INDUSTRIAL FERMENTATIONS

BY

PAUL W. ALLEN, M.S., Ph.D.

Professor of Bacteriology and Head of Department
University of Tennessee

Formerly

Associate in Bacteriology, University of Illinois; Bacteriologist of Washington Experiment Station; for some time Chief Chemist for Food Manufacturing Companies

BOOK DEPARTMENT

The CHEMICAL CATALOG COMPANY, *Inc.*

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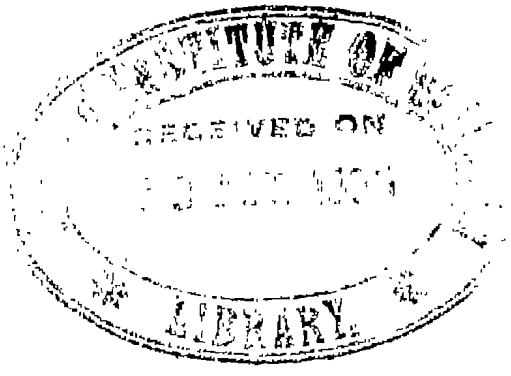

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To

MY FATHER AND MOTHER

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Preface.

The object of this book is to bring together in a general way some of our present information concerning the application of micro-organisms to industry. In so far as possible the plan of arrangement has been to place together as groups those pages having to do with closely allied products. In each chapter the different products have been discussed somewhat as to history and use of product, processes of manufacture, microbiology involved, and bibliography.

There is no intention of treating any of these subjects exhaustively. These subjects are developing so rapidly and the fields are so large that it is out of the question to try to do more than to indicate some of the lines of their development in America. The omission of much important work is recognized.

Mechanical steps having little to do with the microbiology involved are only briefly described. It is often necessary, however, to deal with processes as a whole in order to bring out the relation and importance of the fermentations considered.

Manufacturers are beginning to appreciate the breadth and great value of study in this field. The criterion of present day industry is to find the most economical methods of production and to approach as near as possible to complete utilization of all by-products. Microbiology has made many valuable contributions to the industries and it is very evident that many industries based more or less on biological processes will be altered further. Already the relation of fermentation to manufacturing has been emphasized to such an extent that many manufacturing concerns are employing men versed in fermentation to work on their processes and problems.

The advantages to industry of dealing with micro-organisms may be classified and illustrated as follows: the accomplishment of desirable physical or chemical changes (as cheese ripening); the prevention of undesired changes (as canning); the achievement of certain results unattainable by any other method (as bread-making); and the accomplishment of certain effects or reactions more economically than by other means (alcohol manufacture). In brief the situation is that economic advantage resulting from the employment of the science of industrial microbiology may be in one or more of the following directions:

(a) Product improvement.
(b) Process improvement.
(c) Creation of new products of commercial value.

I wish to acknowledge my appreciation for the many helpful sug-

gestions which I have received during the preparation of this work from Dr. Fred W. Tanner; Dr. M. J. Prucha; Dr. Walter H. MacIntire; Dr. Judson H. Robertson; Dr. Margaret R. MacDonald; my wife, Linda Utter Allen; and my father, Dr. E. Davis Allen.

PAUL W. ALLEN.

University of Tennessee,
Knoxville, Sept., 1925.

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These theoretical yields of CO_2 and of alcohol are never reached. The reason for the reduced yields was explained by Pasteur who found that other products than alcohol and carbon dioxide were produced in alcoholic fermentation of sugars. He also called attention to the fact that some sugar is utilized by yeasts in building new yeast cells. Pasteur obtained 48.3 per cent of alcohol and 46.4 per cent of carbon dioxide.

The ratio of carbon dioxide to alcohol in alcoholic fermentation has been found to vary according to the age of the fermentation and the age of the yeast. Also it has been found that the amount of yeast formed per unit amount of alcohol produced varies greatly at different stages of the fermentation, the greater amount of yeast being formed early in the fermentation.

Hoppe-Seyler emphasized the need of sufficient dilution in alcoholic fermentation indicating that the water molecule enters into the reaction.

Harden and Young brought out the opinion that alcoholic fermentation takes place in steps, the first one having to do with a phosphate which it is agreed is necessary in alcoholic fermentation:

$$2C_6H_{12}O_6 + R_2HPO_4 = 2CO_2 + 2C_2H_6O + C_6H_{10}O_4(PO_4R_2)_2 + 2H_2O$$

The second step of Harden and Young is as follows:

$$C_6H_{10}O_4(PO_4R_2)_2 + 2H_2O = C_6H_{12}O_6 + 2R_2HPO_4$$

Neuberg and Reinfurth gave the following steps for alcoholic fermentation of glucose:

Step (1)

$$\underset{\text{glucose}}{CH_2OH.CHOH.CHOH.CHOH.CHOH.CHO} = \underset{\text{glyceric aldehyde}}{CH_2OH.CHOH.CHO} + \underset{\text{dihydroxyacetone}}{CH_2OH.CO.CH_2OH}$$

Step (2)

$$\underset{\text{glyceric alhedyde}}{CH_2OH.CHOH.CHO} \quad \underset{\text{dihydroxyacetone}}{CH_2OH.CO.CH_2OH} = 2CH_3CO.CHO + 2H_2O$$

$$\text{methyl-glyoxal}$$

Step (3)

$$\underset{\text{methyl-glyoxal}}{2CH_3CO.CHO} + H_2O = \underset{\text{glycerol}}{CH_2OH.CHOH.CH_2OH} + \underset{\text{pyruvic acid}}{CH_3.CO.COOH}$$

Step (4)

$$\underset{\text{pyruvic acid}}{CH_3.CO.COOH} + (\text{carboxylase enzyme}) = \underset{\text{acetic aldehyde}}{CH_3CHO} + CO_2$$

Step (5)

$$\underset{\text{acetic aldehyde}}{CH_3.CHO} + \underset{\text{methyl-glyoxal}}{CH_3.CO.CHO} + H_2O = \underset{\text{ethyl alcohol}}{CH_3CH_2OH} + \underset{\text{pyruvic acid}}{CH_3.CO.COOH}$$

Dubrunfaut showed that cane sugar was not fermented directly into alcohol but first had to be converted into another sugar as:

$$\underset{\text{cane sugar}}{C_{12}H_{22}O_{11}} + H_2O + \text{invertase} = \underset{\text{dextrose}}{C_6H_{12}O_6} + \underset{\text{lævulose}}{C_6H_{12}O_6}$$

$$\underset{\text{dextrose}}{C_6H_{12}O_6} = 2\underset{\text{alcohol}}{C_2H_6O} + 2CO_2$$

Pasteur found as a result of his researches on alcoholic fermentation that not all of saccharose goes to alcohol and carbon dioxide but that a certain small amount, 5. to 6.5 per cent is converted to glycerin and succinic acid as:

$$98\underset{\text{dextrose}}{C_6H_{12}O_6} + 60H_2O = 24\underset{\text{succinic acid}}{C_4H_6O_4} + 144\underset{\text{glycerin}}{C_3H_8O_3} + 60CO_2$$

Duclaux held that acetic acid also appears along with alcohol formation.

Pasteur's conception of alcoholic fermentation by yeast was that the yeast plant attacks sugar in the absence of oxygen to obtain oxygen for respiratory purposes.

Pasteur in 1857 and 1858 mentioned succinic acid ($C_2H_4(CO_2H)_2$) and glycerin ($C_3H_5(OH)_3$) as by-products of alcoholic fermentation of sugar. He obtained yields gravimetrically of .673-.76 parts of succinic acid, 3.607-3.64 parts of glycerin, and 1.2-1.3 parts of fats, cellulose, etc., from 100 parts of sugar. A more detailed discussion of glycerin production from the fermentation of sugar will be found in the chapters on acetone and glycerin.

Kruse has given the following reactions to explain the appearance of acetic and lactic acids in alcoholic fermentation of dextrose:

$$2\underset{\text{dextrose}}{C_6H_{12}O_6} = 3\underset{\text{acetic acid}}{CH_3COOH}$$

$$6\underset{\text{dextrose}}{C_6H_{12}O_6} = 2\underset{\text{lactic acid}}{C_3H_6O_3}$$

Fusel oil is another product which usually occurs in alcoholic fermentation of sugar and persists in traces even in alcohol after rectification. Fusel oil is mainly inactive amyl alcohol ($(CH_3)_2.CH.CH_2.CH_2(OH)$) but is always accompanied by active amyl alcohol.

Many explanations of the presence of fusel oil in alcoholic fermentation have been given. Brefeld held that it was produced by decomposition of dead yeast bodies which begin to accumulate toward the end of alcoholic fermentation. Along this same line of thought is that of Ehrlich who made a study of yeast action on amino acids. He found that when leucine or isoleucine was present in the alcoholic fermentation of sugar both active and inactive amyl alcohol were produced as follows:

$$\begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!CHCH_2CHNH_2COOH + H_2O =$$

leucine

$$\begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!CHCH_2CH_2OH + CO_2 + NH_3$$

amyl alcohol

$$\begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!CHCHNH_2COOH + H_2O = \begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!CHCH_2OH + CO_2 + NH_3$$

isoleucine — active amyl alcohol

Concerning these reactions of Ehrlich, Haas and Hill say, "The amounts of these alcohols produced are proportioned to the quantities of leucine or isoleucine added and rise under favorable conditions to as much as 7 per cent; furthermore it was found that although the leucine parted with its nitrogen in the form of ammonia, the latter substance was not lost but appeared to be taken up by the yeast in the production of new protein material; this observation led to trying the effect of adding ammonium salts, when it was found that the yeast, finding these latter to be an easier source of nitrogenous food, gave up attacking the leucine, and consequently less amyl alcohol was produced."

Another explanation of the presence of fusel oil in alcohol is that of Perdrix, of Péreire and Guignard, and of Pringsheim who found bacteria in alcoholic solutions which could produce fusel oil. In this connection Gayon and Dupetit found that fusel oil production was suppressed by the addition of bactericides to alcoholic fermentations.

Other products sometimes produced in small amounts during alcoholic fermentations are formic acid, butyric acid, propionic acid, valeric acid, caproic acid, caprylic acid, etc.

Enzymes of Yeast.

The enzyme in yeast which causes the d-series of hexose sugars to be converted into alcohol has come to be called alcoholase. This enzyme was first described by Buchner who called it zymase. But due to the fact that this term had previously been applied to the saccharose inverting enzyme of yeast previously by Bechamp the newer name, alcoholase, has come into quite general use.

Invertase or sucrase is an enzyme common to most yeasts. It makes possible the alcoholic fermentation of cane sugar, that is, saccharose, by hydrolyzing its molecule to glucose and lævulose, both of which then can be fermented to alcohol.

Other enzymes which are present in many yeasts are maltase (converting the maltose molecule to two molecules of glucose), and lactase (converting the lactose molecule to a molecule of glucose and one of galactose).

The proteolytic enzyme, endotryptase, produced by yeast is very important from the standpoint of yeast cell physiology. This enzyme

is an endo-enzyme remaining within the yeast cell and acting on intracellular material.

Physiology of Yeast.

Concerning the physiology of yeast in industrial alcohol manufacture, Breckler says, "Any process for making alcohol must give careful consideration to the question of yeast nutriment. As the amount of yeast formed is dependent upon the volume of liquid rather than the concentration of the fermentable matter, the most economical process in this respect will evidently be that in which the concentration of the fermentable matter is the greatest practical. About 8 pounds of dry yeast are formed from every 1000 pounds of fermentable liquor of which 6 per cent or ½ lb. is nitrogen. If a liquid contains 10 per cent of fermentable, the amount of nitrogen required is 1/13 of a pound per gallon 160 proof. The potash requirements are about 1/5 of the nitrogen. Just as much attention to yeast poisons is desirable."

Uses of Alcohol.

The four main uses of alcohol are:

(1) Industrial uses as a solvent, etc.
(2) Use in medicines and the preparation of medicines.
(3) As fuel.
(4) Formerly as a beverage.

By the term industrial alcohol is meant ethyl alcohol denatured with a government authorized substance, as pyridin bases, benzin, wood alcohol, iodin, etc. A long list of different denaturing formulas have been made lawful in the United States. These different formulas were originated with the idea of adding a denaturing substance to alcohol which will be beneficial or at least not harmful to the product in which the alcohol is to be used. In other words, the United States Government wishes to make sure that alcohol will not be used as a beverage, and at the same time does not wish to interfere with its industrial uses. However, many complaints have been made that much hardship to industry has resulted from the addition of denaturing substances to alcohol.

The industrial use of alcohol has been greatly extended in recent years, still many believe that it is inevitable that sooner or later its use as a fuel will supersede its use in all other ways. Alcohol and alcoholic mixtures have already grown in use in Europe as a motor fuel. It is reported that the mixture of alcohol and benzol is very satisfactory as a fuel for tractors.

The raw materials which may serve as sources of industrial alcohol are very numerous, as corn, molasses, potatoes, sawdust, beet pulp, agave, palms, apple culls, cactus, sorghum, garbage, fruits, hay, straw, corn stalks, weeds, grains, artichokes, cassava, etc. However, in

this country only molasses and corn have been extensively used as sources. In Europe potatoes are successfully manufactured into alcohol.

In discussing the manufacture of denatured alcohol in the United States, the editor of the *Journal of Industrial and Engineering Chemistry* says that denatured alcohol was first allowed to be manufactured tax-free in the United States by an act of Congress dated June 7, 1906. Since that date up to the time of the signing of the Armistice, denatured alcohol steadily increased. The demands for "completely denatured alcohol" and "specially denatured alcohol" have been gradually increasing and broadening.

It was to be expected that alcohol demands would be greater during the World War than immediately after as is shown by the figures of the following alcohol production table. However, the normal increase in the use of industrial alcohol is being felt again.

A long list of different "Formulas for Completely and Specially Denatured Alcohol" were authorized in 1922 by the United States Internal Revenue Bureau. These formulas have been originated to best adapt the alcohol to the use which is to be made of it in commerce.

The figures in the following table are taken from those of the office of James P. McGovern of the United States Industrial Alcohol Company, published in the *Journal of Industrial and Engineering Chemistry*, Vol. 15, pp. 1086-1087.

DENATURED ALCOHOL PRODUCTION.

Years	*Completely Denatured Alcohol*	*Specially Denatured Alcohol*
1907	.....	.....
1908	1,812,122.38 gallons	1,501,356.45
1909	2,370,839.70	2,185,097.59
1910	3,076,924.55	3,002,102.55
1911	3,374,019.92	3,507,109.94
1912	4,229,741.67	3,933,246.44
1913	5,222,240.78	4,608,417.76
1914	5,213,129.56	5,191,846.03
1915	5,386,646.96	8,599,821.81
1916	7,871,952.82	38,807,153.56
1917	10,508,919.34	45,170,678.29
1918	10,288,321.33	39,707,170.49
1919	9,988,566.17	28,293,615.94
1920	13,476,796.17	15,268,839.25
1921	12,226,518.87	9,967,320.28
1922	16,209,902.83	17,089,263.54

The following note concerning the above figures is given: "Compiled from the Annual Reports of the Commissioner of Internal Revenue. Amounts for 1907, amounts by formulas of Completely Denatured Alcohol for 1908, 1909, 1910, 1911, and 1912, and amounts by formulas of Specially Denatured Alcohol for 1910, and 1911 are not given in such reports and are not available."

Manufacture of Alcohol from Cellulose-Containing Materials.

The civilized world is rapidly increasing its demands for more light, more heat, more electricity, and motive power in all forms. The sun is eventually the source of all this increased physical activity. Human progress and fuel consumption seem to go hand in hand. Coal, petroleum, vegetation, water power, and the sun's rays seem to be quite exclusively the present sources of energy. These sources represent in reality the sun's rays, past and present. When the supply of coal, petroleum, and wood is consumed, many believe we will be restricted to the utilization of the annual fixation of energy from the sun's rays, in other words, annual crops.

The relation of the chemist to this annual crop of fixed energy has been discussed by Hibbert. He says, "According to a recent report of the United States Geological Survey, if the rate of production of crude oil in 1920, namely, about 443,000,000 barrels, continues to be maintained our supply of crude oil will have become entirely exhausted in about 13 years. Does the average citizen understand what this means? In from 10 to 20 years this country will be dependent entirely upon outside sources for a supply of liquid fuel for farm tractors, motor transportation, automobiles, the generation of heat and light for the thousands of country farms, the manufacture of gas, lubricants, paraffin, and the hundreds of other uses in which this indispensable raw material finds an application in our daily life.

"It must be frankly admitted that at the present moment there is no solution in sight, and it looks as if in the rather near future this country will be under the necessity of paying out vast sums yearly in order to obtain supplies of crude oil from Mexico, Russia, and Persia. It is believed however that the chemist is capable of solving this difficult problem on the understanding that he be given opportunities and facilities for the necessarily laborious and painstaking research work involved."

The most common way of thinking of alcohol production from annual crops is the acid hydrolysis of cellulose to sugars and the alcoholic fermentation of the sugars thus produced. However the cost of the acid and fuel required for this mode of hydrolysis throws the cost of alcohol per gallon much higher than is necessary. Other methods of converting starch and cellulose to sugar have been tried out, and show much promise. Hibbert says, "Of all chemical processes those carried out by living organisms or enzymes are, comparatively speaking, the cheapest to operate, since the expense for labor, etc., is small, due to the efficient manner in which the tiny organisms operate.

"The recent work carried on by Boulard in France on the production of alcohol from starch by the action of certain alcohol-producing fungi indicates a new method of approach from which apparently much may be expected. By the action of these new agents it is claimed that starch may be converted directly into alcohol, although

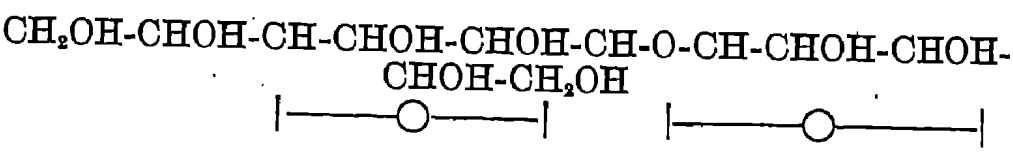
in practice it has been found better to use the fungi only for converting the starch into sugar and then to ferment the latter with yeast. Much higher yields are claimed than where the saccharification is effected by acids or by malt. Large-scale experiments are stated to show a yield of 39 to 44 liters of pure alcohol from 100 kilograms of grain compared with 27 to 33 by the acid and 34 by the malt process."

Hibbert says that Pringsheim guided by the epoch-making work of Buechner on fermentation and the action of ferments, has been able to show that there is a strict analogy between the fermentation of certain carbohydrates such as maltose, cane sugar, starch dextrins, etc., and that of cellulose. He says, "In the former cases fermentation takes place in two stages in which two different groups of ferments play an active rôle. These are the 'hydrolytic' and 'fermenting' types, respectively. The former bring about the hydrolytic conversion of the maltose, starch dextrins, etc., into glucose, while the latter induce fermentation of this with formation of alcohol.

He further adds,

"Similarly under the action of certain ferments, associated with specific microörganisms found in horse-manure, river mud, etc., cellulose is converted into glucose. The first change is brought about by the action of the hydrolytic ferment 'cellulase' which converts the cellulose into cellobiose. Under the action of a second ferment 'cellobiase' the cellobiose is converted into glucose."

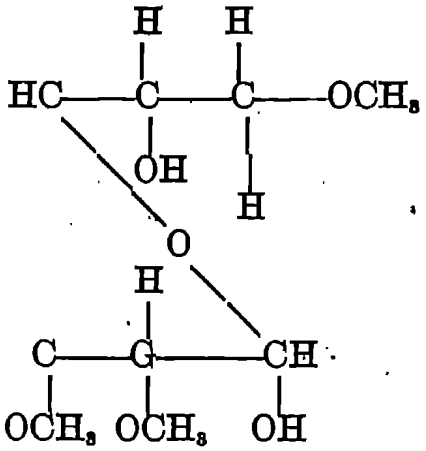
The formula for cellobiose as given by Haworth and Hirst is as follows:



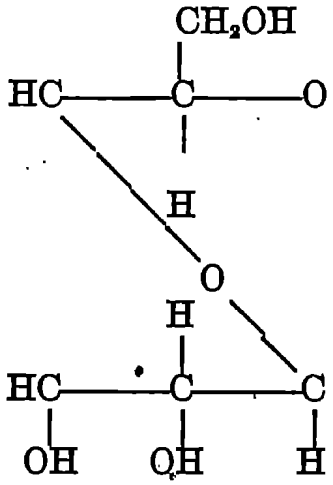
The increasing demands for industrial alcohol and its probable use as power fuel has greatly stimulated interest in the chemistry of cellulose from the standpoint of its possible economic conversion into industrial alcohol.

The empirical formula for cellulose is $C_6H_{10}O_5$; however this does not tell anything about the internal structure of the molecule. With the recent discovery that cellulose, no matter what its source, has the same structural makeup, renewed interest has been given to cellulose chemistry.

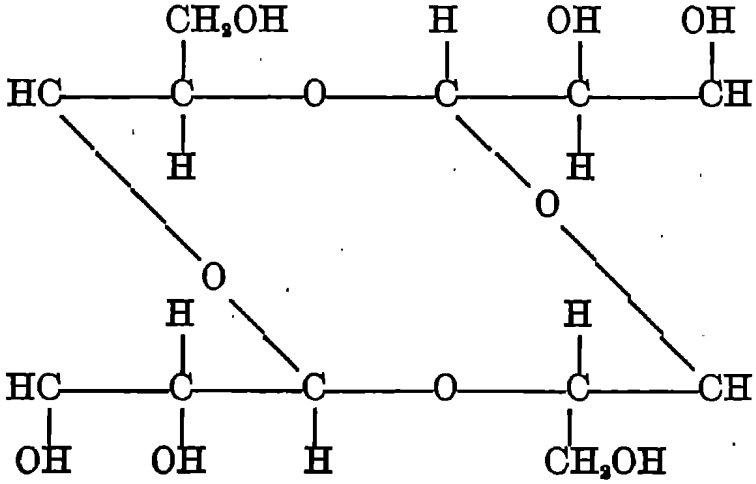
Concerning the structural formula for cellulose, Esselen says, "Cellulose chemists for the most part have been agreed for some time that cellulose contained three hydroxyl groups and no more, but whether these were primary, secondary, or tertiary was not known. Denham and Woodhouse recently answered this question very prettily by repeated treatments of cellulose with dimethyl sulphate in the presence of alkali. On hydrolyzing with weak acid they obtained chiefly trimethyl dextrose, which may be represented.



Then for the first time, it was clear that in cellulose there were two secondary hydroxyl groups and one primary hydroxyl group. With this clue, in addition to the previously known facts, Hibbert suggested the following formula for the cellulose nucleus:



with the idea that the fundamental unit from which the cellulose molecule is built up, is cellobiose made by the union of two of these cellulose nuclei.



Admittedly the cellulose molecule is very much larger than cellobiose and the question is now under discussion as to whether it is a polemerized molecule held together by strictly primary valences or whether it is a colloid molecule of the general type suggested by Langmuir and held together by secondary or residual valences."

In a discussion of the action of bacteria on cellulose material before the 42d Annual Meeting of the Society of Chemical Industry, A. H. Lymn and Herbert Langwell said, "The substances resulting from the fermentation of cellulose represent perhaps the most promising source of light motor fuel at present in sight provided that they are obtained from waste substances, such as maize waste (cobs and stalks), various straws and grasses, etc.

"From 1895 to 1902 Omeliansky published his researches, giving detailed accounts of the products obtained from cellulose by fermentation at about 35° C. In 1899 Macfadyen and Blaxall (*Trans. Inst. Preventive Medicine*, 1899, 162) first described the action of thermophilic organisms on cellulose at about 60° C., gave no detailed account of the product. Later Pringsheim (*Centr. Bakt.*, Abt. 2, Vol. 30) communicated an analysis of the products of the thermophilic fermentation of cellulose at 55°-60° with production of formic and acetic acids, hydrogen and carbon dioxide. All the above were purely laboratory experiments, apparently with no technical exploitation in view. The only experiments on a large scale on record, apart from our own, so far as we are aware, are those of G. J. Fowler and G. V. Joshi (*J. Indian Inst. Sci.*, 1920, 3, 39-60), who concluded that hemicelluloses were more suitable for fermentation than the more resistant celluloses."

Lymn and Langwell isolated an organism from stable manure which would attack "almost every form of cellulose under either anaërobic or aërobic conditions."

The optimum temperature for growth of this organism was said to be 60°-68° C. Some of the carbohydrates which it fermented in their experiments were resistant celluloses, modified resistant celluloses, hemicelluloses, starches, sugars, etc.

As explanation of the mode of attack which this organism uses, they say,

"The following equations are an attempt to trace the course of fermentation in order to account for the products obtained. They are largely based upon Neuberg's well-known work on yeast fermentation, together with our own experimental experience.

"The first action is probably the hydration of cellulose and its breakdown to pyruvic acid and hydrogen. This is endothermic, so that pyruvic acid is not likely to be found as an end product.

(1) $C_6H_{10}O_5 + H_2O \rightarrow 2CH_3.CO.COOH + 2H_2$.

"Under suitable conditions this pyruvic acid and hydrogen continue to give lactic acid.

(2) $CH_3.CO.COOH + H_2 \rightarrow CH_3.CHOH.COOH$

This is an exothermic reaction and lactic acid is actually found in the products.

"Under other conditions pyruvic acid splits off CO_2 to yield acetaldehyde.

(3) $CH_3.CO.COOH \rightarrow CH_3.CHO + CO_2$

This is only faintly exothermic, so that aldehyde-fixing agents would be necessary to prevent further splitting of the aldehyde. The fixation of aldehyde is difficult with the cellulose fermentation owing to its powerful reducing action, and has not yet been successfully accomplished.

"The aldehyde may then according to the conditions of fermentation follow one or both of two courses; it may be reduced to alcohol as No. 4, or hydrolyzed to a mixture of acetic acid and alcohol as No. 5.

(4) $CH_3.CHO + H_2 \rightarrow CH_3.CH_2.OH$

(5) $2CH_3.CHO + H_2O \rightarrow CH_3.CH_2.OH + CH_3.COOH$

"By again changing the conditions, the alcohol once forced may break down to a mixture of acetic acid and methane.

(6) $2CH_3.CH_2.OH \rightarrow CH_3.COOH + 2CH_4$.

"This change has been repeatedly observed and is sometimes difficult to prevent.

"The high yields of acetic acid obtainable can only be explained by a reaction such as:

(7) $C_6H_{10}O_5 + H_2O \rightarrow 3CH_3.COOH$

"A secondary reaction, well known in biological processes, results in the breakdown of lactic acid to butyric acid.

(8) $2CH_3.CHOH.COOH \rightarrow CH_3.CH_2.CH_2.COOH + 2CO_2 + 2H_2$

"Finally, over-aeration results in complete oxidation of any of the above products to CO_2 and H_2O."

Concerning the fermentation of cellulose into fuel gases Esselen says, "Some organisms decompose it into acetic, butyric, and lactic acids, while others give hydrogen, methane, and carbon dioxide. Some scientists in India have recently busied themselves with an investigation to determine the possibilities of using this latter phenomenon to produce heat. While cellulose, particularly in its usual forms, is quite resistant to the action of bacteria, the so-called hemicellulose is quite reactive. It so happens that in India there are ample waste cellulose materials, such as banana skins and stems and other vegetable refuse, which contain hemicelluloses and have been found to give excellent results in fermentation. After considerable experimenting it was found possible to obtain a daily volume of combustible gas equal to 80 per cent of the volume of the space occupied by the fermenting material. When this gas is collected over water, which is of course the usual situation, it contains about 85 per cent of methane, and is therefore of high calorific value. This calorific value is reported as averaging about 930 B.t.u. per cu. ft., which is almost twice the calorific value of the illuminating gas in Boston. The men who conducted the investigation feel that the fermentation of cellulose might

prove a useful process for the production of a power gas for industrial purposes."

A very valuable report on the subject of the ability of the United States' Forests to supply liquid fuel was read by R. C. Hawley before the section of Cellulose Chemistry of American Chemical Society Meeting at Rochester in 1921. He gave the following data concerning the U. S. exclusive of Alaska:

Acres forested with second growth forests	245,000,000
Waste land on which nothing is growing but capable of reforestation	81,000,000
Virgin forests	137,000,000
Total	463,000,000
Present growth of timber (cubic feet) per year (second growth)	5,995,000,000
Possible growth of timber (cubic feet) per year	27,780,000,000
Amount of wood removed annually as lumber, fuel, other products, destroyed by fire, insects and fungi	26,048,915,000
Cubic feet of wood as waste from lumbering, loss by fire, insects and fungi, as excess of possible growth over annual cut and as possible increased growth due to more intensive crop management, which could be used for liquid fuel production without encroachment upon the supply of other forest products	11,030,000,000

Concerning liquid fuel production according to the above data, Hawley says, "In making the calculation a cubic foot of wood is taken as weighing 30 pounds and a ton of wood as yielding 15 gallons of alcohol. On this basis the 11,000,000,000 cubic feet of wood will furnish an annual output of 2,475,000,000 gallons of alcohol or 33 per cent of the total amount of alcohol needed to replace the present output of gasolene.

"The cost of the raw wood laid down at the manufacturing plant is estimated to average 25 cents per gallon of alcohol produced by present methods although where the proper region and species are chosen this cost may be reduced to 7 cents per gallon. It remains for the chemists to develop improved methods of utilizing the cellulose more completely thereby increasing the output secured from a ton of wood."

Motor Fuel from Vegetation.

Concerning the use of alcohol as motor fuel, Boyd says, "Alcohol has been used as a motor fuel to a considerable extent and it has been found to be suitable for this purpose, and indeed it has certain advantages. Its combustion is marked by cleanliness and freedom from any deposition of carbon in the combustion chamber. Because it boils at a definite and comparatively low temperature it can be well distributed in multi-cylinder motors. On account of its low boiling point it should give no trouble from dilution of crank case oil. Alcohol will stand very high initial compressions without knocking and at high compressions its combustion is smooth and highly satisfactory. Because of the high compression at which alcohol may be used the available horsepower of a definite size of motor is much greater with alcohol

than with motor gasolene, if each be run at its most economical compression."

The following disadvantages of the use of alcohol as motor fuel are enumerated by Boyd.

"1. Low heating value—around 80,000 B.t.u. per gallon, as compared to about 120,000 B.t.u. per gallon of gasolene.
"2. High latent heat and low vapor pressure make it hard to start.
"3. Is absorbed by cork carburetor, thus rendering them valueless. Loosens gummy or other materials deposited in fuel system and thereby clogs screens in the fuel lines.
"4. Will not blend with petroleum oils unless it is either practically free from water, or unless a binder is used."

In some preliminary experiments concerning the manufacture of ethyl alcohol from wood waste, F. W. Kressman described a process as follows: "The process of producing ethyl alcohol from wood consists, in general, of digesting sawdust or hogged and shredded wood with a dilute mineral acid at from 60 pounds and more, of steam pressure. This converts part of the wood into a mixture of pentose and hexose sugars. The latter are then fermented, producing alcohol.

"The source of the fermentable sugar, that is, whether derived from the cellulose or lignin of the wood has long been a mooted question and has been the occasion of considerable investigation, but the fact remains that a wood cellulose like soda or sulfite pulp will produce about twice as much fermentable sugar and alcohol as the original wood, the yields being proportional to the cellulose content."

E. C. Sherrard in an investigation of the possibilities of the manufacture of industrial alcohol, that is, ethyl alcohol, from Western Larch (Larx occidentalis, Nuttall), says, "The search for raw materials from which alcohol can be prepared has been carried to all quarters of the earth and to many different products. Several different wood products have been investigated. One of the very interesting attempts to produce alcohol from wood commercially is that reported by Sherrard, who studied the Western Larch as a source of industrial alcohol. His work followed that of Schorger, who found a water-soluble material in Western Larch called galactan which upon hydrolysis with dilute acid yields the sugar galactose. Schorger's work in attempting to ferment this galactose to alcohol with 'S. Carlsbad I' yeast resulted in but a 40% yield of alcohol. Kressman working on the same problem of alcohol production from larch found that when the wood was hydrolyzed, 26.21 per cent to 30.52 per cent of sugar resulted. He further found that when yeast was added to the liquor the sugars resulting from the hydrolysis of cellulose were fermented while the galactose was not attacked at all or at least very little."

Sherrard took up the problem at this point and fermented the hydrolyzed water-soluble galactan and the sugar products of the

hydrolysis of the cellulose residue separately. By this method he was able to obtain the following average yields:

Total Reducing Sugar per cent	29.00
Total Sugar Fermentable per cent	72.00
Theoretical Alcohol per cent of dry wood	10.78
Actual Alcohol per cent	10.65
Fermentation Efficiency per cent	98.7
Alcohol Calcd. 95% per ton of dry wood	33.0

Sherrard says, "The yeast used for the actual fermentation was a pure strain culture of a Hungarian beer yeast. Saccharomyces cerevisiæ, which has been in use at the Forest Products Laboratory for several years and has proved very efficient in the fermentation of sugars resulting from the hydrolysis of wood.

"The sugar solutions were prepared for fermentation by evaporating to a suitable concentration and then adding a sufficient quantity of 10 per cent solution of autolyzed yeast to make the whole correspond to a 2 per cent yeast solution. The yeast water was prepared according to the method of Fred and Peterson by boiling autolyzed yeast with distilled water for one hour and filtering while hot. The solution was then again boiled, filtered, and finally sterilized in an Arnold steam sterilizer."

Concerning the control of the fermentation of the two different liquors obtained from the larch, Sherrard says, "In the fermentation of the sugars resulting from the autoclave cooks of the extracted residue no precautions are necessary other than those already described. (*Phil. Magazine* (6) 9 (1905), 599; *Am. Jour. Sci.* (4) 18 (1904), 378.) In order to obtain a satisfactory fermentation of the solutions containing galactose, however, it is imperative that the temperature and acidity be carefully regulated. The temperature must be held between 85 degrees and 90 degrees F., and the initial acidity of the solution not greater than 5 degrees. If the acidity is greater little or no fermentation takes place. When the galactose solution is fermented alone, but very little increase in acidity occurs as the fermentation progresses, but when the solution resulting from the hydrolyzed wood is fermented, an increase of 4 per cent acidity is quite common."

Manufacture of Industrial Alcohol from Wood Pulp Liquor.

Ellwood Hendrick, writing in *Paper* (1908) says: "The liquor contains from 8 percent to 10 percent of dry residue, which includes the lignin, with all that the word implies. Less than 1½ per cent of the dry residue is inorganic. In varying quantities there is SO_2 both free and combined, sulphuric acid, and about three-quarters of 1 per cent lime. The sugar content varies from a maximum of 3 per cent to something pretty close to zero as the minimum. The per cent of alcohol from the liquor is a very high yield even in Sweden. With good practice about two-thirds of the sugar is fermentable.

"In 1913 the West Virginia Pulp & Paper Company put up the first plant in the United States at Mechanicville, N. Y., to make ethyl alcohol from this material. Operations began in March, 1914. Counting all the costs, it has not been a profitable undertaking. But where should we be if there were nobody to try things out? The feeble of will are discouraged by unsuccessful experiments, and such men lead only at industrial funerals. The real leaders in industry, on the other hand, have the virtue of perseverance along with the quality of sportsmanship, and often, indeed, they can see romance in a scrap-heap that wrings only tears of gloom from their ungifted fellows.

"The alcohol plant was built to treat 100,000 gallons of waste liquor a day, which at that time was the regular product of the establishment at Mechanicville. They have been producing 500 gallons of alcohol a day. This is now running somewhat higher owing to changes in methods.

"Whether any of the sugar found in the liquor is that which was formed of water and CO_2 by the catalytic action of chlorophyll in the green leaves of the trees while still growing seems still open to question, although it is hardly possible that more than a very small portion of it, if any, can come from this source. Dr. Erik Haegglund, in an interesting series of articles, claims that wet wood produces more sugar than that which is dry. This has not been confirmed at Mechanicville. He also expresses the opinion that none of the sugar present has its origin in cellulose, although he says that Dr. Eckstrom, under whose patents these works are operated, holds the opposite view. The impression prevails also that a good part of the sugar is the product of lignin; from all of which we may gather that the chemical history of the sugar in sulphite waste liquors is still more or less guessed at.

"Dr. Haegglund reports that Sweden produces 660,000 gallons of alcohol annually by this method."

In a paper dealing with the manufacture of ethyl alcohol from wood waste, F. W. Kressmann says: "The production of fermentable sugars and ethyl alcohol from cellulosic materials, such as straw, linen, cotton, peat, wood, and in fact, all plant fibers, has engaged the attention of chemists and technologists for nearly a century. It is only within the last two decades, however, that serious attempts have been made to utilize wood waste for this purpose. The principal sources of fermentable sugars from which alcohol is at present derived are the hydrolytic products of starch and the sugars obtained from fruits and such sugar-factory residues as molasses.

"Corn yields about 2.4 gallons of 188-proof spirit a bushel; and, although the price of corn and other grains varies with the season and from year to year, before the war the average cost of the materials for making grain alcohol, fuel excluded, was about 27½ cents a 188-proof gallon. Manufacturing costs, including coal, interest, repairs, depreciation, taxes, labor, etc., ranges from 10 to 17 cents a gallon of 188-proof alcohol, depending upon the location and efficiency of the plant.

"One gallon of molasses yields from 0.45 to 0.48 of a gallon of 188-proof spirit. The price of molasses before the war averaged from 5 to 7.5 cents a gallon, and, therefore, the approximate cost of raw material in a gallon of molasses spirit was from 10 to 15 cents. The cost of production of molasses spirit is slightly less than that of grain spirit, but in either case the cost of raw materials is comparatively high.

"One ton of dry sawdust or other wood waste (or its equivalent on an air-dry or green basis) will yield from 12 to 20 gallons of 188-proof spirit. The disposal of this waste in the vicinity of a sawmill or other large woodworking plant is specifically an item of loss, because most sawmills produce waste in excess of their own power requirements. Sometimes the waste is not worth more than 30 to 50 cents a ton, and this makes the cost of raw material in a gallon of ethyl alcohol from sawdust about 2 cents. This includes also the fuel charge, for the residue after conversion and extraction is available for fuel, whereas in grain distilleries about 7 tons of coal and in molasses distilleries about 4 tons are required in producing 1,000 gallons of 188-proof spirit.

"If the manufacturing cost of producing ethyl alcohol from wood can be reduced to the same figure or nearly the same as that for making it from grain or molasses, there will be a large margin in favor of producing the alcohol from wood waste."

Kressmann says:

"The processes used for the production of ethyl alcohol from wood may be grouped into two general classes: Hydrolysis of wood into fermentable sugars by the use of dilute acid (preferably mineral acid) as a catalyzer, and solution processes, in which the wood is dissolved in concentrated acid and the diluted solution is then subjected to hydrolysis.

"The first process consists, in general, of digesting sawdust or hogged and shredded wood with a dilute mineral acid under 60 pounds or more of steam pressure. This converts part of the wood into a mixture of pentose and hexose sugars. The latter are then fermented into ethyl alcohol.

"Processes of the second class, involving the use of concentrated sulphuric acid and in which the wood is actually dissolved by the acid, as in the Ekstrom process, have not received commercial attention, notwithstanding the fact that Flechsig many years ago showed that cotton cellulose could thereby be converted into dextrose and alcohol almost quantitatively. The more recent work of Willstatter and Feichmeister with fuming hydrochloric acid on cotton and wood has confirmed these results; but in all those experiments the amounts of acid required have been so large that the initial and recovery costs for acid have prevented commercial development.

"Whether the source of the fermentable sugars is the cellulose or the lignin of the wood has long been a subject for debate and has also been the occasion of considerable investigation; but the fact remains that a wood cellulose like soda or sulphite pulp has been found to

produce about twice as much fermentable sugar and alcohol as the same amount of the original wood, the yields being in proportion to the cellulose content."

Nipa Palm of Philippine Islands as a Source of Industrial Alcohol.

The claim is made that this palm furnishes the cheapest raw material in the world for alcohol manufacture. It is estimated that the Philippine Islands could furnish 50,000,000 gallons of alcohol annually from the Nipa palm.

Manufacture of Alcohol from Molasses.

In the manufacture of alcohol from cane molasses, the molasses is diluted, properly acidified, and balanced by adding a nitrogenous compound, usually ammonium sulphate, for the purpose of supplying the yeast with a nitrogen supply.

According to Wiley and Sawyer it is best to dilute cane molasses to about 12% of sugar before starting fermentation. Beet molasses is usually alkaline and has to be acidified before being "pitched."

Manufacture of Alcohol from Corn.

In the manufacture of corn into alcohol the process is much less simple than in the case of cane molasses. The grain must be ground, cooked, and malted before fermentation can take place. The grain is cooked at 50 lbs. pressure in a large pressure cooker with steam coils or steam jacket and a powerful rotating agitator. Water is added to the grain before cooking in the proportion of 20 gallons to the bushel. When the grain is cooked and cooled malt is added. Green malt is used in the proportion of 1 lb. to 20 lbs. of grain. Dry malt is only one-half as strong as green malt. After the malt is added, about an hour is required at 145° F. to convert the gelatinized starch of grain to sugar. The converted mash is then pumped to fermentation cellars, inoculated with distiller's yeast and held at 65° F. until fermentation is complete, which requires from two to five days. When the fermentation is complete the fermented liquor is distilled.

Industrial Alcohol from Potatoes.

In 1910 there was wide interest in the subject of the manufacture of industrial alcohol for power purposes. Many different waste products were being studied as to their possibilities in the way of alcohol production. Wente and Tolman went into considerable detail in a study of potato culls as a source of industrial alcohol.

They say in U.S.D.A. Bul. 410 (1910), "Alcohol is a substance produced by the fermentation of sugar. In practice there are two possible sources of sugar for this purpose; first, plants naturally con-

taining sugar ready to be converted into alcohol by simple fermentation, such as sugar cane, sugar beets, sorghum, fruits, etc.; second, materials containing starch which may be changed into sugar by the action of malt or acids and then fermented, such as potatoes, grains, cassava, etc.

"The so-called 'denatured alcohol' is prepared by the addition of such ingredients as will make the alcohol unfit for drinking purposes. It is used extensively in the manufacture of varnish, explosives, chemicals, and many other commercial articles. It may be also used in various household appliances, both for lighting and heating purposes with much more safety than either kerosene or gasoline. Its cost previous to the enactment of laws making it tax-free was such as to prevent its use in engines and motors, consequently very little was done toward their adaptations to its use. It is, however, being successfully used in both stationary and traction engines in other countries where it can be had at a moderate price, and under similar conditions of economic manufacture would undoubtedly be so used in this country.

"One per cent of sugar or starch in a product will produce approximately one-half of 1 per cent of alcohol. It is not practicable to distill a fermented solution containing less than 2 or 3 per cent of alcohol. It is therefore evident that materials containing less than 6 per cent of sugar or starch cannot be considered suitable for the profitable manufacture of alcohol. Many of the waste materials of the farm may accordingly be eliminated without further consideration. The next point to be considered, after it is decided that the raw material to be used contains sufficient sugar or starch, is the supply of this material and the cost of its delivery to the distillery. Further, there must be available a good supply of water for the condensing apparatus and cheap fuel for the boilers. All of these considerations must be carefully weighed before any attempt is made to establish a distillery.

"The first consideration is that the distillery be centrally located in a potato-raising country; second, that there are railroad facilities for the delivery of raw materials and fuel and the marketing of the finished product at a minimum expense. An abundant supply of cold soft water is of almost equal importance. It is desirable that the plant be near a creek or stream from which the water may be obtained and into which it may be drained after serving its purpose in the distillery. The character of the water should also be considered, and, if possible, it should be such that it will not deposit a scale on the boiler and condenser tubes; this difficulty can be overcome, however, by treating the water with one of the various compounds on the market for relieving such conditions.

"The machinery should be such as will permit of economy in operating together with a high degree of efficiency. As a distillery in most cases would not be operated during the entire year, which invariably means a change in the working force for each season's operation, and as skilled labor is not always available, the machinery

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should be as simple as is practicable. It must be remembered, however, that with more costly machinery and apparatus better results can be obtained. The equipment should be so installed that its upkeeping cost will be reduced to a minimum, and so arranged as to allow any part to be thrown out of motion when not in actual use. It should be as compact as possible, without being crowded, and permit the proper handling of the material with the least amount of labor. The construction should be such that the exact result of each day's operation may be easily ascertained.

"Cleanliness is especially necessary in the case of the yeast and fermenting tubs, where the intrusion of these organisms will cause serious trouble. The walls of the distillery should be kept free from mold by an occasional coat of whitewash. The floors should be flooded daily, and the sewer connections must be adequate to remove the water and other wastes from the premises.

"The products will consist of alcohol and 'slop.' As shown elsewhere, about 1.3 gallons of denatured alcohol, 180 degrees proof, can be obtained from 100 pounds of potatoes. The total amount of alcohol produced per day will therefore be about 104 gallons of 90 per cent alcohol, or about 187 gallons of 100 degrees proof, or 50 per cent alcohol on which the internal revenue regulations are based, which at about 40 cents per gallon will be worth $41.60. There will be about 1,000 gallons of slop. Twenty gallons per day per head is sufficient for fattening oxen, so that the slop from one day's operation will form the major portion of rations for 50 head of cattle.

"Such a distillery as this is somewhat larger than is contemplated for the so-called industrial plant, being better suited for a community or a coöperative plant. A plant with a capacity of 100 proof gallons (50 per cent alcohol) per day or less, designated by the Government as an industrial distillery, for which special regulations and privileges are granted, will be better suited for individual farmers. The cost of the smaller plant will be less, but the operating expense will not be decreased in proportion to the size, which makes the larger plant more economical and therefore more likely to succeed. The cost given may be used as a basis for estimating that of a plant of any size, but the exact figures can be obtained from the manufacturers of distillery machinery.

Details of Operating a Potato Distillery.

"In manufacturing alcohol from potatoes they are first washed and then cooked so that the starch present can be readily converted into sugar by the action of malt. The sugar so formed is fermented by the addition of yeast and the alcohol contained in the fermented liquid is separated from it by the process of distillation. The detailed operation is as follows:

"The potatoes, after being weighed in the weighing bin, are run down a slatted chute into the cooker manhole. The slats on the

underside of the chute are spaced so as to allow only the sticks and the dirt to fall through. When the cooker is filled, the potatoes are washed by playing a stream of water upon them through the manhole, the dirt and water being drained off by means of the escape valve. After the potatoes are thoroughly cleaned the manhole cover is put on and bolted, and steam is admitted into the top of the cooker by the valve, the escape valve being left open so as to allow the condensed water to discharge. After the potatoes have been well warmed and steam begins to come out of the escape valve, the latter is closed. The steam is then shut off at the top of the cooker and admitted at the bottom through a series of inlets from the steam pipe. The blow-off valve at the top of the cooker is now partially opened. By allowing a small amount of steam to escape from this valve the potatoes are shaken up and thoroughly disintegrated. The steam pressure in the cooker is now allowed to rise gradually to about 50 or 60 pounds, when the blow-off valve should be closed. The entire time required for warming the potatoes and reaching the maximum pressure should be about one hour. The stirrer is then started, and the maximum pressure held for about ten minutes to insure a thorough cooking of the starch in the potatoes, after which the steam is shut off.

"The blow-off valve is then opened wide and the temperature inside the cooker allowed to fall to 212 degrees F. Then the temperature of the cooked potatoes is further reduced by means of the vacuum pump to from 140 degrees to 145 degrees F. at which point the malt necessary to change the starch into sugar is added. About 2 lbs. of malt are used for each 100 pounds of potatoes mashed, the exact amount depending upon the quantity of starch in the potatoes and the quality of the malt. This proportion will apply either in the use of green or dried malt, as the diastatic power (i.e., the ability to change starch into sugar) of each is about the same.

"Green malt is crushed between rolls while dried malt is ground in a mill before using. About fifteen minutes before the mash in the cooker is ready for malting, the malt, already crushed or ground as the case may be, is mixed with water in the proportion of 1 gallon of water to 2.5 pounds of dried malt, or three-fourths gallon of water to the same amount of green malt. It is prepared in a tub situated above the cooker and allowed to drop into the latter when the temperature of the cooked mash has been reduced to about 140 degrees or 145 degrees F. The diastase in the malt will dissolve the cooked starch and convert it into a fermentable sugar. This conversion will be complete in about fifteen or twenty minutes, during which time the mash should be constantly stirred. In order to know whether or not the conversion is complete, a few drops of iodine solution are added to a little mash which has been filtered through a cheese-cloth bag and placed upon a porcelain dish or some other white surface. If the mixture turns blue it indicates the presence of unconverted starch and it is then necessary either to increase the amount of malt or the time of conversion. Further tests should be made until the blue color is no

longer obtained, which indicates that the change of starch into sugar has been completed.

"The mash is now ready to be cooled and sent to the fermenter, but to insure easy handling through the pumps and distilling apparatus, it is necessary to remove the skins and the fibrous or woody parts of the potato which have not been broken up during the cooking process. The entire mash on leaving the cooker, therefore, is run through the potato-peel extractor, which is placed in the drop tub. This consists of an upright perforated copper cylinder on the inside of which is a revolving spiral, which carries the hulls and lumps to the top of the cylinder, where they are discharged through a spout, the liquid portion flowing through the perforations into the drop tub. The cleaned mash is now pumped through the mash cooler, where it is reduced to the so-called pitching temperature, by circulating a constant stream of cold water through a pipe surrounding the pipe through which the mash passes. The pitching temperature most favorable for fermentation varies between 60 and 70 degrees F., depending upon the weather conditions and the volume of the mash. It should be such that the mash will show signs of active fermentation in a few hours after being run into the fermenter. At the same time that the mash is run into the fermenter the yeast mash (about 3 per cent by volume of the main mash) is also added. It is prepared in a tub placed above the level of the fermenter, so that it may be easily discharged into it.

Fermenting the Mash.

"After the yeast and mash are in the fermenter the process of fermentation will begin and the sugar in solution be broken down into alcohol and carbon dioxide gas. The gas will pass off into the air and the alcohol remain in the solution. At this point it is important to know the gravity and acidity of the set mash, as it is now called. The specific gravity indicates the amount of sugar or fermentable material contained in the mash and is ascertained as follows: The mash is thoroughly stirred and a small portion filtered through a cheese-cloth bag into a suitable cylinder. A Balling saccharimeter is placed in the filtered liquid and the reading indicated on it at the liquid level will be the gravity of the mash. This reading should be from 16 degrees to 18 degrees, which means that the mash contains from 16 to 18 per cent of solids, most of which is sugar.

"The acidity of the set mash, or the amount of acid present, is due to the acidity acquired by the yeast mash and the natural acidity of the potatoes. It is determined by neutralizing a small portion of the mash with a normal solution of sodium hydroxide and the amount of the latter required will represent the acidity of the mash. The neutral point is determined by placing a drop of the mixture upon litmus paper. When it will not turn blue litmus paper red, nor red litmus paper blue, but leaves it unaltered, the mixture will be neutral, and the number of cubic centimeters of the solution of sodium hydroxide

used, which can be read directly from the burette, will represent the acidity of the mash.

"After the mash has been set about ten or twelve hours the fermentation will become vigorous and the temperature begin to rise rapidly, but it should not be allowed to go much above 80 degrees F. as quite an amount of alcohol due to evaporation would be lost at a higher temperature. To prevent further rise in temperature, it is necessary to equip the fermenter with a coil through which cold water is circulated. This coil is so arranged that it may be raised or lowered very slowly in the mash by means of a suitable device, the simplest way being by the conversion of the circular motion of a pulley into an up-and-down motion by means of rope and tackle. The fermentation is allowed to continue at a temperature between 60 degrees and 80 degrees F. for seventy-two hours, except in the case of mashes made the latter part of the week, when it goes on for ninety-six hours, as no distillations may be made on Sunday. At the end of this time the fermentation will be complete, provided the yeast was in a normal condition.

"To find out how much of the fermentation material originally contained in the mash has been utilized (i.e., the amount of sugar that has been converted into alcohol), it is necessary to determine the gravity of the fermented mash which should have gone down to about 1.5 to 2 on the saccharimeter. It is also extremely important that the acidity of the fermented mash be determined and compared with that of the unfermented or set mash. The acidity should remain about the same during the entire fermentation, but in some cases there may be a slight increase. The fermentation can withstand, and, in fact, is protected by, a certain amount of acid, but the presence of an excess will seriously interfere with its progress. A large increase in acidity in the fermenters is generally due to the formation of butyric acid, which is highly objectionable. This acid can be readily detected by its odor, which resembles that of rank butter and is caused by allowing portions of fermented mash to sour in the fermenters or by not thoroughly cleaning them after each use. Such a condition can be prevented or removed by scrubbing the fermenters as soon as they are emptied, with a 5 per cent solution of formalin or other powerful disinfectant, or by applying a coat of whitewash to the inside of the fermenters and washing it off before refilling. In order to control the fermentation properly the gravity and acidity of the mash are determined every twenty-four hours and a record kept.

"As before stated, the gravity should fall rapidly and the acidity remain about the same or increase slightly. If this is not the case, the mash has either been pitched at a temperature too low for the proper development of the yeast, or acid-forming organisms have become active and are retarding the fermentation. If temperature conditions have been the cause, the following mash can be pitched a little higher; but, if injurious organisms have gained control in the mash, they must be suppressed at once so as to prevent the following mashes

from becoming infected also. The amount of alcohol contained in the fermented mash will vary according to the gravity of the set mash, and as alcohol boils at a lower temperature than the other constituents it can be separated by distillation.

"The yield of alcohol obtainable from potatoes is directly proportionate to the amount of starch which they contain so that it is important to know not only the weight of a consignment, but also the percentage of starch. This is of course absolutely necessary when the potatoes are paid for on the basis of their starch content, which is their real alcohol-producing value. The percentage of starch may be easily determined by means of an instrument especially designed for that purpose. An average sample of the potatoes is washed and thoroughly dried. Exactly 10 pounds are placed in the wire basket (one potato may be cut if necessary to get the exact weight). The instrument with the basket attached is floated in a tank containing clear water at 63.5 degrees F. The stem is so graduated that the percentage of the starch can be read directly from it. Potatoes average from 14 to 20 per cent of starch and 1 pound of starch in practice yields about 0.071 gallon of absolute alcohol or 0.079 gallon of denatured alcohol at 180 degrees proof. One hundred pounds of an average grade of potatoes containing 17 per cent of starch would yield approximately 1.3 gallons of denatured alcohol.

"The denaturing process consists in adding certain ingredients to the alcohol to make it unfit for drinking purposes. Alcohol to be denatured must be at least 180 degrees proof, which is equivalent to 90 per cent alcohol, and the ingredients used must be authorized by the Bureau of Internal Revenue and the denaturing done under its supervision. Wood alcohol and benzin are generally used as denaturing agents, though the Bureau of Internal Revenue allows the use of other agents depending upon the use to which the denatured alcohol is to be put.

Development of a Yeast "Starter."

"Yeast culture is rather difficult, and as any quantity may be grown from one 'starter' yeast, it is best to obtain the initial yeast from a laboratory; if this is not convenient, a hop yeast may be grown, or as a last resource ordinary compressed baker's yeast may be used. It is not necessary, for fermentation purposes, to separate the yeast from the liquid in which it is grown, but the entire liquid, together with the yeast (known as the "yeast mash"), may be put into the liquid which is to be fermented. It requires a yeast mash of about 2 to 3 per cent by volume of the main mash (as the liquid to be fermented is called) to carry on the fermentation properly, so that the 'starter' yeast must be increased or grown by making preliminary yeast mashes, and increasing the volume ten times with each successive mash until the desired quantity is obtained. These mashes are prepared exactly like the one now to be described and may be made in any suitable wood or copper vessel.

"If compressed yeast is used 1 pound will be sufficient to start a 20-gallon mash, and if culture yeast from a laboratory is used 1 gallon (which is the amount usually sold) will start a 10-gallon mash.

Preparation of a Spontaneous Hop Yeast.

"If a spontaneous hop yeast is to be used, it must be obtained in the following manner:

"Boil 1 pound of hops in 5 gallons of water for fifteen minutes, strain off the hops and add 8 pounds of ground barley malt to the extract. Allow the mixture to stand about five hours, then strain it through a fine brass sieve to remove all the particles of grain, cool to about 85 degrees F. and place in a warm room and hold at that temperature. The gravity of the liquid should be about 20 degrees Balling. In about ten hours fermentation will begin and should be allowed to continue until the gravity has fallen to 6 degrees or 8 degrees Balling. The resulting spontaneous or hop yeast is then put into a tin-lined copper jug and kept on ice or in a cool place (preferably in running water or at the bottom of a well) at a temperature never exceeding 55 degrees F., under which conditions it will keep indefinitely and a 'starter' yeast will be obtainable at any time. The jug is made absolutely air and water tight and provided with a faucet for withdrawing the yeast. The use of the quantities given will produce about 2 gallons of yeast, all or part of which may be used to start a yeast mash ten times the volume of the amount used.

Yeast Mashes.

"Yeast will grow rapidly in a liquid containing sugar such as may be obtained in a potato or grain mash in which the starch of these materials is converted into sugar by the action of malt. Rye is most convenient for this purpose, as the malt will act upon its starch without the preliminary cooking, which is necessary in the case of potatoes. As there are many organisms besides yeast that feed upon sugar and are not only incapable themselves of producing alcohol, but are also decidedly harmful to the development of the yeast, it is extremely important that such precautions be taken as will prevent these injurious organisms from developing in the mash, and that conditions be made favorable for the rapid growth of the yeast. This is accomplished, first by allowing the mash to sour, or in other words to increase its natural acidity, which is not harmful to the development of the yeast but is decidedly so to most other organisms; second, by adding a sufficient amount of yeast to carry the fermentation through before the other organisms can be established. These operations are known as souring and yeasting the mash.

The details of preparing a grain yeast mash are given in the following section:

Preparation of a Grain Yeast Mash.

"The yeast mash is prepared in a wooden tub equipped with a rake for stirring and a copper coil fitted with steam and water connections for heating and cooling the mash. The volume, as has already been stated, should be from 2 to 3 per cent of the main mash to be fermented and 10 times that of the yeast mash used to start it. Equal parts by weight of finely ground rye meal and crushed green malt (or ground dried malt) are added to water in the proportion of 1 quart of water to each pound of the grain used. The water is measured into the tub and the temperature raised to 150 degrees F. The stirrer is then started and the rye meal allowed to run in slowly so as to prevent its lumping. The addition of the rye will cause the temperature of the mash to fall to about 140 degrees F. at which point the malt is added. The malt is allowed to act upon the starch for about three hours, during which time the mash is stirred occasionally and the temperature is gradually raised to 145 degrees F. At the end of this time the formation of sugar will be complete and the gravity of the mash should be about 20 degrees to 24 degrees Balling. The mash is then ready to be soured.

Scouring the Mash.

"It has been found that acid solutions tend to suppress organisms which infect starchy materials. This is especially true of lactic acid and as this organism is always present in potatoes and grain the acidity of the mash can be increased by its development under the proper conditions. This is accomplished by keeping the yeast mash at 130 degrees F. for forty-eight hours, at the end of which time the desired acidity will be obtained. By adding a start sour (that is, a culture of lactic acid organisms) to the yeast mash at the beginning of the souring period, the proper acidity can be obtained in the twenty-four hours, so that a forty-eight hour period is only necessary in the case of the first yeast mash or if a new sour is desired. The start sour is a portion of a previously soured yeast mash and should be about 2 per cent of the yeast mash to which it is added. It is important that the proper temperature be maintained throughout the souring period in order to prevent the growth of other acid organisms which interfere with the development of the yeast.

"The acidity of the mash at the beginning of the souring period is called its natural acidity and in a mash prepared as described will be about 0.5 cc. By adding a start sour the acidity will increase in twenty-four hours to about 2.5 cc. or 3 cc. when the start sour for the following day's mash is withdrawn. An acidity of 2.5 or 3 cc. will be sufficient to suppress all undesirable organisms and will not interfere with the proper development of the yeast. Further growth of the lactic acid organisms which have now produced the desired acidity must be prevented by heating the mash to 160 degrees F. and main-

taining this temperature for twenty minutes. The mash is then cooled, by passing cold water through the coil, to a temperature favorable to the growth of the yeast (see following caption). It is very important that the cooling be done as quickly as possible as there are a great many objectionable organisms which develop at the warmer temperatures.

Yeasting the Mash.

"When the temperature has been reduced to approximately 90 degrees F. the yeast (about 10 per cent by volume of the mash) is added; it may be either a preliminary yeast mash or a quantity of mash taken from the previous day's yeast mash, the former being the case when the distillery is just being put in operation, or when a new yeast is desired, and the latter when the plant is running regularly. The temperature is then further reduced to 60 or 70 degrees F. This final temperature is called the "setting temperature" and varies with the volume of the mash and the weather conditions. It should be such as will permit the immediate growth of the yeast. Gas bubbles, due to the escape of carbonic-acid gas, appearing on the surface of the mash after a few hours will indicate that the yeast has become active. The fermentation, which will gradually become more vigorous, is allowed to continue for twenty-four hours. As the activity of the yeast increases, the temperature of the mash will rise perceptibly, but it should not be allowed to go above 90 degrees F., as there will then be danger of the yeast mash becoming infected with other organisms, such as acetic bacteria, which have a harmful effect on the fermentation.

"The yeast in the yeast mash should be active and vigorous when put into the main mash so that fermentation will begin at once. The yeast remains active only so long as there is sugar present for its growth, consequently the yeast mash is added to the main mash before all the sugar in the former is exhausted or when its gravity has fallen to about 4 or 5 degrees Balling. If it is allowed to fall below this point the yeast will become less vigorous from lack of food and delay fermentation of the main mash.

"The setting temperature, as well as that maintained during the twenty-four-hour fermentation period, should be as low as possible and still permit a sufficient growth of the yeast to cause the gravity to fall to 4 or 5 degrees Balling. The acidity of the yeast mash should be carefully taken after the souring period or rather immediately after the mash has been yeasted, and compared with that of the mash twenty-four hours later, namely, after the fermentation period. Not much change should occur as any increase would indicate the presence and development of undesirable acid organisms, the immediate suppression of which is of great importance. They can be easily avoided by employing only the proper temperatures and keeping the tubs sweet and clean. It is best to cover the tubs, thoroughly sterilize them with live steam, and scrub them with clean water after each use. The acidity and gravity of the fermented mash having been found to be

satisfactory, a quantity amounting to about ten per cent by volume of the yeast mash to which it is to be added is removed and kept at a temperature below 55 degrees F. to be used as a start yeast for the following yeast mash, and the rest is added to the main mash. Summarizing this discussion, it is seen that a yeast mash consists of a selected yeast grown in a suitable mash and requires about fifty-one hours for its preparation, of which three hours are required to allow the malt to act upon the starch, twenty-four for souring the mash, and twenty-four for growing the yeast.

Preparation of a Potato Yeast Mash.

"The selection of a yeast and its subsequent development in the mash as just described will be applicable to either a grain or a potato distillery. It will be found more economical, however, in the latter to use rye in the first two or three yeast mashes and then substitute potatoes. A part of each day's cooked and malted potatoes constituting the main mash is pumped into the yeast tub and one-half pound of crushed green malt or one-quarter of a pound of dried malt is added for each gallon of potato mash, this additional malt being added to serve as food for the yeast. It is not necessary to add water. To the malted potato yeast mash is added a start sour taken from a previously soured potato or grain mash, and after twenty-four hours it is yeasted by adding a start yeast taken from a previous grain or potato yeast mash. Exactly the same operations are employed and the same temperature maintained as in the case of the grain yeast mash just described. An economical potato distilling yeast may be obtained, therefore, by the growth of an initial start yeast in a grain mash, the use of grain yeast mashes for the first two or three days' operations, and the subsequent substitution of potatoes for rye in the yeast mashes. The accompanying schedule outlines the various steps necessary in the building up and daily preparation of a potato distillery yeast."

