor texture and is greasy. In some instances this bitter milk does not curdle in the natural way. The exact cause of this condition has not been satisfactorily determined. Weigmann[1] suggests the probability that the peptonizing of the milk proteids may yield bitter-tasting albumoses and peptones, but he also mentions the possibility of the presence in such milk of special bitter substances. Whether these lower forms of milk proteids, the albumoses and peptones, are the result of abnormal physiological action of the cows and are therefore inherent in such milk, or whether they are due to bacterial action by udder microorganisms, is also a matter not experimentally determined. According to Weigmann certain species of the coli and aerogenes groups of bacteria, also Bacterium

[1] Weigmann—Mykologie der Milch, 1911, p. 132.

Zopfii and Bacterium lactis innocuum, are capable of making milk bitter. Jensen[1] reports Streptococcus casei amari as a cause of bitter milk. Harrison[2] discovered a lactose-fermenting yeast, which he gave the name Torula amara, that produced a bitter flavor in milk and cheese made in Canada. This organism produced an intense bitter flavor in 14 hours. His investigation showed that this yeast grows on the leaves of maple trees and contaminated the milk by being blown from maple trees into the milk cans which stood under these trees on the farms. It was necessary to steam these cans very thoroughly in order to destroy this germ. Conn, Burri, Duggeli, Freudenreich, Govini and others[3] report numerous peptonizing microorganisms which are capable of rendering milk and butter bitter.

Bitter milk and butter frequently also are the result of certain feeds and weeds to which the cows have access, among these we find lupines, rag weed, beet tops, rye pasture (excessive), raw potatoes, and especially many classes of decayed and moldy feed stuffs, and moldy bedding, moldy oat and barley straw.

Butter may also derive its bitter flavor from the use of chemically impure salt, especially salt containing relatively large amounts of magnesium salts or calcium chloride, or both.

Butter made from sour cream that has been overneutralized, or improperly neutralized, especially when lime is used as a neutralizer, is prone to show a bitter, limy, or so-called neutralized flavor. For proper neutralization which will reliably prevent bitterness from this source see Chapter VII on Neutralization.

Oily Flavor.—Causes of Oily Flavor.—Oily flavor of butter is a frequent occurrence in creameries receiving sour cream, pasteurizing at a high temperature and cooling by turning the cream over a surface cooler. Butter which has an oily flavor gives the impression of having, and generally does have, inferior keeping quality. Experience has shown that such butter, when in storage often, though not always, develops other and more objectionable flavor defects, such as metallic flavor

[1] Orla Jensen. Die Bakteriologie der Milchwirtschaft, p. 82.
[2] Harrison. Landwirtschaftliches Jahrbuch der Schweiz 14, 1900.
[3] Weigmann. Die Mykologie der Milch, 1911.

and fishy flavor. The oily flavor is more prevalent in butter made in summer than in winter. Oily butter is not suitable for storage. It usually scores a "Seconds."

The specific reactions which produce oily-flavored butter are not well understood, but it is known from practical experience that high temperature pasteurization and the use of a surface cooler for cooling the hot pasteurized cream, are prone to produce an oily flavor in butter. This is especially the case with cream that is excessively sour at the time of pasteurization. The pasteurization of very rich cream and of cream that has been much diluted with water also tends to make butter oily. Overworking of the butter under certain conditions has a similar effect.

The oily flavor has also been attributed by some investigators to bacterial action. Jensen[1] isolated an organism belonging to the group of sour milk bacteria, which was capable, aside from curdling the milk into a solid clot in 24 hours, to produce an unpleasant odor and taste resembling that of machine oil. The oily flavor was transmitted from the cream in which it developed to the butter. Others[2] claim that oily butter is due to the action of microorganisms that decompose the fat, such as Oidium lactis, yeasts and liquefying bacteria. To what extent specific microorganisms are directly responsible for the oily flavor in butter is uncertain, but it is quite possible that they assist in bringing about such combinations of conditions as are conducive to the development of oiliness and thereby may become indirectly responsible for this defect.

The oily flavor of butter occassionably may be due to causes other than those pertaining to the process of manufacture. It has at times been found to be caused by the printer's ink on the butter carton. In this case the oily flavor is usually especially pronounced on the surface of the print while the interior of the butter may be practically free from this defect.

In the case of cartons with heavy, solid coloring, that are inclined to transmit to the butter an oily flavor, the danger can be greatly minimized, if not entirely prevented, by allowing

[1] Russell—Outlines of Dairy Bacteriology, 1902, p. 158.
[2] Marshall—Microbiology, 1911, p. 343.

the cartons to dry out, either by aging them or by aerating them in a warm room, preferably with the aid of forced air circulation, or both. It is advisable to store all printed cartons in a dry room and preferably in a moderately warm atmosphere. This hastens the aging and drying of the ink and the expulsion of ink odors detrimental to the flavor of the butter.

Prevention of Oily Flavor.—In consideration of the above observations concerning the causes of oily flavor in butter, attention to the following points may serve to overcome this defect or to avoid its recurrence:

1. Do not flash pasteurize cream that is high in acid. If the cream cannot be secured in sweet condition, standardize its acidity to about .25% acid before pasteurization. If this is not possible, use the vat or holding process of pasteurization.

2. Do not dilute cream with water. Instead of rinsing the cream cans with water to reclaim the remnants of cream they contain, blow these remnants of cream out of the cans with steam, inverting the cans over steam jets.

3. Use as little water as possible when rinsing cream and foam out of forewarmers and vats. It would be preferable to use skimmilk instead of water for this purpose. If the cream is too rich, containing above about 33% fat, dilute it with sweet milk, skimmilk, condensed milk or dissolved skimmilk powder. This adds solids not fat to the cream and assists in protecting the fat globules against mutilation during pasteurization. Standardize all cream to about 33% fat before the cream is pasteurized.

4. Do not run the flash pasteurizer at excessive speed. Use a machine of such capacity that crowding it is unnecessary.

5. Do not expose the hot cream, while cooling, excessively to air and light. In the place of a surface coil cooler, use a cooler which protects the hot cream against these agents. If no such cooler is available run the cream from the flash pasteurizer direct into the vats and do all the cooling in the vats, preferably with the covers partly down.

6. Do not overwork the butter. Regulate its moisture content by proper adjustment of the churning temperature, rather than by an effort to reincorporate water into too firm butter by overworking.

7. Use butter cartons only that are incapable of transmitting to the butter an oily flavor.

Metallic Flavor.—By metallic flavor is generally understood a semblance in flavor to the astringent, puckery and metallic flavor, characteristic of the taste of metallic salts, such as are formed by iron, copper, zinc, etc., in acid solutions.

This flavor defect is not always sharply defined, often being accompanied by other, more or less pronounced off-flavors. Frequently it borders on oiliness, then again it approaches fishiness and occasionally it appears to be a nuance of tallowy flavor.

Causes of Metallic Flavor.—While direct contact with metals and high acid in cream are undeniably essential and fundamental factors in the production of metallic flavor in butter, they do by no means always produce this defect.

This fact suggests that the metallic flavor, similar to the fishy flavor in butter, is the result of a combination of conditions, of which all the necessary elements are not as yet definitely known.

Slight variations of the factors making up this combination, or slight variations in the extent to which the individual elements of the combination are present, appear to make wide differences in the exact flavor defect produced. The result may be the characteristic metallic flavor, or it may be an oily flavor, a fishy flavor, or a tallowy flavor, etc.

Thus experimental results of the writer show that under the majority of conditions, the presence of traces of such metals as iron or copper or their salts, in butter made from sour cream, causes such butter to develop a metallic or a fishy flavor, while the presence of the same metals, or their salts, in butter in which the acid has been completely neutralized, will produce a tallowy flavor.

Since it is evident that traces of metals or metallic salts are an integral part of the combination of conditions that results in metallic flavor in butter, it is obvious that the condition of the utensils and equipment in which the milk and cream are handled and in which butter is manufactured, exerts a far-reaching influence on the production or prevention of metallic flavor.

Thus the use of rusty utensils on the farm, the holding and shipping of the cream in rusty cans, the use of forewarmers, pasteurizers, coolers, vats, pipes and conduits, etc., in which the copper has become exposed and especially where the copper surface is not scoured thoroughly and regularly and is permitted to accumulate verdigris, furnishes a logical basis for the development of metallic flavor.

Both iron and copper are most active in the presence of acid forming metallic salts. Therefore, this flavor defect occurs most prominently in butter made from cream that reaches the creamery in sour condition and is churned sour. Because of this fact, metallic flavor is generally more prevalent and more pronounced in summer than in winter butter, the cream containing more acid during the hot weather than during cold weather, although metallic flavor is by no means confined to summer butter, and may appear at any time of the year.

Flash pasteurization, combined with the use of the surface coil cooler for cooling the heated cream, further invites metallic flavor, partly because the action of the sour cream in the presence of heat, air and light on the metal surface of the cooler, is intensified, and partly because this method of cooling may result in oily butter, which is often a forerunner or preliminary stage of metallic flavor.

For similar reasons, rich cream (cream testing over 33% fat), and cream that is excessively diluted with water, tends to cause butter to develop metallic flavor. As explained under "Oily flavor," such cream contains a relatively low per cent of solids not fat and its viscosity is slight. This robs the cream of the protecting influence of the solids not fat, the fat globules are subjected to excessive mutilation during flash pasteurization and yield more readily to the oxidizing influence of heat, air and light, to which they are exposed, while the hot cream runs over the surface cooler.

The ripening and holding of the sour cream in the copper vats and similar equipment for a prolonged period of time, such as holding it over night in vats with profusely exposed copper, may lend additional impetus to the development of metallic and similar off-flavors in butter, accelerating the action of the acid on the metal, and the oxidizing and catalizing action of the metallic salts on the ingredients of the cream and possibly enhancing also bacterial and enzyme action. Furthermore, in most vats several metals are exposed to the cream, so that it is not improbable that this bimetallic submersion in the acid of the cream, gives rise to a slight galvanic current, producing electrolytic action which naturally hastens the formation of metallic salts.

Finally, the churning of cream with a high acid content augments the acid content of the resulting butter and this furnishes an additional essential factor in the combination of conditions which cause metallic flavor.

Attempts to attribute the metallic flavor to the presence in the cream of specific bacteria or groups of microorganisms experimentally, have proven abortive. While bacteria, through their power to decompose portions of the ingredients of cream and butter, forming acid and other cleavage products, may assist to a limited extent in the production of metallic flavor, they cannot be considered as the specific cause of this defect.

Nor is the fact that the metallic flavor often does not appear in the fresh butter, but develops after a considerable period of storage, necessarily indicative of bacterial origin. A careful study of the available data dealing with the causes of this butter defect emphasizes the complexity of the combination of factors and conditions responsible for the metallic flavor and the wide variations in the rapidity with which this defect develops. On the basis of the bulk of evidence it appears reasonable to attribute metallic flavor to chemical action.

Prevention of Metallic Flavor.—According to our present limited lights on this subject, the most consistent means to prevent metallic flavor in butter is:

1. To use rust-free cream shipping cans and to return to the farmer cans only that are clean and properly rinsed and steamed and thoroughly dried.

2. To keep forewarmers, pasteurizers, coolers, vats, etc., well tinned, to thoroughly scour exposed copper surfaces, keeping them bright and free from verdigris, and to flush the entire system each day before use with hot water, thus removing any water it may contain and which may have absorbed metallic salts.

3. To protect hot pasteurized cream from air and light by cooling under cover.

4. To avoid excessive dilution of cream with water and to standardize all cream before pasteurization to about 33% fat or below with skim milk or milk, and to about .25% acid by the use of a suitable neutralizer, in the case of sour cream.

5. To not permit the cream to lie in the vats for an abnormal period of time and to churn it at an acidity of about .3% or below. Especially should cream not be held over night in improperly tinned copper vats.

Fishy Flavor.—The fishy flavor is a defect especially common with storage butter, though fishiness in fresh butter and butter only one to three weeks old, is by no means a rare occurrence. Fishiness is a very serious butter fault, objectionable to most consumers and one which greatly depreciates the market value of the product. Fishy butter is shunned on the open market. It seldom grades above a poor "Seconds."

Causes of Fishy Flavor.—Milk, cream and butter may become fishy in flavor when kept in close proximity to fish, in which case the dairy product absorbs the odor. The possibility of tainting butter from this source is pretty generally understood and recognized. In Great Britain and Ireland the law requires railway companies to provide separate cars for the carriage of fish and butter.

Again, the fishy flavor of butter may be due to the cow herself. Weigmann[1] reports a case where an individual cow which received the same feed and care as the rest of the herd, persistently produced a fishy milk. The fishy flavor of her milk was so marked that when mixed with the milk of the remainder of the herd, the mixed milk also became intensely fishy in flavor. In another case a cow produced milk with a fishy flavor only during the hot summer weather. This investigator further states that in Schleswig-Holstein, Germany, the opinion prevails that cows yield fishy milk when they pasture in the marshes which are periodically flooded by the tide and on the grasses of which small crabs and other sea fauna dry and decay. Lewkowitsch[2] also reports that fishy butter is met with in Norway,

[1] Weigmann—Mykologie der Milch, 1911, p. 124.
[2] Lewkowitsch—Chemical Technology and Analysis of Oils, Fats and Waxes, Vol. II, 1914, p. 798.

being obtained from cows fed on fishmeal. In contradiction to the above, Weigmann writes that even in the case of intensive feeding of herring meal or whale meal neither the milk nor the butter show signs of fishiness.

Harding, Rogers and Smith[1] investigated the cause of fishy flavor and odor in milk brought to the New York State Experiment Station by a milk dealer. This fishy taint was so pronounced that the milk was of no commercial value, although coming from a dairyman of more than ordinary carefulness in the handling of his herd. They found that the defect was confined to the milk of one cow that was fed on the same feed and received the same care as the other animals in the herd. This cow was apparently in normal condition. Bacteriological study of her milk revealed no microorganisms capable of producing the fishy flavor.

Piffard[2] suggests that the salt, owing to its ability to absorb odors and flavors of material in close proximity, may occasionally be responsible for fishy butter. This is improbable, the salt has the power to intensify flavors but it does not readily absorb flavors. The same author holds that frequently fishy butter may be due to impure water with objectionable flavor, to which the cows may have access and which he attributes to the development of diatoms and algæ, notably the Oscillaria.

These cases of mechanical absorption by milk or butter of the fishy flavor, or of fishy flavor caused by an abnormal condition of the cow or the milk, are comparatively rare. The great majority of causes of fishy-flavored butter on the market is due to causes, deeper seated, more complex and more difficult to prevent. The seriousness of the defect and the difficulty of avoiding it are augmented further by the fact that the fishy flavor of most of the commercial butter does not show up at the churn. In aggravated cases it may develop within the first few weeks after manufacture, but in the great majority of cases it develops while the butter is in cold storage.

The earlier studies of fishy flavor in butter and its causes, dealt largely with efforts to discover specific bacteria or other

[1] Harding, Rogers and Smith. Notes on Some Dairy Troubles. New York State (Geneva) Agr. Exp. Sta. Bull. 183, 1900.
[2] Piffard. Fishy Flavor in Butter. New York Produce Review and Am. Creamery, Vol. 13, No. 20, 1901.

micro-organisms capable of producing this flavor. O'Callaghan[1] attributes fishiness in butter to the mold Oidium lactis. He claims that this organism when grown in conjunction with Bacillus acidi lactici in cream produces fishiness invariably.

Harrison[2] classes the fishy flavor of butter with bitter, putrid and lardy flavors, the causes of which he attributes to the presence and growth of undesirable microorganisms in the cream. Jensen[3] found certain species of yeast that give butter a fishy flavor. Klein,[4] speaking of oily, fishy and tallowy butter, holds that all these butter defects may well be considered specific forms of rancid butter, resulting from the action of bacteria. Hammer[5] isolated from a can of evaporated cream, which had developed a fishy odor, a bacillus of the Proteus group, which he named Bac. ichthyosmius. With this organism he was able to reproduce the fishy odor in milk, cream and evaporated milk. When inoculated into butter, either direct, or into sweet or sour cream, the butter failed to show fishy odor or flavor.

The later studies and observations relating to the causes of fishy butter indicate that the direct cause of fishy flavor and odor in commercial butter is attributable to chemical action rather than to bacterial development. Fleischmann[6] states that fishy and oily flavor is a butter defect which appears only in butter made from sour cream, that it shows itself as an augmentation of an aroma characteristic of this class of butter, carried to the point where it becomes offensive to taste, and that it is caused by certain species of bacteria which develop in the cream during souring and associatively with the lactic acid ferments.

Rogers[7] found that in all cases where butter became fishy, the butter was made from high acid cream, both in the case of acid produced in the cream by bacteria, and of acid in the form

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[1] O'Callaghan—"Cause and Remedy of Fishy Flavored Butter." The Agr. Gazette of N. S. Wales, Vol. 12, p. 341, 1901.

O'Callaghan—"Butter Classification.' The Agr. Gazette of N. S. Wales, Vol. 18, p. 223, 1907.

O'Callaghan—"That Fishy Flavor." Chicago Dairy Produce, April 25, 1916, p. 8.

[2] Harrison—"Defects in Butter." Twenty-seventh Annual Report Ontario Agr. Exp. Sta., p. 79, 1901.

[3] Jensen—Die Bakteriologie der Milchwirtschaft, 1913, p. 24.

[4] Klein—Milchwirtschaft, 1914, p. 238.

[5] Hammer—Fishiness in Evaporated Milk. Iowa Research Bul., 1917.

[6] Fleischmann—Lehrbuch der Milchwirtschaft, 1915, p. 322.

[7] Rogers—Fishy Flavor in Butter. U. S. Dept. Agr., B. A. I. Circular 146, 1909.

of lactic acid and acetic acid added to sweet cream, although cream with high acid did not uniformly develop fishiness. He further states that overworking of butter produced fishiness with a reasonable degree of certainty. He offers the opinion that fishy flavor is caused by a slow, spontaneous, chemical change to which acid is essential and which is favored by the presence of small amounts of oxygen, and that it may be prevented with certainty by making butter from sweet cream; also that butter made from pasteurized cream with a starter but without ripening seldom, if ever, becomes fishy.

In a subsequent publication, dealing with results on the Manufacture of Butter for Storage, Rogers, Thompson and Keithley[1] show still more conclusively the freedom from fishiness in butter made from unripened pasteurized cream, and the tendency of butter made from ripened, raw or pasteurized cream to become fishy in storage.

Dyer[2], as the result of a chemical study of fresh and stored butter, concludes that "the production of off-flavors" so commonly met with in cold storage butter (and of which the fishy flavor is a very prominent one) is attributable to a chemical change expressed through a slow oxidation progressing in some one or more of the non-fatty substances occurring in buttermilk. The extent of this chemical change is directly proportional to the quantity of acid present in the cream from which the butter was prepared. Dyer further emphasizes that the development of undesirable flavor in butter held in cold storage at a temperature of 0° F. is not dependent upon an oxidation of the fat itself.

The writer's experience has been fully in accord with the findings of Rogers and Dyer, to the effect that high acid cream and overworking of butter are conditions favorable to the development of fishy butter. Fishy butter is very closely related to oily and metallic butter. It appears to be the result of a combination of certain factors, one of which is high acidity and another a weak body of butter due to overworking, which destroys the grain and excessively exposes the butter to the action of air. Other factors may embrace the presence in the

[1] Rogers, Thompson and Keithley—The Manufacture of Butter for Storage, U. S. Dept. Agr., B. A. I. Bulletin 148, 1912.

[2] Dyer—Progressive Oxidation in Cold Storage Butter. Jour. Agr. Research, Vol. VI, No. 24, 1916.

cream and butter of metallic salts, such as iron and copper lactates, which act as oxidizers and catalizers, and the presence in the cream and butter of diverse ferments and their products.

Prevention of Fishy Flavor.—In order to minimize the danger of butter going fishy before, during and after cold storage, attention to the following phases of manufacture is recommended:

1. Secure as fresh, sweet and unfermented cream as possible. Systematically grade the cream for quality and churn first and second grade separately.

2. Use only non-rusty cans that are thoroughly cleaned, rinsed, steamed and dried before they are returned to the farmer.

3. Keep the copper surfaces in forewarmers, pasteurizers, coolers and vats well tinned, do not permit exposed copper surfaces to become coated with verdigris, wash all forewarmers, pumps, pasteurizers, coolers, vats and conduits thoroughly each day and flush them out again with hot water immediately before use the next day.

4. If the cream arrives at the creamery sour, neutralize it to about .25% acid.

5. Do not dilute cream with water. If cream is too rich, standardize it to about 33% fat by the addition of sweet milk or sweet skimmilk.

6. Pasteurize all cream, but do not run the heated cream over an open surface cooler. Protect it against excessive exposure to the air and light.

7. Churn the cream with an acidity of .3% or below.

8. Do not overwork the butter.

Tallowy Flavor.—This butter defect refers to butter which has a distinct taste and odor of spoiled tallow. Tallowy butter is usually, but not always, bleached in color, and may be entirely white. Very old tallowy butter may change to a pinkish brown color. Tallowiness is a defect which renders butter utterly unfit for the market.

Butter may, and frequently does develop a tallowy flavor and odor and a bleached color within a few weeks of the date of manufacture, though this defect usually requires from three to six weeks to become pronounced under commercial conditions of handling butter. Tallowiness is not a usual cold storage defect of butter. In commercial cold storage, butter seldom goes tallowy. This defect develops primarily in butter lying in stores and exposed to rather high temperatures (room temperature). Tallowiness is more prevalent in print butter than in tub butter. The tallowy flavor and the bleaching start on the surface of the butter and gradually work into its interior. Butter may have turned very tallowy and perfectly white on its surface, while the core of the package may still have the normal yellow color, and be free from the tallowy flavor.

Causes of Tallowy Flavor.—Tallowiness, similar to rancidity, is due to a decomposition of the butterfat. These two flavor defects often occur in the same piece of butter and have frequently been confused, or considered synonymous. This confusion is unfortunate, inasmuch as it has led to misleading interpretations of experimental results, rendering difficult the establishment of their true causes and hindering efforts intended toward their prevention.

A careful study of the causes of tallowy butter shows that, unlike rancidity, which is the result of hydrolysis of the fats, tallowiness is due to oxidation.

On the basis of our present knowledge[1] relating to tallowy butter, the causes and prevention of this defect may consistently be summarized as follows:

1. **Oxidation the Cause of Tallowy Butter.**—The butter defect known as tallowy odor and flavor is the result of a process of oxidation. The oxidizing action may, or may not, be on the fat, according to agencies and conditions favoring the oxidation, as outlined in succeeding paragraphs.

2. **Exposure to Air, Light and Heat.**—Air readily brings about oxidation of the fat in butter, and this oxidation is greatly intensified in the presence of light and heat. Butter so exposed is prone to rapidly develop a tallowy flavor. This fact is well known to the layman. Tallowiness, caused through these channels, is comparatively rare, because the great bulk of commercial butter is guarded against these agents. The wrap-

[1] Hunziker and Hosman, Tallowy Butter, Its Causes and Prevention. Journal of Dairy Science, Vol. I., No. 4. 1917.

pers and cartons of print butter and the liners and paraffined tubs and cubes of bulk butter, protect the butter against excessive exposure to air and light. While the butter remains in the creamery, it is usually kept at a temperature considerably below that at which heat alone is capable of producing tallowiness. Butter intended for immediate consumption (within one to three weeks) does not become tallowy, even at ordinary ice box temperature, such as it is exposed to in the store and in the home, unless it contains other agents that cause tallowiness. The bulk of the butter going to the tropics is packed in hermetically sealed tin cans, excluding the air and light and thereby greatly minimizing the action of heat. Butter intended for prolonged storage, rarely develops tallowiness, because the low temperature of commercial cold storage sufficiently retards the action of air and light. Although under present commercial conditions of manufacture and handling of butter, air, light and heat are improbable causes of tallowiness, their importance should not be ignored and every effort should be made to protect butter against these agents.

To run the hot pasteurized cream over a surface coil cooler, located near windows with transparent panes or with open sash, where it is exposed to the direct sunlight, and possibly to air currents; to keep the pasteurizing vats open during the entire process of heating, holding and cooling; to work butter on an open table near the window, and to expose the butter in the print room and later in storage excessively to air, light and heat, are dangerous practices, which jeopardize quality and may readily lead to tallowy flavor in butter.

3. **Presence in Cream and Butter of Metals and Metallic Salts.**—Oxidizing agents, such as metals and their salts, are capable of turning butter tallowy in a very short time. These agents act as oxygen carriers or catalizers. Iron and copper and their salts, also the alloys of copper, such as brass and German silver, belong to this class. The copper, copper salts, and the alloys of copper are the most active metals, metallic salts and alloys that enter into the problem in commercial buttermaking. Iron oxide also has specific catalytic action which aids the oxidation process, while in the case of iron bases and

salts the action is relatively slight. Nickel and tin are practically negative in this respect and do not produce tallowy flavor in butter.

Most of the equipment used in the handling of cream and the manufacture of butter is constructed of iron or copper, usually originally coated with tin. When this tin coating wears off, as it always does to a greater or less extent, the iron or copper becomes exposed, and often the exposed iron is permitted to rust and the exposed copper allowed to become coated with verdigris. In this condition, these metals are most active, considerable portions being dissolved by the acid in the cream and thereby not only act in the cream, but also find their way into the butter, jeopardizing its quality and inviting the development of tallowy flavor.

This danger can best be minimized, if not entirely avoided, by furnishing the farmer with bright and non-rusty cans and by preventing the cans from rusting, by systematic and thorough washing, rinsing, steaming and drying; keeping weigh cans, forewarmers, pasteurizers, coolers, pumps and pipes and conduits well tinned, thoroughly cleaning and steaming them after each day's use and flushing them with hot water each morning before circulating the cream, so as to remove any remnants of water of the previous day which may be pregnant with metallic salts; removing the rust from all parts of the packing and printing equipment and using wrappers and liners only which are free from metallic specks. Water used for washing butter should be free, or nearly so, from iron.

4. **Presence in Butter of Excess Lactose.**—The presence in butter, in excess, of specific compounds which are themselves readily oxidized may yield tallowy flavor, as one of their oxidation products. To these compounds belong lactose, glucose and glycerol. Danger from these products need be considered only, however, when the cream or butter is subjected to alkaline condition, as shown in the succeeding paragraph. When butter is made under proper conditions, and containing a normal amount of acid, the presence of lactose and similar compounds has no injurious effect on its flavor and does not, in itself, constitute a cause of tallowy butter. In fact, the addition of lac-

tose to butter, when in normal acid condition, may have a slight preservative effect, improving its keeping quality.

5. **Neutralization.**—The presence of an unnatural alkaline condition of the butter, or of the cream from which the butter is made, accelerates any oxidizing action by rendering the compounds capable of oxidation, more susceptible to oxidation.

Over-neutralization with any alkali very greatly intensifies the oxidizing action of all the foregoing agents and hastens the development of tallowiness. This can be permanently prevented only by careful standardization of the entire operation of neutralization, including the testing of cream for acid, the preparation of the neutralizer and its addition to the cream. Guess work in neutralization is one of the most potent causes of tallowy butter. The butter should further be protected against direct contact with alkalies, by the complete removal from churns, cubes and diverse packing equipment, of all traces of alkaline wash water, and by the use of parchment wrappers that are free from alkali, such as ammonia, which is used to neutralize the sulphuric acid employed in the parchmenting process.

Storage Flavor.—Where butter is held for any considerable length of time in storage, it gradually surrenders some of its delicate flavor and aroma which is characteristic of good fresh butter, and develops a peculiar flavor known to the butterman as the storage flavor. In butter of good quality this change takes place very slowly and is for a long time hardly perceptible. Rogers[1] reports that, in examining some millions of pounds of butter made and stored for the U. S. Navy Dept., sweet cream butter, almost without exception, kept through several months' cold storage with only slight changes in flavor. In butter of inferior quality the storage flavor generally develops rapidly.

Other conditions being the same, the rapidity with which the storage flavor develops depends largely on the temperature of storage and on the time and temperature at which the butter is held before it enters cold storage. The lower the tempera-

[1] Rogers, Factors Influencing Changes in Storage Butter. Address at the Third International Congress of Refrigeration, Washington-Chicago, 1913.

ture of cold storage and the shorter the time that elapses between manufacture and cold storage, the longer will the butter generally retain the desired aroma and flavor of fresh butter.

The exact cause of this flavor and the nature of the decomposition products responsible for it have not been conclusively demonstrated. Experimental data suggest that this flavor is principally due to spontaneous chemical changes, in which oxidation plays an important part and that this oxidation is accelerated by the presence of catalyzers in the form of metallic salts. Butter made from a poor quality of cream, such as cream that has yielded excessively to fermentation and that is of high acidity, develops storage flavor and its derivatives most rapidly. It is not improbable also that the storage flavor represents a forerunner, or early stage, of other off-flavors which under favorable conditions may supersede it in the form of metallic flavor, or fishy flavor, etc.

Rancid Flavor.—Rancidity is a very common and well known butter defect. The rancid or strong flavor is a characteristic infirmity of old butter. When present to a pronounced extent in butter, such butter is no longer salable as "eating" butter and generally has to be disposed of as packing stock at a great sacrifice in price.

Cause of Rancid Flavor.—Rancidity is a flavor and odor defect that is due to decomposition of the butterfat. It is characteristic not only of spoiled butter or butterfat, but is a common decomposition product of all fats and oils, animal and vegetable. The chemistry of the reactions yielding rancid flavor and odor is not well understood, though it has been the subject of extensive investigations for many years.

In the case of butter, rancidity, and especially the initial phase of rancidity, appears to be due to hydrolysis of the butter fat, which splits the glycerides of the fats into free fatty acids and glycerol. This hydrolysis is in all probability due very largely to bacterial and mold action, since the casein and lactose contained in butter furnish the food elements necessary for the bacteria to thrive on.

The hydrolysis of the fat leading to rancidity, however, is not necessarily dependent on micro-organisms. It may be brought about in pure butter fat and other fats which do not contain bacterial life, by enzymic action in the presence of moisture. Air, light and heat, and the presence of catalizers, such as acids and alkalies, favor the development of rancidity.

In the case of butter, however, it is conceded by the best authorities that bacteria and molds are the chief factors that hydrolize the fats, making the butter rancid. Jensen[1] and Kirchner[2] demonstrated that certain species of micro-organisms, very commonly present in butter, are capable of hydrolizing the fat in butter to a very marked degree and of producing butter with an intense rancid odor and flavor. The chief of these organisms are Oidium lactis, Cladosporium butyri, Bacillus fluorescence liquefaciens and Bacillus prodigiosus. Lewkowitsch[3] suggests the possibility that even in the case of rancidity produced by these micro-organisms, the hydrolysis may be due to enzymes produced by them rather than by their direct action on the fat.

It is generally accepted that in butter the rancid flavor and odor are due to the presence of the free fatty acids resulting from hydrolysis, and it is well known that especially the volatile fatty acids, such as butyric, etc., have a pungent odor that resembles the rancid odor and flavor of butter. The free fatty acids resulting from fat hydrolysis are expressed as, and determined by, the acid value of the fat. The acid value would therefore appear to be a logical and correct measure of the degree of rancidity of the butter. And in a great many cases rancid butter is accompanied by a high acid value, as Jensen has shown.

However, there is a vast volume of experimental data on record which shows that quite often butter may have intense rancidity while the acid value of the fat from this butter shows no appreciable increase over the acid value in fat from the same butter when fresh, and instances are also recorded where a relatively high acid value was not accompanied by a pronounced rancid character of the butter. In fact the fat of perfectly fresh butter shows a considerable acid value.

It is therefore quite probable that even in the case of butter,

[1] Jensen—Ueber das Ranzigwerden der Butter, Landw. Jahrb. d. Schweiz. 1901.
[2] Kirchner—Berichte d. deutsch. botan. Gesellschaft, 1888, p. 101.
[3] Lewkowitsch—Chemical Technology and Analysis of Oils, Fats and Waxes, Vol. I ,p. 53 ,1914.

hydrolysis is only the initial phase of rancidity and that either the free fatty acids, or the glycerol, or both, undergo further decomposition yielding products which produce and intensify rancidity in butter, and this further decomposition must of necesity be an oxidation.

In the case of the saturated fatty acids, the action would be only very slight and if at all, it would probably be of enzymic nature. The unsaturated fatty acids, of which the oleic acid is representative, yield more readily to oxidation. They may be oxidized forming fatty acids of higher molecular weight, such as acids of the hydroxy series. Or they may be broken down to acids of lower molecular weight, forming various fatty acids such as pelargonic, azelaic acid, etc., which may produce or intensify the rancid odor and flavor. Also aldehydes formed by the breaking down of oleic acid may play a part in the production of rancidity; this possibility, however, Lewkowitsch does not consider probable. That the oxidation of the free fatty acids plays a considerable role in the production of rancid butter, is therefore very probable, and is emphasized by the fact that exposure of the butter to air, especially in the absence of refrigeration, and in the presence of light which intensifies oxidation, greatly hastens the development of rancidity. Allen[2] also holds that oxygen and light play a considerable part in the chain of factors instrumental in the production of rancidity.

Again it is possible that the free glyverol, resulting from the hydrolysis of the fats, and which in itself is neutral, odorless and tasteless, may yield to oxidation, forming acids and aldehydes, many of which have a very pungent odor resembling rancidity. Browne[1] attributes the pungent, irritating odor which all rancid fats give off, especially on being warmed, to the decomposition (oxidation) of free glycerol, forming acrolein. He found a decrease in the percentage of glycerol of all fats when they become rancid, the decrease being proportional to the rancidity of the samples.

Furthermore, the lactose of butter, upon oxidation, may assist in the development of products, similar to those result-

[1] Allen, Commercial Organic Analysis, Vol. II, 1912, p. 313.
[2] Browne, A Contribution to the Chemistry of Butterfat, Jour. Amer. Chem. Soc. Vol. 21. 1898.

ing from the oxidation of glycerol and thereby constitute a factor tending toward the production, modification or intensification of the rancid odor and taste. The small amount of lactose naturally present in commercial butter, however, must of necessity limit the power of this butter constituent as an important agent in this respect.

In the presence of our now available information concerning the reactions responsible for rancidity in butter, as briefly outlined in the foregoing paragraphs, the following summary may serve to bring out the most important facts and probabilities.

1. The initial stage of rancidity in butter lies in the hydrolysis of the butterfat. This produces free fatty acids which, when present in considerable amounts, produce a strong rancid taste and odor.

2. The hydrolysis of the butterfat is brought about by bacterial and mold action, or by enzyme action, assisted by catalizers such as acids and alkalies, and in the presence of water and exposure to temperatures higher than those of commercial refrigeration of butter.

3. The rancidity of butter may be greatly intensified by the oxidation of the free fatty acids, or of the free glycerol, or both. The action is greatly hastened by exposure of the butter to air, light and heat.

4. Lactose, upon oxidation, may also assist in the formation of products yielding rancidity.

5. The curd in butter assists in the development of rancid flavor insofar as it furnishes desirable nutrients for the rancidity-producing organisms to thrive on. Butter with a high curd content, other factors being the same, therefore is more prone to become rancid than butter with a low curd content.

It should be understood that rancidity is the result of progressive changes in butter and that most butter, if kept long enough, will ultimately become rancid with age. However, the development of rancidity and the postponement of this common butter defect may be controlled with a reasonable degree of success, by so handling the cream in its production and the butter in its manufacture and storage, as to minimize, if not eliminate entirely, the agencies which are known to contribute towards the appearance of rancid flavor and odor in butter. Attention to the following points will assist towards the prevention of rancidity in butter.

Prevention of Rancid Flavor.—1. Elimination of bacteria and mold from butter. The fresher and sweeter the cream and the greater its freedom from objectionable bacteria and mold and from their products, and the freer the butter from curd, the better will such butter withstand decomposition which results in rancidity.

2. Proper pasteurization of the cream and thorough washing of the butter with pure water greatly lessens the tendency of butter to become rancid. Pasteurization destroys the germs capable of producing rancid butter. Thorough washing removes much of the curd and therefore reduces the necessary food available for rancidity-producing microorganisms. Farm-made butter usually develops rancid flavor and odor very rapidly, because it is made from raw cream teeming with germlife and usually contains excessive buttermilk. Storage butter made during a pasteurization experiment under the direction of the author[1] did not develop rancidity when made from pasteurized cream; raw cream butter when made from ungraded gathered cream almost invariably became rancid, while raw cream butter made from selected gathered cream did not show much rancidity in storage. This emphasizes both, the value of pasteurization and the importance of careful grading of cream. The housewife in many European countries, who purchases a year's supply of cooking butter (Schmelzbutter) melts and boils it until the curd, water and other non-fatty constituents have settled out and the fat has become clear. This fat is stored in a cool place (the cellar) in crocks, covered with parchment, and keeps almost indefinitely (until used up) without showing signs of rancidity. These illustrations emphasize that rancidity can be greatly delayed by removing germ life and the food on which microorganisms thrive. Efficient pasteurization, and thorough wash-

[1] Hunziker, Spitzer and Mills, Pasteurization of Sour, Farm-Skimmed Cream, Produce Bulletin 208, 1918.

ing of butter accomplish this to a large extent, provided that recontamination of cream and butter is avoided by sanitary conditions of vats, churns and packing equipment and proper treatment of tubs, cubes, liners and wrappers.

3. Protection of the butter against air, light and heat, and the absence in it of catalizers, such as metallic salts, high acid, or alkali, will minimize the action of rancidity-producing agencies which may be present in butter. Churn the cream at a low acidity, do not overneutralize and put the butter in the sealed package, and refrigerate it, as promptly as possible after manufacture.

Woody Flavor.—This is not a very common flavor defect of butter, though "epidemics" of woody-flavored butter have occurred, causing serious objection on the market.

The most common cause of butter with a woody flavor is probably the churn. New churns that have not been properly treated before use, may impart to butter a woody flavor. Churns also that are in unclean condition, or the wood of which has become decayed, may become infested with certain species of microorganisms, especially molds, that are capable of giving the butter a woody taste. Such conditions are especially liable to happen with churns that are not in daily use, giving the microorganisms an opportunity to work into the cracks between the staves and also into the pores of the wood, where they are difficult to be reached, dislodged or destroyed, and where they form a continuous source of contamination of succeeding batches of cream and butter. A case of this type, resulting in woody-flavored butter, was noted and investigated at Purdue University[1]. The churn that produced the woody flavor was used only once per week. Investigation showed that the woody flavor was due to a mold lodged in the cracks of an apparently clean churn. This mold produced the same intense woody flavor when inoculated and propagated in sterile milk. For treatment and disinfection of churns see "Preparation of Churn," Chapter X.

Salt, packed in barrels of decayed and infected wood, is also known to be capable of transmitting to butter a woody flavor.

[1] Hunziker and Switzer. Results not published, 1916.

Butter packages, such as tubs, cubes and cartons made of wood which naturally harbors an intensive woody odor, always lend butter a woody flavor. Hence, pine tubs, boxes and cartons are entirely unsuited for packing butter, while spruce, white ash, hemlock, etc., well cured and dried and when properly soaked before use, are generally free from this objection.

However, even spruce and white ash tubs may give butter in storage a pronounced woody flavor. In such cases the woodiness is usually confined to the surface of the butter at the bottom and side, the interior remaining free from it. The flavor at or near the outside, however, is frequently intensely woody and pound prints cut from the outer portions of such butter may be practically ruined from the standpoint of the market.

When butter is stored in tubs made from well seasoned, sound lumber of white ash or spruce, and when they are properly treated before packing, the danger from woodiness is very remote. But when the tubs are made up of a poor grade of lumber, and especially of pithy staves, or lumber that is green and has not been well seasoned and dried, or lumber felled while still in sap, the woody odor is very intense and there is great danger of woody flavor in butter.

This danger can be minimized, if not entirely overcome, by soaking the tubs over night in brine, preferably hot brine, and by drying and heating them thoroughly over a steam jet before paraffining, so that the paraffine will soak well into the wood, forming a uniform and complete coating that will permanently stick and not peel off. For further directions see "Preparation of Butter Tubs," Chapter XII.

Cooked or Scorched Flavor.—As the name implies, this flavor is the result of exposure of the product to heat. It does not often appear in raw cream butter, but is a frequent defect of butter made from pasteurized cream. It is generally due to heating to excessively high temperature or to prolonged exposure to the heat, or improper application of the process of pasteurization. It is probably the direct cause of the action of heat on the caseous matter of the cream.

Most of the butter made from pasteurized cream has a slight pasteurized, or cooked flavor when fresh. This slight cooked flavor, however, disappears in a short time. Only a strong cooked flavor is permanent in butter and is therefore objectionable.

Crowding the pasteurizer and the consequent use of too much steam pressure is a common cause of cooked flavor. When pasteurizing under such conditions, the caseous matter in the cream that comes in direct contact with the overheated heating surface becomes scorched and bakes on to the heating surface. The scorching of the cream on the overheated coil of the pasteurizer is also very often the cause of the scorched flavor.

When butter made from raw cream has a cooked flavor, the cause usually lies in overheating the coil in the forewarmer, by forcing steam through it excessively. In this case the coil usually becomes heavily coated with a layer of burnt cream. It is advisable to heat the coil in the forewarmer with hot water instead of steam, in order to avoid the cooked flavor in butter.

The cooked flavor is occasionally confused with the oily flavor, which is also a frequent characteristic of butter made from improperly pasteurized cream, as explained under "Oily Flavor." The two flavor defects have nothing in common, neither in their origin, nor in their relation to the market value of the butter. The oily flavor is a serious butter defect which is generally indicative of poor keeping quality. The cooked flavor is not seriously objectionable, nor does its presence unfavorably reflect on the keeping quality of the butter.

Coarse Flavor.—This is a rather indefinite and general expression of butter flavor. It refers to butter that lacks the characteristic delicacy of flavor of good butter, though the butter may have no specific "off-flavor." Butter with a coarse flavor is usually the result of high acid cream, or overripened cream or overripened starter and excessive salt. The combination of high acid and high salt seems to be particularly favorable for the production of this so-called coarse flavor, and the presence of undissolved salt crystals further intensifies this defect.

Butter, the flavor of which is termed coarse, is generally not looked upon with favor on the open market. If it shows no other specific defect it usually grades as a poor "Firsts." Its keeping quality is considered questionable, if not unreliable.

DEFECTS IN BODY AND TEXTURE.

Properly made butter has a firm body and a waxy texture. The body and texture of the butter are controlled by the character of the butter fat and the churning temperature primarily, and by the conditions incident to the churning, washing, salting and working of the butter. The character of the butter fat is largely determined by its chemical composition and the size of the fat globules, factors which in turn are controlled by breed, period of lactation and feed of the cows, as explained fully in the chapter on the "Conditions which Affect the Churnability of Cream," Chapter X.

Weak-Bodied Butter.—Such butter lacks a firm, solid body that will stand up well under unfavorable temperature conditions. It softens quickly upon exposure to temperatures of about 65° F. and above. It also is prone to show excessive leakiness. Butter with a weak body is usually the result of too high a churning temperature, or not holding the cream at the churning temperature long enough before churning. It may be due also to overworking, especially when excessively soft.

The fundamental cause of a weak body generally lies in the fact that the cream from which the weak-bodied butter is made was never sufficiently cooled to adequately chill and harden all the butterfat, especially those fats that have a relatively low solidifying point. The butter from such cream then contains a mixture of fats, all of which have not been congealed and some of which are still in a liquid or semi-liquid state. Under these conditions the mixed fat, representing the butter, lacks firmness, it is "weak," and its mechanical stability readily collapses when the butter is exposed to room temperature, or to higher temperatures, though these temperatures may be considerably below the melting point (90—99° F.) of mixed butterfat.

For the same reason a weak bodied butter results when the cream, though it may have been cooled to the proper temperature, is not held at that temperature long enough to enable the fat to actually partake of the low temperature.

The defect is further intensified when this weak-bodied butter is excessively worked in this soft condition.

The proper temperature to which cream must be cooled, in order to prevent the weak body varies considerably with such factors as breed of cows, period of lactation and feed; the relation of these factors to the churning temperature and to the firmness of the butter is fully explained in Chapter X "Churning."

For the assistance of the buttermaker the prevention of weak-bodied butter may best be summarized as follows:

1. Thoroughly chill the cream and hold it at the low temperature not less than two to three hours before churning.

2. Do not guess at the churning temperature but determine it accurately with a correct thermometer.

3. When deciding what the churning temperature should be, be guided by the firmness or softness of the previous churning and by the time required to complete the churning process.

4. Other conditions being the same, have the cream at that churning temperature at which the butter will break in about 40 to 50 minutes.

5. Butter that breaks in 20 to 25 minutes is prone to have a weak body. The cream from which it was made either was not cooled low enough or not held long enough at the low temperature.