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Chapter 2.

Leather and Tanning.

The leather industry of America is greater than that of any other country. The annual product reaches a value of nearly a billion dollars. Not only does the total output exceed that of other countries but from the standpoint of methods, processes, machinery, and fine quality of the product the American industry is foremost.

This is an old industry and the art of tanning was somewhat developed in earliest times. Many half civilized peoples knew considerable about tanning. Even the American Indian was an expert in the preparation of certain hides.

Morton Henderson in the *Travelers' Protective Association Magazine* says: "The leather industry of to-day is an evolution covering many centuries. It is a far cry from the crude, primitive methods employed in the earliest historic period to the highly complex processes of the modern tannery. Probably the first method of curing skins was simply cleaning and drying. Then it was found that the use of smoke, sour milk, various oils, and even the brains of the animals from which the hides were stripped improved the quality and texture of the leather. Still later it was discovered that certain astringent barks and vegetables effected permanent changes in the texture of the skins and stopped decay. This use of bark and vegetable juices has continued and forms the basis of many of the modern tanning processes. The Egyptians possessed this knowledge, for pictures and hieroglyphics describing the methods are found on many of the ancient tombs in the Nile valley. Three thousand years ago the Chinese were familiar with leather preservation, as various relics handed down from antiquity serve to show. Leather preserved and tanned with oil, alum and bark was also used by the Romans."

The buffalo hunters of the western plains after a day's killing of buffaloes went out in the evening to skin them and to stretch or "stake" out the skins so that they would dry and thereby prevent the beginning of putrefaction. It was found that putrefaction quickly ruined a hide. In the arid climate of the West the buffalo skins dried very quickly, and in this dry state were preserved until the buffalo hunter could draw his hides to a trading post from which they were shipped to tanneries.

Preservation of Hides.

Several different methods have been used for the preservation of hides, until they can be shipped to the tannery; rapid drying; salting and drying; and slow curing of wet, salted hides, known as green salting.

In the preservation of hides, drying was no doubt the earliest method used. This method was also very practical in that the weight of the hides was greatly reduced for transportation. However, unless drying is carefully carried out, the subsurface of thick hides may retain enough moisture to allow putrefactive action to start up during shipment or storage and to ruin the hide.

Salt as a preservative of hides has been extensively used and with good results. In green salting, the salt is applied to the flesh side of the washed hide and left in contact with it during storage and shipment. The action of the salt is a rapid diffusion throughout the hide. As concentrated solutions of salt are strongly antiseptic, little putrefactive change goes on in the hide. Some shippers combine drying and salting of hides.

One of the disadvantages resulting from the use of salt on hides is the occurrence of "salt stains." Some of these stains persist throughout all of the tannery processes and therefore greatly reduce the value of the leather after it is tanned. The stains in the finished leather are of different colors as blue, brown, red, and yellow. Much investigation has been carried out concerning the cause of these stains. Some workers believe them to be due to certain iron compounds which had actually combined with the hide constituents. In a bacteriological study of leather stains, Becker found that certain chromogenic bacteria, at least experimentally, produced the same stains in hides.

Disinfection of Hides.

Because of the fact that infectious diseases have often been spread by shipment of infected hides, the custom of disinfecting hides with powerful disinfectants has become imperative in certain localities. It has been found that the hides of animals dying with tetanus, anthrax, foot-and-mouth, and other diseases are dangerous unless disinfected.

An antiseptic solution extensively used is a 2% solution of mercuric chloride in 1% formic acid. This was first advocated by Alfred Seymour-Jones. He recommended that hides be held in contact with the antiseptic for one to three days. After this antiseptic treatment the hides were placed in saturated salt solution for an hour and then dried. Another antiseptic solution used for disinfecting hides is that of Schattenfroh. He advocated the use of a 10% solution of salt in 2% hydrochloric acid. Hides are held in this solution for three days at a temperature of 40° C. It is said that no harm is done to the hides by the use of these antiseptic solutions.

Perhaps anthrax is the most common infection carried by hides

which escape proper inspection and disinfection. This disease is caused by Bacillus anthracis, a rod-shaped organism which grows in compact masses in the lesions of the infected animal. The disease occurs to some extent among sheep and cattle in all parts of the world but is more prevalent in Europe than in America. Infection of humans occurs by way of abrasions resulting in surface lesions, or by way of infected food, resulting in intestinal lesions. Also persons sometimes suffer lung infection by breathing dust from infected hides. The organism produces spores which are quite resistant to drying. These spores have been known to remain alive for years in dust and dirt. A large percentage of persons infected with the disease die within a few days after infection. This is especially true in cases of infection of the face or head.

At the tannery, hides pass through five somewhat distinct processes, as soaking and fleshing; unhairing and scudding; bating or puering; drenching and pickling; and tanning. Each of these processes contributes to the quality of the final leather.

The Soaking and Fleshing Process.

The purpose of soaking hides, as a preliminary treatment at the tannery, is to cause them to become soft and pliable and to make it possible to run them through the fleshing machine. The amount of soaking and handling necessary to bring hides back to their normal thickness and pliability depends upon the method of preservation which has been practiced and the length of time the hides have been in shipment or storage.

Rogers says: "Whether the skins are green, salted, or dried, they must first be soaked in water in order to remove the blood, dirt and salt, and in the case of dried skins to bring them to a soft condition. It is very essential that the skins should be free from all of this foreign matter before entering the limes or other unhairing solution, as the presence of salt retards the plumping and albuminous matter is apt to set up an undesirable fermentation in the after-treatments. The time of soaking varies from one or two days to several weeks, depending upon the thickness of the hide and the age and temperature of the soak. Putrid soaks soften quicker than fresh ones, but great care is necessary in using them lest the decomposition attack the hide fiber itself. For heavy hides, which soften very slowly, it is found very advantageous to run in a drum for a short time with water at a temperature of about 40° F., the tumbling movement thus materially aiding in the softening process."

J. T. Wood says that in the "soaks" the bacterial action is largely liquefaction of some of the hide substance.

In a study of microörganisms active in soak liquors, Andreasch found the following organisms to be present: B. subtilis, B. mesentericus vulgatus, B. mesentericus fuscus, B. mycoides (Flügge), B. liquidus (Frankland), B. gasoformans (Eisenberg), B. fluorescens

liquefaciens (Flügge), B. proteus vulgaris, B. proteus mirabilis, and B. butyricus (Hueppe).

The source of the miscellaneous bacteria is the animal's skin before flaying and the contamination picked up in shipment and handling. Many of these bacteria are spore formers and strong liquefiers. As prolonged action by these organisms results in destruction of or at least damage to the nitrogenous connective tissues which make up hide, it is very important that soaking be carefully controlled.

Putrefactive bacteria in general work most vigorously at a reaction very close to the neutral point. This fact no doubt underlies the method of controlling proteolytic action in soak liquors by the addition of alkaline compounds. Wilson made a study of the hydrogen-ion concentration of soak liquors in which proteolytic bacterial action was most active and found the pH valves between 5.5 and 6.0.

Depilation.

In making leather, only the dermis is saved. The epidermis with its hair and hair roots must be removed. This is accomplished by a number of different ways as liming, the sweating process, use of enzymes, acids, or alkalies.

Rogers says, "Following the soaking operation comes the removal of the hair, which process is known as depilation. This is necessary in all kinds of leather except that used for furs. The earliest method of accomplishing this result was by means of incipient putrefaction in which case the soft mucous matter of the epidermis became affected, thus causing hair to become loosened without materially injuring the true skin. This method is still employed by many tanners of sole leather and is called 'sweating.' The operation is conducted in closed rooms which are kept at a temperature of about 70° F. The hides are hung in small chambers ('sweat pits') holding about 100 hides each. After four to six days of this treatment the hair is sufficiently loosened to be removed by working over a rounded beam with a blunt knife made for the purpose. No matter how carefully this operation may be conducted there is liability, however, that the putrefaction attacks the skin itself, thus causing a weak grain, and for this reason we find it being used less and less."

It is found in the use of lime liquors for depilation that after a liquor has been used for some time it becomes more active in the removal of the epidermal layer. This subject has been studied by Wood and Law who conclude that this increased activity or mellowness of old liquors is due to bacterial enzymes which accumulate as the liquor is used. They found that lime liquors which had been used for several weeks usually contained thousands of proteolytic bacteria as M. flavus liquefaciens, and B. prodigiosus.

Speaking of the action of lime in depilation, Rogers says: "The action of lime on the hide is to swell up and soften the epidermis cells, dissolve the mucous layer and loosen the hair so that it may be scraped

off with a blunt knife. The action on the true skin is also very vigorous, causing the hide to become plump and swollen, at the same time dissolving the cementing material of the fibers, thus causing them to split up into finer fibrils. The swelling is probably due to the formation of a lime soap, caused by the union of the lime with the fatty matter of the hide."

Bating and Puering.

Bating and puering are processes of freeing the hides from lime and calcium salts which were retained by the hides after the process of liming. The bating process makes the hide clean and very pliable, and facilitates the tanning. The process owes its action on the hides to the activity of bacterial enzymes and to the lime neutralizing action of organic acids produced by bacteria.

After hides have been limed they become plump or swelled and rubbery due to some action of the alkaline salts on the hide substance. This "plumping" must be removed so that the tan liquors may properly enter the hide tissues in the process of tanning.

The "bate" liquors were made by adding the dung of fowls to water while the "puers" were made by adding dog dung to water.

Wood holds that the action of "bates" and "puers" is the dissolution of some of the interfibrillar cementing substances by bacteria while the organic acids produced by bacteria neutralize and remove the lime. Becker believes that the principal organisms involved in "puering" are members of the coli group.

Rogers says: "It is very essential that the lime, or other depilating agent, should be completely removed when it has done its work, since its action is very harmful when brought into contact with tanning materials. For most leather, also, it is not only necessary that the lime be completely removed, but that the skin should be brought free from its swollen, to a soft and open condition. To accomplish this result on the heavier classes of dressing leather, such as split hides, kips, colt, and calf skins, the stock is run in a weak fermenting infusion of pigeon or hen manure, the time depending upon the strength of the liquor, and upon the nature of the goods under treatment, the process being known as 'bating.' 'Puering' is a very similar process applied to the lighter and finer skins, such as glove-kid and moroccos, in which dog manure is substituted for that of birds. As the mixture is used warm and the skins are thin, the process is complete in a few hours. Neither 'bating' nor 'puering' are very effective in removing lime, but seem to act by means of bacterial products upon the hide substance, thus causing the pelt to fall, that is to become soft and flaccid."

In deliming, a weak acid fermentation, according to Rogers, is a most satisfactory bate and deliming process for hides which are to be tanned into soft, supple leather by a chrome or a vegetable tannage. He says that excellent results as regards full flanks, good break, and

fine even grain are obtained by allowing grape sugar or common glucose to become sour, and using definite proportions of the same in combination with lactic acid for each pack of hides or grains.

"The presence of suitable bacteria in the 'bate' is very important as certain bacteria produce the desired proteolytic enzymes and at the same time the desired organic acids. These organisms have been found to exist in dog feces and the droppings of pigeons." Concerning this subject Rogers says that despite the unpleasantness of its use, dog dung is an efficient bate for leather that requires a soft, fine, and silky grain.

"In the manufacture of the sole leather the hides are not left in the lime pit solution long but are removed and placed in solutions of lactic acid which neutralize and wash out the lime preventing the extensive breaking down of nitrogenous material of the hide which is necessary to give the leather its proper weight and stiffness.

"In the manufacture of the finer leathers the action of the bacteria and their enzymes on the gelatin and other nitrogenous materials of the hide is not stopped but encouraged and hastened by the puering process. These materials contain bacteria which have been found to best remove the nitrogenous materials of the hides and leave them in the best condition. Even some of the intracellular material of the skins are dissolved."

W. V. Cruess reports that the organisms of these dung infusions are mostly members of the colon group and the proteus group. He reports that Noble, of the University of California, used hay infusions of B. subtilis successfully as bathing liquor.

Cruess and Wilson made a study of the organisms present in pigeon dung and described the organisms which seemed to be characteristic of this bate. They found that some of these organisms in diluted skim milk were able to remove "plumping" the same as pigeon dung bates.

Becker isolated an organism which he named B. erodiens which had the ability of removing "plumping" in the same manner as dog dung bate.

In a study of the enzymes of dog dung bates, Wood and Law found bacterial enzymes resembling trypsin, pepsin, rennin, diastase, and lipase. This work emphasizes the complexity of actions going on in the bating process.

After the hides have been removed from the "bathing wheel," they are placed in the tan pits to which at first is added solutions of tan liquor and then more concentrated solutions. These tan liquors contain all varieties of microbial life, but the tannin from the tan bark has an inhibitive action on the putrefactive organisms.

When all the other steps in the preparation of leather have been completed, it is tanned. There are many different methods of tanning. Rogers says: "The oldest method in vogue is that known as 'oil tannage' which consists in treating the hide or skin with a mixture of fish and other oil in a machine which works the skin by a sort of

ading motion known as the 'stocks.' During this operation heat eveloped, resulting in the formation of aldehydes and other oxida- products. The excess of oil is removed by scraping and pressing, product obtained being known as 'degras.' The skins are then ned with a fairly strong alkaline solution, the alkaline solution ralized with an acid with the result that fatty acids are produced wn as 'sod oil.' This method of tannage is used especially for the alled 'chamois leather.'"

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Chapter 3.

The Retting of Hemp and Flax.

The fibers of flax, hemp, ramie, and other similar fibers are separated by a process called retting. The fibers are placed in vats and allowed to stand. Spontaneous fermentation springs up in the water living on the soluble matter from the fibers. There are a large number of different bacteria present both aerobic and anaerobic which produce enzymes which dissolve the pectin compound encasing the fibers.

Beyerinck attributed this to an organism called Granulobacter pectinovorum. Van Tieghem attributed it to B. amylobacter. Part of this dissolving action has been ascribed also to molds.

Pure culture inoculation of retting tanks has been recommended.

The Hemp Industry and Hemp Retting.

L. H. Dewey in U.S.D.A. Year Book (1913) says: "The two fiber-producing plants most promising for cultivation in the central United States and most certain to yield satisfactory profits are hemp and flax. The oldest cultivated fiber plant, one for which the conditions in the United States are as favorable as anywhere in the world, one which properly handled improves the land, and which yields one of the strongest and most durable fibers of commerce, is hemp. Hemp fiber, formerly the most important material in homespun fabrics, is now most familiar to the purchasing public in this country in the strong gray tying twines one-sixteenth to one-fourth inch in diameter, known by the trade name 'commercial twines.'"

"Production in United States Declining."

"This falling off in domestic production has been due primarily to the increasing difficulty in securing sufficient labor to take care of the crop; secondarily, to the lack of development of labor-saving machinery as compared with the machinery for handling other crops and to the increasing profits in raising stock, tobacco, and corn, which have largely taken the attention of farmers in hemp-growing regions.

"The work of retting, breaking, and preparing the fiber for market requires a special knowledge, different from that for handling grain crops, and a skill test acquired by experience. These factors have been more important than all others in restricting the industry to the bluegrass region of Kentucky, where the plantation owners as well

as the farm laborers are familiar with every step in handling the crop and producing the fiber.

"An important factor, tending to restrict the use of hemp, has been the rapidly increasing use of other fibers, especially jute, in the manufacture of materials formerly made of hemp. Factory-made woven goods of cotton or wool, more easily spun by machinery, have replaced the hempen 'home-spun' for clothing; wire ropes, stronger, lighter, and more rigid, have taken its place in standing rigging for ships; 'abaca' (Manila hemp), lighter and more durable in salt water, has superseded it for towing hawsers and hoisting ropes; while jute, inferior in strength and durability, and with only the element of cheapness in its favor, is usurping the legitimate place of hemp in carpet warps, so-called 'hemp carpets' twines, and for many purposes where the strength and durability of hemp are desired."

Concerning the World's Production of fiber flax, Miles says: "According to the latest available statistics, about 1,300,000 acres are devoted to fiber flax each year, as compared with more than 4,000,000 acres previous to 1914. The present production is about 190,000 tons of fiber, as compared with about 800,000 tons in pre-war years. Russia, which before the war produced about 80 per cent of the world's supply of flax, now produces less than half the quantity needed for its own normal home consumption. The leading flax-fiber producing countries during the years 1917 to 1921 were the following: Belgium, France, Ireland, Netherlands, Czechoslovakia, and Japan. In the United States during these same years from 1,000 to 6,000 acres have been devoted to fiber flax, while about 1,700,000 are devoted to seed flax."

Dewey says: "Hemp was probably the earliest plant cultivated for the production of a textile fiber. The 'Lushi,' a Chinese work of the Sung dynasty, about 500 A.D., contains a statement that the Emperor Shen Nung, in the twenty-eighth century B.C. first taught the people of China to cultivate 'ma' (hemp) for making hempen cloth. The name 'ma' occurring in the earliest Chinese writings designated a plant of two forms, male and female, used primarily for fiber. Later the seeds of this plant were used for food. The definite statement regarding the staminate and pistillate forms eliminates other fiber plants included in later times under the Chinese name 'ma.' The Chinese have cultivated the plant for the production of fiber and for the seeds, which were used for food and later for oil, while in some places the stalks are used for fuel, but there seems to be no record that they have used the plant for the production of the narcotic drugs bhang, charas and ganga. The production and use of these drugs were developed farther west."

Early Cultivation in Kentucky.

"The first crop of hemp in Kentucky was raised by Mr. Archibald McNeil, near Danville, in 1775. It was found that hemp grew well in the fertile soils of the bluegrass country, and the industry was de-

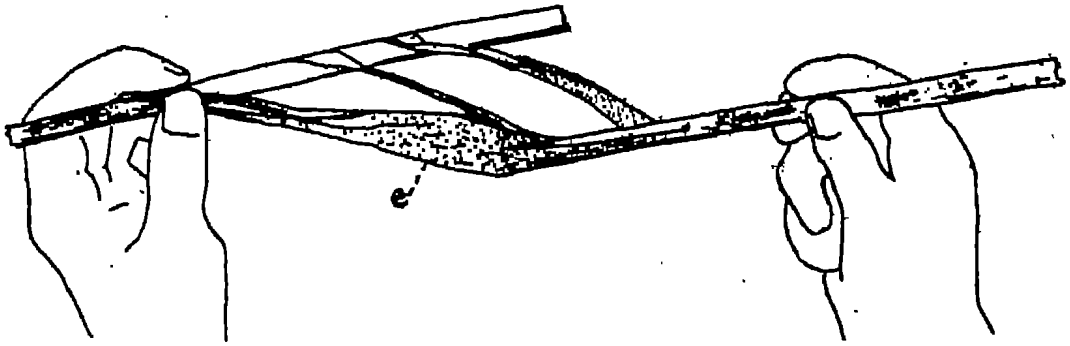
veloped there to a greater extent than it had been in the eastern colonies. While it was discontinued in Massachusetts, Virginia, and Pennsylvania, it has continued in Kentucky to the present time. In the early days of this industry in Kentucky, fiber was produced for the homespun cloth woven by the wives and daughters of the pioneer settlers, and an export trade by way of New Orleans was developed. In 1802 there were two extensive ropewalks in Lexington, Ky., and there was announced 'a machine, moved by a horse or a current of water, capable, according to what the inventor said, to break and clean eight thousand weight of hemp per day. Hemp was later extensively used for making cotton-bale covering. Cotton bales were also bound with hemp rope until iron ties were introduced, about 1865. There was a demand for better grades of hemp for sailcloth and for cordage for the Navy, and the industry was carried on more extensively from 1840 to 1860 than it has been since.

Retting.

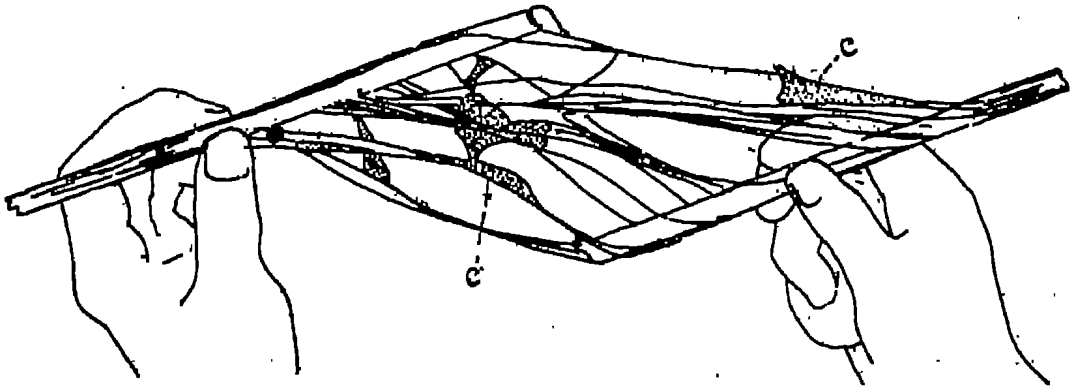
"Retting is a process in which the gums surrounding the fibers and binding them together are partly dissolved and removed. It permits the fiber to be separated from the woody inner portion of the stalk and from the thin outer bark, and it also removes soluble materials which would cause rapid decomposition if left with the fiber. Two methods of retting are practiced commercially, viz, dew retting and water retting.

Dew Retting.

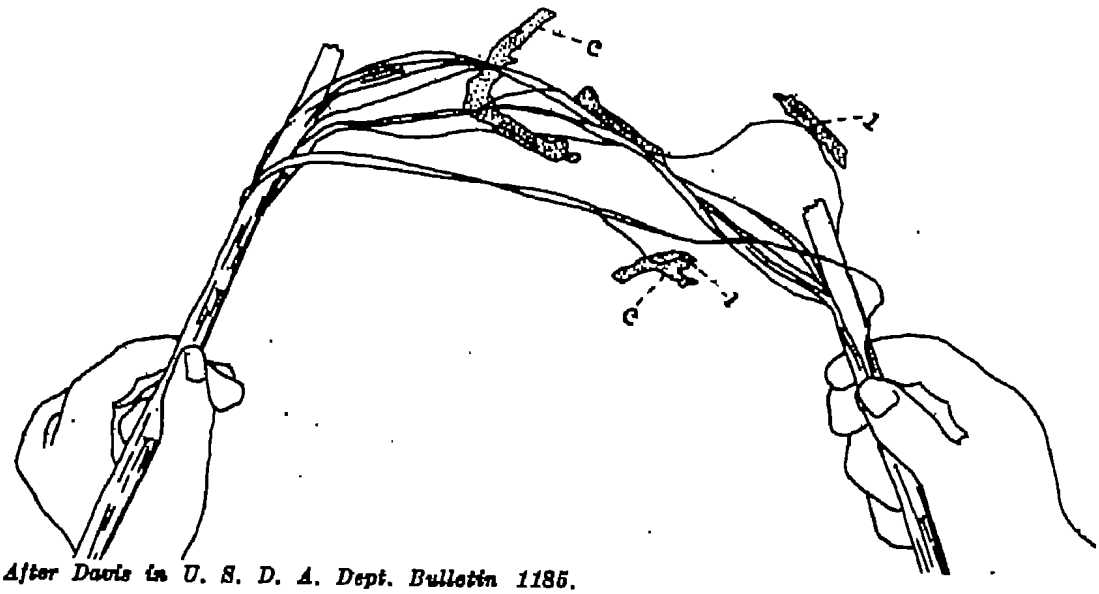
"In this country dew retting is practiced almost exclusively. The hemp is spread on the ground in thin, even rows, so that the butts are all even in one direction and the layer is not more than three stalks in thickness. This work is usually paid for at the rate of $1 per acre, and experienced hands will average more than 1 acre per day. The hemp is left on the ground from four weeks to four months. Warm, moist weather promotes the retting process, and cold or dry weather retards it. Hemp rets rapidly if spread during early fall, provided there are rains, but it is likely to be less uniform than if retted during the colder months. It should not be spread early enough to be exposed to the sun in hot, dry weather. Alternate freezing and thawing or light snows melting on the hemp give most desirable results in retting. Slender stalks one-fourth inch in diameter or less ret more slowly than coarse stalks, and such stalks are usually not overretted if left on the ground all winter. Hemp rets well in young wheat or rye, which hold the moisture about the stalks. In Kentucky most of the hemp is spread during December. A protracted January thaw with comparatively warm rainy weather occasionally results in overreting. While this does not destroy the crop, it weakens the fiber and causes much loss. When retted sufficiently, so that the fiber can be easily separated from the hurds, or woody portion, the stalks are raked



Epidermis test in incompletely retted flax. The epidermis (*e*) is clinging to both nodes and internodes in large pieces, showing that the retting process is not complete.



Epidermis test of flax fibers when retting is nearly complete. The fibers are well separated and of fine diameter. Pieces of cuticle (*c*) are clinging in spots. When this stage of retting is reached it is necessary to swish the fibers to and fro in water in order to tell whether the epidermis is well loosened.



After Davis in U. S. D. A. Dept. Bulletin 1185.

Flax fibers at the completion of the epidermis test. Retting is at the same stage as that shown in figure next above. The cortex is shown after it has been swished to and fro in water. Retting is almost complete, and the cuticle (*c*) is separated except at the leaf scars (*l*).

up and set up in shocks, care being exercised to keep them straight and with the butts even. They are not bound in bundles, but a band is sometimes put around the shock near the top. The work of taking up the stalks after retting is usually done by piece work at the rate of $1 per acre.

Water Retting.

"Water retting is practiced in Italy, France, Belgium, Germany, Japan, and China, and in some localities in Russia. It consists in immersing the hemp stalks in water in streams, ponds, or artificial tanks. In Italy, where the whitest and softest hemp fiber is produced, the stalks are placed in tanks of soft water for a few days, then taken out and dried, and returned to the tanks for a second retting. Usually the stalks remain in the water first about eight days and the second time a little longer.

"In either dew retting or water retting the process is complete when the bark, including the fiber, readily separates from the stalks. The solution of the gums is accomplished chiefly by certain bacteria. If the retting process is allowed to go too far, other bacteria attack the fiber. The development of these different bacteria depends to a large extent upon the temperature. Processes have been devised for placing pure cultures of specific bacteria in the retting tanks and then keeping the temperature and air supply at the best for their development. These methods, which seem to give promise of success, have not been adopted in commercial work.

Chemical Retting.

"Many processes for retting or for combined retting and bleaching with chemicals have been devised, but none of them have given sufficiently good results to warrant their introduction on a commercial scale. In most of the chemical retting processes it has been found difficult to secure a soft lustrous fiber, like that produced by dew or water retting, or completely to remove the chemicals so that the fiber will not continue to deteriorate owing to their injurious action.

"One of the most serious difficulties in hemp cultivation at the present time is the lack of a satisfactory method of retting that may be relied upon to give uniform results without injury to the fiber. An excellent crop of hemp stalks, capable of yielding more than $50 worth of fiber per acre, may be practically ruined by unsuitable weather conditions while retting. Water retting, although less dependent on weather conditions than dew retting, has not thus far given profitable results in this country. The nearest approach to commercial success with water retting in recent years in America was obtained in 1906 at Northfield, Minn., where, after several years of experimental work, good fiber, similar to Italian hemp in quality, was produced from hemp retted in water in large cement tanks. The water was kept in circulation and at the desired temperature by a modification of the Deswarte-Loppens system.

Steaming.

"In Japan, where some of the best hemp fiber is pro
methods of retting are employed—dew retting, water retting
ing, the last giving the best results. Bundles of hemp sta
immersed in water one or two days to become thoroughly
are then secured vertically in a long conical box open at
and top. The box thus filled with wet stalks is raised b
a derrick and swung over a pile of heated stones on wh
dashed to produce steam. Steaming about three hours
The fiber is then stripped off by hand and scraped, to remo
bark. The fiber thus prepared is very strong, but less f
that prepared by dew retting or water retting.

"Cool, moist weather, light snows, or alternate freezing
ing are favorable for retting hemp. Dry weather, not nec
from rain but with a rather low relative humidity, is essenti
factory work in breaking hemp. The relative humidity a
in January, February and March, when most of the hemp
ranges from 62 to 82 per cent. The work of breaking her
carried on when there is snow on the ground. The work o
and cleaning hemp seed can be done only in dry weather.

Robert L. Davis in U.S.D.A. Dept. Bul. 1185 gives th
facts concerning the progress of retting in the different p
stem. He says: "The rapidity and order with which th
tissues in the flax stem are retted depends on the diges
solubility of the cementing substances that bind the tissue
their accessibility, and the relative amounts of them pre
different tissues. The tissues of the flax stems that lie in
may be divided into the fiber bundles, the phloem parenc
between the fiber bundles and the cambium layer, the p
lying between the fiber bundles themselves, the epidermis th
the stem, and the outer parenchyma that lies between the
and the fiber bundles.

"Retting takes place first in the cambium layer where
is quite soluble and where because of the very thin cell
layers of pectin or cementing substance are correspond
When flax stems are sterilized in water at 115 degrees C. m
pectin in the cambium layer is dissolved, and the cortex
loosened from the wooden core that the loose-core test is c
at all as a positive indicator that retting is completed. Th
the tissues of the cortex is less soluble than that in the cam
and is not much affected by the solvent action of the hot w
not entirely because of a difference in accessibility that th
retted after the cambium layer, as at the exposed surfaces o
where all tissues are equally exposed to the attack of th
retting is not materially hastened in the cortex.

"It is true, however, that the cambium layer, located on
of the stem, is somewhat more accessible to the attack of th

than the tissues lying to the outside in the cortex. The stems are partially protected from the outside by the waterproof nature of the cutin in the outer wall of the epidermis. The areas where the leaves drop off are waterproofed by the formation of leaf scars where suberin is deposited. At harvest time the waterproof covering on the outside of the stem is complete with the exception of the stomatal openings. Part of the stomata, as microscopic examination shows, are closed and

After Davis in U. S. D. A. Department Bulletin 1185.

FIG. 1.—Leaf-scar test in partly retted flax, made toward the root end of the stem and parallel to the wooden core. On the right is the beginning of the test and on the left the end of the test. Retting is incomplete. Note how the fibers cling to the leaf scars where the cortex has been peeled away from the core in the left-hand figure.

made water-tight by the formation of cork cambium. The retting liquid and bacteria, however, can find their way through the epidermis, as the flax stems which have been paraffined at both ends will ret. The closing up of the ends, however, does distinctly retard retting, indicating that the bacteria enter more readily through the epidermis than at the stem ends.

"The variables in the retting process itself are the nature of the retting bacteria, the temperature of the water, the rate of water circulation, the water quality (whether hard or soft), and the duration of the

ret. Of these factors the one that causes most trouble is the duration of the ret, or making the decision as to when retting is completed. A study of the process of disintegration of the flax stem as retting proceeded was undertaken in order to find out what changes in the flax stems were closely associated with the completion of retting."

As an end point in the retting of flax, Davis says it is best to supplement the leaf scar test with the epidermis test so that when a positive leaf scar test is secured the epidermis test also may be used to determine whether retting has proceeded far enough to thoroughly loosen the epidermis. He says: "In case the epidermis test does not confirm the positive leaf scar test the retting may be allowed to proceed still farther until a positive epidermis test is secured. It is thought that the leaf scar and epidermis tests are distinctly more reliable than the loose-core test and that even where the dry-straw test is used they may be of some value as indicating when to begin the dry-straw tests.

A Study of Flax and Kindred Fibers.

"The fact that flax and ramie fibers always twist in a clockwise direction when drying, while hemp and jute fibers twist in the reverse direction, is the basis of a convenient method for distinguishing flax and hemp. Microscopic examination of these fibers after treatment reveals a fibrillar structure, the fibrils of flax and ramie being arranged in left-handed spirals, while those of hemp and jute are in right-handed spirals. In some cases, internal spirals with a reverse twist may occur. The drying of the fibers is always accompanied by a twisting up of the component fibrils."

Concerning the possibilities of establishing a flax fiber industry in the United States Miles says:

"It has been demonstrated beyond all doubt that fiber flax of excellent quality can be grown in various sections of the United States, yet it cannot be said that the industry has ever become established here. One reason for this is that much coöperation is necessary between the different branches of the industry, and up to the present time this coöperation has not existed. The farmer can grow the flax, but before doing so he should be assured of a market. On the other hand, the manufacturers should be assured of a sufficient supply of flax in order that they may establish their branch of the industry."

Miles in U.S.D.A. Bul. 669 says: "The best flax fiber is obtained from the Courtrai region of Belgium, where flax is water retted in the River Lys. Flax is also water retted in Ireland and in certain provinces in Russia, but in these countries the retting is done in pools or reservoirs. The bundles of flax are usually placed upright in crates, or nets, and are immersed by placing weights on top of the whole. As fermentation progresses it is generally necessary to add more weights in order to keep the straw under water. The retting process is usually completed in from 6 to 15 days, depending upon the condition of the water. The straw should be removed at just the proper time, as a few

hours' delay often causes loss. The practice in Belgium and in some portions of Ireland is to watch constantly during the latter part of the retting period, in order to remove the straw from the water at the time when the retting process has progressed sufficiently even though this be during the night. The straw is set on end to drain for about 24 hours and is then spread over a meadow for a few days, in order to become thoroughly dry. After drying the straw is stored until time for breaking and scutching. Water retting in tanks is practiced in Oregon."

REFERENCES ON RETTING OF HEMP AND FLAX.

Miles, F. C., 1922. Fiber Flax, U. S. D. A. Bul. 669.
Davis, Robert L., 1923. Flax-Stem Anatomy in U. S. D. A. Dept. Bul. 1185.

Chapter 4.

The Importance, Preparation, and Use of Legume Cultures.

Importance.

That any of the tremendous amount of nitrogen in the air (the air being about four-fifths nitrogen) is available to the farmer to be used for plant growth in a practical way, is due largely to the plants which we call legumes. They constitute the only farm crop plants which can use the nitrogen of the air surrounding their roots. They harbor on their roots nodules containing bacteria which gather nitrogen from the air and furnish it for the plant's growth. The nitrogen which remains in these nodules when the crop is cut is left in the soil and enriches it.

Whiting, at the Illinois Experiment Station, has calculated that if the nine more important crops grown in the United States were to be furnished all their nitrogen requirements by the application of the nitrate of soda, at present the most important commercial nitrogenous fertilizer, the world's supply of this material would be sufficient for this country alone for only about six years. He further calculated that the nitrogen in the air over four acres of land would furnish more than the annual consumption of commercial nitrogen in the entire United States. As a result of these and similar calculations by him and many others, it is now realized that the growing of legumes is essential in many localities if the fertility of the soil, one of the greatest of assets, is to be conserved. That legume crops must ultimately play an important part in permanent agriculture wherever there is worn-out soil, is now well recognized.

The Examination of Legume Plants for Nodules.

In pulling up a legume plant growing in firm soils, the nodules are stripped from the fine roots. To examine properly the root systems of most legume plants for bacteria, therefore, it is necessary to break the ground around the plant and to take the plant up with a quantity of earth about six inches square. Then the soil can be gently jarred loose and the coarse and fine root systems can be examined.

In the case of the ordinary legume crops, if one does not find a uniformly abundant nodule formation on a half dozen representative plants dug up in different parts of the field, one may be quite certain that the crop is utilizing the nitrogen of the soil and impoverishing it

by its growth rather than utilizing the nitrogen of the air and further enriching the soil.

Lack of an abundance of nodules on the roots indicate clearly

After A. L. Whiting in Illinois Exp. Sta. Bul. No. 179.

FIG. 2.—On the left, roots from plant grown in $CO_2 + O$; on the right, roots from plant grown in $N + CO_2 + O$.

that there are an insufficient number of legume bacteria in the soil. A sickly yellowish appearance of the plants also is often general evidence of want of proper inoculation.

Importance of Sufficient Inoculation in Fields Planted to Legumes.

If a field does not contain sufficient legume bacteria in the soil to cause vigorous nodule production at the roots of the plants in all parts

of the field, the legume plants are forced to live on what nitrogen there is in the soil. In the case of this deficiency of the specific legume bacteria, the wonderful faculty which legume plants have, that of taking nitrogen from the air rather than from the soil, is not allowed to operate. If the soil is very rich there will be little difference seen, whether the nodules do or do not form, but in soils of average fertility the difference between inoculated and uninoculated legumes will be very marked.

FIG. 3.—An alfalfa seedling 28 days old, showing how nodule production is accomplished early in the plant's growth in well inoculated soil. The importance of early nodule formation by legume plants grown in average soils cannot be overemphasized, as these crops need more nitrogen than other crops and depend upon the bacteria of the nodules for it.

It has been shown that nodule production on the roots should occur early in the growth of the legume plant to obtain the best results. Legume seedlings begin to utilize atmospheric nitrogen through the agency of nodule bacteria as early as the ninth day after planting. From these facts it is seen that in the early stages of a crop's growth, plants benefited by nodule production may be able to withstand unfavorable weather conditions a little better than those without nodules. In some of the eastern states where the growing of legumes is a practice of long standing, it has been found that a large percentage of the failures in the growing of these crops is due to the lack of the specific legume bacteria in the soil in sufficient numbers to insure a uniform nodule production on the roots of the plants in all parts of

the fields. It is not only important that the specific bacteria be present, but that they be present in sufficient numbers.

FIG. 4.—Typical nodule formation on the roots of four different legumes.

When to Inoculate in Planting Legumes.

The presence of legume bacteria may be secured by proper inoculation of the seed or the soil. Either the seed or the soil should be inoculated when planting any legume crop unless this particular crop has been successfully grown on the piece of ground selected, within the three previous seasons. There are many factors which may cause a legume crop to be a failure, such as drought, freezing, poor seed, animal depredations, unfavorable reaction of soil, etc., but lack of proper inoculation of seed or soil need not be one of them.

Considering the slight cost of bacterial inoculation, it is the best practice to help insure a successful crop by the inoculation of the seed at the time of planting if there is any indication whatever that the soil is not sufficiently inoculated. In the growing of legumes or any other crop there are enough factors beyond man's control, so that no one can afford to neglect to provide for those necessary conditions which are controllable.

What Not to Expect from the Practice of Legume Inoculation.

The proper inoculation of the roots of legume plants should be considered simply as one of the factors which must be taken care of in the growing of these crops. When seeds are inoculated with bacterial legume cultures it must be remembered that this procedure only insures proper inoculation for the crop's growth. In other words, the practice of inoculating legume seeds will not prevent the ill effects of poor seeds, poor preparation of ground, unfavorable climate, unfavorable year, acid soil, etc. These are conditions governing the growth of

legumes apart from the question of bacterial inoculation. To consider that because the inoculation of the seeds has been practiced, other factors can be slighted is a misunderstanding of inoculation and its purpose. The best known cultural methods should always be employed in addition to proper inoculation of seed or soil.

Gross Inoculation of Legumes.

There are a number of different varieties of legume bacteria, each of which will inoculate one or more legumes. The latter may be grouped according to the variety of bacteria that will grow on them. Each one of the following groups has its own bacterium, so to speak, and all members of each group will be inoculated by the same bacterial legume culture.

Group I.
- Red Clover.
- Alsike Clover.
- Crimson Clover.
- White Clover.
- Berseem Clover.

Group II.
- White Sweet Clover.
- Yellow Sweet Clover.
- Alfalfa.
- Bur Clover.

Group III.
- Cowpea.
- Patridge Pea.
- Velvet Bean.

Group IV.
- Garden Pea.
- Field Pea.
- Vetches.

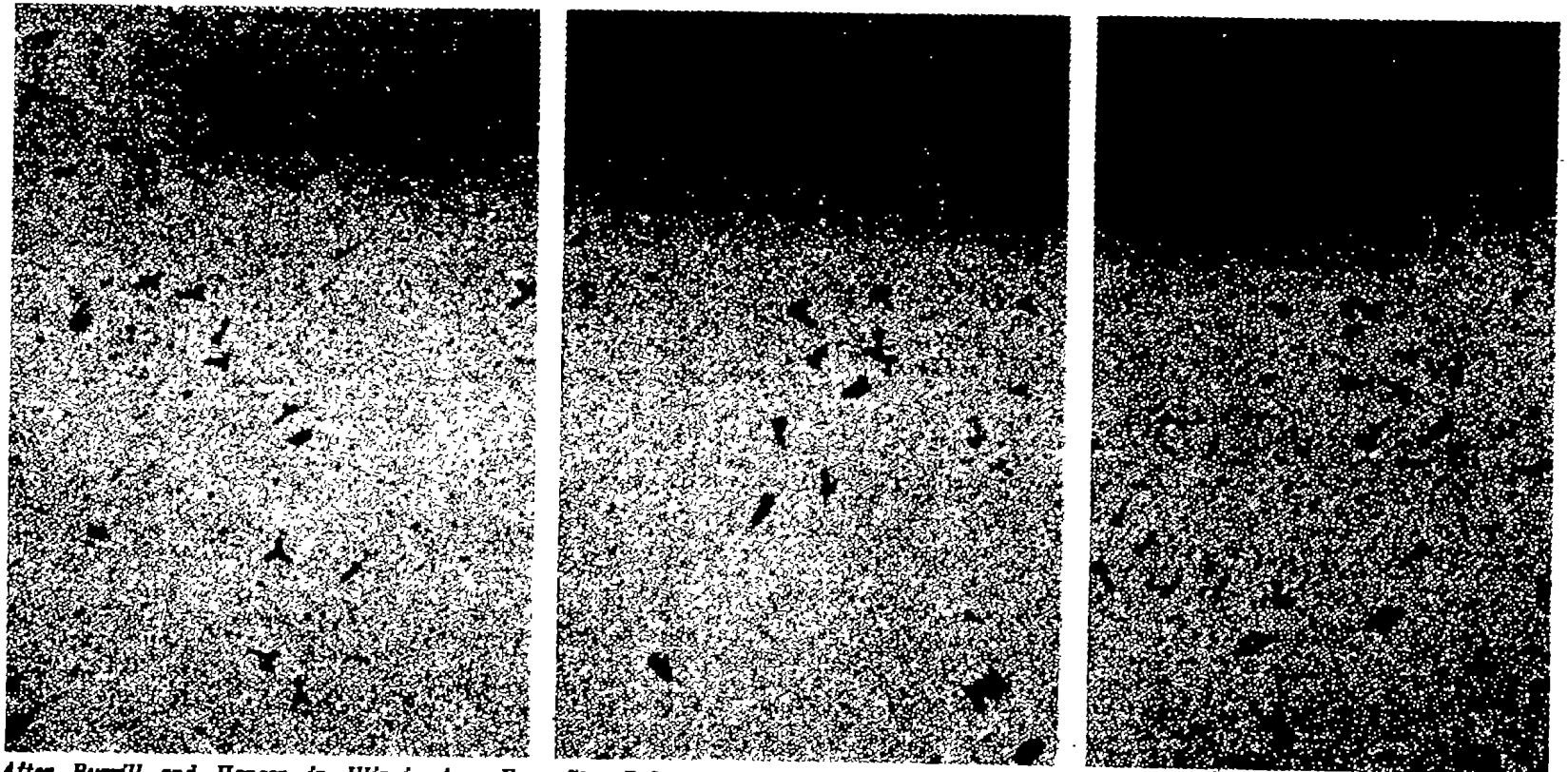
Group V.
- Soybean.

Group VI.
- Garden Bean.

Methods of Inoculating Legumes with Bacteria.

There are several methods of inoculating legumes with bacteria. description of four important methods follows:

1. The Pure Culture Method on Jelly. This is the method which most used at present. It consists in sprinkling legume seeds at the me of seeding with a solution made by rinsing out a bottle containing pure culture of legume bacteria on jelly. It has proven to be more



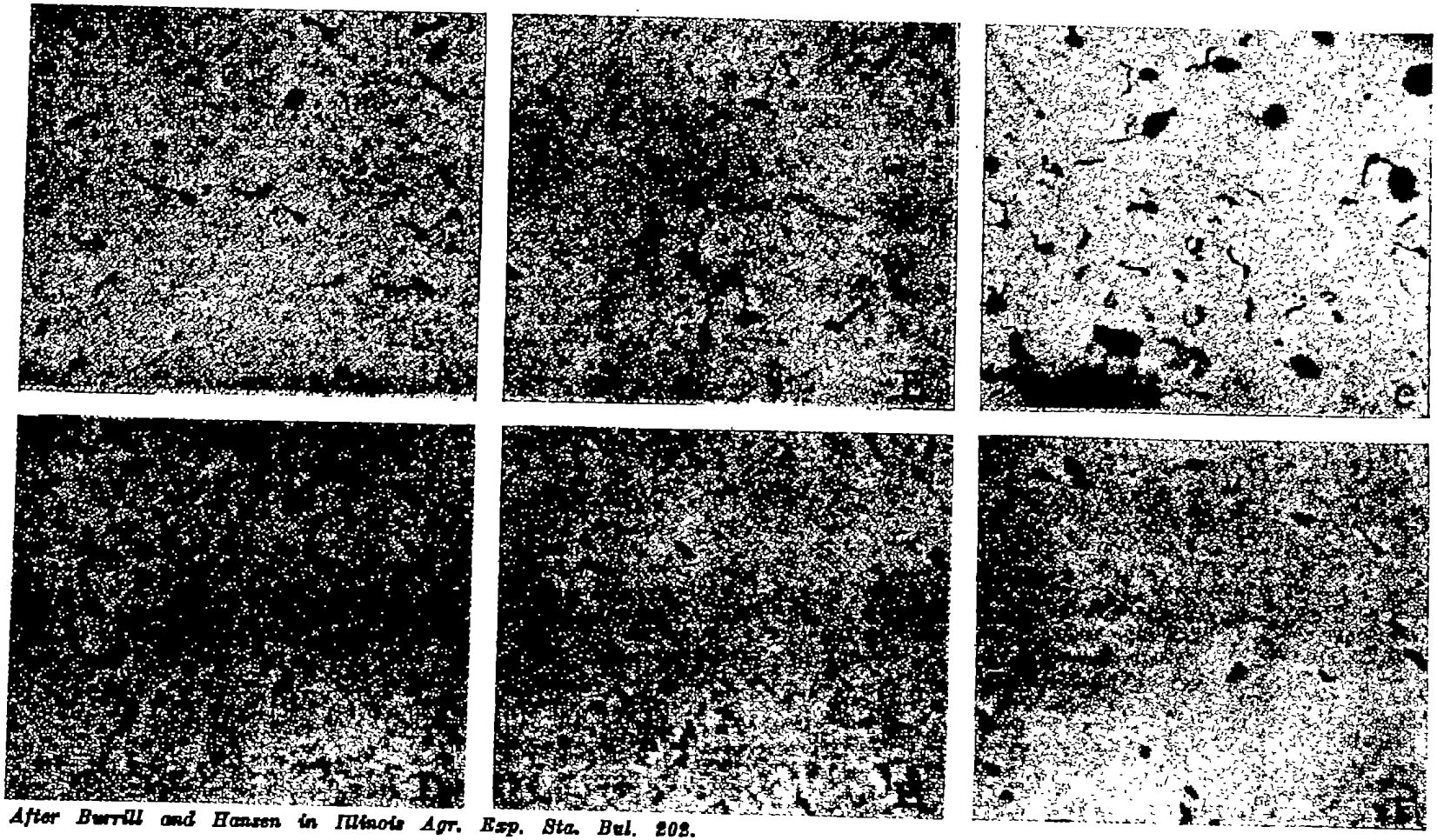
After Burrill and Hansen in Illinois Agr. Exp. Sta. Bul. 202.

MICRO-PHOTOGRAPHS OF NODULES BACTERIA.

FIG. 1.—Bacteroids from a very young nodule of pea (*Pisum sativum*), showing swarmers among the bacteroids. × 1080.

FIG. 2.—Bacteroids from young, growing nodule of hairy vetch (*Vicia villosa*). × 1080.

FIG. 3.—Bacteroids from an older nodule of hairy vetch (*Vicia villosa*), showing vacuolization. × 1080.



After Burrill and Hansen in Illinois Agr. Exp. Sta. Bul. 202.

FLAGELLA STAINS OF NODULE BACTERIA.

Pseudomonas radicicola, showing polar flagellum: A.—Cowpea (*Vigna sinensis*). × 1080; B.—Cowpea (*Vigna sinensis*), more highly magnified; C.—Partridge pea (*Cassia chamæcrista*). × 1080; D.—Acacia (*Acacia floribunda*). × about 1500; E.—Tick trefoil (*Desmodium canescens*). × 1080; F.—Japan clover (*Lespedeza striata*). × 1080.

satisfactory than any other method from the standpoint of general practicability.

2. The Soil Method. Soil is obtained from a field which is growing the legume crop successfully and is broadcasted over the field to be planted, at the rate of about a quarter of a ton per acre. Harrowing should follow immediately after soil broadcasting.

3. The Sand Method. Sand is prepared in the laboratory and inoculated heavily with legume bacteria. This is then mixed with the seed at the time of sowing. This method has been largely discontinued.

4. The Illinois Method. This method consists in preparing heavily

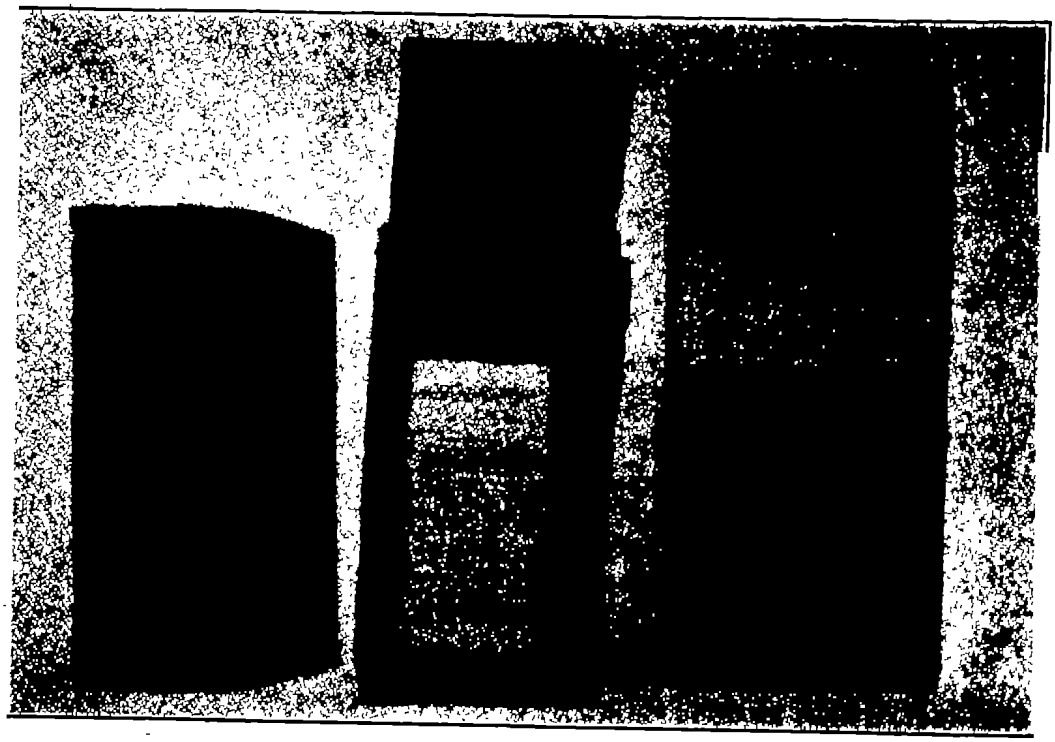


FIG. 5.—Method of sending out legume cultures to farmers.

inoculated soil and mixing it with the legume seeds after they have been sprinkled with a solution of glue and water. The glue causes the particles of inoculated soil to stick to the seeds.

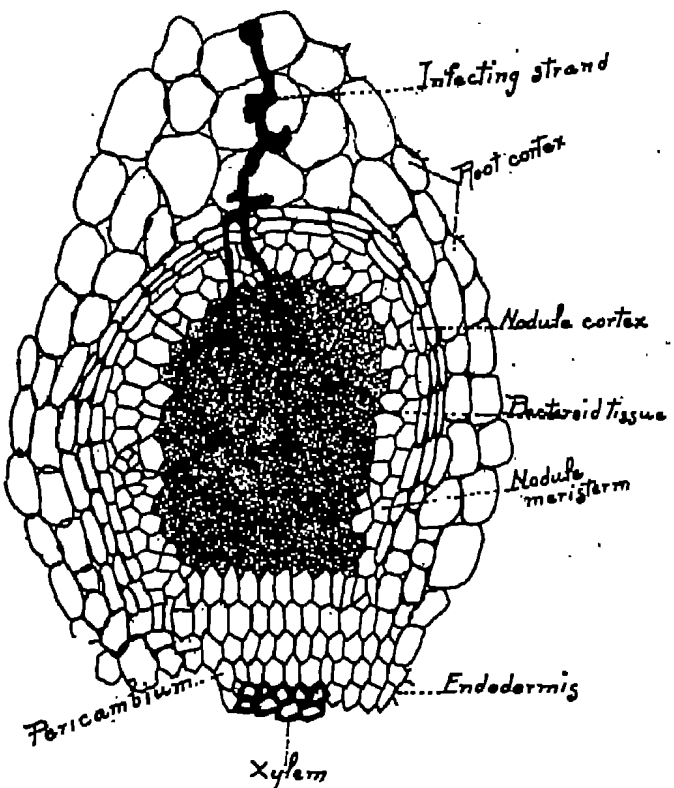
The preparation and sale of legume cultures as an industry has been pushed to considerable extent, both in Europe and America. The United States Department of Agriculture has sent out many cultures to farmers. The United States Experiment Stations in many states have furnished cultures to farmers. The furnishing of these cultures has been a great blessing to agriculture in general, nevertheless much dissatisfaction has resulted also. The disappointments in the use of legume cultures which were sent out a number of years ago was to some extent due to the fact that these cultures were often dead and therefore worthless. No doubt many of those prepared by drying the organisms on cotton were very low in vitality or entirely dead.

However, the art of preparing vigorous cultures has been developed and more recently splendid results are reported from their use. Much of the present disappointment in the use of legume culture comes from other factors than the fact that the soil has not been made fit as to physical and chemical conditions. One of the best forms in which legume cultures are shipped for use by farmers is the jelly culture, contained in a flat bottle. These cultures are usually sent out at a retail price of 25 cents to 40 cents for sufficient culture to inoculate the seed used in planting one acre of any particular legume.

Preparation of Commercial Legume Culture on Agar.

Pure cultures of nodule bacteria are inoculated into sterile flasks of liquid media of the following composition:

Magnesium sulphate	0.2 gm.
Dibasic potassium phosphate	0.2 gm.
Sodium chloride	0.2 gm.
Calcium sulphate	0.1 gm.
Commercial cane sugar	10.0 gm.
Distilled water	1000.0 gm.
Reaction .... pH	7.0



After Prazmowski as adapted by A. L. Whiting.

FIG. 6.—Young nodule, showing the beginning of the differentiation of its tissues.

The above inoculated liquid medium is incubated at 28° C. until it becomes stringy. This may be called a seed culture and is used as

follows to prepare commercial cultures to be sold to farmers. Six, eight, or ten ounce bottles are used for the commercial culture. Solid media of the same constituency as the liquid media above but with the addition of 2% of agar is used. Enough of this media is placed in each bottle so that when it has solidified in the bottle lying flat, it will give a layer of agar a quarter of an inch thick. To each bottle is added 2 cc. of the seed culture. This syrupy seed culture is shaken over the surface of the solid media and then is incubated at 28° C. until it has grown to its greatest amount. Usually 5 to 10 days incubation are required for the growth at which time the culture can be sent out to the farmer.

Directions for Use.

1. Fill the bottle about one-half full with clean cool water.
2. Shake hard in order to get the bacterial slime growth off the surface of the hard jelly. The water will then assume a milky appearance.
3. Do not try to get the solid jelly on which the bacteria are growing into solution for it will not dissolve.
4. Add the water containing the bacteria to the seed.
5. Refill the bottle several times until enough water is added to moisten all the seed.
6. Mix the seeds thoroughly with the hands to distribute the bacteria evenly over all.
7. Spread the seed out on a clean surface away from the sunlight and dry thoroughly.

Precautions.

1. Store in a cool dark place and do not open the package until ready for use.
2. Do not remove cotton plug from bottle until ready for use.
3. Use as soon as possible. Old cultures are not reliable.
4. Do not expose the bottle, culture, or the inoculated seed to direct sunlight. Sunlight will kill bacteria.
5. Inoculate the seed just before sowing and sow as soon as the seed is sufficiently dry.
6. If the seed is sown by hand or broadcast, follow immediately after with the harrow to cover the seed from the sunlight.

Note.—With large legume seeds, such as peas and beans, sowing may be done directly after inoculation. Drying is not necessary with these seeds.

Note.—If convenient sow some seed without inoculation and see by comparison if the bacteria improve legumes on your soil.

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Chapter 5.

Disinfectants and Disinfection.

Both physical and chemical agents have become widely used in killing disease producing germs. McCoy, Stimson, and Hasseltine give the following classification of disinfectants:

- Disinfectants.
  - Physical.
    - Heat.
      - Dry heat....
        - Incineration
        - Superheated at 100°
      - Moist heat...
        - Steam
        - Boiling
        - Temperature below boiling (pasteurization)
    - Sunlight
    - Diffused light
    - Air
  - Chemical.
    - Solid agents.....
      - Lime
      - Chlorinated lime
    - Liquid agents or solutions .....
      - Corrosive sublimate (mercuric chloride)
      - Formaldehyde solution
      - Phenol
      - Crude carbolic acid
      - Pine oil disinfectant (Hyg. Lab.)
      - Cresol
      - Potassium permanganate
      - Lime
      - Chlorinated lime
      - Hypochlorite
      - Chlorine
      - Petroleum
      - Gasoline
      - Carbon disulphide
    - Gaseous agents.....
      - Formaldehyde
      - Sulphur dioxide
      - Chlorine
      - Hydrocyanic acid
      - Pyrethrum fumes
      - Carbon monoxide
      - Carbon dioxide

Incineration, that is, the burning of infectious materials, is an old custom in use long before the idea of the true nature of infection was developed. The ancients found that they could sometimes free them-

selves from certain scourges by the burning of clothing, household effects, and dwellings. The method of the Indians was to burn the tepee of the smallpox infected Indian along with the dead body of the Indian. In modern times incineration has been used for the destruction of garbage and even to some extent sewage. However, incineration of infected materials is an expensive means of destruction of disease germs, and because of this fact, this method has not had an extensive use on a large scale.

The use of dry heat as a method of disinfection has been largely confined to the sterilization of laboratory apparatus. It is used when steam heat would in some way damage the material being sterilized. Hot-air ovens are used in dry heat sterilization. The temperature most generally employed is 180° C. It is found that by slowly raising the temperature much glassware which would break if submitted to steam, can be satisfactorily sterilized.

McCoy, Stimson, and Hasseltine give the following list of advantages and disadvantages of some common disinfectants:

The idea of the test is to compare other disinfectants with a standard. The disinfectant used as a standard is phenol which meets the requirements of the Eighth U. S. Pharmacopœia, that is, the congealing point must not be below 40° C. A fresh 5% sol. of phenol is used as a source in making dilutions. In comparing other disinfectants with standard phenol dilutions the ability to kill Bacillus typhosus (Hopkins strain) is used as a basis of comparisons.

The typhoid germs are grown in the following media:

Beef extract (Liebig's)	3 gm.
Peptone (Armour's for disinfectant testing)	10 gm.
Sodium chloride	5 gm.
Water, distilled	1000 gm.

Boil for 15 minutes.
Make to original weight by addition of water.
Filter through paper.
Tube, 10 c.c. to each tube.
Sterilize.
The pH 7.0.

The culture of Bacillus typhosus used must be a 24 hr. culture which has been transferred at 24 hr. intervals for five days, always using a temperature of 37° C.

The hand method of making the determination of the coefficient is described in U. S. Public Health Report No. 27 of Vol. 36 as follows:

"The object is to add 0.1 c.c. of typhoid culture to 5 c.c. of successive dilutions of the disinfectant and of phenol, and, after this addition to transfer a loopful of each mixture to a separate subculture tube at periods of 5, 7½, 10, 12½, and 15 minutes. The subculture tubes are then incubated for 48 hours at 37° C., and readings of growth or no growth are made and recorded.

"Dilutions are made to cover the expected range of the disinfectant, and 5 c.c. of each dilution is placed in a seeding tube. Dilutions of

ADVANTAGES AND DISADVANTAGES OF COMMONLY USED DISINFECTANTS.

After McCoy, Stimson, and Hasseltine.

Disinfectant.	Availability.	Efficiency.	Convenience.	Dangerousness.	Destructiveness.	Adaptability.	Cost.
Heat.	Universal.	Absolute.	Varies with form of heat used. Burning and boiling easily accomplished. Steam under pressure requires apparatus and expert management. Relatively not time consuming.	No greater than the everyday uses of heat.	Burning absolutely destructive. Boiling injures some fabrics, fixing stains thereon, and causes "running" of colors. It injures cutting instruments. Steaming spoils leather and rubber articles and glued or varnished things.	Limited to inanimate things of classes not excluded by its destructiveness. In the form of hot air in motion it promises a wider field of usefulness.	For small-scale operations, relatively cheap. Costly for extensive uses like disinfection of a water supply.
Corrosive sublimate.	Readily obtainable, subject to provisions of poison laws.	Very efficient, except in the presence of albuminous matter.	Very convenient, of small bulk, and requiring relatively short exposure.	Very poisonous if ingested, and irritating to the skin, if used externally in too great concentration or too often.	Corrodes metals. Fixes stains on fabrics.	Limited by its destructiveness and by the presence of large amounts of albuminous matter.	Less than that of most disinfectants used in solution.
Formaldehyde solution.	Readily obtainable at most drug dealers.	Excellent as germicide, good as a deodorant. Deteriorates with age.	Easily applied. Somewhat bulky. Irritating odor makes its use inconvenient.	Not very poisonous nor likely to be ingested, but very irritating to skin, conjunctiva, and other mucosa.	Very free from injurious effects.	Limited chiefly by its irritating effects. Cannot be used as a disinfectant in the sick room. May be used as a fly poison.	Rather high for extensive use.
Phenol.	Readily obtainable, subject to provisions of poison laws.	Highly efficient.	Easily applied, requires relatively short exposure. Odor is unpleasant.	Very poisonous. Destructive to all tissues when concentrated. Benumbs the skin even when diluted.	In the usual dilutions, not destructive of most materials.	Widely useful within the limitations of a liquid disinfectant. Chief objections are its toxicity, effect on skin, and odor.	Moderate.
Potassium permanganate.	Usually obtainable at drug dealers.	Good, in a limited field. Impaired by organic matter.	Easily applied. Not bulky. Requires long exposure unless very concentrated.	Slightly toxic if ingested in large quantities, which is unlikely to occur.	Stains fabrics.	Very limited. May be used for hands, as in surgery. May be used for disinfecting drinking water containers.	More expensive than chlorinated lime.