6. Cool the cream, according to conditions, to temperatures within the range of about 45° to 53° F. in summer and about 54° to 60° F. in winter. This refers to cream churned in the middle western states.

7. In case the butter comes exceedingly soft, let it rest, in granular condition, in cold water or ice water until it has hardened, so it can be handled and worked without serious danger of becoming greasy.

8. Do not overwork soft butter.

9. Points 7 and 8 do not prevent weak body, at this stage the weak body is already an accomplished fact. But they may help to minimize the unfavorable consequences of the defect.

Greasy Body.—Butter becomes greasy when worked excessively while in very soft condition, due either to too high churning temperature of the cream, too rich cream, or holding the butter in the churn too long before working, allowing it to warm up, or working it on a table worker in a warm room. Greasiness can be avoided by so governing the churning temperature, the period of holding the cream at that temperature and the temperature of the wash water, as to make the butter have a firm body when it is worked. The butter should be churned to small granules and preferably washed with water a few degrees colder than the temperature of the buttermilk.

The danger of greasiness is especially great when churning cream rich in fat, such as cream testing 35 per cent. fat or over. Thin cream may be churned at considerably higher temperatures without danger of yielding a greasy butter, than rich cream. Rich cream should be churned at a relatively low temperature and should be held at that temperature at least three hours before the churning process commences.

Greasiness may be due also to allowing the butter to become very soft before it is worked as frequently happens in summer in a warm churn room where the butter is held unduly long in the churn or is worked on an open worker. For the above reasons greasiness is a very common defect of farm dairy butter, where facilities for cooling the cream and for working the butter in a cool room are usually lacking during the summer season.

Salvy Body.—Salvy butter is butter in which the grain has been destroyed to the extent to where the granules have completely lost their identity. This defect is prone to appear in butter that is overworked when in a very firm condition, especially when the working is done in the absence of water. In exceptional cases the salvy body is due to conditions independent of the working process, and may occur as the result of abnormal churning conditions. In winter when, owing to the advanced stage of the period of lactation of the great majority of the cows, and also owing to the character of the feed ration, the cream is very viscous and contains relatively small fat globules, the cream churns with difficulty. If this cream happens to be very thin and has been exposed for a long time to a low temperature, as is frequently the case with hand separator cream, the solidification of the fat globules may have reached such a stage that these globules are so firm that they coalesce with great difficulty. This prolongs the churning process and frequently from one to three hours are required to make the butter "break" and to form large enough granules for convenient handling. This abnormally prolonged agitation causes these firm globules and small firm granules to grind against each other and to strike the sides of the churn until they completely lose their identity, destroying the grain and giving the butter a salvy body and texture. Such butter is also prone to be abnormally high in moisture. A raise in the churning temperature of cream of this character sufficient to make the butter come reasonably soft, will shorten the time required for churning and avoid the production of butter that is salvy.

Crumbly Body.—The brittle and crumbly texture of butter is characteristic of butter made in late fall, winter and early spring. Most creameries are troubled with this defect to some extent during the winter season. While its consequences are not fatal, the buyer demands a waxy body that permits of drawing a smooth plug with the trier and the consumer criticises butter that refuses to spread on account of its brittleness. The hotel and restaurant trade particularly objects to crumbly butter, because they find it very difficult to cut it into neat slabs and cubes ready for the table. Crumbly butter refuses to respond to knife or wire. On a weak market, crumbly butter often sells at a sacrifice.

Causes of Crumbly Body.—There are two fundamental causes of crumbly butter, neither of which is under the control of the butter maker, namely, the cow and the feed. In winter the great majority of the cows are well advanced in their period of lactation. Cream from stripper cows contains predominatingly very minute fat globules. The small fat globules do not bind together readily when the cream churns, they are firm and persist in retaining their individuality. They do not yield so readily to the forces which overcome the surface tension. They remain intact and are prone to form small, smooth-surface, round, firm, shot-like granules, which do not pack readily and which lend the butter a short-grain and loose body of considerable firmness. This fact was conclusively demonstrated by the author[1] in experiments to determine the effect of the size of the fat globules on the moisture content of butter. In these experiments milk was separated in such a manner, as to produce

[1] Hunziker, Mills and Spitzer, "Moisture Control of Butter." I. Factors not under Control of the Buttermaker. Purdue Bulletin 159, 1912.

churnings of cream in which the small globules, and churnings in which the large globules, respectively, predominated. The large-globule cream churned quickly and yielded a soft, pliable butter that packed readily. The small-globule cream, on the other hand, churned slowly, produced small, round, smooth and hard granules which did not pack readily and which made a very firm, crumbly and brittle butter, from which it was impossible to draw a solid plug.

The second fundamental cause of the tendency of winter butter to be crumbly lies in the feed the cows receive during the winter season. Dry feed and most of the common concentrates always increase the firmness of butter. If the winter ration contains hay or corn fodder and liberal quantities of such concentrates as cottonseed meal, bran, etc., the butter fat in the cream will contain a relatively small percentage of the fats with low melting point, such as olein, and a relatively high percentage of the fats with high melting point, such as stearin, palmitin, myristin, etc., and the resulting butter will, therefore, be firm and tend to be crumbly. Potatoes, beets and beet tops, apples and cornsilage also produce high melting fats conducive of firm and crumbly butter.

Prevention of Crumbly Body.—It is obvious from the above discussion that the fundamental causes of crumbly butter may be eliminated entirely by a change to winter dairying whereby the cows are so bred that most of them freshen in the fall, yielding milk in which the large globules predominate; and by the addition to the feed ration of such feeds as have a tendency to produce butter fat of a lower melting point, such as linseed meal, glutenfeed, etc.

The dairy man who makes butter on the farm has the factors of period of lactation and feed largely under his control and, therefore, is in a position to avoid crumbly butter by the intelligent adjustment of these factors. The average creamery which draws its cream supply from a large number of farms which are often scattered over a wide area, cannot hope for relief from crumbly butter by any efforts to remove these fundamental causes, and must, therefore, aim to minimize their effect by modifications in the process of manufacture.

The only means available to the creamery to prevent crumbly butter is to churn, wash and work at temperatures sufficiently high to secure a reasonably soft butter that binds and compacts readily and makes the butter pliable. Churn at a temperature that will insure the formation of moderately soft, flaky granules, instead of small, round, hard granules, then wash the butter with wash water of the same temperature as that of the buttermilk, or possibly a degree or two higher, especially in a cold churn room, and work it sufficiently to secure a waxy, tough texture.

The crumbly body of butter is frequently also attributed to frozen cream. There is no evidence on record that the freezing of cream has any appreciable influence on the body of the butter, but it is quite possible, that improper methods of thawing of frozen cream, causing it to "oil off," may intensify the tendency of winter butter to be crumbly. See also Chapter VI on the "Handling of Frozen Cream."

Faulty pasteurization, in which the cream is permitted to "oil off," as may be caused by the use of excessively high temperatures, or by allowing the cream, while hot, to lie in the vat undisturbed and without agitation, will intensify the crumbly butter defect for the same reason as is the case with faulty handling of frozen cream.

The crumbliness of brittle butter is augmented by exposure of such butter to very low temperatures. Butter that is inclined toward brittleness and that is intended for the critical hotel trade, should, therefore, be held in a room at a moderate temperature, so that, at the time of delivery, it is not excessively firm and will lend itself more readily to the slab cutter. Such hotels might also advantageously be cautioned not to expose this butter to abnormally low temperatures before cutting.[1]

Mealy Body.—Mealy butter is butter that lacks the smooth, velvety texture of well-made butter. It is a defect that is criticized by the buyer, and when the mealiness is very pronounced, it is seriously objected to.

Causes of Mealy Body.—In the great majority of cases mealy butter is due to a hardened condition of the particles of casein, resulting from excessive exposure to heat in the presence of high acid, as is the case when heating sour cream to too

[1] It is advisable to work butter that is inclined to be crumbly very thoroughly, even to the extent of slight overworking.

high a temperature, heating too slowly, holding at pasteurizing temperature too long, or not cooling rapidly enough.

The acid in sour cream changes the casein to casein lactate, and precipitates it into very fine flakes, or particles of curd. Van Slyke and Hart[1] found that the casein is changed to casein lactate, when the amount of lactic acid in cream exceeds .5 per cent. In sweet cream the casein is largely in the form of calcium casein and some free casein.

When this sour cream is heated for a prolonged period of time, as is often the case in the holding process of pasteurization, these particles of curd contract, expel much of their moisture, become firm and dry and give both the cream and the resulting butter a mealy texture. The mealiness is noticeable in the hot cream, and in the cream after cooling, quite as much as in the butter. Mealy cream always makes a mealy butter.

Mealiness of this type does not occur in sweet or slightly sour cream, because in such cream the casein is present in its original and unchanged form. It has not been acted upon by the acid, it has not been precipitated. However, acid alone does not make cream and butter mealy. The particles of curd in the raw sour cream are soft. It is only in the presence of very high heat or upon prolonged exposure to heat, that sour cream becomes mealy and makes mealy butter.

Mealiness resulting from the above causes can be avoided by shortening the time required to heat the cream to the pasteurizing temperature, by not exceeding 145° F. in the holding process, by holding for 30 minutes only and by cooling rapidly. Under proper conditions, such as adequate steam supply, ample size of steam and water pipes leading to the vat pasteurizer and adequate heating surface, the heating to 145° F. can usually be done in about 15 minutes. Experience has shown that, where the temperature can be raised to 145° F. in 15 minutes, there is very little danger of the cream and butter becoming mealy. If the time required to heat to 145° F. exceeds 30 minutes it is more difficult, and under certain conditions impossible, to avoid mealiness.

Mealy butter is also almost invariably produced from sour

[1] Van Slyke & Hart, "The Proteids of Butter in Relation to Mottled Butter," New York State (Geneva) Agr. Expt. Station Bull. 263, 1905.

cream that is aerated by blowing cold air through it, while the cream is being heated. This is largely due to the longer time required for raising the temperature to 145° F. The blowing of the cream with cold air, as ordinarily practiced in our creameries, prolongs the period of heating from 10 to 15 minutes, which is sufficient to excessively harden the particles of curd and to make cream and butter mealy, when the condition of the cream is such as to favor mealiness.

When persistent trouble from mealiness is experienced and when it is desired to blow the cream, the danger from mealiness may best be avoided by blowing the cream while cold, or with hot air after the temperature of 145° F. has been reached. Blowing the cold cream, however, is less effective from the standpoint of the purpose for which the blowing is done, i. e., to remove objectionable flavors and odors. The volatile substances responsible for these flavors and odors are expelled more readily from hot cream than from cold cream.

The reduction of the acid in the cream by neutralization does not prevent mealiness. In fact practical experience has demonstrated that the excessive use of lime hydrate in sour cream tends to intensify rather than minimize mealiness.

A further cause of mealiness of this type lies in the improper use of lime in the process of neutralization. When neutralization is done in an approved manner and as directed in Chapter VII, the danger of mealiness is removed.

Another type of mealiness of butter is that which is due to a peculiar granular condition of the butterfat, similar to that of renovated butter. In this case the mealy body of the butter is not due to the grainy condition of the cream, but to granulated fat. This type of mealiness is not confined to butter made from sour pasteurized cream, it may occur as well in sweet cream butter. It appears whenever the cream is subjected to conditions that will cause it to "oil off." When this cream with the "oiled-off" or "run-together" butter oil is subsequently cooled and the fat hardens, the fat granulates and refuses to return to its original mechanical condition, and the granulated fat gives the butter a mealy consistency.

This species of mealiness does not appear in the cream while hot; it becomes noticeable only after cooling and in the finished butter. It is caused either by faulty pasteurization or by improper handling of frozen cream.

If, during the process of pasteurization the hot cream is allowed to repose in a vat without agitation, as may be the case with flash pasteurized cream that is not run over a continuous cooler, or with vat pasteurized cream with the coil at rest during the holding period, there is a tendency for the butter fat to run together, "oil-off" and gather in the form of butter oil on the surface of the cream. When the cream is subsequently cooled this butter oil crystallizes or granulates, giving the butter a mealy body. This can best be avoided by guarding against excessively high temperatures of pasteurization and by keeping the cream thoroughly agitated while hot and until it has been cooled to a temperature at which the butterfat congeals, i. e., about 70° F. or below.

The experience of many creameries has been that in winter, when some of the cream arrives at the factory in frozen condition, butter is prone to be mealy, and the mealy condition of such butter has therefore been attributed to frozen cream. A careful study by the author of this phenomenon has shown that frozen cream, as such, does not produce mealiness, but that frozen cream may and does become the cause of mealiness indirectly by improper handling of this cream.

For further details see Chapter IV "Receiving Milk and Cream."

Finally, experience has shown that mealiness resulting from either of the two fundamental causes, the curd precipitation and the "oiling-off" of the fat, is characteristic more especially of the use of the holding process of pasteurization than the flash process. In the flash process the cream is heated and cooled quickly, not giving the particles of curd sufficient time to contract and harden excessively, and the cream is subjected to continuous agitation until it is cooled, thus largely preventing the "oiling-off" of the fat. Butter resulting from the flash process usually has a clearer and smoother body and is more completely free from mealiness than butter made from cream pasteurized by the holding process.

Summary of Prevention of Mealiness.—In brief, then, the mealy body of butter can be avoided by:

1. So regulating the temperature of pasteurization and the period of exposure to pasteurizing temperature, as to avoid the excessive contraction of the curd in the sour cream. Heat rapidly, do not exceed 145° F. in the case of the holding process, limit the time of holding to 30 minutes and cool rapidly. Do not blow the cream.

2. Preventing the cream from "oiling-off." Keep the coil in the vat revolving during heating, holding, and until the cream is cooled to 70° F. or below.

Do not heat the frozen cream to a temperature higher than 95° F. and hold it at that temperature until it has become fluid.

Leaky Body.—This defect is characteristic of salted butter only. Unsalted butter seldom, if ever, shows real leakiness. In leaky butter much of the water present is incompletely incorporated in the fat and oozes out profusely when such butter is handled, cut, packed, shipped and stored. When bored with the trier, brine runs freely from the plug, and when the plug is squeezed, there is further escape of moisture.

Leaky butter, owing to the ready escape of moisture, generally suffers excessive loss in weight between the churn and the market, as well as in storage. Leaky butter usually also has an objectionable briny flavor suggesting excessively high salt content, although the actual percentage of salt it contains may not be high and may even be below the average. The briny flavor in this case is due to the direct appeal to the palate of free brine. For these several reasons leaky butter is not looked upon with favor by the buyer.

Causes of Leaky Butter.—Because the leaky body is largely confined to salted butter only, this defect has been attributed to faulty methods of salting and working, and the popular impression prevails that such is the case. Within relatively narrow limitations leakiness may be intensified or minimized by the processes of washing, salting and working, but the fundamental cause of leakiness lies prior to these processes, it has to do with the treatment the cream receives preparatory to the churning process.

Leakiness is due to incompleteness and consequent instability of the emulsion of buttermilk (or water) in fat, and this emulsion occurs during the churning process. The completeness and permanency of the water-in-fat emulsion is dependent on the relative mechanical firmness of the fat at the time of churning.

If the butterfat in the cream in the churn has previously been thoroughly chilled by cooling to, or below, the proper churning temperature and by holding it at that temperature for the necessary length of time, leaky butter is not likely to result. Butterfat in this condition yields an emulsion of water-in-fat that is relatively stable. The finely divided water droplets are firmly held in this compact fat.

When salt is added to and worked into butter made from incompletely chilled cream, the loosely held emulsion of water-in-fat is disturbed and partly broken. The emulsion yields to the salting-out process. The water droplets are not firmly enough locked up in the body of the butter to resist the attraction of the salt. The salt draws them together into drops and larger aggregates, which leak freely from the butter.

Even when efforts are made on the part of the buttermaker to harden this butter in the churn, either by churning the cream with ice or by holding the butter for a considerable length of time in ice water, a really good body can not be recovered. The defect may be somewhat minimized by these remedial practices but the damage has already been done, and the butter will have a distinctly weak body that will not stand up well under adverse temperature conditions, and that is prone to be leaky.

If cream has been cooled to a point where the fat becomes thoroughly chilled, as it should be, churning at a temperature slightly too high does not produce leakiness, the fat is still of good firmness, because it does not respond to temperature changes rapidly, being a poor conductor of heat and cold.

This leaky butter defect appears largely, though not wholly, only in the spring and early summer. This is the time when, due to the freshening of the cows and the change from dry feed to succulent pasture, the melting and solidifying points of the butterfat drop rapidly.

The average buttermaker fails to fully appreciate this rapid change in the character of the butterfat he receives in the spring, and he often does not respond quickly enough to this change with an adequate lowering of the churning temperature. Therefore the tendency of spring and early summer butter to be leaky. The incomplete chilling of the cream in early summer is in many cases the result of an insufficient supply of cooling medium and inadequate vat capacity to handle the great volume of cream that arrives during the flush.

Leaky butter may result at any other time of the year, whenever the temperature of the cream before churning is not low enough and the period of holding at this temperature is not long enough to thoroughly chill the fat.

Rich cream is more apt to make a leaky body than thin cream, unless the rich cream is churned at a lower temperature. If the cream of different churnings varies in per cent fat considerably, it is more difficult to have successive churnings of butter of good body and free from leakiness. The standardization of each churning for fat greatly assists the buttermaker in his efforts to produce a perfect body, with reasonable regularity.

The tendency toward leakiness is intensified also by any agency that is prone to mutilate or tear apart the body of the butter. Churns that tear the butter during the working process are more apt to yield a leaky butter than churns, the workers of which squeeze it. The tearing and chopping of the butter during the working disturb the texture and tend to liberate some of the otherwise firmly held water droplets.

Summary on Prevention of Leaky Butter.—When the buttermaker is troubled with leaky butter he should pay attention to the following phases of manufacture:

1. Standardize each churning to a uniform percentage of fat, preferably between 30 and 33 per cent.

2. Thoroughly chill the fat in the cream by cooling the cream to a temperature low enough and holding it at this temperature long enough to secure firm butter granules. Unless cooling facilities permit the cooling of the cream to far below the desired churning temperature, the cream should be held at the temperature cooled to for not less than two hours, and preferably three hours.

3. Work the butter until visible water pockets have disappeared and the butter has a compact, solid, tough, waxy body.

This is possible only with butter made from cream that has been thoroughly chilled before churning.

Gritty Body.—This defect is due to the presence in butter of undissolved salt crystals. Grittiness is highly objectionable to the consumer, it conveys the impression of excessive salt, and gives the butter a seemingly strong salty and coarse flavor. In properly salted butter all the salt is present in complete solution. The more complete the solution and distribution of the salt, the more salt butter will stand without tasting objectionably salty.

The usual factors which enter into the presence or absence of grittiness of butter are, moisture content, temperature of butter, amount of working, amount and temperature of salt added and size and shape of salt crystals.

As shown in "Composition of Butter," Chapter XVIII, 100 pounds of water at ordinary temperature is capable of dissolving and holding in solution 35.94 pounds of salt, so that, theoretically, butter containing say 15 per cent moisture is capable of holding in solution $\frac{15 \times 35.94}{100} = 5.39$ per cent salt. Owing to the very fine division of a part of the moisture in butter, the salt added to butter is incapable of gaining access to and of utilizing all the moisture present in butter during the brief time during which butter is worked. In reality, butter containing 16 per cent moisture, makes possible the complete solution of not to exceed about 4.5 to 5 per cent of salt, although this same amount of water, if freed from the other butter constitutents is, in fact, capable of dissolving salt equivalent to a salt content in butter, of 5.75 per cent. Butter containing more than this amount of salt, therefore, is prone to be gritty. All conditions which tend towards a low moisture content invite the production of gritty butter, unless the amount of salt added is reduced correspondingly.

Insufficient working of the butter is another very common cause of gritty butter. When butter is of normal texture it should be worked until the salt is dissolved and all signs of grittiness have disappeared.

Finally the size and shape of the salt crystals may become responsible for grittiness. The use of very coarse salt and especially if such crystals are of cube shape, retards solution, while reasonably fine crystals enhance solution. Too fine salt also is undesirable because it tends to paste and cake in the butter and thereby hinders ready solution and even distribution. Salt of the proper degree of fineness will pass through a sieve with 28 to 30 meshes to the inch.

DEFECTS IN COLOR.

As previously stated, the color of butter must be of the intensity desired by the market where it is sold.

According to Palmer[1] the natural yellow color of cream and butter is derived from two classes of yellow pigment, the carotin and xanthophyll, which accompany the green chlorophyll of plants. These yellow pigments, particularly the carotin, are found in the blood of the cow and it is in this way the carotin passes from the feed to the milk gland where it associates itself with the milkfat. Palmer classifies the following feeds with reference to their carotin content and consequent property to make yellow cream and butter as shown below. This classification explains why cows fed on green pasture, as is the case in early summer, produce a deep yellow butter, while in winter

High Color
Carotin-Rich Feeds.

- Green pasture grass, especially when fresh in the spring or fall.
- Hay, cured with a large part of its original green color, such as most western-cured alfalfa hay.
- All soiling crops.
- Green corn fodder.
- Very new corn silage.
- Carrots, and other yellow roots and tubers.

Low Color
Carotin-Poor Feeds.

- All hay that has lost its green color in curing, such as most timothy and clover hay.
- Dry corn fodder (corn stover).
- All corn silage, except when very new.
- Straw, all kinds.
- Corn, both yellow and white.
- Wheat.
- All so-called mill by-products, such as wheat bran, brewers' grains, cottonseed meal, linseed meal, natural gluten-feed, etc.

[1] Palmer—The Yellow Color in Cream and Butter. Missouri Circular 74, 1915.

when they receive largely dry fodder and grain by-products, the butter has a very light yellow and often an almost white color.

It is well known that the Channel Island breeds, the Jersey and Guernsey, are capable of yielding a much more yellow butter than the Holsteins and Ayrshires. This is explained by Palmer to be due largely to the fact that some breeds (Jerseys and Guernseys) make use of more feed carotin than others (Holsteins and Ayrshires).

It is also a matter of common knowledge that the natural color of butter varies with the period of lactation. Palmer states that no breed difference in color exists immediately after parturition, the colostrum milk of all cows being very highly colored due to a relatively large amount of carotin in the milk-fat. As the period of lactation advances the intensity of the color decreases. In the case of the Jerseys and Guernseys the color does not diminish as rapidly and not to so great a degree as in the case of the Holsteins and Ayrshires, so that even in winter when most of the cows approach the end of the period of lactation and when the carotin content of the feed ration is low, the Channel Island breeds are still producing a light yellow butter, while the butter of the Holsteins and Ayrshires is almost white. This is explained to be due to the fact that the Channel Island breeds are storing up a reserve of carotin in their body fat in summer when the succulent pasture supplies them with an abundance of carotin and on which they draw in fall and winter when the feed is largely devoid of this coloring pigment, while the Holsteins and Ayrshires are unable to do this to the same extent.

In order to satisfy the demand of the butter market and to maintain uniformity of color at a time of the year when, especially in Holstein and Ayrshire localities, the natural color of butter is practically white, artificial butter color is added.

Too High Color.—As previously stated the trend of the best butter trade is toward a light, straw-colored butter. In these markets, therefore, butter with a deep golden yellow color is not desired. While, in winter, when the natural color of butter is very light, the buttermaker is in a position to meet these demands by modifying the amount of artificial color added, in early summer, when most of the cows freshen and have access to green pasture, the butter is often so intensely yellow, without any addition of artificial butter color, that it is criticized as being too high in color. This is especially true with butter produced in localities where the Jerseys and Guernseys predominate.

In the great majority of complaints by the trade, too high color is due to carelessness or accident on the part of the buttermaker. In this case it is caused either by incorrect calculation of the amount of butterfat in the churning on which he bases the amount of artificial butter color to add, or careless measuring of the butter color, or not modifying the proportion of butter color used in accordance with a sudden change in the natural color of the cream, especially in the spring of the year, or a change to a new brand of stronger butter color, or butter color from the bottom of the drum which may contain an accumulation or concentration of the coloring principle due to settling.

The prevention of these difficulties is obvious. The buttermaker should constantly bear in mind that the trade objects to uneven and excessive coloring in butter and that it expresses its objection in discounting the value of the butter to the detriment of the net returns to the creamery. It does not pay to overcolor butter.

Too Light Color.—This is a shortcoming for which butter is seldom criticized and only in very isolated markets which insist on a high-colored butter throughout the year. The excessively light color is usually due to the season of the year and occurs only during the winter months when the cows are receiving dry feed only and no artificial butter color is added to the cream. It can readily be remedied by the addition of the proper amount of artificial butter color.

In some instances the lack of yellowness may be due to the bleaching of the color of the butter after the butter is made and packed.

This is usually due to an oxidizing action taking place in the butter, either on the butterfat itself or on other ingredients which butter may contain. See "Tallowy Butter."

The bleaching of butter may also be the result of holding butter in water. In hotels and restaurants where the butter is cut into small slabs for table use, these slabs are generally dropped from the butter cutter into ice water. In the case of salted butter, if these slabs are permitted to remain in this water for any considerable length of time, portions of the surface begin to bleach, giving the butter a mottled appearance. Continued exposure will bleach the entire surface, the mottles become very indistinct, but the color on the surface of the slabs is much lighter.

This type of bleaching can be readily and entirely avoided, as demonstrated by the work of Hunziker[1], by dropping the slabs of salted butter into a solution of 25 per cent brine instead of water. In this case there is but one kind of liquid present and that is brine, brine in the butter and brine surrounding it, no interchange of liquids takes place and there is no bleaching.

If the slabs consist of unsalted butter they do not bleach when dropped into water, because here again there is but one liquid and that is water, water in the butter and water surrounding it, there is no cause for interchange of liquids and there is no change in the color of the slabs. See also "Mottled Butter."

Excessive working of salted butter also has a marked whitening effect on the butter. This is due to the fact that in normally-worked butter the average size of the water droplets is relatively large and this lends the salted butter a relatively clear, deep yellow color. Overworking causes a finer division of these water droplets and this in turn produces a lighter and more opaque appearance, more nearly like that of unsalted butter, in which the water droplets always average much smaller in size.

Dull Color.—Much of the butter made in some creameries has a dull and lifeless color. This is usually the result of attempts to incorporate a high per cent of moisture, and overworking. When, in an effort to incorporate moisture, the butter is overworked to the extent to where the grain of the butter is destroyed, the fat granules lose their bright lustre. The large amount of moisture held by the fat in very minute droplets and very complete emulsion, together with the very fine division of the air in the butter, also resulting from overworking, hides the

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[1] Hunziker—Defects in the Coloring of Butter. Address American Association of Creamery Butter Manufacturers, Chicago, February 18, 1919.

bright yellow color and gives the butter a dull and lifeless appearance.

It is obvious that this defect can readily be avoided by incorporating a normal amount of moisture and not overworking the butter. The difficulty of incorporating the desired amount of moisture in butter that is naturally very firm and dry, and does not readily take up and hold moisture, in order to secure a reasonable overrun, may best be overcome by raising the churning temperature sufficiently to give the butter a somewhat less firm body.

Mottled and Wavy Butter. General Description.—Unevenness in the color of butter is shown in the butter in the form of streaks, waves and mottles. Streakiness or waviness refers to butter in which the unevenness in color shows in the form of layers or waves of different shades of yellow, the color in the layer or wave itself, however, may be perfectly uniform. In the case of mottles the butter is dappled with spots of lighter and deeper shades of yellow throughout its body.

Unevenness in color, and especially mottles, in butter, are a serious defect from the standpoint of its market value. This defect has nothing to do with the quality of the butter, mottled butter is just as good and just as wholesome as butter that is not mottled. But while the criticism of the trade is a superficial one, the objection is no less real. Butter that is otherwise perfect and might score a good "Extras," if it is mottled, clears as a "Seconds" and is sold on that basis by the dealer.

Causes and Prevention of Mottles.—Extensive experiments by Hunziker and Homan[1] have shown that the causes of mottles are due to the following factors:

1. Mottles are caused by an uneven distribution of the water droplets in butter.

2. The white, opaque dapples in mottled butter are caused by the presence, or localization of innumerable very small water droplets. The small size, high curvature and large number of these droplets bend, refract and deflect the rays of light to such an extent that they render the butter opaque and give it a whitish appearance.[2]

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[1] Hunziker & Hosman. A Study of the Causes of Mottles in Butter. Blue Valley Research Lab., Chicago 1918 and 1919. Journal Dairy Science, Vol. III, No. 2, 1920.

[2] The opacity is further intensified by the difference in the refractive index between butterfat and water.

3. The clearer and deeper yellow blotches in mottled butter are caused by absence, or the relatively small number of the very small droplets or by the presence of a larger number of large droplets, or both. Both, the absence of any water droplets and the presence of relatively large droplets and aggregates of drops, minimize the refraction and deflection of the rays of light, permitting the rays to enter sufficiently to give the butter a clearer and more translucent body and revealing more of the natural golden yellow color characteristic of butterfat.

4. The reason why unsalted butter always has an opaque whitish color, and never is mottled, lies in the fact that in unsalted butter, regardless of the amount of working, the water is always present in the form of exceedingly minute and innumerable water droplets of uniform size and distribution, giving the entire body of butter a uniform opaque whitish appearance. The permanency of this uniform white appearance is due to the absence in unsalted butter of agents capable of breaking this fine emulsion of water-in-fat.

5. The reason why salted butter always has a clearer and deeper yellow color than unsalted butter, lies in the fact that the salt, due to its action on the curd and to its great affinity for water, draws the more loosely held small droplets together into larger aggregates, it makes the emulsion of water-in-fat less complete, it diminishes the refraction and deflection of the rays of light and makes the butter more translucent.

6. Salted butter at the churn is never mottled, because, even in insufficiently worked butter the distribution of the large droplets at the conclusion of the working process is sufficiently complete to hide the localized sections of the very minute droplets.

7. Salted butter, when insufficiently or unevenly worked, invariably becomes mottled upon standing, because in such butter the fusion and the emulsification of brine and water are incomplete. Owing to the difference in concentration, and to osmosis between brine and water, interchange and migration of brine and water takes place in the butter at rest. This causes the more loosely held, larger water droplets to run together into larger aggregates and the portions of butter containing these fewer but larger droplets show themselves as and represent the clearer, more translucent and deeper yellow blotches of mottled butter.

Size of Water Droplets in Light and Dark Portions of Mottled Butter.

Magnified 740 times.

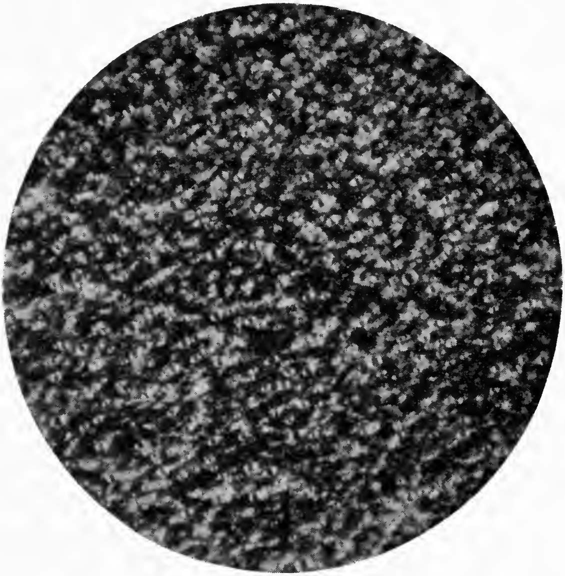

Fig. 81. Light portions

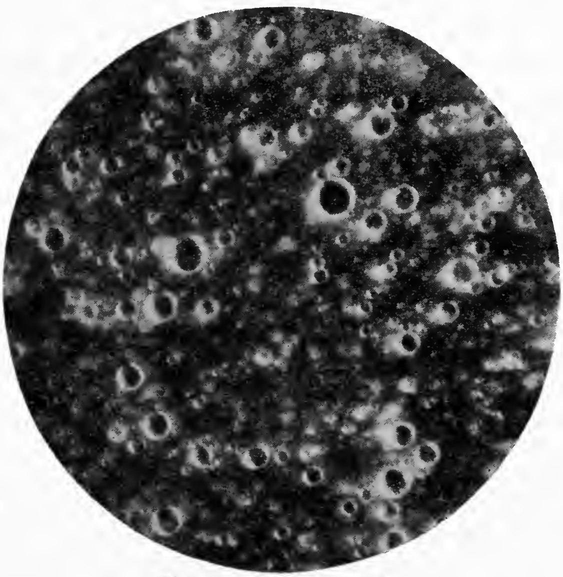

Fig. 82. Dark portions

The running-together of the larger droplets simultaneously also uncovers the localized sections of innumerable very small droplets which, at the conclusion of the working process, were hidden by the larger droplets. And the appearance of these aggregates of very small droplets brings to view the opaque, dense, whitish dapples of mottled butter.

8. The reason why salted butter, when sufficiently and evenly worked, does not show mottles upon standing lies in the fact, that in such butter the large droplets resulting from the action of the salt, have been redivided and remulsified in the butter and the fusion of brine and water has become relatively complete. Hence there is practically only one kind of liquid in this butter and that is brine. There is no difference in concentration, there is no cause for osmosis, and there is no interchange and migration of liquids. And the permanency of the emulsion is further strengthened by the more minute division of the droplets in properly and evenly worked butter.

9. Streaky or wavy butter is caused by uneven working of different portions of butter of one and the same churning, either due to a faulty condition of the workers or an overloaded churn. Those portions of the churning which receive the most working have the lightest color, because the more the butter is worked, the smaller become the water droplets and the smaller the water droplets, the more opaque and the whiter is the butter.

10. Streaky or wavy butter may also result when the distribution of the salt over the entire length of the churn is very uneven. In this case the butter that received the most salt will have larger water droplets and will therefore have a clearer, more translucent and more yellow color than that part of the butter that received the least amount of salt.

Practical directions for the prevention of waves and mottles in butter: 1. **Keep churn and workers constantly in good mechanical repair.**—Make sure that the workers are correctly set, properly adjusted and that they are free from slack and do not slip.

The distance between workers, in the case of churns with two or more workers, and between worker and shelf in the one-worker churn, should be the same over the entire length of the churn. Uneven distance causes uneven working. An uneven distance between workers is due to the fact that either one or more of the workers are crooked, the worker shafts are out of line, the shaft has worn a large hole in the end of the worker, the bearings in which the worker shafts run are worn, the worker shafts themselves are worn, the distance between centers of the worker shaft bearings in one end of the churn is not the same as that in the other end of the churn, the periphery of the workers has become badly damaged in places, or the shelves are not of the same width over their whole length, do not lie straight, have become damaged, or are loose and wobbly.

In churns with more than one worker, the workers must be so set that, when in operation, the ridges of one worker meet the grooves of the opposite worker. If they are so set that ridges meet ridges and grooves meet grooves, the working is very uneven, inviting mottles.

The workers must be taut, and free from excessive slack and from slipping. Slack and slipping workers won't stay set right and therefore cause uneven working and mottles. Slack and slipping is due either to the worker shafts having worn loose in the ends of the workers, the worker shafts slipping in the gear wheels due to a worn key or worn shaft, or to excessive wear of or damage to the cogs of the gear wheels.

The buttermaker who would make butter uniformly free from mottles and waviness must keep close watch of the mechanical condition of his churns and keep the churns and workers in a constant state of good mechanical repair.

2. **Do Not Overload the Workers.**—An overloaded churn needs more revolutions with the workers in gear than a churn not overloaded. But at best such working is prone to lack of uniformity. When the workers are overloaded all of the butter cannot go through the workers with each churn revolution. Some of the butter will fall off over the outside of the workers, and therefore fails to be worked, as fully explained in Chapter XI., "Working."

3. **The Butter must be worked sufficiently for complete solution of the salt and distribution of the brine.**—The process of working is the only means whereby the extraneous water and the brine can be evenly distributed throughout the mass of butter. If this complete solution of salt and distribution of brine is not accomplished during the process of working, it will never be accomplished, and such butter, upon standing, is bound to become mottled. It is only during the process of working that the brine is capable of pene-

trating the fine emulsion of the native water in butter, and that the brine itself is capable of becoming sufficiently fused with the water and emulsified with the protein and fat particles of the butter to preclude interchange of the brine and water after working.

If the salt crystals are not completely dissolved by the working process, the migration of the free liquid in the butter at rest, is intensified by the affinity of the salt for water and the dapples or mottles appear more quickly and more conspicuously.

Fig. 82A. Fissures in salted butter, showing migration of water
Magnified 110 times

So far as the process of working is concerned, therefore, in order to prevent mottles, the butter must be worked sufficiently to dissolve the salt completely, to cause a very thorough fusion of the brine and the water and to produce a sufficient emulsion of the brine, fat and protein of butter to hold it.

The degree of fineness of the salt, or the size of the salt crystals, influences its solubility. Too coarse salt requires more water and more time for the complete solution of each crystal. Too fine salt tends to cake or paste the crystals together, again hindering ready solution. See also Chapter XI., "Salting."

Briefly, then, mottles and waves can be prevented by the use of churns in which the workers and shelves are set correctly and are in perfect mechanical condition, by avoiding the overloading of the workers, by the proper use and even distribution in the churn of readily soluble salt, and by adjusting the working process according to the mechanical firmness of the butter in such a manner, as to insure complete solution of the salt, even distribution and complete fusion of brine and water and producing a butter in which the free brine and water have been sufficiently emulsified, to give the butter a close, tough, waxy texture, free from visible water pockets.

White Specks in Butter.—Butter occasionally is permeated with a multitude of small white specks. This condition is due to the incorporation of small pieces of coagulated casein. The defect is easily preventable and should not occur when proper attention is given to the handling of the starter and the cream. Its most common cause is overripe starter, overripe cream and cream that has been allowed to dry on the surface due to lack of stirring during the ripening process. If the starter is added before it is overripe and has formed a firm curd, or if the coagulum is thoroughly broken up by stirring or pouring and the starter is strained into the cream, if the cream is properly stirred during the ripening process so as to prevent its drying on the surface, if it is not overripened, and is strained into the churn, there is usually no danger of white specks in butter. Cream and starter should never be allowed to enter the churn unless they are run through a fine strainer.

The occasional appearance of white specks in butter may be due to the cream strainer in the churn becoming clogged and flowing over, or to emptying the accumulated material caught in the strainer, into the churn, either through accident or through ignorance.

Yellow Specks in Butter.—This is a very rare defect and yet occasionally it occurs and causes trouble. When these specks are of an orange shade, they are usually due to sediment in the butter color used. If the butter color contains such sediment it should be allowed to settle and only the clear oil on top should be used. These yellow specks occur most generally only when the supply of butter color in the drum or other receptacle is nearly exhausted, so that the very bottom strata of the color in the drum are drawn on. In this case it is advisable to discard the remnant of butter color and draw from a new drum.

Frequently the yellow specks are of a different nature and are due to other causes. There occasionally appear yellow spots in the butter that are of an oily, translucent nature. In this case they are generally due to accidental exposure of that particular portion of butter to some object warm enough to cause partial melting and, when recongealed, the butter in that spot looks deep yellow like clear butterfat.

This defect may occur when the operator uses a packer that was soaked in hot water immediately before use and failed to cool it. The warm butter packer melts a small portion of the butter which it touches, resulting in yellow specks showing up in the butter when examined over the trier, or when cut. The buttermaker frequently argues that the butter packs more easily when a warm packer is used. All tools, packers and ladles should be chilled in cold water or cold brine, before they are used in the packing of butter.

Occasionally prints of butter are found that are completely jacketed in a layer of this same translucent, clear, deep yellow, oily-looking butter. This is caused when unsalted butter is stored in a warm room for a considerable length of time. In this case the surface layer becomes very soft, evaporates most of its moisture and expels a portion of its protein content. When rehardened, a surface layer, varying in thickness according to the temperature exposed to and the duration of the exposure, of very sharply defined, almost pure butterfat, is produced and this is of very translucent deep yellow color, while the remainder of the print retains its natural opaque white color. Chemical analysis shows that the moisture content of this outer layer of yellow butter may be no higher than one per cent. This defect is greatly minimized in its intensity and the evaporation retarded when the butter, in addition to the parchment wrapper, is enclosed in a wax paper and packed in a carton.

Salted butter exposed to similar conditions is not subject to this defect. This is probably due to the fact that the loss of moisture due to evaporation is more evenly distributed throughout the body of the print. As the moisture on and near the surface evaporates, salt crystals form which draw more moisture from the interior of the butter.

It is obvious that the storing of butter in a warm room is objectionable at best, and store-keepers should be urged not to keep more butter on the open shelves of their stores than they may reasonably expect to dispose of each day, or preferably to reserve a compartment in their refrigerator for all the butter they carry in stock.

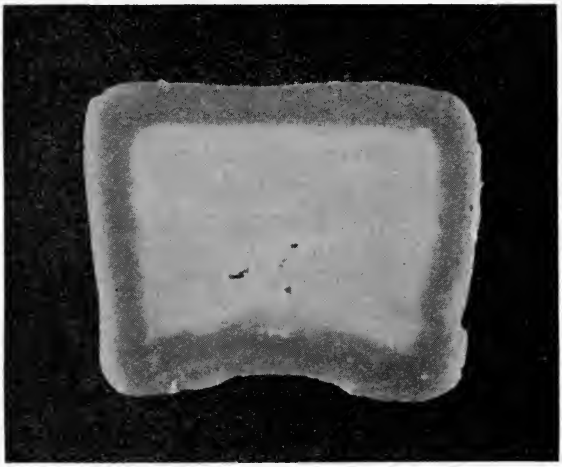

Fig. 83. Unsalted butter held at room temperature for 30 days, showing deep yellow border at periphery due to evaporation of moisture, while interior retained its original color; moisture in surface layer was 1 per cent, in interior 16 per cent.

Green Spots in Butter.—Green spots occasionally appear on the surface or in the interior of butter, other than those described under "moldy butter." This green coloration, especially when found on the surface, usually shows up in the form of small circles or rings, which grow larger with age.

Microchemical examination of these green spots by Hunziker and Hosman[1] showed these spots to contain traces of copper. When they appear on the surface of print butter they can generally be traced to the presence in the parchment wrapper of very minute specks with metallic lustre. These specks in the wrapper have been found, by the authors, to consist of copper or an alloy containing copper, such as German silver, or brass.

Further investigation has revealed that the parchment paper manufacturers are experiencing considerable difficulties to keep

[1] Hunziker and Hosman, Blue Valley Research Laboratory, 1917-1919. Results not published.

filings of these metals out of their paper pulp and that, in order to guard against their appearance in the paper, the manufacturers are employing diverse devices, such as magnets, etc., in the process of manufacture.

The original source of these minute specks of metallic lustre in the parchment paper lies in the rags which constitute a portion of the raw material from which parchment paper is manufactured. In spite of the manufacturers' efforts to eliminate them, metal buttons and buckles of discarded overalls and of similar rags occasionally escape detection, pass into the process with the rags and are thus ground into fine particles or filings which later appear in the finished parchment paper.

Whenever particles of these metal filings become incorporated in the parchment wrapper and the butter is wrapped in such wrappers, the salt and acid in the butter attack the copper contained in these minute specks, forming verdigris. This in turn starts the formation of a small green circle on the butter and on the wrapper, where the metal speck is located.

The green circle grows as the butter ages and the action continues. Around the green coloration there is often also white, bleached butter with an intense tallowy odor. This oxidation, under favorable conditions, may ultimately involve the entire print, causing the whole package to be greenish white and tallowy.

In other cases the green coloration may occur in the interior of the butter. In this case it is also due to particles of copper or an alloy containing copper, but the source of the copper lies in the manufacturing process. It is especially prone to occur when the strainer over the forewarmer or over the pasteurizing vat sags and scrapes the revolving coil, or when accidentally a can cover or other obstruction drops into the bottom of the forewarmer and becomes wedged in between the forewarmer and the revolving coil.

In such instances and other similar cases, particles of the copper of the coil and possibly of the strainer are filed off into the cream and are later worked into the butter. The metal particles may be very small and hardly perceptible to the naked eye, but their corrosion by the salt and acid of the butter is inevitable, causing the appearance of green verdigris in the interior of the butter.

It is obvious that this defect is highly objectionable, verdigris is poisonous and the green coloration is offensive. It can be easily avoided by using wrappers that are free from metallic specks and by avoiding any carelessness in the creamery, that causes the incorporation in butter of metallic elements. The copper coils should never be permitted to scrape against any metal, and if any material or instrument is used to clean the coil or vat lining, that causes violent friction on the copper surfaces, the greatest care should be exercised to flush such surfaces thoroughly so as to remove every vestige of metallic material before cream is again permitted to enter the vat.

Chapter XVIII.

COMPOSITION AND PROPERTIES OF BUTTER, MILK, CREAM, SKIM MILK AND BUTTERMILK.

Butter.

Butter is a mixture of butterfat, small amounts of the non-fatty constituents of milk, cream and water, and it may contain added salt and coloring matter. It is an emulsion of diluted buttermilk-in-fat.