Lime.	Easily obtained in most communities.	Good. Fresh unslaked lime must be used. Air-slaked specimens are inert.	Easily applied. Somewhat bulky and unpleasant to handle. Requires long exposure.	Poisonous, if ingested in concentrated form. Has caustic effect on eyes and skin. With ordinary care offers little danger.	Quite destructive of many kinds of materials.	Useful only for things which are to be destroyed, chiefly for excreta. For this purpose hardly excelled.	Relatively very cheap.
Chlorinated lime.	Easily obtainable in most communities.	Good. Deteriorates rapidly on exposure to air. Must be kept in sealed containers.	Easily applied. For disinfection of drinking water very convenient.	Similar to that of lime, but with the added irritating effects of chlorine, which is slowly given off.	Bleaches and disintegrates fabrics.	Useful for same purposes as is lime. In addition is most useful for disinfection of drinking water supplies.	Moderate. Far cheaper than other disinfectants for water disinfection.
Chlorine (liquid).	Less easily obtained than chlorinated lime.	Excellent for one purpose, i. e., disinfecting water supplies.	Less easily applied than chlorinated lime, requiring more elaborate apparatus.	The fumes of chlorine, if accidentally liberated, are dangerously poisonous.	When in solution acts like chlorinated lime solution.	Practically limited to disinfection of water.	About three times as costly, normally, as chlorinated lime.
Formaldehyde (gas).	Solution from which it is prepared, obtainable at most drug dealers.	Under proper conditions of use, a very efficient germicide. It has feeble penetrative powers and its action is therefore rather superficial. Action impaired by cold and dryness.	Varies with method used. Convenient with permanganate method when available. Otherwise requires rather bulky apparatus. Requires exposures of 4 to 12 hours.	Not directly poisonous or dangerous to life. Very irritating to eyes and respiratory mucosa.	Has hardly any deleterious effects on materials. Offers some danger of fire unless carefully handled.	This is the most generally useful gaseous disinfectant. It does not, however, kill insects and other vermin.	Including the cost of the necessary skilled labor, its cost is rather high.
Paraformaldehyde.	Rather generally available.	The same as formaldehyde if properly handled. If burned, as in candles, practically inert.	Rather easily applied. Solid form and small bulk convenient.	.... do	.... do	Same as above, provided it is properly used.	Comparable to formaldehyde gas.
Sulphur dioxide.	Readily obtainable.	With moisture, a fairly efficient germicide. An efficient destroyer of vermin, with, however, somewhat feeble penetrative power.	Easily generated and applied by the pot method, although the apparatus is bulky. Requires exposure of 8 or more hours.	Dangerously poisonous, but the odor gives warning of its presence.	Bleaches fabrics and ornamental work and attacks metals in the presence of moisture. Some danger of fire.	Now little employed as a germicide. Very useful for destruction of disease-bearing insects and vermin. Limited chiefly by low penetrative power and destructive action.	Cost relatively low.

Disinfectant.	Availability.	Efficiency.	Convenience.	Dangerousness.	Destructiveness.	Adaptability.	Cost.
Hydrocyanic - acid (gas).	Less easily obtained than sulphur.	The most efficient agent for destroying insects and rats. Has no bactericidal power.	Application comparable to that of sulphur dioxide. Only a short exposure is necessary (2 hours), but mush time may be consumed in subsequent airing, to eliminate danger.	The most dangerous and lethal disinfectant known. Does not give sufficient warning of its presence. Can be used only by experts.	The gas itself is not destructive to materials, but spilled or spattered acid may cause damage.	Strictly limited to the destruction of insects, rats, and other vermin, and to expert application with control over human inmates of the inclosure to be fumigated.	Slightly more than that of sulphur.
Carbon monoxide (Harker gas).	Available only where the special apparatus for its production has been installed.	Efficient against rats and other red-blooded vermin. Inefficient against insects and bacteria.	Requires special apparatus and very expert attention to produce an efficient gas.	Danger from its use intermediate in degree between that of sulphur dioxide and hydrocyanic-acid gas.	Not destructive to materials.	Limited to the destruction of rats or other red-blooded pests, where the apparatus has been installed and an expert operator is available.	Operating cost rather low. Installation of apparatus expensive.

phenol are made as follows: 1:80, 1:90, 1:100, 1:110, 1:120, and 1:130, and 5 c.c. of each is placed in a seeding tube.

"The seeding tubes are placed in the water bath at 20° C. and a few minutes are allowed for their contents to reach this temperature.

"To each seeding tube 0.1 c.c. of culture is then added seriatim, allowing 15 seconds for each addition. If there are ten tubes of disinfectant dilutions, this will occupy 2½ minutes. At the end of 5 minutes from the time of adding the disinfectant to the first seeding tube, a loopful of the mixture is transferred from this tube to a subculture tube, and this is done from each successive seeding tube at 15-second intervals. This procedure is repeated after the lapse of 7½, 10, 12½, and 15 minutes from the time of the first addition of culture to the seeding tube. Each loop is placed on the support and flamed with the Bunsen burner immediately after use, and the use of several loops permits them to cool before they are needed again. The operator is obliged to make a transfer every 15 seconds for ten minutes.

"The dilutions of phenol are next treated in the same manner as those of the disinfectant.

"The tubes are properly labeled and are placed in the incubator for 48 hours, at the end of which time readings of growth or no growth are made and entered in a table as — or + signs, respectively."

Example of determination of coefficient of disinfection from U. S. Public Health Report, Vol. 36, No. 27.

Sample	*Dilution*	*Time of Exposure in Minutes*				
		5	7½	10	12½	15
Disinfectant	1:700	—	—	—	—	—
	1:800	+	—	—	—	—
	1:900	+	+	—	—	—
	1:1,000.	+	+	+	+	—
	1:1,000.	+	+	+	+	+
Phenol	1:80	—	—	—	—	—
	1:90	+	+	—	—	—
	1:100	+	+	+	+	—
	1:110	+	+	+	+	—
	1:120	+	+	+	+	+
	1:130	+	+	+	+	+

$$\text{Coefficient} = \frac{\frac{700}{80} + \frac{900}{90} + \frac{1000}{110}}{3} = \frac{8.7 + 10.0 + 9.0}{3} = 9.2$$

Some of the most commonly used disinfectants are:

Carbolic acid (phenol)
Crude carbolic acid
Formaldehyde
Cresol
Bichloride of mercury
Chloride of lime

Lime
Hydrochloric acid
Caustic soda (crude)
Sodium hypochlorite

Carbolic acid is a white substance in the crystalline form. The 5% olution is most often used. It is made by dissolving this amount of rystals in water. Liquefied carbolic acid is made by adding 1 part of ater to 9 parts of the crystals.

M. Dorset gives the following advantages and disadvantages con- erning the use of carbolic acid:

"Advantages:

(1) It is reasonably effective for destroying non-spore-bearing bacteria.
(2) Its action is only slightly interfered with by albuminous substances.
(3) It does not destroy metals or fabrics in a 5% solution.
(4) It is readily available at all pharmacies.

Disadvantages:

(1) It cannot be depended upon to destroy spores of such bacteria as anthrax and malignant edema.
(2) It is expensive.

"Formaldehyde may be used for disinfection either as a solution enerally 5% solution) or as a gas. The 5% solution of formalde- de as a disinfectant is equal to the 5% solution of carbolic acid. e gaseous form is of advantage where everything in a room is to be infected."

Dorset gives the following advantages and disadvantages in the e of formaldehyde:

"The advantages may be summarized as follows:

(1) It is one of the most powerful germicides known.
(2) Its action is not interfered with by albuminous substances.
(3) It is not poisonous and may therefore be used for disinfecting hay and grain without destroying these for food purposes.
(4) It is not injurious to delicate fabrics, paint, or metals. (Formalin solutions will attack iron, but not other metals.)

"The disadvantages are briefly as follows:

(1) The gas has a strong tendency to condense in cold weather and is not reliable as a disinfectant when the air temperature is below 50° F.
(2) It is necessary to seal tightly all compartments which are to be disinfected with the gas in order that penetration may be secured and that the required concentration may be maintained for a sufficient length of time."

Chlorinated lime is a powerful disinfectant but is so destr to all organic material and so corrosive on metals that its usefu is limited.

The advantages and disadvantages in the use of cresol are according to Dorset as follows:

"Briefly, the advantages are:

(1). A 2 per cent solution of cresol is as efficient as a 5 per cent solution of carbolic acid.
(2) It is not interfered with by albuminous substances.
(3) It is cheaper than carbolic acid.
(4) It does not destroy metals or fabrics in a 2 per cent solution.
(5) It is more effective than carbolic acid for destroying spores of bacteria, such as anthrax.

"The main drawback to the use of cresol is that it is not readily soluble in water, hence may be used in too weak solution unless great care is taken in the preparation of the solution."

Bichloride of mercury is one of the most powerful germicides known but great care must be employed in its use due to the fact that it is such a virulent poison for all animals.

Hydrochloric acid is used to considerable extent in disinfecting wooden tanks and reels on which other disinfectants might leave residues which would later show up in the manufactured products. Lime and caustic soda are similarly used in many plants where their grease cutting ability is also an important factor.

Disinfection of articles on a large scale is carried out by the use of large steam chambers.

McCoy, Stimson, and Hasseltine describe a large disinfecting apparatus as follows:

"The Kinyoun-Francis apparatus is the best known in America for large disinfecting plants. A knowledge of the mechanical construction of this apparatus is necessary for its intelligent operation. Briefly, the steam disinfecting chamber consists of a jacketed closed chamber. Steam is admitted to the jacket chamber, and the apparatus is thus heated to avoid condensation when the steam is admitted to the inner chamber. The materials to be disinfected are placed in the inner chamber, which is closed. Air is then removed from the disinfecting chamber by the production of a partial vacuum (15 inches) by a steam vacuum pump. By opening the proper valve steam is then admitted from the jacket to the disinfecting chamber. All steam admitted to the disinfecting chamber must pass through the jacket chamber. The partial vacuum increases the penetrating power of the steam, as the air is partially withdrawn from all interstices and folds of the materials subjected to disinfection. When the desired pressure is reached it is maintained until a proper exposure to this temperature and pressure has been accomplished. By use of the vacuum apparatus a large part of the steam can be removed to avoid condensation and

consequent wetting of the articles exposed. The heated jacket facilitates the drying of the articles. When the articles are removed they are damp, but they soon dry upon exposure to the air.

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Chapter 6.

Wood Preservation.

Because of the greatly increased cost of wood used where there is contact with the earth and the weather, different methods of wood preservation have come to be extensively practiced. Posts, railroad ties, poles, and piling have their durability increased many times by the application of wood preservatives.

Wood placed in water or in damp earth decays, due to the attack of microörganisms. However, wood thoroughly dried or kept submerged in water resists attack by germs much longer than if kept just moist. This is due to the fact that a moist condition is best for the growth of microörganisms.

Some of the more important means of preserving wood are:

I. Painting.
II. Charring.
III. Dipping in tar or creosote.
IV. Soaking in tar or creosote for hours.
V. Impregnating with tar or creosote by heating.
VI. Use of zinc chloride and other salts.

The method in which creosote is used is said to be the most efficient.

G. M. Hunt says, "The United States Government, appreciating the great importance of preservative treatment of wood as a means of conserving the fast-diminishing timber supply, has been investigating preservatives and methods of treatment for many years and much fundamental information on these subjects is now available in the publications of the U. S. Forest Service.

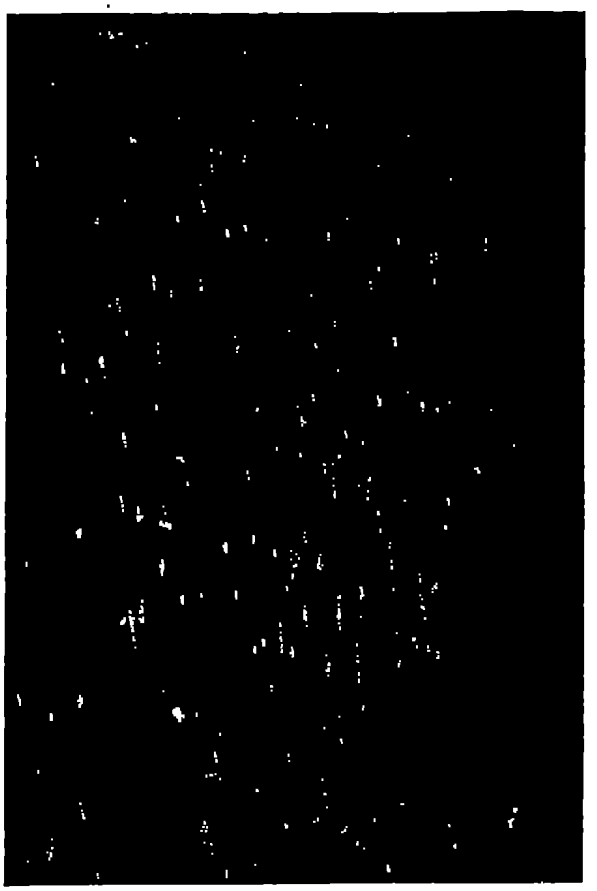
"The experience of nearly a century of use of preservatives and the scientific investigations of twenty years have demonstrated the value of coal-tar creosote and zinc chlorid as wood preservatives so that now they are the standard materials in their respective classes. All new materials or methods offered for wood-preserving purposes are compared with these standards. No material or process that does not compare favorably in efficiency with these standards can expect to find extensive use for the preservation of wood.

"There is no quick method of determining the effectiveness of a wood preservative. Service tests are the only reliable guides. This is unfortunate, because it places a considerable burden upon the legiti-

mate promotion of promising new materials and may result in their abandonment after many years of trial.

"It is possible by proper control of drying and manufacturing processes now in use to make good furniture from wood within a few days from the time the tree is felled. It is not, however, economically practicable or desirable.

"The effect of the presence of albumens or their coagulation or of the fermentation of the sap is of no consequence to the wood-preserver.



From U. S. D. A. Bulletin 1128.

FIG. 7.—Section of yellow-birch propeller stock. The incipient decay here shown is caused by the false tinder fungus.

Sap fermentation does not cause dry-rot or decay. Decay results from the growth of wood-destroying fungi, and good preservatives prevent this growth by poisoning the wood. Tar is not an excellent preservative unless deeply injected into the wood, and this deep injection is seldom accomplished. Surface treatments with tar have been repeatedly shown to be ineffective."

Decays and Discolorations of Valuable Woods.

In a splendid piece of work on this subject, J. S. Boyce in U.S.D.A. Bul. 1128 says, "From an economic standpoint by far the most

important discolorations in wood are caused by fungi." He classifies discolorations into sap stains and decay discolorations. He says:

"Fungi growing on wood may be roughly divided into two groups, depending on the habit of growth of hyphæ. In the first group are

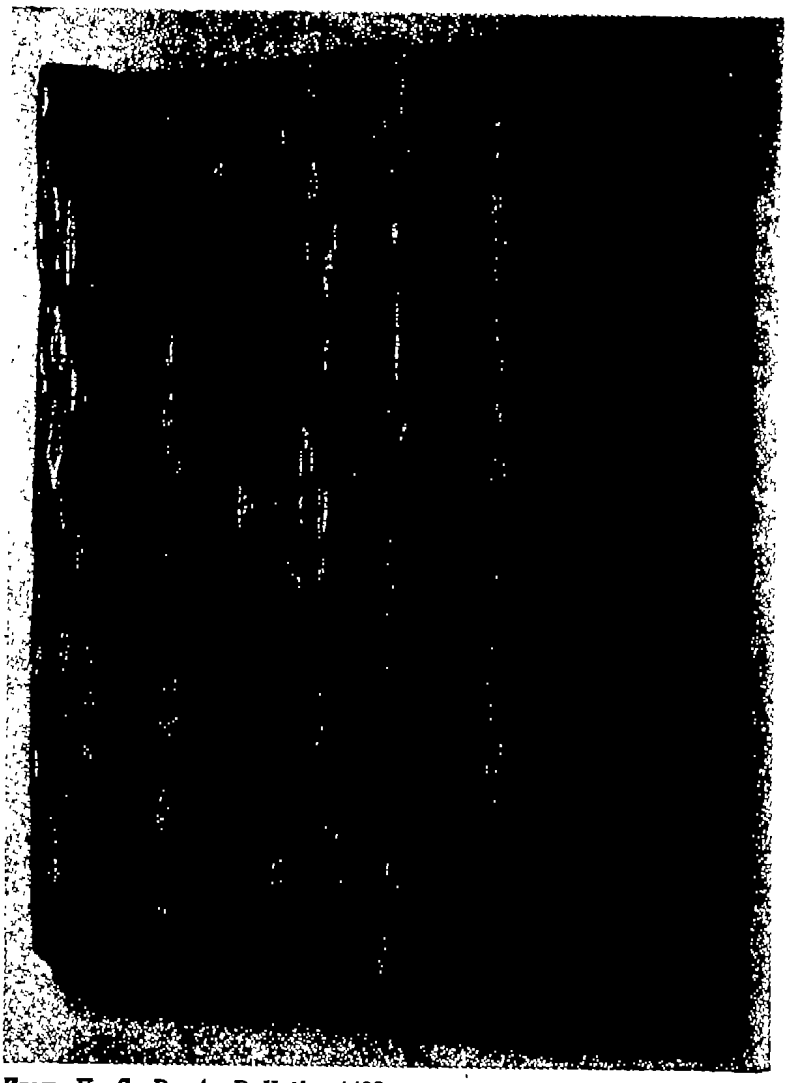
From U. S. D. A. Bulletin 1128.

FIG. 8.—Decay common in the heartwood of pine, larch, and Douglas fir. This typical decay, with the characteristic conspicuous white mycelium felts, is caused by the chalky quinine fungus.

placed those fungi whose hyphæ live on the substances contained in the various cells of the wood, while to the second group belong those whose hyphæ attack the actual wood substance of the cell walls and destroy it. The first group is principally represented by the sap-staining or discoloring fungi, so called because they produce various discolorations which are confined to the sap-wood. To the second group belong the wood-destroying fungi.

Sap-Stain.

"The discoloration is normally limited to the green sap-wood because as a rule there is neither sufficient food material nor moisture in the dry dead heartwood for the development of the fungus. The discoloration is usually most intense in the medullary rays, since in



From U. S. D. A. Bulletin 1198.

FIG. 9.—Section of the heartwood of Douglas fir. The typical decay here shown is caused by the ring-scaled fungus The light-colored wood at the right is sound sapwood.

these tissues the bulk of the food material is found. The stain is produced in two ways, either by a reflection of the color of the hyphæ through the cell walls of the wood or by an actual color solution excreted by the hyphæ which stains the wood itself. These stains vary in color from blue or blackish to reddish, the former being the most common. Since these fungi do not attack the cell walls in which the strength of the wood reposes, except to a negligible extent, discolored

wood is not appreciably weakened. This has been determined by comparative mechanical tests on stained and unstained wood."

The most important of these stains from an economic standpoint is blue-stain caused by various species of ceratastomella, which may be found on almost any hardwood or softwood.

Discussing measures of the control of blue-stain, Boyce says, "Blue-stain may be checked after it has started, but the stain can not be eradicated unless it is so superficial that it can be planed off. Therefore, the keynote of all treatments must be prevention.

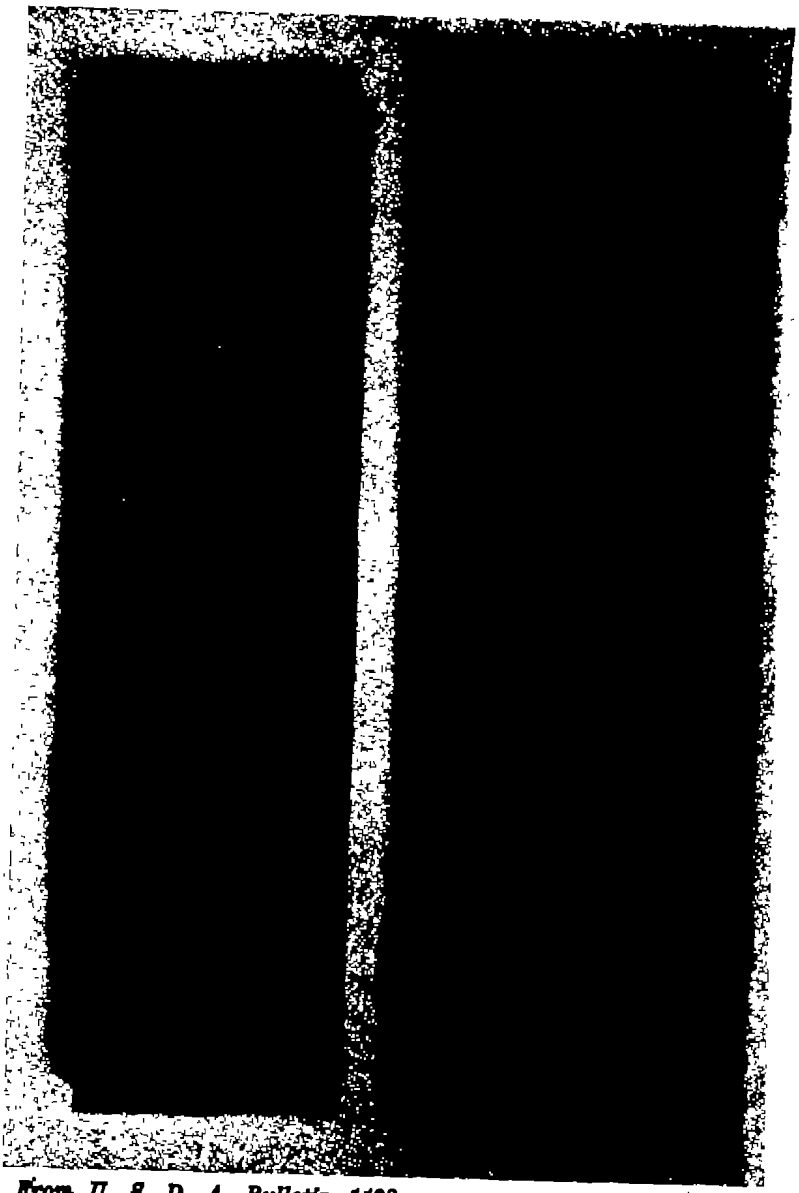
"Unfortunately, there is no one principle that can be applied to the prevention of this discoloration. Staining may take place at any time after the trees are felled or, in the case of dead timber, while they are still standing. Hence, in logging operations in regions where blue-stain is of importance, the logs should be removed from the woods as soon as possible after the trees are felled and bucked (cut up into log lengths). The practice of leaving logs in the woods for months can not be too strongly condemned as this not only causes blue-stain but also promotes the growth of wood-destroying fungi. Furthermore, the inevitable attacks of wood-boring insects assist greatly in the spread of blue-stain and decay. When the trees are bucked the narrow space left by the saw kerf between the logs as they are lying end to end affords an ideal situation for the development of the blue-stain fungi. Such logs often stain deeply, while those with the ends fully exposed remain entirely free from discoloration. As soon as the logs are in the mill pond danger from staining is over for the time being, since the oxygen supply is so reduced that the fungi can not develop.

"The greatest danger of all is encountered during the process of drying the rough lumber as it comes from the saw. The best method of preventing blue-stain is by kiln drying. If the stock checks easily, so that low temperature and high humidities must be maintained over a considerable period, some of the other staining fungi such as molds, may develop. But these can be checked by raising the temperature in the kiln to about 160° F. or slightly more for an hour by turning live steam into the kiln. When this is done, care must be taken to keep the air saturated while steaming and to reduce the humidity gradually after steaming. When the stock has once been dried properly the moisture content has been so reduced that there is no more danger from staining, provided it is kept dry. A dispute that arose over the efficiency of a dry kiln was immediately settled by the fact that the blue-stain fungi had resumed vigorous growth the day after the stock was removed from the kiln. This could not have occurred if the lumber had been properly dried.

"All airplane lumber should be kiln-dried immediately, since this not only prevents blue-stain but also stops the growth of wood-destroying fungi, prevents future checking, and greatly reduces weight without in any way injuring the lumber, provided temperatures that are too high are avoided.

"In case kiln drying is impossible, treatment with antiseptic solu-

tions is of considerable value. As it comes from the saws the green lumber is dipped into a hot or cold chemical solution. The solutions most commonly employed are sodium carbonate or sodium bicarbonate in water. Neither is 100 per cent effective under optimum conditions



From U. S. D. A. Bulletin 1,188.

FIG. 10.—The left-hand section shows blue-stain in sugar pine. The dark-blue specks are the ends of the medullary rays. The heartwood side is uninfected. The right-hand section shows brownish discoloration and white streaks in white-ash longeron caused by incipient white heartwood rot.

for staining, but they aid materially in checking discoloration. These two chemicals, however, color the treated wood a decided yellow or brownish. Sodium fluorid, although it does not stain the lumber and is slightly better for blue-stain, is not so effective against certain molds as the two solutions first mentioned. This chemical is seldom used.

It must be remembered that the strength of the solutions must necessarily vary with the conditions. The more favorable the conditions for blue-stain, the stronger the solutions should be.

"After being dipped in any of these solutions the lumber must be carefully open piled, that is, with spaces between the boards to insure good ventilation. Narrow cross strips or 'stickers' chemically treated should be used, to prevent staining at the points where the boards and cross strips meet.

"Salt is of little or no value in preventing blue-stain in comparison with the other chemicals. The application of salt after blue-staining has well started is almost a waste of money. In fact, the application of wet salt or a strong salt solution may prove detrimental in the long run, for if the lumber is dried after such treatment the affinity of the salt for water may cause the moisture content to remain much higher than normal.

"Mercuric chlorid in a 0.1 per cent solution is exceedingly effective against blue-stain, but on account of its highly poisonous nature and extremely corrosive action when in contact with many metals it is little used.

"Shipping green stock closely piled in closed box cars during the spring and summer months is almost certain to result in severe staining. Indeed, the writer has seen some stock handled in this way which stained even in winter. On the other hand, any measures taken to prevent staining, such as open piling in gondolas or on flat cars, will almost certainly result in severe checking. Of the two evils, checking is by far the most serious in airplane stock, since checked lumber is greatly reduced in strength, while the stained lumber is only somewhat unsightly. Shipping green lumber in the close hold of a vessel, particularly if tropical seas are to be traversed, is an invitation to swift and sure disaster as far as sap staining is concerned. It is doubtful whether dipping in any chemical solution now used, except possibly mercuric chlorid, would be effective under such severe conditions.

"But to repeat, the most effective measure to employ against blue-stain is speed in drying the wood. Get the logs from the woods to the saw with the greatest rapidity and the lumber from the saw directly into the dry kiln."

Discussing sap-stain on soft woods, Boyce says, "Certain species are peculiarly susceptible to sap-stain. This is due both to the character of the wood and to the climatic conditions of the region where the species grows. Western white pine, spruce, and southern yellow pine, the last-named wood including longleaf pine (Pinus palustris Mill.), shortleaf pine (P. echinata Mill.), and loblolly pine (P. tæda Linn.), are very subject to sap-stain, especially blue-stain, while true fir and cedar are not so easily affected. Douglas fir occupies an intermediate position.

"Besides blue-stain, a red stain has been very commonly found on Sitka spruce airplane lumber. It occurred abundantly in the East on stock in cars just arrived from the Pacific coast and also developed

on material along the Atlantic coast which had arrived unstained at the port of embarkation but was held over awaiting shipment. The stain appeared as terra-cotta or brick-red spots on the rough lumber, varying from very faint to a pronounced color. In the stock worked up in the factories in this country it was found that the stain was superficial, usually surfacing out during remanufacture; but reports from abroad indicate that the fungus developed very intensively by the time the lumber reached European ports, and the discoloration penetrated deeply into the sapwood. The appearance of the wood is not marred to the same extent that it is by blue-stain, and as far as is known no reduction in strength results. The fungus causing the discoloration is as yet unknown.

"Blue-stain is very severe on the white pines and is particularly noticeable because of their white wood. Plate 1, left part, shows a section from a sugar pine rib web in which the sapwood is stained to some extent. The small, darker, bluish black spots are the ends of the medullary rays, in which, as before stated, the fungous mycelium is most abundant. The longer streaks are the resin ducts.

"Certain fungi (Penicillium spp.) stain the sapwood of the pines an orange-red to a crimson-red color. Another fungus (Fusarium roseum Link) is responsible for a pink to a lilac color in the same woods. The color is produced by means of a pigment secreted by the hyphæ, which actually dyes the wood.

"A wood-staining fungus (Zythia resinæ (Fr.) Karst.) has been reported in Europe as working on finished pine lumber after the wood has been oiled. The discoloration was characterized by violet to dirty red or even dark grayish brown flecks beneath the oiled surface of the wood. The spots were covered with minute pustules varying from violet, orange, and brown to black. These constitute the spore-producing bodies. The discolored areas extend within the wood as streaks closely associated with the medullary rays and resin ducts. The report does not state whether the discoloration was confined to sapwood. Apparently the wood was not reduced in strength. As far as is known, this stain has not yet been found in the United States."

Boyce gives the following information concerning decay and discoloration in different kinds of lumber:

"The hyphæ of wood-destroying fungi living within the wood feed on the various substances composing the cell walls. They use certain constituents of the cell walls, neglecting others, with the result that these walls are broken down, the wood being thus greatly weakened and more or less destroyed. It is the breaking down of the wood and the change in its physical and chemical qualities that is termed decay. The degree of decay is determined by the energy of growth of the fungus, the length of time it has been at work, and the type of wood it attacks. Some fungi attack many different kinds of wood, while others are limited in their choice. Owing to their less exacting moisture requirements, wood-destroying fungi are able to live on heartwood as well as sapwood. The fruiting bodies, usually quite large, are found

on the surface in the form of brackets, crusts, or mushrooms or toadstools. They are not developed until the hyphæ have been at work for some time; consequently, the presence of fruiting bodies indicates serious decay.

"Two types of wood-destroying fungi may be recognized, (1) those mainly attacking the heartwood, rarely the sapwood, of standing living trees, and (2) those principally confining their activities to the manufactured product, such as sawed lumber, cross-ties, and poles. The former type may continue their work of destruction after the tree has been cut down and worked up into lumber. The latter, attacking the manufactured product, usually invade the sapwood first, since it is far richer in stored food, generally has a higher moisture content than the heartwood, and is not so inherently resistant to decay. Fungi causing this type of decay are often very abundant in yards where the lumber is closely piled on damp earth, with little or no aëration under the piles, and much accumulated wood debris scattered throughout the yard. Unfortunately, such conditions are all too prevalent in mill yards. Sanitary yards both at the mills and the factories are badly needed. Humphrey gives a complete account of the life history and habits of these fungi, the damage caused by them, and methods for their control.

Types of Decay in Logs and Lumber.

"In addition to the wood-destroying fungi which normally attack living trees, and which may continue to decay the wood after the tree is cut, there are fungi which grow only or principally on wood in the form of logs or lumber. Owing to their destructiveness some of these deserve more than passing mention. Although it is true that damage caused by such fungi is due to improper handling of the timber during the course of manufacture and utilization, unfortunately such improper handling does occur and must be reckoned with.

"One of the most important of these fungi is that which causes dry-rot in stored logs or lumber and in timber in structures. The term 'dry-rot' is loosely applied to cover almost any type of decay, but it is correctly applicable only to the work of the dry-rot fungus (Merulius lacrymans (Wulf.) Fr.). This decay is more common on coniferous woods than on hardwoods. The incipient decay appears as a yellow-brown discoloration not easy to detect. Wood with typical decay is yellow to brown in color, much shrunken and cracked, and is so badly disintegrated that it can easily be crushed to a powder. Both sapwood and heartwood are attacked.

"Another common decay on logs and sawed lumber, particularly on railroad ties, is the brown-rot, caused by the brown Lenzites (Lenzites sepiaria (Wulf.) Fr.), which is practically confined to coniferous wood. The typical decay is brown, friable, and easily reducible to a powder. In the early stages of decay, infected wood is darker in color than the normal. Sometimes the early spring wood of the annual rings

may be completely decayed, while the summer wood is scarcely affected. In this condition the wood separates readily along the annual rings.

"Certain fungi (Polystictus versi-color (L.) Fr., Stereum hirsutum (Wild.) Pers., and others) cause a sap rot very difficult of detection in its incipient stage. The typical decay is very light in weight, white in color, rather soft, and easily broken in the hands. But since the first indication of this decay is a faint whitening of the diseased wood and white is the normal color of most sapwoods, it is apparent that the initial stages may be readily overlooked. At the same time the wood is decidedly reduced in strength. The decay is most common on hardwoods, but also occurs to some extent on softwoods. Fortunately none of the fungi causing this white sap-rot attack living trees of the species which furnish airplane timber.

"Red-gum logs when left in the woods for any considerable time are subject to a very serious sap-rot caused by the smoky Polyporus (Polyporus adustus (Wild.) Fr.). The heartwood is comparatively durable. Boards cut from diseased logs are very characteristic and striking in appearance. Normally, red-gum sapwood is a light yellowish white, commonly with a reddish tinge. The sapwood in a decayed board has a number of various-colored streaks or lines irregularly distributed from the end of the board toward the middle. These streaks are light orange at first, but in the more advanced decay are a very light straw color (in fact, almost white) and are intermingled with lines and patches of bluish gray and the normal-colored sapwood. Black zigzag lines may extend from the ends of the board for a distance of 2 inches or more parallel to the grain. The general consistency of sapwood with this incipient decay, which may extend 2 or 3 feet in advance of the typical decay, is firm and solid. Sapwood with the typical decay is badly broken down, being soft and pulpy and without firmness.

"This and other sap-rots may be prevented by shortening the drying period in the woods. Coating the ends with hot coal-tar creosote immediately after the logs are cut is also effective. Where possible, all freshly cut logs, particularly those cut during the spring and summer, when the rot develops best, should be peeled. Sap-rots similar to those found in the red gum are found in tupelo gum (Nyssa sylvatica Marsh) and in maple."

Hunt of U. S. Department of Agriculture in Bulletin 744 says:

"Decay is not due to the chemical action of the soil or to the fermentation of the sap, but is the result of the action of certain low forms of plant life called fungi. These consist for the most part, of very fine thread-like filaments, collectively called mycelium, which penetrate the wood in all directions. Certain substances in the wood constitute the food of the fungi. As these substances are dissolved the structure is broken down, until the wood reaches the condition commonly known as rotten.

"The mycelium usually grows out to the surface to form compact

masses called fruiting bodies. Since there are many kinds of fungi, there are many kinds of fruiting bodies. The various forms of 'toadstools,' 'punks,' 'brackets,' or 'dog ears,' which are so frequently found growing on trees and deadwood, are examples of these. Their presence generally means that decay has made considerable progress in the wood. The function of all fruiting bodies is to produce spores, which are to the fungus what seeds are to higher plants. Millions of spores may be produced by a single fruiting body, and they are so small that they are able to float long distances in the air. When a spore drops into a crack in a piece of wood and conditions are favorable, it germinates and the fungus begins its destructive action.

"Another way in which decay spreads is by the mycelium growing from one piece of wood to another. When a piece of decaying wood is in contact with a sound piece the latter may rapidly become infected in this way and be ruined.

"The four requirements for the growth of fungi are moisture, air, a favorable temperature and food.

"A damp condition of the wood is probably the most favorable to decay. Wood can be either so wet or so dry that the fungi can not live in it. When submerged in water it has been known to last hundreds of years, and in perfectly dry situations it will often last indefinitely. Wood in contact with damp ground usually contains the right amount of moisture for the development of decay. Also, where timber is in contact with wood or other material, water frequently collects in the joints and keeps the wood moist for long periods of time, thus favoring decay at these points."

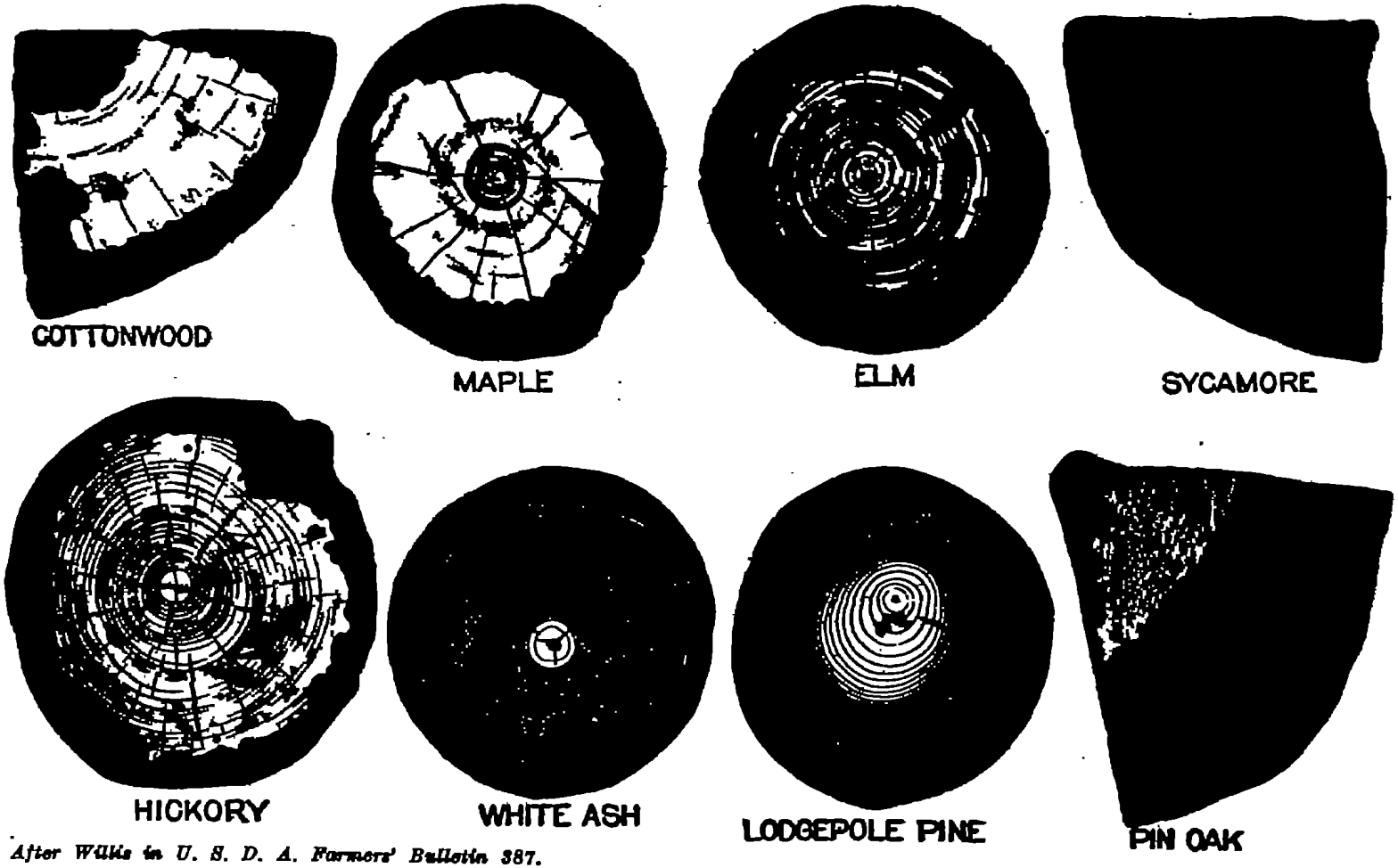
Hunt says, "Wood-destroying fungi can not grow at very high or very low temperatures; but there are few, if any, climates in which the temperature during at least part of the year is not favorable to their growth.

"The wood itself supplies the fourth requirement of the fungi, which is food. In order to prevent decay, it is necessary to deprive the fungus of one or more of these four requirements. It is out of the question in ordinary situations to deprive it of air and warmth; and though moisture can sometimes be eliminated to a certain extent, this can not be done when the wood is exposed to the weather. In general, therefore, the most effective method of preventing decays is to poison the food supply; and upon this principle is based the use of most successful wood preservatives."

Hunt in U.S.D.A. Bul. 744 says that coal-tar creosote penetrates many species of wood satisfactorily and that excellent results can be obtained by its use. He says, "Coal-tar creosotes vary considerably in quality; but satisfactory results may be obtained from any good grade, provided a sufficient amount is put into the wood and a good penetration is secured."

Concerning other wood preservatives for farm timbers Hunt says:

"Carbolineums are proprietary preservatives similar in appearance and preservative qualities to coal-tar creosote, but usually higher in



After Willis in U. S. D. A. Farmers' Bulletin 387.

Sections of posts of various woods treated with creosote by the open-tank process. All the posts are drawn to the same scale, and are approximately 5 inches across. The black areas show the creosote penetration, which corresponds generally to the sapwood.

price. In service tests made by the Forest Service on brush-treated telephone poles they have given about the same increase in durability as coal-tar creosote.

Wood-Tar Creosotes.

"But little reliable data upon the effectiveness of wood-tar creosotes is available, and until satisfactory service tests are completed no definite recommendation can be made. It is likely, however, that good results will be obtained if the wood creosote is of a high grade.

Water-Gas-Tar Creosote.

"Water-gas-tar creosote is an oil similar in many ways to coal-tar creosote, but its value as a fence post preservative has not been fully established. It is possible that good results would be obtained from its use in open-tank work.

Zinc Chloride.

"Zinc chloride is a toxic preservative that gives good results when properly applied and used under the right conditions. It is sold in solid form or in a 50 per cent solution, and is injected into the wood in a solution of from 2 to 5 per cent in water. It is much cheaper than coal-tar creosote. On account of its solubility in water, however, it is washed out of wood in time by the rain or ground water, which is the chief objection to its use.

"In general, zinc chloride is not considered as satisfactory for farm timbers as coal-tar creosote, but there may be cases where its use is advisable. For wood to be used indoors it may in some cases be satisfactory where creosote would be objectionable on account of its odor, color, etc. It is not recommended, however, for use by the brush method.

Tar.

"Tar is not a good preservative for farm use; and, in general, good results have not been obtained with it when applied by methods that are practicable on the farm. Its chief defect is that it does not penetrate the wood readily. Coal-tar and water-gas tar are also much less poisonous to the organisms which cause decay than is coal-tar creosote.

Crude Oil.

"Crude oil is not sufficiently poisonous for a wood preservative. If the wood can be thoroughly saturated with it, water may be kept out and decay prevented; but it is very difficult, if not impossible, to get enough oil into most woods by processes which are practicable on the farm. For treating by the brush method crude oil is entirely unsatisfactorily.

Paint, Linseed Oil, Whitewash.

"Good results cannot in general be expected from paint, linseed oil, or whitewash when used on fence posts, or other timbers in contact with the ground. They do not penetrate the wood deeply, and the only way they can prevent decay is by preventing the entrance of fungi or moisture into the wood. Furthermore, the wood is seldom painted on all sides; so it is usually possible for fungus to enter through an unpainted part. Whenever the painted film cracks or peels off decay can also enter. It is quite common to see wood decaying beneath a coat of paint. If the wood were saturated with linseed oil it might prevent decay by keeping out the water; but this would be difficult to accomplish as well as being too expensive.

Cement Coatings.

"Posts have sometimes been dipped in thin cement and allowed to dry, leaving a coat of cement over the surface of the wood. Such a coating will not keep out water and is easily cracked or broken off. Good results cannot be expected from this treatment."

In the study of the life of treated fence posts under Wyoming conditions Buffum gives his conclusions as follows:

Summary of Results.

"The best treatment, and one which was eminently successful in preserving the posts, was dipping the lower ends in crude petroleum and burning off the oil a sufficient distance to come above the ground when set. This seems to drive hot oil into the post, which with the protecting char cover keeps it from decay. The sixteen years had made but slight inroads on the posts thus treated, and they apparently would last indefinitely. This dipping can be done very cheaply, and will undoubtedly pay."

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Chapter 7.

Fermentation in the Textile Industry.

In the manufacture of textile goods one of the most common sayings of the weaving room is that half the weaving is done in the slasher room. In other words, warps which are properly sized give little difficulty in weaving.

Size for the preparation of warp is made of many different animal, mineral, and vegetable compounds and for each constituent added to size is claimed a certain virtue in weaving. Some of the vegetable constituents sometimes added to size are corn starch, potato starch, sago starch, wheat starch, wheat flour, rice starch, tapioca flour, dextrins and modified starches of many kinds. In general, these grain products give strength to the warp by cementing the fibers together. In addition to these carbohydrates, other constituents added to size are fats, oils, and waxes to give pliability, and mineral matter to give weight.

The carbohydrates above mentioned are used as the basis to carry the other ingredients and are first placed in the size kettle and gelatinized, after which the other ingredients are added. Due to the fact that the starch grains are gelatinized and to the presence of protein in the size, fermentation begins as soon as the mass is slightly cooled. This fermentation is carried by miscellaneous microörganisms and starts progressive changes in the physical properties of the size.

Formerly all dyeing with indigo was carried on by a fermentation process but more recently only wool dyeing is accomplished by vat dyeing. The dyeing liquor is made up of wood, molasses, madder, indigo, lime, and water at room temperature. Fermentation generally begins immediately and at the end of three days the liquor is ready for use as a dye. Evidence of the starting of fermentation after making up the liquor is the vigorous production of gas bubbles. The organisms involved in this process of dyeing have not been extensively investigated but belong to the lactic acid forming bacteria, the hydrogen and carbon dioxide forming bacteria, and to alcoholic yeasts, the gas evolved being mainly carbon dioxide and hydrogen.

This method of dyeing with indigo is very ancient, having been practiced by the Egyptians.

Indigo blue is an insoluble blue substance obtained from the indigo plant. When it comes in contact with reducing agents some of which

produced in the fermentation vat, it is reduced to indigo white
h is soluble as follows:

$$\underset{\text{indigo blue}}{C_{16}H_{10}N_2O_2} + 2H = \underset{\text{indigo white}}{C_{16}H_{12}N_2O_2}$$

When the dyed goods are brought into contact with the air the re-
of the above takes place and the indigo in the goods becomes
o blue which is soluble.

ndigo is one of our oldest dyestuffs. It is a vegetable coloring
er obtained from the stalks of the plant Indigofera tinctoria
n grows in the East and West Indies, Egypt, and in South America.
s been used extensively for calico printing.

he stalks of the plant are cut just before flowering and with
s left on are piled in cement cisterns where they are covered with
and held at a constant temperature of about 30° C. The fer-
ation commences instantly and is allowed to run for 12 hours
the liquid becomes bluish green and contains much indigo white,
$_2N_2O_2$. At this point the liquid is drawn off into other vats
it is agitated vigorously to bring it into contact with the air.
oxygen of the air oxidizes the indigo white to the blue pigment
, $C_{16}H_{10}N_2O_2$, which precipitates and settles to the bottom. The
is then decanted. The indigo is washed, boiled to sterilize it,
nally filtered and dried on cloth screens. The dried powder is
d into cakes and sent to market.

he yield of indigo per ton of plant stalks is low, being not more
3%. As indigo is composed of several coloring matters it is
imes purified by reducing it to indigo white and then reoxidizing
ing a precipitate of a higher percentage of indigo blue. The
blue of commerce averages about 50% purity, the other 50%
indigo red, indigo brown, and nitrogenous substances from the
which do not get fermented out or decanted in the process.

The Fermentation.

e fermentation of the indigo plant as carried out in the Province
gal is due to a bacterium, B. indigogenus which exists normally
leaves of the green plant. The physiological characteristics
orphology of this bacillus is much like the Friedlander's pneu-
bacillus. It is an aërobe and a capsule former. Accompanied
er organisms it ferments the glucoside, indican, $C_{26}H_{31}NO_{17}$, to
white and a sugar, indiglucin, which is partly destroyed by the
tation.

igo is also manufactured by a purely chemical process and
the yield from the plant can be considerably increased it is
that the manufacture of indigo from the plant must give way
to the chemical process. The artificial product is more uni-
nd of higher purity. Due to absence of nitrogenous impurities
or is brighter.

C. M. Hutchinson in 1916 investigated the possibilities of improving the processes involved in the manufacture of indigo by bacterial action and gave the followng report:

(1) The yield of indigo depends largely on bacterial action. (2) Some kinds of bacteria operate beneficially while others act detrimentally. In the absence of the former class in sufficient quantity there will be a reduction in yield. (3) It should be possible to insure the presence of the beneficial kinds by artificial inoculation. (4) It is necessary to bring the bacteria normally present on the walls of the steeping vat into closer contact with the indigo plant in the vat, by altering the shape of the latter so as to reduce the ratio of cubical contents to the wall area. (5) It will probably be found beneficial to modify the character of the wall surface so as to promote a more extensive permanent growth of the beneficial bacteria.

Chapter 8.

Tobacco.

The curing of tobacco according to the studies thus far made is due to enzymes to a large extent, and perhaps to bacteriological activity, while curing in a compressed state. There is a decrease in nicotine and an increase in citric acid during curing.

H. Jensen thinks that in so far as tobacco curing proceeds in the presence of formalin and chloroform, it is not a bacterial process.

Molding of finished cigars has been investigated by R. H. True. He says: "The mold usually appeared most abundantly on the 'head' or closed end of the cigar, less frequently on the veins or other elevated portions of the wrapper, but in some cases the entire surface was more or less involved. The wrapper leaf is usually prepared for use the day before it is actually used in manufacture. It is first brought into the necessary moist condition, or gotten into 'case,' by dipping into water. The leaves are bound into small bundles in which the bases of the leaves are tied together. These bundles, or 'hands' are grasped by their bases and carried down into and through the 'casing' liquid with a scooping motion, so performed as to drag the bundle of leaves with the bases ahead, the blades of the leaves being pulled through the liquid. After this quick dip, the bundles are shaken and set upright on a draining board to permit the surplus liquid to drain away. The pile, loosely packed together, is then covered with a moist cloth and allowed to stand until the droplets of water clinging to the surface of the leaves have been absorbed. In a few hours the leaf becomes soft and pliable without giving the impression of being wet. The ribs are then pulled out and the broad leaf blades are worked up as their size, shape and quality may determine. The freshly made cigars are then sorted according to colors and boxed immediately, or sometimes held in bundles, to be packed later.

"In this condition each cigar is round, and the prescribed number of cigars when placed in the box overfill it, so that the cover must be brought into place by the use of pressure. Here the moist cigars yield to each other and take on such flattened sides and angles as may be required to get the box closed. Sometimes the lids of the boxes are considerably bent by the pressure of the fresh cigars, and the boxes are then placed for a day in large presses before they are nailed up. In warm weather the mold sometimes appears while the boxed cigars are in the presses; that is, within 48 hours after they are made, but

more frequently within a week or two after making. When warm, humid weather conditions prevail it is not rare for molds to appear while the cigars are in transit or in storage. Since heat and moisture are necessary conditions for mold development, it follows that little trouble is experienced in the winter months but much during the hot summer months.

"A number of attempts had been made by the factory managers to remove this source of loss. Small quantities of vinegar in the water (1 pint in 4 or 5 gallons) used for casing wrapper leaf were found to aggravate the trouble. When the leaf was cased in vinegar at full strength the molds were suppressed, but the luster of the leaf was thought to be impaired. Casing in alcoholic solutions was found to be helpful, but too expensive. Small quantities of glycerin were found to be useless in suppressing molds, but helpful in retaining moisture in the wrapper."

True describes ideal remedial measures as follows: "Having located the cause of the trouble in the organisms above discussed and having found the point of their entrance, as well as the seat of their activities, to be in the tragacanth paste, practical remedial measures seemed to lie along the line of sterilizing the paste.

"In view of the conditions governing the subsequent handling and final utilization of cigars, an acceptable sterilizing agency must combine several characteristics. It must be permanent, since cigars sterilized for but a short time are liable to mold at a later period when conditions of heat and moisture concur with or follow the exposure of the cigars to the infecting organisms. The substance must be odorless and tasteless; otherwise it will alter the taste and aroma of the cigar, points on which smokers, and therefore dealers, are very sensitive. It must not alter the color or the luster of the wrapper, since on these the selling quality of the cigars in considerable part depends."

Concerning the organisms which attack finished cigars in the final package, F. W. Patterson found Rhizoporus nigricans (Ehren); Mucor racemosus (Fres. var. brumeus Morini, Penicillium (sp.); and Aspergillus candidus (Link)).

True found that boric acid in the paste was the best preventive. He says: "Gum tragacanth is used in small quantity to fasten the wrapper of the cigar in place. The wrapper is rolled tightly on the cigar, the rolling proceeding from the open end toward the head, the last portion of the wrapper remaining free being a small flap of leaf which serves to finish off the head. This small flap receives a little paste on the under surface and is then carefully brought into place. The cigar is then usually rolled with some pressure between the hand and the board or table at which the cigar maker works, thus giving it the desired regularity of form. Thus, a little paste is always found at the head of the cigar, and if an excess has been applied, especially if the paste is rather thin, a portion is liable to be squeezed out on to the board or table at which the maker works, and the cigars may

receive a more or less extensive smear of paste over the surface of the wrapper.

"The paste as usually made up contains about 10 parts by weight of gum tragacanth to 90 parts of water. A large stock is generally made in one container, sometimes only enough to last for the day and sometimes enough to last for a longer period. An inspection of the paste pots in several factories showed that while some were in fairly clean condition the sides of others were thoroughly covered with molds, indicating that in some cases little attention was paid to cleanliness regarding this feature.

"Since the paste evaporates water between the time of making and of using, a concentration somewhat less than saturation was recommended in making the paste. This would also tend to decrease the liability of the acid to crystallize out in a conspicuous way on the surface of the cigars should paste happen to be smeared on them. The following concise directions were prepared: Place boric acid in warm water at the rate of 1 ounce of dry acid to 1¾ pints of water. Stir till the acid is all dissolved. Use this solution instead of water in making up the paste. Great care should be taken not to use more paste on the cigar than is necessary, since it is liable to be smeared on the surface of the cigar, where the boric acid in the paste tends to crystallize, giving an appearance suggesting mold.

"These directions have been followed for some years in the factory in which the complaints originated, and when the writer was last in communication with those in charge the boric-acid treatment was in use as a routine practice and only in rare instances were molds found troublesome."

Chapter 9.

Silage.

The preservation of corn, or other suitable products, in a silo, that is, the manufacture of silage, is another illustration of the preservative effect of organic acids. In many points, it is similar to sauerkraut manufacture and to pickling. The organic acids formed in silage by the action of microörganisms are mainly lactic and acetic. The acid producing bacteria find the conditions of growth very favorable in the silo and produce large amounts of these acids, creating an acid content of 1% to 2% by weight. The putrefactive bacteria are unable to grow in the presence of this acid and thus the protein of the silage is preserved. In the first stages of silage making there are considerable numbers of yeasts present, and alcohol and carbon dioxide are produced during the first day or two after filling.

The action of microörganisms is not the only action which is going on in the silage, as the plant tissues contain many enzymes which act on the proteins and carbohydrates. This action helps to bring about the condition of the mature silage.

While the fermentative conditions in the silage naturally preserve the protein, still if air gets into the silage either through cracks in the silo or due to the fact that the cut corn stalks are not packed closely enough, molds and other fungi attack the acids and destroy them. When the acids are destroyed it is possible for proteolytic bacteria to set up a vigorous putrefaction of the protein and those spots where air has entered the silo are made unfit for cattle food.

Inoculation of silage materials with cultures of lactic acid bacteria is not necessarily practiced as these organisms exist in abundance naturally on the corn or other plants and silage seldom fails to result under normal conditions.

Silage can be kept for years in a perfectly tight silo which prevents the entrance of air into the silage.

The quality of silage as to feeding value depends considerably on the condition of the corn when it is cut. A. R. Lamb says, "The corn forage should be ensiled when the grains are well dented, which is generally when the lower leaves and husks are beginning to dry up and the corn is nearly ready to be cut for shocking. The sizes of pieces into which the corn should be cut is not of very great importance but an average of ½ to 1 inch long is very generally accepted as

correct. The corn will usually not need added water if cut at the proper time in a normal season."

Many other products than ensilage corn may be siloed with greater or less difficulties.

According to A. R. Lamb, rape makes fair silage but is somewhat more difficult to handle than corn, because of greater water content and greater sugar content. He also mentions the facts that the sulphur of rape may occur in fermentation products and give trouble if the silage fermentation progresses too far, also the acidity may go too high due to the sugar present in rape. However he adds that if the same precautions, especially the exclusion of air, are observed as in making corn silage, there should be no difficulty in preserving rape.

Concerning mixtures of rape and other grains as silage he says, "The mixtures which were made with rape and other plant materials were much better, however, especially in the case of added legumes such as alfalfa and red clover. The rape supplies to the mixture the necessary sugars which are deficient in amount in the legumes. This mixed rape-legume silage may be made in almost any proportion, from 20 to 80 parts per hundred of rape, and the resulting silage, if properly made, will be pleasant and aromatic in taste and odor, and not too sour. The alfalfa-rape mixture will furnish a silage high in flesh-building and growth-producing constituents, and perhaps better for swine feeding than the other mixtures. The following plant materials, however, made successful silage when mixed with rape; corn grain, whole corn plant, potatoes, blue grass and timothy."

C. H. Eckles says that while shock corn silage is not equal to silage made from corn put in at the proper stage, still it may be used to advantage in the silo. He says that according to experiments made at the Missouri Station a pound of water should be added for every pound of dry fodder.

Esten and Christie in a study of silage fermentation arrive at the following conclusions:

"1. The fermentation of corn silage is essentially the change of sugar into several acids. The most important change is the conversion of a part of the sugar by lactic acid bacteria into lactic acid. A secondary change is produced by the action of yeasts on the remaining sugar changing it to alcohol. The acetic bacteria change the alcohol into acetic acid.

"2. The exclusion of air is necessary for the proper production and preservation of silage.

"3. The walls of a silo should be non-conducting to heat, cold and moisture.

"4. Mature corn makes silage of better quality with less waste.

"5. Silage undergoes a ripening, somewhat similar to the ripening of cheese, which softens the fibers, makes more digestible the proteins and adds new and agreeable flavors. This ripening occupies from three to four weeks.

"6. A silo is the cheapest form of storage.

LIBR

"7. Any farm product can be siloed providing there is sufficient sugar in the mixture to be fermented into acid to preserve it.

"8. The following mixtures silo successfully and make a very desirable and nearly balanced ration: Alfalfa and rye, clover and timothy, or wheat, or oats, oats and peas, and corn and cowpeas or soybeans.

"9. A round wooden stave silo, taking all things into consideration, has proven most satisfactory.

"10. Nothing excels the feeding of silage, especially legume silage, during the dry summer months for keeping up the milk flow to its highest point."

Swanson and Tague studied the factors in silage making. They say, "It was found that silage could be made from alfalfa alone if absolute exclusion of air and retention of carbon dioxid could be secured. These conditions are, however, indicated as not practical of realization. The addition of supplements was found to insure a more rapid and plentiful production of acids, which makes conditions for putrefactive organisms unfavorable. Wilted alfalfa was more suitable for silage than unwilted. The addition of water to unwilted alfalfa was harmful, while no decisive results were obtained by the addition of water to wilted alfalfa.

"Molasses was found to be the most effective supplement tried. Germinated corn was more effective as a supplement to alfalfa than sound corn, the results produced being similar to those produced by molasses. It is indicated that rye would be a suitable supplement but for the strong odor which it imparts to the silage.

"The value of tightness of packing lies only in the fact that it makes the exclusion of air more certain.

"In good alfalfa silage about one-third of the nitrogen was found to be in the amino form, while in bad silage the amount was sometimes one-half that of the total nitrogen.

"Most of the acids present in alfalfa silage are produced in the first two weeks. The percentage of acidity may increase after that, but the increase is comparatively slight. The alfalfa, as it is put into the silo, contains only a small amount of nitrogen in amino form. Most of the change of nitrogen into amino form takes place in the first 10 days. Silage from wilted alfalfa contains more nitrogen in this form than that made from fresh alfalfa. Sugar present in the materials used in making silage disappears very rapidly. Completely matured silage contains no sugar."

Evard and Lamb made a study of making silage from soft corn. They say, "The soft corn ears in last roasting stage were husked, run through a silage cutter and tightly packed into small silos. The silage resulting after 12 days of fermentation (ordinary silage is practically made in 10 days) was surprisingly good, having a favorable odor much like ordinary entire corn plant silage. In appearance the soft ear corn silage was good, being quite bright and light colored, clean, free from mold and palatable. Chemical tests showed sufficient silage acids to

have been developed to preserve without over acidity or sourness. Such corn and cob silage will not develop as much acidity as ordinary silage, but enough to preserve it well if properly cut up and packed.

"Snapped corn, or corn ear plus husks, will make good silage, the husks being of advantage in that they will tend to tie or pack the small ear pieces more closely together and hold the desirable moisture.

"Precautions which must be necessarily observed to secure best results are:

"1. Chop quite finely—no pieces should be over an inch across, the smaller the better, within practical limits.

"2. Pack tightly by tamping well, especially near the walls.

"3. Add water. This is best done by adding slowly during the milling, being careful not to add an excess so that the water collects at the bottom of the silo. A good scheme is to have an opening at the base of the silo which will indicate when there is a surplus of added water. Late roasting corn will take a ton of water to about every 6 to 7 tons of silage corn, whereas, milky corn will not require nearly so much.

"4. Cover the filled silo over with cheap material, such as stover, straw or other stuff, in order to avoid loss of good concentrated ear corn feed. Dry stover, well wet down, is usually most economically used and conveniently handled.

"5. It is well not to have too large a proportion of mature or nearly mature corn, because the hard cobs prevent packing and further because it does not contain enough sugar to allow of correct acid fermentation, so necessary for preservation.

"Soft corn, which has been frozen, but not spoiled, will make good silage; this has been demonstrated in special tests.

"Immature snapped or ear corn silage can be fed to the same stock as ordinary silage, but it is to be remembered that it is a concentrate and not a roughage. Swine, for this reason, can use this silage to considerable advantage, whereas ordinary silage has a very limited field of usefulness with them.

"To be able to preserve the soft corn ears in the silo may be the means of saving some of this year's corn grain crop, which might otherwise be lost. To put the soft corn grain in a safe, convenient form and in a convenient place for feeding means much to the economic handling of soft corn."

C. A. Hunter (1921), in *Journal of Agricultural Research*, Vol. 21, No. 10, gives the results of "bacteriological and chemical studies of different kinds of silage." He summarizes this piece of work as follows:

"1. From the bacteriological and chemical analysis, little difference can be noted between the fermentations taking place in silage composed of Canada field peas and oats, corn and soybeans, and corn only. There was a larger number of organisms belonging to the bulgaricus group in corn silage than in the other types of silage studied.

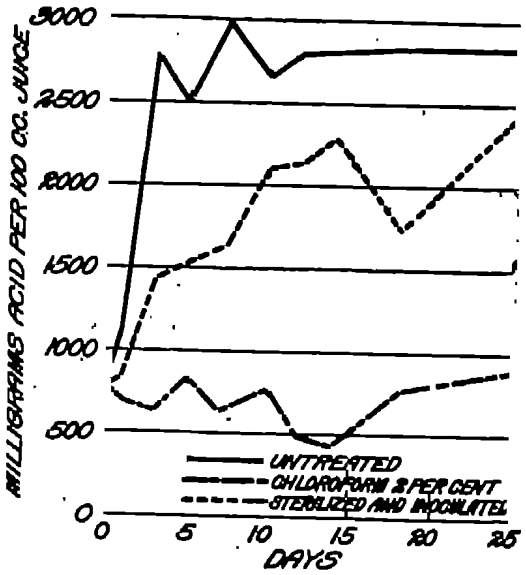
"2. Production of acids was due to microörganisms.

"3. Yeasts apparently had little effect upon the fermentation of silage except during the first few days.

"4. Plant enzymes were chiefly responsible for the hydrolysis of protein with formation of amino nitrogen.

"5. The formation of ammonia was due to both enzymes and micro-organisms."

J. B. Fitch emphasizes the necessity of moisture in silage making. He says: "To make silage it is necessary that the air be excluded. To exclude the air the cut material must be of sufficient weight to pack well. When the crop is dry it comes into the silo in a very fluffy condition, and, as it can not be packed tight enough to exclude all the air, air pockets are formed which cause mouldy spots in the silage. When the material is too dry, water should be added to it as it goes into



After Hunter.

FIG. 11.—Graph showing increase in acidity in Canada field pea and oat silage.

the silo. When corn is cut at the proper time it is near the danger line of moisture. It takes experience to tell whether or not water must be added, but perhaps the best guide is to notice how the material comes into the silo. It should be moist enough to pack firmly under one's foot when tramped, and water should be added to the dry, fluffy material until this condition is reached. While silage that is too wet is not desirable, it is hard to injure silage from adding water to it. Excessive dryness, on the other hand, causes spoiled silage. In case of doubt, therefore, water should be added. The common practice and most desirable method of adding water to silage material is to run a stream of water into the blower. In this way each particle comes into contact with the water and the moisture is evenly distributed throughout the silo. Where it is impossible to add water to the blower, the water can be added in the silo. It should be well distributed in the silo, because a great amount of water added in one

place is apt to run down through the silage and leave dry places at the surface. It is impossible to state the amount of water to add to silage. The material itself is the determining factor. Silage near the top of the silo should receive more water than that lower down. This will make greater weight for the silage near the top of the silo, where it does not have much weight on it."