It is composed chiefly of butterfat, water, curd and salt in the case of salted butter, and butterfat, water and curd in the case of unsalted butter. The remaining non-fatty constituents, are the ash, lactose and acid.

The percentage composition varies considerably with the character of the cream and the method of manufacture. The average composition of butter, made in different localities, during the several seasons of the year and under diverse methods of manufacture would approximate the following figures:

	Salted Butter	Unsalted Butter
Butterfat	82.5%	84.0
Water	13.8	14.5
Salt	2.5	0.0
Curd	.6	.85
Ash	.1	.20
Lactose	.25	.3
Acid	.15	.15
Total	100.00	100.00

Thompson, Shaw and Norton[1], in a study of the normal composition of creamery butter, analyzed 695 samples of dif-

[1] Thompson, Shaw and Norton, The Normal Composition of American Creamery Butter, U. S. Dept. Agr., B. A. I. Bulletin 149, 1912.

ferent churnings of butter from California, Iowa, Michigan, Minnesota, North Dakota, Pennsylvania, Texas and Wisconsin, and found the maximum, minimum and average percentages of butterfat, water, salt and curd to range as follows:

Table 71.—Maximum, Minimum and Average Percentages of Butterfat, Water, Salt and Curd[1] in American Creamery Butter.

Butter.

695 Samples of Butter	Fat	Water	Salt	Curd
	%	%	%	%
Average	82.41	13.90	2.51	1.18
Maximum	87.39	20.65	5.98	3.42
Minimum	73.49	10.13	.68	.12

A study of these figures shows a most unusual range between maximum and minimum percentages of the several butter constituents, while the average percentage appears quite normal. The wide range of percentage composition may be due in part, at least, to the fact that over two-thirds of the samples analyzed represent butter from the very heart of the co-operative and small local creamery, the states of Minnesota, Wisconsin and Iowa. The average buttermaker in these creameries is more of an all around creameryman than an expert buttermaker. His knowledge of the art and science of moisture control is limited and the percentage composition of his butter is prone to lack in uniformity.

Analyses of butter from the larger creameries, whose buttermakers are strictly churnmen, and whose skill in moisture control is more highly developed, would undoubtedly show a much more uniform percentage composition, with a slightly higher average water and salt content and a slightly lower fat and curd content.

The Butterfat.—The butterfat is the chief constituent of butter. It normally varies between about 80 and 85 per cent, averaging about 82½ per cent. Abnormal cases occasionally show variations within much wider limits. In rare cases butter has been found to contain as high as 90 per cent fat and as low as 72 per cent fat.

[1] The term "curd" as used here includes, in addition to the nitrogenous constituents, the ash and lactose.

Normal variations in the percentage of butterfat in butter are due to its natural mechanical firmness which determines its power to absorb and hold water and by the process of manufacture. The mechanical firmness of the butterfat is dependent on such factors as season of year, which largely controls the period of lactation and the character of the feed, and on locality which determines the breed of cows and, in part, the character of their feed.

Butterfat is the fat of milk, milk fat is a natural compound of several different fats which vary in their properties. The chief of these fats are the olein, palmitin, myristin, stearin, laurin, butyrin, caproin, caprylin and caprin.

These fats are present in the form of a chemical combination of glycerol (glycerin), as the base, and of one or more fatty acids, such as oleic, palmitic, myristic, stearic, lauric, butyric, capronic, caprylic and capric acids.

These fats are spoken of as the glycerides. The proportion in which these glycerides, or fats, are present in the mixed milk fat varies according to breed, period of lactation and feed of the cows, hence analyses of milk fat derived from different sources are somewhat at variance. Richmond[1] shows the following composition of milk fat:

Table 72. Composition of Milk Fat.

Fats (Glycerides)	Fats (Glycerides) Per Cent	Fatty Acids of These Glycerides Per Cent	Glycerol of These Glycerides Per Cent
Butyrin........	3.85	3.43	1.17
Caproin	3.60	3.25	.86
Caprylin	.55	.51	.10
Caprin........	1.90	1.77	.31
Laurin........	7.40	6.94	1.07
Stearin........	1.80	1.72	.19
Myristin......	20.2	19.14	2.53
Palmitin......	25.7	24.48	2.91
Olein.........	35.0	33.60	3.93
Total.........	100.0		

[1] Richmond, Dairy Chemistry.

Soluble or Volatile Fats and Insoluble or Non-Volatile Fats.—The milk fats are spoken of as soluble or volatile and insoluble or non-volatile fats. In reality none of the fats are soluble or volatile, but the fatty acids of some of the fats or glycerides, when, as the result of the decomposition of the respective glycerides, they become separated from their base, the glycerol, become soluble and volatile.

Some of the fatty acids are wholly soluble and volatile, to these belong the butyric acid and the caproic acid; others are only partly soluble and volatile, to them belong the caprylic, capric and lauric acids; still others are entirely insoluble and non-volatile, to these belong the oleic, palmitic, myristic and stearic acids.

Of the total milk fat about 8 to 12 per cent yield volatile and soluble fatty acids, while the remainder of 88 to 92 per cent are insoluble and non-volatile.

It is generally accepted, though by no means fully experimentally proven, that the volatile fatty acids, of which the butyrin is the most important, give the dairy products their characteristic odor and flavor and that they derive from the feed of the cows the characteristic feed flavors. Storch holds that it is the slimy, nitrogenous film which he claims surrounds each fat globule, that contains and is responsible for the characteristic flavor and aroma of butter.

Melting Point of Milk Fats.—The melting point of the mixed milk fat ranges between about 90 and 99 degrees F. and the solidifying point ranges betwen 65 and 75 degrees F. Fleischmann[1] gives the melting point at 31 to 36 degrees C. (87.8-96.8 degrees F.) and the solidifying point at 19-24 degrees C. (65-75 degrees F.). The several fats or glycerides of which the milk fat is composed, differ from one another largely in their melting points and in their solidifying points, and since the melting point and the solidifying point of the fat control the mechanical firmness or softness of butter, this fact is of the greatest importance in the art of buttermaking. The melting points of the several more important fats contained in milk are as follows:

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[1] Fleischmann—Das Buch der Milchwirtschaft, 1901.

Table 73.

Tri-butyrin	—60 to —70° C. or	—76 to —94° F.
Olein	5° C. or	41° F.
Myristin	54° C. or	129° F.
Palmitin	61° C. or	142° F.
Stearin	65.5° C. or	150° F.

Both the butyrin and the olein have melting points much lower than the other insoluble fats. A material increase in the proportion of butyrin or olein, or both, therefore suggests a lowering of the melting point of the mixed fat and vice versa. This fact has been amply demonstrated by Eckles[1] and by Hunziker[2]. Exceptions to these facts are not infrequent, however, and they must be largely attributed to the fact that the volatile acids in such cases were made up of unusually high proportions of the less common constituents, such as caprylic, capric and lauric acids, whose melting points are 16.5, 31.3 and 43.6 degrees C., respectively, as suggested by Eckles, or that the relative proportion of the glycerides of the individual soluble and insoluble acids exclusive of oleic, must have exerted a dominant influence, as suggested by Hunziker. Again, Lewkowitsch[3] points out that the melting point of a mixture of fats cannot be predicted from the melting points of the fats themselves; and Twitchell[4] shows the interesting fact that a mixture of palmitic and stearic acids lowers the solidifying points of each other to a greater extent than a mixture of either of these two acids with oleic acid.

Barring these exceptions, and for all practical purposes, the fact remains that a high percentage of butyrin, or of olein, or of both, causes the mixed butterfat to have a relatively low melting point, while a low percentage of butyrin, or of olein, or of both, causes the mixed butterfat to have a relatively high melting point. Therefore, in early summer, when, because of the freshening of the majority of the cows, the per cent of butyrin is relatively high, and because of the cows gorging them-

[1] Eckles and Palmer—Influence of Plane of Nutrition of the Cow Upon the Composition and Properties of Milk and Butterfat. Missouri Research Bulletin 24, 1916.

[2] Hunziker, Mills and Spitzer—Moisture Control of Butter, Factors not under Control of the Buttermaker. Purdue Bulletin 159, 1912.

[3] Lewkowitsch—Chemical Technology and Analysis of Oils, Fat and Waxes, Vol. I, 1909.

[4] Twitchell—Journal Ind. Eng. Chem., Vol. VI, p. 564, 1914; also Analyst, Vol. XXXIX, p. 448, 1914.

selves with succulent pasture grass, the per cent olein is also high, often amounting to about 50 per cent of the total fat, the melting point of the mixed fat is relatively low and the butter made from this butterfat is relatively soft.

Physical Structure of Butterfat.—In freshly drawn milk and cream the butterfat consists of miscroscopic, liquid fat globules. These fat globules are present in the form of a fairly permanent emulsion in the skim milk which consists of water in which are dissolved the milk sugar, albumen and part of the milk ash, and which contains in suspension the casein. The casein is of colloid nature and the skim milk may logically be considered an emulsion of hydrated colloid. Milk and cream, then, are a fat-in-hydrated colloid emulsion, or a fat-in-skimmilk emulsion.

The fact that the butterfat globules remain as independent units, and that they form this emulsion, is due to the fact that nature produces them in this fine state of division in the first place. Fisher and Hooker very interestingly show that the secretion of butterfat is the result of fatty degeneration of the cells in the alveoli of the mammary gland or udder. In this fatty degeneration the cells break down, liberating the minute fat globules in a fat-in-hydrated colloid emulsion, in which they retain their individuality because of the forces of surface tension, adsorption and viscosity, as explained under "Philosophy of Churning," Chapter X.

Size of Fat Globules.—As previously stated the butterfat, or milk fat, is present in milk and cream in the form of very minute fat globules. These fat globules vary in size from about one micromillimeter to about 17.4 micromillimeters; they average about from three to five micromillimeters in diameter. One micromillimeter, or one micron represents about one twenty-five tousandth of one inch.

The size of the fat globules is controlled by breed and period of lactation of the cows, and it is influenced by temporary indisposition of the cows and abrupt changes in feed.

The Channel Island breeds, the Jerseys and Guernseys, produce milk in which the fat globules average nearly three times as large in diameter as those in the milk from the Holsteins and Ayrshires.

At the beginning of the period of lactation the fat globules are largest. As the period of lactation advances the average size of the fat globules gradually decreases and is smallest shortly before the cows go dry. See also Chapter X on Churning.

The relative size of the fat globules exerts a marked influence on the mechanical firmness of the butterfat and butter, and, therefore, on the moisture content of the resulting butter. Butter made from relatively large fat globules is much softer, churns much easier and more rapidly and contains more moisture than butter made from relatively small globules. This is

RELATIVE SIZE OF THE SMALLEST AND LARGEST GLOBULES OBSERVED

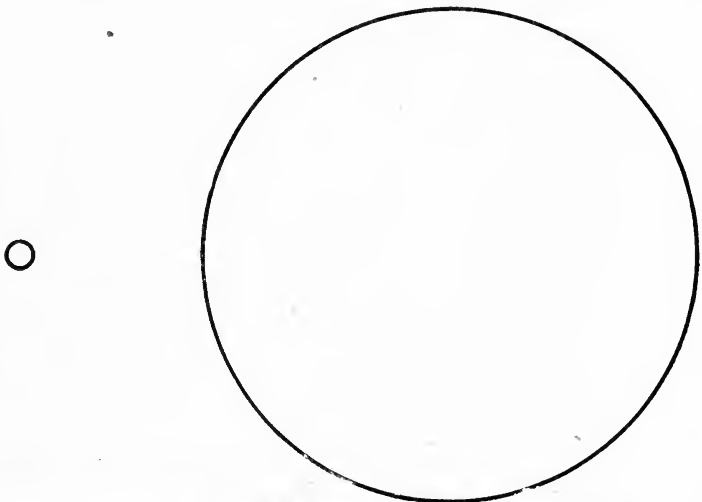

Fig. 84

Volume—.5236 cubic microns
Diameter—1 micron

Volume—2758.32 cubic microns
Diameter—17.4 microns

clearly shown by the results of Hunziker[1], who, by centrifugal separation, produced different lots of cream from the same milk, containing average large globules (54.24 cubic microns) and average small globules (20.72 cubic microns). Sixteen churnings were made from each type of cream. The churning conditions, as to temperature of cream, time held, amount of cream, richness of cream, acidity of cream, etc., were the same for all churnings. The results are shown in the following table: The small-globule cream churned with difficulty, the butter required over twice as much time to "break" as the large-globule cream, and it formed round, hard, smooth granules, which did not pack readily, and made a very firm and crumbly butter. The large-globule

[1] Hunziker, Mills and Spitzer, Purdue Bulletin 159, 1912.

Table 74.—Effect of Size of Average Fat Globules on Per Cent Moisture in Butter

Experiment Number	Large—Globule Cream. Average Volume of Globules 54.249 Cubic Microns		Small—Globule Cream. Average Volume of Globules 20.724 Cubic Microns	
	Churning Number	Moisture in Butter Percent	Churning Number	Moisture in Butter Percent
1	1	19.38	2	17.70
	3	20.19	4	17.75
2	5	26.62	6	21.24
	7	26.28	8	19.20
3	9	21.70	10	16.21
	11	21.40	12	17.72
4	13	19.05	14	16.03
	15	18.54	16	15.47
5	17	19.76	18	15.69
	19	17.61	20	16.28
6	21	20.41	22	17.01
	23	20.61	24	16.28
7	25	23.06	26	17.20
	27	20.00	28	17.50
8	29	18.50	30	18.14
	31	19.95	32	17.17
Average		20.82		17.29

cream churned rapidly, formed soft, irregular, ragged-edged flakes, which packed readily and made a rather soft-bodied butter. The milk from which the two kinds of cream were produced came from cows of the same breed, of as nearly the same age and the same stage of the period of lactation as possible.

These results suggested that the difference in the firmness of the butter may have been due to a difference in chemical composition of the fat, between the large and the small fat globules. Lemus[1] and Kluseman[2] claim that such a difference does exist. Lemus found more volatile acid and less olein in the small fat globules than in the large ones. Kluseman states that

[1] Lemus, Diss. Leipzig, 1902.
[2] Kluseman, Diss. Leipzig, 1893.

the large fat globules contain more of both the volatile acids and the olein than the small fat globules. On the other hand, Siedel and Shaw and Eckles found no difference in the chemical composition of the large and small fat globules of the same milk. Hunziker's results agree with the findings of the last four investigators as shown in the Table 75.

These findings suggest that the softer butter with the higher moisture content, resulting from the large-globule cream is not due to a lower melting point of the fat in these globules, but is largely due to physical or mechanical influences. The forces overcoming the surface tension are greater in the larger globules, causing them to lose their equilibrium and to collapse more readily, and yielding a butter with a softer body which is more miscible with water and which retains water more readily than the firmer butter, which results from the smaller fat globules.

Table 75.—Chemical Composition of Butter Fat from Cream with Large Average Globules and from Cream with Small Average Globules.

Large and Small-Globule Butter	Reichert-Meissl Number	Iodine Number	Saponification Number	Melting Point	Soluble Acids %	Insoluble Acids %	Refractive Index
Large	30.34	28.92	232.2	33.9	6.07	88.90	42.2
Large	30.35	28.90	231.6	34.1	6.00	88.50	42.0
Small	30.20	29.50	231.3	33.7	6.09	89.15	42.0
Small	30.30	29.30	231.6	34.0	5.98	89.00	41.7
Average large globules	30.34	28.91	231.9	34.0	6.04	88.70	42.1
Average small globules	30.25	29.40	231.4	33.9	6.04	89.08	41.9

The Water, Moisture Control.—The water in butter represents quantitatively the largest non-fatty constituent of butter. Under normal conditions of manufacture the water content in finished butter ranges about from 12 to 16 per cent. In very abnormal cases butter has been found to contain less than ten per cent and over 20 per cent water, but butter can be made to contain considerably less than 10 per cent and very much more than 20 per cent water. The water content of butter averages about 14 per cent.

The water content of butter after washing and draining, but before working and salting, and while the butter is still in granular form, under normal conditions of churning, firmness of butter and size of granules, generally averages above 16 per cent, but it varies considerably with the firmness of the butter and size of the butter granules.

Other factors being the same, soft butter granules have a higher water content than firm and hard granules. In the case of normal firmness and very fine granules, similar in size to small rice kernels, the water content of butter before working and salting averages around 20 to 24 per cent. In the form of small corn kernels butter averages around 17 to 18 per cent water and in still larger form, such as in lumps, the water content may drop below 16 per cent, always provided, however, that the butter is of normal firmness at the time it "breaks."

If the large granules or lumps are excessively soft, such as is the case when the churning temperature was too high in proportion to the melting point of the fat, then such lumps usually show a high water content. In such cases both the softness of the butter and the over-churning are the direct result of the high churning temperature which causes the butter to "break" and gather so rapidly that excessive massing takes place before the churn is stopped.

In unsalted butter and in properly worked, salted butter, the water is present largely in the form of microscopic droplets, varying widely in size and ranging in diameter from less than one micron (one twenty-five thousandth of one inch) to over 15 microns (three five thousandths of one inch). In butter prior to working and in much of the salted butter there are present also considerable quantities of water in the form of large drops and water aggregates larger than drops.

As previously stated with relation to the physical structure of butterfat and the philosophy of churning, butter represents an emulsion of hydrated colloid-in-fat, that is, it is an emulsion of buttermilk-in-fat. When the butter is worked, a portion of the buttermilk, that which adheres to the surfaces of the butter granules, is removed and replaced by the water and when the butter is salted and worked a portion of the remaining buttermilk and water is replaced by or fuses with, the brine, or both.

When the butter is worked, most of the free water is expelled, while the firmly held and finely emulsified microscopic droplets in the interior of the butter granules remain in the butter. For this reason, during the first stages of the working process the water content of butter decreases, and under normal conditions drops to about 13 per cent or slightly lower.

As the working process progresses, the butter loses its granular state and becomes less friable and more plastic. When this state is reached further working causes the butter to "pick up" water from the churn and the water content increases again. The amount of water which the butter now assimilates and the extent to which the water content increases, depends on the mechanical condition of the butter, as determined by the melting point of the butterfat, the temperature of the cream and the washwater, and on the amount of water there is in the churn. The amount of water present in the churn obviously is largely governed by the extent of draining, with the churn doors ajar before and during the working process. If the churn is stopped with the doors ajar and down after every few revolutions of the churn, and the butter is allowed to drain completely each time, so that all the free water escapes, further working decreases the water content of the butter.

But even when working with the churn doors closed, so that free water remains in the churn, a point is gradually reached when further working no longer materially increases the water content of the butter. A point of saturation has then been reached that does not permit of additional incorporation of water. The time when this point is reached depends largely on the mechanical firmness of the butter and the temperature of the water in the churn. The softer the butter and the warmer the water, the greater the amount of water that can be incorporated before the point of saturation is reached.

Conditions that tend to disturb the emulsion of buttermilk-, water-, or brine-in-fat, reduce the amount of water that is capable of remaining in butter in the form of very finely divided droplets, unaided by working.

In sweet-cream, unsalted butter, the fine state of division of the water droplets present in butter before working remains practically intact and is not materially affected by working. In sour-cream butter the lactic acid present has a tendency to slightly lower the permanency of the emulsion by its action on the nitrogenous constituents of the buttermilk and such butter may be expected to show a slightly smaller number of very small droplets and a slightly larger number of larger droplets. The difference, however, is very slight.

In salted butter the effect of the salting-out influence of the emulsion is very marked and during the early stages of the working process salted butter shows a marked decrease in the number of small droplets and a decided increase in the number of the larger droplets. In this condition the water in butter is not permanently fixed, the emulsion is incomplete and the butter is leaky. This butter, therefore, has to be worked until the body is sufficiently plastic to permit, by means of the working process, the redivision and re-emulsification of the water droplets until the size of these droplets is again reduced nearly to the point that prevailed before the salting and working commenced, otherwise this butter remains permanently leaky.

It may be logically considered, therefore, that the water in butter is present in two forms; namely, in the form of very finely divided droplets, as originally emulsified and locked up in the granules during the churning process, and in the form of larger droplets, drops and aggregates of drops of free moisture, which is loosely held in the interstices between the butter granules and a part of which adheres to their surface.

The control of moisture in butter, then, resolves itself into the retaining in the butter of the first form of water, the finely divided and thoroughly emulsified droplets originally present, and the dividing and emulsifying into the butter of a portion of the free water; and the ease with which the moisture content is controlled depends on the control by the buttermaker over the mechanical firmness of the butter and the temperature of the cream and wash water.

The natural firmness of the butter varies with locality and season of year, but the actual firmness can be controlled readily by the proper adjustment of the churning temperature, and the proper adjustment and control of the churning temperature is the foundation of satisfactory moisture control. When, in the spring, the butterfat becomes softer, the churning temperature must be lowered sufficiently to maintain the desired firmness of the butter. In the fall, when the natural change in the character of the butterfat tends towards a firmer butter, the churning temperature must be raised sufficiently to offset this change. The extent to which the butter is drained before, or during the working process, or both, will further influence the control of its moisture content.

In the case of unsalted butter, moisture control is largely a matter of giving the free water an opportunity to escape, since, under average conditions, the amount of water present in its original, finely divided and thoroughly emulsified form, represents a very large portion of the total per cent of water that legal butter is permitted to contain. In unsalted butter the tendency naturally is toward a high moisture content.

In the case of salted butter the salt, owing to its great affinity for water, causes a large number of the very small droplets to run together into drops and to escape as free water. Moisture control, here, therefore, has to do with the re-division, re-emulsification and reincorporation of a sufficient amount of the free water, in order to bring the per cent moisture back to that desired, and this is accomplished by proper working.

Moisture Control.—Factory Directions.—Owing to the many and ever-changing factors which influence the property of the butter to retain or take up and hold water, such as type of churn, character of butterfat, churning temperature, etc., it is, as yet, not possible to reduce the art of moisture control to a mathematical, exact science, whereby a given formula may be depended upon to produce the desired results. Moisture control is an art, the success of which demands local experience and judgment on the part of the buttermaker, quite as much as scientific knowledge. For this reason, the specific method that should be used for best results, must be left to the judgement of the buttermaker, who, operating his churns daily, is familiar with his local conditions and is in the best position to know how to go about under his particular conditions.

Attempts to reduce moisture control to a fixed method, by reducing the moisture content of butter by means of preliminary draining and working to a figure below the percentage desired, then testing for per cent moisture and adding the mathematically calculated correct amount of water to increase the moisture content to the desired per centage in the finished butter, have not proven entirely successful.

In the absence of the availability of a more specifically exact method, the following procedure is recommended:

1. Have the churning temperature of the cream sufficiently low to complete the churning process in 40 to 60 minutes and to produce butter of a good firm body. Do not overload the churn and run the churn at about 30 revolutions per minute.

2. Hold the cream at the churning temperature not less than two hours.

3. Wash with water at a temperature the same, or nearly the same, as the temperature of the buttermilk, drain well and give the churn a revolution or two to bring the butter up on the shelves.

4. If the butter happens to be unexpectedly soft, use wash water several degrees colder than the buttermilk. This condition, however, tends toward a leaky body.

5. If the butter happens to be excessively firm, use wash water a few degrees warmer than the temperature of the buttermilk.

6. Trench the butter, distribute the salt uniformly over the entire trench, wet the salt with a small amount of water and close the trench. In the case of a tendency toward excessive moisture, omit wetting of the salt.

7. Give the butter from 12 to 20 revolutions in a four-roll churn, or 25 to 35 revolutions in a two-roll or one-roll churn, according to needs, and test for moisture.

8. If previous experience has shown that there is a tendency for butter to take up excessive moisture, stop the workers after every few revolutions of the churn and allow the butter to drain, with churn doors down and ajar and the churn swinging freely.

9. If previous experience has shown that there is a tendency for butter to be low in moisture, work with the churn doors closed.

10. If the moisture test taken at the churn (see paragraph 7) is high, allow the butter to set for a few minutes, then give the churn another revolution with the workers in gear and again let drain with the churn doors down and ajar. Repeat this until the test shows that excessive moisture is no longer present.

11. If the excess moisture refuses to be expelled by following directions in paragraph 10, remove the butter to the cooler in tubs or other containers, allow it to harden overnight. The next morning strip the tubs, cut the butter into small pieces with wire, and rework as in paragraph 10. This will usually bring the moisture down to the desired point.

12. If, after following directions in paragraph 11, the moisture is still excessive, put the butter in the cooler again and repeat the reworking next day.

13. If the moisture test (see paragraph 7) is slightly too low, give the butter a few more revolutions with the churn gates closed and test again.

14. If the moisture test (see paragraph 7) is considerably too low, calculate the amount of water needed to raise it to the desired point and add the calculated amount of water at a temperature a few degrees higher than the temperature of the buttermilk and work again with the churn doors closed until the desired per cent moisture has been reached. Calculate the amount of water needed by multiplying the difference between the test secured and the test desired by one ond one-fourth times the pounds of fat in the churn and divide by 100.

Example: Test desired ....15.9 per cent
Test secured ....13.5 per cent

Difference .... 2.4 per cent
Fat in churn............800 lbs.

$$\frac{2.4 \times 1.25 \times 800}{100} = 24 \text{ lbs. water to be added.}$$

15. It will be found, in following the above suggestions, that the results may fall short of those desired under many conditions, in which case they need modification to suit conditions.

For instance, in churns in which the free water in the churn precedes the butter in its movement toward and through the workers, increase in moisture content may be found exceedingly difficult. Under these conditions great care should be taken not to drain and especially not to work the butter excessively before salting. Continued working and draining before salting also renders complete solution of the salt difficult because it may cause such a reduction of the moisture in butter, that not enough water is left to readily dissolve the salt and these conditions make the assimilation of free water difficult, in spite of overworking.

The author's purpose of submitting these very inexact suggestions is merely to place before the buttermaker, especially if he be a beginner, some concrete idea of the principles involved and their practical application, which may assist him in working out his own method of moisture control that will best suit his local conditions and equipment.

Relation of per cent moisture to quality of butter.—Within reasonable limits, not exceeding about 16 per cent, the moisture content of butter has no marked effect on its quality. Butter containing 16 per cent moisture, other conditions being the same, may have as good quality and may keep as well, as butter containing only 12 per cent moisture. Generally speaking, however, excessive moisture does not improve the quality of the butter, and it may give rise to butter of very inferior quality, developing such off-flavors as oiliness and fishiness. This is not necessarily due so much to the actual amount of water present, but rather to the process of manufacture that was responsible for the high water content.

Whenever the high per cent of water is the result of overworking the butter, quality is sacrificed. The breaking down of the grain and the emulsification of air in butter, which are inevitable incidents to such moisture incorporation, are antagonistic to good flavor and keeping quality. They invite oxidation and other channels of decomposition. This is especially the case with butter made from sour cream.

Butter made in summer readily holds 16 per cent water without overworking. Such butter is entirely normal, its grain has suffered no mutilation. It may therefore be of just as good flavor and keeping quality as butter containing much less water. In fact, if the low-moisture butter required excessive working in order to reduce the water content, the high-moisture butter may be superior.

On the other hand, high-moisture butter made in winter is often very inferior to low-moisture butter, because overworking was necessary in order to hold up the moisture content.

In winter, when the butterfat is naturally firm and the butter tends to be low in moisture, it may be preferable, from the standpoint of quality, if the buttermaker insists on incorporating the maximum water permitted by law, to raise the churning temperature sufficiently to make the butter "come" in very slightly softer condition, rendering it more miscible with water and thereby making unnecessary excessive working, rather than to mutilate the body of very firm butter by overworking, always providing, however, that the slightly less firm butter is not overworked. The buttermaker should clearly understand that the less firm the butter, the greater the danger of overworking. Soft butter does not stand much working without injury to its grain. It also usually tends to have a leaky body.

The Curd.—The curd represents the nitrogenous constituents of butter. It is generally thought of as the casein (casein lactate) derived from the buttermilk. This impression may be somewhat erroneous, as it appears that there are other nitrogenous substances in butter with properties differing somewhat from those of casein and casein lactate. Storch[1] separated from butter a nitrogenous substance which formed a slimy precipitate in acetic acid, quite different from the usual white, cheeselike, lumpy or flocculent precipitate formed by the casein. This slimy precipitate was insoluble in weak ammonia, and in a 2 per cent solution of sodium hydroxide, while the casein dissolves exceedingly readily in these solutions. According to Storch, this nitrogenous substance corresponds completely with a protein associated with the fat globules. He claims that on the basis of its insolubility in the above alkalies, this slimy substance

[1] Storch—36 Bericht des Koenigl. Veterinar- und Landbauhochschule-Laboratoriums, Kopenhagen, Denmark.

constituted a little over 60 per cent of the protein, or curd, in butter, while the remainder of about 40 per cent is casein.

Storch's findings and conclusions may assist in the explanation why, even when the churning process is stopped while the butter granules are still exceedingly minute, and when this butter is subsequently very thoroughly washed with repeated washings, so that the butter drains perfectly clear, it is not possible to reduce the curd content, as determined by the Kjeldahl method, to any appreciable extent below about .4 per cent. This slimy protein substance does not wash out.

The curd content of butter is determined and expressed in one or the other of two entirely different ways and yielding results in per cent curd, that differ from one another. One way is to determine the nitrogen content of butter, and by multiplying the results by the factor 6.38, expressing it as per cent protein. This represents the true curd content. The other way is to determine the per cent curd by difference, by deducting the sum of the per cent of fat, moisture and salt from 100. In this case the per cent curd so obtained embraces, aside from the protein, also the traces of ash, acid and lactose contained in butter. This is termed the physiological curd.

In the case of the true curd of butter, the percentage of curd usually fluctuates between about .5 per cent and one per cent, averaging about from .6 to .7 per cent, provided that the butter is washed in a normal manner.

Butter made from sweet cream, and unsalted butter, has a slightly higher curd content than butter made from ripened cream and butter that was salted. Butter that is only very slightly washed contains more curd than butter in the manufacture of which the churn is stopped when the granules are still very small and which are washed thoroughly. Butter that is not washed at all usually contains from about 1 to 1.5 per cent curd.

In case of expressing the curd content as physiological curd, the percentage of curd averages from .5 to .6 per cent higher than the true curd.

The Salt.—The salt is the one constituent of butter strictly foreign to the natural composition of butter, unsalted butter containing only very minute traces of sodium chloride as a part of its mineral content. Being added to the butter, the amount of salt which butter may contain is controlled exclusively by the buttermaker.

The great bulk of all butter manufactured in the United States is salted butter, and most of the foreign butter intended for export trade is also salted butter.

Salted butter contains from about 1 to 5 per cent of salt. Most of the salted butter on the market averages from about 2.5 to 4.0 per cent salt, and the great bulk contains between 3 and 3.5 per cent salt.

For the best interests of the butter industry, excessive salting should be avoided and the per cent salt should be held down to below 4 per cent.

The consumer's objection to excessively salted butter is clearly expressed by the San Francisco Wholesale Dairy Produce which issued a ruling that after February, 1, 1916, the salt content of all butter coming into San Francisco shall be three per cent. They further state that practically all the butter that had been coming into San Francisco recently (prior to February 1, 1916) contained a much higher per cent of salt and that one of the chief complaints on all butter was that butter contained too much salt. See also Chapter XI on Salting.

The Lactose, $C_{12}H_{22}O_{11} + H_2O$.—Normal butter contains from about .20 to .45 per cent of lactose, or milk sugar. The lactose is the sugar of milk which is present in solution in the milk, cream and buttermilk, and a portion of which the butter-granules, in their process of forming, pick up and lock up. The per cent lactose in butter obviously varies somewhat according to the extent of washing and removal of buttermilk. The more thorough the washing, the less lactose the butter will contain.

In instances where skimmilk powder is added to the butter in the churn, such as is done in some creameries for the purpose of incorporating extraneous curd in the butter, the lactose content of the butter also increases. In experiments with skimmilk powder, conducted by Hunziker and Hosman,[1] butter contained as high as 1.26 per cent lactose.

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[1] Hunziker and Hosman—A Study of the Composition of Butter. Blue Valley. Research Laboratory, 1917.

The lactose content of butter decreases slightly in storage, partly because of the probable conversion of small portions of the lactose, through bacterial, or through chemical action, into lactic acid, glycolic acid and other acids, and partly due to loss of water or brine by leakage.

The lactose is one of the unstable and readily fermentable constituents of butter, it rapidly yields to bacterial action, splitting up into simpler compounds, of which lactic acid is a very prominent one, but not necessarily the only one.

Under certain conditions lactose also readily yields to chemical decomposition detrimental to the market value of the butter. Being itself a powerful reducing agent, it invites and accelerates oxidation in butter, especially in a weakly alkaline condition. In butter made from over-neutralized cream, the lactose may give rise to most disastrous butter defects, such as bleached and tallowy butter, as demonstrated by Hunziker and Hosman.[1]

In butter with a decided acid reaction, on the other hand, lactose appears to have no deteriorating action, on the contrary, it tends to exert a slight, but distinct preservative influence. It is for this reason that some butter manufacturers purposely add lactose to their butter.

The Acid.—Fresh butter contains from about .1 to .35 per cent acid, presumably largely, but generally not exclusively, lactic acid. In a similar manner, as in the case of curd and ash of butter, the acid is derived from the cream of which it is a natural constituent. Therefore, sweet cream butter contains less acid than ripened-cream butter, and butter made from sour cream that has been neutralized contains less acid than butter from unneutralized sour cream. Butter made from pasteurized cream contains less acid than butter made from raw cream. This is especially the case with the flash process, or high temperature pasteurization, as shown by Hunziker, Spitzer and Mills[2] in Table 77.

The decrease of the acidity of butter, due to pasteurization of the cream is in all probability due to the presence, in the raw

[1] Hunziker & Hosman—Tallowy Butter, Blue Valley Research Laboratory, also Journal of Dairy Science, Vol. I, No. 4, 1917.
[2] Hunziker, Spitzer and Mills—Pasteurization of Sour, Farm-Skimmed Cream for Butter Making. Purdue Bulletin 203, 1917.

cream, of carbon dioxide and other volatile acids which are expelled by the heat of pasteurization, and the higher the temperature of pasteurization the more readily do these volatile acids escape. It has been noticed also by the author and others that the reduction of acid due to pasteurization is much greater in the case of cream that had undergone considerable fermentation before pasteurization, than in cream that is comparatively fresh and unfermented.

Table 77.—Per Cent Acid in Butter Made from Different Portions of the Same Cream Before and After Pasteuriza- at 145° F. 20 Minutes, 165° F. Flash and 185° F. Flash.

	Per Cent Acid in Butter.			
	Raw Cream Butter	Pasteurized Cream Butter. 145° F. 20 Minutes	165° F. Flash	185° F. Flash
Fresh butter	.3260	.2448	.2250	.2034

In storage the acidity of the butter increases slightly, due to the breaking down of a portion of the milk sugar as shown in the following results by Hunziker, Spitzer and Mills,[1] and

Table 78.—Showing Relation of Per Cent. Lactose and Per Cent. Acid in Fresh and Stored Butter Made from Raw and Pasteurized Cream—Averages of 44 Churnings.

Raw and pasteurized cream	Age of butter months	Lactose per cent.	Lactose decrease in 3 months	Acidity per cent.	Acidity increase in 3 months
Raw	fresh	.339		.3073	
Raw	1 month	.367		.3613	
Raw	3 months	.336	.063	.4073	.1000
145 degrees F. 20 minutes	fresh	.398		.2565	
145 degrees F. 20 minutes	1 month	.360		.2745	
145 degrees F. 20 minutes	3 months	.353	.045	.2835	.027
165 degrees F. flash	fresh	.388		.2295	
165 degrees F. flash	1 month	.343		.2543	
165 degrees F. flash	3 months	.315	.073	.2655	.036
185 degrees F. flash	fresh	.389		.2093	
185 degrees F. flash	1 month	.360		.2295	
185 degrees F. flash	3 months	.350	.039	.2655	.056

[1] Hunziker, Spitzer and Mills—Pasteurization of Sour, Farm-Skimmed Cream for Butter Making. Purdue Bulletin 203, 1917.

probably also as the result of partial cleavage of the proteins and fats.

It was formerly believed that the acidity was favorable to the keeping quality of butter, and that ripened cream butter would keep better than sweet cream butter. The great bulk of experimental data on the relation of acidity to keeping quality, and the experience in the commercial manufacture of butter, have amply demonstrated that such is not the case. It is now conceded by the best authorities on the subject, that the acid content of butter, is one of the active agents, which, in combination with other factors, hastens decomposition, leading to the development of specific flavor defects, and shortening the life of good butter.

The Ash.—The Ash, or mineral matter, is present in butter in very small amounts only, ranging from about .09 to .20 per cent. It very rarely exceeds .14 per cent and it averages about .12 per cent. It is derived from the ash of milk and cream and therefore has a similar composition as the ash of milk, which is as follows:

Table 79.—Composition of Ash in Butter from Sour Cream, Butter Not Washed but Thoroughly Worked.[1]

Potassium Oxide	19.329	per cent
Sodium Oxide	7.714	" "
Calcium Oxide	23.092	" "
Magnesium Oxide	3.287	" "
Iron Oxide (Ferric) and Sulphuric Acid	.288	" "
Phosphoric Acid (Anhydride)	44.273	" "
Chlorine	2.604	" "
	100.587	" "
Less Oxygen Equivalent to Chlorine	.587	" "
	100.000	" "

[1] Fleischmann—Lehrbuch der Milchwirtschaft, 1901.

COMPOSITION OF MILK.

Table 80.—Average, Maximum and Minimum Composition of Cow's Milk.

Constituents of Milk	Maximum per ct.	Minimum per ct.	Average Composition by Different Investigators				
			Farrington & Woll[1] per ct.	Van Slyke[2] 5552 analyses per cent	Eckles[3] per ct.	Babcock[4] per cent	Fleischmann[5] per cent
Water	90.0	82.0	87.4	87.1	87.1	87.17	87.75
Fat	7.8	2.3	3.7	3.9	3.9	3.69	3.40
Casein }	4.6	2.5	3.2	2.5	3.4	3.02	2.80
Albumin }				.7		.53	.70
Milk sugar	6.0	3.5	5.0	5.1	4.75	4.88	4.60
Ash	.9	.6	.7	.7	.75	.71	.75
Total Solids			12.6	12.9	12.80	12.83	12.25
Solids, not fat			8.9	9.0	8.90	9.14	8.85

Specific gravity at 60° F. 1.029—1.034; average 1.032.

Specific heat at 61-62.6° F. .9406—.9523. (Chanoz and Vaillant.)

At 57-61° F. .9457, at 81° F. .9351 (Fleischmann.[5])

Freezing point —.54 to —.57° C. Average —.555° C. (31° F.) (Grimmer.[6])

Table 81.—Average Composition of Cow's Milk, by Major Breeds. Percentage of Fat in Total Solids.[3]

Breeds	Fat Per Cent	Total Solids Per Cent	Solid not Fat Per Cent	Parts of Fat in 100 Parts of Total Solids
Holstein	3.45	12.29	8.84	28.
Ayrshire	3.85	12.98	9.13	29.6
Guernsey	4.98	14.20	9.22	35.0
Jersey	5.14	14.90	9.76	34.5
Brown Swiss	3.91	13.28	9.37	29.4

[1] Farrington and Woll, Testing Milk and Its Products, 1908.
[2] Van Slyke, Modern Methods of Testing Milk and Its Products, 1916.
[3] Eckles, Dairy Cattle and Milk Production, 1911.
[4] Babcock, Wing Milk and Its Products, 1909.
[5] Fleischmann, Das Buch der Milchwirtschaft, 1901.
[6] Grimmer, Chemie und Physiologie der Milch, 1910.

Table 82.—Composition of Ash in Normal Cow's Milk.[1]

Mineral Constituents in Milk	In Ash Per Cent	In Milk Per Cent
Potassium oxide (potash)	25.02	.175
Sodium oxide (soda)	10.01	.070
Calcium oxide (lime)	20.01	.140
Magnesium oxide (magnesia)	2.42	.017
Iron oxide (ferric)	.13	.001
Sulphur trioxide	3.84	.027
Phosphoric pentoxide	24.29	.170
Chlorine	14.28	.100
Total ash	100.00	.700

Table 83.—Composition of Colostrum Milk.[2]

Time After Calving	Specific Gravity	Water %	Fat %	Casein %	Albumin %	Sugar %	Ash %	Total Solids %
Immediately	1.068	73.07	3.54	2.65	16.56	3.00	1.18	26.93
After 10 hours	1.046	78.77	4.66	4.28	9.32	1.42	1.55	21.23
After 24 hours	1.043	80.63	4.75	4.50	6.25	2.85	1.02	19.37
After 48 hours	1.042	85.81	4.21	3.25	2.31	3.46	.96	14.19
After 72 hours	1.035	86.64	4.08	3.33	1.03	4.10	.82	13.36

Table 84.—Composition of Ash in Colostrum Milk.[3]

Potassium oxide	7.23	per cent
Sodium oxide	5.72	" "
Calcium oxide	34.85	" "
Magnesium oxide	2.06	" "
Iron oxide (ferric)	.52	" "
Phosphoric acid (anhydride)	41.43	" "
Sulphuric acid	.16	" "
Chlorine	11.25	" "
	103.22	" "
Less oxygen equivalent to chlorine	3.22	" "
	100.00	" "

[1] Leach—Food Inspection and Analysis, 1914.
[2] Engling-Leach—Food Inspection and Analysis, 1914.
[3] Fleischmann—Lehrbuch der Milchwirtschaft, 1901.

Table 85.—Composition of Mammalian Milks.

Kind of Milk	Analyst or Author	No. of Analyses	Specific Gravity	Water %	Total Solids %	Fat %	Total Protein %	Casein %	Albumin %	Lactose %	Ash %
WOMAN—											
Minimum..	Koenig[1]........	....	1.027	81.09	8.60	1.43	.50	.18	.32	3.88	.12
Maximum.	"	....	1.032	91.40	18.91	6.83	4.32	1.96	2.36	8.34	1.90
Average...	"	200	......	87.41	12.59	3.87	2.29	1.03	1.26	6.21	.31
	Grimmer[2].......	1	1.0348	88.13	11.87	2.24	2.41	1.96	.45	....	.25
	"	1	1.0285	89.47	10.53	3.02	1.89	.95	.94	4.37	.32
COW—											
Minimum..	Farrington & Woll[3]	....	1.0290	82.0	10.00	2.3	2.5	....	....	3.5	.60
Maximum.	"	....	1.0340	90.0	18.00	7.8	4.6	....	....	6.0	.90
Average...	"	....	1.0320	87.4	12.60	3.7	3.2	....	....	5.0	.70
	Van Slyke[4]......	5552	......	87.1	12.90	3.9	3.2	2.5	.70	5.1	.70
	Babcock[5].......	....	......	87.17	12.83	3.69	3.55	3.02	.53	4.88	.71
GOAT—											
Minimum..	Koenig[1]........	....	1.0280	82.02	9.84	3.10	3.22	2.44	.78	3.26	.39
Maximum.	"	....	1.0360	90.16	17.98	7.55	5.05	3.94	2.01	5.77	1.06
Average...	"	200	1.0305	85.71	14.29	4.78	4.29	3.20	1.09	4.66	.76
	Fleischmann[6]....	Avg.	1.0320	85.80	14.20	4.50	5.00	3.80	1.20	4.00	.70
	Scheurlen[2]	1	1.0313	87.11	12.89	4.45	3.67	2.00	1.67	4.09	.72
EWE—											
Minimum..	Koenig[1]........	....	1.0298	74.47	12.98	2.81	4.42	3.59	.83	2.76	.13
Maximum.	"	....	1.0385	87.02	25.53	9.80	7.46	5.69	1.77	7.95	1.72
Average...	"	32	1.0341	80.82	19.18	6.86	6.52	4.97	1.55	4.91	.89
	Sartori[2].........	2500	1.0377	78.70	21.30	8.94	6.34	....	....	5.02	1.00
	Fleischmann[6]....	Avg.	1.0369	83.00	17.00	5.30	6.30	4.60	1.70	4.60	.80
BUFFALO—											
Minimum..	Szentkiralyi[2]....	....	1.0310	81.56	15.77	6.69	3.99	....	....	4.16	.72
Maximum.	"	....	1.0336	84.23	18.44	9.19	7.78	....	....	5.18	.85
Average...	"	....	1.0323	82.69	17.31	7.87	5.88	....	....	4.52	.76
	Fleischmann[6]....	2	1.0339	82.93	17.07	7.46	4.59	....	....	4.21	.86
	Rimini[2].........	....	......	81.67	18.33	9.02	3.99	3.63	.73	5.06	.86

[1] Koenig—Chemie der Menschl. Nahrungs- und Genussmittel. Compiled by Leach.
[2] Grimmer—Chemie und Physiologie der Milch, 1910.
[3] Farrington and Woll—Testing Milk and Its Products, 1908.
[4] Van Slyke—Modern Methods of Testing Milk and Its Products, 1916.
[5] Babcock-Wing—Milk and Its Products, 1909.
[6] Fleischmann—Das Buch der Milchwirtschaft, 1901.
[7] Richmond—Dairy Chemistry, 1914.

Table 85.—(Continued.)*

Kind of Milk	Analyst or Author	No. of Analysis	Specific Gravity	Water %	Total Solids %	Fat %	Total Protein %	Casein %	Albumin %	Lactose %	Ash %
Mare.......	Fleischmann[6]....	....	1.0310	90.70	9.30	1.20	2.00	....	....	5.70	.40
	Koenig[1].........	47	1.0347	90.78	9.22	1.21	1.99	1.24	.75	5.67	.35
	Vieth[2]...........	....	1.0350	90.13	9.87	.94	1.65	....	....	6.98	.30
Ass.........	Schlossman[2].....	....	1.0330	88.85	11.15	.36	1.31	.98	.33	4.94	.31
	Koenig[1].........	5	1.0360	89.64	10.36	1.64	2.22	.67	1.55	5.99	.51
	Ellenberger[2].....	....	1.0320	91.23	8.77	1.15	1.50	.94	.53	6.00	.40
Mule.......	Aubert & Colby[2].	....	......	89.14	10.86	1.98	2.31	....	....	6.04	.53
	Leed[2]...........	....	......	91.59	8.41	1.59	1.64	....	....	4.80	.38
Sow........	Henry & Woll[2]...	Avg.	......	80.96	19.04	7.06	6.20	....	....	4.25	1.07
	Koenig[1].........	....	......	84.09	15.91	4.55	7.23	....	....	3.13	1.05
Dog........	Koenig[1].........	....	......	77.00	23.00	9.26	9.72	4.15	5.57	3.11	.91
Cat.........	Koenig[1].........	....	......	81.63	18.37	3.33	9.08	3.12	5.96	4.91	.51
Rabbit......	Pizzi[2]...........	....	1.0493	69.50	30.50	10.45	15.54	....	....	1.95	2.56
Guinea Pig..	Purdie[2]..........	....	......	41.11	58.89	45.80	11.19	....	....	1.33	.57
Delphin.....	Franklain[2].......	....	......	48.76	51.24	43.71	7.57				.46
Whale......	Scheibe[2].........	....	......	69.80	30.20	19.40	9.43	....	....	0.00	.99
	Richmond[7].......	....	......	48.67	51.33	43.67	7.11				.46

* For references to above table, see previous page.

Table 86.—Composition of Cream.

Constituents of Cream	By Centrifugal Separation					By Gravity Creaming
	Snyder[1] %	Richmond[2] %	Fleischmann[3] %	Fleischmann[3] %	Fleischmann[3] %	Koenig[4] %
Water..........	66.41	39.37	29.6	68.5	72.9	68.82
Fat.............	25.72	56.09	67.5	25.0	20.0	22.66
Casein.......... Albumin........	3.70	2.29	1.3	2.8	3.0	3.76
Milk Sugar.....	3.54	1.57	1.5	3.3	3.6	4.23
Ash............	.63	.38	.1	.4	.5	.53
Total Solids....	33.59	60.63	70.4	31.5	27.1	31.18
Solids not Fat..	7.87	4.24	2.9	6.5	7.11	8.42

Specific gravity.—See Standardization of Milk and Cream.

Specific heat of cream testing 19.18% fat at 14-16° C. .9833; at 27.5° C. .8443 (Fleischmann).[3]

[1] Snyder—Dairy Chemistry.
[2] Richmond—Dairy Chemistry, 1914.
[3] Fleischmann—Lehrbuch der Milchwirtschaft, 1901.
[4] Leach—Food Inspection and Analysis, 1914.

Table 87.—Composition of Ash in Cream.[4]

Potassium oxide	28.381	per cent
Sodium oxide	8.679	" "
Calcium oxide	23.411	" "
Magnesium oxide	3.340	" "
Iron oxide (ferric)	2.915	" "
Phosphoric acid (anhydride)	21.735	" "
Chlorine	14.895	" "
	103.356	" "
Less oxygen equivalent to chlorine	3.356	" "
	100.000	" "

Table 88.—Composition of Skimmilk.

Constituents in Skim Milk	Centrifugal Separation				Gravity Creaming
	VanSlyke[1] %	Snyder[2] %	Rich-mond[3] %	Fleisch-mann[4] %	Fleisch-mann[4] %
Water	90.30	90.25	90.48	90.35	89.85
Fat	.10	.20	.12	.20	.75
Casein	2.75	3.60	3.22	4.00	4.03
Albumin	.80		.42		
Milk Sugar	5.25	5.15	4.88	4.70	4.06
Ash	.80	.80	.78	.75	.77
Total Solids	9.70	9.75	9.52	9.65	10.15

Specific gravity at 60°F. 1.035 to 1.038; average 1.036.

Specific heat at 14 to 16° C. .9388; at 27.5° C. .9455 (Fleischmann)[4]; at 0° C. .940; at 15° C. .943; at 40° C. .952 (Hammer and Johnson)[5].

[1] Van Slyke—Modern Methods of Testing Milk and Its Products.

[2] Snyder—Dairy Chemistry.

[3] Richmond—Dairy Chemistry, 1914.

[4] Fleischmann—Lehrbuch der Milchwirtschaft.

[5] Hammer and Johnson—The Specific Heat of Milk Products. Iowa Research Bulletin 14, 1913.

Table 89.—Composition of Ash in Separator Skim Milk.[5]

Potassium oxide	31.634	per cent
Sodium oxide	10.265	" "
Calcium oxide	21.913	" "
Magnesium oxide	3.115	" "
Iron oxide (ferric)	.921	" "
Phosphoric acid (anhydride)	19.478	" "
Sulphuric acid (anhydride)	1.000	" "
Chlorine	15.071	" "
	103.397	" "
Less oxygen equivalent to chlorine	3.397	" "
	100.000	" "

Table 90.—Composition of Buttermilk.

Constituents in Buttermilk	From Ripened Cream					From Sweet Cream	
	Van Slyke[1] %	Storch[2] %	Snyder[3] %	Vieth[4] %	Fleischmann[5] %	Storch[2] %	Richmond[6] %
Water	90.6	90.93	90.5	90.39	91.30	89.74	90.98
Fat	.1	.31	.2	.50	.50	1.21	.35
Casein	2.8	3.37 (casein and albumin)	3.3	3.60	3.50	3.28	3.51
Albumin	.8						
Milk Sugar	4.4	4.58	5.3	4.06	4.00 (milk sugar and lactic acid)	4.98	4.42
Lactic Acid	.6			.75			.01
Ash	.7	.81	.7	.80	.70	.79	.73

Specific gravity of sweet-cream buttermilk 1.0331[6].
Specific gravity of sour-cream buttermilk 1.0314[6].

Table 91.—Composition of Ash in Buttermilk.[5]

Potassium oxide	24.53	per cent
Sodium oxide	11.54	" "
Calcium oxide	19.73	" "
Magnesium oxide	3.56	" "
Iron oxide (Ferric) and Sulphuric acid	.47	" "
Phosphoric acid (anhydride)	29.89	" "
Chlorine	13.27	" "
	102.99	" "
Less oxygen equivalent to chlorine	2.99	" "
	100.00	" "

[1] Van Slyke—Modern Methods of Test Milk and Its Products.
[2] Storch—Richmond's Dairy Chemistry.
[3] Snyder—Dairy Chemistry.
[4] Vieth—Richmond's Dairy Chemistry.
[5] Fleischmann—Lehrbuch der Milchwirtschaft, 1901.
[6] Richmond—Dairy Chemistry, 1914.

Table 92.—Composition of Whey.

Constituents of Whey	VanSlyke %	Fleischmann %	Koenig %	Smetham %	Vieth from Skim Milk %
Water	93.40	93.15	93.38	93.33	93.00
Fat	.35	.35	.32	.24	.09
Casein	.10	} 1.00	.86	.88	.92
Albumin	.75				
Milk Sugar	4.80	4.90	4.79	5.06	5.45
Ash	.60	.60	.65	.49	.52
Total Solids	6.60	6.85	6.62	6.67	7.00

Specific gravity 1.025 to 1.028 (Fleischmann[1]).

Specific heat, at 0° C., .0978; at 15° C., .976; at 60° C., .972. Hammer and Johnson.[2]

Table 93.—Composition of Separator Slime.

	Richmond[3] per cent	Fleischmann[1] per cent
Water	66.24	68.20
Fat	.50	1.44
Protein	22.	25.34
Milk sugar	.50	} 1.80
Other organic matter	7.75	
Ash	3.01	3.22
Total milk solids	26.01	30.00

Table 94.—Composition of Ash in Separator Slime.[1]

Potassium oxide	3.155	per cent
Sodium oxide	1.325	" "
Calcium oxide	45.025	" "
Magnesium oxide	3.361	" "
Iron oxide (ferric)	1.846	" "
Phosphoric acid (anhydride)	43.976	" "
Chlorine	1.691	" "
	100.381	" "
Less oxygen equivalent to chlorine	.381	" "
	100.00	

[1] Fleischmann—Buch der Milchwirtschaft, 1901.

[2] Hammer and Johnson—The Specific Heat of Milk and Milk Derivatives. Iowa Research Bulletin 14, 1913.

[3] Richmond—Dairy Chemistry, 1914.

CHAPTER XIX.

HEALTHFULNESS, FOOD VALUE AND BIOLOGICAL PROPERTIES OF BUTTER

Sanitary Purity and Healthfulness: The degree of freedom of butter from products of decomposition and from microorganisms harmful to man, must of necessity vary greatly with the purity of the raw material, the milk and cream from which the butter is made and with the process used for manufacture. And these factors in turn are subject to wide variations.

Whole milk creameries which receive their milk in fresh condition and have exclusive control over the cream, are in a position to prevent undesirable fermentations that render both cream and butter unpalatable though not necessarily unwholesome. All creameries receiving cream instead of milk, depend to a large extent on the cream producer for the quality and degree of freshness of their raw material.

Most gathered-cream creameries receive their cream in more or less sour condition, the degree of acidity varying from sweet cream with no more than .2 per cent acid, to sour cream with an acidity of from .3 to 1.2 per cent and averaging about .5 per cent acid. The acidity of the cream naturally varies with such conditions as location, season of year, facilities and inclination of the producer to cool the cream on the farm, and frequency of delivery or shipment.

Cream coming from territory in the southern tier of the dairy belt, where the climate is relatively warm and the temperature of the available water on the farm is too high to permit of sufficient cooling to check acid development entirely, will naturally average higher in acidity than cream produced in the northern sections of the dairy belt where the nights are generally cool and the available water for cooling the cream is cold.

During the hot summer months the cream naturally contains a higher per cent of acid than is the case with winter cream. Farmers who have a proper understanding and appreciation of the importance of taking adequate care of their cream, and who are equipped with cooling tanks for the cooling and storing of their cream, are in a position to furnish a much sweeter cream than producers lacking this knowledge, appreciation and equipment.

Creameries located in territories in which the cow population is dense, the herds relatively large and the radius of cream supply condensed, are able to receive cream with a lower acidity than creameries that draw their supply from territories with a sparse cow population, where the herds are small and far between and where dairying is merely a side line of general farming. In such territories the volume of cream is too small to permit of shipments or deliveries sufficiently frequent to insure its arrival in sweet condition.

Aside from the production of acid in the cream, other fermentations may and frequently do set in, which tend to lower the quality of the cream and the flavor, keeping quality and market value of the butter. The great majority of these fermentations, while objectionable from the standpoint of the market value of the butter, are so far as is known, entirely harmless as related to the health of the consumer. In rare cases isolated cans of cream may contain matter of putrefaction. The shipment and acceptance of such cream is unlawful in most states. Such cream is rejected or discarded by the creameries, or confiscated by the health authorities.

In the process of manufacture efforts are made to minimize the effect of the conditions which tend to jeopardize the keeping quality of the product. These efforts largely consist in standardizing the acidity of the cream by the use of a neutralizer, in pasteurization to remove objectionable microorganisms, in using a pure culture starter of lactic acid bacteria to intensify the desirable flavor, and in washing the butter with pure water to eliminate much of the buttermilk.

None of these steps in the process of manufacture are objectionable from the standpoint of the health of the consumer. The neutralizer most commonly used is milk of lime which in itself is a necessary food element of man and if it were taken up by the butter in appreciable quantities could do no possible harm. However, analyses have shown that butter made from cream in which the acidity was standardized by the use of lime, contained no appreciable increase in lime content over butter made from cream not so treated. Pasteurization has no noticeable effect on the digestibility and wholesomeness of the butter. The use of lactic acid starter is bound to have a salutary effect on the wholesomeness of the butter, since lactic acid and lactic acid bacteria aid in digestion and assist in keeping the intestinal tract in a healthy condition. And the washing of the butter with pure water, aside from freeing the butter from much of the elements of buttermilk that yield most readily to decomposition, such as curd and lactose, assists in removing any soluble decomposition products if such products were contained in the cream. American butter contains no preservatives of any kind. The addition of preservatives to butter is prohibited by the Federal Pure Food Act which went in force January 1st, 1907.

It may therefore, be safely stated that commercial butter is devoid of chemical ingredients, such as decomposition products derived from the cream, or chemicals added in the process of manufacture, that have any known harmful effect on the health of the consumer.

The number of bacteria, yeast and mold, that may be expected to be found in sour, farm-skimmed cream, as is received at the average gathered cream creamery, is shown in Table 95. These figures represent 136 separate churnings, made at all seasons of the year. This table further shows the germ-killing efficiency of the holding and the flash process of pasteurization. It indicates that in either process the reduction of bacteria is very great, averaging over 99.9 per cent in the case of the holding process and about 99.5 per cent in the case of the flash process.

The rate of reduction of the different types of microorganisms was practically the same for one and the same process of pasteurization, showing that pasteurization, as practiced in the commercial creamery, is quite as efficient in its destruction of the more objectionable types of germs, such as the liquefying or peptonizing bacteria and the yeast and mold, as it is of the mere acid producing types.

Freedom from Germs of Disease: Milk is capable of becoming the carrier of germs of bovine diseases infectious to man, such as tuberculosis, foot and mouth disease, milk sickness, and of germs of human diseases such as tuberculosis, typhoid fever, scarlatina, diphtheria, etc. The question is therefore not only pertinent but very important, does butter made from milk and cream infected with these diseases, contain the disease germs or viruses and if so, is it capable of causing the disease among the consuming public?

Table 95.—Average Number of Microorganisms of 136 Churnings of Raw and Pasteurized Cream and Per Cent Reduction Due to Pasteurization.[1]

Types of Germs	Raw Cream Germs per c.c.	Pasteurized Cream			
		145° F. 20 Min.		185° F. Flash	
		Germs per c.c.	Decrease %	Germs per c.c.	Decrease %
Total Count.....	209,714,285	113,574	99.95	1,416,029	99.33
Acidifiers	123,985,714	42,928	99.97	837,357	99.33
Liquefiers	16,182,854	3,035	99.98	81,429	99.49
Yeast and Molds.	4,032,000	2,201	99.95	16,782	99.58

So far as the writer is able to determine there are no cases on record which show that any of these diseases were transferred to man through the medium of butter. On the other hand, experimental data of considerable magnitude are recorded, which unmistakably show that cream produced either by gravity creaming or by centrifugal separation of milk infected with Bacillus tuberculosis, also contains this organism and that butter made from such cream, when inoculated into guinea pigs produced the disease and caused the animals to die from generalized tuberculosis.

Thus Moore[2] showed that when milk containing tubercle bacilli is separated by centrifugal force, both the skim milk and the cream harbored these bacilli. Inoculation of the skim milk and cream, respectively, into guinea pigs caused them to die with the disease in 24 to 60 days. Burri and Griflinger[3] demonstrated that the products of tubercle-infected whey, separated by centrifugal force for the purpose of making whey butter,

[1] Hunziker, Spitzer and Mills, The Pasteurization of Sour, Farm-Skimmed Cream for Butter Making, Purdue Bulletin 203, 1917.
[2] Moore, Inefficiency of Milk Separators in Removing Bacteria, U. S. Dept. of Agriculture, Yearbook, 1895.
[3] Burri and Griflinger, Die Gefahr der Ausbreitung der Tuberkulose unter den Schweinen infolge der Verfütterung nicht erhitzter Zentrifugenmolke, Landw., Jahrbuch der Schweiz, 1915.

caused tuberculosis in guinea pigs. Schroeder[1] reports that when cream is separated from milk infected with Bacillus tuberculosis, either by gravity or by centrifugal force, it also contains these germs, and that butter made from such cream contains the tubercle bacillus as determined by testing it with guinea pig inoculation. Broers[2] found that tubercle bacilli will live three days in milk, even when it has undergone changes that make it unfit for use as food, and twelve days in buttermilk, and that they remain virulent three weeks in butter. Cornet[3] reports that Laser could find no live bacilli in butter after twelve days, that Heine records that all tubercle bacilli eventually die in butter and that their maximum life in it is thirty days, that Gasperini found a reduction of virulence after thirty days, though the bacilli were still alive after 120 days, and that Dawson did not observe a reduction of virulence until after the passage of three months, and claims to have produced tuberculosis in a guinea pig by inoculating it with butter eight months old. Schroeder and Cotton[4] state that living tubercle bacilli will retain their infective properties for at least 160 days in salted butter when kept without ice in a house cellar. They fed over 60 guinea pigs, from time to time up to 100 days, with butter from a cow infected with tuberculosis. With the exception of five that died prematurely, and one that was killed, all died with generalized tuberculosis. Swithinbank and Newman[5] tested 498 samples of market butter (in England) and found 76 samples or 15.2 per cent to contain tubercle bacilli. Schroeder[1] states that since salt has distinct though weak germicidal properties, tubercle bacilli in heavily salted butter may live only a short time, while in unsalted butter they may live and remain virulent indefinitely. No appreciable attenuation of tubercle bacilli occurs in ordinary salted butter in 49 days, even though the butter has become rancid and moldy. They are still alive and capable of causing rapidly fatal tuberculosis in guinea pigs after 133 days. Mohler showed that 153 days is not long enough to kill them in butter held in cold storage under ordinary commercial conditions, and

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[1] Schroeder, Milk and Its Products as Carriers of Tuberculosis Infection, U. S. Dept. of Agr. B. A. I. Circular 143, 1909.
[2] Broers, Zeitschrift fuer Tuberkulose, Vol. 10. No. 3, 1907.
[3] Cornet, Die Tuberkulose, Second Edition, Vol. 1, 1907, pp. 122-123.
[4] Schroeder and Cotton, The Relation of the Tuberculous Cow to Public Health, U. S. Dept. Agr. B. A. I. Circular 153.
[5] Swithinbank and Newman, Bacteriology of Milk, 1903, p. 221.

Mohler, Washburn and Rogers[1] further state that constant storage in an icy temperature does not destroy the virulence of butter which contains dangerous tubercle bacilli and that no dependence should be placed on the action of the salt that is added to butter, as an agent in the destruction of tubercle bacilli, the action being very slight at best. The bacilli retained virulence in salted butter for six months.

The findings quoted in the preceding paragraphs show considerable variations in the length of time butter infected with Bacillus tuberculosis retains virulent bacilli. However, this evidence shows conclusively that butter made from tubercle-infected milk or cream harbors these bacilli and is capable of spreading the disease. It further shows that neither does the separation of the milk by centrifugal force insure freedom of these bacilli in the cream nor does the salt in butter destroy their virulence.

Fortunately the tubercle bacilli, as well as the germs and viruses of other common milk-borne diseases infectious to man, such as those of foot and mouth disease, typhoid fever, diphtheria, scarlatina, dysentery, septic sore throat, are readily destroyed by pasteurization of the milk or cream and all butter made from properly pasteurized milk or cream may safely be considered free from the germs or viruses of these diseases. Thus Rosenau[2] as the result of his own extensive investigations, and summarizing the work of other investigators of acknowledged authority states that it is justifiable to assume that ordinary market milk pasteurized by heating to 60° C. (140° F.) for 20 minutes, would be safe for human use by mouth so far as tubercle bacilli are concerned, that the virus of foot and mouth disease is killed with certainty at a temperature of 60° C. for twenty minutes, that milk heated to 60° C. for two minutes destroys the typhoid fever germs, that the diphtheria bacillus and the cholera vibrio die at comparatively low temperatures (55 to 60° C.), that the dysentery bacillus is killed at 60° C. in ten minutes, that the infective principle of Malta fever, M. Melitensis, is destroyed at 60° C. and that a temperature of 60° C. for twenty minutes is

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[1] Mohler, Washburn and Rogers, The Viability of Tubercle Bacilli in Butter, U. S. Dept. of Agr. B. A. I. Twentieth Annual Report, 1909, pp. 179-185.

[2] Rosenau, The Milk Question, 1912.

sufficient to destroy the virus of scarlet fever, streptococci and other pathogenic organisms. He therefore concludes that milk heated to 60° C. and maintained at that temperature for twenty minutes may be considered safe so far as conveying disease with the micro-organisms tested is concerned. Schroeder[1] states that the minimum effective temperature of pasteurization that will destroy the non-spore bearing disease germs is 60° C. for twenty minutes. Mohler, Washburn and Rogers[2] recommend heating the cream to 60° C. for twenty minutes or to 80° C. momentarily, as a reliable means to effectually destroy all the tubercle bacilli that may have found lodgement in it. Marshall[3] holds that milk should be heated to 85° C. (185° F.) momentarily in order to insure freedom from tubercle bacilli. Ayres[4] reports that such disease producing bacteria as Bacillus tuberculosis, Bacillus typhosus, Bacillus diphtheria and the dysentery bacillus are destroyed when heated to 140° F. for twenty minutes and that the same process safeguards the public against the virus of scarlet fever. Dr. H. D. Pease,[5] Director of the Lederle Laboratories, New York City, who conducted an extensive investigation on the efficiency of the holding process of pasteurization to destroy the germs of tuberculosis, typhoid fever and diphtheria in milk, found that the use of temperatures from 142° to 147° F. for a fraction of a minute and the additional holding of the heated milk for thirty minutes, at temperatures ranging from 143° to 145° F. is sufficient to insure the total destruction of these germs, even when present in milk in large numbers. His experiments were made with commercial equipment, under strictly commercial conditions and with milk heavily inoculated with these disease germs.

In Denmark the pasteurization of cream for buttermaking at 82° C. to 85° C. (180° F. to 185° F.) is compulsory.

These citations may suffice to conclusively show that, since the milk and cream from which butter is made, may be and frequently are contaminated with germs of infectious disease,

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[1] Schroeder, The Relation of the Tuberculous Cow to Public Health, U. S. Dept. Agr. B. A. I. Circular 153, 1910

[2] Mohler, Washburn and Rogers, The Viability of Tubercle Bacilli in Butter, U. S. Dept. Agr. Twenty-sixth Annual Report, B. A. I., 1909.

[3] Marshall, Tuberculosis and Its Management, Mich. Bull. 184, 1900.

[4] Ayres, The Pasteurization of Milk, U. S. Dept. Agr. B. A. I. Circular 184, 1912.

[5] Pease, Pasteurization Experiments, Lederle Laboratories, N. Y. City, 1915. Results not published.

both bovine and human, and since these disease germs are able to pass from infected milk and cream to the butter, and maintain their virulence in butter for a considerable length of time, regardless of salt content and low storage temperature of the butter, the public welfare demands that milk and cream used for buttermaking should be pasteurized. They further clearly indicate that the temperature to which the milk or cream should be heated, and the time of exposure necessary to destroy all non-spore bearing disease germs should be, for the holding process, not less than 145° F. for at least twenty and preferably thirty minutes, and for the flash process not less than 180° F. momentarily.

In some states the pasteurization of cream for buttermaking is compulsory, and the result of recent investigations indicates that the great bulk, approximately 90% of all butter made in American creameries is manufactured from pasteurized cream. The processes of pasteurization used in the creameries are largely those above prescribed or their equivalent, so that it is reasonable to state that by far the majority of American factory-made butter that enters state and interstate commerce may be considered safe from the standpoint of its freedom from virulent disease germs and viruses.

Most of the farm dairy butter, however, is made from raw cream. If the cream from which it is made is free from disease germs it is obviously equally safe as the creamery butter, but similar to farm-peddled milk, which is rarely pasteurized, so does farm butter offer no guarantee as to its safety to the consuming public.

Digestibility and Caloric Value of Butter.

Digestibility.—The digestibility of butter, based on the completeness of its utilization, or on its losses in digestion, is very high, similar to that of products containing other fats in about the same proportion. Thus Luhrig found the coefficient of digestibility to be 97.86 per cent for butter and 97.55 per cent for oleomargarine.

The coefficient of digestibility of butterfat, or the percentage consumed that is assimilated, as determined by various investigators, and assembled by Langworthy and Holmes, is as follows:

Table 96.

Investigator	Fat Assimilated Per Cent	Investigator	Fat Assimilated Per Cent
Rubner[1]	96.3	Huldgren & Landergren[5]	95.4
Rubner[1]	97.3	Luhrig[6]	96.0
Malfatti[2]	97.7	Luhrig[6]	97.0
Mayer[3]	98.0	Wibbins and Huizenga[7]	97.3
Mayer[3]	97.0	Wibbins and Huizenga[7]	96.5
Bertarelli[4]	94.0	Von Gerlach[8]	97.0
		Langworthy and Holmes[9]	97.0

Langworthy and Holmes* show the following comparative coefficients of digestibility, with allowance for metabolic products, for butterfats, animal fats and vegetable fats:

Table 97.

Kind of Fat	Coefficient of Digestibility Per Cent
Butterfat	97.0
Animal fats:	
Lard	97.0
Chicken fat	96.7
Goose fat	95.2
Fish fat	95.2
Egg yolk fat	93.8
Beef fat	93.0
Mutton fat	88.0

[1] Rubner, Zeitschrift für Biologie, Vol. 15, No. 1, 1879, and Vol. 16, No. 1, 1880.

[2] Malfetti, Sitzber, K. Akad. Wiss. etc., Vol. III, No. 5, 1884.

[3] Landwirtschaftl. Versuch. Station, Vol. 29, 1883.

[4] Bertarelli, Riv. Ig. e. Sanit. Pub. Vol. 9, Nos. 14 and 15, 1898.

[5] Huldgren and Landergren, Skand. Arch. Physiol. Vol. 2, Nos. 4 and 5, 1890.

[6] Luhrig Zeitschift für Untersuch. Nahr. u. Genussmittel, Vol. 2, Nos. 6 and 10, 1899.

[7] Wibbins and Huizenga, Pflüger's Arch. Physiologie, Vol. 83, Nos. 10, 11, 12, 1901.

[8] Von Gerlach, Zeitschrift Phys. u. Diätet, Vol. 12, No. 2, 1908.

[9] Langworthy and Holmes, U. S. Dept. Agr. Bull. 507, 1917.

* Langworthy and Holmes, U. S. Dept. Agr., Bulletin 310, 1915; Bulletin 505, 1917; Bulletin 510, 1917.

Table 97.—(Continued).

Vegetable fats:	
Peanut oil	98.3
Sesame oil	98.0
Cocoanut oil	97.9
Olive oil	97.8
Cottonseed oil	97.8
Cocoa butter	94.9

On the basis of digestibility, however, butter is probably superior to most other fats. Sherman[1] points out that the fats generally retard the secretion of the gastric juice and tend to make the food stay longer in the stomach, and that to the extent that the ease of digestion is inferred from the rapidity with which a meal passes through the stomach to the intestines, the eating of fat appears to retard the process, this being true to a greater extent, the higher the melting point of the fat. Langworthy and Holmes conclude that butterfat may be considered more completely assimilated, than any other of the animal fats which they considered in their investigation. This statement refers to lard, beef fat and mutton fat.

Caloric Value.—The caloric calue of butter varies with its composition. It largely depends on the per cent of fat contained in butter. The curd content is fairly uniform and is usually assumed to be about 1 per cent.

The caloric value should be calculated only on the digestible nutrients. The coefficients of digestion in butter average about 94.1 per cent for the curd, or protein, and 97 per cent for the fat. The digestible nutrients in butter with varying percentages of fat, then, are approximately as follows:

80% { Protein $\frac{1. \times 94.1}{100} = .941\%$; Fat $\frac{80 \times 97}{100} = 77.6\%$

82.5% { Protein $\frac{1. \times 94.1}{100} = .941\%$; Fat $\frac{82.5 \times 97}{100} = 80.025\%$

85% { Protein $\frac{1. \times 94.1}{100} = .941\%$; Fat $\frac{85 \times 97}{100} = 82.45\%$

[1] Sherman Food Products, 1916, P. 390.

A calorie (large calorie) is the amount of heat required to raise the temperature in 1,000 grams of water 1° C. The caloric value of protein is 4100, and that of fat is 9300. 1,000 grams are equal to 2.2 pounds, hence the caloric value of one pound of protein is $\frac{4100}{2.2} = 1863$, and the caloric value of one pound of fat is $\frac{9300}{2.2} = 4227$.

The caloric value of one pound of butter containing 80, 82.5 and 85 per cent fat, respectively, therefore is as follows:

Butter with 80% fat	1% protein	$\frac{.941 \times 1863}{100}$	=	18	Calories
	80% fat	$\frac{77.6 \times 4227}{100}$	=	3,280	"
	Total calories		=	3,298	"
Butter with 82.5% fat	1% protein	$\frac{.941 \times 1863}{100}$	=	18	Calories
	82.5% fat	$\frac{80.025 \times 4227}{100}$	=	3,382	"
	Total calories		=	3,400	"
Butter with 85% fat	1% protein	$\frac{.941 \times 1863}{100}$	=	18	Calories
	85% fat	$\frac{82.45 \times 4227}{100}$	=	3,485	"
	Total calories		=	3,503	"

Biological Properties of Butter

Butter Contains Growth-Promoting and Curative Properties.—The butterfat of butter contains certain biological properties, which are not present in vegetable fats, nor in the ordinary animal fats. These properties are absolutely essential for an adequate diet. A diet that is lacking in these biological properties is inadequate to produce normal growth in the young, it prevents well being of the adult and gives rise to certain deficiency diseases.

By biological properties is meant those properties, recently discovered by McCollum[1], and subjected to extensive investiga-

[1] McCollum, The Newer Knowledge of Nutrition, 1918.

tion by McCollum, Hart, Steenbock, Fink, Hopkins, Osborne, Mendel and other nutrition experts and physiological chemists,[1] which have to do with the life functions of the living organism. These properties cannot as yet be determined by any now known

TABLE 98

AMOUNTS OF NUTRIENTS IN A POUND OF MILK AS COMPARED WITH A POUND OF MEAT, BREAD AND OTHER FOOD PRODUCTS.[2]

Food materials	Refuse	Edible portion					Fuel value
		Water	Nutrients				
			Protein	Fat	Carbohydrates	Min. matter	
	Lbs.	Lb.	Lb.	Lb.	Lb.	Lb.	Cal.
Milk (1 pint or 1 pound):							
Whole milk	....	0.87	0.03	0.04	0.05	0.01	325
Skim milk (0.3 per cent fat)	....	0.90	0.04	....	0.05	0.01	170
Buttermilk	....	0.91	0.03	0.01	0.05	0.01	165
Other food materials (1 lb. each):							
Cheese	....	0.34	0.26	0.34	0.02	0.04	1965
Butter	....	0.11	0.01	0.85	....	0.03	3605
Beef:							
Round	0.08	0.61	0.18	0.12	....	0.01	870
Shoulder clod	....	0.69	0.19	0.11	....	0.01	835
Sirloin	0.13	0.53	0.16	0.17	....	0.01	1040
Fore quarters	0.19	0.50	0.14	0.16	....	0.01	950
Hind quarters	0.16	0.51	0.15	0.17	....	0.01	1000
Mutton, side	0.19	0.43	0.13	0.24	....	0.01	1275
Pork:							
Loin	0.16	0.44	0.14	0.25	....	0.01	1340
Ham	0.14	0.35	0.13	0.34	....	0.04	1655
Salt, fat	....	0.07	0.02	0.87	....	0.04	3715
Chicken	0.35	0.48	0.15	0.01	....	0.01	325
Codfish:							
Fresh	0.30	0.58	0.11	....	....	0.01	205
Salt	0.25	0.40	0.16	....	....	0.19	315
Mackerel, salt	0.23	0.38	0.17	0.17	....	0.10	1050
Oysters, solids	....	0.88	0.06	0.02	0.03	0.01	235
Wheat flour	....	0.12	0.11	0.01	0.75	0.01	1645
Corn meal	....	0.13	0.09	0.02	0.75	0.01	1655
Oatmeal	....	0.07	0.16	0.07	0.68	0.02	1860
Wheat bread	....	0.35	0.10	0.01	0.53	0.01	1205
Crackers	....	0.08	0.11	0.10	0.69	0.02	1895
Dried beans	....	0.13	0.22	0.02	0.59	0.04	1590
Beets	0.20	0.70	0.01	....	0.08	0.01	170
Potatoes	0.15	0.67	0.02	....	0.15	0.01	325
Turnips	0.30	0.62	0.01	....	0.06	0.01	135
Apples	0.25	0.62	0.01	....	0.12	....	255

[1] McCollum, The Newer Knowledge of Nutrition, 1918.
[2] U. S. Dept. of Agr., Farmers' Bulletin No. 74.

method of chemical analysis, their presence has only become recognized by means of experimental feeding trials with young animals.

These feeding trials, largely though not exclusively conducted with young white rats, showed that when the animals were put on an artificial diet, containing all the chemical elements necessary for nutrition, both for maintenance and for growth, such as protein, carbohydrates, fats and mineral salts, but in which the fat part of the ration consisted of a vegetable oil or of lard, the rats would after a brief period cease to grow, so that they rarely attained more than two-thirds of the normal growth of fully grown rats. As this diet was continued they would lose weight and gradually develop sore eyes which culminated in blindness and ultimate death of the rats. When, before the death of the rats, a portion of the animal or vegetable fat in the ration was replaced by butter or butterfat, they recovered from their disease, gained in weight and resumed their normal growth.

Fat-Soluble A.—Further experiments in which the pure butterfat was separated from the butter, and the butterfat instead of the butter was used to replace a part of the lard in the feed ration, yielded identically the same results as in the case of butter, showing therefore that this growth-promoting and curative property of the butter is located in the butterfat. Being soluble in the butterfat, McCollum gave this unknown substance the name fat-soluble A.

Fat-Soluble A Present in Liquid Portion of Butterfat.—Osborne and Mendel succeeded in concentrating the fat-soluble A substance contained in butterfat by fractional crystallization of the fat from alcohol. They found that the fat-soluble A substance remains in the mother liquor, or oily portions, those portions which have a low melting point, while the other portions, those that have a high melting point, proved entirely ineffective. This fact assists in explaining why beef fat, which also contains small quantities of this substance, is much less effective in its growth promoting powers than the butterfat. The liquid portion in the beef fat is relatively small.

Fat-Soluble A Not Affected by Pasteurization, Neutralization or Age.—Additional experiments showed that the fat-soluble

A substance is of a stable nature, and that it is neither destroyed, nor its growth-promoting and curative effect lessened by heat, saponification, or age.

Butterfat boiled with live steam for several hours did not lose its biological properties. This is important, because it demonstrates conclusively, that the pasteurization of cream does not rob the resulting butter of its growth-promoting and curative properties. Pasteurized cream butter is equally valuable therefore from the dietary standpoint as raw cream butter.

Butterfat or butter when completely saponified into a soap, by admixture of alkali in excess, fully retains its growth-promoting and curative properties. Butter soap so made, when fed to the rats had the same biological effect as normal butter or pure butterfat. This fact is important because it removes every vestige of doubt that the reduction of the acid in sour cream by the use of an alkali, as practiced in so-called neutralization of sour cream, in no way destroys or weakens the growth-promoting and curative properties of butter. Butter made from sour cream that has been neutralized, has equal dietary value as butter made from cream that was not neutralized.

Age does not change the biological value of butter. The changes which butter undergoes in storage fail to deprive it of its growth-promoting and curative effect. Butterfat held in the cold and at room temperature, in the light and in the dark, for ten months, when subsequently fed to rats which had ceased to grow and had developed the characteristic sore eyes, as the result of the absence in their diet of the fat-soluble A, brought about resumption of growth to normal stature, and recovery and healing of the eyes. The biological potency in all samples of butterfat held in storage was retained and was equal to that of fresh butter or fresh butterfat. This fact is important, because it furnishes indisputable proof that storage butter, relative to biological properties, is equally wholesome as fresh butter.

Other Sources of Fat-Soluble A.—The only substances in which the fat-soluble A has been found, other than butter and butterfat, are the fat contained in the yolk of the egg, cod liver oil, leaves of plants and the fat of the vital organs.

So-called Butter Substitutes Cannot Take the Place of Butter.—This discussion makes it clear that there is no substitute for butter. So-called butter substitutes, all of which are largely made up of vegetable or animal fats, or both, cannot take the place of butter. They may have equal, or nearly equal, caloric value as butter, but they lack this most important property, the fat-soluble A, without which the diet is not complete. Their substitution for butter in the diet of the family is jeopardizing the well being, vitality and maximum mental and physical development and vigor of the child, and to that extent limits the future greatness of the nation.

CHAPTER XX.

DEFINITIONS AND STANDARDS OF BUTTER, MILK, CREAM, SKIM MILK AND BUTTERMILK

Butter.—Butter manufactured in the United States is subject to two standards and definitions; the control of enforcement of each is vested in two separate and distinct institutions.

One standard and definition deals with the maximum per cent moisture which by a ruling of the Internal Revenue Department was placed below 16 per cent. The other deals with the minimum per cent of fat which by a ruling of the United States Department of Agriculture was placed at 82.5 per cent.

The Moisture Standard.—The moisture standard is based on the definition of butter by Act of Congress August 2, 1886, which reads as follows:

"The food product usually known as butter, which is made exclusively from milk or cream, or both, with or without common salt and with or without additional coloring matter,"
and by Act of Congress of May 9, 1902, which reads as follows:

"That for the purpose of this act 'butter' is hereby defined to mean an article of food as defined in 'An Act defining butter,' also imposing a tax upon and regulating the manufacture, sale, importation, and exportation of oleomargarine, approved August 2, 1886; that adulterated butter is hereby defined to mean a grade of butter produced, by mixing, reworking, rechurning in milk or cream, refining or in any way producing a uniform, purified or improved product from different lots or parcels of melted or unmelted butter or butterfat, in which any acid, alkali, chemical, or any substance whatever is introduced or used for the purpose or with the effect of deodorizing or removing thereform rancidity, or any butter or butterfat with which there is mixed any substance foreign to butter as herein defined, with intent or effect of cheapening in cost the product, or any butter in the manufacture or manipulation of which any process or material is used with intent or effect of causing the absorption of abnormal quantities of water, milk or cream; that 'process butter' or 'renovated butter' is hereby defined to mean butter which has been subjected to any process by which it is melted, clarified, or refined and made to resemble genuine butter, always excepting 'adulterated butter' as defined by this act."

In defining adulterated butter as distinguished from butter, the Internal Revenue Department offers the following explanation and makes the following ruling:

"The definition of adulterated butter as contained in the Act of May 9, 1902, embraces butter in the manufacture of which any process or material is used whereby the product is made to contain abnormal quantities of water, milk or cream, but the normal content of moisture permissible is not fixed by the act. This being the case it becomes necessary to adopt a standard for moisture in butter, which shall in effect represent the normal quantity. It is therefore held that butter having 16 per cent or more of moisture, contains an abnormal quantity and is classed as adulterated butter."

This law and ruling is now in force. It makes unlawful the incorporation in butter of 16 per cent or more, of moisture, and its interpretation also makes unlawful the incorporation of extraneous curd by working curd into the butter in the churn in the form of starter, casein or skim milk powder.

The Fat Standard.—The fat standard is a part of the Federal Standards and Definition for Dairy Products, accompanying the passage of the Federal Food and Drugs Act June 30, 1906 and which became effective January 1, 1907.[1] It reads as follows:

"Butter is the clean, non-rancid product made by gathering, in any manner, the fat of fresh or ripened milk or cream into a mass, which also contains a small portion of the other milk constituents, with or without salt, and contains not less than eighty-

[1] Standards of Purity for Food Products, U. S. Dept. of Agriculture, Circular No. 19, 1906.

two and five tenths (82.5) per cent, of milk fat. By act of Congress approved August 2, 1886, and May 9, 1902, butter may also contain added coloring matter."

This standard has never been and is not now enforced.

Within recent years the Federal Joint Committee on Definitions and Standards for Food Products has had under advisement a revision of this butter standard and definition. This joint committee consists of three members each, the United States Bureau of Chemistry, the American Association of Official Agricultural Chemists and the Association of American Dairy, Food, and Drug Officials, under the chairmanship of the chief of the Bureau of Chemistry. At the time of the completion of this manuscript, no decision had as yet been reached.[1,2,3,4]

Numerous states have definitions and standards for butter, most of them similar to the standard adopted by the United States Department of Agriculture as per circular No. 19. Few states have standards differing slightly from the above standard. The State of Minnesota,[5] by Act of the State Legislature 1915, amended its section relating to the use of preservatives as follows:

"Dairy Products—Preservatives. Sec. 1756. No person shall manufacture for sale, advertise or sell, any mixture or compound designed, or offered for sale or use, as an adulterant, preservative or renovator of milk, cream, butter or cheese, or as a neutralizer of the acidity of milk, cream, butter or cheese; nor shall any person add, or apply to milk, cream, butter or cheese, any borax, boric acid, salicylic acid, formaldehyde, formalin or other anti-ferment or preservative, nor any alcohol, viscogen, lime, salpeter, sal-soda, soda ash, or other neutralizer, provided however, that this section shall not apply to pure salt added to butter or cheese."

The above section makes the practice of reducing the acidity in cream unlawful in the State of Minnesota.

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[1] Veeder, McManus, Jones and McCabe, Attys. for Swift & Co., Suggestions for a Standard for Butter, presented to the Joint Committee on Definitions and Standards, November, 1917.

[2] Hunziker, Butter Standards. Address before Joint Committee on Definitions and Standards. Chicago, May, 1917.

[3] McKay, Facts about Butter, Suggestions for a Standard, June, 1918.

[4] Hunziker, Bouska, Borman and McKay, Statements on the Subject of Definitions and Standards of Butter, Presented to the Joint Committee on Definitions and Standards, September, 1918.

[5] Farrell, Manual of the Dairy and Food Laws, Rules and Regulations, 1915.

Generally speaking the state standards for butter are not enforced. The only butter standard that is systematically enforced is the 16 per cent moisture ruling of the Internal Revenue Department.

The following list shows the butter standards in some of the foreign countries, compiled by the United States Bureau of Chemistry:

TABLE 99

BUTTER STANDARDS IN VARIOUS COUNTRIES.

Compiled By and Secured Through Courtesy of United States Bureau of Chemistry, 1919.

Countries	Date of Enactment of Law	Fat Minimum Per Cent.	Water Maximum Per Cent.	Non-Fatty Milk Constituents Maximum Per Cent.	Boron Compounds as Boric Acid Maximum Per Cent.
Australia	1902	82	16		
Belgium	1900			18[1]	
Brazil	1915	80			
Canada	1910	82.5	16		
Cuba	1914		15		
Denmark	1911				
Domestic			20[2]		
Export			16		
Germany	1902				
Salted		80	16		} .3
Unsalted		80	18		
Great Britain	1902				
Genuine			16		} .5
Milk-Bl'ded			24		
Italy	1890	82			
Netherlands	1909	80			
New Zealand	1913	80	16		
Queensland	1902	83			
	1906[3]	80	16		.5
Roumania	1895	82	14		
Spain	1908		16		
Sweden	1911		16		
Switzerland	1914	82			
United States	1902[4]		16		
	1906[5]	82.5			
Venzuela	1916	80–88	10–15	Salt 2-10; C's'n 1-3	
Victoria	1906[6]	80	15		
West. A'str'lia	1911–12	82	15		

[1] Butter which contains more than 18 per cent non-fatty constituents such as water, milk sugar, casein, must be sold under the designation "beurre laiteux" (milky butter).

[2] Butter which contains over 16 per cent water, but less than 20 per cent water, must bear the designation "water butter" (Vandsmeer).

[3] Allen's Commercial Organic Analysis, Fourth Edition, Vol. II, 1914.

[4] Inforced by Internal Revenue Dept.

[5] Standard of United States Department of Agriculture, not enforced.

[6] Allen's Commercial Organic Analysis, Fourth Edition, Vol. II, 1914.