Concerning the value of packing in silage making, Fitch says: "Perhaps the most important operation in filling a silo is getting the silage properly packed. More silage is spoiled by improper packing than by any other cause controlled by the farmer. When the silage is not tramped sufficiently to exclude the air, spoiled silage results. It is known, too, that the more the silage is tramped in the filling process, the less it settles afterwards. When the silage settles in the silo it tends to draw away from the wall, thus leaving an air space which results in spoiled silage. The amount of tramping necessary depends upon the rate of filling. When a small outfit is used over several days, the slow filling gives more time for the silage to be tramped, and the silage settles from day to day. With a large outfit, however, the silage should be well tramped, as it goes in more rapidly, and if not well tramped will settle several feet after the silo is filled. The capacity of the silo, unless refilled, will thus be reduced and a large amount of spoiled silage may also result."

Round and Gore studied the possibilities of potato silage and found that the use of 2 to 5% of corn meal mixed with crushed potatoes insures an acid fermentation which converts potatoes into good silage. The process can be carried out on either a large or small scale and with reasonable care the losses are negligible. The potatoes should be first well washed and then properly crushed. The container in which the fermentation takes place must be tight and so covered as to exclude as much air as possible. They consider that the resulting product is very desirable and can be eaten freely by cattle. Hogs learn to like it as well as cattle.

R. M. Washburn reports that most weeds can be ensiled without much danger of the viable weed seeds returning to the soil after feeding to stock.

Hunter and Bushnell emphasize the importance of B. bulgaricus in the maturing of silage. They say:

"The presence of Bacterium bulgaricus group was first observed from the preliminary examinations of miscellaneous samples of ensilage. Since that time several hundred bacteriological analyses have been made from different kinds of ensilage, and at all stages of fermentation. The results obtained offer sufficient evidence to indicate the importance of this Bulgarian group in the ripening of normal ensilage.

"Detailed studies of many kinds of ensilage were made from the time the material entered the silo and at frequent intervals until ensilage was formed. The following kinds of ensilage were examined: cane, kaffir, cane fodder, alfalfa, and several kinds of ensilage made

from the mixture of alfalfa and different carbohydrate materials. In every case the Bulgarian organisms were present in sufficient numbers to be very influential in silage fermentation.

"The presence of this group, in all normal ensilage, in large numbers, at a very important stage of fermentation, together with the fact that their characteristic fermentation is acid producing, seem to offer sufficient evidence to support the view that a large part of the acid formed in normal ensilage is the result of their activities."

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Chapter 10.

Organic Acid Production.

Lactic Acid.

Lactic acid is used to a slight extent in many industries of which the tanning industry is perhaps the largest. It is used for neutralizing the lime left in the hides after liming.

The sources of lactic acid are skimmed milk, and the carbonaceous part of grains. The reaction from hydrolyzed starch to lactic acid is $C_6H_{12}O_6 = 2C_2H_4OHCO_2H$.

Lactic acid bacteria producing high percentages, 1/3% acid, are used in fermenting skimmed milk or hydrolyzed starches. A carbonate, either calcium carbonate or zinc carbonate, is added to the fermenting liquor to neutralize the acid and change it into calcium or zinc lactate as fast as formed, thus preventing the checking of the vigorous action of the lactic organisms due to high acid content.

Friedberger uses B. delbrückii in a hydrolyzed starch liquor containing chalk submerged in it. After the fermentation is well along B. bulgaricus is added to the liquor. Tannin is used to clarify the fermented liquor. Sulphuric acid is used to free the lactic acid as follows:

$$2C_2H_4OHCO_2H + CaCO_3 = Ca(C_2H_4OHCO_2)_2 + CO_2 + H_2O$$
$$Ca(C_2H_4OHCO_2)_2 + H_2SO_4 = CaSO_4 + 2C_2H_4OHCO_2H$$

Following the work of LaForge and Hudson on the utilization of corn cobs, Fred and Peterson have carried on further investigations with corn cobs as a source of lactic and acetic acid. They say: "The commercial utilization of corn cobs as a source of organic acids is a possibility which deserves careful investigation. When partially hydrolyzed and inoculated with certain bacteria, Lactobacillus pentoaceticus n. sp., the extract of corn cobs ferments readily and yields almost equal quantities of acetic and lactic acids. If the yields on a commercial scale should prove equal to what has been obtained in the laboratory, it is estimated that every ton of corn cobs would be capable of yielding more than 300 lbs. of acetic acid and about 320 lbs. of lactic acid. The development of this process on a commercial scale would involve numerous chemical and technological problems, but the possibility of producing chemicals in this way was successfully accomplished during the war; more than 5,000,000 lbs. of acetone were obtained by a fermentation process. The organism Lactobacillus pento-

aceticus n. sp., has certain characteristics that make it especially suitable for a commercial process. It grows rapidly, produces large amounts of acid, and is able to compete successfully with other organisms. Some idea of the possible value of corn cobs may be gathered from the fact that there are produced in the U. S. alone more than 20,000,000 tons of corn cobs annually. A small amount of this material is used in the various stock feeds, but in general the cobs are discarded or used as fuel."

Fred and Peterson emphasize the fact that while xylose, a hydrolysis product from corn cobs had a limited use, still lactic and acetic acids which can be made from xylose have wide application in industry. They give the following theoretical equation as a close approximation of the fermentation of xylose to lactic and acetic acid.

$$\underset{150}{C_5H_{10}O_5} = \underset{60}{C_2H_4O_2} + \underset{90}{C_3H_6O_3}$$

Xylose Acetic acid Lactic acid

Fred and Peterson summarize their work as follows:

1. Corn cobs offer a promising raw material for the commercial production of acetic acid and lactic acid.
2. These acids are obtained by fermenting a syrup made from corn cobs hydrolyzed with dilute sulphuric acid. This hydrolysis is easily brought about and yields from 30 to 40% of xylose.
3. Crude xylose syrup is rapidly fermented by certain microorganisms, for instance, Lactobacillus pentoaceticus n. sp., with the production of the above acids. The fermentation is almost quantitative, since 85 to 90 per cent of the xylose can be accounted for by the two acids.

Citric Acid.

While lemons constitute the major source of citric acid of commerce, still it is possible to obtain this organic acid from fermentation sources. Certain molds ferment the sugars, maltase, succharose, glycerol, producing as one of the major products citric acid. The mould most active in producing citric acid is called Citromyces and works best in 5% solutions of the sugars, converting from 25% to 50% of the sugar into citric acid. Citric acid is not at present prepared to any extent commercially by use of these organisms.

The reaction caused by Citromyces is as follows:

$$C_6H_{12}O_6 + 3O = \underset{\text{citric acid}}{C_6H_8O_7} + 2H_2O$$

Chapter II.

Acetone.

There are two fermentation methods of producing acetone (CH_3COCH_3). Amylaceous products may be fermented either into acetic acid from which acetone may be made or they may be fermented directly to acetone, alcohols, etc. Previous to the World War the acetone of commerce was prepared by the destructive distillation of calcium acetate but with the increased demands for the product in the manufacture of smokeless gun powder and as a solvent, the less expensive direct fermentation method known as the Fernback method was developed.

Concerning the rise in importance of acetone, Northrop, Ash, and Morgan say, "Acetone was one of the substances for which the war created a greatly increased demand. It was needed by all the allies for the dope used on airplane wings and by the English in addition for the manufacture of cordite. The ordinary source of acetone, the dry distillation of wood, proved quite inadequate to supply the qualities needed. It became necessary therefore to develop some new method for the production of acetone. Large quantities were made from calcium acetate which was in turn produced from acetic acid obtained by the oxidation of alcohol. The expense of this process, however, rendered it unpracticable. It seemed important, therefore, under these conditions, to attempt the development of a direct fermentation process for the production of acetone, inasmuch as such a method, if successfully developed, would furnish acetone in practically unlimited quantity and at a low cost."

Arthur D. Little says, "Acetone is used principally in the manufacture of smokeless powder as a solvent, particularly in cordite manufacture and it has various other uses, 'peace' uses, in connection with cellulose nitrates. It is used as a basic raw material in the manufacture of chloroform, for low grade, as an absorbent for acetylene, and for other minor uses."

Remler in an address before the Division of Industrial and Engineering Chemistry at the 64th meeting of the American Chemical Society at Pittsburgh, Sept., 1922, said, "The excellent solvent properties of acetone have established its useful application in many industries notwithstanding the fact that data relative to its value as a solvent are widely disseminated in the literature and are also sometimes indefinite. The large quantities of this solvent used during the World

War, in the manufacture of cordite and airplane 'dope' exceeded the production from calcium acetate, with the result that new methods for its manufacture were developed. At the present time the supply of the chemical is greater than the demand, and consequently there has been a drop in price. The availability of acetone in any quantity at a reasonable cost, together with its technically important solvent properties, has suggested consideration to the extension of its present applications and to finding new uses for it in industry."

Remler gives the following advantages of the use of acetone as a solvent:

1. The grade of acetone obtained at present from calcium acetate is of good quality and homogeneity.
2. It is entirely volatile and does not impart an odor to the solute of minus 94.6° C. at normal pressure.
3. Acetone has a boiling point of 56.5° C. and a freezing point of —94.6° C. at normal pressure.
4. Acetone is inflammable, but not to as great a degree as ethyl ether, carbon disulfide, benzene, toluene, gasolene, petroleum ether, and pentane.

Dr. Squibb has pointed out that acetic acid can be easily converted into acetone by passing through a tube or a chamber heated to about 500° C. over a catalyzer.

Mezzadroli, an Italian, describes the use of cultures called B. invertenti lattici and B. invertenti acetici in the manufacture of acetone from cane sugar and cane sugar waste.

An illustration of the use of the direct fermentation method is described in British Patent 4845 (1915) by C. Weizmann. In this process acetone and butyl alcohol was produced from carbohydrate material as maize, rice, wheat, oats, rye, dari, and potatoes. A culture of bacteria obtained from soil, cereals as maize, rice, flax, was used. This organism is resistant to 90-100 degrees C. for 1-2 minutes, and liquefies gelatin. It is supposed to be B. granulobacter pectinovorium. The method used in preparing the culture was the inoculation of sterile maize mash with maize meal heated to 90-100° C. for 1-2 minutes. The mixture was allowed to ferment at about 37° C. A pronounced odor of butyl alcohol was considered the indication of the active existence of the organism desired.

The Freer Company have patented a process for acting on sugars in the presence of inert and neutral material by Bacillus macerans and thereby producing ethyl alcohol and acetone.

In the original Fernback fermentation process for the direct production of acetone the carbohydrate matter is mixed with water and a suitably degraded yeast is added. The mixture is then sterilized and a ferment of the type of the butylic bacillus of Fitz is added. The mixture is then fermented in the absence of air.

In U. S. Patent 1,293,172, J. H. Northrup, describes the use of a

culture called Bacillus aceto-ethylicum which produces acetone and alcohol by the fermentation of carbohydrates. The following yields of acetone were obtained from various materials:

Galactose	4 to 5%
Maltose	6 to 7%
Mannose	6 to 7%
Raffinose	8 to 10%
Arabinose	6 to 7%
Starch	8 to 10%
Beet molasses	8 to 10%
Potatoes	2 to 4%
Dextrin	6 to 7%
Dextrose	9 to 10%
Lævulose	8 to 10%
Xylose	4 to 5%
Sucrose	8 to 9%
Corn	10 to 13%
Corn cobs	1 to 5%
Horse chestnuts	7 to 8%

NOTE: The yield of alcohol along with acetone was 3 to 5 times the amount of acetone formed.

Summary of description of organism used by Northrop, Ash, and Morgan in their fermentation process for acetone production.

Proposed Name: Bacillus acetoethylicum.
Source: Old Potatoes.
Morphology: (1) Vegetative cells, motile. From 24 hrs. agar slant, 40 C.—Short rods. 4-6 μμ. 0.2-0.3 μμ. No chains. Ends rounded.
(2) Spores—Elliptical form at end of rods. 0.5-1.0 μμ in diameter.
Optimum Reaction of Media: For growth, pH = 8.0-9.0. For fermentation, pH = 6.0-8.0.
Optimum Temperature Relation: 40-43° C. Spores stand boiling 20 minutes.
Relation to Drying: Resistant.
Typical Products: Formic acid, ethyl, propyl, and butyl alcohol and acetone.
Acetone Production in Sugars: 4-10 per cent.
Alcohol Production in Sugars: 12-25 per cent.
Air Relation: Facultative Anaërobe.

The sources of raw material for the fermentative production of acetone have been grains and particularly molasses. Fred, Peterson, and Anderson have investigated the use of wood waste, straw seed hulls, and corn cobs as cheap sources of raw material and the use of Bacillus acetoethylicum as the fermentating organism.

Concerning the physiology of this organism, these workers say, "The chief products formed by this organism are acetone, ethyl alcohol, formic and acetic acids, and carbon dioxide. The biochemical rela-

tions of these products to one another are very intimate, as may be seen from the fact that a high production of acetone and alcohol is accompanied by a low yield of volatile acids. Conversely when the acid production is high, the acetone and alcohol yields are low. The condition determining this variation of the products is the reaction of the medium. An alkaline reaction, pH 8.0 favors the production of acid, while an acid reaction of pH 5 to 7 increases the yield of acetone and alcohol."

This investigation was summarized by these workers as follows:

"1. Corn cobs may be utilized for the production of acetone, ethyl alcohol, formic acid, and acetic acid. These products may be obtained by fermenting a syrup which is made from corn cobs by hydrolysis which is easily brought about and, based on the weight of corn cobs, yields from 25 to 30 per cent of reducing sugars, mainly xylose.

"2. This crude xylose syrup is readily and almost completely fermented by Bacillus acetoethylicum with the production of the above products. On the basis of 100 lbs. of corn cobs, the yield of products is 2.7 lbs. of acetone, 6.8 lbs. of alcohol and 3.4 lbs. of volatile acids.

"3. The best results are obtained by conducting the fermentation in a container partly filled with cinders. The bacteria become attached to these cinders, thus bringing about a good distribution of cells throughout the culture. At the end of the fermentation the solution is removed and a fresh charge is added without disturbing the bacterial slime. An immediate and vigorous fermentation ensues. An important condition that must be observed is the reaction of the medium. This should be between pH 7.6 and 8.4 at the beginning of the fermentation and an abundance of calcium carbonate should be present to neutralize the acids that are formed.

"The crude lime neutralized syrup resulting from oat and peanut hulls hydrolysis with sulphuric acid for 2 hours at 15 lbs. steam pressure was fermented by Bacillus acetoethylicum by Fred, Peterson, and Anderson. They report that better yields are obtained from oat hulls than from peanut hulls." They say, "Because of the larger percentage of reducing sugars obtained from oat hulls, the yield of products per hundred pounds of dry material is greater than from peanut hulls. On the basis of 100 lbs. of oat hulls, about 3.9 lbs. of acetone, 7.2 lbs. of ethyl alcohol, and 1.4 lbs. of volatile acid were obtained."

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Chapter 12.

Glycerin Manufacture by Microörganisms.

According to A. B. Adams the production of glycerol industrially divides itself into three important parts:

(1) Selection of a yeast.
(2) Modification of atmosphere of fermentation.
(3) Modification of the yeast culture.

He used S. ellipsoideus var. Steinberg, No. 637 of American Museum of Natural History and S. ellipsoideus var. yeast No. 45, University of California. He found that the production of glycerol was favored by alkaline reaction and a temperature between 30° C. and 32° C., and obtained a yield of 3.1 to 3.3% glycerol.

In the production of glycerol on an experimental scale best results were obtained when the following medium was used:

40 grams sucrose
2 grams ammonium dihydrogen phosphate
1 gram dipotassium hydrogen phosphate
10 grams pressed yeast in 400 cc. water
30 grams sodium sulphite added after the starting of fermentation.

Bode reports that the addition of alkali in amounts not damaging to the yeasts increased materially the amount of glycerin formed in alcoholic fermentation. Sodium sulphite exerts a particularly favorable influence. He thinks the kind of yeast and temperature has little influence on the fermentation. In some tests as much as 15% of glycerin was produced in liquids containing only sugar and mineral salts. He says that on a large scale one may secure from 100 parts of sugar, 20 parts of glycerin, 27 parts of alcohol, and three parts of aldehydes. The yeasts remain active in spite of some morphological changes and in spite of the high concentration of salt and the strong alkaline reaction of the nutrient solution. The appearance of aldehyde in addition to alcohol is characteristic. The amounts of aldehyde and glycerin increase with the addition of the sulphites while the amounts of alcohol and carbon dioxide decrease.

Lind says that as high as 20 to 25% of molasses may be converted into glycerin by fermentation.

Due to the fact that large amounts of glycerin are imported into this country annually the development of glycerin production should be an inviting enterprise.

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Chapter 13.

Sewage Disposal.

In the plan of nature, microörganisms seem to have been designed to destroy the compounds and tissues built up by larger plants and animals. The breaking down of organic compounds then is simply a part of the cycle around which certain elements naturally revolve. In sewage disposal advantage is taken of this fact and conditions are made favorable for the most rapid and thorough destruction of such organic residues as are found in sewage.

Microörganisms have two modes of decomposition of organic compounds of plant and animal origin; the aërobic, and the anaërobic method. Aërobic action is that kind of microbic decomposition which takes place in the presence of abundance of air, that is, oxygen, while anaërobic destruction is that which is caused by microörganisms when air is entirely excluded.

In the microbic destruction of sewage many different kinds of fermentations proceed abreast. A great variety of different organisms take part in the attack on the cellulose, proteins, and fats and their residues. An understanding of many of these complex changes has never been worked out.

Rice and Gardner give the following outline of sewage treatment:

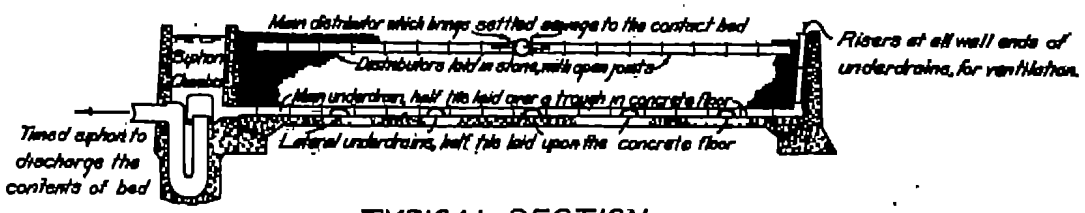
1. Primary Treatment—
   - Screening,
     - a Coarse screens.
     - b Fine screens.
   - Sedimentation,
     - a Grit chambers.
     - b Sedimentation with or without coagulants.
     - c Septic tanks.
     - d Imhoff tanks.
2. Secondary Treatment—
   - Activated Sludge Method,
   - Filtration,
     - a Broad irrigation and sewage farming.
     - b Sand filters.
     - c Contact beds.
     - d Sprinkling filters.

3. Final Treatment.
   - a Sedimentation.
   - b Roughing filters.
   - c Disinfection.

4. Ultimate Disposal.
   Dilution with
   - a Ground water.
   - b Stream.
   - c Lake or ocean.

Hammond (1917) says, "While much was done abroad in the early days of sewage disposal study especially in England it was in our own country that the most important experimental results were accomplished, and the honor of carrying the work onward to success belongs, very largely, to the Commonwealth of Massachusetts, and to the Lawrence Experiment Station.

CONTACT FILTER



TYPICAL SECTION

After Rich and Gardner of Mich. State Board of Health.

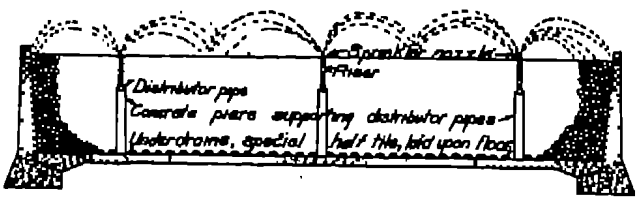
FIG. 12

"As a result we now recognize that the object to be aimed at in sewage treatment is biochemical oxidation of the unstable organic materials contained in the sewage, and we employ methods and processes which make use of bacterial life. If now we use chemical precipitation, we expect that the effluent finally will reach stability by means of natural biological agents, and as at Worcester, either prepare it for dilution in a river containing myriads of bacteria or discharge it upon filter beds, removing previously as much suspended matter as possible, to be treated in a more intensified form. We have found that the removal of solids from the sewage, as soon as practicable, prevents their becoming dissolved and saves the expense of removing the organic material after it has disseminated through a vast quantity of water, to handle which is attended with a cost in proportion to its amount and the contained pollution. Such matters as we are able to remove by screens or tanks decreases the burden on filter beds, or on the oxygen content of water ways, into which the sewage may be discharged, where the method employed is dilution.

"It has become the principal object of sanitary engineers, in design-

ing sewage treatment and disposal plants, to bring together in the most suitable and efficient manner the decomposable materials, the oxidizing bacteria and an abundant air supply for the bacteria. All forms of sewage disposal on land, in the method known as broad irrigation or sewage farming, all filtration methods, such as sand filter, the percolating or sprinkling filter, called in England a 'bacteria bed,' the contact filter, etc., no less than the various forms of methods of treatment using compressed air forced into sewage in a tank or a filter bed, depend upon this fundamental principle, which is also nature's principle, by means of which brooks, streams, rivers, ponds, and indeed all natural waters are purified. This principle in short consists of the biochemical oxidation of the decomposable materials present in foul water or sewage."

TRICKLING FILTER



TYPICAL SECTION

After Eich and Gardner of Mich. State Board of Health.

FIG. 13

The Dilution Method of Sewage Disposal.

One of the earliest methods of sewage disposal by a community was the use of dilution. In other words, communities along rivers or streams and along the ocean disposed of sewage in these waters. These people depended upon the fact that sewage conducted into large amounts of water quickly becomes greatly diluted and does not become a nuisance because of this fact. Later there was developed the idea of preliminary treatment of sewage before disposal into natural bodies of water.

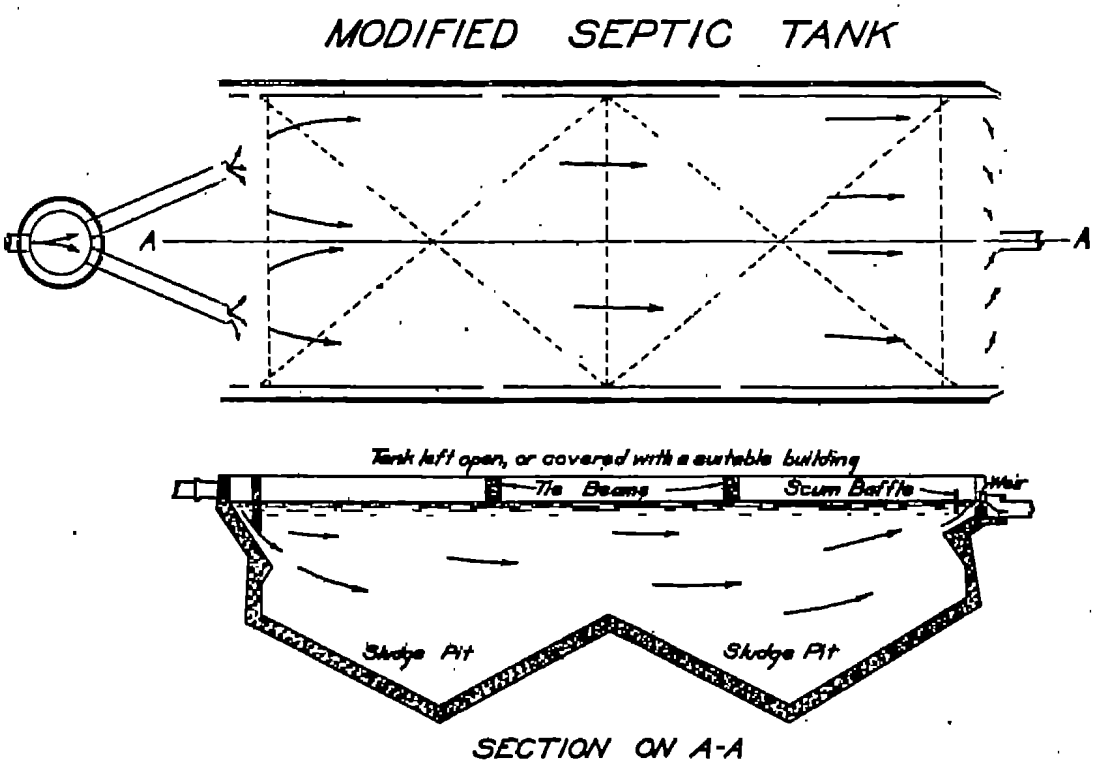
Hommon et al. (1920) say, "Dilution has for a long time been the most common means of sewage disposal practiced in the United States. Formerly it was regarded as a temporary and undesirable expedient, to be ultimately abandoned as soon as sewage purification became sufficiently developed. During recent years, however, the economic need for utilizing to the greatest possible extent the self-purification capacity of natural water sources has been apparent, with the result that the disposal of community wastes by natural dilution has become recognized as a legitimate and desirable process where carried out in such a manner as not to endanger the public health."

Much work has been carried out by way of determining the allowable bacterial count and the minimum reserve oxygen supply for a

natural water used as a depository of sewage or sewage effluent. The Report of the International Joint Commission on Pollution of Boundary Waters recommends that the sewage effluent should not impose upon water purification plants, water fifty per cent of whose 0.1 cc. samples should contain B. coli.

Screens.

The preliminary treatment of sewage usually consists of coarse screening and fine screening. Revolving fine screens have been found to be very efficient in removing a large part of solids in suspension.



After Rich and Gardner of Mich. State Board of Health.

FIG. 14

Grit Chambers.

After screening, some sort of sedimentation is generally practiced. Grit chambers are long, narrow tanks designed so that the flow is about one foot per second allowing the heavier suspended matter to settle.

The Septic Tank.

The septic tank has a sedimentation action as well as the destruction of putresible matter. It is often a large tank constructed so that solids may settle into a sloping bottom where bacterial action goes on anaërobically. Anaërobic putrefactive bacteria here destroy nitrogenous matter and evolve gases due to their action. This bacterial

action takes place spontaneously in properly built and handled septic tanks.

Septic tanks differ from sedimentation tanks in the main purpose for which they are built to accomplish. Sedimentation tanks are for sedimentation of solids in suspension. Sometimes coagulants as lime, alum, sulphate of iron, etc., are added as sewage enters the sedimentation basins. On the other hand septic tanks are constructed with the idea of favoring bacterial and enzymatic destruction of the organic matter of sewage.

Not all of the organic matter in the septic tank becomes destroyed although a large percentage of it is broken into simple compounds which disappear as gases and as simple products in solution. Some of the gases produced are carbon dioxide, hydrogen, hydrogen sulphide and marsh gas. For best action the sludge at the bottom of the septic tank is left undisturbed and sewage is not allowed to remain in its passage through the tank for more than six to twelve hours. Slower movement of sewage through the tank reduces the efficiency of the action on the sewage material.

The Imhoff Tank.

There have been numerous kinds of septic tanks designed but perhaps the best is the "Imhoff" tank designed by Dr. Karl Imhoff in Germany. The "Imhoff Tank" is built in such a way as to prevent gas sewage scum and solids from rising to the surfaces of the liquid. Anaërobic bacterial action and enzymatic action proceed to such an extent that the sludge is much less foul than is the case with ordinary septic tank sludge. The "Imhoff Tank" sludge can be dried into an inoffensive humus mass.

The Activated Sludge Method.

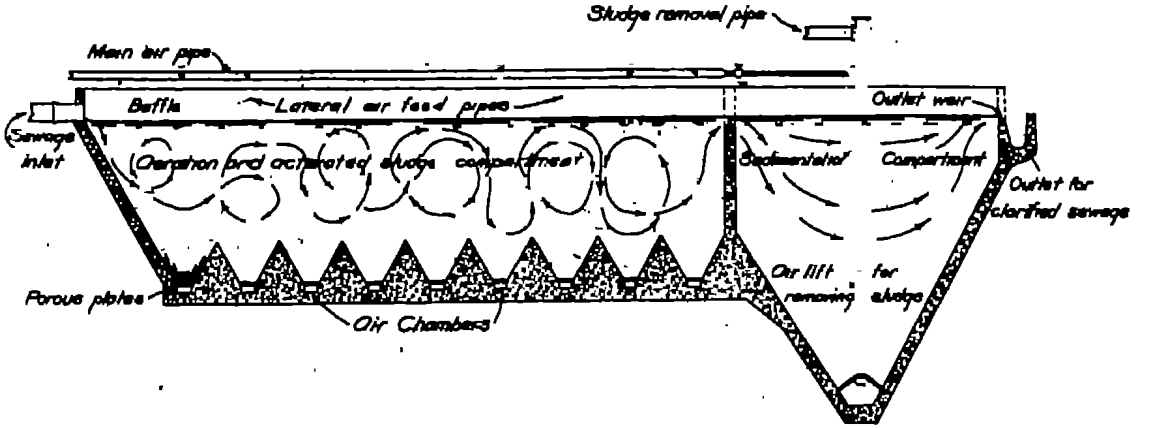
The activated sludge method of treating sewage developed by Fouler of England is a biological process in which sewage is artificially aërated in the presence of what is called "activated sludge." This is in reality sewage constituents carrying aërobic protein attacking microorganisms. The aeration favors the most rapid action of the organisms and the chemical reactions which they cause. The treated sewage is allowed to settle and the clear liquid standing above the sludge line is drawn off. In this method according to Hohlman there is an oxidation of ammonia nitrogen to nitrate nitrogen and then to nitrates.

According to the Report of Comm. of American Public Health Ass'n, the process is "the agitation of a mixture of sewage with about 15% or more of biologically active liquid sludge in the presence of ample atmospheric oxygen for a sufficient period of time at least to coagulate a large portion of the colloidal substances, followed by sedimentation adequate for the subsidence of sludge flocculi; the activated sludge having been previously produced by aeration of successive

portions of sewage and maintained in its active condition by adequate aeration by itself or in contact with sewage."

W. R. Copeland describes the activated sludge action as follows: "The sludge contained in sewage and consisting for the most part of organic matter when agitated with air for a sufficient period, assumes a flocculent appearance very similar to little pieces of sponge. Bacteria gather in these flocculi in immense numbers, some of them having been strained out of the sewage and others developed by natural growth. Among the latter are species which possess the power of decomposing organic matter, especially of an albuminoid or nitrogenous nature, setting the nitrogen free; and others of absorbing this nitrogen, converting it into nitrates and nitrites.

ACTIVATED SLUDGE PROCESS



TYPICAL SECTION OF A CONTINUOUS FLOW INSTALLATION
After Rich and Gardner of Mich. State Board of Health.

FIG. 15

"These biological processes require time, air, and a favorable environment, such as suitable temperatures, food supply and sufficient agitation to distribute them through all parts of the sewage."

Bartow (1922) says, "It is conceded that the activated sludge process is the most perfect method of sewage disposal at the present time. Its growth in America and European countries has been quite widespread. Since the discovery of the process early in 1914, the method has been adopted for several municipalities and an exceeding large number of experimental plants have been put in operation."

Wilkinson of England gives the following correlation between the plain filtration method of sewage treatment and the activated sludge process. He says, "In starting up a new filter the sewage shows but little change after passing through, but as time goes on a growth shows itself in the body of the filter, in what may be termed the stationary

framework, and colonies of bacteria accumulate there, which attack the sewage and effect purification.

"These bacteria being mainly aërobic, an ample supply of air is necessary, in order that they may thrive, hence the necessity for adequate ventilation of the under drainage.

"Let us take a given volume of the stationary framework from a ripe filter, and carefully remove the coating, or growth, throughout the material. We shall then have a certain volume of what may be termed sludge, rich in aërobic bacteria which may be referred to as the activated sludge of this particular process. In the new process (activated sludge), the active sludge is circulated throughout the sewage in the presence of air, as against the present day practice of passing sewage in thin films over active sludge retained on a stationary framework, as in the case of percolators.

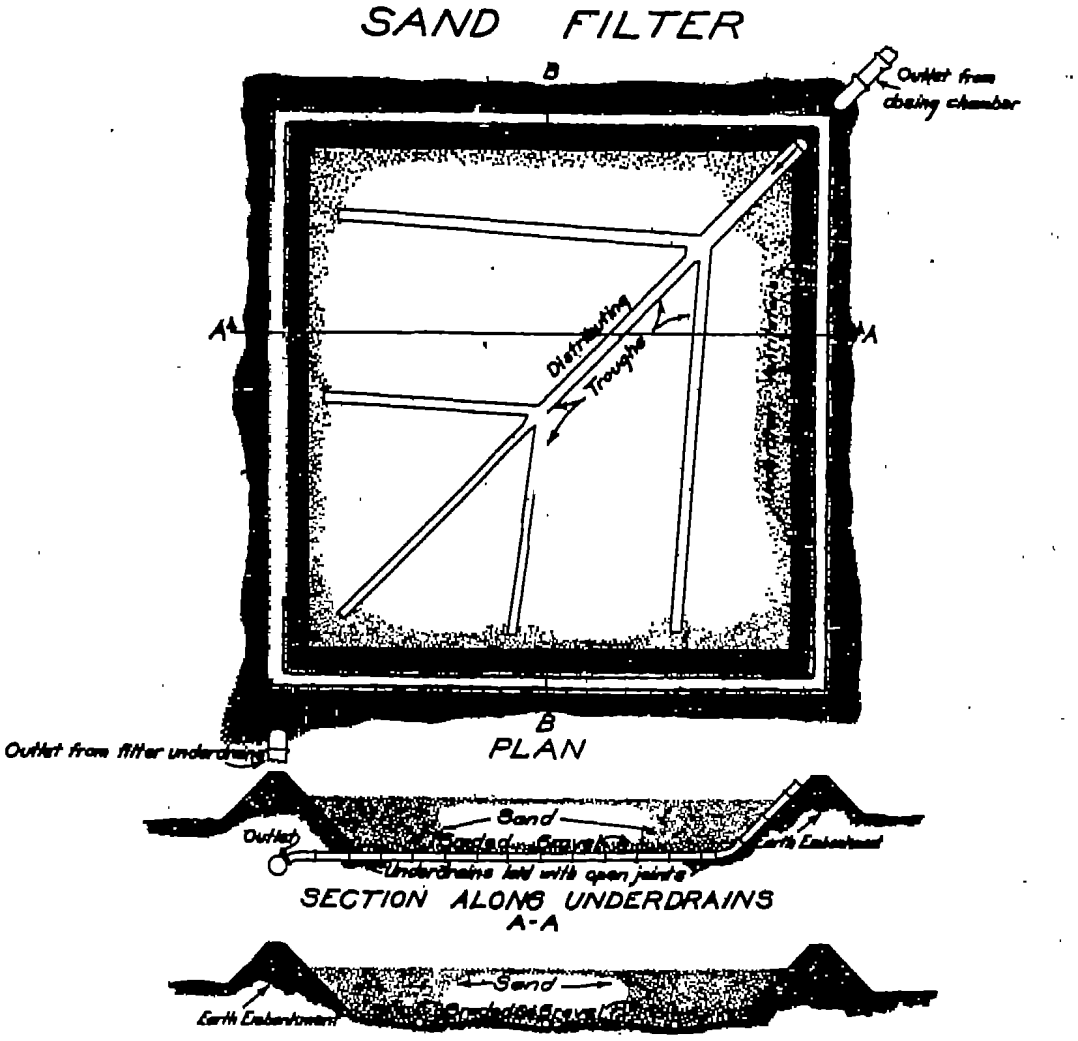
"The real problem, then, is as follows; To ascertain the most economical method of applying air to sewage with maintenance of complete circulation of the activated sludge without any formation of dead banks of material. The problem may now be said to resolve itself into one of reproducing in a tank the changes which take place in a percolating filter. We have our tank which represents the walls and floor of the filter; we have our colonies of bacteria and the air necessary to support their life; and what we require to do is to provide means for supporting an even distribution of this life throughout the body of the tank, other than by allowing the bacteria to adhere to a stationary framework, such as stone, slate, or chamber material. Compressed air will both insure sufficient agitation and effect the desired results as regards preserving uniform contact and even distribution in the liquid."

An explanation of the theory of the activated sludge process is given by Hommon et al. as follows: they say, "Aeration of sewage with finely divided air causes the suspended and colloidal matter in the sewage to gather, forming a flocculent precipitate in which large numbers of bacteria are accumulated. Conditions in the flocculus thus formed and in the presence of air appear to be very favorable for the multiplication of nitrifying organisms. Sludge thus formed and 'seeded' with nitrifying bacteria is known as 'activated sludge.' When such activated sludge is added to fresh sewage and the whole aerated for short periods with finely divided air a nitrification of the sewage, a high removal of bacteria, and a quick settling sludge formation takes place. The affluent from plants of this type shows a bacterial reduction of over 90 per cent, and is clear and stable.

"The sludge formed contains approximately 98 per cent water, and is therefore voluminous. The proper handling and disposing of the large amount of putrescible sludge has constituted one of the objections to this type of plant."

Hommon et al. say, "The process in general is as follows: approximately 20 to 25 per cent of well activated sludge is added to the raw sewage as it enters the aerating tank. As the sewage with its added

activated sludge passes through the tank it is constantly aerated by air fed through diffusers in the tank bottom. From the aerating tank the mixed sewage and sludge pass to the settling tank in which the sludge settles rapidly, the supernatant matter passing off through the effluent outlet.



After Eich and Gardner of Mich. State Board of Health.

FIG. 16

"From the settling tank a portion of the sludge is drawn off to the sludge aerating tanks and further aerated to prepare it for addition to the incoming fresh sewage. The sludge accumulations in the settling tank are drawn off for dewatering and decomposition."

Pure culture work is being carried on in connection with the development of the activated sludge process. Organisms which are found to be especially rapid nitrifiers are chosen and added in large amounts to the activated sludge tanks.

The Filtration Methods.

The treatment of sewage by filtration, like the activated sludge method, depends for its success upon the destructive action of bacteria on putrescible matter. This destruction of nitrogenous matter may take place in the soil as in the case of sewage farming, in the sand of sand filters, among the broken stones of contact filters, or among the broken stones of sprinkling filter beds. The passage of sewage liquids through contact filters and through sprinkling filters is intermittent to give the aërobic bacteria of the beds optimum oxygen supply.

The three general types of sewage filters in use in the United States are contact filters; trickling, sprinkling, or percolating; and intermittent sand filters. Hommon says, "The main function of all three types of filters is primarily the stabilizing of the organic constituents of sewage oxidation, though intermittent sand filters in addition remove very high percentages of bacteria.

Contact Filters.

"The contact type of filter, which is described fully by Metcalf and Eddy and by Fuller, consists of a tight tank filled with broken stone and provided with regulating devices for controlling both inflow and outflow. The ordinary cycle of operation of these filters consists of filling them with sewage, allowing them to stand full for a specified period (termed the 'contact period'), emptying them, and allowing them to rest for a relatively long period (termed the 'rest period').

Trickling Filter.

"The trickling (sometimes termed 'sprinkling' or 'percolating') filter represents a further step in the evolution of the contact bed in an effort to produce a more efficient and economical apparatus for oxidizing the putrescible matters of sewage. The filtering medium employed is similar to that which is used in contact filters, but it is so arranged as to facilitate as far as possible the free access of air throughout the interior of the bed. The method of applying sewage to this type of filter consists of spraying it as uniformly as possible over the surface of the bed, allowing it to percolate freely through the medium to a tight underdrain floor, whence the effluent is conveyed to outflow conduits. Ordinarily the sewage is applied intermittently, the regulation of dosage being automatic. An average operation schedule consists of about 5 minutes of application followed by about 10 minutes of rest. The particular schedule adopted depends upon local conditions.

"The active purifying element of trickling filters consists of films of bacterial zooglea which form on the surfaces of the broken stone or slag composing the medium. Until these films form and the filter is 'ripe' it accomplishes practically no work. The material composing

the films, which is virtually activated sludge, removes, by adsorption and absorption, the suspended and dissolved organic substances brought into contact with it. The activities of aërobic bacteria growing within the films then bring about the oxidation of such substances, the basic supply of oxygen for this purpose being supplied by the air circulating within the bed. The stabilized products of oxidation resulting from this process are gradually returned in solution to the films of percolating sewage and thus carried off in the effluent.

Intermittent Sand Filters.

"The intermittent sand filter is extremely simple in construction, consisting of a layer of natural sand about 4 feet deep graded to a level surface and underdrained with either a deposit of natural sand or a tile underdrain system. It is provided with apparatus, usually radiating surface troughs, for distributing the sewage evenly over the filter, and in some cases, with automatic devices for controlling the intermittency of application of the sewage.

"The action of an intermittent sand filter consists of both mechanical straining and biochemical oxidation. The former mechanically removes a high proportion of the suspended matter and bacteria contained in the applied sewage, while the latter, by biochemical processes very similar to those taking place in the trickling filter, brings about an oxidation of dissolved organic matter into stable products. A large proportion of the mechanical straining action takes place in the upper layer of the filter, this being aided materially by the 'ripening' of the sand grains and the decomposition of a gelatinous zooglea mat at the surface. After a certain period of operation of the bed, it becomes clogged and must be cleaned. This is usually accomplished by removal of the top layers of sand and the accumulated mat. While as noted above, the oxidizing action of this type of filter is similar to that of the trickling filter, the degree of nitrification which it accomplishes is in general greater.

The operation of intermittent filters is simple, consisting of the intermittent application of sewage from one to three times daily, followed by draining and a period of rest sufficient in length to permit the circulation of air throughout the bed."

Disinfection Method.

The treatment of sewage by disinfectants has been tried out to some extent and according to some authorities has considerable possibilities. The disinfectants used are chlorine and copper salts.

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Chapter 14.

Soy-Bean Sauce Manufacture.

M. Church of U. S. D. A. has given a very informative description of Soy-Sauce making by the Japanese. She says: "The process of manufacture which produces soy-bean sauce, or, as it is called in Japan, shoyu, begins with the preparation of the ingredients and includes a preliminary mold fermentation, followed by a ripening in brine. The soy beans, having been cooked and mixed with prepared wheat, are inoculated with the shoyu mold or ferment. This mold is procured commercially in Japan under the name 'tane-koji' in which form it consists of starchy rice particles overgrown with the vegetative and yellow-green fruiting portions of the fungus. The action of the shoyu mold and its enzymes on a mixture of cooked soy beans and crushed roasted wheat, under specific conditions of temperature and moisture, produces in from three to four days a mold-fermented product known in Japan as 'shoyu-koji.'

"The mold-fermented material is emptied into a strong brine, thus producing a mash. Constant, daily attention is given to aeration, even distribution, and stirring of the solid ingredients. Progressive changes take place over a period of from six months to several years, until at last mature 'moromi,' as the mash is designated by the Japanese, is produced. These changes are due partially to the activity of bacteria and yeasts, but chiefly to the enzymes of the mold introduced into the mash with the koji. Purely chemical alterations in the ingredients also appear probable.

"The rather thick, dark-brown mash resulting is siphoned or pressed to produce the soy sauce, which is brought to a boil, filtered, and in the more modern of the Japanese factories processed or partially pasteurized. The completed sauce is distributed in casks or bottles."

M. Church says that the manufacturers of soy sauce in the United States have many difficulties to overcome. She says: "The variations in the flavor of Oriental soy sauce should reduce the task of American manufacturers of this product. The American product would not be compelled to compete with a product having only one recognized standard of flavor. If the sauce the manufacturer developed had an individual flavor of its own, there would be less prejudice to break down when he placed it on the market. All of which, however, should not lead to satisfaction with an output lacking uniformity nor to the acceptance of flavors produced by hurried or improper processes of ripening. It has been shown that unsatisfactory flavors in soy sauce

can readily be correlated with a predominance of bacterial instead of mold activity. A low brine content in the moromi while fermentation is in progress, as well as too high a temperature during this period, produces conditions favoring these undesirable flavors.

"There are many difficulties in conducting a process like the manufacture of soy sauce. If this were not true the process would not be regarded as secret, as it so generally is in the Orient. In Japan the process of shoyu manufacture is conducted in relatively modern factories. The reasons for the practices followed in the various steps in the ripening of the shoyu-koji have been but partially worked out. The established practices are based upon accumulated manufacturing experience rather than upon carefully planned investigations. Available scientific studies on the moromi fermentation or the brining have up to the present been either futile or inadequate from a practical point of view.

"The great obstacle in the way of developing a soy-sauce industry in the United States lies not only in the fact that soy-sauce is not an everyday necessity, as it is with the people of the Far East, but also in the very little realized truth that a properly flavored and uniform output can be readily produced only at comparatively great expense and after a certain amount of experimentation has been conducted. The majority of soy-sauce makers and manufacturers in the Orient employ purely rule-of-thumb methods which have been handed down and individually perfected by more or less successful experience. Accurate knowledge of the reasons for the steps involved in the process as practiced is not common.

"The possible manufacturer of soy-sauce in America needs to remember that an attempt at transplanting an old, established fermentation practice to a new land carries with it difficulties due to new atmospheric and climatic conditions. Further, in bringing to this country a process which has arisen in a land where human labor is cheaply obtained there will be economic and technical factors to be adjusted to the new conditions. Imported technical assistance may secure a successful product, but it admits of no interpretation of the cause of failure, should such failure arise.

"Soy bean seed is used as a food as well as for its oil and meal. Of the almost innumerable ways in which soy beans are used in the Orient as more or less elaborately prepared foods, soy-sauce seems to offer prospects of more immediate adoption in the United States than any other product. Soy-sauce and related substances, such as red miso and white miso among Japanese bean products and the various sauces and mold-fermented bean cheeses among Chinese foodstuffs, are highly relished in the Orient. Occidentals who have had the good fortune to become acquainted with the seasonings of oriental cookery readily adapt soy-sauce and other soy-bean products to their home dishes. Soy-sauce has already gained a strong foothold with frequenters of Chinese-American restaurants.

"Table sauces containing soy-sauce as an ingredient are to be

had in a great variety of grades and flavors. They also presen unlimited field for futher variation. Concentrated forms of seasoning, such as yeast and vegetable extracts suitable as meat substitutes in flavoring soups and other prepared dishes, are receiving consideration by manufacturers. Soy-sauce is of value in any table sauce and it can easily rank with yeast or vegetable extracts when prepared in concentrated form. Soy-sauce, as developed in the laboratory of this department and concentrated under a vacuum, made delicious bouillon, especially when flavored with a little celery seed extract and garlic. It need scarcely be said that the method of concentration to be employed, as well as that of removing excess salt from a concentrated soy-sauce, is one which modern machinery can ably cope with. United States Patent, 1,322,448, of Sadakichi Satow, of Sendai, Japan, specifies a dry powder form of soy-sauce."

Margaret Church in U.S.D.A. Bul. 1152 says: "The manufacturers of table sauces and condiments interested in soy-sauce are among the largest and best known firms of the United States. Their evident desire for information in regard to the work of the department on soy-sauce has led in part to the preparation of this bulletin. The experimental work of a purely laboratory nature included in this bulletin is indicative of the stage which the soy-sauce industry has reached and suggestive of what problems the prospective soy-sauce manufacturer in a new country must contend with, if he is to carry on the fermentation process in anything but a blind or haphazard way. Several manufacturers at present have soy-sauce experiments under way in their laboratories. One company at least in the United States manufactures a wholly domestic product."

In discussing fermentations related to soy-sauce, she says: "Soy-sauce is only one of the mold-fermented food products originating in the Orient, the majority of which are ripened by means of the molds represented by the yellow-green group of Aspergilli.

"Miso, one of these products, is one of the most common breakfast foods for children. There are two types of miso, white or shiro miso and red miso. Miso is prepared from a koji ripened by means of the A. flavus oryzæ group of molds. The soy beans are cooked in miso before the fermentation is undertaken. The treatment subsequent to the cooking and preparatory to the fermentation doubtless varies in different localities. It is said that the beans may be made into a paste before being ripened by the mold. As bought in this country, however, miso shows the bean intact. White miso is said to be made from a koji of soy beans and a starchy material, as rice or barley. The koji is ripened as is shoyu-koji and placed in a weak brine for 10 days. Unfinished rice wine may be added to improve the flavor and to preserve the product, which is rather perishable. Red miso is prepared in the same way as the white miso, but is ripened for from one to three months in a stronger brine. White miso has been bought in the United States in two forms. One type is very salty and therefore less perishable than the other. Probably because of longer fer-

mentation red miso is dark red. It is very cheap, whereas white miso is expensive.

"In China the curd, or to-fu, made from soy-bean milk, is ripened with a mold preparatory to a ripening in brine. Such products are commonly termed cheese by travelers. The to-fu is cut into square, rather thick pieces which are arranged on the narrow face in rows upon traylike racks. The racks are stacked zig-zag fashion, or so that aeration is possible under damp conditions. The squares of bean curd become overgrown with a mold. The final cheese as received in the United States shows the mold on the squares of curd as white mycelium with no fruit. After the development of the mold on the curd the squares of to-fu are placed in brine for further ripening. At the completion of this ripening the product is utilized as a food product. It comes into this country commonly as canned white or red squares of fairly salty bean curd, covered with a salty liquid which is thick because of the crumbling from the curd itself. The red color in such mold-ripened and brined to-fu is due to red rice, made by changes produced upon rice kernels by the mold Monascus purpureus Went."

Takamine has spent years investigating the possible industrial applications of the fungi Aspergillus oryzæ which is so important as a food preparing organism in Japan. He says, "For many centuries Aspergillus oryzæ has been employed in Japan for varied purposes: Sake or rice beer, Soy and Miso are the products which are made by the use of this fungus." He says that the value of the products made in Japan by the use of this fungus aggregate two hundred million dollars.

Concerning the scientific interest shown in Aspergillus oryzæ he says, "It has attracted the attention of Occidental investigators as far back as 1875. Prof. Kozai, of Tokyo Imperial University, reviewed the literature regarding the early investigations on the subject of Aspergillus oryzæ and its industrial applications, and gives credit to Hoffman and Korshelt as the first writers upon the subject. Korshelt made an important contribution to the knowledge of the fungus in Europe. His report was upon Sake fermentation with special reference to an amyloclastic enzyme which occurs in the culture of the fungus on rice and which he named Eurotius. In his "Chemistry of Sake Brewing" Atkinson discusses the function of the enzyme just named. The fungus was then known as Eurotium oryzæ, being first identified by Ahlburg in 1876 but Cohn's later investigation led to renaming it Aspergillus oryzæ.

"It was re-examined by Bosgen, Schröter and later Wehmer who gave full morphological descriptions of it."

In a study of the enzymes secreted by Aspergillus oryzæ and Aspergillus flavus, Oshima and Church say, "The supposition that fungi produce extracellular and intracellular enzymes is accepted provisionally. The extracellular enzymes can be obtained by percolating mature fungi with water but the latter cannot be obtained by mere

treating with water. Some investigators have tried to get the intracellular enzyme from Koji residue—i.e., a mold ferment grown on a large scale on some substratum, and the whole washed free of extracellular enzymes, by treating with many solvents, but negative results were always obtained. Experiments show that extracellular and intracellular enzymes are the same, and after a certain period of growth all enzymes are excreted. Many investigators have shown the same results with other fungi."

Oshima and Church worked quantitatively with the ratio of exo- and endo-enzymes of Aspergillus oryzæ and Aspergillus and from their experiments they concluded that soon after spore formation almost all enzymes have been excreted into the culture media. They say, "It is also known that the increase and decrease of enzymes in the mycelium is quite rapid but in the culture media it is quite slow. It is doubtful whether the excretion of enzymes is due to the autolysis of the mycelium, because at the time of the most rapid excretion of enzymes the weight of mycelium is found to be increasing and the maximum amount of exo-enzyme occurs simultaneously with the maximum quantity of mycelium. Consequently, it may be concluded that in experiments intended for the study of the influence of culture media, etc., on the production of mold enzymes, the estimation of the enzymes produced in the mycelium is quite an erroneous manner of procedure, particularly when it is realized that through differences in culture media the rate of growth and the time of sporing may be varied."

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Chapter 15.

Bread-making.

Bread-making is a custom which has been handed down to us from prehistoric times, but the manufacture of bread as a highly specialized business is one of our recent industries. The somewhat recent invention of bread-making machinery and the introduction of exact methods of controlling the factors involved in the bread-making process have made possible the present popular use of the modern commercial loaf.

Although within the last twenty years bread has improved to a marked degree, still the modern loaf is gradually changing. It is considered that we have much to learn about bread as yet. Many of those engaged in the bread industry feel that we are just now entering a period of great improvement in bread-making.

The loaf of bread as we have it to-day represents the accumulated improvements of all ages and all peoples. The most important of all these improvements in bread-making no doubt was the introduction of the use of the leaven. We first hear of the art of leavening bread with yeast in Biblical times in Israel.

The importance of bread as a food is well set forth in "Give us this day our daily bread." Wells in the Bulletin of the Pan-American Union says, "Secondary foods may be more important than bread with certain classes of society—the rich for example—in certain localities, and at certain limited periods; but through civilization and even beyond, bread and bread alone is the basic common food. What milk is to the infant, bread is to the world."

It is hard to define bread definitely. However, we may say that bread is the commonest food of man and is made of the common cereal of the land.

It is easy to conceive how bread in different parts of the world, because of differences in peoples and kinds of cereals grown, may vary to a great extent. W. C. Wells in the Bulletin of the Pan-American Union says: "The bread grains are first, wheat and rye; second, barley, buckwheat, oats, and a few localities use grass seeds like quinua (in South America), millet (in Europe), Kaffir corn (in Africa); third, Indian corn. First is wheat, more broadly used as a bread grain than all others and until now more important than all others combined. Next in importance is rye, the principal bread grain of northern Europe and extensively used elsewhere. As bread grains, barley, oats, buckwheat, quinua, millet, Kaffir corn, and the like are not very important. Indian corn occupies a singular and not easily definable place as a

bread grain. It has been denied that Indian corn, buckwheat, and oats are bread grains. Unquestionably, wheat as a bread grain has been in the process of rapidly superseding corn even in localities like the Southern United States, where corn was supposed to be firmly established. Notwithstanding the enormous increase in the production and use of corn in the United States, far outstripping wheat and all other grains combined, yet the fact remained that as bread grains, wheat and rye were gaining on corn."

The *American Food Journal* during the World War, published the following: "Recent dispatches from Germany have referred to bread made of beechnuts and acorns. This serves to recall that in the earliest days both of these were put to the same usage. Acorns are still made into bread by certain Indian tribes, and in Colonial times acorn meal was common among the natives. It is said that after being boiled several times the acorns lose their bitter taste, becoming sweet and wholesome.

"Almost everything that grows has been called upon to make bread for man. In remote ages the Egyptians of the Nile Valley prepared bread from the seed of lotus flowers. These flowers grew abundantly in the mud of the river bottom, and when the annual overflow receded there was a harvest of lotus flowers, just as we harvest wheat to-day.

"Early records of the North European peoples, particularly in Scandinavia, show that the poor subsisted partly on bread made of nothing more substantial than ground moss. But this had such slight nutritive value that it was almost worthless as a food. The Germans are eating potato flour bread, also a familiar makeshift of other days. When the ground potatoes are mixed with rye or wheat the bread is not unpalatable.

"The Italians are adding to scant war rations with chestnut bread. The chestnuts of Italy and Spain are much larger than those of America, and chestnut bread is a familiar article of diet in both lands. We also hear much of banana flour, which is used to some degree in South America. Numerous attempts have been made to introduce it into this country, and it is now being manufactured commercially. If we may believe those who profess to know, banana flour is both nutritious and palatable.

"The Mexicans and South Americans grind peas and beans into a meal which is then made into little cakes and fried. All kinds of cereals are eaten as bread the world over, millet being one of the most popular in the East. Should the war continue for a number of years, it is just possible that the American people may be compelled to make the acquaintance of other breadstuffs than those to which they are accustomed."

Bread-making is primarily a biological process in which yeast, bacteria, and the enzymes of the cereals themselves, play active parts. From the harvest to the consumption of the bread, biology is continually the controlling factor.

There are few achievements in history which have had as far-

reaching effect on the welfare of mankind as the invention of the idea of using yeast in bread-making. W. C. Wells says: "Since he first found out how to use fire to cook his food man has made but two other really important food discoveries. These are the preserving of meats and other perishables by salt, smoking, or drying, and the use of leaven in bread-making. These two discoveries are both prehistoric. The importance of leaven in bread making can not be overestimated because without leaven, wheat (and rye) would never have become leading food grains. Without leaven the cultivation of wheat and rye would now cease. Without leaven wheat is the most stubborn and intractable of possible foods. Even an amateur cook can make an edible bread from Indian corn, or barley flour and water without leaven, but a professional would be stumped to make anything edible from wheat flour and water alone. But with leaven, yeast or baking powder, wheat becomes the supreme bread-making grain. In other words, wheat, the least suitable of all the grains for use as a human food, with leaven becomes the most suited. This is because it is best suited for making that kind of food, bread, which is the base food of all civilized peoples. Here we are at the root of one of the most significant facts of present-day civilization. Man, by the discovery of leaven has been able to raise one grain, and that in its natural state the least promising of all grains, to be not only the prime grain but the prime food as well. This marvel was wrought by prehistoric man. Can it be possible that chemists of this age can not work an equal marvel with corn? Or, if not the chemists, the mechanical inventors? It may be a problem of chemistry or it may be a problem of mechanics."

At different times in the past there has been considerable agitation in favor of mechanical aeration of bread. These chemical aerators were generally in the form of a powder and were generally composed of acid phosphate and sodium carbonate. Some years ago these chemical mixtures were used to a considerable extent in some countries, however at the present time, they have come to be used mainly for pastry. Some of the reasons why bakers consider chemical aerators unsuccessful in common bread making are the poorer flavor and lessened digestibility of the bread.

Liebig, the famous German chemist, at one time advocated chemical aerating agents for bread and laid great emphasis on the loss in bread nutrients due to the use of yeast or micro-organisms. The aerating agents advocated by Liebig and at the present time used for pastry are now called "baking powders." They are for the most part carbonates mixed with acid salts or organic acids, the mixture being made chemically stable by the addition of a large amount of low moisture starch which prevents any chemical action between acid and alkaline salt. When water is added, however, the acid and alkali groups come in contact and the carbon dioxide of the carbonate is liberated. The most common combinations of carbonate and acid radicals used in the manufacture of baking powder are as follows:

$$3NaHCO_3 + H_3(PO_4)_2 = 3CO_2 + Na_3(PO_4)_2 + 3H_2O$$

Acid Sodium Carbonate — Phosphoric Acid — Carbon Dioxide — Sodium Phosphate — Water

$$2NaHCO_3 + H_2C_4H_4O_6 = 2CO_2 + Na_2C_4H_4O_6 + 2H_2O$$

Acid Sodium Carbonate — Tartaric Acid — Carbon Dioxide — Sodium Tartrate — Water

$$NaHCO_3 + KHC_4H_4O_6 = CO_2 + KNaC_4H_4O_6 + H_2O$$

Acid Sodium Carbonate — Cream of Tartar — Carbon Dioxide — Potassium Sodium Tartrate — Water

$$2NaHCO_3 + CaH_4(PO_4)_2 = 2CO_2 + CaNa_2H_2(PO_4)_2 + H_2O$$

Acid Sodium Carbonate — Calcium Acid Phosphate — Carbon Dioxide — Calcium Sodium Tartrate — Water

In making baking powder there should be added to every part of acid sodium carbonate 2.238 parts of cream of tartar (acid potassium tartrate) or .893 part of tartaric acid, or 2.260 parts of acid calcium phosphate.

In answer to Liebig's contention that chemical aerating agents should be used instead of yeast in the making of bread, the bread technologists of the present time hold that Liebig knew far more about chemistry than he did about bread. They agree that yeast produces a bread of far better quality than can be produced by chemical aerating agents. The lightness and sweetness of yeast-made-bread and its increased digestibility are factors which greatly outweigh any consideration of the loss of materials by the use of yeast in bread-making.

Parenti in *Boll. Chem. Farinae* (1903), No. 42, gives the following results of the effect of yeast fermentation on the dough:

"(1) Analysis of bread dough before and after fermentation showed that the quantity of starch and dextrin suffered no loss.

"(2) The reducing sugars were all consumed except a trace.

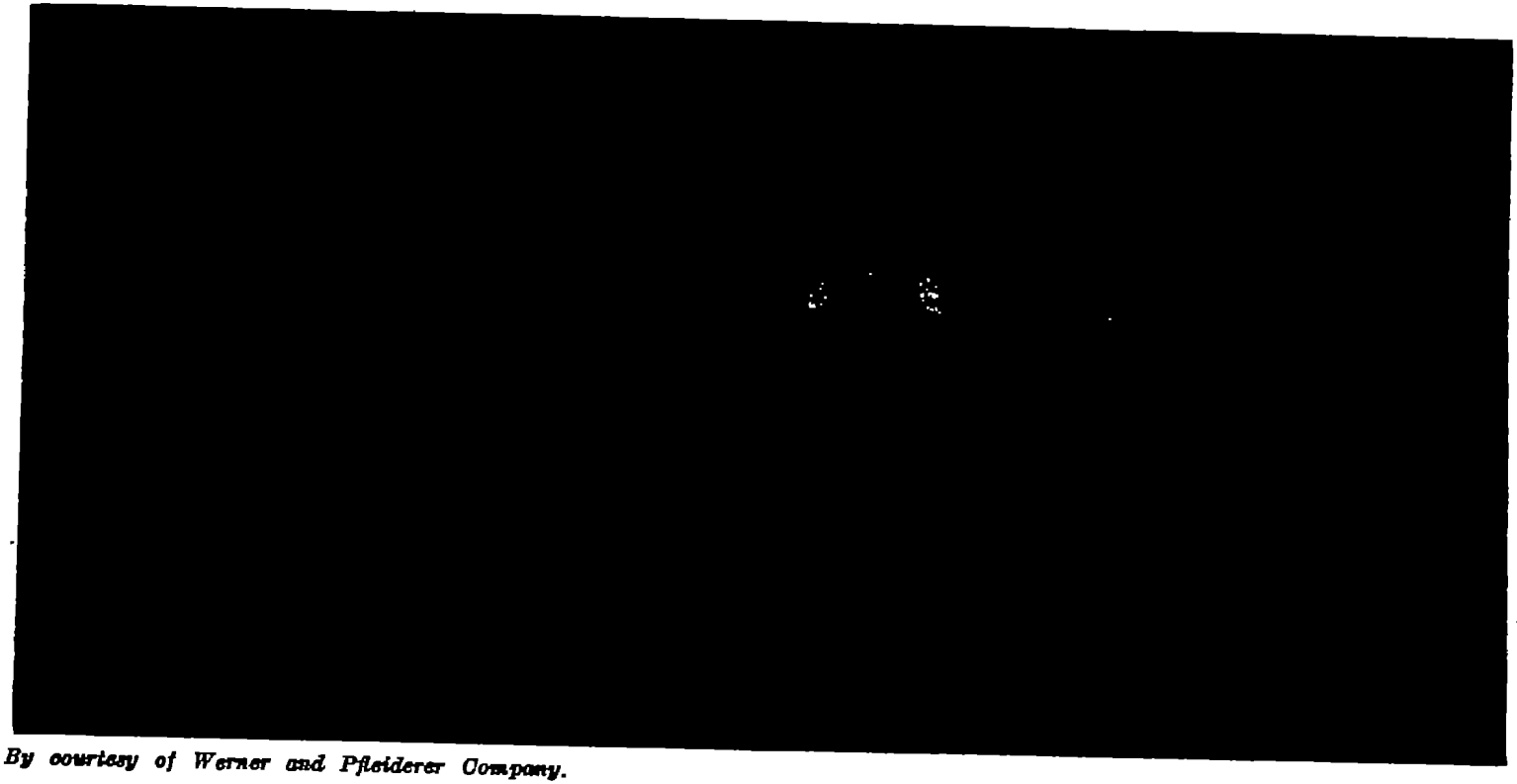
"(3) Substances precipitatable in alcohol increased from 2.86% to 4.15%.

"(4) No gluten was found in the dough when it was washed."