MILK, CREAM, SKIMMILK AND BUTTERMILK

On April 17, 1919, the Secretary of Agriculture issued, under Food Inspection Decision 178[1], the following definitions and standards for milk, cream, skimmilk and buttermilk. These definitions and standards were adopted by the Joint Committee on Definitions and Standards July 30, 1917, and were approved by the Association of American Dairy, Food and Drug Officials August 3, 1917, and by the Association of Official Agricultural Chemists November 21, 1917:

"1. **Milk** is the whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy cows, properly fed and kept, excluding that obtained within fifteen days before and five days after calving, or such longer period as may be necessary to render the milk practically colostrum-free.

"2. **Skimmed milk** is milk from which substantially all of the milk fat has been removed.

"3. **Cream, sweet cream,** is that portion of milk, rich in milk fat, which rises to the surface of milk on standing, or is separated from it by centrifugal force. It is fresh and clean. It contains not less than eighteen per cent (18%) of milk fat and not more than two-tenths per cent (0.2%) of acid-reacting substances calculated in terms of lactic acid.

"4. **Whipping cream** is cream which contains not less than thirty per cent (30%) of milk fat.

"5. **Pasteurized milk** is milk that has been subjected to a temperature not lower than 145 degrees Fahrenheit for not less than thirty minutes. Unless it is bottled hot, it is promptly cooled to 50 degrees Fahrenheit or lower.

"6. **Buttermilk** is the product that remains when fat is removed from milk or cream, sweet or sour, in the process of churning. It contains not less than eight and five-tenths per cent (8.5%) of milk solids, not fat.

"7. **Homogenized milk or homogenized cream** is milk or cream that has been mechanically treated in such a manner as to alter its physical properties, with particular reference to the condition and appearance of the fat globules."

[1] Milk and Cream, U. S. Department of Agriculture, Food Inspection Decision 178, April 17, 1919.

Table 100.—Legal Standards for Dairy Products by States.

States.	Milk.			Skim milk.	Cream.	Butter.			Whole-milk cheese.	Skimmed-milk cheese.	Condensed milk (sweetened).		Evaporated milk (unsweetened).		Ice cream (plain).		Ice cream (fruit and nut).	
	Total solids.	Solids not fat.	Fat.	Total solids.	Fat.	Fat.	Water.	Salt.	Fat.	Fat.	Total solids.	Fat.	Total solids.	Fat.	Fat.	Gelatin.	Fat.	Gelatin.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per cent.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Alabama																		
Alaska [2]																		
Arizona [3]																		
Arkansas [1]																		
California		8.50	3.00	8.80	18.0	80.0			[4] 50.0	Half-skimmed, [4] 25.0. (5)	24.5	7.70	25.5	7.80	10.0	0.6	8.0	0.6
Colorado			3.00		16.0	80.0	16.00				28.0	7.70	(6)	(8)	14.0		12.0	
Connecticut	11.75	8.50	3.25		16.0	(7)	(7)	(7)			28.0	[4] 31.00	(6)	(8)				
Delaware [1]																		
District of Columbia	12.50	9.00	3.50	9.30	20.0	83.0	12.00	5.00	(8)	(8)	(8)	(8)	(8)	(8)		(9)		(9)
Florida		8.50	3.25	9.25	18.0	82.5					28.0	7.70	24.0	7.80	12.0			
Georgia		8.50	3.25	9.25	18.0	82.5	16.00		(7)		(7)	(7)	(7)	(7)	12.0		10.0	
Hawaii	11.50		2.50		18.0													
Idaho	11.20	8.00	3.20	9.30	18.0	82.5	16.00		[4] 50.0		28.0	[4] 27.60	(7)	(7)	14.0	(10)	12.0	(10)
Illinois		8.50	3.00	9.25	18.0	82.5			[4] 50.0		28.0	7.70	25.5	7.70	8.0		8.0	
Indiana		8.50	3.25	9.25	18.0	82.5	16.00		[4] 50.0		34.3	7.80	25.5	7.80	8.0	.7	8.0	.7
Iowa	12.00		3.00		16.0	80.0				(11)	(7)	(7)	(7)	(7)	12.0	1.0	10.0	1.0
Kansas			3.25		18.0	80.0	16.00		[4] 50.0						14.0		12.0	
Kentucky		8.50	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.66	28.0	[4] 27.66	14.0		12.0	
Louisiana		8.50	3.50	8.00	(7)	(7)	(7)	(7)	(7)		(7)	(7)	(7)	(7)	10.0	1.0	8.0	1.0
Maine	11.75	8.50	3.25		18.0				[4] 50.0	(12)	26.5	[4] 29.50	26.5	[4] 29.50	14.0	(13)	12.0	(13)
Maryland	12.50		3.50	9.25	18.0						34.3	7.80			4.0		6.0	
Massachusetts	12.15		3.35	[14] 9.30	15.0						(15)	(15)			7.0		7.0	
Michigan	12.50		3.00		18.0	80.0			[4] 30.0	(16)	(7)	(7)	(7)	(7)	10.0	.7	8.0	.7
Minnesota	13.00	9.75	3.25		20.0		16.00		[4] 45.0	(17)	28.0	8.00	25.5	7.80	12.0		12.0	
Mississippi [7]																		
Missouri	12.00	8.75	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.67	28.0	[4] 27.67	14.0		12.0	
Montana	11.75	8.50	3.25		20.0	82.5	16.00								12.0	1.0	10.0	1.0
Nebraska			3.00		18.0										14.0		12.0	
New Hampshire	12.00			8.50	18.0	80.0	16.00		(7)		(7)	(7)	(7)	(7)	14.0	.2	14.0	.2
New Jersey	11.50		3.00	9.25	16.0	82.5			[4] 50.0									
New Mexico [1]																		
Nevada	11.75	8.50	3.25	9.25	18.0	82.5	16.00		[4] 50.0		28.0	[4] 27.50	25.5	7.80	14.0		12.0	
New York	11.50		3.00		18.0					(18)	(19)	(19)						
North Carolina	11.75	8.50	3.25	9.25	18.0	82.5			[4] 50.0		25.5	7.80	25.5	7.80	10.0		8.0	
North Dakota	12.00		3.00		15.0	(7)	(7)	(7)	(7)		(7)	(7)	(7)	(7)	14.0	(20)	12.0	(20)
Ohio	12.00		3.00						(21)		(22)	(22)						

Table 100.—Legal Standards for Dairy Products by States.

(Continued)

Oklahoma [16]																		
Oregon	11.70	8.50	3.20		18.0	80.0	16.00		30.0	(23)			32.3	7.80	12.0	1.0	9.0	1.0
Pennsylvania	12.00		3.25	(7)	18.0	(7)	(7)	(7)	32.0	(24)	(7)	(7)	(7)	(7)	8.0	.5	6.0	.5
Philippine Islands	11.75	8.50	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.50	25.5	7.80	14.0		12.0	
Porto Rico [15]																		
Rhode Island	12.00		2.50			82.5			[4] 50 0		25 0	7.80	25.0	7.80	8.0	1.0	8.0	1.0
South Carolina [1]																		
South Dakota		8.50	3.25	9.25	18.0	80.0			[4] 50.0		28.0	[4] 27.50	28.0	[4] 27.50	14.0		12.0	
Tennessee	12.00	8.50	3.50	9.00	20.0	82.5	15.99		[4] 50.0		25.5	7.80	25.5	7.80	8.0		7.0	
Texas	12.00	8.50	3.25	9.25	18.0	82.5			(7)		(7)	(7)	(7)	(7)	8.0		6.0	
Utah	12.00	8.80	3.20		18.0	80.0	16.00		30.0	(25)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)
Vermont	11.75	8.50	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.50	34.3	7.80	14.0		12.0	
Virginia		8.50	3.25	9.25	18.0	82.5	16.00		[4] 50.0		28.0	[4] 27.50	28.0	[4] 27.50	8.0	(23)	8.0	(23)
Washington	12.00	8.75	3.25	9.30	18.0				30.0	(26)								
West Virginia [1]																		
Wisconsin		8.50	3.00	9.00	18.0	82.5			[4] 50.0		28.0	8.00	28.0	8.00	14.0		12.0	
Wyoming [7]																		
United States		8.50	3.25	9.25	18.0	82.5	[27] 16.00		[4] 50.0		28.0	[4] 27.50	25.5	7.8	14.0		12.0	

1 No State standards.
2 No Territorial standards.
3 Federal standards for all food products. Fillers in ice cream may be used if large label is displayed in all places of sale.
4 Percentage of fat based on total solids.
5 Must be labeled.
6 Classed as condensed.
7 United States standard.
8 United States food and drugs act of 1906 applies to the District of Columbia.
9 Should be labeled.
10 Not allowed.
11 Must be so branded.
12 Defined, but no standard.
13 Any amount if fat is maintained.
14 Solids in fat.
15 Must correspond on stated dilution to State standards for milk.
16 Any less than 30.
17 All below 45.
18 Less than 13 marked skim; 13 to 18, medium skim; 18 or over, special skim.
19 Must correspond to 11.5 per cent solids in crude milk; one-fourth to be fat.
20 Two ounces in 10 gallons if labeled gelatin ice cream.
21 Full cream, 30. Standard, 21.
22 Must correspond to 12 per cent of solids in crude milk; one-fourth to be fat.
23 Less than 7.5, skim; 7.5 to 15, three-fourths skim; 15 to 30, half skim.
24 Three-fourths cream, 24; one-half cream, 16; one-fourth cream, 8. Skim, less than 8.
25 Less than 30.
26 Less than 30; less than 15 not allowed.
27 Less than 16. This applies to all butter made in United States territory.

28 The United States Standards for milk, cream, skim milk and sweetened condensed milk have since been revised as follows: Milk and skim milk, figure standards removed; cream acidity not over .2 per cent; sweetened condensed milk fat 8 per cent.

No reports gave standards for powdered milk.

CHAPTER XXI.

WHEY BUTTER

Whey butter is the butter manufactured from whey, the by-product of the cheese factory. Whey contains from about 0.3 per cent fat in the case of American cheddar cheese making, to about 1 per cent in the case of Swiss cheese making.

Since the invention of centrifugal whey separators, it is possible to skim the whey very exhaustively and there is no consistent reason why the butterfat derived from the whey should not produce a butter equal in quality, or nearly so, to that of ordinary creamery butter, provided that the whey is skimmed promptly after it leaves the cheese vat, or cheese kettle, and that the whey cream is promptly and properly cooled until churned or until shipped. Sammis[1] recommends that the separator cream screw be so set as to secure a whey cream containing from 50 to 75 per cent of fat, so as to permit the addition of a large amount of starter to this cream. He further recommends that on the evening before the day when the whey cream is to be churned about 75 to 100 per cent of a good, thick cold starter be stirred into the cream, that the cream be churned at 50 degrees F. or below, that the churn be stopped when the granules are still very small and washed with water at a temperature from 40 to 50 degrees F. These precautions are recommended in order to facilitate the completeness of washing and because whey butter has a greater tendency than ordinary butter to soften on warming.

Sammis states that buyers of whey cream for churning often pasteurize it when received, by heating it rapidly nearly to boiling, then cooling as quickly as possible, adding starter and churning the next day.

The Federal law does not differentiate between whey butter and creamery butter. Whey butter is subject to the adulterated butter ruling which provides that when butter contains 16 or more per cent moisture it is classed as adulterated butter.

The Legislature of the State of Wisconsin enacted the follow-

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[1] Sammis, Making Whey Butter at Cheddar Cheese Factories, Wisc. Bulletin 246, 1915.

ing law which defines whey butter and provides that all butter made from whey shall be classed, branded and sold as whey butter:

Wisconsin Whey Butter Law

"**Whey Butter Section 4707d-3.**—No person shall by himself, his agent or servant, sell, offer or expose for sale or have in his possession with intent to sell or exchange or deliver, any butter, manufactured in whole or in part, from whey cream, unless such butter shall have the words 'whey butter' conspicuously stamped, labeled, or marked in plain Gothic letters, at least three-eights of an inch square, so that the words cannot be easily defaced, upon two sides of each and every tub, firkin, box or package containing said whey butter; or if such butter is exposed for sale uncovered, or not in a case or package, a placard containing said words in the form described in this section shall be attached to the mass in such a manner as to be easily seen and read by the purchaser. Any person who violates any of the provisions of this section shall be guilty of a misdemeanor and upon conviction thereof, shall be fined not less than twenty-five dollars nor more than one hundred dollars[1]."

RENOVATED BUTTER

Definition: Renovated butter, or process butter, is a product which resembles butter and which is made from one or more parcels of butter, which has been or have been "subjected to any process by which it is melted, clarified or refined and made to resemble genuine butter, always excepting 'adulterated butter' as defined by this act."[2]

In order for butter to be subject to this definition, it must have been melted or reduced to a fluid oil, the melted oil must have been subjected to a process by which it is "clarified or refined," which may be done by skimming, aerating, washing and other processes, through the action of heat, cold, agitation or rest; and this melted and refined oil must then again be converted into a product "to resemble genuine butter," in appearance, consistency, texture and flavor. This last requisite is accomplished by mixing the melted, refined oil with milk, or

[1] Supplement to Wisconsin Dairy and Food Laws of August, 1913, issued by Geo. J. Weigle, Dairy & Food Commissioner, July, 1917.
[2] By Act of Congress approved May 9, 1902.

skimmilk, or buttermilk, or cream, sweet or sour, and by granulating the mix by cooling. Renovated butter may, or may not have added to it, common salt, or harmless coloring matter, or both.

Renovated butter is usually made from an inferior grade of butter, the quality of which is such that the butter is no longer acceptable to the trade as eatable butter. It is made from packing stock.

Development of the Renovated Butter Industry.—The renovated butter industry had its inception in the presence upon the market, of butter of poor quality, that could neither be sold as butter nor made over into a salable quality of "ladles." It had to undergo processes that freed it from its obnoxious odors and flavors of which rancidity was a dominant one, before it could be made again to appeal to the palate. This industry, therefore, owes its existence to faulty methods of manufacture and of storing of butter.

The renovated butter industry, then, is the result of efforts, on the part of the dairymen, butter merchants and others, to convert the surplus of poor country butter, or of packing stock, into a marketable product. The bulk of dairy butter made during the summer months is handled by the country store. For a considerable portion of this butter the country store has no immediate market. The butter accumulates and owing to its inherent poor keeping quality and the usually unfavorable conditions to which it is exposed, it deteriorates rapidly, and by fall it is generally of very poor quality. This butter is a burden to the store keeper and a drag on the market.

Before the days of renovated butter, the only reasonably profitable method of handling this surplus was to rework the different lots together, adding salt and if necessary, color. This gave the product uniformity of body, salt and color. The flavor however, was not improved, except that heavy salting assisted in hiding to a limited extent the undesirable flavors.

In the early eighties, various isolated attempts were made to free this butter from its disagreeable flavors. Levi Wells[1] states that "melting butter and separating the fat from the

[1] Wells, Renovated Butter, Its Origin and History, U. S. Dept. of Agriculture, 1905.

other ingredients, then canning the fat and shipping it to tropical countries to be used as a substitute for butter, was practiced in some sections of Europe many years ago, but restoring the ingredients extracted and again converting the substance into butter is an American invention."

"Renovated butter," began to appear on the markets of this country in considerable quantities in the early nineties. It was generally quoted and sold as creamery seconds. Its source and mode of preparation were unknown to the general public. Its keeping quality was poor.

"The name renovated butter, was first adopted by the dairy and food commission of Pennsylvania, 1897, it being considered appropriate for the product involved, and one that conveyed to the consumer an idea of its nature.

"In 1899 the legislatures of several states enacted laws requiring this product to be labeled and sold as renovated butter, and on May 9, 1902, through passage of the Grout bill, a Federal law became effective, which defined this product, and required its manufacture and sale under the name Renovated Butter, or Process Butter."

Output of Renovated Butter in the United States.—The manufacture of renovated butter during the early years of this country grew rapidly and assumed very considerable proportions. In 1905 there were in operation in this country, according to Wells, 78 renovated butter factories with an investment of nearly $1,000,000.00. The total production during that year was 60,000,000 pounds of renovated butter, and the annual output and demand for the better grades seemed to be limited only by the availability of the packing stock.

Within recent years, however, the output of renovated butter has been on the decline, largely as the result of the introduction and more general use of the farm cream separator, which caused more butterfat to be shipped to the creamery and less to be made into butter on the farm. The rapid development of the creamery industry and the increased demand for milk by the market milk plants, milk condenseries and ice cream factories, have further reduced the annual production of farm butter. Less farm butter is made every year and this means less packing stock available for the renovated butter factory. If the present trend of the butter industry may be accepted as a correct criterion of the future of the renovated butter industry, it may be consistently assumed that the days of the renovated butter industry are numbered, and that it will continue to decline, for the best interests of the milk and cream producer, who cannot afford to sell the product of the dairy cow on the basis of packing stock prices.

Manufacture of Renovated Butter—Quality of packing stock.—The better the quality of the packing stock the better will be the quality of the renovated butter. The packing stock, which largely consists of a poor grade of dairy butter, is gathered up by the renovated butter agents from country stores in all parts of the country where farm butter is made. It is packed in barrels and tubs and placed into cold storage until ready to be made over into renovated butter.

Melting.—The barrels and tubs of packing stock are emptied into the melting tank, which is a tank or vat, equipped in its bottom with a series of coils through which hot water is passed. Jacketed vats, similar to cheese vats, are also used for this purpose. In these vats or tanks, the butter is melted, at a relatively low temperature. The temperature of the melted fat is generally held at about 120 degrees F. or below.

Clarifying.—From the melting vats the butter oil flows into the settling tank, which is usually cylindrical in shape, of considerable depth and has preferably a pointed bottom. Here the butter oil remains until the so-called slush, consisting of curd, water and other impurities, have settled to the bottom. The slush is then drawn off from the bottom and is passed through a centrifugal separator for the purpose of reclaiming any fat that may have escaped with the slush. A hollow bowl separator is preferred for this separation. The residue, which consists largely of curd and is quite solid and dry, is used for the manufacture of paste by treating it with oxalic acid.

Purifying.—The butter oil, thus freed from the slush, is now subjected to prolonged aeration. For this purpose it is conveyed into large, cylindrical, jacketed tanks. A powerful current of purified air is blown through a distributing rosette located in or near the bottom of the tank, violently percolating upward through the melted butter oil. The butter oil is kept in melted condition by the passage of hot water through the jacket of the purifying tank. It is aimed to maintain a temperature of approximately 110 degrees F. This aeration is continued until the liquid fat has became "Neutral," that is until apparently all foreign odor and free acids have been blown out of it.

Addition of Starter.—This butter oil is now without flavor. In order to return to it, the characteristic butter flavor, starter made from skimmilk or whole milk is added. Lactic acid cultures, the same as are used in cream ripening, are employed for making this starter, care being taken that the starter does not become overripe, in which case there would be danger of impregnating the finished renovated butter with white specks. The amount of starter used varies greatly, ranging from about two per cent to fifty per cent. The starter is thoroughly mixed with the butter oil, either in the blower tanks or in special tanks equipped with mechanical agitators.

Coloring.—It is usually not necessary to add color to the mixture. Most of the dairy butter surplus is made during the summer season, when butterfat has naturally a high color. In case the butter oil is deficient in natural color, a sufficient amount of artificial coloring matter is added to suit the market.

Crystallizing.—The emulsion of butter oil and starter is plunged, in the form of a fine stream, into ice water, or water cooled by artificial refrigeration, to a few degrees above the freezing point. This sudden chilling immediately crystallizes the fat, precipitating it in the form of flakes. The crystallizing is accomplished in long vats filled with cold water. The end of the vat that receives the liquid butter oil is equipped with a revolving paddle wheel. The fat drips down into the water slowly, as soon as it strikes the water it solidifies in the form of flakes. The revolving paddle wheel starts these flakes toward the opposite end of the vat, so that the thin stream of melted fat always strikes the cold water direct and does not pile up on the flakes already formed.

In the case the cooling is done in ice water, instead of in water kept cold by artificial refrigeration, cakes of ice are usually anchored in the bottom of the vat, so as to avoid warming up of the water.

Ripening and Hardening.—As the flakes gather at the further end of the crystallizing vat, they are scooped out into large trays, placed on trucks which are subsequently stacked into the ripening or hardening room. Here the butter is allowed to remain at a temperature of about 65 to 70 degrees F. for 12 or more hours. During this period of incubation, the butter ripens, developing flavor. Before salting and working, this butter is usually transferred to and held in a cold room in order to further chill and harden it.

Salting and Working.—Next day these trays are emptied into combined churns and workers, sufficient salt is added and the butter is worked. Close attention is paid to the control of moisture keeping the moisture below 16 per cent, in order to comply with the law defining adulterated butter.

Packing.—The renovated butter thus manufactured is placed on the market in firkins, tubs, wooden boxes, or in prints, bricks or rolls. When packed in tubs or boxes each package must contain not less than ten pounds, and when packed in a solid body or mass, there must be stamped or branded into the upper surface of the butter the words "Renovated Butter," in one or two lines, the letters to be of Gothic style, not less than one-half inch square and depressed not less than one-eighth inch.

The prints, bricks and rolls must weigh not less than one-half pound. Each package must have stamped on the butter the words "Renovated Butter," in two lines, the letters to be of Gothic style, not less than three-eighths inch square and depressed into the butter not less than one-eighth inch.

Every package must be marked on the outside on two sides with the words "Renovated Butter" in Gothic letters, not less than one-half inch square and so placed as to be plainly visible and easily read. The package must also bear the necessary revenue stamps and the manufacturer's declaration, saying that he has complied with the requirements of the law and the regulations authorized thereby. Renovated butter for export must be stamped and marked the same as for the domestic market.

Markets.—The market for good grades of renovated butter is usually active in this country, as well as abroad. Quotations fluctuated before the war at from three to about seven cents below creamery "extras." Then it usually sold about on a par with poor creamery "firsts" or good creamery "seconds." Since the conclusion of the war, renovated butter quotations have dropped very considerably, being as low as ten to fifteen cents below creamery "extras."

Renovated Butter Definitions, Standards and Laws.—By Act of Congress, approved May 9, 1902, renovated butter is defined as follows:[1]

"Sec. 4 . . . . 'Process Butter,' or 'Renovated Butter' is hereby defined to mean butter which has been subjected to any process by which it is melted, clarified or refined and made to resemble genuine butter, always excepting 'adulterated butter,' as defined by this act."

The following explanation of the definition and law on adulterated butter, offered by the Department of Agriculture[2], will assist as guidance in the interpretation of the renovated butter law, as above defined:

"(f) But if, in such process, 'or in any (other) way,' 'any acid, alkali, chemical, or any substance whatever is introduced' or used, or if 'there is mixed (therewith) any substance foreign to butter,' or if in any way the substance is made to hold 'abnormal quantities of water, milk or cream,' the substance or commodity is to be recognized and treated as 'adulterated butter' under this act.

"(g) Renovated butter having 16 per cent or more of moisture will be held to contain 'abnormal quantities of water, milk or cream,' and be, therefore, classed as 'adulterated butter.' "

As a part of the Standards of Purity for Food Products[3] Supplementary to the Federal Food and Drugs Act, which went in force January 1, 1907, renovated butter was defined as follows:

"Renovated butter, process butter, is the product made by melting and reworking, without the addition or use of chemicals or any substances except milk, cream or salt, and contains not more than sixteen (16) per cent of water, and at least eighty-two and five-tenths (82.5) per cent of milk fat."

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[1] Revised Regulations concerning Oleomargine, also Adulterated butter and process or renovated butter, U. S. Internal Revenue Dept., Regulations No. 9. Revised July, 1907.

[2] U. S. Department Agriculture, B. A. I. Order No. 127, 1904.

[3] Standards of Purity for Food Products, U. S. Dept. of Agriculture, Circular No. 19, 1906.

Taxes imposed on the manufacturer and dealer of renovated butter:

Sec. 4, Act of May 2, p. 1906.

"That upon process and renovated butter, when manufactured or sold or removed for consumption for use, there shall be assessed and collected a tax of one-fourth of one cent per pound to be paid by the manufacturer thereof and any fraction of a pound shall be taxed as a pound."

"Manufacturers of process or renovated butter shall pay $50 per year. Every person who engages in the production of process or renovated butter as a business shall be considered to be a manufacturer thereof.

"Every manufacturer of renovated butter, before commencing business or at least within the month in which liability to special tax commenced, must register with the collector of the district in which the business is to be carried on his name, or firm or corporate name, place of residence, nature of business, and the place where such business is to be carried on, and procure a special tax stamp at the rate of $50 per annum, which stamp he shall place and keep conspicuously posted in his establishment or place of business; and on the first day of July in each year he must again so register and procure a new special tax stamp and post it as above stated."

LADLED BUTTER.

The product commonly known as "ladled" butter is a grade of butter made by mixing and reworking different lots or parcels of butter so as to secure a uniform product. This is known by various names to the trade. This product will not be held to be renovated butter unless in addition to being reworked it is melted and refined. It will not be held to be adulterated butter unless materials foreign to statutory butter are added to it, or it is made to contain 16 per cent or more of water. Persons who engage in the production of "ladled" butter as a business will be held liable to special tax as manufacturers of renovated butter if they melt and refine their product, and to special tax as manufacturers of adulterated butter if they use in it substances foreign to statutory butter or produce a butter having 16 per cent or more of water. Persons who sell "ladled" butter which is adulterated, will be liable to special tax as dealers in adulterated butter.

CHAPTER XXII.

STANDARDIZATION, TESTS AND CHEMICAL ANALYSES OF MILK, CREAM, SKIM MILK, BUTTERMILK AND BUTTER

Standardization of Milk and Cream for Butterfat

In commercial creamery operation as well as in experimental work it frequently becomes desirable, and sometimes necessary, to standardize milk or cream of any richness to a definite per cent of fat.

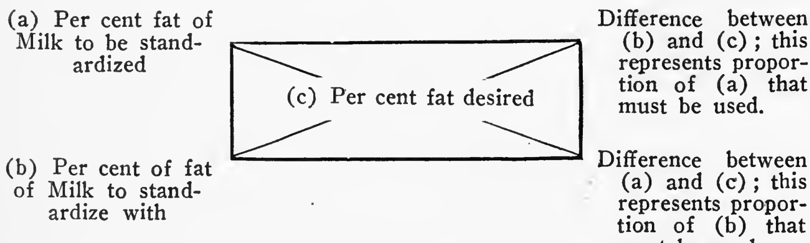
In case the milk is richer than desired, it may be reduced to the desired per cent of fat either (a) by simply adding skim milk, or milk of a per cent of fat lower than that desired, to the milk to be standardized, or (b) by skimming a certain portion of it and returning the skim milk to that portion which was not skimmed. If cream is to be standardized to a lower per cent of fat, the same method as given under (a) for standardizing milk is used, except that in addition to skim milk and milk, cream of a lower per cent fat than that desired may also be used. It is never advisable, and under certain conditions it is unlawful, to reduce the per cent of fat in milk or cream by adding water.

In the case the milk is lower in fat than desired, its fat content can be increased to the desired standard, either (c) by adding to the milk or cream, a sufficient quantity of milk or cream that is richer in fat than that of the standard desired, or (d) by skimming a portion of the milk to be standardized and returning the cream so produced to the portion of milk that was not skimmed.

For the correct determination of the amount of skim milk, milk or cream to be added or the portion of milk to be skimmed, so as to utilize all of the milk or cream which is to be standardized, or of the correct amount of the milk or cream to be standardized and of the skim milk, milk, or cream to be added for standardization in order to obtain the desired volume of standardized mixture, it is necessary to apply a simple and accurate method of calculation. Such a method has been devised by Dr. A. R. Pearson.[1] The following directions for standardization of milk and cream are based on Pearson's method:

[1] A. R. Pearson, formerly Professor of Dairying, Cornell University, and now President Iowa State College, Ames, Iowa.

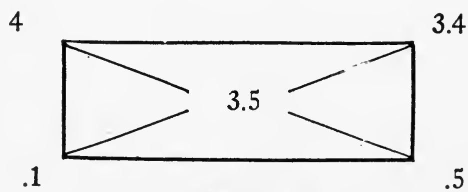
Draw a rectangle as shown below. In the center place the per cent of fat desired. In the upper and lower left hand corners place the per cents of fat contained in the milk or cream to be standardized and in the skim milk, milk or cream to be added. In the upper right hand corner place the difference between the figure in the center and that in the lower left hand corner, and in the lower right hand corner place the difference between the figure in the center and the figure in the upper right hand corner. The figures in the upper and lower right hand corners then represent the correct proportion of the two liquids which are to be mixed. The figure in the upper right hand corner refers to the liquid of which the per cent of fat is given in the upper left hand corner, and the figure in the lower right hand corner refers to the liquid of which the per cent of fat is given in the lower left hand corner.



Examples of How to Reduce Per Cent Fat in Milk or Cream

EXAMPLE 1.

500 lbs. of 4 per cent. milk are to be reduced to 3.5 per cent milk by the use of skim milk containing .1 per cent fat. How much skim milk must be added?

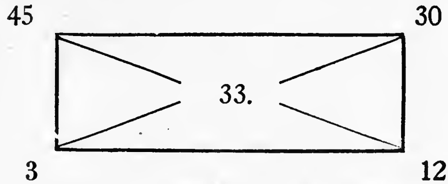


3.4 : .5 = 500 : X; X = 73.5.

73.5 lbs. of skim milk must be used to reduce the 500 lbs. of 4 per cent milk to milk testing 3.5 per cent fat.

EXAMPLE 2.

2,000 lbs. of 45 per cent cream are to be reduced to 33 per cent cream by the use of 3 per cent milk. How much milk must be added?

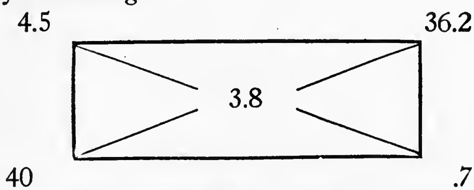


$$30 : 12 = 2000 : X; \ X = 800$$

800 lbs. of 3 per cent milk must be added to the 2000 lbs. of 45 per cent cream in order to reduce the fat in the cream to 33 per cent.

EXAMPLE 3.

1000 lbs. of milk testing 4.5 per cent fat are to be reduced to milk testing 3.8 per cent fat. How much 40 per cent cream must be removed by skimming?



$$36.2 : .7 = 1000 : X; \ X = 19.3$$

19.3 lbs. of 40 per cent cream must be removed from 1000 lbs. of 4.5 per cent milk in order to obtain milk testing 3.8 per cent fat, after the skim milk is returned to that portion of the 4.5 per cent milk which was not separated.

EXAMPLE 4.

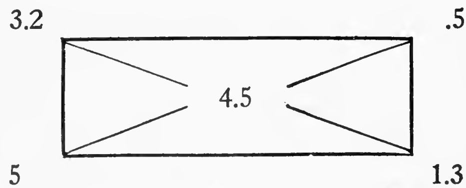
How much of the 4.5 per cent milk in Example 3 must be run through the separator to remove the 19.3 lbs. of 40 per cent cream?

Amount of 40 per cent cream of each 100 lbs. of milk $\frac{4.5}{40} \times 100 = 11.25$ lbs. 40 per cent cream. Hence, $11.25 : 100 = 19.3 : X$; $X = 171.55$. 171.55 lbs. of the 1000 lbs. of 4.5 per cent milk must be separated in order to remove 19.3 lbs. of 40 per cent cream and to reduce the per cent fat in the remaining milk, after the skim milk is returned to it, to 3.8 per cent fat.

Examples of How to Increase Per Cent of Fat in Milk or Cream

EXAMPLE 5.

500 lbs. of milk testing 3.2 per cent fat are to be standardized to secure milk testing 4.5 per cent fat. How much 5 per cent milk must be added?

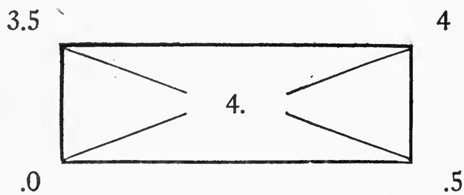


$.5 : 1.3 = 500 : X; \; X = 1300$

1300 lbs. of 5 per cent milk must be added to the 500 lbs. of 3.2 per cent milk in order to secure milk testing 4.5 per cent fat.

EXAMPLE 6.

1000 lbs. of milk testing 3.5 per cent fat are to be standardized to milk testing 4 per cent fat. How much skim milk, containing no fat, must be removed?



$4 : .5 = 1000 : X; \; X = 125$

125 lbs. of skim milk must be removed in order to standardize 1000 lbs. of 3.5 per cent milk to 4 per cent milk.

EXAMPLE 7.

How much of the 1000 lbs. of 3.5 per cent milk must be skimmed in order to remove the 125 lbs. of skim milk required in Example 6?

In order to answer Example 7, the richness of the cream separated must be known. Assuming that the separator is set so as to skim a 30 per cent cream the answer is as follows:

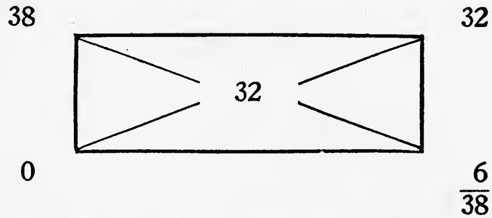
Amount of cream per 100 lbs. of 3.5 per cent milk is $\frac{3.5}{30} \times 100 = 11.67$ lbs. cream.

100 lbs. 3.5 per cent milk yield 11.67 lbs. of 30% cream and 88.33 lbs. skim milk $(100 - 11.67 = 88.33)$.

The removal of 125 lbs. of skim milk necessitates the separation of 88.33 : 100 = 125 : X, or 141.5 pounds of the 1000 lbs. of 3.5% milk.

EXAMPLE 8.

2000 lbs. of 32 per cent cream are wanted. How many pounds of skim milk starter and how many pounds of 38 per cent cream must be mixed?



38 : 32 = 2000 : X; X = 1684 lbs. 38% cream
38 : 6 = 2000 : X; X = 316 lbs. starter.
2000 lbs. 32% cream.

In order to secure 2000 lbs. of 32 per cent cream, 1684 lbs. of 38 per cent cream must be mixed with 316 lbs. of skim milk starter.

TESTING MILK, CREAM AND STARTER FOR ACID

The acidity in milk, cream and starter is intimately related to the flavor and keeping quality of the resulting butter. It is important for the creamery to know the acidity of the milk when it arrives at the factory so as to determine its fitness for manufacture. In the ripening of cream and starter the acidity expresses the degree of ripeness, and in the neutralization of sour cream the acidity must be accurately determined in order to enable the operator to use the correct amount of neutralizer that will reduce the acidity to the desired point. It is important, therefore, that the creamery use systematically a simple, practical and accurate test of milk, cream and starter for acid.

Principle of Acid Tests.—Numerous acid tests have been devised for this purpose, all of which are based on the principle of measuring the per cent acid by the amount of alkali needed to reduce a measured volume of the sample to be tested to the neutral point. These tests are devised on the basis that a given volume of a normal solution of an alkali neutralizes the same volume of a normal solution of an acid. By the term "normal solution" is meant a solution which is so prepared that one liter shall contain the hydrogen equivalent of the active reagent weighed in grams (Sutton).[1]

In other words, a normal solution of an acid is a solution which contains in one liter as much of the active reagent, the acid, as is represented by the molecular weight of the acid in grams. In the case of lactic acid ($C_3H_6O_3$) the molecular weight is 90.

A normal solution of an alkali is a solution which contains in one liter as much of the active reagent, the alkali, as is represented by the molecular weight of the alkali in grams. In the case of caustic soda or sodium hydroxide (NaOH) the molecular weight is 40. Since equal amounts of normal solutions of acids and alkalies neutralize each other, 1 c.c. of *N* Na OH (1 c.c. of a normal solution of caustic soda or sodium hydroxide) neutralizes 1 c.c. of *N* $C_3H_6O_3$ (1 c.c. of a normal solution of lactic acid).

The acid contained in milk, cream and starter is largely lactic acid and is always calculated as such. The alkali used for determining the per cent acid is sodium hydroxide (NaOH), commonly known as caustic soda. In order to know when a liquid is alkaline and when it is acid, or when enough alkali has been added to reduce all the acid and render the liquid neutral, a color indicator is used that shows different color reaction in acids and in alkalies. Of the several indicators available, that known as phenolphthalein is most commonly and most suitably used in acid tests of milk and cream. In acids, such as sour milk, sour cream and starter, phenolphthalein is colorless similar as water. In alkaline solutions, such as sodium hydroxide, phenolphthalein turns to a deep pink color. Hence, when enough sodium hydroxide has been added to milk, cream or starter, to neutralize all the acid, these products turn pink. The moment a permanent faint pink color appears, the test is completed and the number of cubic centimeters of sodium hydroxide needed to produce this permanent faintly pink tint, serves as the basis upon which the per cent acid is calculated.

In order to augment the sensitiveness and accuracy of the test, alkaline solutions, much weaker than a normal solution, are used. In most tests the alkaline solution is a tenth normal solution of sodium hydroxide ($\frac{N}{10}$ NaOH).

The alkaline solution must be of standard strength, it must be accurate, otherwise the test cannot be dependable in its results. It

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[1] Farrington & Woll, Testing Milk and Its Products.

is not feasible for the average creamery which has no chemical laboratory, and no skilled chemist, to weigh out the dry sodium hydroxide and to make up the desired strength solution from it. Attempts to do this work under ordinary creamery conditions almost invariably result in alkaline solutions that are not of standard strength and that yield erroneous tests.

The creamery may, however, purchase standard alkaline solution of a strength suitable to be used without further dilution, or it may purchase a concentrated standard alkaline solution which can be diluted in accordance with the directions furnished on the bottle, or it can purchase the chemically pure, dry sodium hydroxide of exact known weight and dissolve the contents of the entire package in the necessary amount of distilled water, or the sodium hydroxide may be purchased in the form of tablets of known strength, which, when dissolved in a given amount of water, produce the desired standard solution.

Any of the above enumerated forms of alkali will yield standard alkaline solutions, when purchased from a reliable supply house, when diluted with or dissolved in the correct amount of distilled water, or rain water, or other water free from alkalies or acids, and when care is taken that all of the alkali contained in one and the same purchased container is used and that none of it is spilled. For creameries that are not equipped with a chemical laboratory and that do not have the services of a skilled chemist the purchase and use of sodium hydroxide in any of the forms enumerated above will generally place at their disposal uniformly accurate alkaline solutions.

For creameries that maintain their own chemical laboratory, the following method, devised by Hunziker and Hosman,[1] may assist in the further "fool-proofing" of tenth normal alkali solutions: Use a common large stock bottle, a two gallon bottle, such as can be readily purchased from and easily replaced by any drug store. These bottles, when filled to just below the neck, hold 7500 cubic centimeters. Fill them with water to the 7500 c.c. mark and mark the 7500 c.c. level by a scratch on the shoulder of the bottle with a file. Crush in a mortar, or otherwise, sodium sticks and weigh 30 grams of the crushed sticks each into glass tubes. The tubes should

[1] Hunziker and Hosman, A Practical Method for the Preparation of Accurate $\frac{N}{10}$ NAOH Solutions for Acid Tests. Blue Valley Research Laboratory

be constructed of reasonably thin glass, the ordinary test tubes used in the chemical laboratory are very suitable for this purpose. They should have an outside diameter of 7/8 inch and should be about 7 inches long, so that they readily slip through the mouth of the two-gallon bottle.

Seal these tubes by fusing the glass over the flame. In order to make up a tenth normal solution, all the operator has to do is to drop one of these tubes filled with dry sodium hydroxide into the two-gallon bottle. The tube breaks as it strikes the bottom of the bottle, releasing the alkali. Now fill the bottle with water to the scratch on the shoulder. Mix thoroughly by placing hand over mouth of bottle and inverting it several times, until the alkali is all dissolved. This is now a tenth normal solution which is ready for use.

When the solution has been used up, empty the bottle of the remnant of solution and the broken glass tube, drop into the bottle a fresh tube and again fill up with distilled water and mix.

If commercial sodium sticks are used, which are not chemically pure, from 31 to 32 grams are required, according to the extent of impurities present. In this case the sodium hydrate should be carefully titrated against standard acid, so as to determine the exact amount of sodium hydrate to be weighed into the glass tubes that will yield, in the 7500 c.c. of distilled water, a tenth normal solution.

Calculation of Per Cent Acid When a Tenth Normal Solution of Sodium Hydroxide is Used

1 c.c. $\frac{N}{10}$ NaOH neutralizes 1 c.c. $\frac{N}{10}$ $C_3H_6O_3$.

1 c.c. of a $\frac{N}{10}$ lactic acid solution contains .009 grams lactic acid.

Hence, in order to find the per cent acid in milk, cream or starter, multiply the cubic centimeters of alkali solution required to neutralize the milk or cream with .009, divide the product by the grams of milk or cream used and multiply by 100.

$$\frac{\text{c.c. } \frac{N}{10} \text{ alkali solution} \times .009}{\text{grams milk or cream}} \times 100 = \%\ \text{lactic acid.}$$

For all practical purposes the measuring of the milk or cream gives sufficiently accurate results to obviate the less practical and more time-consuming work of weighing. While the size of the sample may vary, factory experience has shown that 18 grams makes a very practical sample. It represents enough material to insure reasonable accuracy and it obviates complex calculations to determine the per cent acid. In the case of milk the 18 grams are measured with the standard 17.6 c.c. Babcock test pipette. In the case of cream an 18 c.c. or possibly a 9 c.c., pipette is used. The cream pipette must be rinsed with water and the rinsings added to the sample.

Example: 7.4 c.c. of tenth normal alkali solution are required to neutralize 18 c.c. of cream to a faint pink color. What is the per cent acid?

$$\frac{7.4 \times .009}{18} \times 100 = .37\% \text{ acid.}$$

Or, for more rapid calculation, simply divide the c.c. alkaline solution required, by 20.

$$\frac{7.4}{20} = .37 \text{ per cent acid.}$$

If instead of an 18 c.c. pipette, a 9 c.c. pipette is used, then only one-half as much alkaline solution, or 3.7 c.c., is required and the per cent acid is calculated as follows:

$$\frac{3.7 \times .009}{9} \times 100 = .37\% \text{ acid.}$$

Or the c.c. alkaline solution required is simply divided by 10.

$$\frac{3.7}{10} = .37 \text{ per cent acid.}$$

Phenolphthalein indicator is prepared by dissolving 1 gram dry phenolphthalein in 100 c.c. of a mixture of one-half alcohol and one-half water.

Standard Acid Tests and their Equipment for Factory Use.—The following are practical and satisfactory acid tests, the equipment and chemicals for which can be readily secured from glassware manufacturers and from dairy and creamery supply houses:

Mann's Acid Test.—Apparatus needed: 50 c.c. graduated burette with burette stand for measuring the alkaline solution; a 50 c.c. pipette for measuring the cream, a white cup and stirring rod or teaspoon.

Reagents needed: $\frac{N}{10}$NaOH (a one-tenth normal solution of sodium hydroxide) and an alcoholic solution of phenolphthalein. Both of these solutions may be purchased from creamery supply houses or chemical supply houses.

Making the Test.—With the 50 c.c. pipette transfer 50 c.c. of the cream into the white cup, rinse pipette with water and add rinsings to sample in cup. Add one-half c.c. of phenolphthalein solution. Fill the 50 c.c. burette with the tenth normal solution of sodium hydroxide. Run this solution slowly from the burette into the white cup, stirring the cream constantly. Each drop of sodium hydroxide will give the cream a pink color which at first immediately disappears. As more of sodium hydrate solution is added the pink color disappears more gradually until, when the neutral point has been reached the pink color of the cream remains constant for several minutes. When this point is reached, that is, when upon stirring a faint pink color remains in the cream, enough sodium hydroxide has been added and the test is completed. Now read off on the graduations of the burette the number of c.c. of decinormal alkali solution that was used and multiply this by the factor .018. ($\frac{.009}{50} \times 100 = .018$). This gives the per cent acid in the cream.

Example.—35 c.c. $\frac{N}{10}$ NaOH are required to neutralize 50 c.c. of cream. What is the per cent acid?

$$\frac{35 \times .009}{50} \times 100, \text{ or } 35 \times .018 = .63\% \text{ acid.}$$

The detection of the pink color is facilitated by adding a pipette full of water to the cream in the cup before titrating.

A Practical Factory Test.—For practical creamery operation the Mann's acid test is modified to the extent of using a 17.6 c.c. pipette for milk or an 18 c.c. pipette for cream instead of a 50 c.c. pipette. Measure 17.6 c.c. or 18 c.c. of the milk or cream to be tested into the white cup. Add 5 drops of phenolphthalein indicator and then add tenth normal alkaline solution from the burette until a permanent faintly pink color appears, stirring the milk or cream in the cup with the rod while adding the alkaline solution. Do not add alkali until the sample is deep pink. If not sure that the neutral point has been reached and that enough alkaline solution has been added, pour one drop of phenolphthalein indicator into cup. If the milk or cream turn pink the test is completed, if no pink color appears, add more alkaline solution from the burette. When the test is completed divide the number of c.c. tenth normal alkaline solution required to produce the pink shade, as indicated on the graduation of the burette, by 20. The result represents per cent acid.