Parenti says that he agrees with Boutroux whose view is that panary fermentation consists chiefly in the alcoholic fermentation of the sugars in flour by the yeast added, and in a conversion of the gluten which in breaking up produces soluble proteins. The origin of this conversion of protein he finds not in the yeast but in an enzyme contained in the flour.

Concerning the necessity of fermentation in the manufacture of good bread J. C. Summers in *Bakers' Weekly*, March, 1918, gives some very pointed reasons as follows:

"It is of the greatest importance that doughs ferment in order that the starches and proteins be split up into simpler forms and gotten into a condition in which they are more readily assimilated by the



By courtesy of Werner and Pfleiderer Company.

FIG. 17.—Ageing of flour in storage.

body. In his eager desire for the loaf to possess certain important physical qualities, such as volume, color of crust and crumb, and grain, the baker often overlooks the important chemical changes that take place during fermentation, which accounts for a greatly increased digestibility of the finished loaf. This very valuable property, however, is increasing in importance, and the day is certainly not far distant when the baker, in making comparison of his bread with that of his competitors, will not be satisfied by superior physical properties alone, but will endeavor to produce a loaf that is also superior in nutritive properties, or food value.

"Without doubt, the most important reason for fermenting a dough is because of its softening effect upon the gluten. If loaves were made, proofed, and baked from dough freshly mixed, it would be found that they would not show sufficient 'jump' in the oven and would be seriously lacking in lightness and volume. The reason for this would be that the gluten in the young dough would be tough, strong, and nonpliable. In this condition this substance would offer too much resistance to the gases held within the loaf, and they would be unable (although pressing with the same force when heated) to inflate the loaf and produce that cellular formation and give to the loaf that volume that it should have.

"During the fermentation period the acids produced in small quantities have this softening effect upon the gluten, having a tendency to render it more soluble. When this "developing" of the gluten has proceeded far enough (which requires a great skill on the part of the bakers to determine) then the doughs 'should be taken' and one could expect, as a result, good bread."

R. E. Lee of The Fleischmann Co. says: "Over fifty per cent of the dry substance of yeast is protein. It is rich in nuclein, that wonderful brain and nerve food which extracted from yeast, physicians prescribe in all run-down conditions of the nervous system.

"It has long been known that the lack of certain substances in our diet brings about serious conditions known as deficiency disease. To these substances the name vitamines has been given. Yeast is the chief source of these marvelous substances without which life would be impossible. The rich bread flavor of which man never tires is the result of the interaction of the products of yeast fermentation and its importance cannot be overestimated."

The particular kind of yeast which is of interest to the bread maker is Saccharomyces cerevisiæ. However, other kinds of yeast have been used in bread making, as for instance wild yeast was used before the time of pure cultures.

Yeasts are generally classified as follows:

I. Saccharomyces cerevisiæ. These organisms are divided into three groups: bottom yeasts of German beers, top yeasts used in making English beers, and distillery yeasts producing larger amounts of alcohol than the beer yeasts. These are the yeasts generally used in the manufacture of bread.

II. Saccharomyces ellipsoideus. These yeasts are used in the manufacture of wine and distillery products to some extent. They are sometimes called wild yeasts as they occur naturally on grapes in the vineyards. In some countries they are still used in bread making.

III. Torula. These are sometimes called pseudo or false yeasts. Their only importance to industry is as trouble makers.

There are three different preparations of yeast for bakers, on the market: compressed yeast, dry yeast, and liquid yeast. Compressed yeast is made from distillers' wort. After the yeast has been collected from the wort, it is thoroughly washed, and then passed through wire and silk sieves to free it from foreign materials. After this cleaning process the yeast is pressed, cut into cakes, and wrapped in tin foil. Compressed yeast cakes are liable to start decomposition unless kept in a cool place.

Dry yeast is prepared by taking fresh liquid yeast and mixing it with corn meal, flour, or other starchy materials. This mixture is dried at carefully regulated temperatures. If the dry yeast is made properly it will keep for a long time. However, the percentage of living cells in dry yeast slowly decreases and it must be remembered that the number at the start is less than in the case of compressed yeast.

Liquid yeast is made by collecting the yeast from distillers' wort and selling it as a concentrated liquid. This yeast preparation has the disadvantage that it is very liable to be contaminated with bacteria which cause the development of bad tastes and odors. It is only with difficulty that uniformity is maintained in liquid yeast.

A kind of yeast used extensively before the innovation of pure culture yeast cakes was known as "potato yeast" or "wet yeast." This was made by developing the wild yeast on potatoes or hops. Either potatoes or hops were made into a decoction with water and were allowed to stand in a warm place until the wild yeast had had time to multiply in sufficient numbers. This decoction was added to the dough in bread making.

The "barms" of Scotland were made by adding malt to a mass of cooked flour and water and placing the liquor in a warm place to give the yeast opportunity to multiply. When this mixture began to foam the froth and scum were taken from the top and added to the bread dough. Jago describes the making of "barm" in the household as follows: "Malt is crushed in warm water, hops and boiling water are poured over it, then flour is added and the mixture is allowed to stand until the starch granules of the flour have been burst open by the hot water and the starch thus freed has been changed into sugar by the diastase of the malt. The resulting sweet liquid is drained from the mixture and is mixed with flour and water, the resulting sticky mass being subjected to the action of yeast either acquired spontaneously by exposure to the air (virgin barm) or added in the foam of a little old barm or ordinary yeast (parisian barm). The

fermentation thus started is allowed to continue several days and then the barm is ready for use in the sponge."

Salt rising bread according to several writers is bread raised by the gases produced by yeast and bacteria of corn meal and milk. To make "salt rising bread," milk and corn meal are mixed and slightly warmed and then set aside until spontaneous fermentation by the yeasts and bacteria present is well under way. At this point a sponge of wheat flour, to which a little salt and water has been added, is kneaded with the corn meal and milk mixture. The whole mass is then kept warm for several hours to raise. The rôle of salt in the making of this bread is to prevent high acid producing bacteria from developing and to make possible the production of a loaf which is not too sour.

Concerning salt rising bread Paul Richards in *Bakers' Helper,* Jan., 1918, says: "In the making of salt rising bread a warm temperature of from 105 to 110 degrees Fahr. must be maintained during the whole process. The corn meal used should not be sterilized or kiln-dried (most mills sterilize the corn before grinding). Where it is practical, grind your own corn for this purpose, using white corn. Put five to six ounces of meal, one-half teaspoonful of soda and a pinch of salt in a small bowl or pan; add one and one-half pints boiling milk and one-half pint of boiling water gradually to the meal and stir to a soft batter. This forms the start. Set this bowl well covered on the top of the bake oven in the sand, or in a pan of warm water, where the given temperature can be maintained. It is best to set this ferment in the evening, as it takes about twelve hours to become light. When this ferment is light, take a larger bowl or dishpan, put in three quarts of water and sufficient bread flour to make a thick batter of about the consistency of a griddle cake batter, add the first ferment and beat well together. Have this batter at the right temperature and set in proving closet, which should be warm and moist. This sponge will be light in one hour at a temperature of 110 degrees Fahr. Then make the dough, add three quarts of water, five ounces salt, five ounces sugar and eight ounces lard; make a medium dough. Let dough come only so it shows life, then scale and mold in pans. Set in warm proofer, do not give as much proof as for yeast bread, and bake as usual."

"In another process the milk is left out in the first ferment, water is used, with the addition of one pound mashed potatoes, the corn, potato water, two ounces of brown sugar, one ounce of ginger. This is said to hasten the start."

From an extensive study of the biology of salt-rising bread, Kohman concludes that the leaven in salt-rising bread is not yeast as is indicated by the literature on the subject, but certain bacteria. He says, "These bacteria aerate the bread by decomposing certain of its constituents, principally the sugars, into gaseous products and not, as has been suggested, by producing acids which liberate carbon dioxide from the soda. The microbic flora involved varies greatly,

epending upon the temperature to which the meal is subjected in etting the 'batter.'

"The organisms that predominate in the batter when it is made y stirring the meal into boiling milk or water are only occasionally ound upon plates made from batters that were not subjected to temeratures which destroy non-spore-bearing organisms. The chief ource of the bacteria is not the air and utensils as has been sugested in the literature but the corn meal used in making the batter. ne organism was isolated which in pure culture produces the gas ecessary to properly aerate bread. This bacterium seems to be a ember of the coli group and was never found in batters that were eated to 75° C. It in all probability belongs to the same group as e organism described by Wolffin and Lehman, which they call acillus levans. This organism could be propagated in liquid media ch as milk, or could be grown in a batter and subsequently dried, be used in the preparation of bread."

This author found that when the temperature of the batter was rought to 75° C. or higher most organisms died except certain gas roducing spore-bearing organisms which readily produced the gas hich aerated the bread dough. He found that these organisms could e cultivated in fresh liquid media and he was also able to make a y starchy material which carried the organism along satisfactorily d could be used at any time in making salt-rising bread.

He found that the gases produced by these salt-rising bread rganisms were nearly 2/3 hydrogen and a little more than 1/3 carbon oxide.

Another kind of bread similar to salt-rising bread studied by ohman is "Sauerteig."

He says, "Long before the existence of microörganisms was disvered, it was known that when meal or flour and water were made to a paste it would, after a time, begin to ferment and evolve gas. his was early made use of in the preparation of bread and it was on learned that a portion of the dough could be saved to start the rmentation in the next baking. This portion of dough would continue ferment and become sour hence its name 'Sauerteig,' but when ixed with fresh flour and water it would again become active and ise the bread. This method of making bread was, and in some untries is still, used very extensively particularly in making whole eal bread, 'Schwarzbrot' and rye bread. It is similar to the saltising method in that the fermentation in both is spontaneous; they ffer however in that the former is started with hot water or milk, ually boiling, while the latter is made with tepid water. They ffer also in that salt-rising bread is made from fresh meal each time hile by the 'Sauerteig' method a portion of fermented dough is saved r the next baking, and when a housewife or baker is out it is usually tained from a neighbor. This method of making bread while it is ude and uncertain compared with the methods of to-day which inlve the use of compressed yeast is as would be expected, more

certain than the salt-rising method because each time a portion of dough is saved for the next baking which insures the presence of the essential organisms although they may be badly contaminated with others.

"Bread made by the 'Sauerteig' method differs from salt-rising in that the gaseous fermentation in the latter is due entirely to bacteria, while in the former the leavening power owes its origin primarily to yeasts, and it is a question whether the bacteria present, some of which are gas formers, are desirable or not; they differ also in that the latter is made from fresh material each time, while in the preparation of the former a portion of dough is saved to start the fermentation in the next baking."

Use of Wild Yeast.

Wild yeasts were used by man for the preparation of fermented beverages and in the making of bread as early as we have historical records. E. Atwater writes: "A microscopic examination was recently made of some bread over 4,400 years old found in Egypt with other remains of a long vanished people. It was made of barley and the dead yeast cells were plainly visible."

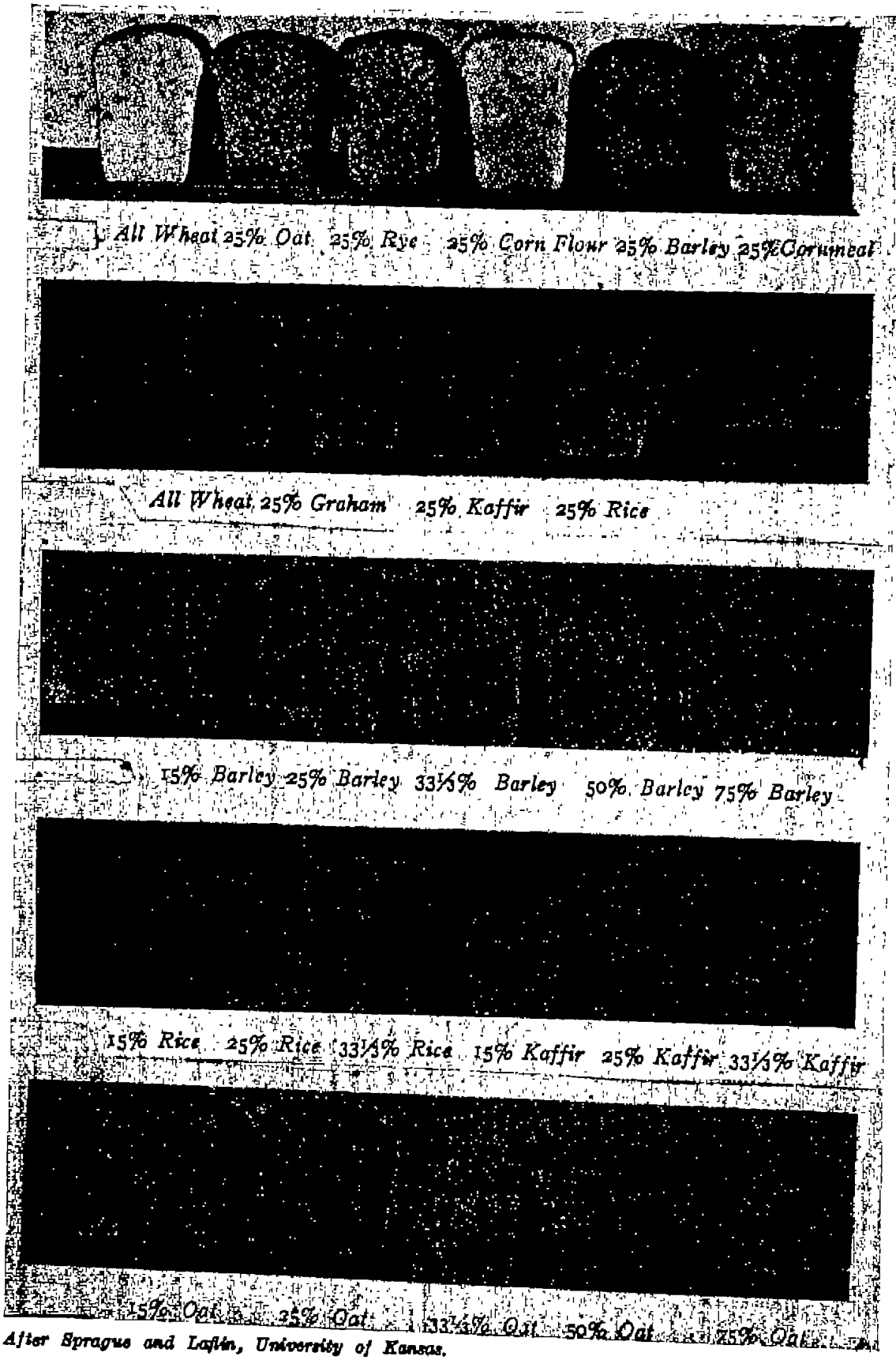
Wheat Substitutes.

The use of wheat substitutes which is an innovation of recent years has brought new difficulties in the handling of dough during the fermentation period. However, accurate control measures have been developed and good results have been obtained. It has always been considered that the more gluten contained in a flour the more the fermentation period should be extended. This theory holds true when wheat substitutes are used, the total wheat gluten present is reduced and therefore the period of fermentation must be shortened.

Frank C. Pelky says in *Bakers' Helper,* "Of all the substitute flours available for conserving wheat there is none equal to corn. Chemical analysis shows it to be a very nutritious article of food. It is the one that we can produce most cheaply and abundantly in this country. It is an excellent food product. The present process of milling corn flour is especially adapted for making a flour suited for blending with wheat flour for bread-making. Good bread can be made with wheat flour and 20 per cent of added cereals, but we must remember that the actual effect of putting them into the wheat flour is to produce a flour of a softer type, and it must be treated as such in the dough. In using any of the substitute flours in bread-making, my advice is to use plenty of yeast and salt and a short fermentation.

"Barley, rice, corn meal, corn flour, corn starch and oats, which are the substitutes being used to the greatest extent, will accelerate the fermentation of the dough and therefore must be given a short fermentation. No certain time can be given for the fermentation,

PLATE 5



After Sprague and Lafin, University of Kansas.

Comparison of wheat loaf with wheat substitute loaves.

as the time will vary with the quality of the wheat flour used, amounts and kinds of substitutes, temperature of doughs and shop, and amounts of other ingredients used. All doughs must be treated cool. For sponges I recommend a temperature of from 74 to 78 degrees.

"The sponge should be taken when it begins to break. I do not advise putting cereals in the sponge, but in the dough. The temperature of the dough should be from 76 to 80 degrees. The average time for the sponge should be 4 hours; for the dough 1 hour. In making straight doughs I recommend a temperature of 78 to 80 degrees. The time of fermentation will be governed by the temperature of your dough and the kind of cereals used, but best results will be obtained with a fermentation time of from 3 hours and 15 minutes to 4 hours. In making doughs with good, strong wheat flour we could strike a happy medium, but in using our present flour with added cereals there is no medium; we must take the doughs on the young side if we get results.

"The question of which will produce the best loaf of bread with wheat flour and added substitutes, flour sponge or straight dough, depends entirely on the wheat flour being used, the size of the pans, the substitute and the equipment. Good bread can be made with wheat flour and cereal flours if the following instructions are followed carefully:

"Treat all mixed flours during fermentation as you would weak wheat flour. Use enough yeast to insure good, strong fermentation. Keep your doughs cool. Use plenty of salt, from 1½ to 2 per cent. Take your doughs on the young side—they can't stand age. Don't give too much proof in the pans—not over three-fourths the usual proof. Use steam in the oven, and a good, solid heat."

Paul Richards explains why the sponge and dough process of bread making is best for bread made with mixed flours. He describes the process as follows:

"While the straight dough method is less troublesome for bread making (being a process of one operation), when adding other weaker cereals to wheat breads, cereals which contain no gluten, the sponge and dough method is preferable. For this reason the majority of rye breads are made by the sponge and dough or by the sour dough process. The straight dough method can be used, there is no doubt about it, but by using the sponge and dough process the weaker flours may be worked to a better advantage and give more volume.

"A loaf of good volume always appeals to the baker as well as to the consumer, and the sponge and dough method has always been the method to obtain volume. In the making of the old-time New England breads as much as 2½ pounds of scalded mush was used for each gallon of dough. The sponge was set with two-thirds of the liquid, and for doughing the other third of the liquid was added with the scalded cereal, followed by a short-time dough. Sponges and doughs were treated young. If a small trial batch is to be made (say,

a 12-quart pail batch) the usual formula would read, using wheat flour only, like this:

12 qts. water; 6 ounces compressed yeast; 10 ounces salt; 10 ounces sugar; 2 ounces malt extract; 6 ounces shortening; 40 to 42 pounds bread flour.

"If other cereals are to be used singly or in combination with the wheat flour, take about 5 pounds of corn flour, or oatmeal or barley flour, reducing the wheat flour about 6 pounds, as the absorption of these cereals is larger, or more water must be used at the doughing stage. A part of the corn flour may be scalded, say ¼ of it, the rest used for doughing or in the sponge. Very coarse oatmeal is best, used soaked or scalded, and the barley flour may be used either in the sponge or soaked in part of the remaining liquid and used for doughing. When making the darker breads, such as graham and whole wheat, with admixture of corn or oatmeal or barley flour, these breads may be sweetened with molasses, saving the other kinds of sugar.

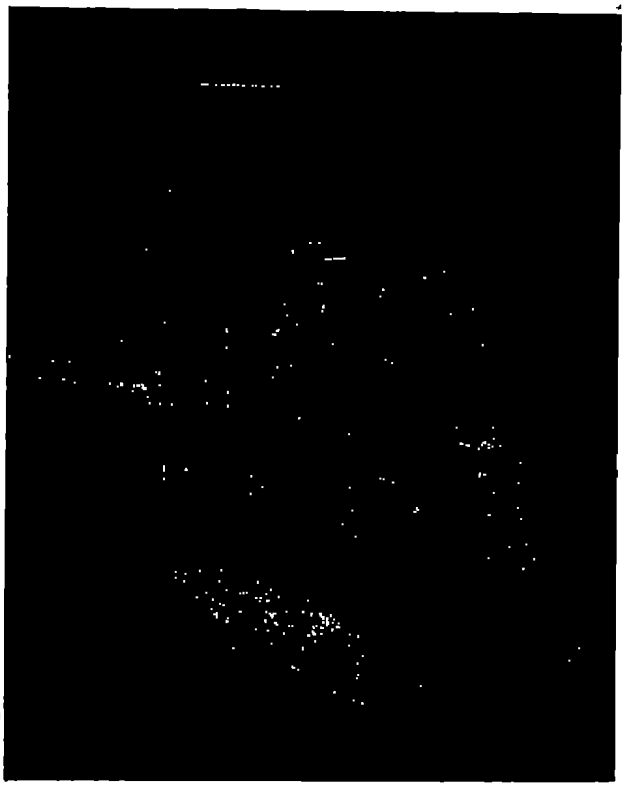
"Set the sponge cool with 2/3 of the liquid and the yeast, using a part of the wheat flour and other cereals as directed. Take sponge as soon as it is ready and breaks, making the dough cool and baking it young. When the dough is about half up it may be taken and worked up. The more of the short cereal used, the sooner the dough must be taken. A little practice will soon teach how long a dough can stand, and much of this must be left to and depends on the practical skill of the baker. Treat the dough cool and young; don't save yeast; do not give much proof in the pans; bake in medium heat; and do not underbake."

Domestic and Commercial Bread.

Bread, no doubt, ought to be classed into two great classes: home-made bread, and factory-made bread. These two kinds of bread are distinctly different and the tendency is to make them still more different. With the exception of home-made bread the product of the especially gifted housewife, it is safe to say that factory-made bread is superior.

The making of bread in the home is usually by the straight dough method, using flour, water, salt, yeast, shortening, milk and sometimes sugar. The sponge method is also used extensively either as a short sponge method or as an over night sponge method. The factors of time, temperature, fermentation and bread improvers are varied by each different housewife and the bread varies accordingly from best to poorest. From the microbiologist's standpoint, it is appreciated that many housewives have shown wonderful ability in being able to produce such fine bread in the home with its variable factors of humidity, temperature and fermentation. In other words, the making of bread is complex and the home is seldom equipped for the making of uniformly good bread. In the home there is no attempt to standardize the factors involved, but to depend upon skill in sensing the proper time to carry out each step in bread-making.

The manufacture of bread in 80% of large commercial bakeries is by the straight dough method. It is a very different process from making bread in the home. Each step is standardized as to temperature, time and amounts. The object is economy of operation, economy of material, fuel, labor and space. The resulting bread, however, must sell and therefore must be of good quality. Yeast and flour act differently in large quantities. Large ovens bake differently than small ones. Continuation of operations for the purpose of economy has to be considered in large bakeries. Baker's bread is the result of all these considerations. An art of bread-making on a large scale by



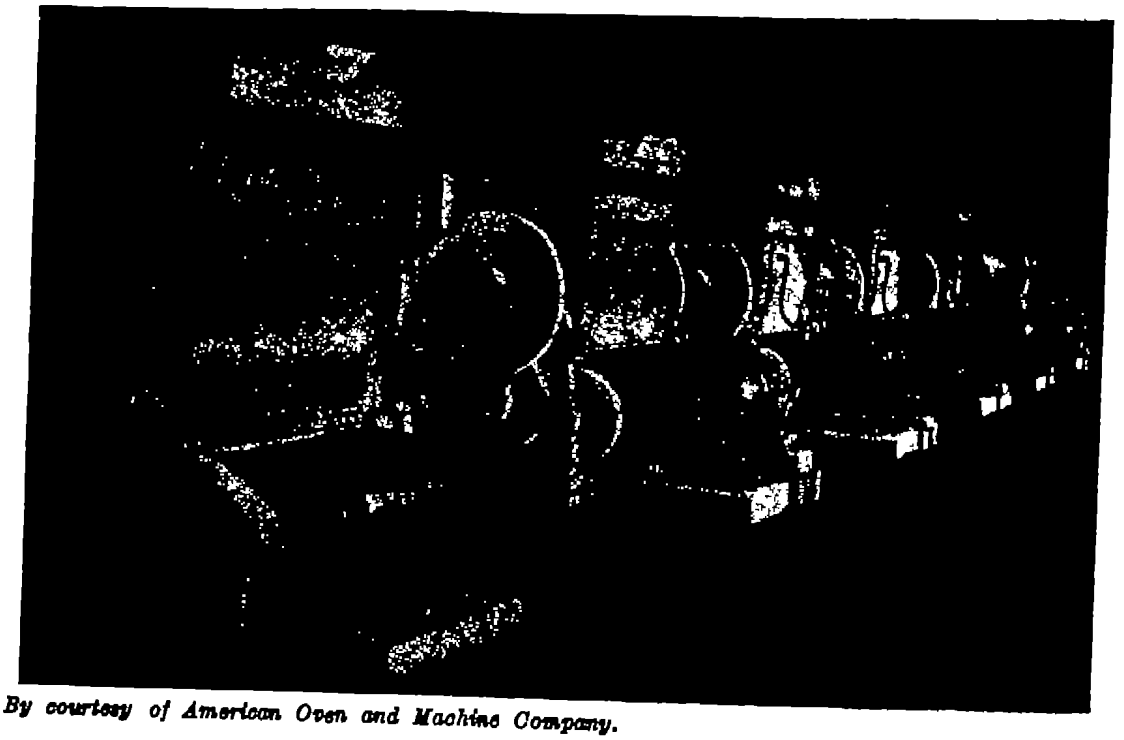
By courtesy of Jabury Bros.

FIG. 18.—Mechanical dough divider.

machinery has been developed. Many bakers advertise "bread which has never been touched by human hands."

In building a large bakery, the interior is arranged to fit the process of bread-making. The bread constituents often go from the top floor by gravity to the mixers. The dough from the mixers also moves by gravity on through the process until the finished product is wrapped by the wrapping machines and dropped into shipping baskets. Storage of flour for the purpose of ageing it is practiced by most large bakeries. The top floor is often used for this purpose. The flow of materials through the process from flour to finished product is often as follows: Ageing, sifting, blending, mixing, fermenting, dividing, rounding, proofing, moulding, baking, cooling, sealing.

What goes on while flour is ageing is a matter of speculation. However, something happens to the gluten of the flour. It is more easily "developed" as the baker says, after ageing. The enzymes



By courtesy of American Oven and Machine Company.

FIG. 19.—A battery of dough mixers.

of the wheat and the bacterial enzymes are acting slowly in the direction of preparing the gluten for the breaking down process.

The sifting and blending of flour have no biological significance.

FIG. 20.—Ovens of Whiteside Bakery, Louisville, Ky.

The mixing of the water, flour, yeast, salt and flour-improvers is an important step from the standpoint of yeast action in bread-making. Whether the "straight dough" or "sponge and dough method" is used, mixing is very important and few bakeries mix thoroughly enough to get the best results. The yeast cell aggregates are broken up best by thorough mixing. Most bakers dissolve the yeast in tempered

water before adding it to the dough. The pains taken in thoroughly dissolving the yeast in the water is well repaid by improved results. The yeast cells should enter the bread, divided into as small groups as possible, and preliminary dissolving and shaking up of the yeast cake aids this cell separation greatly. Mixing thoroughly gives further breaking up and also disseminates the yeast cells throughout the dough. Each yeast cell produces gas from the sugars of the dough, and generates the gas as small bubbles in the dough. The smaller the aggregates of yeast cells the smaller the gas bubbles will be. The gas from large aggregates of cells collects in large bubbles. Where the yeast cell aggregates have not been properly broken up and disseminated the gas bubbles collect and cavity formation in the finished loaf is often the result.

After fermentation the dough is passed through the divider to cut it into proper amounts for loaf making. These pieces then go to the rounder which rounds them so that proofing will take place uniformly in each bunch of dough. From the rounder the balls of dough are conveyed into the enclosed proofer where they are carried back and forth until they have raised properly. When the dough balls have doubled in volume in the proofer the molder takes them and molds them into loaves and drops them into pans for the oven.

The automatic wrapping machine along with the other automatic bakery machinery above mentioned has made it possible for the baker to guarantee to the public bread which contains no disease germs.

The richness of bread is directly associated with the fermentation of the dough. The rich bread flavor is supposed to be due to "split-protein products" produced during fermentation. The flavor of flour is a very different thing from the flavor of rich bread. The bread flavor is something very complex and delicate as shown by the fact that any small change in manipulation changes the flavor of the bread.

Bread made from dough, not fully fermented, is hard and horny while bread made from dough over-fermented is crumbly. In the first case the gluten is not sufficiently broken down and in the latter it is broken down to such a point that it no longer holds the bread constituents together, that is, it has lost its elasticity.

Lactic and acetic bacteria develop in dough from the start of fermentation and play some part in giving bread its flavor. If bread dough is fermented too long these bacteria produce so much acid that the bread is sour.

In fermenting straight doughs, four and one-half hours is the most commonly used fermentation period. As the dough comes from the mixers its temperature is usually 82 degrees F. in winter and 79 degrees F. to 80 degrees F. in summer. The amount of yeast used is usually one and one-half per cent. The dough should be about 58 per cent water, and one and three-quarters per cent salt, one and one-half per cent sugar and one and one-half per cent malt. In addition, bread generally contains milk or milk powder, and shortening.

During fermentation the dough is usually given three "punches." The first comes at the end of three hours when the dough is high in the fermenting trough. To determine the proper time to punch requires long baking experience. The second punch is 30 minutes later, and the third is thirty minutes after the second.

Bread Improvers.

The four fundamental constituents of bread are: flour, water, salt and yeast. All bread contains these and most bread contains one or more of a long list of substances known as bread improvers. The quantity of these four fundamental constituents used by all bread-makers is about the same. The manufacture of yeast has become so standardized that the product is uniform, giving the same results from day to day and year to year. The grading of flour is perfected to the extent that standard brands of flour can be counted on to give satisfactory results although there is some variation which becomes important when bread is made on a large scale. The water of different localities makes considerable difference in bread.

Bread improvers consist of substances which, added to the four fundamental bread constituents mentioned above, will improve the bread. These bread improvers are added to perfect the bread in one or more of the following ways: color, bloom, size of loaf, shape of loaf, grain, texture, velvetiness of crumb, taste, flavor, aroma, zest of loaf, length of time required for staling, economy of gas production in dough, or water absorption capacity.

The largest users of bread improvers are the bakeries where hundreds of thousands of loaves of bread are produced per day. The use of certain improvers in bread might not be found of any great value from the standpoint of profits to the small bakery with an output of a few hundred loaves per day but when figured on an output of thousands of loaves per day, the saving becomes considerable. The introduction of many bread improvers has been due to the struggle to improve the loaf and at the same time cut costs.

Many of the bread improvers are compounds or products which have an advantageous effect on the yeast in bread making. Yeast attacks the sugars of bread and converts them into alcohol and carbon dioxides, thus aerating the bread dough. Also due to the enzyme, endotryptase made by yeast, it acts on the proteins of dough, breaking them down into simpler compounds, which is spoken of as the ripening of the dough. Compounds which stimulate the yeast to greater enzyme production aid in the ripening of the dough. There are several such compounds on the market. Not only do they affect the yeast as to enzyme production but as to speed of reproduction and as to kinds of biologic products created. They have to do with the flavor of the finished bread.

Malt is very extensively used as a bread improver. Its action in bread is varied. It not only contains diastase but several proteolytic

enzymes important in bread-making, both from the standpoint of yeast food and gluten splitting.

Some bread improvers are made of modified starch, some of certain chemicals which stimulate yeast activity, and some contain shortening materials.

Concerning the use of flour improvers Wahl and Wahl, in *Bakers' Helper* say: "The common interpretation of the word 'improver' in the baking industry is 'some substance which, when added to the dough will effect an improvement, either in the economic production of the bread or in the bread itself.' For instance, improvers may increase the water absorbing power of a flour or lessen the time of fermentation, or effect a saving in the amount of yeast. Other improvers produce much greater color of the crust, or whiteness in the crumb or effect a larger volume per weight of bread, or may cause an improvement in the flavor.

"Thus, it is convenient to classify those various items, which influence directly the economic production of the bread and which may be altered by added improvers, and it is also convenient to classify those properties of the bread itself which may be effected by added improvers. The points to be considered in the economic production of bread are as follows: 1st—Time of dough fermentation; 2nd—Amount of water absorbed; 3rd—Amount of yeast required; 4th—Amount of wheat flour necessary; 5th—Amount of fermentation losses.

"Any decrease in the time of fermentation will effect the economic production of a loaf of bread inasmuch as it lessens the amount of labor required and decreases the time of use of the various dough apparatuses, thus allowing a larger bread production with the same equipment. Certain substances may be added to the bread dough which will ripen the gluten of the flour in less than normal time, thereby conditioning the dough for the baking thereof in a much shorter than normal time and would in that case lessen the economic production of the bread, giving the added substance value accordingly.

"The economic production of bread is greatly influenced by the amount of water incorporated into the dough, a large proportion of which is retained through the baking stage and remains in the bread. Bread sold by weight will in this case be much more economically prepared than if less moisture were contained in the bread. Several substances may be added to the dough to allow a greater addition of water, either by its influence upon the water absorbing capacity of wheat flour or by the greater water retaining capacity of the added substance itself.

"Yeast not alone aerates the dough through the evolution of carbonic acid gas, but it also excretes a substance, termed by the biochemist, 'endotryptase,' which acts on the glutenous substances of the dough in such a manner as to modify it in the direction of greater elasticity, that is, to 'ripen' it."

It has long been known that fermentation cannot go on without more or less loss to the substance fermented.

Bread-Making Losses.

Kohman says, "In making bread with yeast it is found that best results are obtained when the dough is allowed to rise from 1 to 4 times depending upon the strength of the flour previous to moulding into loaves. During this period of fermentation which generally ranges from 5 to 8 hours in the 'straight dough' process of making bread, various chemical and physical changes take place which render the gluten more elastic and better suited for the production of light bread. These changes are chiefly: (1) The formation of alcohol and carbon dioxide from the sugars; (2) the production of soluble carbohydrates as sugars and dextrins, from insoluble forms as starch; (3) the production of various organic acids such as lactic, acetic, and at times butyric; (4) a partial solution of the proteid compounds in the flour; (5) the formation of amid and ammonium compounds from insoluble proteins; and various other changes that are only incompletely understood. Inasmuch as many of the substances formed during the processes of fermentation are either gases or are volatile, appreciable losses of dry matter occur during the fermentation, and baking of bread."

The loss of dry bread substance during bread-making has been given by different authors as between 1.5 per cent to 11 per cent. As a general rule the loss increases the longer the fermentation.

Kohman, Hoffman, Godfrey, Ash, and Blake have studied the use of certain yeast nutrients in bread making. They say, "One of the important problems studied in our bread investigations was the effect of certain mineral salts (such as commonly found in natural waters) upon the fermentative activity of the yeast in bread-making. It was found necessary by the Ward Baking Company (who operate bakeries in several cities) to change the quantity of yeast as well as the fermentation period of their dough batches in the different cities, in order to produce a standard product, or nearly so, even though all the raw materials used were identical (being purchased through a central office). Upon investigation it was found that variations in the activity of the yeast were due to the differences in the mineral content of the waters used for making bread in these cities.

"The carbonates are especially common in natural waters and as a class are objectionable in bread, since they neutralize the acids of the dough and thus interfere with the progress of the fermentation. More particularly, the carbonates of magnesium and the alkali metals should be considered as being detrimental to the fermentation of the yeast."

They say, "Like many other acids, glutamic acid matures or ages the dough and, in addition increases the gas production of the yeast. This accelerating effect upon the yeast was observed in bread and likewise in fermentating cane sugar, dextrose, and malt extract.

"In fermentation of this kind other acids failed to increase the fermentation as did glutamic acid hydrochloride, so we were led to

believe that it was not a matter of acidity but that the glutamic acid hydrochloride owes its accelerating effect to its nitrogen content."

The fate of calcium compounds added to bread dough is explained by these authors (Kohman, Hoffman, Godfrey, Ash, and Blake) as reacting with the phosphate of the wheat. They say, "It has been shown by Teller that the phosphoric acid in flour exceeds by ten times the calcium and it may be safely said that even by the use of the new process, the bread contains several times as much phosphoric acid as is required to combine with the calcium. Under these conditions, the potassium phosphate of the wheat undoubtedly interacts with the calcium sulphate, as it does in wort in accordance with the following equations:

$$KH_2PO_4 + CaSO_4 = CaHPO_4 + KHSO_4$$
$$2K_2HPO_4 + 3CaSO_4 = Ca_3(PO_4)_2 + K_2SO_4 + KHSO_4$$

"The increased lime content of bread by the use of the new process is a very happy coincidence even though incidental. Unfortunately, in modern methods of milling the greater part of the mineral constituents of wheat is lost to white flour. As indicated by Teller seven-eighths of the phosphoric acid, eleven-fourteenths of the potash and lime of wheat are found in the stock feed; consequently, a partial restoration of the lime in white bread must be considered highly desirable."

Kohman, Hoffman, Godfrey, Ash, and Blake draw the following conclusions from their work with yeast nutrients in bread-making:

"I. By the use of minute quantities of ammonium and calcium salts, and potassium bromate in bread, from 50 to 65 per cent of the usual amount of yeast can be saved.

"II. Incident to the economy in yeast thus effected, there is a saving of about 2% fermentable carbohydrates, calculated upon the total flour used, due to the greatly diminished consumption of these by the yeast.

"III. The proper use of nutrient salts for the yeast gives greater control over the dough batches and aids in the production of better and more uniform bread regardless of the locality.

"IV. The added salts conserve the inherent qualities of the dough and consequently maintain its stability and strength to a far greater degree than by the old process.

"V. The finished loaves are improved in quality, flavor, texture, bloom, and uniformity."

Wahl says that bread-making losses are generally due to carbonic acid gas and to volatile alcohols. He adds, "The more rapid the fermentation phenomenon, and the longer the time, the greater will be the loss from this cause. Improvers may effect the properties of a loaf of bread, making it much more readily salable, thus: these properties may be listed as follows:

"1. The volume per weight and the shape of bread.

"2. The color, bloom and softness of crust.

"3. The color, grain, texture and velvetiness of the crumb.
"4. The taste, flavor and aroma.
"5. The zest, palatability and appetizing qualities.
"6. The wholesomeness and digestibility."

In *Bakers' Helper,* A. Wahl and R. Wahl say that they have demonstrated, "That the globuli (gluten) of wheat flour which is insoluble in water, is digested and broken down into a soluble form during dough ferments. This is accomplished by the activity of peptase in the dough, which is incorporated to a small extent with the flour itself, but more abundantly with the yeast. The peptase which exists in the interior of the yeast cell is termed 'endotryptase,' and is excreted by the yeast in order to digest the insoluble protein (gliadin and glutenin) material surrounding the yeast cell to simple soluble forms so that they can be absorbed by the yeast as food. The result of the action of endotryptase of yeast and the peptase of flour is known to the baker as 'ripening of the dough.' The activity of the proteolytic enzymes (endotryptase and peptase) not alone modifies the gluten in the direction of greater elasticity (ripening of the dough), but producing from the peptonization of the globulin (gluten) certain simpler substances known to the chemist as the albumins and amino bodies. The latter, nitrogenous substances, are in the best form for yeast nourishment and consequently act to stimulate and activate the yeast by affording it increased nutriment which increases the number of yeast cells and gas evolving power of each cell. The yeast in its enlivened condition also tends to separate into individual cells and thus disintegrate the cell aggregations so often formed by bakers' yeast of to-day. These cell clusters produce irregularity of texture with oftentimes larger holes. The digestion of the gluten to albumins by the proteolytic enzymes referred to, aids in forming a flaky texture since this class of substance coagulates with heat (becomes insoluble by the heat of the oven). Thus the peptic digestion is beneficial not alone in that it modifies the gluten in the direction of greater elasticity, but also produces the albumins, a class of proteins which are so changed by the heat of the oven as to give a flaky texture, thereby causing a whiter appearance of the crumb (this action is similar to the change occurring during the boiling of the white of an egg). The invigoration of the yeast causes the production of a large number of fermentation gas cells, thereby producing a greater column per weight of bread, and producing an even, uniform texture.

"Any substance added to the dough containing active peptase will tend to shortening the time of dough fermentation and to improve the production of bread or the bread itself in the above directions. The volume per weight and shape of a loaf of bread depends largely on the size and number of fermentation gas cells and on the thickness of the walls of these cells. The quality and quantity of the elastic material in the bread dough is largely responsible for the conditions of these cells, and any material added to the dough which will modify the glutenous substances of the dough in the direction of greater

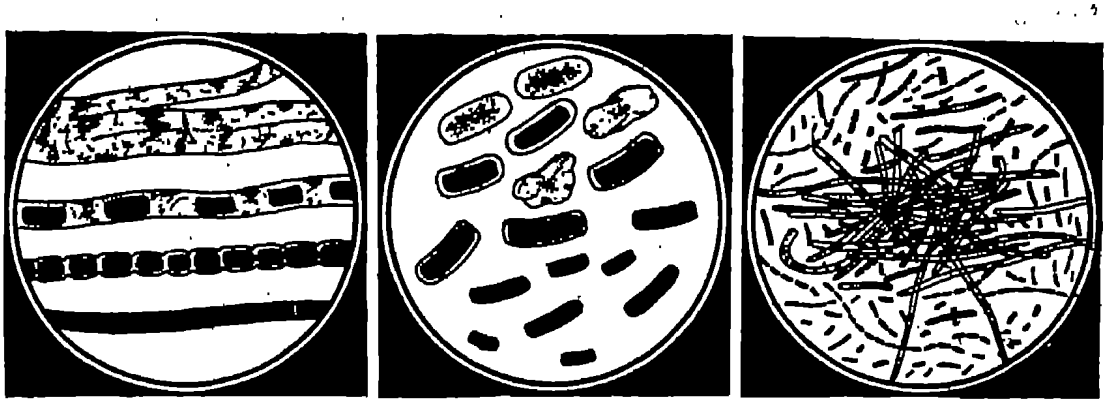
elasticity, so as to allow the production of a large number of small thin-walled fermentation gas cells will cause an improvement in the volume and shape of the bread. The number and size of the fermentation gas cells is also largely dependent on the number and activity of the individual yeast cell groups existing in the dough and any principle which tends to increase the distribution of the invigorated and activated yeast as to make it separate into individual cells or very small clusters would effect a similar improvement in the bread.

"The color and bloom of the crust is dependent largely upon the amount and kind of caramelizable sugars existing in the bread dough at the time of baking. Wheat flours contain very little natural sugar of this kind and various substances containing this principle may be added to bread doughs which will give a deeper color to the crust of the resulting bread than would be obtainable by the use of cane sugar alone.

"The color of the crumb of a loaf of bread is influenced largely by the way light strikes the texture and upon the physical condition of the starch and nitrogenous material after baking. During the baking of the dough, the soluble albumins coagulate into white flaky masses. Certain substances added to bread dough either act in such a manner as to render the starch and nitrogenous material white in appearance or effect the production of a comparatively large amount of albumins in the dough."

Bread Diseases.

"Sticky" or "Slimy bread" is a bread disease which often occurs during hot weather. After eight or ten hours the bread affected gradually becomes slimy, until at the end of two or three days it



After Hunter.

FIG. 21.—Potato bacillus causing "rope" in bread.

may be pulled into strings. The bread takes on a faint sickly odor and finally brown spots appear. This disease is due to bacterial growth. Vogel in Germany found "ropy" bread to be due to the growth of potato bacilli, B. panis viscosus I and B. panis viscosus II.

Watkins in the *Journal of the Society of Chemical Industry*, 1906, says that in bread held at 18 degrees C. ropiness did not occur but in

bread at 25 to 30 degrees C., ropiness developed readily. He found that .1% acetic acid prevented ropiness in bread and that lactic acid had the same effect. The organisms stood boiling for 30 minutes on three consecutive days. He found these organisms often on wheat and in flour.

Experiments at Wisconsin Experiment Station (Wisconsin Report 1898, page 110) showed that the bacillus entered the bread with the yeast. It also was shown that the bacillus could survive the heat of baking.

Summers in *Bakers' Weekly* gives the following method of control of rope in the bakery:

"The best method of procedure is to use up all raw materials on hand. These are very likely to be contaminated. To prevent the development of rope in bread made from the ingredients in stock a small quantity of some organic acid should be added to the doughs. Both lactic acid, the acid of sour milk or buttermilk, and acetic acid, the acid of vinegar, are found to be satisfactory. Acetic acid seems to be somewhat more active in suppressing the trouble but its flavor is undesirable in bread. Lactic acid, on the other hand, is odorless and does not produce so disastrous an effect upon the gluten. It is found necessary to use more lactic acid than acetic acid to produce the same effect. While these acids do not kill the organism, still they prevent its growth.

"One should not use more than 0.3% or one-third pint, of acetic acid per 100 lbs. of flour, or 0.5% or one-half pint of lactic acid per 100 lbs. flour. Greater amounts will disintegrate the gluten, weaken the dough and a loaf of small volume will result.

"In order to entirely eliminate the rope bacteria one should fumigate the shop with formaldehyde candles, or spray the floor, walls, ceiling and all pieces of machinery with a 10% solution of formaldehyde.

"If fumigation is practiced all walls and floors should be first wet down with water and all cracks tightly sealed. The rooms should be left closed from six to twelve hours after fumigation.

"In open air shops, such as are found in army baking, rope has been checked by using a piece of old dough in each newly made dough. This old dough will contain enough lactic and acetic acids to prevent the development of the rope bacteria in the finished loaf."

Chromogenic Breads.

Micrococcus prodigiosus sometimes causes blood red stains in bread; however this bread trouble does not occur very often. Other chromogenic organisms give bread other colors.

Sour Bread.

During fermentation bread dough sometimes becomes abnormally sour due to the excessive growth of lactic and butyric acid bacteria.

These organisms exist in air, water, and soil. They are normally suppressed in dough fermentation by the growth of the yeast. Sometimes, however, due to the use of too little yeast or of weak yeast these bacteria become dominant in the dough. When this is the case these organisms not only make the dough too sour but also often give the bread bad flavors due to putrefactive products. Some authorities say that butyric acid organisms are often found in flour.

Summers, in *Bakers' Weekly* says the causes of sourness in bread may be summarized as follows:

"(a) The acids of sour breads are acetic and lactic acids, with occasional small quantities of butyric acid. Lactic acid, in most cases, is present to the extent of two or three times that of acetic acid.

"(b) The acid is produced by bacteria to be found in the dough.

"(c) These bacteria may be introduced by the yeast, by the use of dirty vessels, and by flour, but their presence in the flour is the most general cause of acidity. Some high-grade flours contain very few bacteria, while low-grade flours are often teeming with them.

"(d) The use of high temperatures facilitates the activity of the bacteria which may be present, and is therefore objectionable.

"(e) The bacteria are present, but do not to any large extent become active until the alcoholic fermentation commences to flag. Hence, over proofed dough is especially liable to develop acidity.

"(f) Slackness of dough contributes to the acidity of bacteria, and therefore is undesirable.

"(g) Excessive exposure to air, by supplying the acetic ferment with oxygen, favors its activity."

Poisonous Bread.

Uglow describes bread in Russia which was poisonous due to the fact that Fusarium roseum had grown in the dough. This bread was bitter and caused a serious condition in those who ate it.

Bread Constituents.

While in this country and in Europe wheat is considered the main bread grain still wheat is not absolutely essential and from the standpoint of nutrition some other grains are as sustaining as wheat. However, from the standpoints of ease of bread manufacture and appetizing qualities of the finished loaf at the present time, there is no other grade which can take the place of wheat in America and in Europe.

During the World War with its abnormal demands upon the wheat supply of the world, the U. S. Food Administration restricted the use of wheat rigidly and in so doing brought up the question as to the effect which wheat restriction might have upon the nutrition of people in general. A committee of experts was appointed as a commission to determine the ability of the public to do without wheat.

This commission was composed of the following men: Dr. R. H. Chittenden, Prof. of Physiological Chemistry and Dean of Sheffield Scientific School at Yale; Dr. Graham Lusk, Prof. of Physiology at Cornell Univ.; Dr. E. V. McCollum, Prof. of Bio-chemistry at Johns Hopkins Univ.; Dr. L. B. Mendel, Prof. of Physiological Chemistry at Yale; C. L. Alsberg, Chief of the Bureau of Chemistry of the Dept. of Agriculture; Dr. F. C. Langworthy, Chief of the Home Economics Division of the State Extension Service, Department of Agriculture; Prof. Vernon Kellogg, of Stanford Univ.; Dr. Alonzo E. Taylor, Professor of Physiological Chemistry at the Univ. of Penn.; Dr. Raymond Pearl of the School of Hygiene of Johns Hopkins Univ. and the U. S. Food Administration; and Dr. Ray Lyman Wilbur, formerly Dean of the Stanford Univ. Medical School and now President of the University.

The *American Food Journal* says: "The question most seriously asked of this committee by the Food Administration was: To what extent can the wheat to which we are now accustomed in our diet be reduced without injury to the health of the individuals of the nation?

"The answer was direct and unequivocal. 'It is the scientific opinion of the committee that in a mixed diet wheat may be entirely replaced, without harm, by other available cereals, namely, rice, barley, oats, and corn. However, we should not recommend this except as an emergency measure.'

"The report then explains that the particular reason for not recommending this, apart from the fact that wheat is perhaps the most convenient cereal for use because of its special qualities connected with the making of bread in loaves that will stand up and remain sweet and palatable for several days, is that going without wheat would be a psychological, though not a physiological deprivation. We are accustomed as a nation, just as most of the nations of Europe are, to the use of wheat bread, and a sudden break in our custom would have for some people a psychological significance more or less disturbing it.

"However, if these people could well understand the emergency leading to the change, and then could recognize that they were aiding their country in the great emergency by making the change, this psychological disturbance would be much reduced.

"Exactly this condition of a great national emergency, for the meeting of which the loyal and patriotic efforts of all the people are needed, is the condition today. It is only because of this great national emergency that the Food Administration makes use of this deliberate judgment of the physiological experts called in for advice.

"Even under these circumstances it is recognized that because of economic and commercial reasons not all of the people of the country can go without bread based on wheat, but it is certain that a great many people in this country can easily do this, and it is the belief

of the Food Administration that most of the people in this country who can dispense entirely with wheat from now until the next harvest will be glad to do it for the sake of maintaining the wheat-bread supply for the armies and civilians of our fighting associates in Europe as well as our own soldiers in France."

Some experiments by R. L. Corby with rolled oats as wheat flour substitutes are reported in the *National Baker* for November, 1917. He says:

"We find many statements of a general nature which cause much trouble and give very poor results when actually carried out. In each of several publications suggesting the use of oats as a possible channel through which the problem might be solved, by mixing wheat and other flours to make a tasteful and nutritious bread, rolled oats were advocated. It is a well-known fact that in the process of manufacture these patent foods are steamed, thus destroying all flexibility of a flour when made from the product. A good substitute must at least aid the wheat gluten in giving normal volume. Oat flour would be a hindrance, and act as so much dead matter similar to chalk. The untreated oats when ground and milled in an experimental mill give an entirely different product. This was substantiated by actual laboratory experiments. The oat and wheat flours being mixed in the following proportions:

	No. 1 Per Cent	*No. 2 Per Cent*	*No. 3 Per Cent*	*No. 4 Per Cent*	*No. 5 Per Cent*
Oat flour.....	0	10	20	30	40
Wheat flour.....	100	90	80	70	60

Not only were the ordinary grains tried as bread-makers but many other preparations as fruit flours, legume flours, and in one case pulverized fish was added to the bread. One interesting flour was banana flour which is said to have some qualities which adapt it remarkably well to the manufacture of bread. However, it was found that the banana is unable to compete with grains as a bread-maker, at least under the present conditions.

Cotton seed flour has come into use to some extent as a wheat flour substitute. While it is not as adaptable as some of the substitutes it has its high protein and fat content in its favor if this protein and fat content are in a form in which they are readily available as nutrition in the human system. In considering any substitute for wheat flour in bread-making we must remember that practically no experimentation has been carried on to determine the condition of its nutrients after passing through the bread-making process. Practically all investigations in the past have taken into consideration mainly wheat as the bread grain.

F. C. Pelky in *Bakers' Weekly* says: "The actual food value of the loaf with substitute flour will compare very favorably with that of wheat flour. The protein content is as large if not larger than

the total protein contained in the wheat flour. Only small amounts of substitute flours can be used, for the reason that they contain no gluten, the tenacious rubbery mass that retains the gases produced during the dough fermentations. Gluten is the life of the loaf; without it there can be no light bread. When the fermentation starts within the dough gas is formed. If it were not for the gluten the gas would simply push its way through the dough and escape, leaving the dough a lifeless mass; but the gluten furnishes a kind of envelope within the dough which confines the gases produced in the form of cells. These cells, being constantly formed by the action of the gas, cause the dough to expand, forming when baked a large porous loaf.

"In using any of the substitutes named with wheat flour, we must remember that they do not increase its strength, although they do supply protein to the amount that is contained in them. Barley flour is highly nutritious and is proving to be a very valuable substitute, both in bread and cake making. Rice makes a very fine flour, with a wonderful absorption. It can be used alone or with other cereals as a substitute. I advise against the use of too much rice flour, as it is inclined to sogginess. Ten per cent each of rice and corn gives splendid results. The food value of rolled oats is shown to be very high. They are being extensively used, in combination with other cereals, both in Victory and war bread. It is advisable to soak the oats in water for from 15 to 30 minutes before using.

"Potato flour cannot be secured, but potatoes may be used as a wheat flour substitute, although on account of their high moisture content four pounds of potatoes must be used as the equivalent of one pound of substitute flour. If potatoes are used in excess of 5 per cent, I advise that after boiling or steaming they be beaten down to a dry mass."

The Baking Division of the U. S. Food Administration issued the following ruling in 1918: "Due to short supply of wheat flour, substitutes must be used in all bakery products beginning April 14, 1918, as follows:

Class 1.	You must increase substitute content of all bread and rolls to	25 per cent
Class 2.	Sweet Yeast Dough Goods to	33⅓ per cent
Class 3-A.	Crackers to	15 per cent
Class B.	Biscuits (Cookies) and Ice Cream Cones to	33⅓ per cent
Class 4-A.	Cakes to	33⅓ per cent
Class 4-B.	Pies to	33⅓ per cent
Class 4-C.	Fried Cakes to	33⅓ per cent
Class 4-D.	Pastry to	33⅓ per cent
Class 5.	Batter Cakes, Waffles, Quick Breads, and Boston Brown Bread to	66⅔ per cent

W. C. Wells in the *Bulletin of the Pan-American Union* says: "Take the grains alone and one grain, corn. In nutritive value and digestibility corn and wheat are approximately equal. Corn is a deli-

cious 'vegetable,' wheat is not. Except in the bread form corn more than holds its own with wheat as human food. It is as bread that corn fails. Corn enthusiasts deny this last statement, but the fact is that plain wheat bread is constantly ousting plain corn bread. The enthusiasts themselves eat very little corn bread when compared with the amount of wheat bread they eat. In fact in many localities 'corn-bread' has come to mean bread made of corn flour, milk, eggs and often wheat flour added, which, of course, is not bread in the ordinary acceptance of the term as applied to other grains. Something is needed in the conversion of corn flour into bread; something which will work the marvel that leaven works when wheat flour is baked into bread. This may be a field for chemistry or it may be a field for a sister science. No one can guess what this something will be or how applied, yet it may be confidently predicted that this something, a process, an apparatus, or a substance, will be discovered. Certainly civilized man in the twentieth century is not less fruitful in food utilizations than was the prehistoric savage who first used barm in making his bread."

It is believed by leaders in the baking industry that we are just entering a period of great increased information concerning bread-making. There has been many bread-making facts brought out during the last few years, which have been great surprises to new and to experienced bakers alike. It is surely true that baking in all its details is being placed on a solid scientific foundation and the old rule of thumb procedure is slowly giving away to real bread technology.

Great numbers of wheat substitutes were tried out during the World War and usable products were distinguished from the unusable ones. At the same time much information as to the use of wheat substitutes was gained.

Some of the substitutes for wheat flour which were used in America during the war were:

Corn Starch
Corn Meal
Corn Flakes
Corn Flour
Modified Corn Starch
Oat Meal
Rice Flour
Tapioca Flour
Potato Flour
Barley Flour
Rye Flour
Banana Flour
Cotton Seed Flour
Sorghum Flour
Etc.

J. C. Summers in *Bakers' Weekly*, March 16, 1918, speaks as follows of corn starch as a wheat flour substitute:

"To our great surprise, recent experiments showed that the bread made by using twenty per cent starch to be by far better than those made from twenty per cent corn flour, or 10 per cent starch and ten per cent corn flour. The bread possessed an excellent color and grain and had large volume. From physical appearances, the loaves were perfect and equally as good as the original 100 per cent white wheat flour loaf. But, of course, the protein content of such a loaf would be decreased one-fifth, while the percentage of carbohydrates will be increased. This is undesirable, since the ratio of proteins to carbohydrates is already too low, and for that reason bread cannot be classed as a balanced ration, but has to be eaten with meat, milk, butter or cheese in order that one should have the desired proportion of these substances.

"The following is the formula used in producing above-named bread:

Wheat flour	80	per cent
Substitute	20	" "
Water	60	" "
Sugar	1½	" "
Malt	1½	" "
Salt	1¾	" "
Yeast	1¼	" "
Shortening	1	" "

"Using corn starch and corn meal as wheat flour substitutes to the extent of 36% Max Strasser of the White Rose Baking Co. of New York produced a very acceptable loaf, the formula for which is as follows:

Make a blend:

196 lbs. wheat flour
60 lbs. corn starch
50 lbs. corn meal

The following is the mixture:

196 lbs. of the blend
120 lbs. water
3½ lbs. salt
2 lbs. fat
4 lbs. malt extract
1 lb. milk powder
3½ lbs. yeast (minimum)

"Temperature according to shop, 78 to 81 degrees; straight dough method; one punch; mould pieces over at least once, better twice. Entire fermentation not over three hours."

Charles Hunter in *Bakers' Weekly*, April 20, 1918, says that this bread has surprising quality of texture, crumb, color, and volume. In commenting on it further he adds:

"In adapting this formula to large-shop practice, the flour and substitutes may not be blended or mixed in their dry state, as this mixture would not be uniform if dropped by automatic weighing machine. The retail baker, however, may easily mix or blend these materials in his trough and put them in the machine by hand.

"It is to be noted that the entire fermentation shall not be over three hours; consequently, a large amount of yeast must be used, and the 3½ pounds mentioned in this formula represents a minimum which must be increased if this dough does not finish under possible unfavorable shop conditions within three hours."

The strongest characteristic of the yeast plant is its ability to attack sugar and to convert it into carbon dioxide and alcohol. Bread dough always contains more or less sugar in one form or another. In bread dough made of flour, salt and water, the sugar is mainly maltose, produced as a result of the action of wheat diastase on the starch of the flour. The longer bread dough is held before baking the more starch is turned into sugar thus furnishing the yeast more sugar to attack.

Yeast should be added in the making of bread in such a way that the yeast cells are thoroughly disseminated throughout the dough. Time spent in thoroughly breaking up a package of yeast in warm water before using it is well rewarded in improved results. As far as possible each cell should be isolated in the dough so that it finds itself imbedded in a sugar containing medium. Its production of gas should form one bubble or pore in the finished bread. The better the quality of gluten in bread, the more effectively will the bubbles of carbon dioxide remain isolated. As these bubbles grow the bread is said to rise. To a considerable extent the quality of a finished loaf of bread depends upon the thinness of these little membranes separating the pores.

The yeast cell requires a slight amount of nitrogen in its nutrition and to obtain this it produces an enzyme, endo-tryptase, which has some effect on the gluten of bread. However, the amount of carbohydrate which the yeast cell splits is enormous as compared with the weight of the yeast cell itself.

It has been determined at the New Jersey Agricultural Experiment Station, that 1.5% to .8% of the nutrients in the dough are split up and lost by the action of microörganisms of which yeast is the most active during the preparation of the bread for the oven. During the fermentation of bread dough the loss in weight of bread constituents is due to a complexity of causes of which the most important are: the action of yeast, the action of bacteria, and the action of enzymes.

The physiology of the yeast cell shows that its need for nitrogenous products is infinitesimal as compared with its sugar requirements. Of the many different kinds of fermentation the alcoholic fermentation of sugars by yeast is the most common. This term fermentation was first applied to the alcoholic phenomena observed

in sugar solutions. This conversion of sugar into alcohol and carbon dioxide is caused by an enzyme called zymase secreted by the yeast plant. Grape sugar is split by this enzyme as follows:

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$$

Grape sugar is not one of the constituents usually added to bread. In bread made of flour, water, salt, and yeast, the yeast is furnished with sugar by the action of the diastatic enzymes of the wheat. In other words, each kernel of wheat contains within itself enzymes which are capable of converting all of the starch stored in the kernel into sugar. When wheat is manufactured into bread flour these enzymes are carried over into the flour and when the flour is mixed with water and kept warm the wheat diastase gradually changes the wheat starch into maltose.

When starch has been changed into maltose the maltose is attacked by enzymes called maltase present in the wheat flour to some extent but also supplied by the yeast. These enzymes change the maltose into grape sugar as follows:

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6$$
Maltose.

Grape sugar is converted into alcohol and carbon dioxide by yeast as mentioned above. The carbon dioxide gives the bread its proper aeration and on baking both it and the alcohol are largely driven off by the heat of the oven.

While yeast must have some nitrogen for cell building still this requirement is so small that as far as the bread manufacturer is concerned the yeast may be considered to have little effect on the gluten of the bread flour. On the other hand the fact must not be overlooked that the protein of bread dough exerts a more or less definite effect upon the activity of yeast on the carbohydrates of bread dough. That there is a toxic action by the protein of wheat bread dough on yeast has been determined by several workers.

Concerning the toxicity of different flours Glabau says: "In using different flours, the baker often receives a flour which will not ripen as readily as others in the fermentation which he has used, and he terms such flour hard, or harsh; then again he will get a flour which acts just the reverse. In some instances it will ripen in one-fourth less time. The dough will also be softer and have a tendency to run. Such effects are due to the physical constitution and chemical composition of the protein constituents of wheat flour.

"Schutzenberger and other European workers have demonstrated the toxic action of wheat flour on brewers' yeasts, but state that the bakers' compressed yeast is immune to the toxicity of wheat flour. I find, however, from the experiments performed that the bakers' compressed yeast is not entirely immune from the toxicity of wheat flour, though the action is far more pronounced on brewers' yeast.

The question which probably arises in the bakers' minds is, What causes this toxicity or retarding action of some flours in fermentation?

"The cause, as already stated, is due to the constituents of the proteins of flour. The proteins of wheat are glutenin and gliadin, which constitute the ordinary insoluble protein gluten. The soluble proteins are vegetable albumin and globulin; also the proteoses, and amino acids, and amides occur in the process of fermentation.

"In the process of reproduction the yeast cells need nitrogenous substances for new cells, and therefore it gives off a proteolytic enzyme, which has the property of breaking up the complex proteins into the amino acids and amides, which are then synthesized into the protoplasmic structure of the yeast cells.

"It is known that if we take other cereals, such as barley, rye, oats and rice, and start fermentation with brewers' yeast, the process will be continuous if we furnish the yeast with new food. But if we should use wheat flour and brewers' yeast in place of the above cereals, fermentation would commence, but there would be only one rising and then it would cease, due to the toxicity of the proteins of wheat.

"Now then is it not logical to assume that it is the gluten which causes the retarding action on the proteolytic enzymes of the yeast, thus upsetting to a certain extent the process of fermentation? The writer is of the opinion that it is caused by the glutenin of the wheat, the most insoluble protein. Glutenin has the physical property of resisting the tension of the gas evolved, thus retarding the functions of the yeast to some extent. It has the chemical property of resisting the proteolytic enzymes in their digestive actions. It is the proper conditioning of this body in fermentation if the best results are to be obtained in bread making. The writer has had a good many different flours in shop practice with varying degrees of toxicity."