Example.—12 c.c. $\frac{N}{10}$ NaOH are needed to neutralize the 18 c.c. of milk or cream.

$$\frac{12}{20} = .6 \text{ per cent acid.}$$

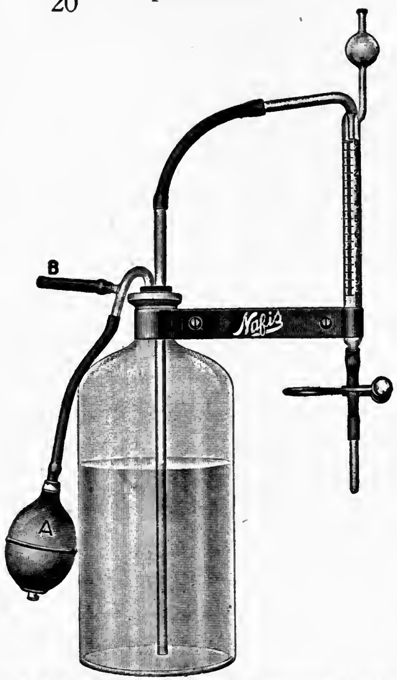

Fig. 85. Nafis Alkali Bottle and Burette for Acid Test
Courtesy of Louis F. Nafis

Farrington Alkaline Tablet Test.—Apparatus Needed. One 100 c.c. graduated glass cylinder with stopper; one 17.6 c.c. Babcock pipette; one white cup.

Reagents.—Farrington Alkaline tablets.

Making the Test.—Dissolve 5 tablets in 97 c.c. water in the glass cylinder. As these tablets require about six hours for complete solution it is advisable to place the tablets in the water in the cylinder on the evening before the day when the solution is to be used; stopper tightly and lay the cylinder horizontally. This insures complete solution by the time the tablet solution is needed. When ready for the test, pour with the pipette 17.6 c.c. cream into the white cup and add tablet solution from the cylinder until the cream remains faintly pink. Then read off the number of c.c. of tablet solution used on the graduations of the cylinder. Each c.c. tablet solution represents .01 per cent acid.

Example.—60 c.c. tablet solution are required to neutralize the cream, in the cup. $60 \times .01 = .6$ per cent acid. The Farrington alkaline tablets are especially convenient because they contain both the alkali and the indicator. They may be purchased from any creamery supply house. They should be kept perfectly dry and in the dark. Otherwise they will weaken and the indicator will bleach out. For maximum accuracy an 18 c.c. pipette should be used for cream.

Marshall Acid Test.—Apparatus Needed. One alkaline solution bottle with graduated burette, one 9 c.c. pipette, one white cup, one bottle for indicator.

Reagents Needed.—Tenth normal solution of sodium hydroxide (neutralizer) and phenolphthalein indicator same as in Mann's test.

Making the Test.—With the pipette pour 9 c.c. of cream into the white cup; add a few drops of indicator. Fill neutralizer bottle with the $\frac{N}{10}$ solution of sodium hydroxide. Fill the graduated burette by tipping the bottle until the burette is full and run neutralizer from the burette into the cream in the cup until the cream remains slightly pink. The number of c.c. of neutralizer solution used, as indicated on the graduation of the burette, represents per cent acidity.

Soxhlet-Henkel Acid Test.—This test is very similar to the previous tests, but instead of expressing the results in number of cubic centimeters of decinormal alkaline solution required, as is the case in Mann's acid test, or in per cent of acid in the cream as is the case of the Farrington Tablet test and the Marshall Acid test, the Soxhlet-Henkel Acid test gives its results in degrees acid. One degree is equivalent to approximately .045 per cent acid or to 2.5 c.c. decinormal alkaline solution of Mann's acid test using 50 c.c. of cream. In this test a one-fourth normal solution of sodium hydrate is used for neutralizing the acid.

Apparatus Needed.—One Soxhlet-Henkel titration apparatus consisting of one 50 c.c. graduated burette with pinch cock; one solution bottle with double perforated stopper and equipped with rubber bulb and connection with burette; one 50 c.c. pipette for measuring cream; one white cup or porcelain dish; one 2 c.c. pipette for measuring the indicator.

Reagents Needed.—One-fourth normal solution of sodium hydrate and an alcoholic solution of phenolphthalein.

Making the Test.—With 50 c.c. pipette pour 50 c.c. of the cream to be tested into the white cup. Add 2 c.c. of the phenolphthalein indicator. Fill the burette to the top graduation with the alkaline solution from the bottle by pressing the rubber bulb. Then draw from the burette enough of the alkaline solution into the cup until after rotating the cup, or stirring the contents, a faint pink color remains. The number of cubic centimeters of the alkaline solution required, as shown on the graduation of the burette, are termed degrees of acid. Each cubic centimeter of the one-fourth normal alkaline solution represents one degree of acid.

This method was later modified by Soxhlet-Henkel to the extent of using 100 c.c. of cream instead of 50 c.c. and increasing the phenolphthalein from 2 c.c. to 4 c.c. Here again each cubic centimeter of one-fourth normal alkaline solution required to neutralize the acid in the cream represents one degree of acid. In this case one degree of acid is equivalent to .0225 per cent acid, or 1.25 c.c. of decinormal alkaline solution of Mann's test. In stating the degree of acid by the Soxhlet-Henkel method it is necessary therefore to know whether they refer to the use of 50 c.c. or of 100 c.c. of cream.

DETERMINATION OF SPECIFIC GRAVITY OF MILK SKIM MILK, CREAM AND BUTTERMILK

Definition.—By the specific gravity of a liquid is meant the weight of a given volume of the liquid, such as milk, skim milk, cream, etc., as compared with the weight of the same volume of water at the same temperature. The specific gravity of water is 1. That is, one cubic centimeter of water weighs one gram. Milk is heavier than water, therefore its specific gravity is greater than that of water. Average milk has a specific gravity of 1.032. The specific gravity is usually determined or calculated at a temperature of 60° F.

The specific gravity of liquids is readily determined by means of instruments called hydrometers. The hydrometer is a floating glass spindle, so constructed that it rests in the liquid to be tested in an upright position. The spindle bears a graduated scale on which the specific gravity, or its equivalent at a given temperature (usually 60° F.), can be read at a glance. In order to make the divisions on the scale as far apart as possible and to thereby make the instrument most sensitive and accurate, different hydrometer scales have been devised and are used for different liquids. The hydrometers used for milk are called lactometers, of which there are two types, namely, the Quevenne lactometer and the New York Board of Health lactometer.

Quevenne Lactometer.—The Quevenne lactometer is the one most generally used for determining the specific gravity of milk and skim milk. It consists of a spindle with a scale graduated from 15 to 40, a weighted bulb, and usually a thermometer. The scale is divided into 25 equal parts, ranging from 15 to 40. Each division is called a degree and every fifth division is numbered on the scale. Each division corresponds to one point of the third decimal of the specific gravity scale. The Quevenne degrees are converted into specific gravity by adding 1000 and dividing by 1000.

Example.—Quevenne Reading is 32. What is the specific gravity?

$$\frac{1000 + 32}{1000} = 1.032 \text{ specific gravity.}$$

The Quevenne lactometer is so constructed that the scale records the correct degree at a temperature of 60° F. At a temperature above 60° F. the reading is corrected by adding one-tenth point to the actual reading for each degree F. above 60. At a temperature below 60° F. deduct one-tenth point for each degree F. below 60.

Fig. 86. Quevenne Lactometer

Courtesy Mojonnier Bros. Co.

Fig. 87. N. Y. Board of Health Lactometer

Courtesy Mojonnier Bros. Co.

Example.—Quevenne reading at 65° F. is 33. What is the corrected reading?

$$33 + .5 = 33.5, \text{ corrected Quevenne reading.}$$

For the use of the Quevenne lactometer provide a glass or tin cylinder about 10 inches high and one and one-half inches wide. Fill the cylinder with the milk to be tested. The temperature of the milk should be within the limits of 50 to 70° F. Insert the lactometer and when it has found its equilibrium, note the point on the scale at the surface of the milk. This represents the Quevenne degrees. The milk should be free from foam. Freshly drawn milk, and skim milk direct from the centrifugal separator will yield too low readings because of the incorporated air. Such milk should be allowed to stand at rest until the air has had a chance to escape.

New York Board of Health Lactometer.—This type of lactometer has an arbitrary scale, it does not show the specific gravity direct. It was originally constructed for the use of milk inspectors in eastern cities, but its use is now only very limited.

It has a graduation from zero to 120. The zero point is the point to which this lactometer sinks in water. The 100 mark is the point to which the scale sinks in milk of a specific gravity of 1.029 at 60° F., which is assumed to be the lowest specific gravity of normal milk, or milk to which no extraneous water has been added. The distance between zero and 100 is divided into 100 equal points and the scale is extended beyond the 100 divisions to 120. To convert New York Board of Health lactometer degrees into Quevenne degrees, multiply the B. of H. reading by .29 and to convert Quevenne degrees into B. of H. degrees divide the Quevenne degrees by .29.

EXAMPLES.

Milk tests 110 B. of H. lactometer degrees at 60° F. What is the Quevenne reading at 60° F.

$$110 \times .29 = 31.9 \text{ degrees Quevenne.}$$

Milk tests 34 degrees Quevenne lactometer at 60° F. What is the B. of H. reading at 60° F.?

$$\frac{34}{.29} = 117.2 \text{ degrees B. of H. lactometer.}$$

Table 101.—Degrees on Quevenne Lactometer Corresponding to Degrees on New York Board of Health Lactometer.

Board of Health Degrees	Quevenne Degrees	Board of Health Degrees	Quevenne Degrees	Board of Health Degrees	Quevenne Degrees
60	17.4	81	23.5	101	29.3
61	17.7	82	23.8	102	29.6
62	18.0	83	24.1	103	29.9
63	18.3	84	24.4	104	30.2
64	18.6	85	24.6	105	30.5
65	18.8	86	24.9	106	30.7
66	19.1	87	25.2	107	31.0
67	19.4	88	25.5	108	31.3
68	19.7	89	25.8	109	31.6
69	20.0	90	26.1	110	31.9
70	20.3	91	26.4	111	32.2
71	20.6	92	26.7	112	32.5
72	20.9	93	27.0	113	32.8
73	21.2	94	27.3	114	33.1
74	21.5	95	27.6	115	33.4
75	21.7	96	27.8	116	33.6
76	22.0	97	28.1	117	33.9
77	22.3	98	28.4	118	34.2
78	22.6	99	28.7	119	34.5
79	22.9	100	29.0	120	34.8
80	23.2				

For temperatures above 60° F. add one lactometer degree for every 3° F. above 60.

For temperatures below 60° F. deduct one lactometer degree for every 3° F. below 60.

The New York Board of Health lactometer is used in a similar manner as the Quevenne lactometer.

Specific Gravity of Cream and Buttermilk.—The aerometric or hydrometer method of determining the specific gravity is not generally suitable for cream and buttermilk. The viscosity of the cream and the usual presence of varying amounts of air in cream render the results unreliable. In the case of buttermilk, the chief objection lies in the fact that when this product is fluid enough to afford reasonably free movement of the lactometer, the curd drops to the bottom rapidly and before a satisfactory reading can be taken; and when the consistency of the buttermilk is such as to prevent the rapid separation of the curd, it is too viscous to permit the hydrometer to find its equilibrium in a reasonable length of time. It is advisable, therefore, to resort to the gravimetric, or picnometer method of determining the specific gravity in cream and in buttermilk.

Gravimetric Determination.—This consists of the filling of a perfectly dry picnometer or other graduated flask of known measure with milk at the standard temperature (60° F., or 15.5° C.) and weighing the flask and contents. The weight of the flask is then deducted from the weight of the flask plus contents and the difference is divided by the weight of an equal volume of water at standard temperature. The result is the specific gravity of the milk.

The Westphal balance method furnishes another accurate means of determining the specific gravity. Both the gravimetric method and the Westphal balance method, while accurate when operated by the skillful chemist, require considerable time. Experimental comparisons have demonstrated that for all practical purposes of testing milk and skim milk the Quevenne hydrometer, when accurately graduated, yields correct results, and the simplicity and rapidity of its operation render its use in the determination of specific gravity of milk and skim milk highly advantageous and satisfactory.

Weight of One Gallon of Butterfat, Water, Milk, Skim Milk and Cream in Pounds.—In the standardization of milk and cream it is necessary to know the amount of milk and cream by weight in pounds and not by measure in gallons. In American creameries the weight of milk and cream is frequently not definitely known. For the convenience of the operator, therefore, a table is here given showing the weight per gallon of these liquids at a temperature of approximately 60° F.

The weight of one gallon of cream obviously varies with its butterfat content. As the cream increases in richness, its specific gravity is lowered and its weight per gallon decreases. The weight of one gallon of cream or any other liquid is determined by multiplying the weight of one gallon of water, which is 8.3389, by the specific gravity of the liquid in question. For example, skim milk has an average specific gravity of about 1.036. One gallon of skim milk therefore weighs $1.036 \times 8.3389 = 8.6391$ lbs.

The specific gravities of cream of different richnesses were calculated by the following formula adopted by and secured through the courtesy of Professor E. H. Farrington[1]:

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1 Farrington, by correspondence, 1916.

Table 102.—Specific Gravity at 60° F. and Weight in Pounds, of One Gallon, of Butterfat, Water, Milk, Skim Milk and Cream.

Kind of Liquid	Specific Gravity at 60° F.	Weight of one Gallon Pounds
Butterfat	0.9300	......
Water	1.0000	8.3389
Milk average	1.0320	8.6057
Skim milk average	1.0360	8.6391
Cream, 10 per cent fat	1.0243	8.5417
15 " " "	1.0186	8.4938
16 " " "	1.0174	8.4843
17 " " "	1.0163	8.4749
18 " " "	1.0152	8.4654
19 " " "	1.0140	8.4560
20 " " "	1.0129	8.4465
21 " " "	1.0118	8.4372
22 " " "	1.0107	8.4278
23 " " "	1.0096	8.4184
24 " " "	1.0085	8.4090
25 " " "	1.0073	8.3997
26 " " "	1.0062	8.3905
27 " " "	1.0051	8.3812
28 " " "	1.0040	8.3719
29 " " "	1.0029	8.3626
30 " " "	1.0017	8.3534
31 " " "	1.0006	8.3443
32 " " "	0.9995	8.3352
33 " " "	0.9984	8.3260
34 " " "	0.9973	8.3168
35 " " "	0.9963	8.3076
36 " " "	0.9952	8.2985
37 " " "	0.9941	8.2894
38 " " "	0.9930	8.2804
39 " " "	0.9919	8.2714
40 " " "	0.9908	8.2624
41 " " "	0.9897	8.2534
42 " " "	0.9886	8.2444
43 " " "	0.9875	8.2354
44 " " "	0.9864	8.2265
45 " " "	0.9854	8.2176
46 " " "	0.9843	8.2087
47 " " "	0.9832	8.1998
48 " " "	0.9821	8.1909
49 " " "	0.9811	8.1821

Table 102.—Continued.

Kind of Liquid	Specific Gravity at 60° F.	Weight of one Gallon Pounds
50 " " "	0.9801	8.1733
51 " " "	0.9790	8.1646
52 " " "	0.9780	8.1558
53 " " "	0.9770	8.1470
54 " " "	0.9760	8.1382
55 " " "	0.9749	8.1294
56 " " "	0.9738	8.1207
57 " " "	0.9728	8.1121
58 " " "	0.9718	8.1035
59 " " "	0.9707	8.0948
60 " " "	0.9637	8.0861
70 " " "	0.9595	8.0007
80 " " "	0.9494	7.9172
90 " " "	0.9396	7.8353
100 " " "	0.9300	7.7552

Specific gravity of fat at 15° C., .93.

Specific gravity of fat-free serum at 15° C. = 1.036.

F = per cent of fat in any cream.

100 — F = per cent of serum.

Volume of fat in 100 grams of cream $= \frac{F}{.93}$ c.c.

Volume of serum in the same cream $= \frac{100\text{-}F}{1.036}$ c.c.

Volume of 100 grams of cream must equal the sum of the above quantities, or $\frac{F}{.93} + \frac{100\text{-}F}{1.036}$ cc.

Since volume in cubic centimeters multiplied by the specific gravity equals the weight in grams

$$\left(\frac{F}{.93} + \frac{100\text{-}F}{1.036}\right) \times \text{specific gravity of cream} = 100.$$

By reduction the following formula is obtained:

$$\text{Specific gravity of cream} = \frac{96.348}{93 + .106\,F}$$

The values in the Table 102 are theoretical and apply only to cream free from air, in which the specific gravities of fat and serum conform to the above assumptions. The actual weights found in most cases will be somewhat less than the weights given in the table because of the varying amounts of air in the cream. They are calculated on the bases of a temperature of approximately 60° F. Cream at a higher temperature will weigh slightly less and cream at a lower temperature will weigh slightly more.

DETERMINATION OF TOTAL SOLIDS IN MILK, SKIM MILK, CREAM AND BUTTERMILK

By Means of the Babcock Formula.—For rapid and reasonably accurate work the total solids of milk may be determined by the use of the Babcock formula, which is as follows:

$$\text{Total solids} = \frac{L}{4} + 1.2 \times f.$$

L = Quevenne lactometer reading.

f = per cent of fat.

Example: Lactometer reading is 32; per cent fat is 4.

$$\text{Total solids} = \frac{32}{4} + 1.2 \times 4 = 12.8 \text{ per cent.}$$

For the determination of the solids not fat use the formula:

$$\frac{L}{4} + .2 \times f. = \text{per cent solids not fat.}$$

or deduct the per cent fat from the per cent total solids.

The Babcock formula for the determination of total solids and solids not fat is applicable only to milk and skim milk. For cream and buttermilk the gravimetric method is recommended. See also Table 103, showing per cent total solids in milk and skim milk when per cent fat and lactometer reading are known.

Gravimetric Method.—"Heat from three to five grams of milk, skim milk or buttermilk at the temperature of boiling water until it ceases to lose weight, using a tared flat dish of not less than 5 c.c. diameter. If desired, from fifteen to twenty grams of pure, dry sand may be previously placed in the dish. Cool in a desiccator and weigh rapidly to avoid absorption of hygroscopic moisture. In the case of cream use only two to three grams of sample."

Table 103.—Per Cent Total Solids, When Per Cent Fat and Quevenne Lactometer Reading at 60° F. are Known.

Fat per cent	Quevenne Lactometer Reading at 60° F.										
	26	27	28	29	30	31	32	33	34	35	36
	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent
0.0	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00
0.1	6.62	6.87	7.12	7.37	7.62	7.87	8.12	8.37	8.62	8.87	9.12
0.2	6.74	6.99	7.24	7.49	7.74	7.99	8.24	8.49	8.74	8.99	9.24
0.3	6.86	7.11	7.36	7.61	7.86	8.11	8.36	8.66	8.86	9.11	9.36
0.4	6.98	7.23	7.48	7.73	7.98	8.23	8.48	8.73	8.98	9.23	9.48
0.5	7.10	7.35	7.60	7.85	8.10	8.35	8.60	8.85	9.10	9.35	9.60
0.6	7.22	7.47	7.72	7.97	8.22	8.47	8.72	8.97	9.22	9.47	9.72
0.7	7.34	7.59	7.84	8.09	8.34	8.59	8.84	9.09	9.34	9.59	9.84
0.8	7.46	7.71	7.96	8.21	8.46	8.71	8.96	9.21	9.46	9.71	9.96
0.9	7.58	7.83	8.08	8.33	8.58	8.83	9.08	9.33	9.58	9.83	10.08
1.0	7.70	7.95	8.20	8.45	8.70	8.95	9.20	9.45	9.70	9.95	10.20
1.1	7.82	8.07	8.32	8.57	8.82	9.07	9.32	9.57	9.82	10.07	10.32
1.2	7.94	8.19	8.44	8.69	8.94	9.19	9.44	9.69	9.94	10.19	10.44
1.3	8.06	8.31	8.56	8.81	9.06	9.31	9.56	9.81	10.06	10.31	10.56
1.4	8.18	8.43	8.68	8.93	9.18	9.43	9.68	9.93	10.18	10.43	10.68
1.5	8.30	8.55	8.80	9.05	9.30	9.55	9.80	10.05	10.30	10.55	10.80
1.6	8.42	8.67	8.92	9.17	9.42	9.67	9.92	10.17	10.42	10.67	10.92
1.7	8.54	8.79	9.04	9.29	9.54	9.79	10.04	10.29	10.54	10.79	11.04
1.8	8.66	8.91	9.16	9.41	9.66	9.91	10.16	10.41	10.66	10.91	11.17
1.9	8.78	9.03	9.28	9.53	9.78	10.03	10.28	10.53	10.78	11.03	11.29
2.0	8.90	9.15	9.40	9.65	9.90	10.15	10.40	10.66	10.91	11.16	11.41
2.1	9.02	9.27	9.52	9.77	10.02	10.27	10.52	10.78	11.03	11.28	11.53
2.2	9.14	9.39	9.64	9.89	10.14	10.39	10.64	10.90	11.15	11.40	11.65
2.3	9.26	9.51	9.76	10.01	10.26	10.51	10.76	11.02	11.27	11.52	11.77
2.4	9.38	9.63	9.88	10.13	10.38	10.63	10.88	11.14	11.39	11.64	11.89
2.5	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.26	11.51	11.76	12.01
2.6	9.62	9.87	10.12	10.37	10.62	10.87	11.12	11.38	11.63	11.88	12.13
2.7	9.74	9.99	10.24	10.49	10.74	10.99	11.24	11.50	11.75	12.00	12.25
2.8	9.86	10.11	10.36	10.61	10.86	11.11	11.37	11.62	11.87	12.12	12.37
2.9	9.98	10.23	10.48	10.73	10.98	11.23	11.49	11.74	11.99	12.24	12.49
3.0	10.10	10.35	10.60	10.85	11.10	11.36	11.61	11.86	12.11	12.36	12.61
3.1	10.22	10.47	10.72	10.97	11.23	11.48	11.73	11.98	12.23	12.48	12.74
3.2	10.34	10.59	10.84	11.09	11.35	11.60	11.85	12.10	12.35	12.61	12.86
3.3	10.46	10.71	10.96	11.22	11.47	11.72	11.97	12.22	12.48	12.73	12.98
3.4	10.58	10.83	11.09	11.34	11.59	11.84	12.09	12.34	12.60	12.85	13.10
3.5	10.70	10.95	11.21	11.46	11.71	11.96	12.21	12.46	12.72	12.97	13.22
3.6	10.82	11.08	11.33	11.58	11.83	12.08	12.33	12.58	12.84	13.09	13.34
3.7	10.94	11.20	11.45	11.70	11.95	12.20	12.45	12.70	12.96	13.21	13.46
3.8	11.06	11.32	11.57	11.82	12.07	12.32	12.57	12.82	13.08	13.33	13.58
3.9	11.18	11.44	11.69	11.94	12.19	12.44	12.69	12.94	13.20	13.45	13.70
4.0	11.30	11.56	11.81	12.06	12.31	12.56	12.81	13.06	13.32	13.57	13.83
4.1	11.42	11.68	11.93	12.18	12.43	12.68	12.93	13.18	13.44	13.69	13.95
4.2	11.54	11.80	12.05	12.30	12.55	12.80	13.05	13.31	13.56	13.82	14.07
4.3	11.66	11.92	12.17	12.42	12.67	12.92	13.18	13.43	13.68	13.94	14.19
4.4	11.78	12.04	12.29	12.54	12.79	13.04	13.30	13.55	13.80	14.06	14.31
4.5	11.90	12.16	12.41	12.66	12.91	13.16	13.42	13.67	13.92	14.18	14.43
4.6	12.03	12.28	12.53	12.78	13.03	13.28	13.54	13.79	14.04	14.30	14.55
4.7	12.15	12.40	12.65	12.90	13.15	13.40	13.66	13.91	14.16	14.42	14.67
4.8	12.27	12.52	12.77	13.02	13.27	13.52	13.78	14.03	14.28	14.54	14.79
4.9	12.39	12.64	12.89	13.14	13.39	13.64	13.90	14.15	14.40	14.66	14.91

Table 103.—Continued.

Fat per cent	Quevenne Lactometer Reading at 60° F.										
	26	27	28	29	30	31	32	33	34	35	36
	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent	Total solids per cent
5.0	12.51	12.76	13.01	13.26	13.51	13.76	14.02	14.27	14.52	14.78	15.03
5.1	12.63	12.88	13.13	13.38	13.63	13.89	14.14	14.39	14.64	14.90	15.15
5.2	12.75	13.00	13.25	13.50	13.75	14.01	14.26	14.51	14.76	15.02	15.27
5.3	12.87	13.12	13.37	13.62	13.87	14.13	14.38	14.63	14.88	15.14	15.39
5.4	12.99	13.24	13.49	13.74	14.00	14.25	14.50	14.76	15.01	15.26	15.51
5.5	13.11	13.36	13.61	13.86	14.12	14.37	14.62	14.88	15.13	15.38	15.63
5.6	13.23	13.48	13.73	13.99	14.24	14.49	14.75	15.00	15.25	15.50	15.75
5.7	13.35	13.60	13.85	14.11	14.36	14.61	14.87	15.12	15.37	15.62	15.87
5.8	13.47	13.72	13.97	14.23	14.48	14.74	14.99	15.24	15.49	15.74	15.99
5.9	13.59	13.84	14.10	14.35	14.60	14.86	15.11	15.36	15.61	15.86	16.12
6.0	13.71	13.96	14.22	14.47	14.72	14.98	15.23	15.48	15.73	15.98	16.24
6.1	13.83	14.08	14.34	14.59	14.84	15.10	15.35	15.60	15.85	16.10	16.35
6.2	13.95	14.20	14.46	14.71	14.96	15.22	15.47	15.72	15.97	16.22	16.48
6.3	14.07	14.32	14.58	14.83	15.08	15.34	15.59	15.84	16.09	16.34	16.60
6.4	14.19	14.44	14.70	14.96	15.20	15.46	15.71	15.96	16.21	16.46	16.72
6.5	14.31	14.56	14.82	15.08	15.32	15.58	15.83	16.08	16.33	16.58	16.84
6.6	14.43	14.68	14.94	15.20	15.44	15.70	15.95	16.20	16.45	16.70	16.96
6.7	14.55	14.80	15.06	15.32	15.56	15.82	16.07	16.32	16.57	16.82	17.08
6.8	14.67	14.92	15.18	15.44	15.68	15.94	16.19	16.44	16.69	16.94	17.20
6.9	14.79	15.04	15.30	15.56	15.80	16.06	16.31	16.56	16.81	17.06	17.32

TESTING MILK, CREAM, SKIM MILK AND BUTTER-MILK FOR BUTTERFAT

Volumetric Methods

The Babcock Test

Principle of Babcock Test.—The principle of the Babcock test is based on the fact that when sulphuric acid in sufficient strength and amount is added to milk, cream or other dairy product, the acid breaks down the non-fatty constituents without materially affecting the fat. The action of the acid, together with the heat generated, destroys the emulsion of fat-in-milk serum, causing the fat to separate out. The completeness of this separation is facilitated by subjecting the mixture of acid and milk to centrifugal force.

In order to make possible the ready measurement of this practically pure, separated fat in terms of per cent, the neck of the test bottle, in which the fat appears in the finished test, is graduated. Each one per cent graduation has a capacity of .2 cubic centimeter. The specific gravity of butterfat at about 135 degrees F., which is the temperature at which the test is read, averages .9. The .2 cubic centimeter of butterfat therefore weighs $.2 \times .9 = .18$ grams. In order to have .18 grams butterfat represent 1 per cent of the milk or cream tested, $.18 \times 100$ or 18 grams of milk or cream must be used.

In the case of milk, the sample, for convenience's sake, is measured, instead of weighed into the test bottle. The average specific gravity of milk is 1.032. Hence 18 grams of milk have a volume of $\frac{18}{1.032}$ or 17.44 cubic centimeters. But when milk is poured from the pipette, approximately .15 c.c. remain in the pipette and fail to be discharged into the test bottle. For this reason a poured from the pipette, approximately .15 c.c. remain in the pipette delivers 18 grams of milk.

In the case of cream, the specific gravity varies very greatly with the richness of the cream and the amount of foam it contains, hence the measuring of the cream into the test bottle introduces considerable error. For this reason the cream is weighed, and not measured, into the test bottle, using 18 grams. In the course of the development of the Babcock test for cream, it was found desirable to reduce the charge of cream used for the test from 18 grams to 9 grams, and accordingly the percentage graduation in these cream test bottles was modified to the effect that each 1 per cent of the graduation has a capacity of .1 cubic centimeter which corresponds to .09 grams of butterfat. In the use of these so-called 9 gram cream test bottles, therefore, $.09 \times 100$, or 9 grams of cream are weighed into the test bottle and the graduation again represents per cent.

SPECIFICATIONS FOR STANDARD APPARATUS AND CHEMICALS FOR TESTING MILK AND CREAM FOR BUTTERFAT BY THE BABCOCK TEST[1]

1. Apparatus and Chemicals.

Milk Test Bottle.—8 per cent 18 gram milk test bottle, graduated to 0.1 per cent. Graduation—The total per cent graduation shall be 8. The graduated portion of the neck shall have a length of not less than 63.5 mm. (2½ inches). The graduation shall represent whole per cent, five-tenths per cent and tenths per cent. The tenths per cent graduations shall not be less than 3 mm. in length; the five-tenths per cent graduations shall be 1 mm. longer than the

[1] Hunziker, Journal of Dairy Science, Vol. I, No. 1, May, 1917.

tenths per cent graduations, projecting 1 mm. to the left; the whole per cent graduation shall extend at least one-half way around the neck to the right and projecting 2 mm. to the left of the tenths per cent graduations. Each per cent graduation shall be numbered, the number being placed on the left of the scale.

The maximum error in the total graduation or in any part thereof shall not exceed the volume of the smallest unit of the graduation.

Neck.—The neck shall be cylindrical and of uniform internal diameter throughout. The cylindrical part of the neck shall extend at least 5 mm. below the lowest and above the highest graduation mark. The top of the neck shall be flared to a diameter of not less than 10 mm.

Bulb.—The capacity of the bulb up to the junction of the neck shall be not less than 45 cc. The shape of the bulb may be either cylindrical or conical with the smallest diameter at the bottom. If cylindrical, the outside diameter shall be between 34 and 36 mm.; if conical, the outside diameter of the base shall be between 31 and 33 mm., and the maximum diameter between 35 and 37 mm.

The charge of the bottle shall be 18 grams.

The total height of the bottle shall be between 150 and 165 mm. (5⅞ and 6½ inches).

Cream Test Bottle 1.—50 per cent 9 gram short-neck cream test bottle, graduated to 0.5 per cent. Graduation—the total per cent graduation shall be 50. The graduated portion of the neck shall have a length of not less than 63.5 mm. (2½ inches). The graduation shall represent 5 per cent, 1 per cent, and 0.5 per cent. The 5 per cent graduations shall extend at least half-way around the neck (to the right). The 0.5 per cent graduations shall be at least 3 mm. in length, and the 1 per cent graduations shall have a length intermediate between the 5 per cent and the 0.5 per cent graduations. Each 5 per cent graduation shall be numbered, the number being placed on the left of the scale.

The maximum error in the total graduation or in any part thereof shall not exceed the volume of the smallest unit of the graduation.

Neck.—The neck shall be cylindrical and of uniform internal diameter throughout. The cylindrical part of the neck shall extend at least 5 mm. below the lowest and above the highest graduation mark. The top of the neck shall be flared to a diameter of not less than 10 mm.

Bulb.—The capacity of the bulb up to the junction of the neck shall not be less than 45 cc. The shape of the bulb may be either cylindrical or conical with the smallest diameter at the bottom. If cylindrical, the outside diameter shall be between 34 and 36 mm.; if conical, the outside diameter of the base shall be between 31 and 33 mm. and the maximum diameter between 35 and 37 mm.

The charge of the bottle shall be 9 grams. All bottles shall bear on top of the neck above the graduations, in plainly legible characters, a mark defining the weight of the charge to be used (9 grams).

The total height of the bottle shall be between 150 and 165 mm. (5⅞ and 6½ inches), same as standard milk test bottles.

Cream Test Bottle 2.—50 per cent 9 gram long-neck-cream test bottle, graduated to 0.5 per cent. The same specifications in every detail as specified for the 50 per cent 9 gram short-neck bottle shall apply for the long-neck bottle with the exception, however, that the total height of this bottle shall be between 210 and 235 mm. (8¼ and 9 inches), that the total length of the graduation shall be not less than 120 mm., and that the maximum error in the total graduation or in any part thereof shall not exceed 50 per cent of the volume of the smallest unit of the graduation.

Cream Test Bottle 3.—50 per cent 18 gram long-neck cream test bottle, graduated to 0.5 per cent. The same specifications in every detail as specified for the 50 per cent 9 gram long-neck bottle shall also apply for the 18 gram long-neck bottle, except that the charge of the bottle shall be 18 grams. All bottles shall bear on top of the neck above the graduation, in plainly legible characters, a mark defining the weight of the charge to be used (18 grams).

Pipette, capacity 17.6 cc. Total length of pipette not more than 330 mm. (13¼ inches). Outside diameter of suction tube 6 to 8 mm. Length of suction tube, 130 mm. Outside diameter of delivery tube, 4.5 to 5.5 mm. Length of delivery tube, 100 to 120 mm. Distance of graduation mark above bulb, 15 to 45 mm. Nozzle straight. To deliver its contents when filled to the mark with water at 20° C., in five to eight seconds. The maximum error shall not exceed 0.05 cc.

Acid measure, capacity 17.5 cc.

Cream Testing Scales.—Sensibility reciprocal of 30 mgm., i. e., the addition of 30 mgm. to the scales, when loaded to capacity, shall cause a deflection of the pointer of at least one division on the graduation.

Weights.—9 gram weights for 9 gram cream test bottles and 18 gram weights for 18 gram cream test bottles, preferably stamped correct by the United States or State Bureau of Standards.

Tester.—Standard Babcock test centrifuge and speed indicator.

Dividers for measuring fat column.

Water bath for cream samples, with proper arrangement for regulating and recording temperature of samples.

Water bath for test bottles, of sufficient size and with necessary equipment to insure proper control of temperature. The following dimensions for a twenty-four bottle water bath are recommended: Metal box, 14 inches long, 11 inches wide, and 8½ inches deep and equipped with a bottle basket 9½ inches long and 6½ inches wide, capacity twenty-four bottles, a steam and water inlet, a drain, a thermometer holder with thermometer.

Chemicals.—Commercial sulphuric acid, specific gravity 1.82 to 1.83; glymol, or white mineral oil, high grade.

OPERATION OF THE BABCOCK TEST

Milk Test

Milk Samples.—The sampling of milk is fully discussed in Chapter VI on "Receiving Milk and Cream."

Preparation of Milk Sample for the Test.—Before testing, the samples should be brought to the proper temperature; this may range from 55 degrees to 70 degrees F. If the samples have been exposed to summer heat or to temperatures near the freezing point, the sample bottles are best set into a tank, sink, or tub and allowed to stand in water at about 60 degrees F. until the temperature of the milk is neither below 55 degrees F. nor above 70 degrees F.

If to be transported by mail, express, or otherwise, the sample bottle should be completely full and tightly stoppered and the samples should be preserved as previously directed, see Chapter VI.

The contents of each bottle must be thoroughly mixed before pipetting into the test bottle. If the composite sample has received the proper care, as directed in Chapter VI, the gentle shaking of the sample bottle and the pouring of the contents from one bottle to another several times should be sufficient.

Fig. 88 **Fig. 89** **Fig. 90** **Fig. 91**

Standard Babcock Milk and Cream Test Bottles
Courtesy Louis F. Nafis

Samples containing lumps of cream or granules of butter cannot be tested properly without extra preparation. They should be heated to at least 110 degrees F., or until all lumps of butterfat have melted and disappeared; they should then be shaken vigorously and pipetted into the test bottle at once. Even with this precaution it is difficult to transfer to the test bottle a representative portion from such a sample. Avoid incorporation of air bubbles while mixing the sample.

Curdy and churned samples are not dependable. Sour and curdy samples should be treated as follows: add one-half teaspoonful of soda lye or potash lye, shake, and let stand until all lumps of curd have disappeared. The sample is then ready for the test. When testing samples to which soda lye or other alkali has been added, the acid should be added slowly and carefully to avoid accidents and to prevent the loss of a portion of the contents of the bottle by excessive effervescence.

Measuring the Milk Into the Test Bottle.—Use standard milk test bottles and a standard 17.6 cubic centimeter pipette. Measure 17.6 cubic centimeters (representing 18 grams) of the properly prepared sample into the test bottle. In order to do this rapidly, and without spilling, the delivery tube of the standard pipette has been constructed of such diameter, that this tube readily drops into the neck of the standard 8 per cent milk test bottle. Hence drop the delivery tube of the pipette into the neck of the test bottle until the bulb of the pipette rests on the neck of the bottle, then release the milk. Blow the last drop of milk out of the pipette before removing it from the bottle. Mark each bottle with a number corresponding with the number of the respective patron on the sample bottle. The marking is best done with an ordinary lead pencil on the etched shoulder of the test bottle. Or equip the test bottles with metal tags which bear consecutive numbers. Slip one tag over the neck of each test bottle. In this case the test bottle number may and usually does differ from the patron's number shown on the sample bottle. It is necessary therefore, to record the test bottle number on the test report blank opposite the respective patron's name or number at the time of filling each test bottle.

Adding the Acid.—Use commercial sulphuric acid, specific gravity 1.82 to 1.83. The temperature of the acid should be the same as that of the milk, 55 degrees F. to 70 degrees F. In order to insure the proper temperature of the acid it is advisable to set the acid bottle into the tank containing the milk sample bottles.

Add 17.5 cc. of acid to the milk in the test bottle and mix by giving the bottle a rotary motion until the lumps of curd are completely dissolved and the mixture presents a brown-black color. It is advisable to add the acid in about three installments, shaking the bottle after each addition. Attention to this precaution helps to secure clear tests.

Whirling and Adding Water.—Set the test bottles into the Babcock centrifuge. If the test bottles containing the mixture of milk and acid are held over and allowed to become cool, they **should be heated by setting in hot water before whirling.**

Steam turbine and electric driven testers with not less than twenty-four pockets are best adapted for factory use. They are constructed of two general sizes,—those having a twelve-inch diameter wheel and those having an eighteen-inch diameter wheel.

Table 104.—Correct Speed of Testers of Different Diameters[1]
Measuring from Pocket Bottom to Opposite Pocket Bottom

Diameter of Wheel Inches	Revolutions of Wheel per Minute
10	1,074
12	980
14	909
16	848
18	800
20	759
22	724
24	693

Fill the bottles to the bottom of the neck with hot, soft water; whirl again for two minutes and fill the bottles with hot, soft water to about the 7 per cent mark; whirl for one minute. The temperature of the water added should be not lower than 140 degrees F. and preferably near that of boiling water (212 degrees F).

Reading the Test.—Place the test bottles in a water bath and read after a temperature of 130° F. to 140° F. has been maintained for not less than three minutes. Measure the fat column with a pair of dividers, including the meniscus or curve, both at the bottom and at the top of the fat column. Each subdivision represents .1 per cent; each main division represents 1 per cent. Record the percentage of fat thus found on the test sheet.

Abnormal Appearance of the Fat Column.—When the test is made properly and in accordance with above directions, the fat

[1] Farrington & Woll, Testing Milk and Its Products.

column is clear, translucent, has a golden yellow or amber color and the top and bottom curves are sharply defined.

The presence of whitish curd in or immediately below the fat column is the result of excessively cold milk and acid, or the use of too little or too weak acid. The presence of charred matter in the fat column is the result of the use of too much or too strong acid, or too high a temperature of milk or acid, or both, at the time of adding the acid.

The appearance of foam on the surface of the fat column is caused by the use of hard water. The carbonates, when acted on by the sulphuric acid, break down, liberating carbon dioxide gas which, rising through the fat column, gathers on its surface in the form of air bubbles. Where soft water, distilled water, or rain water is not available, the water may be softened by boiling it or by the addition to it of a few drops of sulphuric acid before use.

All tests which are milky, or foggy, showing the presence of curd or charred matter in or below the fat column, or of which the reading is indistinct or uncertain, should be rejected. Duplicate tests are essential in all work where special accuracy of results is required, such as in official testing and experimental investigations.

Cream Test

Cream samples.—The taking of cream samples, at the factory, at the cream station and on the cream route is fully discussed in Chapter VI on "Receiving Milk and Cream."

Cream samples should be tested as soon as possible and not later than three days after they are taken. Composite samples representing portions of consecutive deliveries of the same patron are prone to be unreliable. Samples should at all times be kept in non-absorptive containers, sealed air-tight and held in the cold.

Immediately before testing, mix the sample until it pours readily and a uniform emulsion is secured. If in good condition shake, pour, stir or blow until properly mixed. If very thick, warm to 85 degrees F. and then mix. In case of lumps of butter, heat the sample to from 100 degrees F. to 120 degrees F. by setting in water bath, mix thoroughly and weigh out at once. For commercial work on a large scale it is advisable to temper all samples to 100 degrees to 120 degrees F. in a water bath previous to mixing. Great care should be exercised to avoid overheating the sample, causing the

Fig. 93. Acid Dipper for Cream [1]

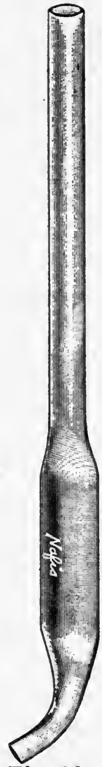

Fig. 94
Cream Pipette [1]

Fig. 92
Standard
Milk Pipette [1]

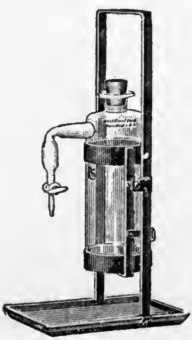

Fig. 95
Combined
Acid Bottle [2]

Fig. 96
Acid Cylinder [1]

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[1] Courtesy Louis F. Nafis.
[2] Courtesy Mojonnier Bros. Co.

cream to "oil off." This precaution is especially necessary with thin cream.

Cream Test Bottles.—Use standard 50 per cent 9-gram short-neck, or standard 50 per cent 9-gram long-neck, or standard 50 per cent 18-gram long-neck cream test bottles. The divisions on each of the three standard cream test bottles represent .5 per cent, 1 per cent and 5 per cent. The 5 per cent divisions bear a figure to the left of the graduation.

Cream Test Balances.—Only high-class balances which are in satisfactory operating condition should be used. The reliability of the cream test balance depends in the first place on its sensitiveness and capacity. Experiments conducted with different types of cream testing scales by Hunziker, Spitzer and Ogle[1] showed the following results and conclusions:

1. Results of tests of 4623 cream samples made in commercial creameries show that where the one-bottle balances were used, 96.43 per cent of the tests checked with the retests within .5 per cent, while the best performance of the twelve-bottle balance yielded only 80.43 per cent of tests that checked with the retests.

2. Balances with a sensibility reciprocal of .01 to .03 grams produced tests, 98.2 per cent of which checked with the retests, and the average variation between duplicate tests was .119 per cent.

3. Balances with a sensibility reciprocal of .1 gram yielded only 36.1 per cent of tests which checked with the retests, and the average variation between duplicate tests was .993 per cent.

4. The condition, care and manipulation of the cream test balance greatly influence its sensitiveness, reliability and length of usefulness.

5. The general adoption of standard cream test balances with a sensibility reciprocal of thirty milligrams would materially augment the reliability of cream tests.

6. Preference should be given to small capacity balances.

7. Balances, with a graduated beam which carries a traveling poise are less reliable than those with a beam of equal arms, balancing in the center and requiring the use of separate weights.

8. Balances of simple principle and construction are generally superior under average commercial conditions, retain their sensibility reciprocal longer and are more durable than balances of more complex principle and construction.

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[1] Hunziker, Spitzer and Ogle, Cream Testing Scales, Purdue Bulletin 189, 1916.

SPECIFICATIONS AND TOLERANCES FOR STANDARD CREAM TEST BALANCES

UNITED STATES BUREAU OF STANDARDS[1]

Definition.—A cream-test or butterfat-test scale is a scale especially designed and adapted for determining the fat content of cream or butter.

Specifications.—1. *All scales shall be provided with a graduated scale or arc divided into at least 10 equal spaces, over which the indicator shall play.*

2. The clear interval between the graduations on the graduated scale or arc shall not be less than 0.05 inch.

3. The indicator shall be of such length as to reach to the graduated divisions and shall terminate in a fine point to enable the readings to be made with precision.