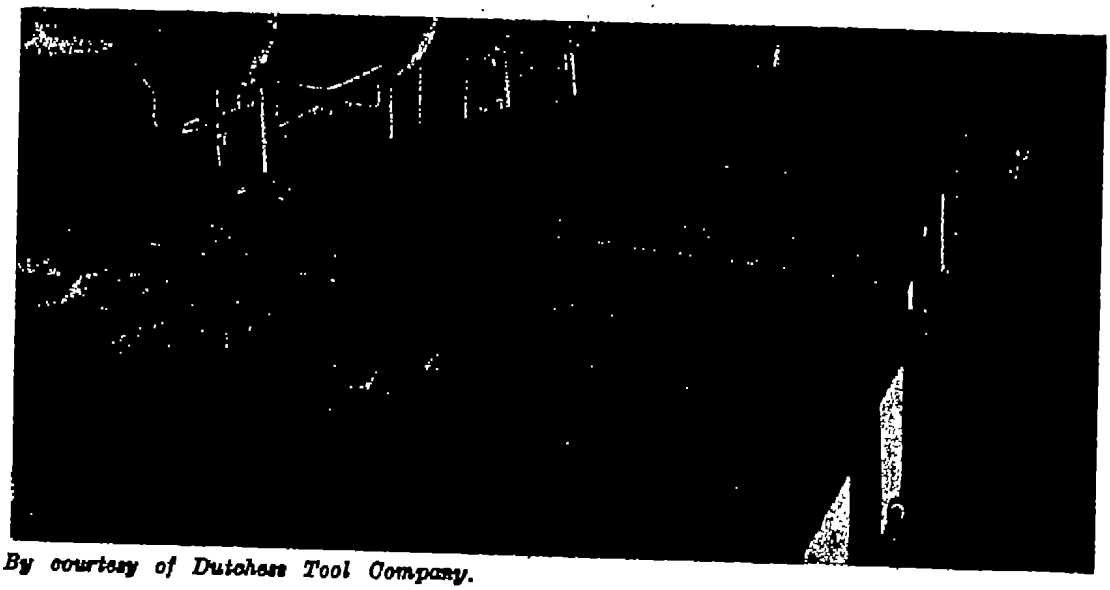
The Temperature Factor.

The main changeable factors which influence the growth of yeast in bread dough are time, temperature, and bread constituents. Other factors as reaction, oxygen relations, and biological environment are normally favorable in bread dough without being controlled. In several large bakeries making bread, the temperature of the water used was about 78 degrees F., and the temperature of the flour was between 75 and 78 degrees F. After mixing all of the constituents of the bread in the power dough mixers for one minute the temperatur of the mix was 77 degrees F. After the mixer had been running for 10 minutes the temperature was 81 degrees F. and after mixing 5 minutes longer a temperature of 82 degrees F. was reached. In summer weather a degree or two lower than 82 degrees F. is insisted upon when the dough comes from the mixer. This lower temperature is sometimes obtained by the use of ice in the water before the mixing. The temperature of the dough after 5 hours in the dough

troughs should be about 84 degrees F. There will be slight cooling when the dough goes to the bench but it should not cool more than 2 degrees. It is extremely important that the dough should not be chilled on the bench. To prevent this the room should be kept at even temperature and all drafts avoided.

There is nothing in the bread factory more important than temperature control. Thermometers should be used continually in the bread constituents before mixing, in the dough at periods during mixing and while the dough is fermenting in the dough troughs, as well as at the time of each "punch." It goes without saying that the different rooms should be carefully regulated as to temperature.

Not only should the temperatures for each step all through the process be observed and controlled but the time required for each step must be accurately controlled.



By courtesy of Dutchess Tool Company.

FIG. 22.—Dough troughs.

Uniform results can never be maintained if either temperature or time factors vary. In case of trouble, if only one factor has varied the cause of variation can be determined and the fault remedied but if more than one factor has varied from the set practice then it is impossible to know what is responsible for the bread failure or difficulty. To sum up one may say that uniformly successful bread-making is the result of systematic accuracy as to time, temperature, and ingredients, and that luck is not a factor in bread-making. While there is no definite time and temperature relation which can be uniformly followed out in all plants, still it is true that these factors do not vary widely in successful bread-making.

C. E. Bridwell says: "Over-fermentation more often causes trouble than under-fermentation. There are practically five methods or changes that can be used to overcome the difficulties of over-fermentation; first, lower temperature; second, reduce time; third,

use more salt; fourth, reduce the amount of yeast; fifth, if several yeast foods are used, eliminate all but one. The baker, after taking into consideration his formula can decide which of these changes is the most needed and the most suitable to fit in with his conditions and method of working. If under-fermentation is the cause of the difficulty, the above changes should be reversed.

"You know from past experience that heat hastens fermentation while cold retards it. This being true, there must be a point where the temperature is normal. Experience has also taught us that this point is between 78 degrees and 82 degrees with the shop temperature

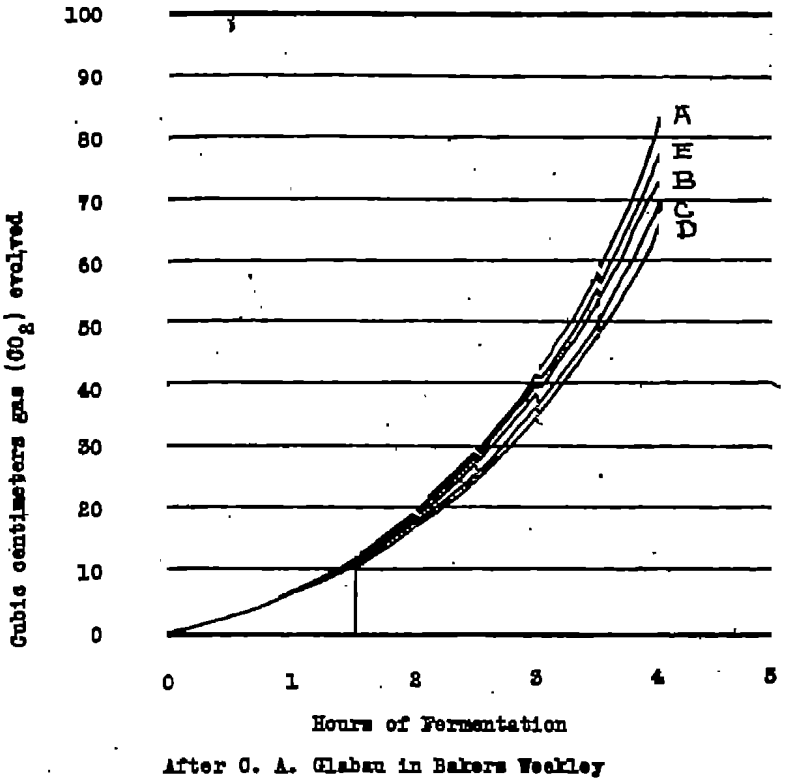


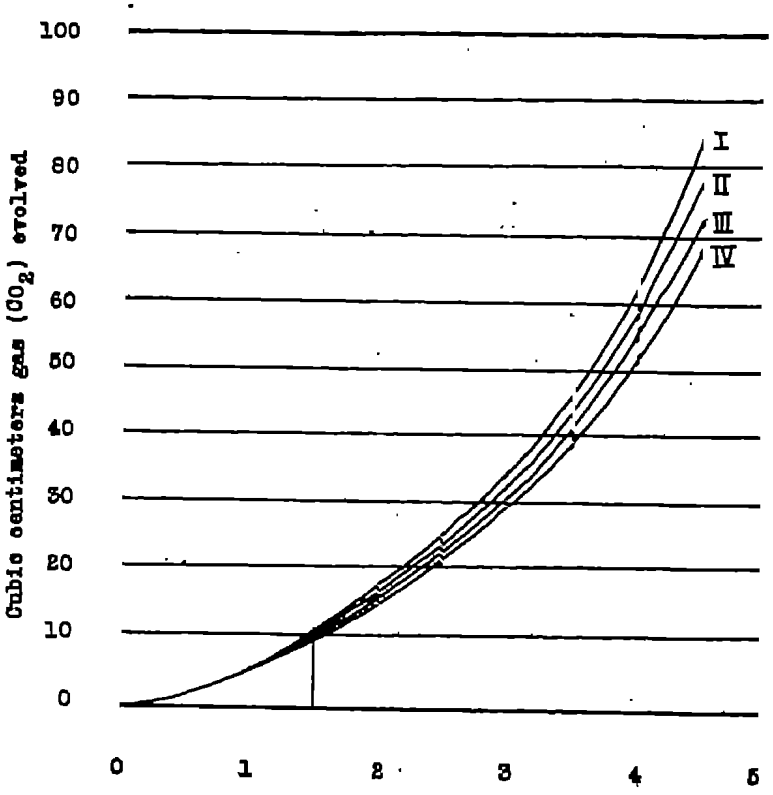
FIG. 23.—Chart showing effect of salt on rate of CO_2 production of yeast in 100 cc. of a uniform sugar solution. The amount of salt varies from 1% as (A) to 2% as (D).

ranging not much above or below these figures. Of course, where you have unfavorable surroundings in the shop it requires very good judgment when adjusting the temperature and time to meet these conditions.

"A dough mixed at a high temperature will develop undesirable ferments which cause sourness and will make an unsatisfactory loaf in general. These results are due partially to the fact that the yeast cannot produce the proper fermentation when subjected to such unfavorable temperatures. The gluten in the flour will also be softened and deteriorated to such an extent as to seriously affect its gas retaining power and cause it to absorb from one to three per cent less moisture.

"Do not try to reduce the cost by using a small amount of yeast and a high temperature, it is always better to use a larger quantity of yeast and a low temperature. The added cost will be more than offset by the increased yield and the quality of the finished product."

There is a long list of materials which are added to the four fundamental constituents of bread for the sake of economy or improvement in the finished loaf. Some of these materials were mentioned under the head of bread improvers.



The dough constituents in each of the fermentations above were the same. The temperature used was 80 Fahr't. and the humidity was 70% in each case.

After O. A. Glabau.

FIG. 24.—Chart showing the difference in toxicity of four different flours on the CO_2 production of yeast.

Salt is not considered a bread improver but one of the fundamental constituents. While it is necessary in bread to give it savor it also has an effect upon the action of yeast on the dough in that in excess of 3% it retards fermentation.

The chart on page 161 shows the effect of salt on rate of CO_2 production of yeast in 100 c.c. of a uniform sugar solution. The amount of salt varied from 1% as (A) to 2% as (D).

Concerning the amount of salt to be used in bread-making, Glabau comes to the following conclusion: "From the above data we can readily see how necessary it is to consider the various factors in using salt in doughs, and the writer would advise the safe zone be-

tween 1.5% and 1.75% of the weight of flour used in dough making. After years of shop practice and laboratory work the writer finds that the best results can be obtained between the above points, providing all other conditions are normal."

Water in different localities differs in chemical analysis and it has been found that due to this fact the same materials and the same procedure do not produce the same bread in different bakeries. The materials in the water may have retarding effects upon the growth of yeast in dough. As a general rule the more mineral matter in the water used the greater is the retardation of the yeast fermentation, while soft water is often observed to have a hastening effect on yeast fermentation in dough.

A general idea of the salt content of the water of a locality can be obtained from the U. S. Geological Survey table of river waters which follows:

TABLE I.

MINERAL ANALYSES OF SURFACE WATERS FOR THE EASTERN UNITED STATES.

Source of Sample (River, except as noted).	Average mineralisation (parts per million)										
	Suspended matter	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and Potassium (Na-K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total dissolved solids.
Allegheny, Kittanning, Pa.	30	7.0	.18	14	3.0	11	38	17	.7	14	87
Arkansas, Little Rock, Ark.	748	28	.82	55	18	144	148	98	2.0	208	680
Big Vermilion, Danville, Ill.	82	14	.29	54	25	18	248	42	12	4.5	281
Brazos, Waco, Tex.	488	22	.26	131	19	284	158	279	2.2	338	1136
Cahaba, Birmingham, Ala.	32	16	.44	18	2.5	9.1	52	8.8	.6	2.2	76
Cape Fear, Wilmington, N. C.	21	9.9	.78	5.0	1.5	7.2	25	8.2	.2	5.8	57
Cedar, Cedar Rapids, Ia.	61	14	.09	48	15	12	209	30	3.1	3.4	228
Chippewa, Eau Claire, Wis.	8.7	12	.22	18	4.7	8.1	48	14	.6	1.1	90
Colorado, Austin, Tex.	351	18	3.1	52	17	49	196	42	...	59	321
Cumberland, Nashville, Tenn.	94	20	.42	26	3.6	9.6	92	14	1.2	3.1	119
Erie (Lake), Buffalo, N. Y.	Trace	5.9	.07	31	7.6	6.5	114	18	.8	3.7	133
Fox River:											
Elgin, Ill.	23	12	.15	51	30	11	268	38	2.4	5.2	290
Ottawa, Ill.	37	11	.20	60	32	14	275	61	4.9	7.9	335
Grand, Grand Rapids, Mich.	43	14	.07	56	19	10	214	33	2.3	7.7	258
Hudson, Hudson, N. Y.	16	11	.15	21	8.3	7.9	78	16	.9	4.0	108
Huron (Lake), Port Huron, Mich.	Trace	12	.04	24	7.0	4.4	100	6.2	.4	2.6	108
Illinois River:											
La Salle, Ill.	136	12	.21	50	22	16	203	50	6.6	18	278
Peoria, Ill.	26	12	.21	49	21	17	198	48	7.8	13	271
Iowa, Iowa City, Ia.	120	19	.25	49	17	14	210	36	2.8	3.6	247
James, Richmond, Va.	71	18	.5	14	3.0	6.7	60	7.1	.3	2.3	80
Kalamazoo, Kalamazoo, Mich.	19	17	.05	55	18	8.2	216	2.3	1.9	3.4	242
Kankakee, Kankakee, Ill.	32	15	.27	58	21	12	215	57	4.1	4.9	288
Kentucky, Frankfort, Ky.	142	15	.49	31	8.7	6.8	78	3.3	2.5	2.0	104
Lehigh, South Bethlehem, Pa.	21	8.8	.10	14	5.7	7.5	40	30	2.2	4.9	95
Maumee, Toledo, O.	112	17	.27	57	16	24	178	48	4.5	40	298
Miami, Dayton, O.	94	17	.15	59	24	9.0	244	40	8.6	4.1	289
Michigan (Lake), St. Ignace, Mich.	Trace	10	.04	26	8.2	4.7	112	7.2	.3	2.7	118
Minnesota, Shakopee, Minn.	142	28	.09	82	35	28	296	144	2.0	4.7	480

Mississippi:											
Minneapolis, Minn.	7.9	15	.07	40	14	10	188	18	1.4	1.6	200
Quincy, Ill.	119	18	.46	36	16	11	175	25	2.2	4.4	208
Memphis, Tenn.	519	24	.61	36	12	19	129	48	1.7	8.6	202
New Orleans, La.	...	11	.53	32	8.4	18	111	24	2.5	9.7	166
Missouri, Kansas City, Kans.	2022	37	.73	62	18	44	202	185	2.2	18	426
Monongahela, Elizabeth, Pa.	84	8.4	.49	12	2.2	7.8	18	38	1.8	3.2	81
Muskingum, Zanesville, O.	70	14	.18	48	9.5	28	115	43	1.6	40	244
Neuse, Raleigh, N. C.	68	26	1.4	5.9	1.8	7.9	35	8.4	.8	4.4	78
North Platte, North Platte, Nebr.	311	40	.26	46	12	32	166	78	1.2	6.9	295
Ocmulgee, Macon, Ga.	174	26	.9	6.8	1.2	8.8	28	4.9	.7	2.8	69
Pearl, Jackson, Miss.	46	18	.37	7.1	1.1	8.9	32	6.4	.7	8.4	59
Platte:											
Columbus, Nebr.	300	32	.20	63	18	48	186	152	1.3	14	487
Fremont, Nebr.	392	47	.26	47	11	30	178	66	1.0	6.4	302
Potomac, Cumberland, Md.	29	8.2	.14	24	4.6	9.0	36	58	.9	6.4	130
Raritan, Boundbrook, N. J.	35	16	.15	12	3.9	9.1	51	12	1.9	4.7	85
Red, Shreveport, La.	870	30	1.1	74	17	90	185	140	.4	121	561
Rio Grande, Laredo, Tex.	...	29	3.6	104	28	119	178	228	...	164	791
Roanoke, Randolph, Va.	127	21	.95	9.5	3.5	5.9	58	4.4	.5	2.2	79
Rock:											
Rockford, Ill.	92	15	.44	45	25	10	252	22	4.1	4.6	250
Sterling, Ill.	286	15	.31	49	27	12	263	25	3.8	5.5	267
St. Lawrence, Ogdensburg, N. Y.	Trace	6.6	.05	31	7.2	6.8	116	12	.8	7.7	134
Sangamon, Decatur, Ill.	37	19	.27	55	26	14	268	35	3.5	5.4	295
Sangamon, Springfield, Ill.	39	16	.32	52	24	16	247	37	3.4	7.5	276
Savannah, Augusta, Ga.	142	28	.44	5.7	.8	12	30	6.0	.6	2.1	60
Shenandoah, Millville, W. Va.	39	15	.08	32	8.2	6.7	132	6.2	2.6	8.0	140
Superior (Lake), Sault Ste. Marie, Mich.	Trace	7.4	.06	18	3.1	8.2	56	2.1	.5	1.1	60
Susquehanna:											
West Pittston, Pa.	22	10	.12	18	3.4	6.3	63	14	1.5	4.2	90
Williamsport, Pa.	18	7.6	.11	12	3.4	6.0	28	26	.7	4.0	74
Danville, Pa.	21	8.7	.09	21	4.6	8.9	54	31	3.4	8.1	112
Tennessee:											
Knoxville, Tenn.	156	25	.54	22	4.8	8.2	36	6.4	.8	9.6	122
Gilbertsville, Ky.	127	20	.39	19	4.1	7.7	72	11	1.2	8.0	101
Tombigbee, Epes, Ala.	100	25	.63	18	1.8	10	67	6.8	.6	8.0	94
Wabash:											
Logansport, Ind.	117	14	.28	32	35	142	284	79	5.9	292	807
Vincennes, Ind.	195	18	.24	61	23	25	230	55	6.4	36	336
Wateree, Camden, S. C.	214	25	.28	6.5	1.8	8.4	34	4.2	.4	2.8	73
White, Indianapolis, Ind.	38	14	.15	74	29	48	291	58	6.1	78	450
Wisconsin, Portage, Wis.	4.6	13	.22	14	6.8	8.1	58	17	.9	2.1	98
Youghiogheny, McKeesport, Pa.	168	8.5	4.70	28	6.7	9.8	0	128	1.1	4.5	197

When the water used in a bakery contains considerable amounts of carbonate of calcium or of magnesium it has a distinct retarding effect on the CO_2 production of yeast. This retarding effect is thought to be the result of the acid neutralizing property of these carbonates as it is a fact that the physiological functions of yeast require a slightly acid medium. The use of buttermilk powder in bread-making is often recommended, where the water contains considerable amounts of carbonates. Tartaric acid has been used but the quality of the bread is not so good as where the lactic acid of buttermilk is depended upon to acidify the dough properly. The carbonates of calcium and magnesium in the presence of lactic acid are converted into calcium and magnesium lactate which are considered beneficial to the growth and activity of the yeast organism. Also these salts favor good quality in the finished loaf.

The effect on yeast fermentation in bread dough, of water containing mineral salts, as given by A. Wahl in *Bakers' Helper*, is as follows:

TABLE OF RESULTS FROM EXPERIMENTS WITH WATER CONTAINING MINERALS.

Process	*1* *Normal Distilled Water*	*2* *Normal Tap Water*	*3* *60 Parts per Million CaO*	*4* *50 Parts per Million CaO Neutralized with Acid*	*5* *100 Parts per Million CaO*	*6* *100 Parts per Million CaO Neutralized with Acid*
Flour	750 grams	750 grams	750 grams	750 grams	750 grams	750 grams
Yeast	10 "	10 "	10 "	10 "	10 "	10 "
Sugar	20 "	20 "	20 "	20 "	20 "	20 "
Salt	10 "	10 "	10 "	10 "	10 "	10 "
Water	500 cc.	500 cc.	500 cc.	500 cc.	500 cc.	500 cc.
Time to 1st Punch...	1 hr. 53 min. 84°-83° F.	1 hr. 59 min. 84°-83° F.	2 hrs. 17 min. 84°-83° F.	1 hr. 56 min. 84°-83° F.	4 hrs. 8 min. 84°-83° F.	2 hrs. 11 min. 84°-83° F.
Time to 2nd Punch..	52 min. 84° F.	1 hr. 3 min. 83° F.	1 hr. 4 min. 83° F.	53 min. 84° F.	1 hr. 12 min. 84° F.	1 hr. 4 min. 83° F.
Time to Bench	I hr. 3 min. 84° F.	56 min. 83° F.	58 min. 84° F.	1 hr. 3 min. 84° F.	2 hr. 14 min. 84° F.	1 hr. 83° F.
Time to Oven	1 hr. 25 min.	1 hr. 32 min.	1 hr. 26 min.	1 hr. 29 min.		1 hr. 35 min.
Total time to Bench...	3 hrs. 48 min.	4 hrs.	4 hrs. 25 min.	3 hrs. 52 min.	6 hrs. 34 min.	4 hrs. 15 min.
Total time to Oven.....	5 hrs. 13 min.	5 hrs. 32 min.	5 hrs. 51 min.	5 hrs. 21 min.		5 hrs. 50 min.

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Chapter 16.

Corn Products.

The corn products industry originally was entirely an American industry. However, large amounts of corn products are now exported and some European countries have corn products plants. In this country this industry is becoming one of our greatest industries and the demands placed upon it for variety and amounts of products increases yearly.

Three-quarters of the corn of the world is produced and consumed in the United States, nevertheless until a few years ago outside of its use in corn bread, corn was not seriously considered as food for humans. For many years practically all of the corn of the country, more than three billion bushels, was fed to animals. Early in the settlement of the Middle West, corn became the primary crop due to the fact that more food could be produced in the form of corn than in the form of any other crop.

During the World War when American wheat was needed in Europe the real value of corn as a human food was better appreciated and greater quantities than ever before were manufactured into products. During this period great progress was made in perfecting new products, new processes, and in making old processes more efficient.

The list of products derived from corn is quite long. One product after another has been perfected and added to the list until we have at present a complicated industry dependent upon technical processes and strict laboratory control.

In *Farmers' Bulletin* 877, W. J. Spillman gives a table (see opposite page) which shows very clearly why corn is and must always be the dominating crop on the great Middle Western plains of the United States.

In the early days of manufacturing in the United States there was but one product separated from corn and this was corn starch. All the remainder of the kernel of corn was destroyed in the process of obtaining the starch. This early process was practically a case of rotting away the protein of the corn in order to free the starch granules. It was found that the putrefaction of the protein of corn can go on without injuring in any way the starch granules. This fact is explained when one observes that the starch granules are each covered with a cellulose wall which can be pierced only with difficulty by microörganisms.

TABLE II.

After W. J. Spillman in Farmers' Bul. 877.

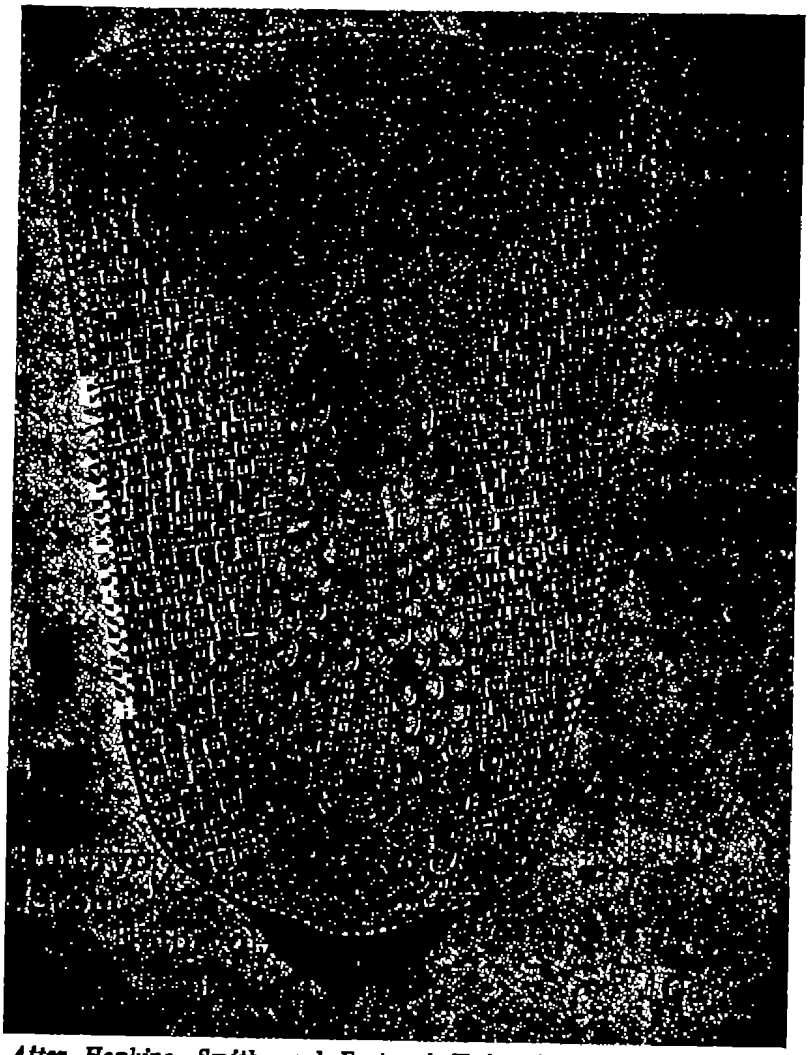
A Comparison of the Food Produced Annually by an Acre of Land When Utilized in the Production of Various Food Crops and Live-Stock Products.

Food Products	Yield per Acre		Calories per Pound	Pounds Protein per Acre (Digestible)	Calories per Acre
	Bushels	Pounds			
Food crops:					
Corn	35	1,960	1,594	147.0	3,124,240
Sweet potatoes	110	5,940 [a]	480	53.5	2,851,200
Irish potatoes	100	6,000	318	66.0	1,908,000
Rye	20	1,200	1,506	118.8	1,807,200
Wheat	20	1,200	1,490	110.4	1,788,000
Rice, unpolished	40	1,154	1,460	55.4	1,684,840
Rice, polished	...	1,086	1,456	50.0	1,581,216
Soy beans	16	960	1,598	294.7	1,534,000
Peanuts	34	524	2,416	126.2	1,265,018
Oats	35	784 [b]	1,600	89.4	1,254,400
Beans	14	840	1,337	157.9	1,123,080
Cowpeas	10	600	1,421	116.4	852,600
Buckwheat	24	600 [c]	1,252	34.5	751,800
Dairy products:					
Milk	...	2,190	325	72.3	711,750
Cheese	...	219	1,950	56.7	427,050
Butterfat	...	98.55	3,605	1.0	355,273
	Live (Pounds)	Dressed (Pounds)			
Meat:					
Pork	350	273	2,465	22.7	672,945
Mutton	205	113	1,215	14.7	137,295
Beef	26	125	1,040	18.5	130,000
Poultry: [d]					
Meat	103	66	1,045	12.7	68,970
	Dozen	Pounds			
Eggs	73.8	110.7	720	14.8	79,704
Total	...	...	....	27.5	148,674
	Live (Pounds)	Dressed (Pounds)			
For poultry meat alone	267	171	1,045	33.0	178,695
	Dozen	Pounds			
For eggs alone	122.4	183.6	720	24.6	132,192

Somewhat later in the manufacture of starch it was the custom to sell the slop from corn starch manufacture to farmers for cattle feed. This wet mash brought only a small price at first, but after

some experimentation farmers found it to be a very valuable feed. At the present time this residue from starch manufacture brings about twice the price of an equal weight of corn. This feed is now known as corn gluten feed and is made of gluten meal, corn bran, and germ oil meal.

The third commercial product to be produced from corn was corn oil. This is expelled from the germs. The value of this oil for



After Hopkins, Smith, and East, of University of Illinois.

FIG. 25.—The structure of the corn kernel.

cooking and salads has been appreciated only very recently. These three products, corn starch, corn gluten feed and corn oil are the three primary corn products. From these many secondary products have been manufactured as glucose, corn-syrups, corn sugar, dextrins, gums, etc., from starch; fatty acids, soaps, rubber substitutes, etc., from corn oil; and many mixed feeds from the corn gluten.

The yield of starch, feed and oil from one bushel of corn may be as follows:

	Theoretically	*Practically*
Starch	36.0 lbs.	32.5 lbs.
Feed:		
Gluten meal	7.0 lbs.	9.0 lbs.
Corn bran	5.0 lbs.	7.0 lbs.
Germ oil meal	2.2 lbs.	2.0 lbs.
Steep water	4.0 lbs.	4.0 lbs.
Corn oil	1.8 lbs.	1.5 lbs.

Very little starch is made in the United States from any other grain than corn. Corn starch has proven most satisfactory as to quality and as to cost.

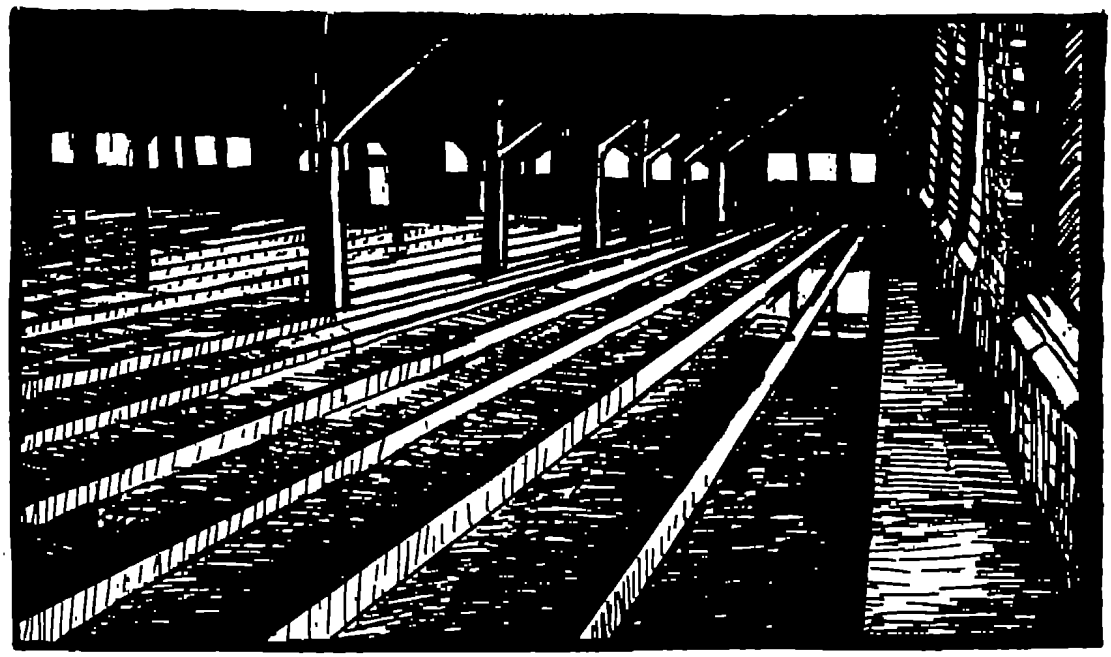


FIG. 26.—Starch settling tables.

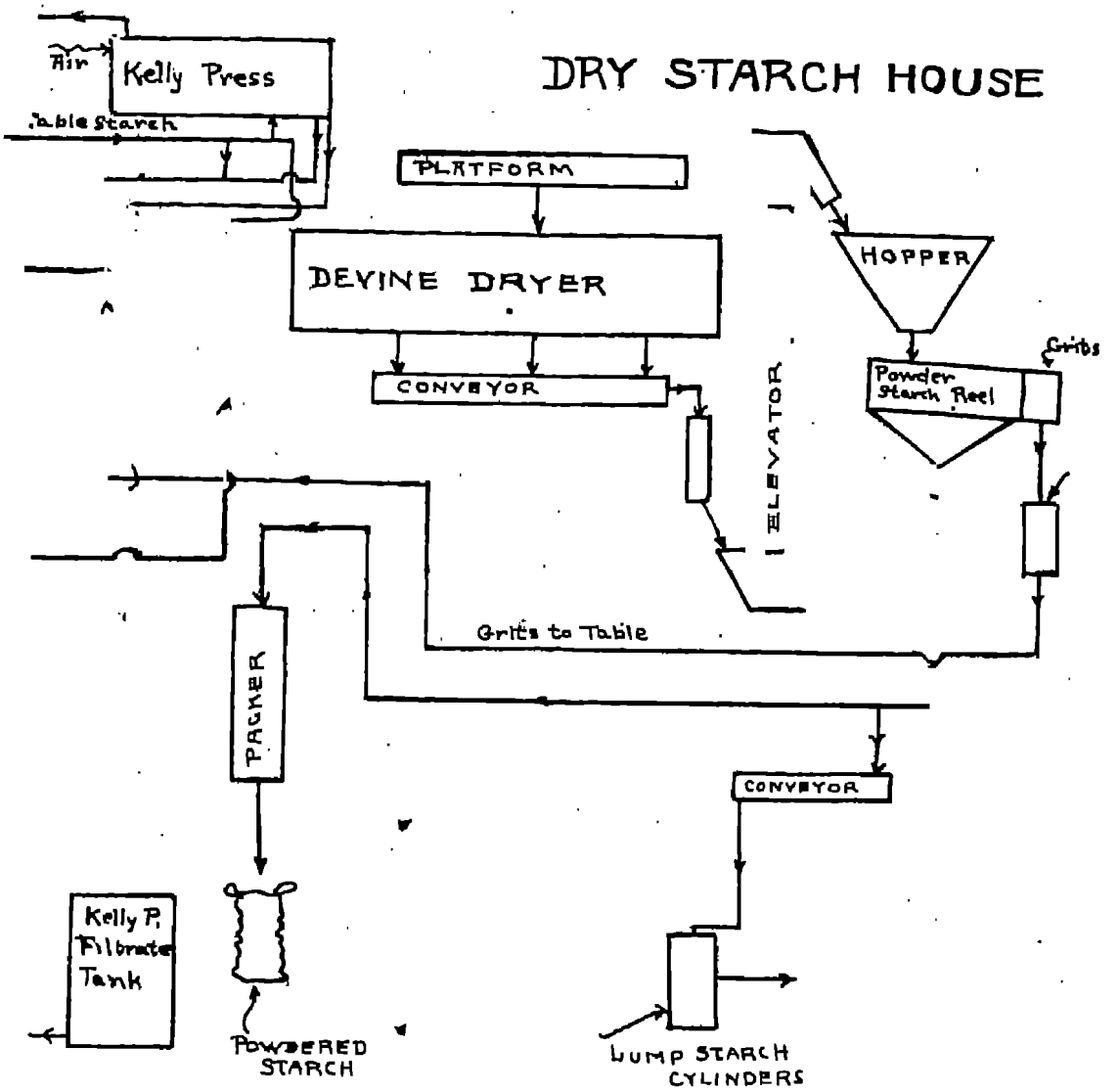
In the manufacture of starch there are different methods of separating it from corn but there is only one process, the wet process, which produces a starch of high quality from corn.

In the wet process shelled corn is purchased by the carload and is cleaned by fanning mills and sieves. After the cleaning it goes to the steeps which are upright tanks holding about two thousand bushels each. In these large tanks the corn is steeped for about forty hours with warm water containing sulphurous acid. The sulphurous acid is used to prevent fermentation and to soften the glutenous part of the corn. From the steeps the softened corn goes to the degerminating mills, which tear the corn so that the germs are freed from the kernels. The mass from the degerminating mills is passed into long vats where the germs are separated by taking advantage of the fact that they are lighter than the other parts of the corn and thus float while the remainder sinks. The germs float

over a weir and are sent to the oil house to have their oil expelled. The remainder of the corn constituents sinks and passes down to fine grinding mills of the Buhr Stone type which disintegrates the starch, gluten, and fiber very thoroughly.

From the Buhr Stone mills the finely ground mass of starch,

PLATE 6



Simplified flow sheet of a dry starch house.

gluten and fiber goes down through the mill house, story by story, passing first through perforated copper and then silk reels. The fineness of these is increased on each lower floor. These reels separate first the coarser material from the starch, as the skins or bran of the corn kernel. The finest silk reels separate from the starch everything but the liquefied gluten. The material separated from the starch by the reels is passed on to the feed house. The separation of liquefied gluten from the starch is accomplished by passing the dilute

starch and gluten mixture slowly over long narrow tables which have a very gentle slope. The starch settles on these tables and the gluten flows off at the end. After tabling, the starch goes to large presses in which it is washed with filtered water until a starch of purity is obtained.

Steeping the Corn. The purpose in steeping the corn as already mentioned is to soften the glutenous part of the kernel and to facilitate the removal of the skin and germ and to hasten the disintegration of the starch grains. There has been much study on the process of steeping corn in the manufacture of corn products, but nearly all manufacturers steep their corn differently. While no one method has ever become standard still practically all corn at the present time is steeped in the presence of sulphurous acid. The sulphurous acid is used both for its softening effect on the glutenous part of the corn, and because it is a strong germicide and checks to a great degree putrefaction in the steep tanks. The amount of sulphurous acid placed in the steep water is between .25% and .4%. The mechanics whereby this amount of sulphur dioxide is added to water consists of a sulphur burner and a tower containing baffles over which water trickles. The water in the sulphur tower collects the sulphur dioxide gas as it passes upward.

The steep tanks as a rule hold about 2,000 bushels of corn each. After they are filled with shelled corn, water at about 110 degrees F. and charged with sulphur dioxide as above mentioned, is added to each until the corn is completely covered. The corn is steeped at this temperature for about 40 hours. The temperature is kept constant throughout the different parts of the tank by circulating the sulphur water.

The present practice in steeping corn has grown up almost of itself, that is, no one person has ever studied it enough to master it but numerous superintendents have each contributed small points. It may be said that at present the steeping of corn is carried on in a crude way.

There are certain controlling factors which have to be observed in steeping. The temperature must be high enough to rapidly soften the corn, as time is money in the operation of large plants. Still the temperature must not be high enough to start in any way the gelatinization of starch or in any manner injure the amylo-cellulose walls of the starch granules. In steeping, temperatures are necessarily used at which putrefactive bacteria flourish. In the earlier factories the corn in the steep tanks was a foul putrefying mass causing a nuisance in the neighborhood. Because of this condition corn starch manufacturers in looking about for germicides to place in the steep tanks decided on the use of sulphur dioxide and this practice has become quite universal.

There are three important results obtained by the use of sulphurous acid in steep water. First, the foulness of the steep tanks is eliminated. Secondly, the sulphurous acid is found to soften the corn more effi-

ciently than just warm water alone. This is due to the action of sulphurous acid on the proteins of the corn. Thirdly sulphurous acid reduces the loss of corn proteins in steeping. This is due to the elimination of putrefaction which in the absence of a germicide converts much protein into foul gases.

This reduction of protein putrefaction is a great improvement over the early factories in which 60% of the constituents of the corn was lost. At present only 1% to 5% of the total constituents of the corn is lost in the processes of manufacture.

While sulphurous acid does keep down putrefaction, that is, the growth of putrefactive organisms, still many bacteria do grow in the steep tanks during steeping with sulphurous acid and a certain amount of proteolysis is continuously going on as is shown by the following data:

BACTERIA IN STEEP-WATER AT END OF STEEPING.

Samples	*Bé.*	*Bact. per cc.*
1	2	187,000
2	1.8	102,500
3	2.5	168,000
4	2.1	172,000
5	2.7	412,000
6	2.2	297,000

Kind of Bacteria in Steep-water. Out of 60 cultures inoculated into litmus milk 28% peptonized the casein. Of these 60 cultures examined 53 were spore-formers.

That there is considerable corn protein (zein) liquefied by the presence of sulphurous acid during steeping is indicated by the following figures:

LIQUEFACTION OF PROTEIN IN CORN DUE TO .138% SO_2 DURING 40 HRS. STEEPING AT 110 F.

10g Samples	*Protein Liquefied in SO_2 Water*	*Protein Liquefied in Distilled Water*
1	4.160%	2.516%
2	4.386%	2.328%
3	4.250%	2.014%

NOTE.—There were considerable numbers of bacteria in the samples steeped in distilled water.

The chemical analysis of an average sample of corn is:

Moisture	14%
Ash	1.85% D.S.
Protein	10.10% D.S.
Starch	80.63% D.S.
Fat	4.12% D.S.
Fiber	3.50% D.S.
Soluble	4.70% D.S.

During steeping, some of the salts, proteins, and soluble carbohydrates pass out through the covering membranes of the corn kernel and are recovered only by evaporating the steep water down to 18 degrees Bé. and spraying this syrupy mass upon the corn gluten feed during drying.

Bacterial action sets in immediately upon starting a steep as mentioned above. In spite of the sulphurous acid the germ count goes to hundreds of thousands per cubic centimeter. Considerable amounts of lactic and acetic acid also accumulate during steeping. Also a certain more or less uniform amount of protein is liquefied due to bacterial action, to the liquefying effect of sulphurous acid, or to the proteolytic enzymes of the corn. The steep water which is drained from the steeped corn is generally from 2 to 6 degrees Bé., depending on whether a circulating system or a simple holding system of steeping is employed. The bacteria of the steep tanks are very largely high acid resisting types, B. bulgaricus being readily isolated from the steeps when lactose agar plates containing .4% lactic acid are used for culturing. It is this organism which often produces ropiness of the corn further on in the process, that is, in the starch and feed reels. From each 2,000 bushel steep tank there is obtained after steeping about 9,000 gallons of light steep water. The analysis of this light steep water may be as follows:

Baumé	3.0
Ash	20. %
Protein	38. %
Organic not protein	49. %
Acidity, figured as HCl	4.5%
SO_2	0.0%

NOTE.—Elements present in the above ash are Ca, Mg, P, Al, Fe, Na, K, and Cl.

The "Sweet Process" or "Alkaline Process" is an older method of steeping than the sulphurous acid method. The nature of this process is indicated by the name. This method was in use for many years and is in use to some extent to-day. By this process the corn was placed in large tanks of lukewarm water to which alkali had been added. The corn in these tanks of alkali was allowed to rot for several days. The putrefaction became very foul and only the starch was used as a commercial product. The remainder of the constituents of corn were made useless by the alkali or were destroyed by the putrefaction. A starch of high purity was made by this process but the process was too foul and wasteful to be practiced to any extent. It should be noted that this process utilized a combination of the actions of alkali and of bacteria. Little starch was lost in this form of steeping due to the fact that bacteria are practically helpless in their attack upon the starch granule so long as the starch cellulose wall remains intact.

Still another method of steeping corn used some years ago was

the "Durgen Process" which was the steeping of corn by allowing a stream of water heated to just below the gelatinizing point of corn starch, to pass continuously through the corn in the steep tanks for about three or four days or until the grain had softened properly. This method had advantages over the "Rotting Process" and the "Sweet Process," in that the glutenous matter of the corn could be used for feed. However, it is not as satisfactory as the "Sulphurous Acid Process" in that it requires more time and fuel. Also large amounts of corn solubles are lost, the volume of water passing out of the steeps being too great to be condensed for the retention of corn solubles.

In any process of steeping it must be remembered that whatever amounts of carbohydrates, proteins, or of salts are in solution inside of the swelled corn kernels at the end of the steeping process are lost as the kernel is then cracked in the degerminator and only solid matter is recovered. This is partly the reason why in the modern process of the manufacture of corn products it is impossible to do better than to reclaim from 95% to 97% of the weight of corn taken into the factory. Under the subject of gluten settlers it will be mentioned that the waste water flowing away from the corn products plant contains about 350 grains of solid matter per gallon or nearly a ton of material lost for every thousand bushels taken into the plant. This solid matter in the waste water is about one-half protein. This material is in a colloidal condition to a considerable extent and has resisted all attempts directed toward its reclamation.

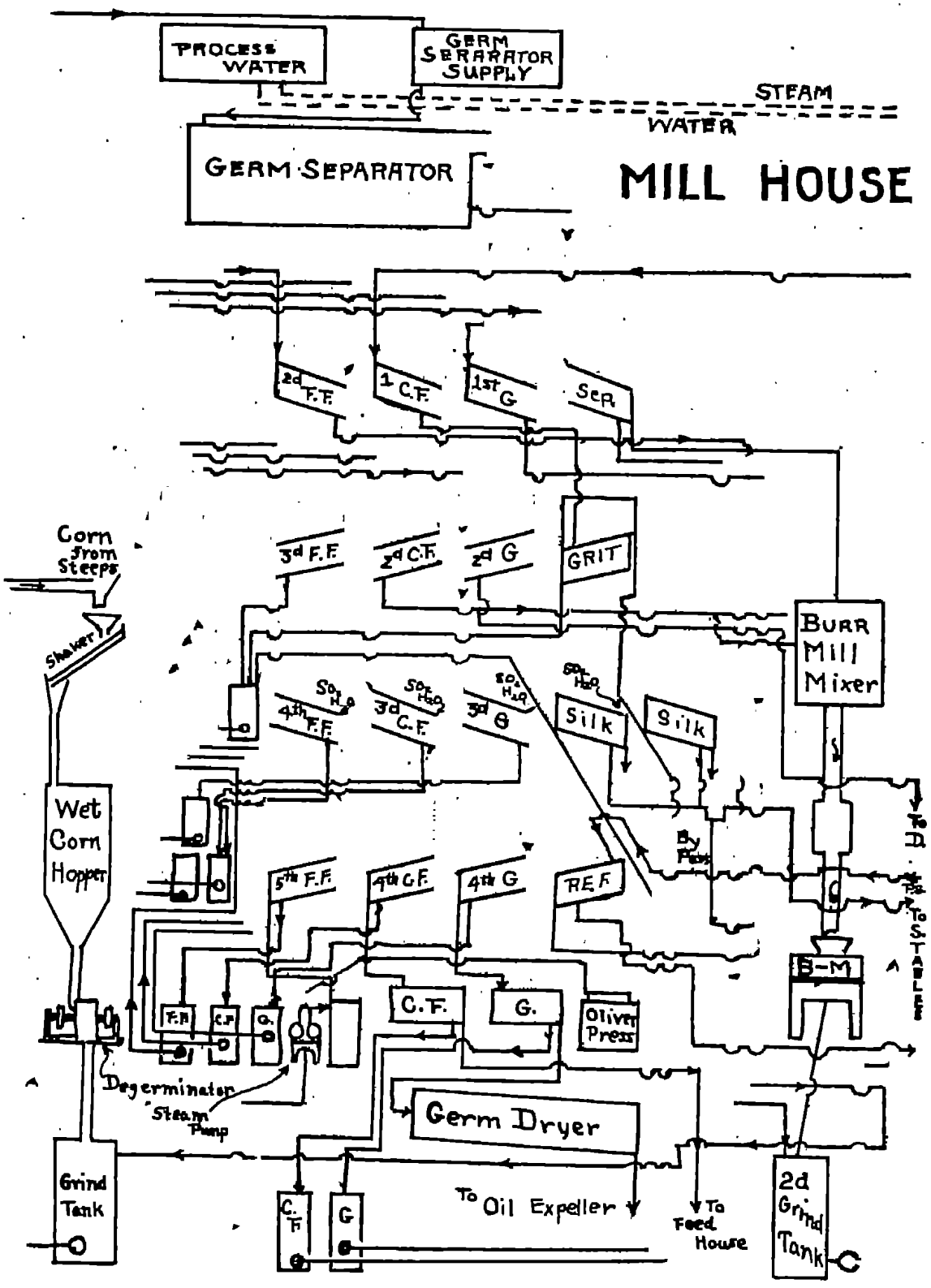
The secret of high efficiency in reclaiming corn constituents in the wet process of corn products manufacture, and also the proper separation of the different parts of corn, lies in the control of steeping. If the steeping is wrong, the whole system goes wrong. The subject of steeping invites much study and research. In other words the steep tanks should be reduced to both chemical and bacteriological control.

The separation of the germ, gluten and starch is accomplished in the wet process by the reels. These are long open cylinders covered with perforated copper or silk depending upon the work to be done by the reel. The germs are separated by the coarse copper reels. The starch is separated from the coarse and fine feed, by the coarse feed reels, the No. 9, the No. 12 and the No. 17 silk reels. Sometimes even No. 20 silk reels are used.

FINENESS OF REEL COVERINGS.

Perforations in coarse copper reels.....	8 per inch
Perforations in fine copper reels.....	20 per inch
Mesh of No. 9 silk.....	86 per inch
Mesh of No. 12 silk.....	122 per inch
Mesh of No. 17 silk.....	167 per inch
Mesh of No. 20 silk.....	178 per inch

There are many problems to be considered in the operation of the reels but perhaps the worst is a bacteriological trouble, that is, ropiness



Simplified flow sheet of mill house.

which absolutely stops up the silk on the reels. There are many "rope" producing organisms. Many of these have been investigated in connection with milk but little work has been done in connection with corn products plants. However, it is safe to say that any organism which can produce ropiness at all can produce it in the presence of corn.

In the sulphurous acid process of corn products manufacture many "rope" producing organisms are unable to survive at all in the presence of a slight amount of sulphurous acid. This is not true of B. bulgaricus and a few spore bearing members of the "rope" producing group of bacteria which have been found to stand 18% SO_2 in a solution containing ground corn.

The "rope" producing organisms of milk as given by Hammer are:

Bact. visco-fucatum
Bact. album
Bact. healii (sp. nov.)
Bact. bulgaricum
Bact. casei
Bact. surgeri
Bact. lactis acidi
Bact. visco-doccoidium
Bact. lactis viscosum (Adametz)
Bact. para viscosum (sp. nov.)
Bact. lactis pituitosi
Bact. aërogenes (Escherich)
Bact. cartilagineum
Bact. peptogenes
B. rubefaciens
B. droseræ
B. harisonii
B. viscosymbioticum (sp. nov.)
B. hessii
B. vulgatus
B. kleinii
B. pruchii
Str. taette
Str. pyogenes
Str. lacticus var. hollandicus (comb. nov.)
Str. viscosus
M. rosaceus
M. viscosus b.
M. pituitoparus
M. mucofaciens
M. freudenreichii

The "liquor-containing" ground corn going to the reels for separation is made up with water which has been tempered to between 85 degrees and 87 degrees F. The factor of temperature is carefully controlled in reeling in order to have uniform separation by the reels and a definite yield of starch. As 85 degrees F. is a very suitable temperature for the growth of bacteria more SO_2 gas is added to the starch liquor and feed liquor to prevent the production of ropiness in the reels. It is found that at the end of steeping the percentage of SO_2 in the steep water has dropped from 25% to 10% and at the separator heads the SO_2 is .032%. Thus it can be seen that in the feed reels especially, more sulphur dioxide must be added as the gluten ferments very quickly unless there is a germicidal agent present.

The gluten settlers are large tanks usually made of cement into which the gluten which flows from the tables passes and is allowed to stand until the gluten has settled out. It generally requires 14 to 24 hours for the gluten to settle from the water. The supernatant water is then drawn off and runs away as waste water. As mentioned under steeping this waste water or "gluten settlers water" contains about 350 grains of solid matter per gallon. To reduce this amount of solid matter per gallon is one of the big problems yet unsolved in the corn products industry. About half of this 350 grains per gallon is protein in the water soluble state. This protein is very likely the result of bacterial action on the protein of corn in the steep tanks.

TABLE III.

GELATINIZING TEMPERATURES OF SOME COMMON STARCHES AS DETERMINED BY THE THERMO-SLIDE AND WATER-BATH METHODS.

	Temperatures Are Degrees Centigrade			
	Thermo-Slide Method		*Water-Bath Method*	
Kind of Starch		*Average*		*Average*
Arrowroot	74.4 74.8 74.6	74.6	74 to 75	74.5
Corn	70.6 71.2 71.0	70.9	71 to 72	71.5
Navy bean	76.0 75.4 75.4	75.6	75 to 76	75.5
Sweet potato	82.6 82.6 82.4	82.5	82 to 83	82.5
Irish potato	67.6 67.8 67.8	67.7	67 to 68	67.5
Wheat	65.5 65.0 65.1	65.2	65 to 66	65.5

GELATINIZING TEMPERATURE OF STARCHES FROM THE GRAIN SORGHUMS.

Kinds of Starch	Thermo Slide Readings	Average
White kaoliang	78.0° C. 78.0° C. 78.1° C.	78.0° C.
Brown kaoliang	76.2° C. 76.4° C. 76.4° C.	76.3° C.
Feterita	75.4° C. 75.6° C. 75.6° C.	75.5° C.
Orange cane	72.2° C. 72.4° C. 72.6° C.	72.4° C.
Red kafir	74.8° C. 75.0° C. 75.0° C.	75.0° C.
White kafir	72.0° C. 72.1° C. 72.4° C.	72.2° C.
Pink kafir	64.6° C. 65.0° C. 64.6° C.	64.7° C.
White milo	74.0° C. 73.8° C. 74.4° C.	74.1° C.

After C. K. Francis and O. C. Francis.

An analysis of a sample of "gluten settlers water" resulted as follows:

Ash	12.195%
Protein	49.600%
Organic not protein	38.207%

NOTE: Half of the ash is composed of phosphorus and potassium salts.

Glucose and Corn Sugar. The two most important products manufactured from corn starch are glucose and corn sugar. When a starch solution containing a mineral acid as hydrochloric acid is heated, the hydrolysis of the starch takes place. Brown and Morris represent this fact by the following group of reactions:

$$5[(C_{12}H_{20}O_{10})_{20}] = \underset{\text{Starch}}{(C_{12}H_{20}O_{10})_{20}} + \underset{\text{Stable Dextrin Amylin Groups}}{4(C_{12}H_{20}O_{10})_{20}}$$

$$(C_{12}H_{20}O_{10})_{20} + H_2O = \begin{bmatrix} (C_{12}H_{22}O_{11}) \\ (C_{12}H_{20}O_{10}) \end{bmatrix} \text{etc., etc.}$$

$$\text{to } (C_{12}H_{20}O_{10})_{20} + 19\ H_2O = \begin{cases} (C_{12}H_{22}O_{11})_{19} \\ (\text{Maltose}) \\ (C_{12}H_{20}O_{10}) \end{cases}$$

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Dextrose.}}{2C_6H_{12}O_6}$$

Note—The above reactions may take place either from the effect of an acid or from the effect of diastase and maltase enzymes.

Glucose made from corn starch is labeled by the manufacturer "Corn Syrup Unmixed" or C.S.U. It is also often spoken of as crystal syrup, corn syrup or starch syrup. Nearly all glucose in the United States is made from corn starch. Germany makes large amounts of glucose from potato starch. In this country the use made of corn syrup is continually becoming more extensive and varied. This was especially true during the war when the government put restrictions on cane sugar. It is used as a table syrup flavored with maple, sorghum, cane, honey, etc. It is becoming extensively used in canning, in the manufacture of jellies, jams, bread, beer, ice cream, candies, and tobacco. Special grades are used in the leather industry, in the textile industry, and the moulding of metals.

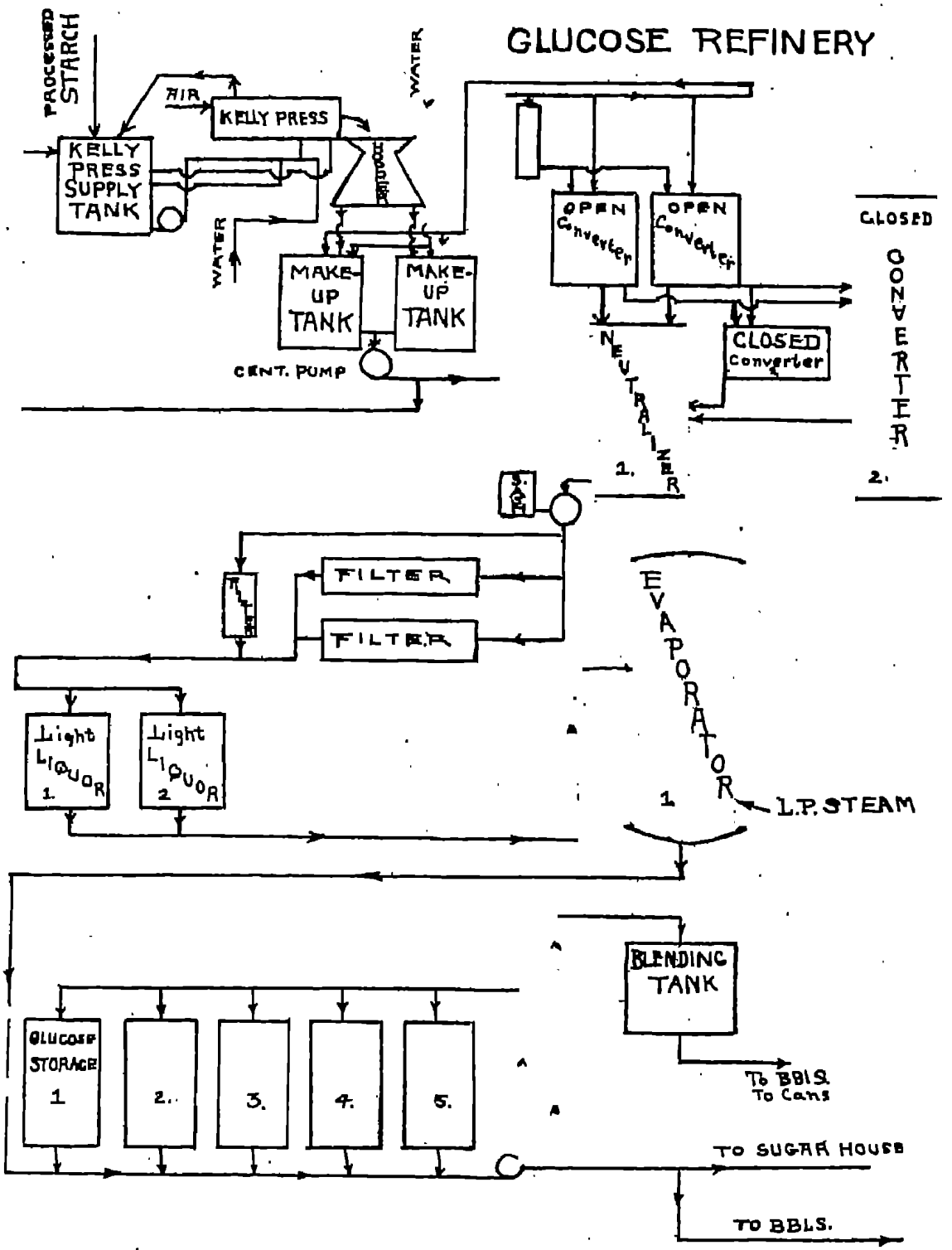
The chemical analysis of glucose shows it to be on dry basis about 40% dextrose, 40% dextrin, 19.5% maltose, and .5% ash. Leech gives the following analysis for glucose:

Dextrin	29.8 % to 45.3%
Maltose	4.6 % to 19.3%
Dextrose	34.3 % to 36.5%
Ash	.32% to .5%
Water	14.00% to 17.2%

U. S. Standard glucose is 41 degrees to 45 degrees Bé. at 100 degrees F. and 41 degrees Bé. Glucose should not contain more than 1% ash.

Glucose should be made at least 40 degrees Bé. as less than this consistency is subject to fermentation due to the high percentage of water present. Glucose should also contain at least 40% of sugar. When the sugar content is less than this percentage fermentation is not inhibited and cloudiness results as it is a fact that the germicidal effect of sugar in glucose containing less than 40% sugar is not great enough to preserve the glucose. Also the dextrose content of glucose should not be greater than 50% as on storage crystallization may set in.

In the manufacture of glucose, starch liquor at about 18 degrees Baumé from the starch tables is run slowly into a large tin-lined or porcelain lined converter containing steam coils. Before starting the stream of starch liquor into the converter a small amount of water containing .12% to .2% hydrochloric acid is placed in the bottom and made to boil vigorously. The starch solution is then run in, while a vigorous boiling is maintained inside the converter. The amount of acid used in the manufacture of glucose is generally .08% acid. When the converter is three quarters full of liquefied starch solution, it is closed and the steam pressure is raised to a temperature between 15 and 40 pounds. Different plants use different steam pressure for converting. When the steam pressure is up samples are taken and tested with iodine solution to determine by color reaction when



Simplified flow sheet of one type of glucose refinery.

the proper conversion stage is reached. A type sample from the previous batch is generally used for comparison. The period of conversion is from a few minutes to a half hour depending upon the amount of steam pressure and also upon the percentage of acid used.

After conversion of the starch solution to glucose liquor it is neutralized with sodium carbonate. This neutralization converts the hydrochloric acid present in the glucose into salt and water. The glucose liquor as it comes from the neutralizer is dark in color and bitter. To overcome these two faults the liquor is customarily passed through bone black which removes much of the color and the bitterness. The filtered liquor is then evaporated in a vacuum pan to about 30 degrees Bé. Next it is passed through a bone black filter again. The final bone black treatment removes practically all of the color and bitterness. After this last filtration the heavy liquor is evaporated to 43 degrees Bé., which is the consistency at which it is generally found on the market.

There has never been found a material which will exactly take the place of bone black in decolorizing and removing the bitterness from glucose and corn sugar solutions. This powerful decolorizing effect of bone char on sugar solutions has not been adequately explained. However it is believed to be due to the specific adsorption of the color substances. While it might seem that vegetable charcoals should have as great decolorizing power still they are not found to be efficient in practice. The search for a substitute for bone black is now a century old, but perhaps no product has been found which has the peculiar decolorizing power of charred bone. There are some new products on the market known as filtering carbons for which is claimed decolorizing powers as great as bone black; however, none of these specially prepared carbons have come into use in glucose and corn sugar plants as unaided decolorizers.

The chemical analysis of bone black is as follows:

9% Carbon.
81% Calcium phosphate.
9% Calcium carbonate.
1% Iron compounds, compounds of silica, nitrogenous compounds, and a small amount of hydrogen.

The bone black filters used in decolorizing glucose are tall iron cylinders each having a capacity of from 16 to 20 tons of bone. There is a syrup inlet at the top and a syrup outlet at the bottom. However, the syrup outlet pipe is carried up the side of the filter until it reaches the level of the top of the bone on the inside of the filter. There is a manhole at the bottom for removal of spent bone.

Before filling the filter with bone black a filter cloth of burlap is placed on the wooden or wire rack at the bottom. Then the bone is carefully packed in, acidified and washed.

The bottom of the bone filter has four connections, outlet, hot water, steam, and waste pipe. The top of the filter has seven different

connections, inlets for syrup, for steam, air vent, compressed air pipe, light liquor pipe, heavy liquor pipe, wash water pipe and tempering acid inlet.

Bone black in the granular form corresponding to a 12″ x 28″ mesh is generally used in the filters.

The value of having the syrup outlet pipe rise as high as the bone on the inside of the filter is to prevent rapid passage of syrup through the filter and channeling of the bone.

After a filter has been freshly filled the first syrup to run is almost entirely free from coloring matter but after a time the decolorizing power of the bone begins to weaken and faint color begins to appear in the syrup coming from the filter. This weakening of the bone increases until the bone loses its decolorizing power entirely. However, in practice this point is never reached. When the decolorizing power of the bone shows considerable weakness the filter is filled with water which displaces the light liquor and washes the remaining glucose from the bone. When this wash water becomes 10 degrees Bé. it is called sweet water. Water is continuously run through the bone as long as the Bé. does not fall below 1 degree Bé. When the wash water becomes less than 1 degree Bé. the attempt to reclaim sugar left in the bone is discontinued and the washing of the bone with boiling water is begun. This wash water goes to the sewer. This is an important loss of sugar but there is no way of remedying it. The reason for discontinuing the washing of the bone before all of the sugar or glucose is removed is because with the high cost of fuel it is impractical to reclaim sugar from wash water by evaporation when the sugar content of the water falls below 1 degree Bé. or 1.81% dry substance. After being washed with boiling water as long as any solids can be removed the bone is drained and "steamed down" to remove the last of the wash water. From the filter it goes to the drying tubes over the kilns. When dry it is dropped into long tubular retorts where it is kept at red heat until all foreign matter is burned out. It next passes through cooling tubes before dropping to a belt conveyor which takes it back to reels or sieves which take out the powdered portion of the bone. This part constitutes from 1 to 3% of the bone after revivification. After replacing the bone in the filter it is boiled for a half hour with dilute hydrochloric acid and then thoroughly washed with pure water, thus making the filter ready to receive the sugar liquor again. The decolorizing capacity of 20 tons of bone may be 30,000 lbs. of finished glucose of 43 degrees Baumé.