4. All scales whose weight indications are changed by an amount greater than one-half the tolerance allowed, when set in any position on a surface making an angle of 5 per cent or approximately 3 degrees with the horizontal, shall be equipped with leveling screws and with a device which will indicate when the scale is level. The scale shall be rebalanced at zero each time its position is altered during this test.

5. All scales shall be so constructed and adjusted that when the pans are released or disturbed, the pointer will return to its original position of equilibrium.

Sensibility Reciprocal.—The maximum sensibility reciprocal allowable for these scales shall not exceed one-half grain, or approximately 30 milligrams, when the maximum load is placed upon the scale.

(The term "sensibility reciprocal" means the weight required to move the position of equilibrium of the beam, pan, pointer, or other indicating device of the scale a definite amount. In scales provided with a pointer and a graduated scale or arc, such as the above, the sensibility reciprocal is the weight required to cause a change in the position of rest of the pointer equal to one division on the graduated scale or arc.)

Tolerances.—The tolerance to be allowed in excess or deficiency on all cream-test and butterfat-test scales shall not be

[1] United States Bureau of Standards, Tolerances and Specifications for Weights and Measures, Proceedings of Tenth Annual Conference on the Weights and Measures of the United States, May 25-28, 1915.

greater than one-half grain or approximately 30 milligrams, when the scale is loaded to capacity."

Manipulation of Balance.—1. Level the balance each time before using.

2. Adjust or balance the instrument immediately before weighing and make sure that its beam swings freely and does not "stick."

3. Protect the balance from air currents. If resting on an open bench have the nearest doors and windows closed. The setting of the balance in a box large enough for convenient operation and with the near side open is recommended.

4. Use accurate weights only and be sure that they are clean.

5. Don't release the balance with a jerk so that the pans strike the rest; release them easily and slowly and handle them gently when they are moved. Careless and rough handling may damage spring bands and dull knife edges.

6. Don't try to use the balance when out of repair.

7. Use painstaking care and reasonable judgment in all operations.

SPECIFICATIONS FOR STANDARD NINE AND EIGHTEEN GRAM WEIGHTS

1. Weights shall be made of brass or aluminum.

2. Weights shall have smooth surfaces and no sharp points or corners.

3. Weights shall not be covered with a soft or thick coat of paint or varnish.

4. All weights shall be clearly marked with their nominal value i. e. 9 for nine gram weights and 18 for eighteen gram weights.

5. The tolerance shall be forty milligrams for nine gram weights and fifty milligrams for eighteen gram weights.

Weighing the Cream Into the Test Bottle.—The cream must be weighed into the test bottle, not measured. This is necessary in order to secure the correct amount by weight. Cream varies in weight with its richness and its mechanical condition, and no one measure will hold the correct amount of cream of varying richness. The correct amount of cream by weight is 9 grams or 18 grams, respectively.

Set the cream test bottles on the scales and balance the scales accurately. The cream is most readily transferred into the test bottles from the properly mixed sample by means of a 9 or 18 cc. pipette which has a short, wide-bore delivery tube. In this manner spilling is readily avoided and the work is most rapid. If any cream is spilled over the outside of the bottles or on the balance, it should be wiped off immediately and before the weighing is completed.

Making the Test.—Three methods of performing the test have been adopted as standard methods; each of which, when properly executed, insures accurate results, but methods II and III are preferred to method I, as they leave less to the judgment of the operator and therefore are more nearly "fool-proof:"

Fig. 97. Jalco Electric Centrifuge
Courtesy Jalco Motor Co.

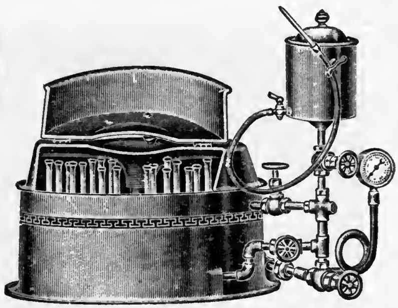

Fig. 98. Facile Steam Turbine Tester
Courtesy D. H. Burrell & Co.

Method I. Add standard commercial sulphuric acid until the mixture of acid and cream, immediately after shaking, resembles in color, coffee with cream in it. Usually about 8 to 12 cc. of acid is required in the case of the 9-gram bottle or 14 to 17 cc. of acid in the case of the 18-gram bottle, the amount needed depending on the temperature of acid and cream and on the richness of the cream.

Whirl in Standard Babcock centrifuge at proper speed, five, two and one minutes, respectively, filling the bottles with hot, soft water, temperature 140° F. or above, to the bottom of the neck after the first whirling and to near the top graduation after the second whirling.

Method II. Add 9 cc. of water after the cream has been weighed into the test bottle and before the acid is added, then add 17.5 cc. acid and proceed as in previous method. This method is applicable with the 9-gram bottle only.

Method III. Add 8 to 12 cc. of acid in the case of the 9-gram bottle or 14 to 17 cc. of acid in the case of the 18-gram bottle, or add acid until the mixture of cream and acid, after shaking, has a chocolate brown color. After the cream and acid have been thoroughly mixed and all lumps have completely disappeared, add a few cubic centimeters (not less than 5 c.c.) of hot, soft water, whirl five minutes, add hot, soft water to near top of scale and whirl one minute.

The proper speed of the centrifuge is 800 revolutions per minute for an 18-inch diameter wheel and 1000 revolutions per minute for a 12-inch diameter wheel.

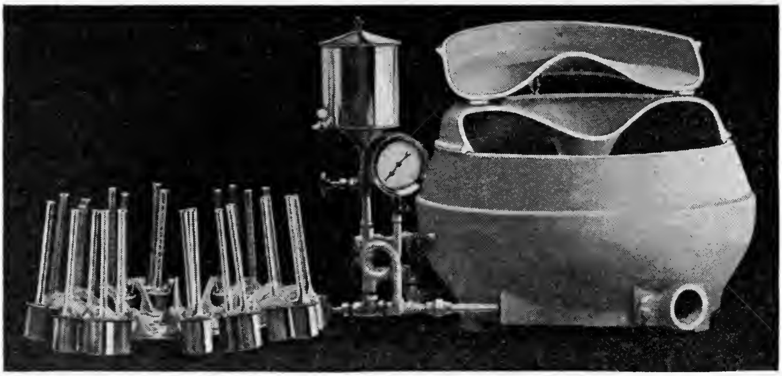

Fig. 99. Babcock Tester
Courtesy Davis-Watkins Dairymen's Mfg. Co.

Reading the Cream Test.—Place the test bottles into the water bath and read after a temperature of 130 to 140 degrees F. has been maintained for not less than three minutes. Just before reading the test and when taking the bottles from the water bath, add a few drops of glymol. The glymol removes the meniscus or curve on top of the fat column, leaving a straight line which is sharply defined and readily seen.

Measure the fat column, preferably using dividers, and record the percentage of fat on the test sheet, opposite the test bottle number of the respective patron.

Purpose and Use of Glymol.—Glymol is a high quality of white mineral oil, similar to typewriter oil. It is slightly lighter than butterfat and therefore floats on top of the fat column.

The object of using glymol is to remove the meniscus or curve present at the top of the fat column. This curve, owing to refraction of the light, is indistinct and renders correct reading difficult. When a few drops of glymol are placed on top of the fat column, the meniscus disappears and a straight, sharply defined line is formed

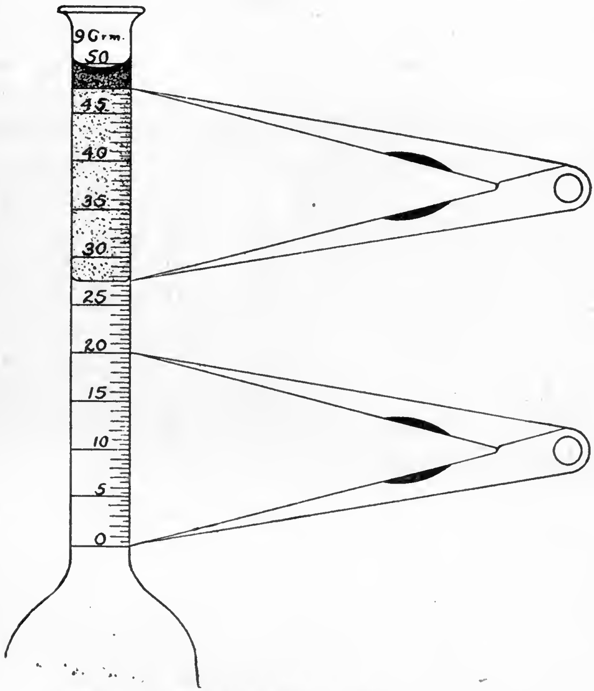

Fig. 100. Reading Cream Test

between the top of the fat and the bottom of the glymol. In this condition the test can be read easily and accurately.

For the best results the glymol should be added immediately before reading. The glymol may be conveniently transferred to the test bottle from a pipette, burette, or by squirting from a small oil can.

Experienced testers are able to secure correct readings without glymol by reading to the bottom of the upper meniscus, but the use of glymol is urged for maximum accuracy.

Glymol should be used in the reading of the cream test only; the milk test should be read without glymol, otherwise the results of the milk tests would be too low. Experimental results by Hunziker[1] have indicated that in the milk test the meniscus compensates for the loss of residual fat. It therefore must be included in the reading. In the cream test the proportion of residual fat lost is very small and is amply compensated for by the usual impurities in the fat column.

Coloring Glymol.—Some operators prefer the use of colored glymol, though equally satisfactory results are obtained with the uncolored glymol. Glymol is best colored with an aniline dye. A dye that is sold under the trade name "oil red" proves highly satisfactory for this purpose. Add 1 gram of oil red to 4 gallons glymol.

Abnormal Appearance of Fat Column.—When the cream test has been properly performed the fat column in the neck of the bottle is clear, translucent and free from milky, curdy and charred matter in or below the fat. Any tests in which the fat column is not free from visible impurities, or in which the fat column rests on a layer of non-fatty material, or of which the reading is otherwise indistinct or uncertain, should be rejected. See also abnormal appearance of fat column of milk tests.

Testing Skim Milk, Buttermilk and Whey for Butterfat

Test Bottles.—For the Babcock test of skim milk, buttermilk and whey use bottles with double necks, which are especially constructed for this purpose. The graduation of these bottles varies somewhat with the make of bottle. In some bottles the total graduation is .25 per cent and the subdivisions represent .01 per cent. In others the total graduation is .5 per cent and the subdivisions represent .05 per cent.

Making the Test.—Measure the properly mixed skim milk into the test bottles with the 17.6 cc. pipette used for milk testing. Add 20 cc. of sulphuric acid. For best results add the acid in several installments and shake until all the lumps of curd have completely disappeared. Whirl in tester for 10 minutes.

[1] Hunziker, Indiana Agricultural Experiment Station Annual Report, 1914.

Special attention should be given when the bottles are placed into the tester. Test bottles in which the lower end of the funnel-neck extends perpendicularly along the side of the bulb to the bottom of the bottle, should be so placed that the funnel-neck faces the center of the tester, otherwise the fat rises into the funnel-neck. Test bottles in which the lower end of the funnel-neck extends diagonally to the bottom of the bottle should be so placed that the graduated neck faces the center of the tester. This will prevent excessive breakage of this type of bottles. The tester should run perfectly smooth in order to prevent excessive breakage, as these bottles are of very delicate construction.

Add distilled water or rain water at a temperature of 140° F. or over to the bottom of the neck of the bottle; whirl 5 minutes. Add hot water to near top of neck, whirl 10 minutes and read.

In the case of buttermilk and whey use the same method as described for skim milk. In the case of buttermilk, especially that derived from pasteurized sour cream, the buttermilk should be stirred very thoroughly before sampling. This is necessary, because upon standing the curd precipitates out and settles to the bottom very rapidly, and it is the curd that holds the bulk of the fat contained in the buttermilk.

The amount of fat contained in skim milk, buttermilk and whey, particularly in the first two liquids, is, or should be, so minute, the fat globules are so small and the construction of the test bottle is so crude, that it is difficult to secure very accurate tests by this method, the proportion of fat actually shown in the test often representing only a very small part of the total fat content of the original sample.

The results of testing skim milk and buttermilk with the standard Babcock test should not be relied upon absolutely for accuracy, but if the tests are carefully made, the results may serve as a convenient guide, showing the operator whether these products contain comparatively little or much fat. Investigations in which both Babcock tests and chemical fat estimations of skim milk and buttermilk were made, indicate that the fat content of these products seldom drops below .1 per cent as determined by the chemical estimation. It is reasonable to assume, therefore, that when the Babcock test shows only .05 per cent fat or less, the results are considerably lower than they should be.

Bouska[1] recommends that 1 cc. of amyl alcohol be added to the test before centrifuging in order to facilitate the separation of the fat, improve the clearness of the fat column and augment the accuracy of the test. He found, however, that blank tests made by this method also show a layer in the neck of the test bottle, resembling butterfat, and recommends the advisability of additional experimental work with the use of amyl alcohol.

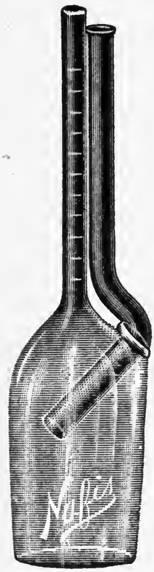

Fig. 101
Skim Milk Test Bottle [2]

Fig. 102. Wizard Steam Tester [3]

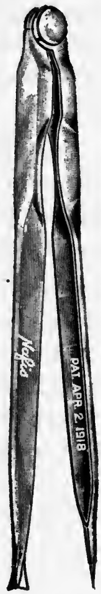

Fig. 103
Calipers for Reading [2]

THE GERBER TEST

This test[4] was invented by Dr. N. Gerber, Zurich, Switzerland. It became available for commercial use in Europe shortly after the introduction of the Babcock test in this country and has found wide application, especially in European countries.

Apparatus and Chemicals.—1. Acido-butyrometer. This is a glass bulb, extended at its top into a closed, graduated neck. The graduations represent per cent and tenths per cent. The bottom of

[1] Bouska, Report before American Association of Dairy Science, 1918.
[2] Courtesy Louis F. Nafis.
[3] Courtesy Creamery Package Mfg. Co.
[4] Gerber, Die praktische Milchprüfung, 7th edition, 1900.

the bulb terminates into a threaded neck into which fits a rubber stopper.

2. Butyrometer stand and water bath.
3. 11 cc. pipette for milk.
4. 3 cc. pipette for cream.
5. 10 cc. pipette graduated to .1 cc.
6. 8.2 cc. pipette for diluting cream.
7. 10 cc. bulb pipette for acid, or automatic acid measuring apparatus.
8. 1 cc. pipette for amyl alcohol.
9. Centrifuge.

Commercial sulphuric acid, specific gravity 1.82 to 1.825 at 15° C. (59° F.).

Pure amyl alcohol, specific gravity .8165 to .818 at 15° C. (59° F.) boiling point 124-130° C., should give a clear solution with an equal volume of strong hydrochloric acid.

Operation of Test

Milk, Skim Milk, Buttermilk, Whey.—Place the butyrometers in rack or stand. Add 10 c.c. sulphuric acid to each, measure 11 c.c. of properly mixed sample of milk and then 1 cc. of amyl alcohol into the butyrometers.

Insert corks, place thumb over cork and shake until all the curd is dissolved. Completely invert the stand several times to insure thorough mixing.

Place the butyrometers into the centrifuge with corks toward the periphery, and whirl two to three minutes, or until the fat column is perfectly clear.

Place butyrometers into water bath at 60 to 70° C. (140-158° F.) and read. So adjust the rubber stopper in the bottom of the bulb while reading, that the bottom of the fat column coincides with the zero graduation. Read to the bottom of the meniscus. Comparative tests have demonstrated that this test yields very accurate results.

Skim milk and buttermilk should be whirled longer and at maximum attainable speed and .05 per cent must be added to the reading.[1]

Cream.—Wyssmann and Peter[2] recommend dilution of the cream at the rate of one part of cream to four parts of water, mak-

[1] Richmond, Dairy Chemistry, 1914.
[2] Wyssman und Peter, Milchwirtschaft, 1907.

ing a dilution of 1 in 5, and requiring the multiplication of the reading by five. This appears to be the most practicable method of cream testing with the Gerber test.

Richmond[1] recommends the use of a 3 cc. pipette for measuring the cream and the subsequent addition of 8.2 cc. water, and the reading to be interpreted into per cent by the use of a calculated table; claiming accurate results for cream testing not over 32 per cent fat. For richer cream he advises a dilution of equal parts, by weight, of cream and water and then proceeding as with cream testing not over 32 per cent fat.

Either of the above two methods for cream testing is obviously rather unsuited for use in creameries that purchase their butterfat in the form of cream. The first is undeniably inaccurate and the second, while somewhat more accurate, is too complicated for practical purposes under American conditions.

BUTTER

Determination of Per Cent Moisture

Preparation of Sample.—Official.[2]—"If large quantities of butter are to be sampled, use a butter trier or sampler. Melt completely the portions thus drawn, 100-500 grams, in a closed vessel at as low a temperature as possible. When softened, cool and, at the same time, shake the mass violently until it is homogeneous and solidified sufficiently to prevent the separation of the water and fat. Then pour a portion into the vessel from which it is to be weighed. The sample should completely or nearly fill the vessel and should be kept in a cool place until analyzed.

Moisture.—Official.—"Weigh 1.5 to 2.5 grams of the sample into a flat-bottomed dish, having a surface of at least 20 sq. cm., dry at the temperature of boiling water and weigh at hourly intervals until the weight becomes constant. The use of clean, dry sand or asbestos is admissible."

For factory purposes the official method is obviously not well adapted, largely because of its time-consuming element. It is necessary to make moisture tests while the butter is still in the churn and here quick work, consistent with reasonable accuracy, is indispensable. Creameries whose motto is "Safety First" will also make

[1] Richmond, Dairy Chemistry, 1914.

[2] Journal of the Association of Official Agricultural Chemists, Vol. II, No. 3, Nov. 15, 1916.

moisture tests of the butter in the cooler, so as to be doubly sure that no butter leaves the factory that does not comply with the Federal ruling.

Factory Moisture Tests

Preparation of Sample.—It is an open and disputable question as to whether the butter sample should be especially prepared, or whether a sample large enough only for immediate weighing should be used. Both methods, if properly executed, are capable of yielding practically equally reliable results.

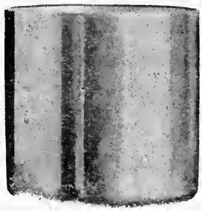

Fig. 104. Aluminum Evaporating Dish

If the sample is especially prepared, a larger sample and more portions of butter from different parts of the churning or package can be taken. This obviously has the advantage, theoretically at least, of securing a more representative sample, but this advantage is often offset by irregularities in the preparation of the sample and by the extra time consumed. However, when it is necessary to hold the sample for a considerable length of time before testing, when it is to be transported, either by mail or otherwise, when it is to be tested by more than one party, or when a composite sample is taken from more than one churning or package, special preparation of the sample is indispensable.

In all these cases churn samples should be taken with a dry, warm spoon or spatula from both ends and the center of the churn. Tub or box samples should be taken by boring the butter diagonally with a dry trier and removing from different parts of the trier segments for the sample, with a knife or steel spatula. In the case of prints a thin cross section through the center of the entire print may be cut out for the sample.

The sample jar should be tightly sealed. In order to prepare the sample the butter is allowed to soften by warming until it has a creamy consistency, in which condition it must be thoroughly shaken. If used immediately, portions of this thickly flowing butter emulsion may be weighed out without rehardening. If not used immediately the sample should be cooled and constantly vigorously shaken while cooling.

Brown[1] recommends the preparation of the butter sample without warming by inserting in the sample jar a rapidly revolving spiral wire, in a similar manner as milk shakes at the soda fountain are emulsified.

Taking Samples without Subsequent Preparation.—Where the sample is to be immediately tested after it is taken, quite satisfactory results may be obtained without special preparation. In this case the following method of sampling is recommended:

From Churn: Bring butter upon workers, wipe water off door frame, cut top off butter with ladle, so as to have surface smooth and solid, with knife cut three small cones of butter and place in aluminum dish. Take second sample from the other end of the churn, and place in another aluminum dish. The sample in each aluminum dish should be large enough to weigh approximately ten (10) grams.

From Cooler: Run trier diagonally through Friday box or through tub and take portions from the plug at each end and in the center. Do not shake the trier, or the butter, at any stage of the process of sampling, to remove loose moisture. This moisture belongs to the butter. Bore at least two packages of cooler butter from each churning and make a test of each. The sample in each evaporating dish should be large enough to weigh approximately 10 grams.

From Prints: Cut the print into two halves, and cut a slab about one-fourth inch thick from the fresh surface. Quarter this slab and transfer one of the quarters to the aluminum dish.

Making the Moisture Test.

Equipment: One steel spatula,
One butter trier.
Aluminum cups of medium size.
One balance, sensibility reciprocal .01 gram.

[1] Brown, Chemist Beatrice Creamery Co., Lincoln, Neb.

One heating arrangement, consisting of an alcohol or gas burner with tripod and small piece of fine copper wire gauze, or preferably an electric plate,

One thermometer registering to 300° F.

Weighing: Have balance properly balanced. See that it swings freely. Keep pans perfectly clean. Check balance several times during the day. Check up weights of aluminum cups weekly by re-weighing, in order to detect loss in weight. Before taring aluminum cups, wash them, dry them, and heat them. Do not use dry scouring powders for aluminum cups. If washing powder is used dissolve it first. Weigh to the third decimal point. Handle weights with forceps only and keep them clean. If they show signs of wear, have them replaced by new ones.

In the case of the unprepared sample, simply weigh the butter which was transferred direct from churn or package to the tared aluminum dish and record the weight thus obtained. In the case of the prepared sample transfer a small portion, about 10 grams, of the butter in the sample jar to the tared dish, weigh and record weights. The butter is now ready for the evaporation of the moisture.

Heating: Slowly heat over flame or on hot plate, stirring constantly with thermometer. When temperature has risen to 260° F. remove flame. The temperature will usually continue to rise to about 280° F. When it has dropped back to about 240° F. heat again as before. Evaporation of moisture then is complete. Weigh the aluminum cup again and calculate per cent moisture. For heating, use moderate heat. Too large a flame produces so intense a heat that the contents are liable to sputter over and also may become burnt. When using an alcohol flame, have a wire gauze or light steel plate between flame and cup. When using a gas flame, have a thin asbestos board between flame and cup. This helps to give a more uniform heat.

When the heating has been done properly, the curd in the bottom of the cup should be slightly brown. A whitish yellow curd indicates insufficient heating, which is conducive of too low tests. A dark brown curd suggests overheating, which usually causes too high tests.

When done using the thermometer, scrape it off on one side of cup, but do not wipe it off, so as to avoid removing fat from the test, and getting the next test too high.

Second Weighing: Weigh cup again and calculate the per cent moisture by deducting the second weighing from the first weighing, dividing the difference by the net weight of the sample (first weighing) and multiplying the result by 100.

Example:

Butter plus cup........	23.463
Cup	12.863
Net weight of butter..	10.600
First weighing.........	23.463
Second weighing.......	21.784
Net loss in weight......	1.679

$$\frac{1.679}{10.60} \times 100 = 15.8\% \text{ moisture.}$$

Determination of Per Cent Fat in Butter

Volumetric Methods

The Volumetric methods of testing butter for fat, which have been devised, are all modifications of the Babcock test. The modifications refer almost exclusively to such changes in the type and graduation of the Babcock test bottle as to make the bottle applicable for the butter test. In these methods the butter is weighed into the butter test bottle and the per cent fat is read off the graduation on the neck of the bottle.

The testing of butter by these methods cannot as yet be considered a complete success and the results have not as a whole been entirely reliable. The chief obstacles with which the operator is confronted in his efforts to determine the per cent of fat in butter by the modified Babcock test are:

1. The reaction of the sulphuric acid used in the test with the salt contained in the butter. The reaction generates hydrochloric acid gas which tends to char the fat and the escape of which causes violent foaming to the extent of forcing a portion of the contents out of the bottle.

The danger of charring the fat has been largely overcome by adding water before the addition of the acid and by filling the bottle to the bottom of the neck with water, immediately after the acid has been added and mixed.

The danger of violent foaming and expulsion of a portion of the sample is minimized materially, if not entirely prevented, by adding the acid very slowly, in numerous installments and mixing thoroughly after each addition.

2. The experimental error in a product containing so high a percentage of the ingredient to be determined as is the case with fat in butter (butter contains 80 or more per cent fat) is naturally proportionally great, and the causes which introduce the experimental error are fixed and cannot be removed. Thus, in estimating fat by volume, it must be assumed that the butterfat has a definite specific gravity, that is, that a given weight occupies a definite volume. This is not the case. Butterfat represents a compound of several fats, varying widely in specific gravity and the proportion in which these different fats are present in the mixed butterfat varies considerably with breed, period of lactation and feed, as determined by locality and season of the year. While the variations in the specific gravity of the mixed butterfat are not large, yet, with butter containing 80 per cent fat or over, they do affect the volume of the fat column and therefore the accuracy of the reading. This one factor is entirely beyond the control of the operator.

Again, the temperature of the fat column when read is another factor introducing experimental error. By the intelligent use of the water bath, the temperature can be controlled within reasonable limits, thus minimizing the effect of this interfering factor to a considerable extent.

The modified Babcock tests for butter which have been devised are those in the operation of which the Hepburn bottle, the Wagner bottle and the Wright bottle are used. They are briefly described in the following paragraphs.

Hepburn[1] Test Bottles.

Two types of bottles have been designed by Hepburn, namely, the 9 inch, 9 gram, 90 per cent bottle, and the 6 inch, 6 gram, 90 per cent bottle.

The 9 inch, 9 gram, 90 per cent bottle.—The graduated portion has a capacity of 90 per cent of the sample tested. 90 per

[1] Hepburn, A Modified Babcock Method for Determining Fat in Butter. Thesis for Degree of Ph.D., Cornell, 1918.

cent of 9 grams is 8.1 grams. Since the specific gravity of butterfat, under test conditions, averages approximately .9, the 8.1 grams of butterfat occupy a space of $\frac{8.1}{.9}$ or 9 cc. The volume of the neck, from 0 to 90, therefore, must occupy exactly 9 cc. This volume calls for a test bottle of the following dimensions: Height over all, approximately 8.8 inches. Length of graduated portion of neck,

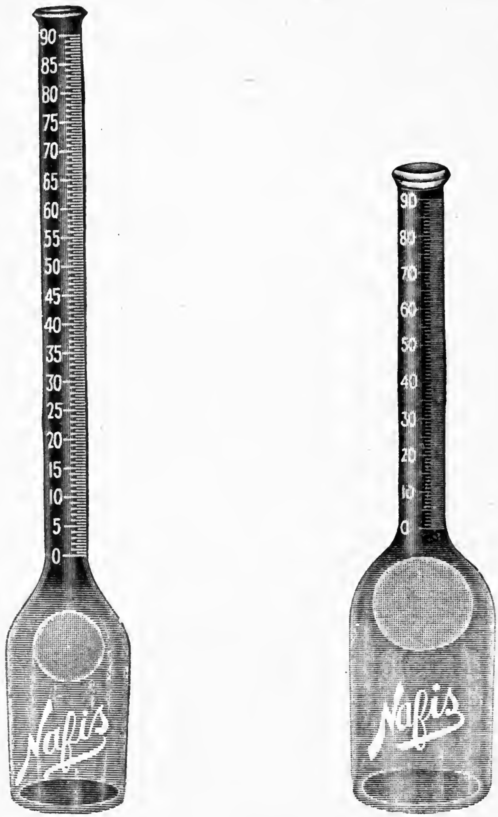

Fig. 105 **Fig. 106**

Hepburn Butter Test Bottles
Courtesy Louis F. Nafis

139 mm. Diameter of graduated portion of neck, 9.07 mm. The graduated portion of neck is divided into 90 divisions. This bottle is applicable for a Babcock centrifuge with a wheel diameter of 18 inches or more.

The 6 inch, 6 gram, 90 per cent bottle.—The graduated portion of the bottle has a capacity of 90 per cent of the sample tested. 90 per cent of 6 grams = 5.4 grams. Since the specific gravity of butterfat, under test conditions, averages approximately .9, the 5.4 grams of butterfat occupy a space of $\frac{5.4}{.9}$ or 6 cc. The volume of the neck of the test bottle, from 0 to 90, therefore, must be exactly 6 cc. This volume calls for a type of bottle with the following dimensions: Height over all, approximately 6.5 inches. Length of graduated portion of neck, 93.5 mm. Diameter of graduated portion of neck, 9.04 mm. The graduation from 0 to 90 is divided into 90 divisions. This bottle is adapted for Babcock testers with a diameter of less than 18 inches.

Scales, sensibility reciprocal .01 grams.

Chemicals, commercial sulphuric acid, specific gravity 1.82 to 1.83. Glymol, or high grade white mineral oil.

Operation of Test with 9 inch, 9 gram, 90 per cent bottle.—Transfer, preferably by pouring, 9 grams of the properly prepared, thickly fluid sample of butter into the test bottle previously balanced on the scales. Add 9 cc. of lukewarm water and then 17.5 cc. commercial sulphuric acid. Add the acid carefully, in small portions, mixing thoroughly after each addition, until all of the 17.5 cc. has been added. This precaution is necessary in order to avoid excessive foaming and loss of sample due to action between acid and salt in the butter.

After the contents of the bottle have been thoroughly mixed, add a sufficient amount of water to fill the bottle to the base of the neck. Centrifuge in Babcock tester for five minutes at the usual speed for the same size tester as used for milk and cream. See Table 104. Add hot water to near the top of the graduation and whirl for four minutes. Transfer bottles to the hot water bath and hold at a temperature of 125° to 130° F. for not less than three minutes. Add a few drops of glymol and read at once. The reading gives the percentage of butterfat direct.

Operation of Test with the 6 inch, 6 gram, 90 per cent bottle.—Follow the directions given for the operation of the test with the 9 inch, 9 gram, 90 per cent bottle with the following modifications: Instead of 9 grams, weigh 6 grams of the butter into the test bottle, and instead of 9 cc. add 12 cc. of lukewarm water just before the acid is added.

Accuracy of Results.—Hepburn, as the result of a comparison of tests between the two 90 per cent butter test bottles and the official, chemical analysis, and embracing work with 124 separate samples of butter, finds the modified Babcock test, as described above, applicable as a successful commercial method for estimating the percentage of fat in butter.

Other Modifications of the Babcock Test.—Earlier attempts to modify the Babcock test, so as to make it suitable for the rapid determination of the fat in butter, resulted in the construction and use of the Wright bottle and the Wagner bottle. In these bottles the graduated portion of the neck has a very narrow diameter and the bulk of the fat is assembled in a bulb which is a part of the graduated neck.

Tests with these bottles have proven very uncertain and unreliable, probably largely because even slight temperature changes, during the reading of the test, caused very great expansions or contractions of the fat column in the graduated portion of the neck, due to the relatively large volume of fat affected in the bulb of the neck and to the very narrow diameter of the graduated neck. This intensity of expansion and contraction of the thin fat column that is directly connected with the relatively large volume of fat in the bulb of the neck rests on the same principle as the mercury column in the thermometer. For these reasons, therefore, the use of these modified Babcock bottles, equipped with bulbs in the neck of the bottle, is prone to yield entirely erroneous results and cannot be recommended for the determination of the percentage of fat in butter.

Gravimetric Determination.

Indirect Method.—Official.—Dissolve the dry butter, obtained in the moisture determination[2] in which no absorbent was used, in absolute ether or petroleum ether, transfer to a weighed Gooch, with the aid of a wash bottle filled with the solvent and wash until free from fat. Dry the Gooch and contents at the temperature of boiling water until the weight is constant and determine the fat.

Direct Method.—Official.[1]—From the dry butter, obtained in the determination of moisture,[2] either with or without the use of an

[1] Journal of the Association of Official Agricultural Chemists, Vol. II, No. 3, November, 1916.

[2] See Determination of Moisture in Butter (Official).

absorbent, extract the fat with anhydrous, alcohol-free ether, receiving the solution in a weighed flask. Evaporate the ether, dry the extract at the temperature of boiling water and weigh at hourly intervals until the weight is constant.

Fat Determination by Kohman Method.[1]

Kohman recommends the following fat determination in connection with the moisture test:

"The moisture is determined as usual over a small flame in a tall, rather narrow, lipped aluminum beaker with a capacity of about 100 cc., using a 10 gram sample. After the beaker is weighed to determine the loss of moisture, it is filled with petroleum ether and the contents are stirred with a glass rod to secure a thorough mixture. It is then covered with a watch crystal and allowed to stand two or three minutes for the mixture of curd and salt to settle, when the solvent is gently decanted off without disturbing the sediment. The beaker is then filled with fresh solvent. The curd and salt mixture settles rapidly in the fresh solvent and the liquid can be decanted off after a very short time. By gently heating the beaker now, either on a water bath or a hot plate, or directly over a small flame, but not so rapidly as to cause sputtering, the sediment can be completely freed of petroleum ether by evaporation in a very short time. The per cent of fat is then determined by difference upon reweighing the beaker with its contents. The salt is now in ideal condition to be determined by titration, using a solution of such strength that the number of cc. used represents the per cent of salt.

Before trying to evaporate the petroleum ether from the mixture of curd and salt, it is well to loosen it from the bottom of the beaker, gently tapping it on the desk in order to lessen the tendency to sputter." According to Kohman, this test requires about 15 minutes.

Fat Determination by Shaw.[2]

"In this test for fat, the salt and part of the curd are first removed with hot water, the remaining curd is dissolved in dilute sulphuric acid, the acid solution is removed from the fat, and the latter weighed.

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[1] Kohman, A Rapid and Accurate Method for Butter Analysis, Suitable for Factory Control Work. Journal of Ind. and Eng. Chemistry, Vol. 11, No. 1, 1919.

[2] Shaw, A New Method for Determining Fat and Salt in Butter, Especially Adapted for Use in Creameries. U. S. Dept. of Agriculture, B. A. I. Circular 202, 1912.

Apparatus Required.—"A Babcock contrifuge. A special separatory funnel. A balance which is sensitive to 0.01 gram. (A torsion balance such as is used in the moisture test will answer if it is in good condition.) An accurate set of metric weights. A 10-cubic centimeter graduated glass cylinder. A 100-cubic centimeter glass beaker.

Special Separatory Funnel.—"This is essentially a separatory funnel with a capillary stem. The capacity of the funnel should be about 75 cubic centimeters and its weight when empty should not exceed 70 grams. The stopper may be dispensed with if desired. It is a convenience in the final weighing, but not a necessity.

Special Socket.—"This is a double socket for holding the above funnel while centrifuging, and is made of heavy sheet copper with hangers of steel. Each socket will hold two funnels. The cut shows the construction and dimensions. It differs in no material way from the socket ordinarily used on the Babcock centrifuge, except for the opening in the side. If the dimensions given fail to fit the centrifuge at hand, they may be changed to suit so long as the dimensions of the barrels are not altered. Care must be taken that the capillary stem of the funnel does not project far enough through the hole in the socket to strike against the side of the centrifuge when being whirled. It is best to fit a disk of rubber gasketing to the bottom of the socket.

Sampling the Butter.—See previous directions.

Determining the Fat.—"It will be found more economical in some cases if 4 or multiples of 4 determinations are made at once. In this case the 2 double sockets containing the funnels will balance when placed opposite in the centrifuge. If but 1 or 2 determinations are to be made it will be necessary to balance the centrifuge by putting weights in the opposite socket. First of all the weight of the clean and dry separatory funnel must be ascertained, and this as well as the other weighings involved must be done with care. This weight once found will suffice for all determinations made with that particular funnel unless by accident some of the glass should be chipped off. A slight scratch made with a file can serve to identify the funnels. A paper label can not be used.

I. Weighing the Charge.—"Counterpoise the small beaker on the balance and carefully weigh out 20 grams of the sample mixed as directed.

II. Transferring the Charge to the Separatory Funnel.—"Place the beaker containing the charge on a radiator or steam pipe until the butter is melted. (This may also be accomplished by adding a small quantity of boiling water.) Next pour the charge into the funnel, which must be maintained in an upright position, and no

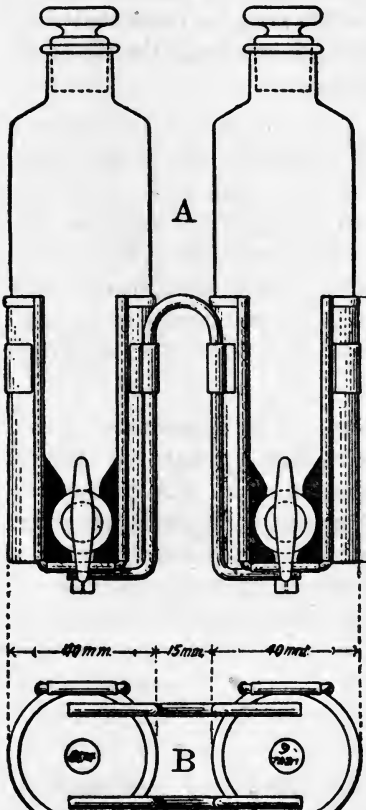

Fig. 107. Shaw Butter Fat Tester

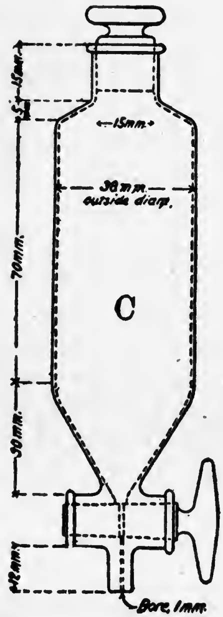

Fig. 108. Separatory Funnel with Capillary Tube

part of the charge must be lost in transferring. With a fine stream of hot water rinse down the sides of the beaker and pour the rinsings into the funnel. Repeat this, using not more than a teaspoonful of water at a time until the funnel is full to within one-quarter of an inch of the shoulder. The rinsing can be done very conveniently with the arrangement on many steam centrifuges for filling the

Babcock test bottles, i. e., the rubber tube ending in a glass or metal point and connecting with a water tank heated by steam. The point must be fine, however. Should it be larger than three-sixteenths of an inch it can be replaced with the tip of a small oil can. Should this arrangement not be at hand one can easily be improvised from a tin can, a rubber tube, and an oil-can tip. In transferring the melted butter and rinsings the last drop may be prevented from running down the outside of the beaker, by touching the lip of the beaker to the neck of the separatory funnel.

III. Centrifuging.—"Insert the separatory funnel in the special socket, allowing the stem to project through the hole in the bottom and the handle of the stopcock through the open side. (Caution: The socket must always be placed in the centrifuge with the open side facing the direction in which the wheel revolves. This is very important, for if the opening faces the reverse direction the stopcock will be thrown out and broken.) Whirl one minute at the same speed used in testing milk with the Babcock test. The centrifuge must be kept warm.

IV. Removing the Water.—"Remove the separatory funnel from the socket and allow the water to flow through the stopcock until the fat (or curd) is within one-eighth of an inch of the stopcock. In this and subsequent operations involving the stopcock one must be sure it does not stick. It must always be under control, and it is best to give it frequent slight movements when the water or acid is running through it to be sure that this control is maintained; otherwise it might stick at a critical moment and the determination be lost. The most of the salt and part of the curd are taken out by the water. The remainder of the curd and all of the fat stays in the funnel.

V. Dissolving the Curd.—"Measure out 9 cubic centimeters of cold water, preferably condensed steam, with the glass graduate and pour into the beaker. Add to this 11 cubic centimeters of sulphuric acid of the same strength used in testing milk and cream (specific gravity, 1.82-1.83) and mix by gently shaking. (Caution: Always add acid to water and not water to acid, or a serious accident may result.) While still very hot add the mixture to the contents of the separatory funnel. Now dissolve the curd by giving the funnel a circular motion with the hand grasping the neck. Centrifuge one minute, as before. Draw off the acid solution till the fat layer is within one-fourth of an inch of the stopcock and repeat the operations in this paragraph.

VI. Freeing the Fat from the Acid Solution.—"The fat will now be in a clear transparent layer free from curd, and the solution below it will be practically colorless. To separate these two, draw off the latter until the fat nearly reaches the stopcock and centrifuge another minute. Now allow the fat to come down through the stopcock till it just reaches the end of the capillary stem. This last step offers no difficulties, providing the stopcock is kept in control, but it requires care.

VII. Determining the Percentage of Fat.—"Carefully dry the separatory funnel on the outside with a clean soft towel and weigh it. The weight thus obtained minus the weight of the empty funnel represents the weight of butterfat in 20 grams of the sample. The percentage is obtained by dividing this weight by 2 and multiplying by 10.

Sometimes it is possible to obtain a clear fat layer with but one addition of acid, but in the majority of cases it will be found necessary to add it the second time, as directed. The proportion of acid and water selected is the outcome of a number of experiments, and is the one that yields the best results. The test for fat alone involves 4 centrifugings of 1 minute each. The centrifuge should be kept warm and the contents of the funnel in a melted state when the acid is added. The time consumed should not be much longer than it takes to test cream with the Babcock test, and the operations involved are simple and easily learned. No difficulty has been experienced in obtaining a clear fat. Occasionally there will appear a slight emulsion at the bottom of the fat layer when the fat is drawn into the stem. This is so small in amount that it does not seem to affect the accuracy of the test to any considerable extent. The emulsion should be weighed as fat and considered as such.

Cleaning the Separatory Funnels.—"The separatory funnels should be washed after each determination, but it is not necessary to dry them before use providing their weight, when clean and dry, has been found. The cleaning is easily done with hot water and either soap or cleansing powder. They should be well rinsed off with clean water and drained."

Comparative tests by Shaw show that this test yields results which compare very closely with those of the official fat estimation. The test can be completed in 20 minutes.

Determination of Salt in Butter

Principle of Salt Tests.—All salt tests are based on the same principle. In their operation two chemicals are used, namely silver nitrate ($Ag\ NO_3$) and potassium chromate ($K_2\ Cr\ O_4$). The silver nitrate has the power of chemically acting on both, the salt or sodium chloride ($NaCl$) and the potassium chromate. With sodium chloride the silver nitrate forms silver chloride which is a white precipitate. With the potassium chromate the silver nitrate forms silver chromate which is a brick-red precipitate. The silver nitrate acts first on the sodium chloride. Hence, when silver nitrate is added to a solution of sodium chloride (salt) which contains some potassium chromate, the silver nitrate first combines with the sodium chloride until all the chloride is used up and has been converted into silver chloride. This precipitate is white. Now, if more silver nitrate is added, the silver combines with the chromate, changing the color of the precipitate to a brick-red. The moment the brick-red color becomes permanent, therefore, all the salt has been neutralized, and the amount of silver nitrate required to produce this brick-red color furnishes the basis for the calculation of the per cent of salt in butter.

Calculation of Per Cent Salt in Butter.—The calculation of the per cent salt in butter rests on a similar principle as the calculation of the per cent acid in cream. A normal solution of silver nitrate neutralizes an equal amount of a normal solution of sodium chloride. A normal solution of silver nitrate contains, in 1,000 cc. of water, 170 grams of silver nitrate. A normal solution of sodium chloride contains, in 1,000 cc. of water, 58.5 grams of sodium chloride. Hence, 1 gram of sodium chloride is neutralized by $\frac{170}{58.5}$ or 2.906 grams of silver nitrate.

If, therefore, a silver nitrate solution is used which contains, in 1,000 cc. of water, 29.06 grams of silver nitrate, then each cc. of this solution will contain $\frac{29.06}{1000}$ or .02906 grams of silver nitrate, and .02906 grams of silver nitrate will neutralize $2.906 : 1 = .02906 : X$, or .01 gram of sodium chloride. If a 10 gram sample of butter is used and all of this sample is tested, each cc. of silver nitrate solution required represents $\frac{.01 \times 100}{10}$ or .1 per cent salt.

Example.—10 grams of butter are tested. 32 c c. of silver nitrate are required to produce a brick-red color. What is the per cent salt?

$$32 \times .1 = 3.2 \text{ per cent salt.}$$

If, however, the sample of butter, after melting, is made up with water to a 250 cc. solution, and only 25 cc. of this solution are tested, then each cc. of silver nitrate represents 1 per cent salt. Supposing in this case that 3.5 cc. of silver nitrate are required to neutralize the 25 cc. of the 250 cc. solution to which the 10 gram sample of butter was made up, then the per cent salt would be $3.5 \times 1 = 3.5$ per cent. In the case of some salt tests the silver nitrate solution is not made as strong as above. Instead of 29.06 grams of silver nitrate per 1,000 cc. water, the solution may be made up to only one-half or one-quarter this strength, containing 14.53 grams or 7.265 grams, respectively, of silver nitrate and each cc. would represent only .05 or .025 per cent salt, respectively, if all of a 10 gram sample of butter is used.

The potassium chromate solution is prepared by dissolving 10 grams of dry potassium chromate in 100 cc. of distilled water.

Salt.—Official Method.[1]—Weigh in a counterpoised beaker 5-10 grams of butter, using portions of about 1 gram from different parts of the sample. Add about 20 cc. of hot water and, after the butter is melted, transfer the whole to a separatory funnel. Insert the stopper and shake for a few moments. Let stand until all the fat has collected on the top of the water, then draw off the latter into a flask, being careful to let none of the fat globules pass. Again add hot water, rinsing the beaker, and repeat the extraction 10-15 times, using 10-20 cc. of water each time. The washings will contain all but a mere trace of the sodium chloride originally present in the butter. Determine the amount in the whole or an aliquot of the liquid by titration with standard silver nitrate, using potassium chromate as an indicator.

Kohman Salt Test.—See Fat Determination by Kohman.

Determination of Salt by Shaw.[2]

This is a continuation of the Shaw test for fat in butter.

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[1] Journal of the Association of Official Agricultural Chemists, Vol. II, No. 3, November 15, 1916.

[2] Shaw, A New Method for Determining Fat and Salt in Butter, Especially Adapted for Use in Creameries. U. S. Dept. of Agriculture, B. A. I. Circular 202, 1912.

Additional Apparatus Required.—"A 50-cubic centimeter burette graduated in tenth cubic centimeters. A 250-cubic centimeter volumetric flask. A 25-cubic centimeter pipette. A 250-cubic centimeter beaker or white cup.

Chemicals Required.—"An aqueous silver-nitrate solution containing 14.525 grams pure silver nitrate per liter. This solution may be obtained from a chemical supply house. A 10 per cent aqueous solution of potassium chromate, which may be obtained at a drug store.

Method.—"To determine the percentage of salt the wash water, obtained as previously directed in Paragraph IV, see Shaw test for fat, is allowed to run into the 250-cubic centimeter flask, and the operations in Paragraph IV conducted 3 times instead of but once, the water each time being allowed to run into the flask.

After the washings have become cool the flask is filled to the mark with cold water and the contents mixed. Twenty-five cubic centimeters, which represents 2 grams of the original sample, are then measured with the pipette into the beaker or cup and titrated with the silver-nitrate solution from the burette, using 2 or 3 drops of the potassium-chromate solution as the indicator. The first appearance of a permanent red is the end point. The silver-nitrate solution is of such strength that 2 cubic centimeters represent 1 per cent of salt if a 1-gram charge is used. In the above test where 2 grams are represented $\left(\frac{25}{250} \times 20\right)$ the number of cubic centimeters divided by 4 gives the percentage of salt in the original sample. As an example, if the burette reading showed that 10.6 cubic centimeters of the silver-nitrate solution were consumed in reaching the end point, then 10.6 divided by 4, or 2.65, would be the percentage of salt in that particular sample of butter.

The Perkins Salt Test.

Professor A. E. Perkins of the Ohio Agricultural Experiment Station recommends the following method for the determination of the per cent of salt in butter:

Weigh out either 5 or 10 grams of the butter to be tested, which has previously been warmed to a salvy consistency and very thoroughly mixed, into any receptacle, such as a beaker or cup. Warm gently until just melted, then add 20 or 30 cc. of commercial acetone, and about 1 cc. of a saturated water solution of potassium chromate. A solution of silver nitrate containing 29.06 grams per liter, is then added slowly from a burette, the mixture containing the butter being thoroughly shaken or stirred. After the first appearance of a brick-red coloration, the silver nitrate solution is added, a drop at a time, until a brick color develops which is permanent for several minutes after thorough stirring or shaking.

If 10 grams of butter have been taken, each cc. of silver nitrate solution used represents .1 per cent of salt in the butter; thus, if the burette reading showed 29 cc. of silver nitrate solution had been used, the butter under examination contained 2.9 per cent salt. If only a 5 gram sample is taken, each cc. of silver nitrate solution used will represent .2 per cent of salt in the butter.

The residue from any of the moisture tests can be used by adding a little water to replace that driven off by drying, and the chemicals as directed above. (The titration can be made in the same cup used for the moisture determination.)

If the commercial acetone is not available a mixture of equal parts of alcohol and ether may be substituted with equally good results. (Denatured alcohol such as is sold for fuel purposes, and the cheaper grades of ether are entirely satisfactory.)

SALT TEST FOR FACTORY USE

By Hunziker and Hosman.[1]

Equipment.—One salt tester. This is a copper container, 3½ inches deep, 2½ inches in diameter, and holding about 250 c.c. It is equipped at its top edge with a heavy rubber ring on which the moisture evaporating dish is inverted, and with a lightning jar wire clamp for pressing the evaporating dish down on the rubber ring.

One 100 c.c. glass cylinder (low style).

One 25 c.c. pipette.

One or more 150 c.c. flasks (cone shape) for titrating.

One 50 c.c. burette with stand.

One large bottle, with glass tubing and clamps to connect with burette, for standard silver nitrate solution.

One small bottle for potassium chromate solution.

Chemicals.—Silver nitrate solution containing 7.265 grams silver nitrate in 1000 c.c. water.

Potassium chromate solution.

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[1] Hunziker and Hosman, Blue Valley Research Laboratory, 1918.

Operation of Test.—This test is intended to be a continuation of the moisture test in which an evaporating dish of a diameter of 2⅝ inches is used.

(1). At the conclusion of the moisture test fill the 100 c.c. cylinder to the mark with warm water, temperature about 100° F., and pour this water into the salt tester.

(2). Invert moisture evaporating dish over rubber ring of salt tester and make the dish fast by means of wire clamp.

Fig. 109. Hunziker Salt Tester and Evaporating Dish

Fig. 110. Hunziker Salt Tester Ready for Shaking

(3). Now shake the salt tester vigorously, giving it about 30 shakes. This causes the salt in the evaporating dish to be washed out by the warm water.

(4). Remove evaporating dish and transfer with pipette 25 c.c. of the salt solution from the salt tester into the titrating flask.

(5). Add 1 c.c. of potassium chromate solution to the titrating flask and from burette slowly add silver nitrate solution until a permanent brick-red precipitate is obtained. The titrating flask must be constantly and thoroughly agitated by a rotating motion while the silver nitrate solution is added.

(6). If a 10-gram sample of butter is used in the moisture test, each c.c. silver nitrate solution represents .1 per cent salt. Assuming that 35 c.c. silver nitrate solution was used, the butter then contained $\frac{35}{10} = 3.5\%$ salt.

(7). If the sample of butter is not exactly 10 grams, but somewhat more or less, the per cent of salt is readily calculated by dividing the c.c. silver nitrate solution required, by the exact weight of the sample of butter. Say the sample weighed 10.5 grams and required 35 c.c. of silver nitrate solution, the butter then contained $\frac{35}{10.5} = 3.3\%$ salt.

(8). This salt test occupies about five minutes. It is exceedingly simple and accurate, when made in accordance with the above directions. It eliminates the weighing of the sample for the salt determination and it automatically washes the moisture evaporating cup. For uniformly reliable results the following precautions must be observed:

(*a*). Do not slobber the melted butterfat in the evaporating dish, over the outside of the salt tester. The butter must stay inside of the periphery of the evaporating dish, when the latter is inverted over the tester.

(*b*). Do not use water at a temperature lower, nor much higher than 100° F. Water must be warm enough to melt the fat. If too warm it will generate pressure when shaking the tester, causing loss of contents.

(*c*). Strap the evaporating dish down to the tester so that there is no leak around the rubber ring.

(*d*). Shake vigorously thirty (30) times.

(*e*). Give the titrating flask the proper rotating movement for vigorous and continuous agitation, while the silver nitrate solution runs from the burette.

(*f*). Stop titration when the desired color has been reached (brick-red).

(*g*). It is necessary to give the fat time to rise in the tester after shaking. This requires about one minute. For this reason, the tester should be set down after shaking, and the aluminum cup taken off and wiped dry and gotten ready for the next weighing of butter. While this is done, the fat in the tester automatically rises to the surface.

(*h*). If the edges of the evaporating dish become uneven, due to wear, causing the cup to leak when inverted over the rubber ring of the tester, invert the cup over a piece of fine emery cloth, and wear down the edges until even.

10. The speed of the entire test will much depend on the proper planning and organizing of the work of both the moisture and the salt test, so as to avoid any waiting between steps, such as waiting for the evaporating dish to cool, or for the fat to rise to the surface in the tester. It has been found that the maximum speed is obtained by running the moisture and the salt tests of three samples together.

11. Use only evaporating dishes without lips.

Determination of Curd.

Casein, Ash and Chlorin.—Official.—Cover the crucible, containing the residue from the fat determination by the indirect method, see official fat determination, and heat gently at first, then raise the temperature gradually to just below redness. The cover may then be removed and heating continued until the contents of the crucible are white. The loss in weight represents casein, and the residue in the crucible, mineral water. Dissolve this mineral matter in water slightly acidified with nitric acid and determine chlorin, either gravimetrically or volumetrically.

The curd or casein content of butter as determined by the Official Method includes the lactose also. Since normal butter contains approximately .3 per cent lactose, the nitrogenous curd content of butter is in reality about .3 per cent lower than the per cent curd as determined by the Official Method.

For making an exact determination of curd, in contradistinction to the curd determination, as the term is used in the Official Method, the following method is recommended:[1]

Dry about 10 grams of butter in a flat-bottom porcelain evaporating dish in a steam drying oven at about 98 to 99 degrees C. Remove the fat by dissolving with petroleum ether and filter, transferring the entire contents of the evaporating dish to the filter, and rinsing with petroleum ether. Transfer filter paper and contents to a Kjeldahl flask and determine the nitrogen by the Kjeldahl method, using the factor 6.38 in calculating the per cent of protein or curd.

The United States Bureau of Chemistry[2] recommends the same method but suggests the use of a 25 gram sample.

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[1] Hunziker, Spitzer and Mills, The Pasteurization of Sour, Farm-Skimmed Cream for Butter Making. Purdue Bulletin 203, 1917.

[2] United States Bureau of Chemistry, Information by Correspondence, March, 1919.

Determination of Lactose.[1]

"The lactose in butter is never determined direct, but always by difference, unless adulteration of the sample with sugar is suspected, in which case the water extract of the curd may be examined by the polariscope or by the copper reduction method.

Determination of Acid.[2]

Weigh 5 grams of butter into a 250 cc. tall beaker, and add 25 cc. of distilled water free from CO_2. Warm the mixture to about 40 degrees C., or until the butter is all melted. Add .5 cc. of a 1 per cent solution of phenolphthalein and titrate to a sharp pink with $\frac{N}{10}$ NaOH.

The Mojonnier Test for Fat and Solids in Milk, Skim Milk, Buttermilk and Cream, and for Fat and Moisture in Butter

Equipment.—Install the tester on a solid foundation in a room protected against excessive fluctuations in temperature.

1. Tester for butter fat.
2. Tester for total solids.
3. Fat extraction flasks.
4. Eight 3½-inch aluminum dishes without covers and with tall counterpoise which tares the eight dishes, for fat tests.
5. Eight 3-inch aluminum dishes with covers and short counterpoise for solids tests.
6. Fat oven. Keep temperature at 135° C.
7. Cooling chamber.
8. Solids oven. Keep temperature at 100° C.
9. 250° C. thermometer for solids oven. Have mercury bulb fit snugly into brass mercury well. Brass mercury well must always form good contact with hot plate.
10. 250° C. thermometer for fat oven. Observe same precautions as in (9).
11. Vacuum gauge on main suction line, registers either or both ovens.
12. Solids plate. Must be level and held at 180° C.
13. Fat plate. Hold at 135° C.

[1] United States Bureau of Chemistry, Information by Correspondence, March, 1919.

[2] Hunziker, Spitzer and Mills, Pasteurization of Sour, Farm-Skimmed Cream for Butter Making. Purdue Bulletin 203, 1917.

14. Rheostat for fat plate. Lever must make good contact with one button, not with two at a time. When right button has been found that maintains constant temperature, mark this point on rheostat rim. When starting tester each day, turn handle on full until temperature has risen to within right point, then turn back to previously marked button.

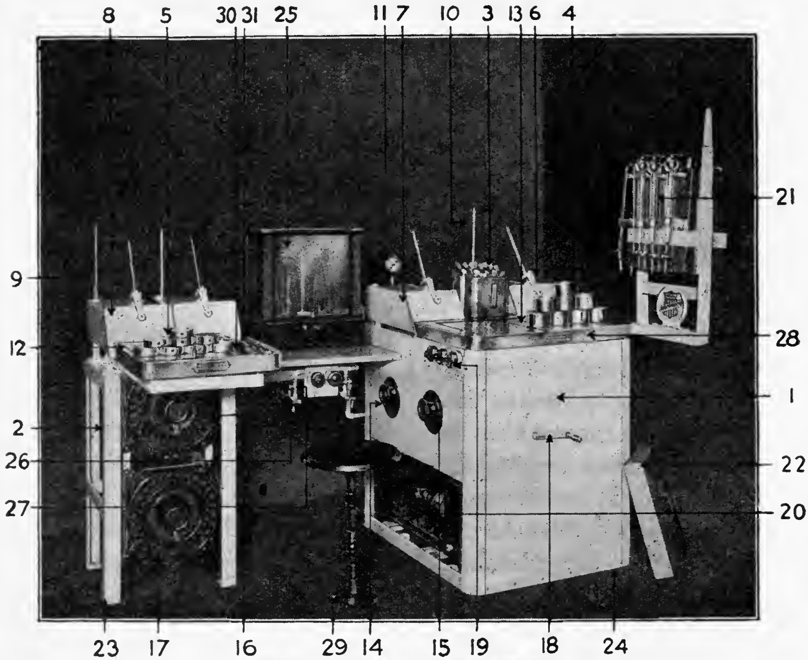

Fig. 111. Mojonnier Tester
Courtesy Mojonnier Bros. Co.

15. Rheostat for oven. Observe same precautions as in (14).

16. Rheostat for solids oven. Observe same precautions as in (14).

17. Rheostat for solids plate. Observe same precautions as in (14).

18. Handle for centrifuge.

19. Snap switches for each hot plate showing temperature and time for treating samples at various points.

20. Power unit, consisting of vacuum pump, water circulating pump and motor for same. Keep pump filled to air cock with oil furnished with tester.

21. Automatic burettes and cans holding the water, ammonia, alcohol, ethyl ether and petroleum ether, placed in the order in which they are used. Each division on burettes delivers the proper amount of the desired reagent for a single extraction.

22. Hood, to be placed over fat dishes when evaporating off ether.

23. Legs, to be fastened to floor with lag screws.

24. This side need not be fastened to floor. If necessary to take out power unit disconnect connections in rear of machine and move this part of machine forward.

25. Chemical balance. Keep level, clean and handle carefully. Raise knife edges gradually and with care. Clean balance daily. Keep weights clean. When weights show signs of wear, order new ones.

26. Cock, to exhaust vacuum from oven when cock (27) is closed. Must be kept closed where vacuum is turned on oven.

27. Cock, that switches vacuum from main line into vacuum oven. Set of cocks at right for solids oven, set of cocks at left is for fat oven.

28. Hole in top of fat plate holder, communicating with suction fan, on power unit. Run exhaust pipe on suction fan out of window and keep hood over the dishes in order to drive all ether fumes from room.

29. Stool, to be screwed to floor.

Fresh Milk, Skim Milk, Buttermilk and Whey

Butterfat Determination

(1). Keep fat dishes in vacuum oven at least five minutes while oven is heated, with vacuum on.

(2). Cool fat dishes in cooling oven for seven minutes, with pump turned on and bell set at seven minutes.

(3). Weigh fat dish without cover and return it to cooling oven.

(4). Use the ten-gram pipettes for measuring out ten grams of milk into cleaned but not necessarily dried Mojonnier extraction flask. Use only ten-gram pipettes furnished with tester and do not use 10 c.c. pipettes. The pipette is graduated to deliver ten grams of milk after allowing all milk to run out and letting it drain for fifteen seconds longer, then blowing gently to remove last drop. The pipette must be perfectly clean and dry before being used. Wash frequently with sulphuric acid, water, alcohol and ether to insure having a clean pipette.

(5). Remove flask from holder and run 4 c.c. water (one charge on water burette) into each flask. Be careful not to add more. Shake well until all of sample is mixed with water. This can be done without inserting cork.

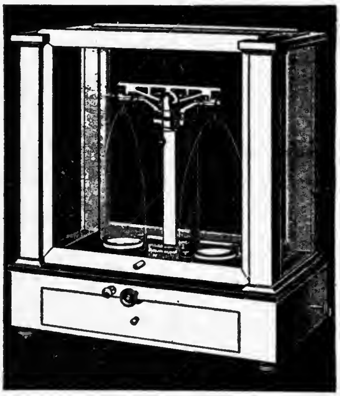

Fig. 112
Chianomatic Balance

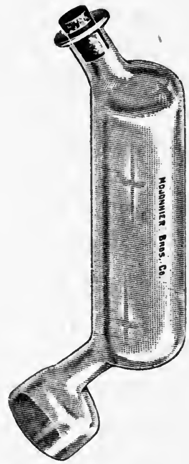

Fig. 113
Extraction Flask

Courtesy Mojonnier Bros. Co.

(6). Before replacing flask into holder, add 1½ c.c. c.p. ammonia. Shake well so that all of sample is well mixed with ammonia. This can be done without inserting cork.

(7). Add 95 per cent alcohol up to base of top bulb of extraction flask. Insert cork, using best quality corks only. Replace flask into flask holder. Shake thoroughly and see that no milk adheres to any part of flask undissolved. In case particles of milk stick to side of flask, shake thoroughly until these are washed away. It is of the utmost importance to shake thoroughly at this point.

(8). Add 25 c.c. ethyl ether, insert corks and shake vigorously, lengthwise of flask, with liquid in large bulb of flask, and small bulb extended upward. Stop shaking at end of five seconds until all liquid has run into large bulb and repeat vigorous shaking for four five-second periods.

(9). Add 25 c.c. petroleum ether and shake in same way.

(10). Place extraction flasks into centrifuge and whirl for thirty turns at speed of about 600 R. P. M. Have centrifuge balanced with small oil sample bottles furnished with tester.

(11). Place four 3½-inch dishes in line on shelf adjoining hot plate, keeping them in order in which their weights were posted upon record sheet. Aim to have numbers on flasks correspond with number of dishes.

(12). Pour ether extraction above dividing line into proper dishes, and slide dishes over onto hot plate, which should be held at a temperature of 135 degrees C., as indicated by thermometer inserted in nickel plated mercury well. Cover dishes with hood.

(13) Repeat the extraction, shaking first to prevent formation of precipitate. then adding successively 5 c.c. of 95 per cent alcohol, then 15 c.c. ethyl ether, and then 15 c.c. petroleum ether, and shake vigorously after the addition of each of above three reagents for four five-second periods.

(14). Whirl in centrifuge for thirty turns.

(15). Move aluminum dishes back upon shelf adjoining hot plate and pour the second extraction into proper dishes. Never pour extraction into hot dish. Remove dish from hot plate as soon as ether is all evaporated.

(16). When all of ether has evaporated place dishes into vacuum oven, which should have a temperature of 135 degrees centrigrade. Keep them there for five minutes after the vacuum gauge shows at least twenty-two inches of vacuum.

(17). Place dishes into cooler for seven minutes, with pump outfit running. See that water is running through cooling plates.

(18). Place counterpoise for dish and the approximate weight for fat on right hand balance pan.

(19). Transfer dish to left hand balance pan and weigh quickly to 0.10 milligram (0.0001 gr.).

(20) Weight of fat divided by weight of sample taken, multiplied by 100, represents per cent butter fat.

Total Solids Determination

(1). Keep solids dishes in vacuum oven, while oven is heated, with vacuum on.

(2). Cool solids dishes in cooling oven for five minutes, with pump turned on and bell set at five minutes.

(3). Weigh solids dish, with cover on. Return dish to cooling oven.

(4). Fill one two-gram pipette with the milk from properly mixed sample, place upon weighing cross, weigh and record.

(5). Transfer contents of pipette to tared solids dish, return pipette to weighing cross, reweigh and record.

(6). Place solids dish with contents on solids hot plate, temperature 180° C.

(7). When evaporation has been completed (in about two minutes) place dish in solids oven, temperature 100° C.

(8). Turn on vacuum and set bell for ten minutes.

(9). When bell rings, transfer dish to cooling oven and set bell for five minutes.

(10). When bell rings, weigh dish and calculate per cent total solids by dividing net weight of dry solids by net weight of milk taken (2 grams) and multiplying result by 100.

Cream

Preparation of Sample.—Mix sample thoroughly in the container. Homogenized cream requires no special treatment. Very thick, lumpy or churned cream should be warmed sufficiently to secure uniform and homogeneous mixture. Heat till butterfat is all just barely melted.

Fat Determination

(1). Prepare fat dishes as directed in paragraphs 1 to 3, inclusive, for Butterfat Determination of Fresh Milk.

(2). Weigh one gram of the sample into the tared butter boat, or directly into the tared extraction flask.

(3). Remove flask from holder and add enough water to make a total of 10 c.c. Insert cork and mix thoroughly by shaking.

(4). Add 1.5 c.c. (one charge) of ammonia in the case of sweet cream, or 3 c.c. of ammonia in the case of sour cream. This is very important.

(5). From this point on to the end of the test continue as per directions for Butterfat Determination of Fresh Milk, paragraphs 7 to 20, inclusive, with the following exceptions:

(a). For the second extraction, paragraph 13, use 25 c.c. of each ether, instead of 15 c.c.

(b). At the end of the second extraction it may be necessary to add quite a little more alcohol, in order to bring the dividing line up to the required height.

Total Solids Determination

(1). Prepare solids dishes as directed in paragraphs 1 to 3, inclusive, for Total Solids Determination of Fresh Milk.

(2). Use a one gram sample. Add 1 c.c. distilled water to the sample in the dish.

(3). Place not more than two dishes at once upon hot plate. Allow all visible moisture to evaporate. During evaporation, turn the dishes around with crucible tongs, slowly, so as to produce an even boiling over the whole bottom surface of the dishes. Evaporation should require not more than two minutes. The end point is reached when bubbling and cracking ceases and sample shows first trace of brown.

(4). Place dishes into vacuum oven at 100° C., and turn on vacuum. Heat for 10 minutes. The gauge should register not less than 22 inches of vacuum. If for any reason the vacuum is lower than 22 inches, leave dishes in oven for 20 minutes.

(5). Transfer dishes to cooler. Allow them to cool for five minutes.

(6). Weigh dishes with covers on, being careful to weigh quickly and very exactly.

(7). Net weight of dried solids divided by net weight of cream taken, multiplied by 100, represents per cent total solids.

Butter

Preparation of Sample.—Method I. Remove about one-half pound butter from different parts of churn, or tub, or other package, with a butter trier, to a widemouth bottle or Erlenmeyer flask, insert rubber stopper which carries a thermometer that reaches down into the mass of butter. Heat bottle with contents in hot water to 40° C. (104° F.). Do not heat to higher temperature. Shake vigorously. Or, Method II. Transfer butter from churn, tub or other package into mason jar, beaker or glass tumbler, wide-mouthed bottle, or any other receptacle that permits of covering tightly to prevent evaporation. Allow sealed receptacle to stand in warm room or in warm water until the butter is soft enough for thorough stirring, with table knife, spatula or mechanical stirrer. At 75 to 80° F. butter stirs into a waxy mass from which water or casein will not separate. In this form it is put into boat or flask, to be weighed.

Butter Fat Determination

(1). Transfer about one gram of butter sample to butter boat, weigh quickly and insert boat into extraction flask.

(2). Remove extraction flask from holder and add 9 c.c. hot water. Shake vigorously so as to mix butter and water thoroughly.

(3). Before replacing flask into holder add 1.5 c.c. C. P. ammonia and shake thoroughly until mixture is complete.

(4). Add 10 c.c. of 95 per cent alcohol. Insert cork. Replace flask into holder. Shake thoroughly. Use best quality cork.

(5). Cool flask by running cold water over lower end of extraction flask, if flask is very hot. Otherwise cooling is not necessary.

(6). Add 25 c.c. ethyl ether. Insert cork, shake vigorously until all butter is dissolved out of boat. Then add 25 c.c. petroleum ether and repeat operation.

(7). Centrifuge flask, turning handle thirty turns after a speed of about 600 R. P. M. has been reached.

(8). Pour off extractions into proper weighed 3½-inch aluminum dishes. Repeat above extraction, adding successively 5 c.c. of 95 per cent alcohol, then 25 c.c. of each of the ethers. For extreme accuracy repeat extraction for third time. The second extraction will remove all but .10 to .15 per cent of the fat. For factory control work, therefore, the third extraction is not necessary.

(9). Evaporate off ether at 135° C. on fat plate and when all ether is off, dry fat in fat oven held at 135° C. for five minutes after the vacuum has reached at least 22 inches.

(10). Cool, weigh and calculate per cent butterfat by dividing net weight of extracted fat by net weight of sample taken, and multiplying quotient by 100.

Moisture Determination

(1). Weigh about one gram of properly prepared sample into solids dish which has previously been treated as per directions for Total Solids Determination of Fresh Milk, paragraphs 1 to 3, inclusive.

(2). Heat solids dish with contents on hot plate at 180° C. until foaming ceases.

(3) Place in vacuum oven held at 100° C. for seven minutes.

(4). Cool,weigh and calculate per cent moisture by dividing loss in weight by net weight of original sample, and multiply quotient by 100.

Detection of Butter, Renovated Butter and Oleomargarine

Microscopic Examination.—Official.[1]—"Place a small portion of the fresh unmelted sample, taken from the inside of the mass, on a slide, add a drop of pure sweet oil, cover with gentle pressure, and examine with a one-half to one-eighth inch objective for crystals of lard, etc. Examine the same specimen with polarized light and a selenite plate without the use of oil. Pure fresh butter will neither show crystals nor a particolored field with selenite. Other fats melted and cooled and mixed with butter will usually present crystals and variegated colors with the selenite plate.

For further microscopic study dissolve from 3 to 4 cc. of the fat in 15 cc. of ether in a test tube. Close the tube with a loose plug of cotton wool and allow to stand from twelve to twenty-four hours at 20° to 25° C. When crystals form at the bottom of the tube, they are removed with a pipette, glass rod, or tube, placed on a slide, covered, and examined. The crystals formed by later deposits may be examined in a similar way."

Foam Test[2]

Heat a small piece of butter (2 to 3 grams) either in a spoon or in an evaporating dish, over a free flame. Heat slowly until the fat boils briskly. If it is butter it will boil quietly and noiselessly and it will foam abundantly. If it is renovated butter or oleomargarine, it will boil noisily, it will bump and sputter, like a mixture of hot

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[1] Journal Association Official Agricultural Chemists, Vol. II, No. 3, 1916.
[2] Patrick, Household Tests for the Detection of Oleomargarine and Renovated Butter, Farmers' Bulletin 131.

grease and water when boiled, and it will produce little or no foam. Leach[1] finds that a very slight foam is sometimes observable with occasional samples of renovated butter, but nothing like the abundant amount of foam produced by genuine butter.

Appearance of the Melted Fat.—Provisional.[2]—"Melt from 50 to 100 grams of butter or process butter at 50° C. The curd from butter will settle, leaving a clear supernatant fat. On the other hand, the supernatant fat in the case of process butter does not assume that clear appearance, but remains more or less turbid." Butter which has been overworked will also melt in a cloudy manner.[1]

The Waterhouse Test[3]

Heat about 50 cc. of well-mixed sweet milk, or sweet skim milk, in a beaker to boiling and add from 5 to 10 grams of the sample to be tested. Stir, preferably with a small wooden stick, until all the fat is melted. Then place the beaker in a dish of ice-cold water and continue the stirring, until the fat hardens and solidifies. If the fat is oleomargarine, it can be readily gathered and formed by the stirrer into one lump or clot. If the fat is genuine butter, or renovated butter, it cannot be so collected, but it remains, in a granulated condition, distributed throughout the milk in small particles.

CHAPTER XXIII.

BACTERIOLOGICAL ANALYSES

It is frequently desirable and advantageous for the creamery to make bacteriological analyses of its butter, or of the products which enter into the process of manufacture, such as milk, skim milk, starter, cream before and after pasteurization, and to also examine bacteriologically some of its equipment, particularly the cream cans, vats, pipe lines, churns, etc.

Some creameries make bacteriological determinations of their butter regularly, either of each churning, or once per week, etc. Others in their attempt to locate the cause of certain flavor defects or inferior keeping quality, resort to bacteriological studies of certain stages of the process of manufacture.

Many of the butter defects are not caused by bacterial action,

[1] Leach, Food Inspection and Analysis, 1914.
[2] Journal Association Official Agricultural Chemists, Vol. II, No. 3, 1916.
[3] Parsons, Journal Am. Chem. Soc., 23, 1901.

and therefore cannot be avoided through a study of the bacterial flora of the product or the equipment, nor through the inauguration of precautions which minimize bacteriological contamination, while others are known to be of bacterial origin and in the latter type of cases bacteriological counts may lead to channels through which permanent solution may be made possible.

As a whole the direct benefit of bacteriological work in the creamery is very limited, but such work may be of value indirectly inasmuch as the results are an index, within reasonable limitations, of the thoroughness with which some of the more important work relating to quality is performed.

While it is obviously beyond the province of this volume to give detailed directions in the technique of bacteriological analyses, in the preparation of culture media and in microscopic study of bacteriological preparations, for all of which the reader is referred to Manuals on Bacteriology, it is deemed advisable to here offer some suggestions relating to these special products, that may serve for the guidance of those who are interested in a bacteriological study of creamery problems.

Sampling.—Samples of milk, skim milk, cream and similar products are best taken into small sterile glass jars with screw top lined with cork or similar material, or in small sterile glass-stoppered bottles. The liquid from which the sample is taken must be thoroughly mixed and the dipper or tube with which the sample is taken must be perfectly sterile, otherwise the results are not dependable. About 10 cc. is usually sufficient.

In the case of butter the sample may be placed into a sterile petri dish or in a sterile bottle as in the case of milk. This is most conveniently done with a sterile trier, the surface of the plug being removed and a segment from one to two inches in length is transferred with a sterile knife or spatula to the petri dish or bottle.

All samples should be analyzed as soon as possible. If this cannot be done immediately the receptacles containing them should be placed on ice or otherwise kept at a temperature as near 32° F. as possible. Especially, milk and cream samples should be immediately cooled to 35° F. or below and kept at that temperature until needed.

Dilutions for Numerical Counts.—For dilutions sterile, glass stoppered 250 cc. flasks are conveniently used. In the case of milk or cream use 2 cc. of sample and 198 cc. of sterile water. The milk or cream is most readily measured and transferred to the dilution flask by the use of sterile, straight stem, bulbless pipettes. This constitutes the first dilution.

In the case of butter, weigh two grams of the sample into a tared flask. Mix with enough sterile water at a temperature of 98 to 100° F. to make up 100 cubic centimeters. This constitutes the first dilution. If yeast and mold counts only are made of butter, dilutions may be dispensed with entirely. In this case the butter sample is melted at low heat (not exceeding 100° F), and 1 cc. of this warm melted butter is transferred direct to the petri dish to which previously was added 1 cc. of tartaric acid and the plating is finished by pouring over the mixture of melted butter and tartaric acid 10 cc. of nutrient agar.

Further dilutions of milk, cream and butter are made in a similar manner as the first dilution, using in the place of the original sample, portions of the diluted sample. Dilutions should be sufficient to limit the number of colonies on the plates to about 50 to 100 colonies per plate. Whole milk as it arrives at the factory averages a total count of from about 100,000 to 1,000,000 bacteria per cc. Cream at gathered cream creameries contains from about 500,000 to 500,000,000 bacteria per cc. before pasteurization and from about 1,000 to 300,000 bacteria per cc. after pasteurization. Butter made from raw gathered cream usually contains from about 1,000,000 to 2,000,000 bacteria per cc., and butter made from properly pasteurized gathered cream contains from about 2,000 to 1,000,000 bacteria per cc. In properly pasteurized cream butter the count of yeast and molds is usually below 10 and often it is 0. When above 10 colonies of yeast or mold or both, either the pasteurization was imperfect, or the butter was recontaminated after the pasteurization of the cream, or the count includes colonies which, though they may thrive in the special medium used for yeast and molds are other than yeast and molds.

Plating.—For plating the following media are recommended:

Media for Total Counts and also for Acidifiers

4 grams beef extract
10 grams peptone
30 grams lactose
4 grams sodium chloride
12 grams thread agar
1000 cc. distilled water
Acidity 0.1 per cent.

For acidifiers add 1 cc. of sterile litmus solution to each plate before pouring the agar.

Media for Liquefiers

4 grams beef extract
10 grams peptone
30 grams lactose
4 grams sodium chloride
150 grams gelatin
1000 cc. distilled water.
Acidity 0.1 per cent.

Media for Yeasts and Molds

4 grams beef extract
10 grams peptone
12 grams agar
1000 grams whey
Acidity 0.2 per cent.

Add 1 cc. of sterile 1 per cent tartaric acid solution to each plate before pouring the medium over the dilution.

Incubation.—Incubate agar, litmus agar and whey-agar plates at 35° C. (95° F.) for at least three days before making counts. Incubate gelatin plates at 21° C. (70° F.) for four to five days before making counts.

Making Counts.—The colonies on the plates are counted most conveniently by placing the plates over a standard counting plate. In the absence of such a plate, place the petri dish upside down on a dark surface and draw, with a blue crayon, radial lines, dividing the field into segments. For plates containing not to exceed 100 colonies; eight to sixteen segments are sufficient for easy counting.

Table 105.—International Atomic Weights

Element	Symbol	Weight Atomic	Element	Symbol	Weight Atomic
Aluminum	Al	27.10	Neodymium	Nd	144.30
Antimony	Sb	120.20	Neon	Ne	20.20
Argon	A	39.88	Nickel	Ni	58.68
Arsenic	As	74.96	Niton (radium		
Barium	Ba	137.37	emanation)	Nt	222.40
Bismuth	Bi	280.00	Nitrogen	N	14.01
Boron	B	11.00	Oscium	Os	190.90
Bromine	Br	79.92	Oxygen	O	16.00
Cadmium	Cd	112.40	Palladium	Pd	106.70
Caesium	Cs	132.81	Phosphorus	P	31.04
Calcium	Ca	40.07	Platinum	Pt	195.20
Carbon	C	12.00	Potassium	K	39.10
Cerium	Ce	140.25	Praseodymium	Pr	140.60
Chlorine	Cl	35.46	Radium	Ra	226.40
Chromium	Cr	52.00	Rhodium	Rh	102.90
Cobalt	Co	58.97	Rubidium	Rb	85.45
Columbium	Cb	93.50	Ruthenium	Ru	101.70
Copper	Cu	63.57	Samarium	Sa	150.40
Dysprosium	Dy	162.50	Scandium	Sc	44.10
Erbium	Er	167.70	Selenium	Se	79.20
Europium	Eu	152.00	Silicon	Si	28.30
Fluorine	F	19.00	Silver	Ag	107.88
Gadolinium	Gd	157.30	Sodium	Na	23.00
Gallium	Ga	69.90	Strontium	Sr	87.63
Germanium	Ge	72.50	Sulphur	S	32.07
Glucinum	Gl	9.10	Tantalum	Ta	181.50
Gold	Au	197.20	Tellurium	Te	127.50
Helium	He	3.99	Terbium	Tb	159.20
Holmium	Ho	163.5	Thallium	Tl	204.00
Hydrogen	H	1.008	Thorium	Th	232.40
Indium	In	114.80	Thulium	Tm	168.50
Iodine	I	126.92	Tin	Sn	119.00
Iridium	Ir	193.10	Titanium	Ti	48.10
Iron	Fe	55.84	Tungsten	W	184.00
Krypton	Kr	82.92	Uranum	U	238.50
Lanthanum	La	139.00	Vanadium	V	51.00
Lead	Pb	207.10	Xenon	Xe	130.20
Lithium	Li	6.94	Ytterbium (Neoyl-		
Lutecium	Lu	174.00	lerbium)	Yb	172.00
Magnesium	Mg	24.32	Ytterium	Yt	89.00
Manganese	Mn	54.93	Zinc	Zn	65.37
Mercury	Hg	200.60	Zirconium	Zr	90.60
Molybdenum	Mo	96.00			

Table 106.—Comparison of Metric and Customary Weights and Measures

Customary weights and measures.	Equivalents in metric system.	Metric weights and measures.	Equivalents in customary system.
1 inch	2.54 centimeters.	1 meter	39.37 inches.
1 foot	0.3048 meter.	1 meter	1.0936 yards.
1 square inch..	6.452 square centimeters.	1 square centimeter.	0.155 square inch.
1 square foot..	9.29 square decimeters.	1 square meter.	10.764 square feet.
1 cubic inch...	16.387 cubic centimeters.	1 cubic centimeter.	0.061 cubic inch.
1 cubic foot...	0.0283 cubic meter.	1 cubic centimeter.	0.0338 fluid ounce.
1 fluid ounce..	29.57 cubic centimeters.	1 cubic decimeter.	61.023 cubic inches.
1 quart	0.9464 liter.	1 liter	1.0567 quarts.
1 gallon	3.7854 liters.	1 dekaliter ..	2.6417 gallons.
1 grain	64.8 milligrams.	1 gram	15.43 grains.
1 ounce (av.).	28.35 grams.	1 gram	0.035274 ounce.
1 pound (av.).	0.4536 kilogram.	1 kilogram ..	2.2046 pounds (av.)

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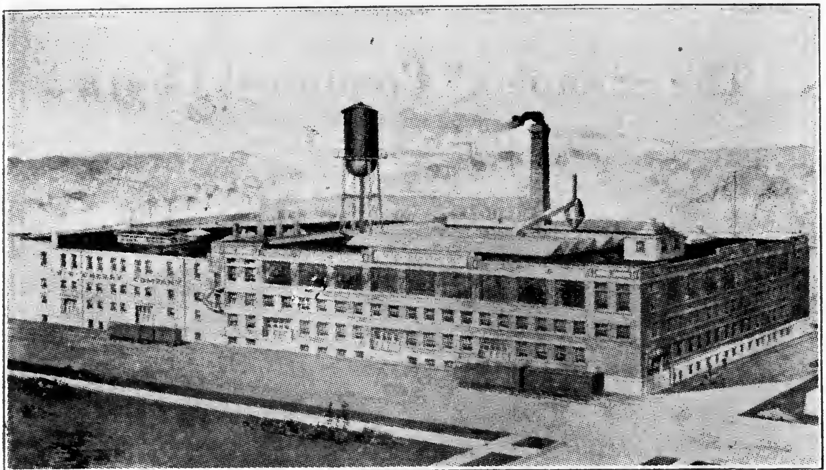

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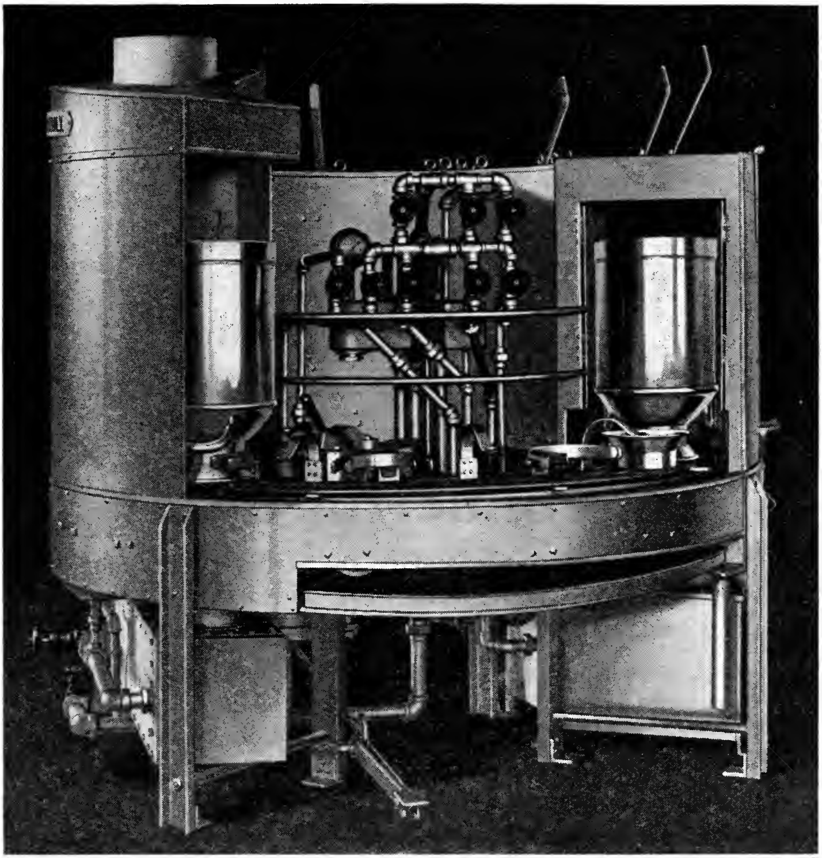

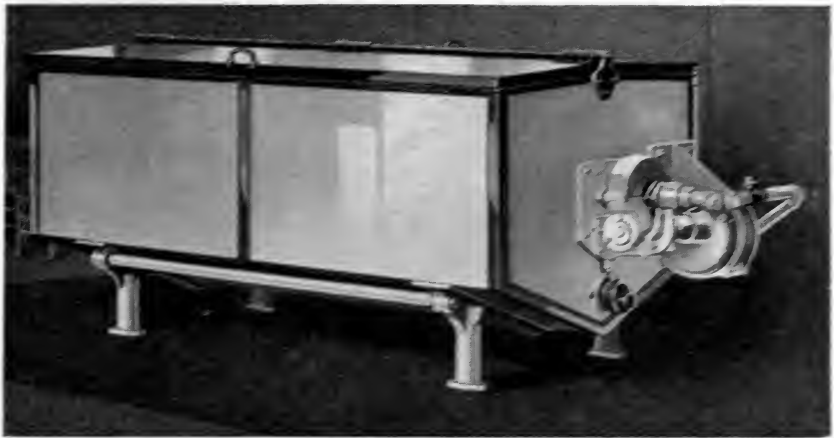

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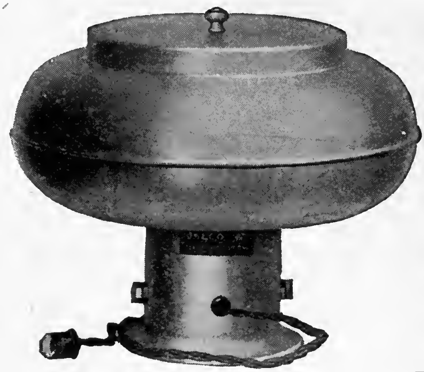

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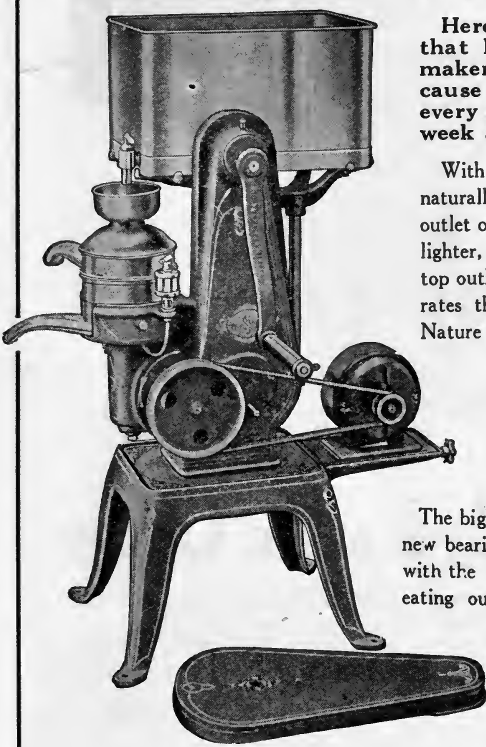

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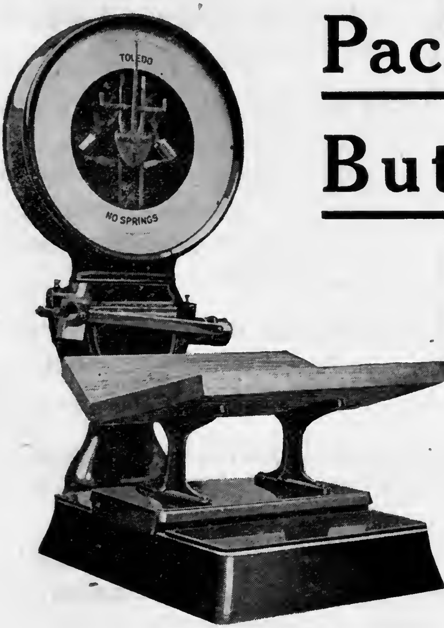

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