A later method for the manufacture of glucose and corn sugar without the expense of bone black filtration has been invented and perfected by the writer and A. W. H. Lenders. In this method the action of certain bacteria is utilized to rid the starch of its nitrogenous impurities before starting the process of manufacturing the hydrolyzed products. The organism most generally used in destroying the protein residue in the starch as it comes from the starch tables is a member of B. putrificus group of bacteria. This organism is a success in

this application in that it has the ability to liquefy the residual protein of starch but does not have the ability to attack the starch granules themselves.

Corn sugar or grape sugar is the name given to dextrose sugar made from starch. This sugar exists commercially in four different forms, 70% sugar, 80% sugar, 90% sugar, and anhydrous corn sugar. "Seventy sugar" is sometimes called "Brewers' sugar." It is hydrous starch containing 70% dextrose and not more than .8% ash. "Eighty sugar" is hydrous starch sugar containing not less than 80% dextrose and not more than 1.5% ash. "Ninety sugar" contains not less than 90% dextrose and not more than .8% ash. "Anhydrous" sugar is the invention of Dr. Behr and contains very nearly 100% dextrose and a low ash content. It contains no water of crystallization. On account of the high cost of manufacture of this last sugar little has been used commercially.

The process for the manufacture of corn sugar is the same as that for the manufacture of glucose except that the conversion period instead of being a few minutes is about one and a half hours long. After the two filtrations and the production of 43 degrees Bé. liquor, the sugar is crystallized on long tables. After the sugar is crystallized the cakes are pressed in hydraulic presses to press out the "hydrol," a dark bitter liquid which if left in the sugar gives darkness of color and great bitterness of taste to the sugar. The amount of "hydrol" which is pressed out of the sugar is about 40% of the original weight of the sugar. It has been stated that grape sugar is bitter and has an unpleasant flavor due to nitrogenous impurities. This description was true a few years ago but many improvements have been made in this product during the last few years. Combining their bacterial starch purification process with corn sugar-making, the writer and A. W. H. Lenders have invented a process of sugar-making, which can produce a corn sugar in the form of a dry white powder containing no bitterness and having the quality of great solubility.

The terms glucose and dextrose are often used in texts on chemistry as synonyms but in the corn products industry the terms glucose and dextrose have come to have very different meanings. The corn syrup containing about 40% grape sugar, 40% dextrin, and 20% water is called glucose while dextrose is the term designating the grape sugar $C_6H_{12}O_6$ which is usually manufactured from corn starch and exists in the form of the crystalline monohydrate $C_6H_{12}O_6H_2O$. This substance is nearly white and may be dried to about 9% moisture and then may be powdered. It melts at about 90 degrees C.

In the conversion of starch into dextrose or corn sugar a higher percentage of hydrochloric acid is used than is the case in the manufacture of glucose. Whereas, .08% HCl is sufficient for glucose manufacture, .2% HCl is often used in the production of high purity dextrose or corn sugar, and the period of conversion is nearly two hours with a steam pressure maintained at 20 pounds or more in the converter. The following table gives the resulting purity of several

experimental conversions in which .2% hydrochloric acid was used in the starch liquor.

% Dextrose as D.S.
95.1
94.2
95.0
93.0
97.0
95.4
95.9
96.5
96.3
96.0

average 95.44% Dextrose.

As given by Martin the comparative hydrolyzing power of different acids is as follows:

Acid	*Equivalent Weight*	*Hydrolysing Power*
Hydrochloric Acid	36.5 grams	100
Sulphuric Acid	49. grams	100
Nitric Acid	63. grams	2.5
Tartaric Acid	150. grams	1.6
Formic Acid	46. grams	100

For practical purposes the rate of hydrolysis is proportional to the concentration of the hydrogen ions.

The purity of the sugar resulting from a conversion of starch depends upon the purity of the starch which goes into the converter. As was mentioned under starch manufacture the starch as it comes from the tables contains about .4% of protein. It has been found that this starch is capable of being converted into 90% dextrose but that when starch with as low as .05% protein is converted it produces a sugar of as high as 99% dextrose.

The advantage of the bacterial method of purification of starch in corn sugar making, over the old bone black method is very marked in several different steps in the process. In the manufacture of corn sugar from purified starch no dark bitter modified protein derivatives are produced during the conversion, thus bone black is not necessary for decolorization. Further it is found that a higher purity sugar is produced due to the absence of these modified proteins.

In crystallizing this sugar on the casting floors it is found that 100% crystallization can be obtained whereas corn sugar as ordinarily made by the bone black method gives only a 60% to 80% crystallization. The remaining uncrystallized portion of the sugar contains the bitter protein derivatives and that sugar which the presence of proteins has not allowed to crystallize. This material is pressed out of the cakes of sugar by great pressure and appears as a dark brown syrup called "hydrol." This has little or no use and is generally run into the sewer.

From the standpoint of economy of production there are three losses common to the bone black method of producing corn sugar which are not common to starch purification methods: the loss of 20% to 40% of the original weight of the sugar in the form of hydrol; the loss of sugar liquor in the bone after filtration; and the expense of bone black, its use, and revivification.

CORN PRODUCTS PLANTS IN U. S.

Name of Firm	*Location*
Penick & Ford.	Cedar Rapids, Iowa.
Clinton Sugar Refining Co.	Clinton, Iowa.
J. C. Hubinger Bros. Co.	Keokuk, Iowa.
Corn Products Refining Co.	Granite City, Ill.
Corn Products Refining Co.	Pekin, Ill.
A. E. Staley Co.	Decatur, Ill.
Corn Products Refining Co.	Argo, Ill.
American Maize Co.	Roby, Ind.
Piehl Bros.	Indianapolis, Ind.
Union Starch Co.	Edinburgh, Ind.
Huron Milling Co.	Harbor Beach, Mich.
Keever Starch Co.	Columbus, Ohio.
Corn Products Refining Co.	Oswego, New York.
Corn Products Refining Co.	Edgewater, New Jersey.
Corn Products Refining Co.	Kansas City, Missouri.

Manufacture of Feed. There are four by-products in the manufacture of starch from corn which have feeding value. These are corn bran, gluten meal, germ oil meal, and germ meal. These products are separated at different points in the process. Corn bran is separated by the coarse feed reels, gluten meal is the gluten which runs from the tables after being dried. Germ oil meal is the ground germ after all but 10% of the oil has been expelled in the oil presses. Germ meal is the ground germ after all but 2% of its oil has been extracted by gasolene or other oil solvent. The above constituents are frequently combined and called corn gluten feed.

The chemical composition of the above by-products of corn as given by Bowman and Crossley is as follows:

Feeding Stuff	*Water*	*Ash*	*Protein*	*Crude Fiber*	*Nitrogen Free Extract*	*Ether Extract*
Corn Bran..	9.1%	1.3%	9.0%	12.7%	62.2%	5.8%
Germ Meal.	8.1	1.3	11.1	9.9	62.5	7.1
Gluten Meal	8.2	.9	29.3	3.3	46.5	11.8
Corn Gluten	7.8	1.1	24.0	5.3	51.2	10.6

The value of corn gluten feed is considerably affected by the fermentations in the steeps, by the skill used in neutralizing the sulphurous acid and the acids produced by fermentation in the steeps, and the care in drying the feed before shipment.

There has been much investigation during the last few years as to the ability of certain bacteria to produce poisonous products from corn in the silo and it has been established that silage poisoning of

cattle and horses may be due to the consumption of corn silage in which toxin producing bacteria gain entrance and flourish. That a similar fermentation occasionally occurs in corn gluten feed in shipment is undoubtedly true. Now and then car-loads of feed are sent back to the manufacturers of corn gluten feed because it injures the animals which consume it. There is no literature on this subject as far as the handling of corn gluten feed is concerned. However, it is inevitable that manufacturers of corn products must maintain strict fermentative control over their products.

The percentage of moisture to be left in feed is a very important question in feed manufacture. It is a common custom to ship high moisture feeds west and to ship low moisture feeds east. This is simply another way of saying that the weather conditions after the feed has left the factory have something to do with the condition of the feed when it reaches the consumer. The moisture content of corn gluten feed usually runs about 10%, but many plants run the moisture at 12% or even higher. In allowing a moisture content of above 10% there is always the danger of fermentation as in shipping into territory of higher humidity or higher temperature the feed undergoes more or less fermentation often accompanied by heating and caking. Fermentation in feeds of relatively high moisture content is generally the result of two groups of organisms. First Asp. fumigatus weaves its mycelium all through the feed, after which strongly proteolytic bacteria begin to flourish in the inner parts of bags or in the center of heaps of feed, producing considerable heat and finally caking the feed into large blocks which cattle refuse to consume even when reground.

After the germs have been separated in the germ separator mentioned above they pass to the germ reels to be further washed. From the germ reels the germs go to the moisture expellers which squeeze out the major part of the water, after which the germs are steamed and ground and sent on to the oil expellers. In the oil expellers about 90% of the oil is pressed out. This oil is known as crude oil and before it can be used as a cooking oil it must be refined.

The refining of corn oil is accomplished by the following process. The oil from the expellers is forced through Canton flannel in a plate press and is collected in a large tank where sodium hydroxide is added to bring the whole mass to slight alkaline reaction. This excess of sodium hydroxide saponifies the free fatty acids and precipitates them. After the precipitate is allowed to settle the free oil is decanted into another tank where it is heated gently after adding 1.5% of fuller's earth. The oil is next passed through a Kelly press to take out the fuller's earth with its absorbed matter. From the Kelly press the oil is passed into a deodorizer which is a large iron tank equipped with steam coils so that the oil may be heated to a point where no moisture will condense when super-heated steam is passed through it. Care is taken at this point that the atmosphere above the oil is always steamed in order that no oxidation of the oil may take place. The oil is next chilled and filtered through filter-board in a plate press to give

a crystal clear product. The oil is then packed in various sized containers for marketing.

The percentage of fatty acids occurring in the refining of corn oil depends very largely upon the condition of the corn, in other words it depends upon the season and especially upon the weather during corn harvesting, and the condition of the corn while left in the field. The production of fatty acids is the result of several agencies among which may be mentioned the proteolytic ferments of the corn and the proteolytic and lipolytic bacteria on the corn.

The manufacturers of corn products by the wet process generally use corn of grades 3, 4, and 5. Each grade of corn varies in certain respects but the standard of the products made from it is not supposed to vary. As a matter of fact, as good starch can be made from soft corn as can be manufactured from the best corn but this is not true of corn oil or corn gluten feed made from corn. The poorer the corn the poorer the corn oil as a general rule, also darker and poorer corn gluten feed is made from poorer corn.

In the shipping of corn abroad it has been found that corn inspected and graded as No. 2 or "prime sail" has often arrived at foreign ports in such bad condition that it could not be used even for feeding animals. There are two factors which determine whether corn will or will not deteriorate on being stored or shipped. These are temperature and moisture. Corn as it usually comes from the field contains from 20% to 30% of moisture. If the weather is cold and dry as it usually is at this time of the year, no fermentation of the corn takes place. If the corn is carried over until the warm weather of spring arrives and its moisture content has become low, then there is no danger of fermentation. But whenever high moisture corn and warmth occur at the same time the corn is sure to be ruined.

In the shipment of corn there are at least three actions going on in the corn which result in shrinkage in weight. The greatest cause of change in weight is simple loss of moisture. Also the corn is suffering slight loss of weight due to respiration. A further loss which may be considerable is that due to the action of fermentation organisms in the corn.

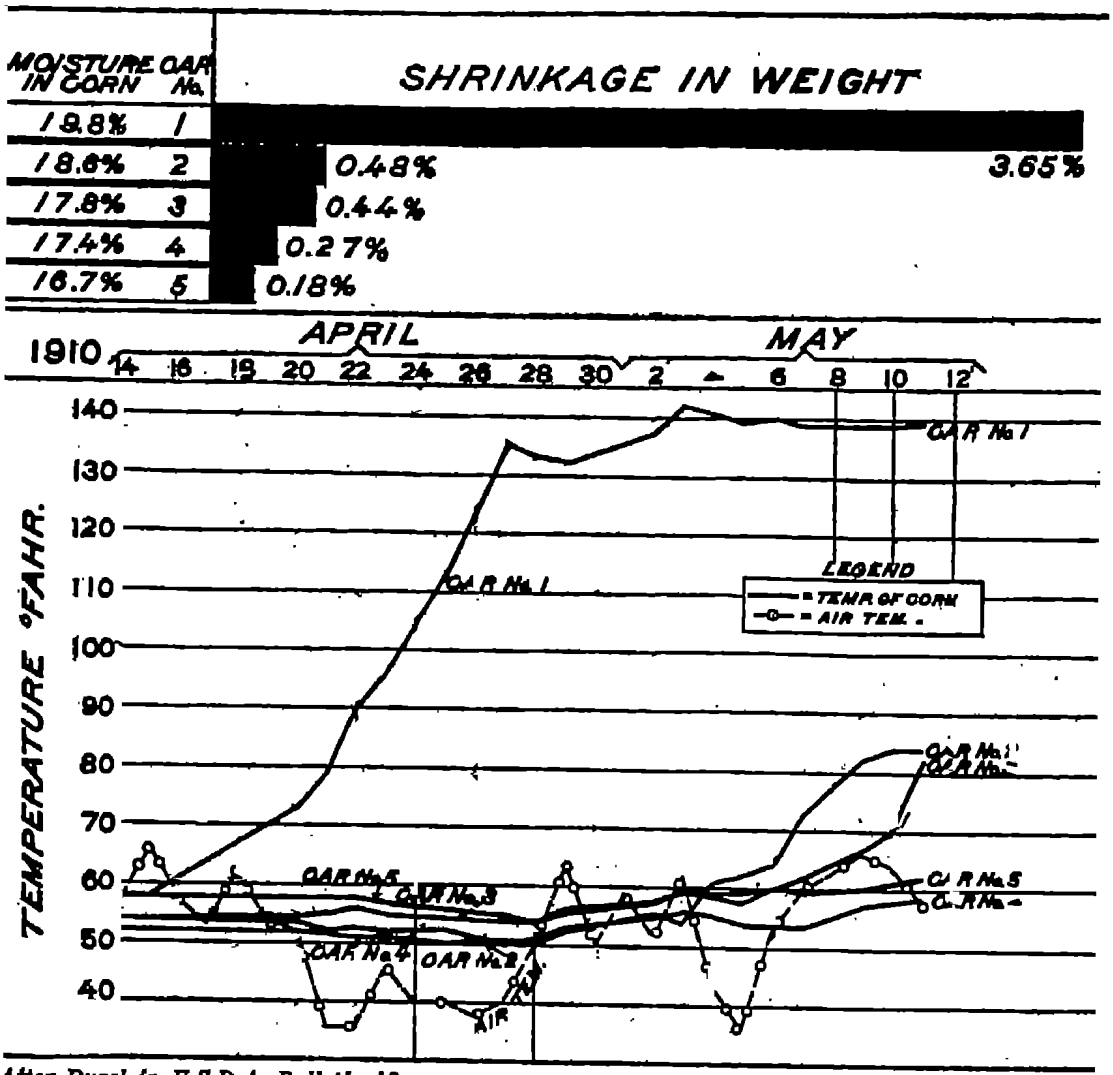
J. W. T. Duvel in U. S. Dept. Agr. Bull. No. 48 (1913) has reported an investigation of the shrinkage of shelled corn in cars in transit, and gives the following conclusions:

"(1) There is unquestionably a natural shrinkage in commercial corn during transit and while in storage.
"(2) Natural shrinkage varies with the moisture content of the corn and the atmospheric conditions to which it is exposed.
"(3) Natural shrinkage in corn that has become sour and hot is very rapid and may amount to several per cent within a day."

The conditions under which corn is stored before it reaches the market are very important to the corn products manufacturer. Con-

cerning the storage of corn the Weekly News Letter of U. S. Dept. of Agr., Vol. 4, No. 10, says:

"There was a time in the history of the corn-producing belt when rail pens were about the only available means of storing the corn crop. Much to the discredit of some corn growers this method of

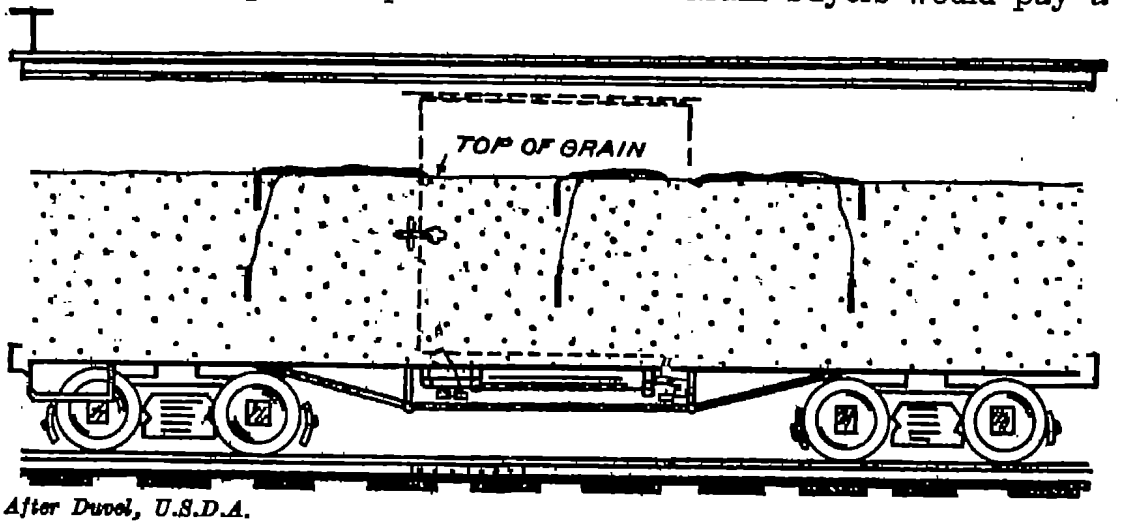


After Duvel in U.S.D.A. Bulletin 48.

FIG. 27.—Diagram showing the shrinkage in weight of the corn in each of five cars in transit from Baltimore to Chicago and return, the average temperature of the corn in each car, and the mean daily air temperature through which the cars passed from April 14 to May 11, 1910.

storing is still in vogue, even in sections where good means of storage could be afforded at little expense. It is no uncommon sight to see rail pen after rail pen filled with ears of corn and without any cover, exposed to all the rains and snows of winter, and these in sections of the country that produce the most corn and are consequently most interested in higher-priced corn. This corn remains in apparently good condition during the cold weather and is usually placed upon

the market in early spring. Filled with water, it is not long after it is loaded into box cars or vessels until it heats and spoils. The installation of elevators where such corn can be kiln dried has been brought about by this poor manner of storing the corn crop. There is a general prejudice against kiln-dried corn, resulting from the fact that kiln drying was first employed and is at present employed to a very large extent to prevent further heating and fermentation of corn that was not allowed to dry properly or was poorly stored before being placed upon the market. This state of affairs, which results from allowing the corn to remain wet during winter and necessitates the removal of the water by expensive means, keeps the price of corn lower than it would be if the corn were allowed to dry in the fields and were kept dry until placed upon the market. Grain buyers would pay a



After Duvel, U.S.D.A.

FIG. 28.—Sectional view through the center of a freight car showing the position of six electrical resistance thermometers in the determination of heat accumulation in stored or shipped corn.

better price if the general supply of corn reached them in a condition that would insure its preservation without drying and the resulting shrinkage.

"In addition to affording thorough ventilation to the stored grain and protection from driving rains, cribs should be constructed in such a manner that they can be filled and emptied with the least possible labor. For level ground double cribs with an elevated driveway and approaches that will enable the loads to be driven through the cribs and dumped or scooped out of the wagons without any high pitching are very satisfactory."

The moisture determination on corn for shipment was formerly on a very inaccurate basis but with the invention of the Brown-Duvel moisture tester the testing of corn for moisture is accurate. This method is based on the fact that when oil in which corn is placed is heated to a point above the boiling point of water, the water will all be driven out of the corn. This water which is driven out is condensed and measured and the percentage of moisture in the corn is thus calcu-

lated. Duvel, in Bur. Plant Ind. Circular 72, gives a thorough description of this tester.

Grades for Commercial Corn.

In 1914 the Secretary of Agriculture fixed the following grades for corn:

GRADE CLASSIFICATION OF WHITE, YELLOW AND MIXED CORN, SHOWING MAXIMUM ALLOWANCES OF MOISTURE AND OTHER FACTORS.

Grade Classification	*Moisture*	*Maximum Allowance of Damaged Corn*	*Foreign Material Including Dirt, Cob, Other Grains, Finely Broken Corn, etc.*	*Cracked Corn Not Including Finely Broken Corn. See General Rule No. 9*
	per cent		per cent	per cent
No. 1	14.0	2 per cent (exclusive of heat damaged or mahogany kernels)	1	2
No. 2	15.5	4 per cent (exclusive of heat-damaged or mahogany kernels)	1	3
No. 3	17.5	6 per cent (exclusive of heat-damaged or mahogany kernels)	2	4
No. 4	19.5	8 per cent (may include heat-damaged or mahogany kernels not to exceed one-half of 1 per cent)	2	4
No. 5	21.5	10 per cent (may include heat-damaged or mahogany kernels not to exceed 1 per cent)	3	3
No. 6	23.0	15 per cent (may include heat-damaged or mahogany kernels not to exceed 3 per cent)	5	7
Sample		See general rule No. 6 for sample grade.		

General Rules.

(1) The corn in Grades No. 1 to No. 5, inclusive, must be sweet.

(2) White corn, all grades, shall be at least 98% white.

(3) Yellow corn, all grades, shall be at least 95% yellow.

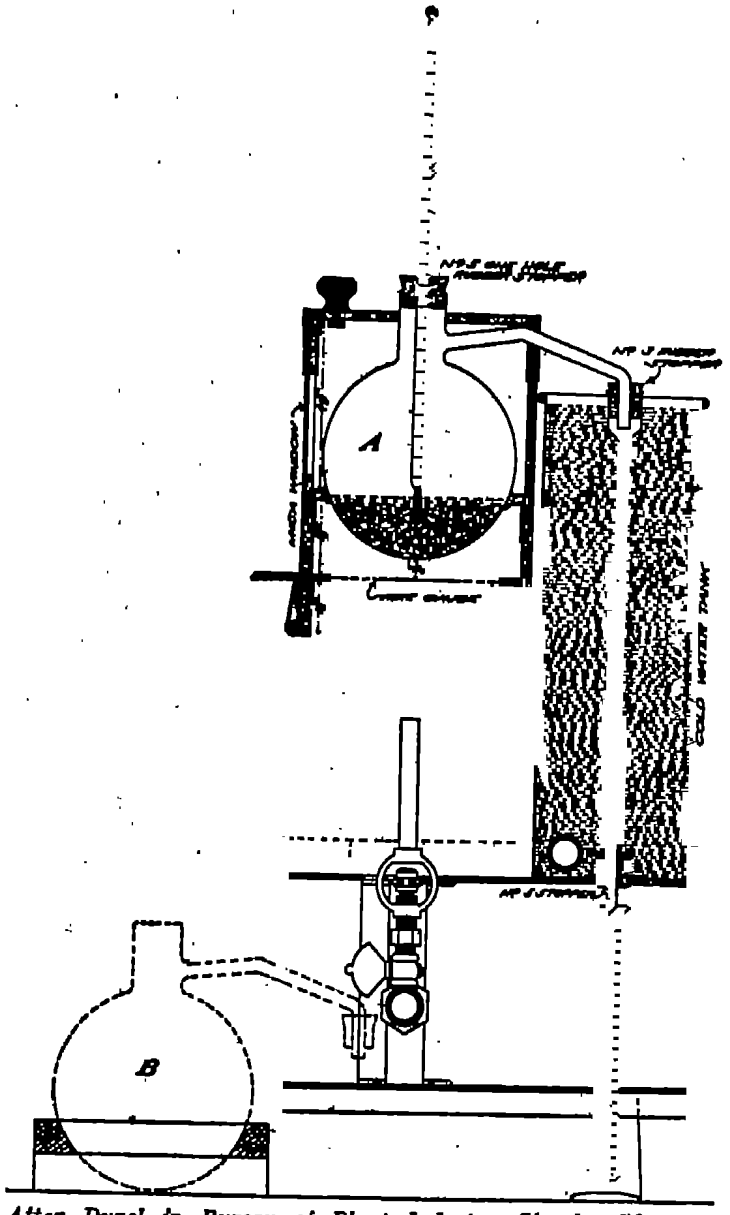
(4) Mixed corn, all grades, shall include corn of various colors not coming within the limits for color as provided for under white or yellow corn.

(5) In addition to the various limits indicated, No. 6 corn may be musty, sour, and may also include that of inferior quality, such as immature and badly blistered corn.

(6) All corn that does not meet the requirements of any of the six numerical grades by reason of an excessive percentage of moisture, damaged kernels, foreign matter, or "cracked" corn, or corn that is hot, heat damaged, fire burnt, infested with live weevils, or otherwise of distinctly low quality shall be classed as sample grade.

(7) In No. 6 and sample grades, the reasons for so grading shall be stated on the inspector's certificate.

(8) Fine broken corn shall include all broken particles of corn



After Duval in Bureau of Plant Industry Circular 72.

FIG. 29.—Moisture tester for corn. Sectional view, showing the various parts properly connected for use. *A*, Distillation flask in position, three-eighths of an inch above the wire gauze; *B*, distillation flask in wooden rack, used only during filling.

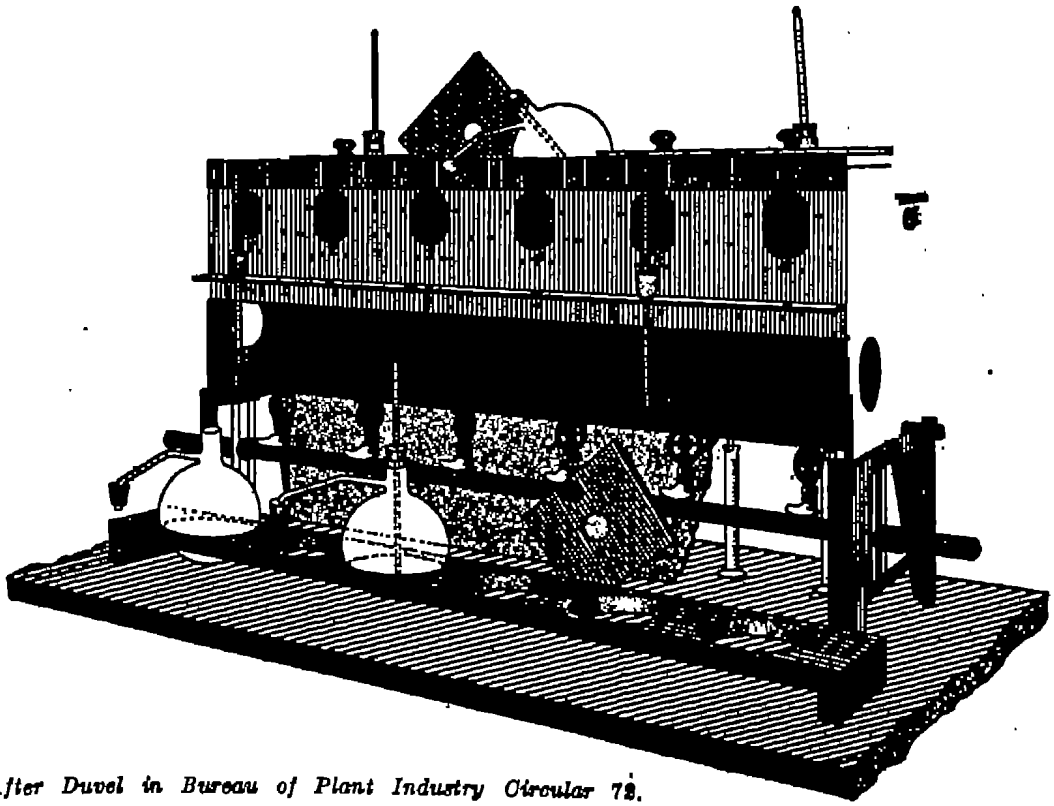
that will pass through a metal sieve perforated with round holes nine sixty-fourths of an inch in diameter.

(9) "Cracked" corn shall include all coarsely broken pieces of kernels that will pass through a metal sieve perforated with round holes one-quarter of an inch in diameter, except that the finely broken

corn, as provided for under rule No. 8, shall not be considered as "cracked" corn.

(10) It is understood that the damaged corn, the foreign material (including dirt, pieces of cob, finely broken corn, other grains, etc.), and the coarsely broken or "cracked" corn as provided for under the various grades, shall be such as occur naturally in corn when handled under good commercial conditions.

(11) Moisture percentages, as provided for in these grade specifications, shall conform to results obtained by the standard method and



After Duvel in Bureau of Plant Industry Circular 72.

FIG. 30.—Six-compartment corn tester with rack.

tester described in Circular No. 72, Bureau of Plant Industry, U. S. Department of Agriculture.

The following description and illustration of the different types of corn is taken from Duvel in U.S.D.A. Bul. 168.

Damaged Corn.

"As shown in the grade classification, the grades 1, 2, and 3 may contain not to exceed 2, 4 and 6 per cent, respectively, of damaged corn, such as "cob-rotten" corn, "blue eyes," etc., but these first three grades shall not include heat-damaged or mahogany kernels. Grades 4, 5 and 6 may contain not to exceed 8, 10 and 15 per cent, respectively, of damaged corn, a portion of which may consist of heat-damaged or mahogany kernels. The heat damaged or mahogany kernels per-

missible as a part of the damaged corn, shall not exceed one-half of 1 per cent in No. 4 grade, 1 per cent in No. 5 grade and 3 per cent in No. 6 grade; but the total damaged in these three grades shall not exceed 8, 10 and 15 per cent respectively."

In an investigation of the use of the acidity as a factor in determining the degree of soundness of corn Besley and Boston arrived at the following conclusions:

"(1) All corn, unless in a state of putrefaction, contains acid-reacting substances which impart to the corn a certain degree of acidity.

"(2) There is a great variation in the degree of acidity of corn, ranging from 9 or 10 c.c. to over 100 c.c. The degree of acidity can be determined by the acid test to within 0.5 c.c.

"(3) The source of corn acidity is mostly in the germ. The source of increase in the degree of acidity is almost entirely in the germ.

"(4) All corn judged damaged by the eye is higher in degree of acidity than corn judged sound by the eye.

"(5) In a general way the degree of acidity of corn varies inversely with the germinative power.

"(6) The degree of acidity of corn increased directly with the percentage of damaged kernels as determined by mechanical analyses.

"(7) The degree of acidity of corn is greatly increased by the action of fermentation and high temperature.

"(8) Throughout the year, from harvest to harvest, there is a gradual increase in the degree of acidity and a corresponding decrease in the percentage of germination of corn arriving at terminal markets.

"(9) With respect to quality and soundness the degree of acidity of corn is commensurate with the commercial grading at terminal markets.

"(10) The degree of acidity of corn is a criterion of soundness and quality.

"(11) From the standpoint of commercial grading, corn with a degree of acidity less than 22 c.c. is normally sound and of good commercial quality; corn with a degree of acidity between 22 and 26 c.c. is somewhat inferior in quality and soundness, due to deterioration of the germ; corn with a degree of acidity between 26 and 30 c.c. evidences marked deterioration and is unsound; and corn with a degree of acidity greater than 30 c.c. is badly damaged and should be considered from a commercial standpoint as sample-grade corn."

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20	1207	Starch Table	R. Graves	248,734	1881
20	1594	Corn Sugar	A. Behr	250,333	1881
20	1594	Corn Sugar	A. Behr	250,334	1881
21	589	Starch Mfg.	E. Roat	254,239	1882
21	377	Starch Mfg.	A. Atkinson	253,337	1882
21	1997	Starch Drying	G. Full	260,188	1882
21	1264	Laundry Starch	R. Traylor	257,108	1882
21	1333	Starch Mfg.	G. Burkhard	251,827	1882
21	1499	Starch Mfg.	T. Jebb	258,070	1882
21	574	Starch Mfg.	E. Roat	254,158	1882
21	1701	Starch Mfg.	J. Craushaw	258,895	1882
21	518	Starch Mfg.	H. Hamlin	253,923	1882
21	589	Starch Press	E. Roat & H. Hamlin	254,240	1882

PATENTS CONCERNING THE MANUFACTURE OF CORN PRODUCTS—*Continued.*

Vol.	*Page*	*Title*	*Name*	*No.*	*Year*
	1156	Starch Separator	W. T. Booth	256,630	1882
	1079	Starch Separator	G. S. Graves	256,315	1882
	1554	Agitator	J. J. Tobin	258,265	1882
21	1058	Starch Table	T. A. Jebb	256,221	1882
21	540	Starch Table	C. Lautz	254,029	1882
21	547	Starch Table	M. J. Stark	254,063	1882
21	1475	Starch Table	F. O. Matthessen & A. Behr	257,959	1882
21	1475	Washing Table	F. O. Matthessen & E. E. Quinby	257,958	1882
21	574	E. Root	Starch Washing	254,157	1882
22	1338	Starch Separator	P. H. Grimm	266,136	1882
22	1003	Starch Separator	P. H. Grimm	264,688	1882
22	836	Starch Mfg.	E. S. Renwick	263,958	1882
22	736	Starch Refuse	W. T. Jebb	263,525	1882
22	619	Starch Mfg.	W. Durngea	263,030	1882
22	9	Starch Washer	J. & F. Firmenich	260,380	1882
23	1688	Starch	J. Gunthas	276,806	1883
23	154	Starch	T. A. Jebb	270,439	1883
23	1354	Molding	W. Tress	275,394	1883
23	100	Glucose Starch	J. Duff	270,210	1883
23	277	Vinegar Starch	J. Duff	270,894	1883
23	2448	Wheat	T. P. Ringsford	280,044	1883
23	2078	Starch Mfg.	L. P. Best	278,490	1883
23	610	Starch Mfg.	E. S. Renwick	272,324	1883
23	110	Saccharification	F. P. Stiker	270,260	1883
23	884	Starch Separator	T. H. Muller	273,128	1883
23	1321	Starch Separator	W. Allen	275,320	1883
23	120	Starch Separator	G. S. Graves	270,304	1883
23	1328	Starch Separator	F. H. Kimball	275,340	1883
23	1320	Table	W. Allen	275,318	1883
23	908	Table	F. O. Matthessen	273,572	1883
23	1321	Washing	W. Allen	273,319	1883
24	963	Starch Mfg. Mold	W. Liess & M. Maker	284,447	1883
	1111	Starch Mfg.	J. Polson & J. M. Harley	285,067	1883
26	870	Starch Mfg.	W. W. Underhill	294,530	1884
26	870	Starch Mfg.	W. W. Underhill	294,531	1884
27	1228	Starch Mfg.	H. Duryea	300,700	1884
27	28	Starch Refuse	P. H. Grumm	296,000	1884
27	1089	Starch Separator	C. W. Treman	300,165	1884
28	961	Starch Filling	I. E. Palmer	304,851	1884
28	711	Starch Refuse	P. H. Grimm	303,930	1884
30	589	Starch Dryer	W. Duryea	312,341	1885
30	589	Starch Dryer	W. Duryea	312,342	1885
29	350	Starch Mfg.	J. H. S. Wildsmith	307,366	1884
30	395	Liquefaction of Starch	L. Cuisiner	311,646	1885
30	389	Drying of Starch	W. Duryea	312,341	1885
30	389	Drying of Starch	W. Duryea	312,342	1885
31	367	Mfg. of Starch	J. C. Schuman	316,404	1885
31	367	Mfg. of Starch	J. C. Schuman	316,405	1885
31	368	Treating Starch	J. C. Schuman	316,406	1885
31	880	Mfg. of Starch	J. C. Schuman	318,308	1885
31	880	Treating Starch	J. C. Schuman	318,207	1885
31	880	Grape Sugar, Glucose	J. C. Schuman	318,309	1885
31	1136	Starch and Glucose	P. Radenhausen	319,315	1885
31	1433	Starch Table	W. Duryea	320,430	1885
31	1433	Starch Table	W. Duryea	320,431	1885

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Vol.	*Page*	*Title*	*Name*	*No.*	*Year*
31	1427	Mfg. Starch	J. C. Schuman	320,400	1885
31	1428	Mfg. Starch	J. C. Schuman	320,402	1885
31	1413	Prep. of Starch	M. T. Jebb	320,361	1885
31	1427	Prep. of Starch	J. C. Schuman	320,401	1885
32	532	Starch Drying	P. Johnson	323,425	1885
32	1494	Mfg. Starch	F. P. Stiker	327,034	1885
32	1494	Mfg. Starch	F. P. Stiker	327,035	1885
32	1567	Mfg. Starch	F. P. Stiker	327,345	1885
33	445	Mfg. Starch	S. Spitzer	329,229	1885
33	575	Mfg. Starch	W. F. Berge	329,701	1885
35	430	Mfg. Starch	W. Duryea	340,705	1886
35	585	Mfg. Starch	J. C. Schuman	341,282	1886
35	585	Mfg. Starch	J. C. Schuman	341,285	1886
35	746	Laundry Starch	W. H. Midgley	10,722	1886
35	1460	Treatment of Starch	J. C. Schuman	344,410	1886
35	1461	Starch Mfg.	J. C. Schuman	344,411	1886
35	1461	Starch Mfg.	J. C. Schuman	344,412	1886
34	161	Mfg. Starch	J. C. Schuman	334,090	1886
34	1085	Quality of Starch Laundry	H. A. Gray	337,490	1886
36	414	Starch Mfg.	J. C. Schuman	346,320	1886
36	303	Starch Mfg.	J. C. Schuman	345,926	1886
36	303	Starch Mfg.	J. C. Schuman	345,927	1886
36	158	Starch Mfg.	W. F. Birge	345,409	1886
36	161	Starch Mfg.	E. E. Duryea	345,417	1886
36	775	Starch Mfg.	W. T. Jebb	347,611	1886
36	775	Starch Mfg.	W. T. Jebb	347,612	1886
36	547	Mfg. Starch	G. Luthy	346,820	1886
36	161	Mfg. Starch	E. E. Duryea	345,418	1886
36	158	Degerminator	W. Birge	345,408	1886
41	1094	Cooking Starch	H. A. Coats	374,346	1887
42	1014	Preparing of Starch	J. C. Schuman	379,034	1888
44	308	Mfg. of Starch	S. Spitzer	386,363	1888
45	654	Mfg. of Starch	H. Wiegand	392,389	1888
46	215	Mfg. of Starch	J. N. Hurty	395,977	1889
47					
48	167	Mfg. of Starch	A. Behr	406,559	1889
49	167	Mfg. of Starch	A. Behr	406,559	1889
53	809	Starch Drying	P. H. Grimm	440,262	1890
54	1284	Continuous Starch Table	J. A. Ostenberg	447,790	1891
54	51	Starch Mfg.	J. H. C. VanDenise & M. J. Reiseger	444,127	1891
55	253	Starch Mfg.	J. A. Ostenberg	450,492	1891
58	1719	Starch Mfg.	G. A. Kerr	471,614	1892
59	502	Starch Mfg.	G. A. Kerr	473,511	1892
60	876	Laundry Starch	F. C. Norfolk	480,669	1892
62	802	Starch Mfg.	A. Behr	491,234	1893
62	1678	Starch Mfg.	J. Dubiel	493,689	1893
68	894	Starch Sol. for Bran	S. Pratt	524,651	1894
71	807	Starch Separator	W. F. Rickleschel	538,794	1895
72	42	Starch Mfg.	A. Moffatt	541,941	1895
72	1240	Starch Mfg.	A. Moffatt	545,128	1895
75	1229	Preparing Grain for	J. & G. Fermenech	560,699	1896
78	1522	Treating Sol. Starch	J. Kantoromcy	578,566	1897
79	1479	Starch Drier	L. P. Bauer	583,783	1897
79	1719	Mfg. Starch	J. G. O'Neill	584,399	1897

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Vol.	*Page*	*Title*	*Name*	*No.*	*Year*
71	807	Starch Separator	Rockteschel	538,794	1896
72	42	Starch Mfg.	A. Moffatt	541,941	1896
72	1240	Starch Mfg.	A. Moffatt	545,128	1896
75	1229	Steeping	J. & G. Fermenich	560,699	1896
78	1522	Treating Starch	J. Kantoromcz	578,566	1897
79	1479	Starch Drier	L. P. Bauer	584,399	1897
81	2161	Laundry Starch	N. H. Hageman	596,265	1897
81	1692	Starch Mfg.	C. A. Gordon	595,265	1897
81	1829	Starch Treatment	C. Pope	595,408	1897
89	2079	Mfg. Starch	T. Gaunt	638,707	1899
90	1249	Treatment of Starch	C. B. Duryea	643,323	1900
91	1160	Laundry Starch	M. D. Peterson	649,210	1900
92	2240	Starch Treating	C. B. Duryea	685,105	1900
93	2259	Starch as Food	T. Gaunt	664,259	1900
93	2260	Mfg. Starch	T. Gaunt	664,260	1900
93	2260	Germ Separator	T. Gaunt	664,259	1900
93	2259	Treating Grain in Starch	T. Gaunt	664,258	1900
94	1488	Starch Mfg.	W. H. Uhland	668,427	1900
95	496	Starch Mfg.	W. H. Uhland	672,086	1901
95	822	Mod. Starch	C. B. Duryea	675,822	1901
95	996	Mod. Starch	A. Woolner	672,996	1901
96	1258	Starch Breaker	J. M. Lyman	680,261	1901
96	189	Starch Treatment	J. H. Tool	677,822	1901
98	2478	Starch & Zinc Mfg.	H. Wulkan	696,156	1902
99	951	Mod. Starch	L. Cerf	698,632	1902
99	252	Mod. Starch	C. B. Duryea	696,949	1902
99	2629	Starch Mfg.	J. Lorselet	702,571	1902
100	1956	Laundry Starch	C. H. Tolhurst	707,985	1902
100	1924	Treating Starch	A. P. Anderson	707,892	1902
100	390	Mfg. Starch Rice	E. Leconte & J. Lorselet	704,349	1902
100	1957	Treating Starch	C. H. Tolhurst	707,986	1902
101	2971	Starch Mfg.	H. A. Frasch	717,184	1902
101	25	By-products	A. S. Hoyt	710,461	1902
102	64	Starch Mfg.	A. P. Murdock	717,699	1903
102	1626	Lump Starch	J. M. Lyman	721,314	1903
102	70	Starch Mfg.	A. P. Murdock	717,700	1903
103	1486	Starch Mfg.	W. H. Uhland	725,180	1903
106	2142	Sol. Starch	C. H. Meyer	742,469	1903
107	1531	Mfg. Starch	A. A. Osborne	746,369	1903
109	2050	Mfg. Starch	R. Schrader	757,778	1904
109	1010	Mfg. Starch	R. Goldschmidt	755,479	1904
111	2448	Sol. Starch	J. David	769,061	1904
112	2042	Sol. Starch	W. Browning & J. J. Bonham	773,469	1904
113	2188	Sol. Starch	C. F. Cross & J. Traqciair	778,173	1904
113	111	Sol. Starch	W. Browning & J. J. Barlow	773,783	1904
				779,421	1904
114	282	Nitrated Starch	F. B. Holmes	779,422	1904
114	282	Nitrated Starch	F. B. Holmes	779,422	1904
115	204	Mfg. Starch	W. H. Uhland	784,450	1905
115	582	Mod. Starch	J. Kantorowian	785,216	1905
116	286	Lump Starch	E. Gudeman	789,127	1905
117	2565	Sol. Starch	R. Hartwig	798,509	1905
120	738	Starch Mfg.	W. F. Rudel	810,086	1906
120	2559	Sol. Starch	A. F. J. S. Haake	813,647	1906

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Vol.	*Page*	*Title*	*Name*	*No.*	*Year*
121	718	Lump Starch	T. B. Wagner	815,373	1906
121	1398	Starch Lump	E. E. Perkins	816,624	1906
127	1046	Treating Starch	F. Drittler	847,658	1907
127	1208	Treating Starch	F. Drittler	847,985	1907
129	962	Starch Washing App.	W. H. Uhland	860,068	1907
130	1320	Laundry Starch	J. Benoid	867,235	1907
132	81	Nitrated Starch	F. B. Holmes	875,913	1908
133	237	Thin Boil Starch	T. E. Breyer	881,105	1908
133	237	Thin Boil Starch	T. E. Breyer	881,104	1908
134	1515	Starch Mfg.	W. J. Marshall	890,524	1908
138	787	Sol. Starch	F. Fritsche	910,524	1909
141	718	Treated Starch	F. Suff	918,925	1909
148	1007	Sol. Starch	Militz	941,159	1909
152	423	Mod. Starch	W. Thompson	951,666	1910
162	944	Starch	B. Herstem	982,673	1911
163	396	Laundry Starch	E. Weingartner	984,330	1911
163	446	Sol. Starch	J. Kanborowicz	984,483	1911
164	295	Starch Mfg.	L. P. Bauer	986,540	1911
164	296	Starch Mfg.	L. P. Bauer	986,541	1911
167	137	Starch Mfg.	J. J. Berregan	994,497	1911
169	589	Starch Mfg.	E. O. Eckland	1,000,726	1911
171	93	Starch Shovel	C. F. Black	1,007,912	1911
172	47	Steeping	F. L. Jefferies	1,007,782	1911
172	48	Starch Washing	F. L. Jefferies	1,007,784	1911
172	48	Starch Mfg.	F. L. Jefferies	1,007,785	1911
172	47	Steeping	F. L. Jefferies	1,007,783	1911
174	142	Starch Mfg. Wheat	F. A. V. Kloffer	1,013,497	1912
174	452	Starch & Dextrin Mfg.	S. M. Lillie	1,014,311	1912
177		Starch Conversion Process	S. M. Lillie	1,023,257	1912
175	182	Starch & Glucose	C. C. Moore	1,016,761	1912
181	549	Treating Starch	A. P. Anderson	1,035,829	1912
181	552	Puffing Starch	A. P. Anderson	1,035,836	1912
181	554	Puffing Starch	A. P. Anderson	1,035,840	1912
181	334	Starch Drying	L. P. Bauer	1,035,302	1912
181	549	Starch Materials	A. P. Anderson	1,035,842	1912
181	552	Starch Materials	A. P. Anderson	1,035,830	1912
181	551	Starch Materials	A. P. Anderson	1,035,835	1912
181	550	Starch Jellets	A. P. Anderson	1,035,831	1912
181	551	Treated Starch	A. P. Anderson	1,035,834	1912
181	550	Starch Treat.	A. P. Anderson	1,035,832	1912
182	442	Starch & Glucose	S. M. Lillie	1,038,397	1912
185	778	Treated Starch Mod. Starch	H. C. Newberger & F. P. Berlle	1,047,831	1913
188	99	Starch Agitator	V. Taschl	1,057,685	1913
190	435	Starch Drying	L. P. Bauer	1,061,720	1913
192	491	Starch Derivatives	S. M. Lillie	13,592	1913
201	773	Starch Heater	O. M. Steffaeber	1,094,175	1914
203	353	Starch Drying	L. P. Bauer	1,099,276	1914
204	1202	Starch Separator	N. C. Newell & J. A. Harrington	1,105,294	1914
212	1598	Starch Treat.	F. P. Berghand & H. C. Newberger	1,133,914	1915
212	547	Starch Shovel	C. F. Back	1,131,318	1915
213	194	Starch Setting Tables Removing Starch	F. L. Jefferies	1,134,615	1915
216	1286	Starch Product	A. S. Hoyt	1,148,453	1915

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Vol.	*Page*	*Title*	*Name*	*No.*	*Year*
216	1090	Starch Table	R. F. Sheaman	1,147,899	1915
217	362	Starch Composition	C. S. Perkins	1,149,216	1915
219	538	Starch Mfg.	C. A. Tyler	1,157,738	1915
220	1379	Starch Purifying	L. P. Bauer	1,161,826	1915
221	14	Starch Mold	C. F. Haug	1,162,771	1915
222	689	Starch Machine	A. L. Bausman	1,168,240	1915
222	821	Angular Starch	A. W. H. Lendon	1,168,516	1916
228	567	Starch Treating	C. A. Tyler	1,190,690	1916
228	833	Mod. Starch	A. W. H. Lenders	1,191,324	1916
229	160	Freeing Starch from Dust	A. W. H. Lenders	1,193,274	1916
233	135	Sol. Starch	J. Kmtorowicz	1,207,177	1916
234	370	Starch Table	W. Bartholomew & C. M. Leary	1,211,385	1917
235	941	Starch Dusting	A. W. H. Lenders	1,223,406	1917
238	346	Starch Mfg.	C. C. Moore	1,224,951	1917
247	251	Starch Cooler	J. B. Adt	1,255,842	1917
247	148	Stirring Device	C. C. Moore	1,255,626	1917
248	975	Curing Starch	A. W. H. Lenders	1,260,983	1918
252	602	Dustless Starch	A. W. H. Lenders	1,272,682	1918
253	758	Laundry Starch	S. B. Chamber	1,276,722	1918
268	67	Starch Products	R. W. G. Stutzke	1,320,719	1919

Chapter 17.

Food Preservation Processes.

The Bacteriology of Food Preservation.

The different methods of preserving food may be classified according to the following headings:

I. Preservation by heat.
   (a) Boiling.
      Fruits, vegetables, etc., in glass cans.
   (b) Steam Pressure.
      Sweet corn, etc., in tin cans.
   (c) Pasteurization.
      Market milk, beer, wine, fruit juices.

II. Cold storage.
   (a) In frozen state.
      Beef, etc., meats, milk, ice cream, etc.
   (b) Refrigeration.
      Vegetables, fruits, beverages, meats, dairy products, etc.

III. Drying.
   (a) In natural state.
      Raisins, currants, prunes, etc.
   (b) In powdered condition.
      Eggs, gelatin, milk, etc.
   (c) After curing.
      Dried beef, etc.

IV. Preservation by concentration.
   (a) Jellifying.
      Jelly, jams, etc.
   (b) Plasmolysis.
      Maple syrup, beef extract, etc.

V. Preservation by smoking.
      Meat, fish, etc.

VI. Pickling.
   (a) By organic acids.
      Cucumbers, sauerkraut, etc.

VII. Salting.
      Fish, meat, vegetables, etc.

VIII. Preservation by spices and essential oils, etc.
      Fruit cake, mincemeat, condiments, etc.

IX. Filtration.
Liquids, liquid media, etc.

X. Sealing.
Eggs, fruit, etc.

XI. Preservation by chemicals spoken of as preservatives.
Benzoate of soda, sulphurous acid, etc.

NOTE: In the above list few of the illustrations are examples of food preservation due to one method alone, but in most cases preservation is due to a combination of preservative factors.

After McBryde in U.S.D.A. Year Book 1911.

FIG. 31.—Cooking room in modern canning establishment.

I. Preservation by Heat.

The preservation of foods by heat is as old as the use of fire by man. However, the systematic and intelligent use of heat for food preservation did not become widespread until the time of Pasteur. While it is true that in many different food industries, the principle of sterilization by boiling had long been used, still it was not until the theory of spontaneous generation had been thoroughly disproved that the great usefulness of sterilization of foods by heat became appreciated. Nicholas Appert, who has become known as the "Father of the Canning Industry," published his original work on food preservation as early as 1811 and even at this time some foods as fish, fruits, and vegetables were being preserved in hermetically sealed cans in England.

Since 1860, the canning industry has had a steady growth and in recent years has practically revolutionized the food supply of the country. In the home, the use of the boiling method is generally used in canning, while in commercial canning the use of steam pressure has

become extensively used. It is thought by many that canning in the home must also change over to the use of steam pressure. This idea seems to be emphasized more and more strongly as the prevalence of botulism due to home canned foods is investigated.

Certain spores are not killed by the temperature of boiling water and in the canning of many vegetables causes spoiling. To increase the germicidal effect of boiling water in canning, the cans are often heated on three successive days. Early in the practice of commercial canning, the food products in containers were submerged in water which had had salts added to it for the purpose of raising the boiling point. Thus canned products were subjected to a temperature higher than boiling water and had improved keeping qualities. In recent development in the industry of canning, steam pressure cookers and autoclaves have become universally used.

O. H. Benson in Farmers' Bulletin, No. 839, gives the following figures concerning the time and temperature required in the canning of fruits, vegetables, and meats:

TABLE IV.

TIME TABLE FOR SCALDING, BLANCHING, AND STERILIZING VEGETABLES, SOUPS, FRUITS, AND MEATS.

Products by Groups	*Scald or Blanch*	*Hot Water Bath Outfits at 212 Degrees*	*Water-seal Outfits, 214 Degrees*	*Steam Pressure 5 to 10 Pounds*	*Pressure Cooker 10 to 15 Pounds*
SPECIAL VEGETABLES	Minutes	Minutes	Minutes	Minutes	Minutes
Tomatoes	1½	22	18	15	10
Pumpkin	3	120	90	60	40
Squash	3	120	90	60	40
Hominy	3	120	90	60	40
Sauerkraut	3	120	90	60	40
Corn, sweet	5	180	120	90	60
Corn, field	10	180	120	60	50
Mushrooms	5	90	80	50	30
Sweet peppers	5	90	75	60	40
POD VEGETABLES & OTHER GREEN PRODUCTS					
Beans, wax	5–10	120	90	60	40
Beans, stringless	5–10	120	90	60	40
Okra	5–10	120	90	60	40
Peppers, green or ripe	5–10	120	90	60	40
Cabbage	5–10	120	90	60	40
Brussels sprouts	5–10	120	90	60	40
Cauliflower	3	60	40	30	20
ROOT & TUBER VEGETABLES					
Carrots	5	90	80	60	40
Parsnips	5	90	80	60	40
Salsify	5	90	80	60	40
Beets	5	90	80	60	40
Turnips	5	90	80	60	40
Sweet potatoes	5	90	80	60	40
Other roots and tubers	5	90	80	60	40

TABLE V.

TEMPERATURE EQUIVALENTS OF STEAM PRESSURE.

Steam Lbs. on Gage	*Absolute Pressure in Lbs. per Sq. In.*	*Temperature Fahrenheit*
0.3	15	213.0
1.3	16	216.3
2.3	17	219.4
3.3	18	222.4
4.3	19	225.2
5.3	20	228.0
6.3	21	230.6
7.3	22	233.1
8.3	23	235.5
9.3	24	237.8
10.3	25	240.1
11.3	26	242.2
12.3	27	244.4
13.3	28	246.4
14.3	29	248.4
15.3	30	250.3
16.3	31	252.2
17.3	32	254.1
18.3	33	255.8
19.3	34	257.6
20.3	35	259.3
21.3	36	261.0
22.3	37	262.6
23.3	38	264.2
24.3	39	265.8
25.3	40	267.3
26.3	41	268.7
27.3	42	270.2
28.3	43	271.7
29.3	44	273.1
30.3	45	274.5
31.3	46	275.8
32.3	47	277.2
33.3	48	278.5
34.3	49	279.8
35.3	50	281.0
36.3	51	282.3
37.3	52	283.5
38.3	53	284.7
39.3	54	285.9
40.3	55	287.1

It is impossible to consider heat contact as the only effective agent in the preserving of food products in canning as there are always more or less organic acids, essential oils, or other substances which make the heat more effective. In canning certain foods there are special difficulties. For instance, peas, corn, and beans must be specially handled for the reason that they are low in acidity and are generally accompanied by very resistant bacteria which find the conditions in the can favorable for development.

When cans are sealed at high temperatures and then cooled it is

found that there exists several inches of vacuum in the can. This is desirable as it increases the difficulties in the way of the growth of any aërobes which may have withstood the processing. In some plants, vacuum apparatus is used for creating as great a vacuum as possible in the processed can.

Pasteurization is a process applied to certain foods to check the growth of germ life. It consists in heating the liquid to a temperature below the boiling point followed by rapid cooling. It has been best applied to milk, cream, wine, beer, vinegar, and fruit juices.

In 1865, Pasteur undertook a great work for the benefit of the agriculture of France. France was a land of vineyards and the returns from the growing of grapes meant prosperity or poverty to a large proportion of the farmers. The price paid for grapes depended entirely upon what the manufacturers of wine were able to obtain for their product. It was at this time that the spoiling of wine spoken of as "the diseases of wine" became so extensive that the wine industry faced a crisis and French wines were about to lose their world-wide reputation for flavor and bouquet. Five hundred million francs invested in the wine industry were affected by these malfermentations which took place in the products of the manufacturer. Pasteur felt the gravity of the situation and concluded that he could serve his countrymen in no better way than in solving this problem. He went to Arbois, France, in the heart of a vast grape-growing district, built a small laboratory and began to investigate the germ content of wines which spoiled. He soon discovered that this spoiling was due to the presence of undesirable bacteria. After much experimentation as to the best methods of killing these organisms, foreign to wine manufacture, without harming the delicate flavor of the wine, he found that heating the grape juice to 130 degrees or 140 degrees F. for a short period of time killed these bacteria and at the same time in no way injured the final product.

So great were the benefits of this investigation of Pasteur's that this process of improving the keeping quality of liquids by heating has been called "pasteurization" after the name of this great genius.

Although the benefits received by the farmers of France from the introduction of the process of pasteurization in the wine industry were great, far greater service to mankind has come from the application of this principle to the improvement of market milk.

Commercial pasteurization as it is carried out in the modern market milk plant (heating of the milk to 145 degrees F. and holding for 30 minutes) guarantees that the milk as it comes from the pasteurizer is free from disease, and people in general have come to accept the word "pasteurized" on a bottle of milk as a genuine protection from infectious organisms. Proper pasteurization is considered by many to be the great fundamental step in making market milk a safe food.

II. Cold Storage.

The practice of cold storage is a modern development. It gives certain economic advantages in food distribution and conservation which many believe will still further revolutionize diet and food handling.

Mendel says that the ability of a locality to supply food limits the concentration of population. In our modern system of transportation, however, this limitation has been removed to a great extent. Competition in railroad building in combination with the developments

After U.S.D.A. Year Book 1914.

FIG. 32.—Loading beef for export in Argentina. (Frozen meat.)

of the methods of food preservation has resulted in making all important foods quite universally available. Mendel calls attention to the remarkable facts of Australian meats in London, Californian fruits in Boston, Wisconsin milk in Manila, and eggs from China in the Chicago market. However, he says that the end is not in sight but that even better methods of transportation and of food preservation are in the future.

Problems Resulting from Cold Storage of Foods.

When we adopt cold storage, it is necessary to consider its effect as seriously as we consider those of the other methods of preservation. For instance, there is liable to be just as important differences between

cold storage food and fresh food as there is between condensed milk and fresh milk. We can sum up the situation by saying that a normal phenomenon happens to foods under normal conditions while an abnormal action is sure to follow when the food is placed under abnormal conditions. There is no commoner illustration of this than the fact that milk under normal conditions spoils because of the lactic acid fermentation of Bact. lactis acidi but when the same milk is held at low temperatures the lactic acid fermentation disappears and in its place there may occur other kinds of decomposition of a less harmless nature than the changes caused by the lactic acid organism. However, this viewpoint does not argue against cold storage or any other kind of food preservation. The economic situation demands that cold storage be more and more extensively practiced. As population becomes denser fluctuations in production and consumption of food are bound to become more extensive.

In the preservation of eggs, meat, and dairy products we have perhaps the greatest problems of cold storage. But with the bacteriologist it is not a question of advocating a decrease in the practice of cold storage, but of solving the problems of cold storage and counteracting the weak points in the practice. We have in this subject a good illustration of how the science of a process follows many years behind its practical application. For instance, cold storage of dairy products to a considerable extent began in 1876 but studies concerning this practice were not carried out until recently.

There are many commercial illustrations of the problems resulting from a few degrees difference in the storage of food but there is none more unique than that worked out by Thom in connection with Camembert cheese. He showed that the flavor of Camembert cheese is probably due to the associative action of Odium lactis and P. camemberti and that the change of a degree from the storage temperature would allow one organism or the other to forge ahead of its associate and spoil the cheese.

Cold may act as a preservative in two different ways, either by retarding growth or by actually bursting the bacterial cells. To explain how cold or in reality the absence of heat energy retards growth would be to explain the mechanism of growth in general. This is on the border line of our present knowledge or probably considerably over the border, however, Kruse gives a few ideas on this subject. He says that growth in bacteria is a combination of syntheses and that these syntheses result in the formation of cell substance out of common food materials. This is well illustrated by the assimilation of carbon dioxide by the nitro-bacteria in the absence of light and chlorophyll and by a similar process of certain sulphur bacteria. The process and the mechanism of syntheses is not understood but our recently acquired knowledge of fermentation indicates that the building up of protoplasm, that is, growth, is due to the power of particular enzymes. Assimilation and dissimilation may have the same mechanism. Kruse says that it would be unwise not to consider these

possibilities. For years the idea was considered unacceptable that the phenomena of dissimilation occurred within the living cells through a special enzymatic material formed by the cells and which could not be isolated because of its delicate nature. In recent years, however, the zymase of alcoholic fermentation and the enzymes of lactic acid and acetic acid fermentations have been isolated.

If we accept this explanation of the mechanism of growth it becomes easy to see how low temperatures are preservative but it would follow according to this theory that the lower the temperature the less the growth for any particular organism. This may be true.

The multiplication of B. coli at different temperatures illustrates very well how bacteria have a certain temperature range within which they grow.

The generation time of B. coli according to Russell is as follows:

TABLE VI.

45	degrees	C.	113	degrees	F.	20	minutes
40	"	C.	104	"	F.	17.2	"
35	"	C.	95	"	F.	22	"
30	"	C.	86	"	F.	29	"
25	"	C.	77	"	F.	40	"
20	"	C.	68	"	F.	95	"
15	"	C.	60	"	F.	120	"
10	"	C.	50	"	F.	14 hrs.	20 minutes

Many bacteria have a range of growth much narrower than the coli group and when we consider that some bacteria grow at temperatures between 70 and 80 degrees C., a temperature which coagulates albumin and a minimum temperature of above 30 degrees C. then we can appreciate that there are also organisms which grow best at temperatures below zero.

In the case of most bacteria there is a destruction of bacterial cells when the storage temperature is low enough to freeze them as the intracellular fluid in freezing expands and bursts the cell walls. The amount of preservation due to this phenomenon is not considered so very important.

The three different temperatures which are largely used in storing dairy products are 10° C. for storage of milk and cream which cannot be frozen; 0° C. for frozen milk, a product shipped somewhat in Europe; and —9° C. for storage of ice cream and butter. Temperatures below —9° C. are used mainly experimentally.

The effect of freezing milk on creaming, churning, and upon the quality, according to Hills and Kirby, is very slight. In freezing milk the fat freezes out at first and remains in the liquid portion according to Farrington. He says that when about 25% of the milk is frozen the fat content of the liquid portion rises about .5%. On the other hand, the casein, milk sugar, and ash was not separated to any great extent by freezing. Marshall says that milk and butter must not be frozen in order to stop bacterial growth completely but that enzymic

action does not necessarily stop when milk or butter are frozen. Deterioration of these products may take place slowly although these products are frozen.

In 1895, a patent was taken out by a Swedish engineer for frozen milk for shipment, and according to some reports the practice was very successful. Frozen milk was shipped from Gothenburg to London in large pine barrels containing about 1200 lbs.

Siegfeld analyzed samples of this frozen milk and found the upper portion of the block contained 8.45% fat, the lower portion 2.11% fat, and that the total solids increased toward the center of the cake.

Ice cream manufacturers keep their ice cream below —9° C. in order to maintain its stiffness. The ice cream hardening room is kept at —12° F. as nearly as possible, although the moving in of new batches of ice cream has a tendency to raise the temperature a degree or two.

In the cold storage of fruits it is essential that the conditions of temperature, ventilation, and moisture be adapted to the fruit stored. Practically all fruits have special kinds of microörganisms which they must be protected against. Wrapping fruit is a special protection against spread of fungi in a storage cellar and will help to prevent wilting.

It is impossible to prevent the process of ripening in fruits but it is possible to slow it up. The best temperature at which to hold the cellar is that just above what causes freezing of the fruit.

The same factors which must be regulated for fruit must also be regulated for vegetables. However, different vegetables have their special temperatures and humidity conditions at which they should be stored. For instance, squash should be stored at 50° F. while potatoes are stored best near the temperature of freezing.

The storage of apples for shipment has grown to enormous proportions in recent years due to better knowledge of the factors of storage and to better shipping facilities.

H. J. Ramsey says, "For a proper understanding of the behavior of apples in storage it must be kept clearly in mind that the apple, like all fruits, is a living organism and that its life cycle, which begins in the blossom, ends under natural conditions in the death and decay of the fruit. The function of cold storage is primarily to retard these life processes."

It should be added further that as the life cycle of the apple proceeds after maturity of the fruit there is less and less resistance to the attack of molds, yeasts, and bacteria. By many 32° F. is considered the most favorable temperature at which to store apples.

The organisms attacking apples in storage are both parasitic and saprophytic.

The practice of freezing meat for its storage and shipment was originated by Tellier, a Frenchman, according to Melvin. He says:

"The only South American countries exporting refrigerated meats are Argentina and Uruguay. The large exporting establishments are

situated mostly on the River Plate, and the frozen and chilled meats are in most cases loaded directly into the ocean steamers. The export trade in refrigerated meats owes its beginning and development to the invention by a French engineer, Charles Tellier, of a system for preserving fresh meats by refrigeration during the time required for the ocean voyage from South America to Europe. The pioneer steamship in this trade, *Le Frigorifique,* constructed with refrigerating facilities according to the Tellier system, made a successful trial voyage with fresh meat from Rouen, France, to Buenos Aires in 1876. In the following year this vessel and *Le Paraguay* began the transportation of frozen meat from Argentina to Europe under the respective management of two French firms, the Tellier and Jullien Companies, which were given a five-year monopoly by the Argentine Government."

Preservation of Chickens by Cold Storage.

M. E. Pennington in *U.S.D.A. Yearbook* (1907) says:

"Although it is impossible to obtain exact statistics on the subject, it is estimated that approximately from 75 to 90 per cent of all the poultry produced in the United States is, for a longer or shorter period, preserved in cold storage. While the number of ducks, turkeys, and geese is by no means small, chickens, of course, are greatly in the majority, and from the appearance of the cold-storage warehouses in our large cities it would seem to be almost a matter of routine that every chicken intended for market should sojourn there for a certain, or rather an uncertain time.

"The storage of eggs for preservation by cold is almost exclusively confined to the early spring and summer, since at this time they are most plentiful. The placing of chickens in cold storage, on the contrary, may occur at almost any season, the large poultry raiser killing the birds of the age desired and shipping them to the warehouse, to be sold when the market is most lucrative. At certain seasons, however, practically clean sweeps will be made in the country adjoining large cities of all the birds suitable for market, so that for weeks afterward it is impossible to purchase fresh chickens. This is most apt to occur in the case of stewing and roasting chickens in early summer, when the broilers are well advanced and it is desirable to weed out all unprofitable laying hens and superfluous cocks. Hence, in the early summer the purchaser of any except broiling fowls is very likely to get those which have been in storage.

Temperatures Used in Cold Storage of Chickens.

"It is generally conceded that the freezing of the fowl should be as prompt as possible, therefore some warehouses place the chickens for a few hours at —10 degrees F. (—23.33 degrees C.), transferring them, when frozen, to a temperature of about 15 degrees F. (—9.44 degrees C.) for permanent storage. Others use the latter temperature

exclusively, while there are those who prefer 18 degrees to 22 degrees F. (—7.78 degrees to —5.55 degrees C.). The New Zealand Department of Agriculture supports the latter view, and its report states that such delicate tissues and small bodies as are found in the case of chickens lose their bloom and contract when kept at 15 degrees F. or below. However, it must not be forgotten that the birds so stored are far more carefully handled and selected than are the promiscuous lots shipped to our storage warehouses. De Loverdo advocates —5° F. (—20.6 degrees C.) for freezing and 15 degrees F. (—9.44 degrees C.) for maintenance, though he states that in consequence of such rigorous temperatures the tissues contract and lose their elasticity.

Method of Thawing.

"Another factor in the final condition of the salable cold-storage fowl is the method of thawing. If the bird directly from the freezer be exposed to air at the usual temperature there is likely to be a condensation of moisture on the outer surface and a consequent degeneration of the tissue and often a growth of molds. Hence, it is necessary to thaw in a current of dry, cool air if this method be adopted. The most common practice is simply to place the birds in a vessel of water at room temperature. An appreciable amount of water is absorbed by the dried meat, thereby adding to the price received, since it is sold by weight and, to the householder at least, the chicken is sold in a thawed condition. According to the warehouse men the best results are obtained when the frozen birds are packed in small pieces of ice and more than twenty-four hours allowed for thawing.

Appearance of Chickens Stored for Varying Periods.

"While conducting certain investigations concerning the changes taking place in foodstuffs when preserved by cold, it has been necessary to examine a number of chickens stored for periods varying from a few days to several years. Contrary to the statements generally made by the trade, there have been noted marked differences between fresh and cold-storage chickens, which differences are apparently progressively dependent upon the time of storage. Even after very short periods of storage in a solidly frozen condition, microscopic examination reveals changes in the muscle fibers."

In discussing a chicken stored for three years M. E. Pennington says:

"The most striking difference between this chicken stored for three years and those stored for shorter periods or those which are fresh is this pronounced inflexibility and the general green tint of the skin. The whole appearance of the bird was unpleasant in the extreme. The odor was not that of putrefaction, but was of a sharp, penetrating, unpleasant character having a biting property, which suggested the effect of acrolein on the eyes and nostrils. While this was plainly de-

tected in the unopened bird, the muscles and the viscera gave it far more distinctly, and a decided increase in its intensity was noticed while the study was progressing.

"The texture of the skin was such that its original character would have never been surmised. Every particle of elasticity had vanished and its appearance was that of dirty, green, wrinkled parchment. The feather papillæ were seen only as rather darker areas. Where the skin was stretched over the bones it was exceedingly thin and with very little pressure would crack. This fact is illustrated by the bare breast and the projecting appearance of the leg bones, the skin having split on the breast and being ready to split over the folded joints. The eyeball was much sunken, while the comb and gills had practically disappeared.

Muscles and Internal Organs.

"In the case of chickens which had been in storage three years, the changes in texture and color of both muscles and fat were especially striking. There was a very marked drying out, particularly of the muscles of the upper breast, so that the larger portion of them had become as parchment-like in character as was the skin and might easily have been mistaken for the skin itself. Below this yellow-tinged dried area the breast muscles presented almost a rust red. The gradual paling of the thin muscle as noticed in the fresh chicken was entirely wanting. On the inner part of the thigh, the soft salmon pink of the fresh muscle was replaced by colors varying from a deep brown to bluish red, and there was no trace of the original color to be distinguished. Between these muscles the bands of shrunken fat were of a deep brown orange color. No feature of the entire chicken was more striking by comparison with the fresh fowl than this change in the color of the fat.

"There was also noticed in this chicken, unlike those which had been previously studied, a very distinct indication, by the discoloration of the abdominal wall, that the viscera had not been removed.

"Clipping through the hardened fibers of the pectoralis major and exposing thereby the pectoralis minor, its fibers were seen to be almost, if not quite, as dried out as were those of the outer muscle."

The Preservation of Fresh Caught Fish During Transportation.

M. E. Pennington says: "As a general rule the dominant fish in a market are produced comparatively near by. The catch of the Atlantic, for example, stays almost entirely east of the Alleghenies, except that which is canned or otherwise preserved, which, of course, goes all over the country and is exported. The Gulf and the Lakes and the Mississippi supply the interior and ship but little over the eastern range. The Pacific coast, on the other hand, sends two staple varieties of fish throughout the country, namely, halibut and salmon. These fish are sent (on express schedule) across the continent in carload lots,

packed in fine ice, and constitute, with red snapper from the Gulf, most of the salt-water fish supply of the interior. The distribution of Pacific salmon and halibut extends also to the Atlantic coast cities, which are heavy consumers. For some of our fish we are sending to Canada. Smelts, lobsters, and salmon come to us in quantity from Canadian waters, as does also much of the "winter caught" fresh water fish. The latter are obtained by cutting a series of holes through the ice, stringing gill nets from hole to hole, and pulling the nets up through the holes to remove the catch. This fishing is done when the temperature is below the freezing point, sometimes at 40 degrees below zero, Fahrenheit, and the fish are, therefore, frozen almost immediately upon their removal from the water. They are boxed and held on the ice until hauled by teams to refrigerator cars and so shipped to cold-storage plants in cities. The unparalleled freshness of low temperature weather frozen fish, even after months of storage, is a strong argument for the installation of fish freezers as near the source of production as possible.

"The eastern coast markets carry the following staple varieties, which may be had the year around:

STAPLE VARIETIES OF FISH.

Salt-Water Fish		*Fresh-Water Fish*
Bluefish	Pollock	Ciscoes (lake herring)
Cod	Porgies or scup	Lake trout
Flukes or flounders	Salmon, western	Whitefish
Haddock	Sea bass	German carp
Hake	Smelts	Buffalo carp
Halibut	Shad	
Herring	Weakfish	
Mackerel	Whiting (silver hake)	

"It must be remembered that winter fishing is of but small moment. Most of the fishermen tie up when winter comes and do not ply their trade until spring. Fortunately for the stability of the markets, but even more fortunately for the supply of food, the practice of freezing the excess summer catch and holding it at temperatures close to zero Fahrenheit until winter time, has become so general that from October 1 to April 30, which mark the limits of the storage-stocks season, we have a continuous course of fish in excellent order from the warehouse to the market to be disposed of, generally, at lower prices than the fresh-caught article.

"The foreign-born population in the congested areas of our large cities are not prejudiced in favor of certain varieties; provided the price is within their means the name of the fish is a secondary matter. And if the fish is palatable the fact that it is hard frozen does not weigh against a low price. Consequently, we find hard-frozen whiting and other plentiful fish selling for a few cents a pound in inland towns as well as on the coast, when the shops in the residence districts are charging double the price for the same article thawed to simulate

fresh-caught fish and sold as fresh, a condition directly traceable to the ignorance of the consumer."

III. Food Preservation by Drying.

Preservation of food by drying is one of the most primitive methods of preserving. Nevertheless, its importance in modern food preparation is being more and more emphasized due to the fact that the natural flavors of many fruits and vegetables are best retained by this method of preservation. With the coming of knowledge of vitamines and food accessories, there seem to be additional advantages gained by this method. The variety of food which can be successfully dried has been greatly enlarged in the last few years and efficiency of drying apparatus has been greatly increased. Some of the food products which are specially adapted to drying are:

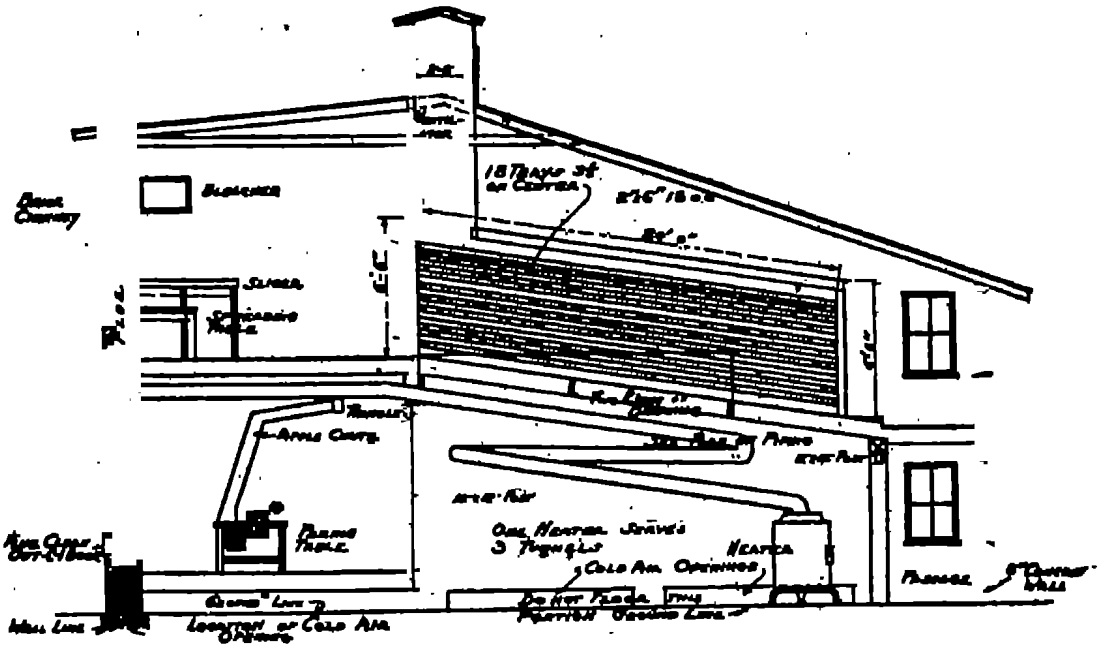
(1) Apples
(2) Peaches
(3) Berries at 125° F.
(4) Cherries
(5) Apricots
(6) Pears
(7) Corn between "milk" and "dough" stage
(8) Eggs
(9) Milk
(10) Buttermilk.

In differentiating between dried and evaporated fruit Caldwell says: "The terms 'dried fruit' and 'evaporated fruit' are popularly used to designate all fruits preserved by reduction of their moisture content to such a point that spoilage does not occur. In the trade the term 'dried fruit' is applied to any product in which moisture reduction has been brought about by exposure of the fresh material to the heat of the sun, while products made by driving off the surplus moisture by the use of artificial heat are known as 'evaporated' fruits, less frequently as dehydrated or desiccated fruits. While the processes of sun drying and drying with artificial heat in evaporating devices are widely different, the differences in the quality of the products obtained are relatively slight, it is possible to apply both processes to any of the fruits ordinarily dried, and the extent to which one or the other method is employed in preserving any given fruit is determined by the climatic conditions prevailing during the period in which the drying must be done. By reason of the possession of an exceedingly favorable combination of dry atmosphere, continuous sunshine, and practical absence of rain or dew during the drying season, California has developed sun drying on a large scale and is the only State which has done so."

Caldwell further says: "The purpose in view in drying any food material is to reduce its moisture content to such a point that the

growth of organisms therein will no longer be possible, and to do this with a minimum of alteration in the food value, appearance, and palatability of the product. The necessity for avoiding changes in physical appearance and chemical composition, other than actual loss of water, puts very definite limitations upon the means which may be employed to bring about drying and makes an understanding of certain principles a prerequisite to successful work."

Concerning the type of evaporator to be used in drying fruit Caldwell says: "The kiln evaporator is designed especially for the handling of apples in large quantities, and is more widely used for that purpose than all others combined, but it is not well adapted to the drying of



—A section through the tunnel drier.

After Caldwell in U.S.D.A. Bulletin 1141.

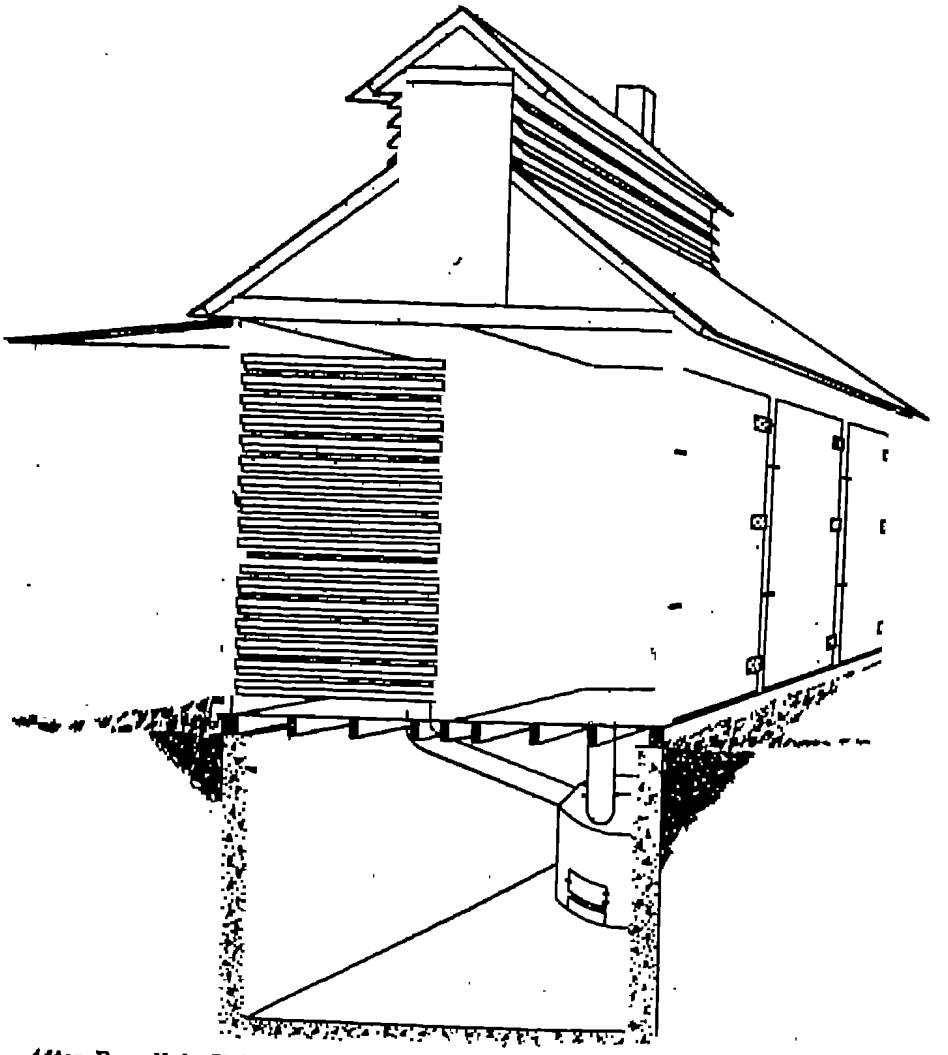
FIG. 33.—The prune tunnel evaporator.

other fruits. For this reason, the building of a kiln evaporator in a district which is devoted to general fruit growing would be ill advised. The prune tunnel evaporator, on the other hand, is a general-purpose evaporator which may be employed for drying other materials as well as apples and is consequently better fitted to the needs of a farm or community which may have occasion to dry peaches, prunes, berries, or other fruits. For this and a number of other reasons, which will be pointed out in a subsequent section, a tunnel or modified tunnel drier should be built wherever a community drying plant is needed.

The Kiln Type.

"Cast-iron, hard-coal furnaces are universally used in apple kilns throughout the Eastern States. These furnaces have a grate of 5 to 8

square feet and are capable of supplying heat for a standard 20 by 20 foot kiln. Such furnaces are of very heavy construction, weighing 1,500 to 1,800 pounds, and consequently they maintain a fairly uniform temperature with only occasional attention from the fireman. The products of combustion pass through sheet-iron pipes arranged in rows under the floor and finally into the chimney.



After Russell in U.S.D.A. Bulletin 1231.

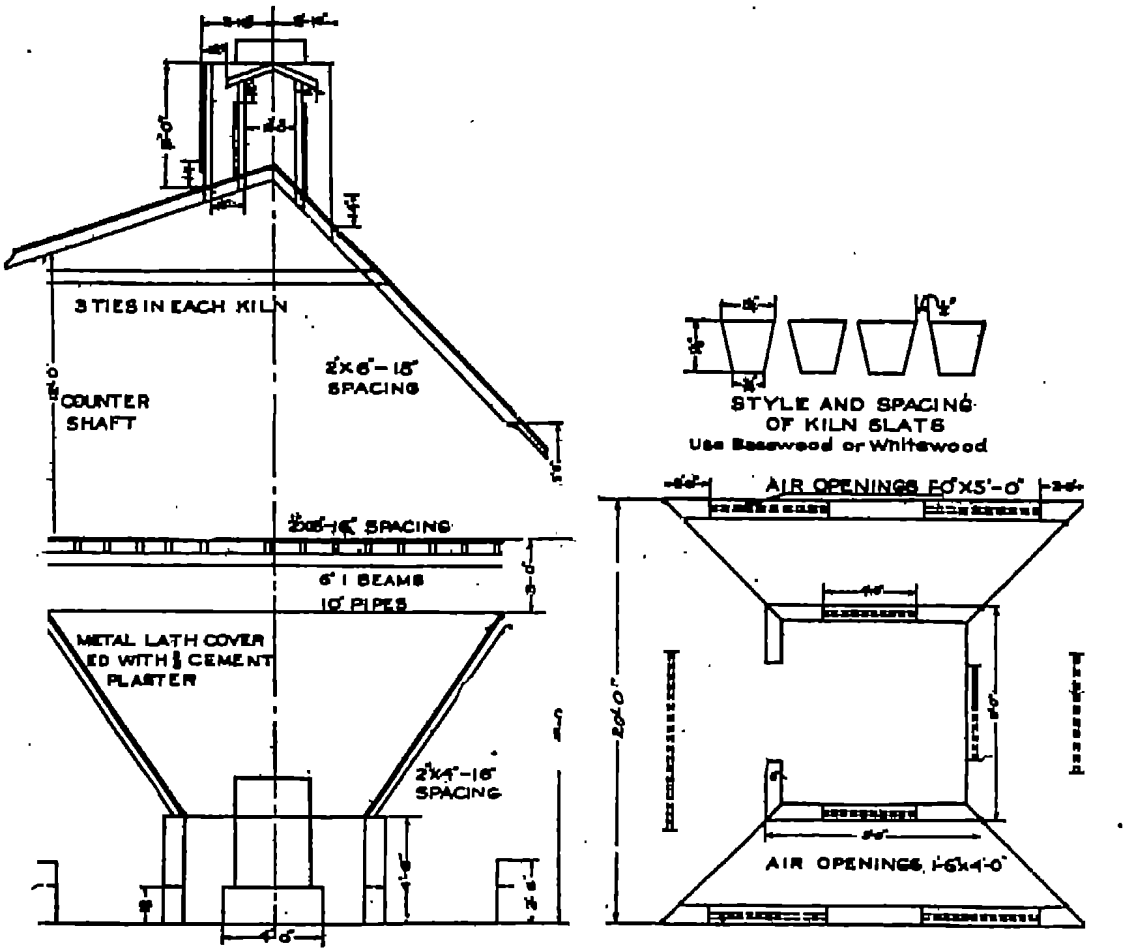
FIG. 34.—Plant of a commercial-size drier in perspective. The arrangement of the trays is shown in one compartment. The side roof on the right is not shown.

"Several individual kilns constitute a drying plant. As it is necessary to have enough drying capacity to keep the machinery and help employed, the number of kilns in a plant varies, but economic considerations would generally forbid the construction of a plant having less than four kilns, since installations of power-driven equipment in a smaller plant would be almost as expensive as in a four-kiln plant. A plant of this size is large enough to keep the operators busy, and plants larger than this increase the fire risk without add-

ing much to the economy. A plan sometimes followed when a larger capacity than is offered by the four-kiln plant is desired is to erect two sets, separated by a space of 75 to 100 feet with an overhead bridge connecting them. One set of machinery and one workroom serve for both, yet the fire risk is considerably reduced."

The Prune Tunnel Evaporator.

Caldwell says: "The term 'tunnel evaporator' or 'prune tunnel' as employed throughout the Pacific Northwest, designates a drying apparatus of a definite type, universally employed in the prune-growing



After Caldwell in U.S.D.A. Bulletin 1141.

FIG. 35.—Cross section and ground plan of a kiln. When the kilns are built in rows the furnace rooms are not separated, but the furnaces have separate inclosures and hoppers for distributing the heat. The drying floors are separated by walls.

districts of Oregon, Washington and Idaho for the curing of that fruit. As it exists to-day, it is the sole survivor from the early years of the prune industry of at least a score of devices for drying prunes, most of which were patented, as was the earliest form of the tunnel drier. It owes its survival and present popularity to the fact that it

originally embodied two or three principles essential to the successful drying of prunes and the expiration of the patients has resulted in gradual modifications and improvements at the hands of users.

"In contrast with the kiln, which is intended for use with apples and is not well adapted to the drying of most other fruits, the tunnel evaporator is an excellent general-purpose drier. The distinctive features of its operation which adapt it to the drying of prunes make it equally well suited to the handling of peaches, apricots, berries, apples and pears, and it is quite generally employed for drying these fruits wherever they are commercially dried in prune-growing territory. That it has not come into use in districts in which apples alone are dried is due to the larger expenditure of labor involved in drying apples on trays.

"In its essential features the drying chamber of the tunnel evaporator consists of a long, narrow compartment, with the floor and ceiling inclined uniformly from end to end, with a furnace placed below the floor at the lower end. The room is cut into a series of narrow chambers, the 'Tunnels,' by parallel partitions extending from floor to ceiling. Warm air is admitted to each tunnel through an opening in the floor at the lower end and escapes through a ventilating shaft at the opposite end. The two ends of the tunnel have doors opening in full width and height. The material to be dried is spread on trays which are inserted on parallel runways at the upper end of the tunnel, pushed gradually along as the drying proceeds, and removed dry at the lower end. The inclination of the tunnel, aided by an arrangement of the trays to be presently described, facilitates uniform flow of air over the trays in all parts of the tunnel."

The Raisin Industry.

G. C. Husmann says: "The principal raisin variety grown is the Alexandria. This has numerous synonyms, but is so well known in this country as Alexandria that no other names need now be given.

"Ripens midseason. Color, yellowish green; when fully ripe, flushed with amber. Cluster straggling, long, loose, and never compact even when perfect. Stem long, reddish brown; pedicel thick, warty, yellowish, one-half inch long. Berry large, five-eights by 1 inch long, tapering toward pedicel, sometimes slightly flattened at apex; surface smooth, yellowish green; bloom white; adherence excellent. Skin tough and thick. Flesh meaty, firm, fairly juicy.

"With the exception of very limited quantities produced in Arizona, Utah, and New Mexico, all the raisins grown in the United States are produced in California."

In discussing the climatic conditions for drying raisins in the raisin belt of California, Husmann says: "So ideal are the climatic conditions for the raisin industry, and they have such an important influence in drying raisins and other fruits, that the temperature and rainfall

records of Fresno and vicinity, furnished by the Weather Bureau, are herewith given.

"Table VII shows the seasonal rainfall (in inches) for fifteen years.

TABLE VII.

RAINFALL AT FRESNO, CAL., FROM JUNE TO NOVEMBER, 1900 TO 1914.

Year	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*
1900	Trace	Trace	0.00	0.16	0.33	4.61
1901	Trace	Trace	Trace	0.59	0.56	0.86
1902	Trace	0.00	Trace	0.00	0.42	2.25
1903	Trace	0.00	0.00	0.00	0.00	0.68
1904	0.00	0.00	0.00	1.78	3.21	0.08
1905	0.00	0.00	0.00	Trace	0.00	0.96
1906	Trace	Trace	0.00	Trace	0.00	0.73
1907	0.24	0.00	Trace	Trace	1.08	0.00
1908	0.00	0.01	0.00	0.15	0.02	0.66
1909	0.80	0.00	0.00	0.00	0.72	2.79
1910	Trace	Trace	0.00	1.00	0.45	0.24
1911	Trace	Trace	0.00	0.01	0.09	0.17
1912	Trace	Trace	0.00	0.10	0.01	0.85
1913	0.10	0.33	Trace	Trace	Trace	1.86
1914	0.23	Trace	Trace	0.22	0.26	0.11

"As to temperature it is noted that in the hottest time of the summer the mercury has risen as high as 115 degrees F. in the shade. The average of the highest daily temperatures is about 100 degrees during July and about 98 degrees in August, while the average of the day and night temperatures for the same months is about 82 degrees. The nights are always much cooler than the days. The coldest weather in winter is 17 degrees F. (above zero). The summers are rainless, and the nights are free from dew or moisture so that a piece of tissue paper, after lying out all night, is crisp and stiff the next morning, without a particle of moisture showing.

"The rainfall averages 10 inches a year. The principal rains occur in January and February, with some showers in October. Frequently it rains enough in November to cause considerable damage to partly dried raisins or grapes."

The Drying of Crude Drugs.

The following description is taken from G. A. Russell in *U.S. D.A. Farmers Bul.* 1231. Russell says: "Crude drugs can be dried either in the air or by means of artificial heat. When dried in the air, either sun-drying or shade-drying is employed, depending upon the type of material and the appearance desired for the finished product. The term 'sun-drying' is self-explanatory. This method can be employed with only drugs in which the quality or appearance is not unfavorably affected by the action of direct sunlight.

"Control of the drying operation is determined only by the nature of the material to be dried and the desired appearance of the finished product. It may be generally stated, however, that leaf and herb drugs

should be dried at moderate temperatures and root drugs at somewhat higher temperatures, the degree of heat to be used depending upon the condition of the green material. Flowers require low temperatures, whereas barks can often be dried at relatively high temperatures. Drugs in which the value depends on aromatic principles that are easily volatilized must be dried at a low temperature, in order that the volatile principle may not be lost through evaporation.

"Crude drugs fall naturally into one of the following classes: Leaves, herbs, roots, rhizomes, barks, fruits, and flowers. Leaf drugs consist either of the whole leaf or the leaf and a small portion of the upper end of the stalk. Herbs consist of the portion of the plant above ground and many contain flowers or fruits. Root drugs consist of the root of the plant, either whole or with the bark removed. Rhizomes are the underground stems, which are sometimes improperly called roots. Barks consist of the bark either of the aerial part of the plant or of the root. The latter are designated as root barks to differentiate them from other barks. Fruit drugs consist of the whole fruits, whereas seed drugs are only the seed of the fruit. Flower drugs consist either of the whole flower or of certain portions of the flower.

"A drying house that will accommodate approximately 1,000 pounds of green leaf drugs or a correspondingly larger weight of green roots is illustrated in perspective in figure above. This drying house is 14 feet 6 inches in length, 11 feet wide and 10 feet 2 inches in height to the eaves.

"The compartments are large enough to accommodate trays 4 by 5 feet in size, outside dimensions, and each compartment holds 17 trays placed one above another, 6 inches being allowed from center to center of the tray supports. This is as great a number as can conveniently be loaded and placed in the drier and is also the maximum number which will permit proper drying without slowing down the drying on the upper trays.

"The drying unit for this dryer is a basement hot air furnace as shown in the illustration."

Preservation of Vegetables by Drying.

F. P. Lund in *U.S.D.A. Department Circular* No. 3, gives the following discussion of vegetable drying. He says:

"Keeping green plants by drying is a very old process. It has been customary for ages to dry grass for cattle feed and store it under the name of hay. It has also long been customary to dry garden herbs and medicinal plants for home use. However, green vegetables dried in the sun and air as hay is dried, become tough and of a brownish color. This is partly due to the so-called 'hay-bacteria.' If the green color and the crisp condition are to be preserved, the drying must be quicker, by artificial heat, and the vegetables should be given a preliminary treatment to prevent or retard the action of the hay bacteria. This preliminary treatment is called

blanching, and consists in subjecting the vegetables to a short cooking in live steam or in boiling water. The steaming is preferable.

"Blanching is done after the vegetables are prepared properly. Besides retarding or preventing the action of the hay bacteria, it gives the vegetables a more thorough cleaning, removes the strong odor and flavor from certain kinds of vegetables and softens and loosens the fiber. This allows the moisture in the vegetables to evaporate more quickly and uniformly. It also quickly coagulates the albuminous matter in the vegetables, which helps to hold in the natural flavors.

"Where it is desirable to preserve the green color of the vegetables, as with strong beans, spinach, etc., it is advisable to blanch in boiling water to which has been added 1¼ level teaspoons of salt and one level teaspoon of bicarbonate of soda (baking soda) for each gallon of water. In case salt and soda are used in the blanching water, the green vegetables, after blanching, are quickly dipped in cold water. Drain well (the surface moisture can be further removed by pressing the vegetables lightly between two towels) and place at once in drying frames. Vegetables so blanched will give a dried product which remains green and crisp. Where no soda and salt are used in blanching water, it is not necessary to dip the products, after blanching, into cold water.

"The vegetables are spread in a thin layer on the trays or drying frames of the drier. The temperature for drying should be rather low to prevent scorching the product.

"Drying of vegetables can be done in two ways, either by starting at a high temperature which is gradually lowered, or by starting at a low temperature which is slowly increased. The first method is often advisable where blanching has been done in water in order to quickly remove surface moisture, but care must be taken to reduce the temperature as soon as this moisture is removed, to prevent the surface from becoming hard and dry and thereby causing difficulty in properly drying the product through and through.

"Equally as great care should be given to the selection and preparation of vegetables for drying as for canning. To secure a fine quality of dried products much depends upon having the vegetables absolutely fresh, young, tender, and perfectly clean. Wash and clean all vegetables well. If steel knives are used in paring and cutting, have them clean and bright so the vegetables will not be discolored."

Preservation of Foods by Drying.

H. W. Banks in *American Food Journal*, Vol. 16, No. 4, says:

"Like canning and refrigeration, dehydration is a method for the seasonable and geographical equalization of the food supply. Each of the three has its important field in the economic life of our population. The three methods of equalization are not rivals, but allies; each will take its logical place in the economic scheme. Dehydration

is newer and less familiar to the public than the other two, but it is on its way to attain its logical place.

"The industry in one sense is as old as civilization, and such products as raisins, dried figs, sun dried meats and similar foods have long been familiar to almost all peoples. The smoking of meat is a process of much the same kind, but here the drying is supplemented by preservative substances occurring in wood-smoke.

"In many of the oldest processes, artificial heat was employed, but in no case are these products exactly comparable to those produced by modern methods.

"The question of terminology has been disputed at some length. It may be said, without attempting a solution of the problem, that the present tendency seems to be to refer to the old, crude products, as 'dried,' and to use the term 'dehydrated' with reference to products prepared with a greater degree of care and with more precise attention to scientific control. In other words, the present connotation of the word 'dehydrated' appears to imply the removal of water without removing or altering other substances present. Desiccate means the same thing as dehydrate, but seems, for some reason or other, to be somewhat in disfavor. Good usage and common consent will settle the question of nomenclature. The writer employs the word dehydrate in the sense of removal of water with the minimum loss or alteration of other constituents of the product.

"Interest in dehydration was, of course, greatly stimulated by the World War. It is interesting to note, however, that Masson in France, as early as 1850, dried a great number of vegetables and fruits by what may be termed modern methods. He then subjected them to hydraulic pressure, producing a highly concentrated food product. A somewhat similar mixture of vegetables used in the German Army is stated to have contained 25,000 rations in a cubic metre. Masson dried his fruits and vegetables with a blast of warm air, generally at temperatures in the neighborhood of 70 degrees C. Years later Passburg of Berlin obtained excellent results with vacuum drying apparatus, and among other commercial installations that at the Guinness brewery in Dublin may be mentioned. From such beginnings arose the modern dehydration industry, which, with the war as a stimulus, has grown enormously. Much work, especially educational work, remains to be done, but the many workers in the field are adding new scientific information almost daily.

"Not only must we consider the great saving of freight charges as compared with canned or refrigerated products, but also the freedom from spoilage, ease of handling, and the cheap containers which may be used. But to realize the potential value of dehydrated products, the dehydration and conditioning must be properly done and under scientific control. It is probable that the greatest advances will first be realized in a strictly commercial manner, rather than in selling direct to the housewife. That is, in such cases as the shipping of dehydrated products to manufacturers of jams, jellies, preserves, candy,

etc. Their use in the kitchen will come in time, but it will be in all probability a gradual development.

"In this connection may be mentioned the shipment of orange and lemon peels from Italy to English manufacturers of marmalade. The present method of shipment is in casks of brine, and the saving in freight and storage by substituting dehydrated products is quite evident. It goes without saying that these materials must be dehydrated in such a way that they will retain their essential oils and flavors."

Concerning the great possibilities in the manufacture and use of dried, dehydrated, or desiccated foods, Banks says:

"The possibilities are enormous. One case may be cited. In preparing a vegetable soup or stew, the cook may choose from a dozen vegetables, picking out whatever combination or quantity is needed for the particular dish wanted. Powdered onion, garlic, mint, peppers and other flavors are quickly available by the same method. Any quantity may be used whenever it is wanted. Home dehydration is only another step, and splendid results can be obtained by the proper equipment and the proper instructions."

Several different types of patented dryers are on the market. Some of the products which these dryers claim to dry without chemical change are: whole or skimmed milk, buttermilk, beef blood; whole eggs, whites of eggs, brewers' yeast, dyewood and tannin extracts, glue and gelatine solutions, etc.

The Storage of Flours and Meals.

The U. S. Food Administration during the World War gave out the following advice concerning the storage of flour, meal, etc.

"Flours and meals should be stored in cool, dry, well ventilated places; warehouses should be whitewashed and swept clean before these products are placed therein; large supplies should not be accumulated. If too large a stock is on hand, it should be reduced and the flours and meals in question should be consumed as soon as possible.

"Flours and meals which contain the outer bran coatings and germ of the grain will not keep so well as when these are removed. Whole-wheat flour sterilized in the process of manufacture will keep much longer than the ordinary whole-wheat product. Corn meal and corn flour made from kiln-dried corn, and which have the germ removed, will keep better than the same products made from corn which has not been so dried and degerminated.

"Special care should be taken of the following products and these should be kept moving or be used as soon as practicable and should not be allowed to accumulate in the warehouse. Bran shorts and middlings, corn products containing the outer coating and germ such as so-called water ground corn meal and grits, etc., oats and oat meals, graham and whole-wheat flours, rye flour, barley flour, peanut meal, soy bran meal.

"Care should also be taken of potatoes as they will rot and begin to sprout in warm weather. If the potatoes begin to sprout it is well to go over them and remove the sprouts, which may easily be done by rubbing, the clean potatoes being transferred into new containers, or by shoveling them over inclines made of three-quarter inch wire screening. This should have sufficient pitch to permit the potatoes to roll into another bin. At the same time, any potatoes which have rotted may be removed.

"To prevent flours and meals becoming infested with weevils the outside of bags containing them should be kept clean and swept often. All sweepings from warehouses should be collected and removed or burned as these contain most of the adult insects, larva and eggs. Sacks containing flours should be kept in good repair as this will prevent the insects from entering the bags. Weevils and other insects will not push their way through even the thinnest cotton bagging.

"Care should be taken in storing bags of flours and meals to have sufficient space between the tiers to allow abundant ventilation and to raise the bags sufficiently from the floor to exclude rats, mice and insects; also to permit cleaning of the floors without the necessity of transferring the products from one part of the warehouse to another. Insecticides must not be used on products which are to be consumed for food except by experts trained in their use."

Preservation of Fruits by Drying.

C. F. Langsworthy in *U.S.D.A. Yearbook* (1912) says:

"Of course the flavor of dried fruits is almost never the same as that of fresh fruits; for eating in the simple state, and for some, though not all, cooking purposes, fresh fruits would usually be preferred were they equally convenient. As everyone knows, fresh fruit will not keep indefinitely, even with the most careful storage, and it is, moreover, so bulky that shipping it from place to place and providing storage room is decidedly expensive. Drying has the double advantage of protecting against decay and rendering the fruit more compact, while at the same time a product results which is palatable and convenient. A pound of fresh fruit will yield an average of about 6 ounces dried. The food value of a pound of dried fruit is, of course, greater than that of the same weight of fresh, since it has been concentrated by evaporating the water originally present.

"The main change which takes place during drying is a loss of water, but other changes also occur, their nature varying greatly with different kinds of fruit and with different methods of drying, particularly with the degree of heat employed. Removing the water depends chiefly on heat and the pressure and water content of the air surrounding the fruit and the rapidity with which the air circulates. The lower the air pressure, the drier and the warmer the air, and the more rapidly it moves, the more easily the fruit will give up its watery juice. If the process of drying is too rapid or too slow, or if the degree

of heat is too great or too little the resulting product will be below standard. The different methods and devices for preparing dried fruits have resulted from a recognition of such facts and an attempt to apply them accurately. The liking for one or the other is a matter of personal preference and habit but the rapid drying achieved by modern methods gives a superior product of different flavor as well as of different color and texture from the old-fashioned home-dried fruit.

"From the point of view of those who finally eat the fruit, the main thing is to have it dried in such a way that it shall retain as much of the natural flavor and food ingredients as possible, together with soft texture, attractive appearance, good keeping qualities, and freedom from insects or dirt or harmful substances of any kind.

"For some kinds of fruit, especially for raisins and figs, artificial drying does not work as well as sun drying. The great difficulty with natural drying in the open air, aside from the uncertainty of the weather, is, of course, the exposure to dust and insects. Everyone knows that dust may be the bearer of all sorts of microörganisms, causing disease, and of other tiny organisms which cause decay in the fruit. Insects, attracted by the sweet fruit, introduce future worms by laying their eggs in it. It is possible to guard against these dangers by choosing clean and protected drying places, by preventing careless and unnecessary exposure, by washing or sterilizing, and by careful packing and marketing. The large establishments in the fruit-growing sections of the United States are setting high standards of cleanliness and are demonstrating that it is profitable to produce really sanitary goods."

Drying of Apples, Prunes, Peaches, Apricots, and Cherries.

Langworthy says: "The complicated machines which peel, core and sometimes even slice the apple at one operation are in very general use. After the fruit has been thus prepared it is usually dipped for a few minutes in a weak solution of salt and water. The purpose of this dipping is to prevent the discoloration which ordinarily occurs when the flesh of the apple is exposed to the air. After dipping, the apples are commonly placed in the drying trays, in which they are later taken to the drying machine. Many manufacturers subject them at this stage to a short fumigation with sulphur, the purpose of which is to make the color lighter and to kill any moth eggs or injurious microörganisms which may be present in the fruit. Sulphuring, which is used with various kinds of fruit, is, in this country, carefully regulated so as not to burn or harden the fruit, which when dried should be soft and pliable. On being removed from the desiccator the fruit is allowed to stand for what is known as the 'sweating' to take place, a process which usually takes several days, and is carried out either in the open air or in well-ventilated chambers. The dried fruit should be packed and marketed in ways which keep it clean and unspoiled."

IV. Preservation by Concentration.

The preservation of food by concentration depends largely upon the fact that when the concentration of a liquid becomes greater than the cell sap of microörganisms they become plasmolyzed and are unable to grow as is illustrated in such foods as syrups, conserves, and molasses. The preservation of jellies is partly due to concentration and partly due to solidification of the product preventing access to it. Molds can attack the exposed surfaces of jellies. The solidification in the manufacture of jellies is due to the pectin of the fruit in the fruit acid. Some fruits which do not contain enough pectin to jell properly are mixed with other fruits which contain pectin abundantly. As a general rule, two-thirds as much sugar as juice is added in jelly making. Jelly in jars is often sealed with hot paraffin as a protection against molds.

TABLE VIII.

SUGARS IN FRUITS ACCORDING TO WILEY.

Kinds of Fruit	*Average Percentage of Total Sugars, Calculated as Dextrose*	*Kinds of Fruit*	*Average Percentage of Total Sugars, Calculated as Dextrose*
Apples	12.2	Pear	10.0
Banana	13.8	Pineapple	11.7
Grape	15.0	Prickly pear	4.2
Orange	5.4	Tomato	2.0
Peach	7.6	Watermelon	2.5

V. Preservation by Smoking.

The preservative effect of smoking certain food products is due to the creosotic compounds of the smoke which enter the product more or less and diffuse through the entire surface layer. Beech wood is generally used in smoking meats.

VI. Preservation by Pickling.

Sauerkraut.

The making of sauerkraut is an old custom. It is made commercially in white cypress tanks of several thousand gallons content. The cabbages are cut into small shreds by being thinly sliced. It is the custom to use the looser heads of cabbage which would not store satisfactorily. Layers of cabbage several inches thick are alternated with sprinklings of salt. Ten pounds of salt are used to 400 gallons of sauerkraut. The cabbage is pressed down as the tank fills. On a commercial scale, sauerkraut requires only two or three weeks for making. Properly fermented kraut is firm and light in color. Starters,

sour milk or vinegar are sometimes added to the cabbage as it is prepared to insure proper fermentation.

According to Lipman, the bacterial activities in sauerkraut making are twofold, that is, flavor production, and the prevention of putrefaction for a period of time. The juices of the cabbage, due to pressure and the presence of the salt, flow out of the tissues and create a medium in which many varieties of acid and gas producing bacteria develop rapidly, evolving considerable gas and increasing the lactic acid content of the liquor. Finally a membrane covers the surface of the liquor formed by Oidium lactis. Yeasts are also active in the liquor attacking the sugars which have diffused from the cabbage.

The action of yeasts in converting the sugars into alcohol and CO_2 and the lactic acid bacteria converting the sugars into lactic acid develop some sort of associative action according to some bacteriologists.

The commercial method of manufacture of sauerkraut according to A. W. Bitting is as follows:

"Sauerkraut is made by the natural fermentation of cabbage in casks. The cabbage heads are stripped of all outside or green leaves, leaving only the white sound head. It is then cut into thin slices in a specially constructed machine. The long, fine-cut cabbage is evenly spread and well packed in casks. To each layer salt is added at the rate of about 2 pounds per 100 pounds of cabbage. The salt is used as flavoring and to modify in some degree the fermentation. If too much salt is used, a pinkish color results; if too little, the fermented product may become more or less slimy. The temperature of the weather at the time of putting up the cabbage also influences the fermentation. If the weather is very warm, the fermentation is too rapid, the product has a very white but more or less slimy appearance, and the cabbage is tough rather than of a natural crispness. If the temperature is very low, fermentation will be arrested. The best temperature is probably between 60 degrees and 70 degrees F. and the process requires about 4 weeks. Fermentation begins as soon as the cabbage is placed in the cask, but there is only a slight rise of temperature as compared with most fermentation processes. A heavy foam rises to the top, which must be skimmed off every day, and when this ceases to form the brine goes down and the process is complete. Use can be made of the kraut at once, though it seems to be better after standing. The kraut will keep in the casks for a long time, provided there is no leakage, and the spoilage is usually limited to a few inches on the top.

"Kraut is easily canned, which is the only clean way of dispensing it in groceries in small quantities. The canning should be done where the kraut is made. The shipping of kraut in barrels to distant points to be canned has nothing to commend it and much to condemn it. The repacking in barrels means labor and loss of material, and in too many cases the loss of natural brine, after which spoilage takes place easily. The canning should be done while it is in the freshest

possible state at the point of production. Kraut is easily kept. The cans should be filled full, weighed, and sufficient hot water added to fill the can; then exhausted, capped and processed at boiling temperature for 25 minutes.

"The gases evolved in sauerkraut are mainly carbon dioxide, and hydrogen. The organic acids, succinic acid, acetic acid in addition to lactic acid are formed. However, lactic acid is the main acid formed.

Dill Pickles.

"The process of making dill pickles does not differ much from that of making sauerkraut as far as the fermentation is concerned. The sugars of the cucumbers diffuse out of the cut cucumbers into the liquor and are fermented by lactic acid bacteria and alcoholic yeasts. As in sauerkraut, B. coli communis and allied bacteria are active fermenters producing hydrogen and carbon dioxide. Oidium lactic finally grows on the surface of the liquor and reduces the acidity.

"Sound cucumbers are used in the manufacture of dill pickles. They are placed in layers with dill stalks, leaves, and seeds in wooden tanks or in earthenware. A brine liquor composed of 10% salt, 15% vinegar and 75% water is placed over the cucumbers.

"Dill pickles, which are much prized and command the highest price among pickles, can be made from fresh cucumbers as they come from the vines, or from vat stock which has been carried for some time at the salting station.

"Dill pickles from fresh cucumbers are of high quality, but not quite as satisfactory keepers as when made from salt stock. In preparing fresh stock for dill purposes, fresh cucumbers as they come from the field are placed in wine casks from which one head has been removed. A layer of pickled dill and one quart of dill spice is placed at the bottom of the barrel. The cucumbers should be assorted carefully as to size, one grade of about 4 inches in length being placed in one receptacle and another grade of 5 inches in length, or approximately this length, in another barrel. After a cask has been filled, a layer of dill is placed over the fruits before the head is replaced. After the cask has been reheaded, the commercial practice is to remove the bung and fill the cask containing cucumbers with a 45 degree Baumé test brine, adding one pound of porous alum to each 45 gallons of brine. The cucumbers are left in this brine five days. The first brine is then replaced by a thirty degree brine, to each forty gallons of which one-half pound of porous alum and 4 gallons of 80-grain vinegar are added, the whole heated to 160 degrees F. before being placed in casks.

"To make dill pickles from salt stock, the cucumbers are removed from the brine, placed in a processing tank and covered with fresh cold water, and allowed to remain twenty-four hours, after which the water is drawn off. The tank is then again filled with fresh water,

to which are added 2 pounds of alum and two ounces of turmeric to each barrel of pickles in the tank. The whole mass is then heated up slowly to 130 degrees F. The fruits are allowed to stand in this cooling mixture for twelve hours, when they are sorted and packed.

"Before beginning to fill the cask with cucumbers, place a layer of pickled dill herb at the bottom of the cask, fill the cask half full of processed cucumbers, and add another layer of dill herb, at the same time placing in the cask one quart of dill spice, consisting of the following proportions of whole spices: 4 pounds of allspice, 2 pounds of crushed black pepper, 4 pounds of coriander seed, and one pound of bay leaves. After adding this spice and the layer of dill herb, complete the filling of the cask, but before replacing the head of the cask scatter another layer of dill herb over the cucumbers. After being reheaded, the bung is removed and the cask filled with dill brine consisting of one-fourth barrel of dill herb, 1½ pounds of alum, and 100 gallons of 30 degree brine. At the time of filling the barrel one gallon of 50 grain vinegar is added to each 10 gallons of the brine. This brine should be allowed to stand twenty-four hours before using it to cover the processed cucumbers packed in barrels, as above described.

The Salting Station.

"The gathering points or receiving depots maintained by pickle factories in communities where cucumbers are commercially grown are called salting stations. The equipment of the salting station consists of a long, low building provided with a large number of wooden tanks, a common size of which is ten feet in depth and sixteen feet in diameter, with a capacity of about 1,500 bushels. An ordinary salting station will contain forty of these tanks, having a capacity of 60,000 bushels.

"The cucumbers as they are received from the farmers, if of comparatively uniform size, are dumped directly from the receptacles in which they are delivered into the vats, the vats being first provided to the depth of 12 to 18 inches with seventy degrees to eighty degrees Baumé brine, which is made by adding 2 pounds of salt to each gallon of water. As cucumbers are added 100 pounds of salt are scattered over the fruits for each thousand pounds of cucumbers which means approximately about 5 pounds of salt to each bushel of cucumbers. If it requires more than a single day to fill the tank a quantity of salt should be scattered over the cucumbers before suspending work at night, and if it is to be carried over Sunday or a holiday the cucumbers should be salted and pressed under the brine from time to time during the interval the work is suspended. This will keep the cucumbers from getting soft and becoming yellow. If the tank is not too large and a false head can be employed this will serve to hold the cucumbers under the brine. In large tanks this is a troublesome process, and the customary means of protecting them is to push them under the brine with a suitable paddle.

"After the tank is full of cucumbers and before the false head has

been put in place, the weight of the cucumbers in the tank should be estimated and one pound of salt added for each hundred pounds of fruit. A part of this salt can be placed on top of the cover and the tank then filled with fresh water until the liquid stands 4 to 6 inches above the top of the cover. The salt should not be washed off the cover by pumping water on it, but the water should be pumped into a tube made of 6-inch boards long enough to reach from the top to the bottom and fitted to one side of the tank, so as to carry the fresh liquid to the bottom.

"After this additional quantity of salt has been given, the brine

After Cook in U.S.B.F. Document 908.

FIG. 36.—The Baronovich salmon saltery; the oldest saltery in Alaska.

should test between 65 degrees and 70 degrees on Baumé's salt scale. After the tank has stood three or four days the top brine will have lost strength until it has fallen to 35 degrees or 40 degrees, when 4 or 5 pounds of salt to each hundred pounds of fruit should be added. After another period of four or five days, or as soon as the brine falls to 45 degrees or 50 degrees, another addition of 4 pounds of salt to each hundred pounds of fruit should be made in the way above noted. After a week's time the brine should test about 55 or 60 degrees, at which point the cucumbers should keep well, the only additional attention required being to pump the brine over by means of a pump placed in a wooden box at the side of the tank above mentioned, every five or six days for the first month and once in three weeks or once

a month thereafter as long as the pickles are held in the brine. The pumping over is for the purpose of raising to the top the heavy brine which naturally settles to the bottom of the tank, and to cause the contents of the tank to be more evenly salted.

"During the time the tank is being filled the brine is kept deep enough to nearly cover the pickles at all times. After the tank has been entirely filled with cucumbers—that is, heaped up with cucumbers to a height of from 18 inches to 2 feet above the rim of the tank—one pound of salt to each hundred pounds of cucumbers in the tank is placed over the top layer of cucumbers, as noted above. The false head of the tank is then put in place, stringers are laid on top of it, and the whole is weighted with barrels of salt or other material to force the cucumbers into the tank and beneath the surface of the brine.

"The gathering and handling of cucumbers at the salting station involve comparatively little labor, but because the cucumbers are not used immediately by the factories, it requires the capital invested to be tied up for a considerable period of time.

"The fact that this salt stock can be held without material loss for several years places the pickling industry upon a comparatively safe basis. A crop failure in one locality in any particular year does not, as a rule, affect the work of the factory or change the price of fresh stock. The reserve stored stock can be drawn upon for the needs of the factory."

VII. Preservation by Salting.

Many vegetables lend themselves to preservation by salt. The most important brine preserved vegetables are cabbages, cucumbers, peppers, cauliflower, green tomatoes, ripe tomatoes, beans, onions and celery. Wooden tanks or tubs of cypress or large earthenware jars prove to be the best containers. Brines containing from 12% to 25% or stronger are used depending upon the vegetable. The vegetables salted should not protrude above the surface of the brine in the container. The growth of fungi on the surface of the brine is sometimes prevented by a film of oil or paraffin.

Small cucumbers and gherkins can be preserved by packing in strong brine. String beans packed in layers of salt keep well but darken slightly.

Pork is placed in strong brine and keeps well. Ducks and wild game have similarly been salted down successfully.

VIII. Food Preservation by Spices and Essential Oils.

Foods are seldom preserved by the use of spices and products containing essential oils, but many products are added to foods which have a preservative effect as cloves, cinnamon, and mustard.

Bitting describes the preparation and canning of sardines in oil as follows: "The sardines caught on the Pacific coast are much larger

than those taken in the East and are handled in a different manner. They are caught in nets at night, and on being brought to the factory in the morning are put into bins and kept wet with running water for some hours. They are then dressed, scaled, head and viscera removed, and again thoroughly washed in two or more changes of water. They are next dipped in strong salt brine for a few minutes, rinsed, and placed in wire trays to dry. In order to expedite the drying the trays are carried through a mechanical drier so that all surface water will be removed. The crates are then dragged through a vat of boiling oil, the length of time being that necessary to cook the fish thoroughly, usually about five minutes. They are left in the crates until cool, which is usually until the following day, placed in the cans by hand, oil or sauce added to fill the interspaces, carefully exhausted, and processed at 240 degrees Fahrenheit for one hour and fifteen minutes."

F. M. Bachmann has made a study of the use of microörganisms to determine the preservative value of different brands of spices. The following tables (IX and X) are from her work:

TABLE IX.

EFFECT OF DIFFERENT BRANDS OF CLOVES ON BACTERIAL GROWTH.

Organism	*Dilution of Spice*	*Brand A*	*Brand B*	*Brand C*	*Brand D*
B. subtilis	1: 50	0	0	0	0
	100	0	0	0	+
	200	0	0	+	+
	300	0	0	+	+
	400	0	+	+	+
B. coli	1: 50	0	0	0	0
	100	0	0	0	+
	200	0	+	+	+
	300	0	+	+	+
	400	+	+	+	+
B. prodigiosus	1: 50	0	0	0	+
	100	0	0	+	+
	200	0	+	+	+
	300	+	+	+	+
	400	+	+	+	+
Sarcina lutea	1: 50	0	0	0	+
	100	0	0	0	+
	200	0	0	+	+
	300	0	+	+	+
	400	+	+	+	+

IX. Filtration as a Preservative Process.

The use of filtration as a preservative is not widely used but is pretty largely confined to laboratory media and laboratory experimentation.

TABLE X.

EFFECT OF DIFFERENT BRANDS OF ALLSPICE ON THE GROWTH OF MOLDS AND YEASTS.

Organism	*Dilution of Spice*	*Brand A*	*Brand B*
Alternaria tenuis (?)	1: 25	0	0
	50	0	0
	100	0	+
Penicillium glaucum	1: 25	0	0
	50	0	0
	100	+	+
Rhizopus nigricans	1: 25	0	0
	50	0	0
	100	0	+
Aspergillus niger	1: 25	0	0
	50	0	+
	100	+	+
Yeast Foam-culture from.....	1: 25	0	0
	50	0	+
	100	+	+
Fleischmann's compressed-culture from	1: 25	0	0
	50	0	+
	100	+	+
Saccharomyces cerevisiæ	1: 25	0	0
	50	0	+
	100	+	+
Saccharomyces ellipsoideus....	1: 25	0	0
	50	0	+
	100	+	+
Saccharomyces anomalus	1: 25	0	0
	50	0	+
	1 00	+	+

X. Food Preservation by Sealing.

Eggs are one of the most important foods preserved by sealing. They may be preserved in water glass. Only fresh eggs are preserved. Water glass is composed of sodium silicate and preserves the eggs by sealing up the pores in the shell through which bacteria normally enter. (See chapter on Bacteriology of Eggs.)

Cheese is generally protected from exposure to miscellaneous organisms by sealing with paraffin. Hams also are often sealed in a similar fashion.

XI. Chemical Food Preservatives.

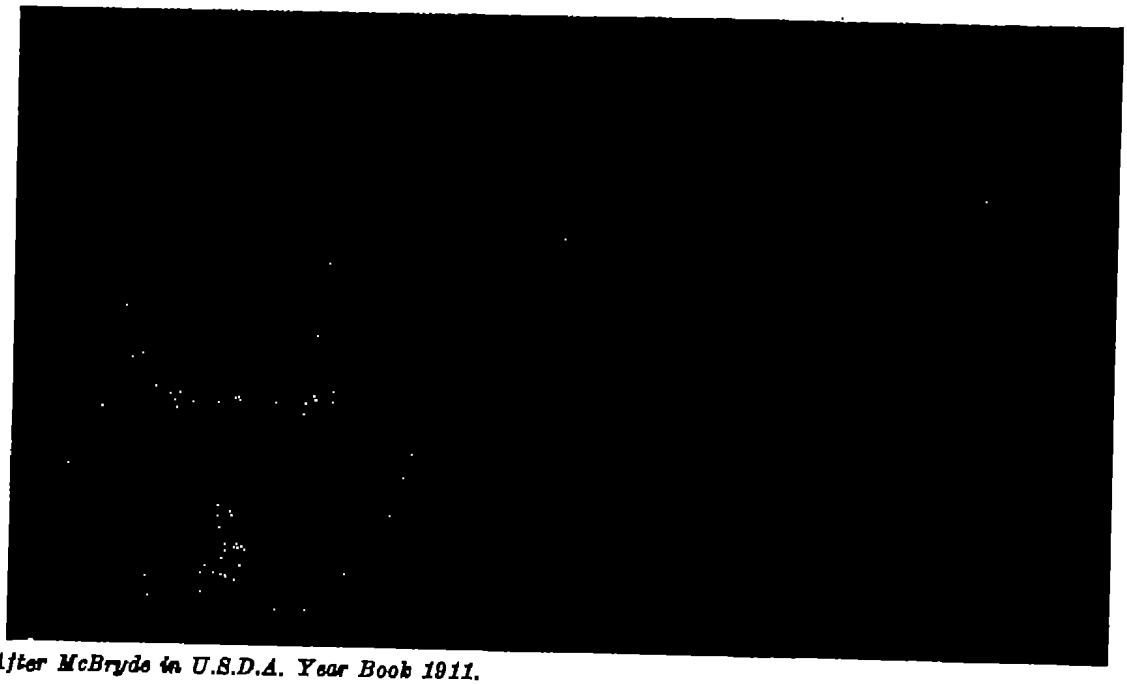
Some of the more important preservatives used in foods are benzoate of soda, boric acid, salicylic acid, alcohol, formaldehyde, sulphuric acid, potassium nitrate or saltpeter.

Boric acid is said to be used in the butter of Australia. Benzoic acid is used in catsup and in sweet cider to some extent in the United States.

Preservation of Pork by Curing.

Priest in *Tennessee Extension Publication* No. 57, discusses the sugar curing of pork in the following paragraphs. He says:

"Salt, saltpeter, sugar and molasses are the principal preservatives used in curing pork. Borax, boric acid, formalin, salicylic acid and other chemicals are sometimes used, but their use is prohibited in connection with meats and products to which the Federal meat-inspection law is applicable and they should not be used.



After McBryde in U.S.D.A. Year Book 1911.

FIG. 37.—Preparing corn beef for canning. Government inspector at center.

"Salt, when applied alone to meat, makes it very hard and dry, because the action of the salt draws out the meat juices and hardens the muscle fibers. Saltpeter is used to preserve the natural color of the meat. It is more astringent than salt and should be used sparingly. Sugar and molasses act differently than salt. They soften the muscle fibers and improve the flavor of the meat. The combination of salt and sugar makes a good cure.

"Sugar cured pork is preferable to plain salt pork because of its better flavor and because the meat is not so dry and hard. Two ways of curing are in common use, brine curing and dry curing. Each has its advocates. It is less trouble to pack meat in a barrel and pour brine over it than to rub it three or four times with salt. The brine keeps away insects and vermin. Dry curing is safer to use during warm weather, and is frequently less expensive. In using either

method, rub the surface of the meat with fine salt and allow it to drain, flesh side down, for six to twelve hours before being put in the cure.

"Brine Curing—Make a mixture as follows for each 100 pounds of meat:

8 pounds salt
2½ pounds sugar or syrup
2 ounces saltpeter
4 gallons water.

"In warm weather 9 to 10 pounds of salt are preferable. Allow four days' cure for each pound in a ham or shoulder and three days for bacon and small pieces. For example, a 15 pound ham will take 60 days; a piece of bacon weighing 10 pounds, 30 days.

"The brine should be made the day before it is used, so that it will be cool. All the ingredients are poured into the water and boiled until thoroughly mixed. Place hams on the bottom of the container, shoulders next, bacon sides and smaller cuts on top. Pour on the brine, and be sure it covers the meat thoroughly. In five days pour off the brine and change the meat, placing the top meat on the bottom and the bottom meat on top, then pour back the brine. Repeat this operation again on the tenth, and eighteenth days. If the pickle becomes ropy, take out all the meat and wash it off thoroughly, also the container. Boil the ropy pickle; or, better, make new pickle. When each piece of meat has received the proper cure, take it out of the pickle and wash in lukewarm water, string and hang in the smokehouse.

"Dry Curing—Make up a mixture, as follows, for each 100 pounds of meat:

7 pounds salt
2½ pounds sugar
2 ounces saltpeter.

"Mix all ingredients thoroughly, then rub one-third of the quantity of this mixture over the meat and pack it away in a box or on a table. The third day break bulk and rub on half of the remaining mixture over the meat and again pack the meat. Break bulk the seventh day and rub the remainder of the mixture over the meat and pack the meat to cure. Allow one day and a half cure for each pound the pieces of meat average. After the meat has cured, wash each piece with lukewarm water and hang in the smokehouse.

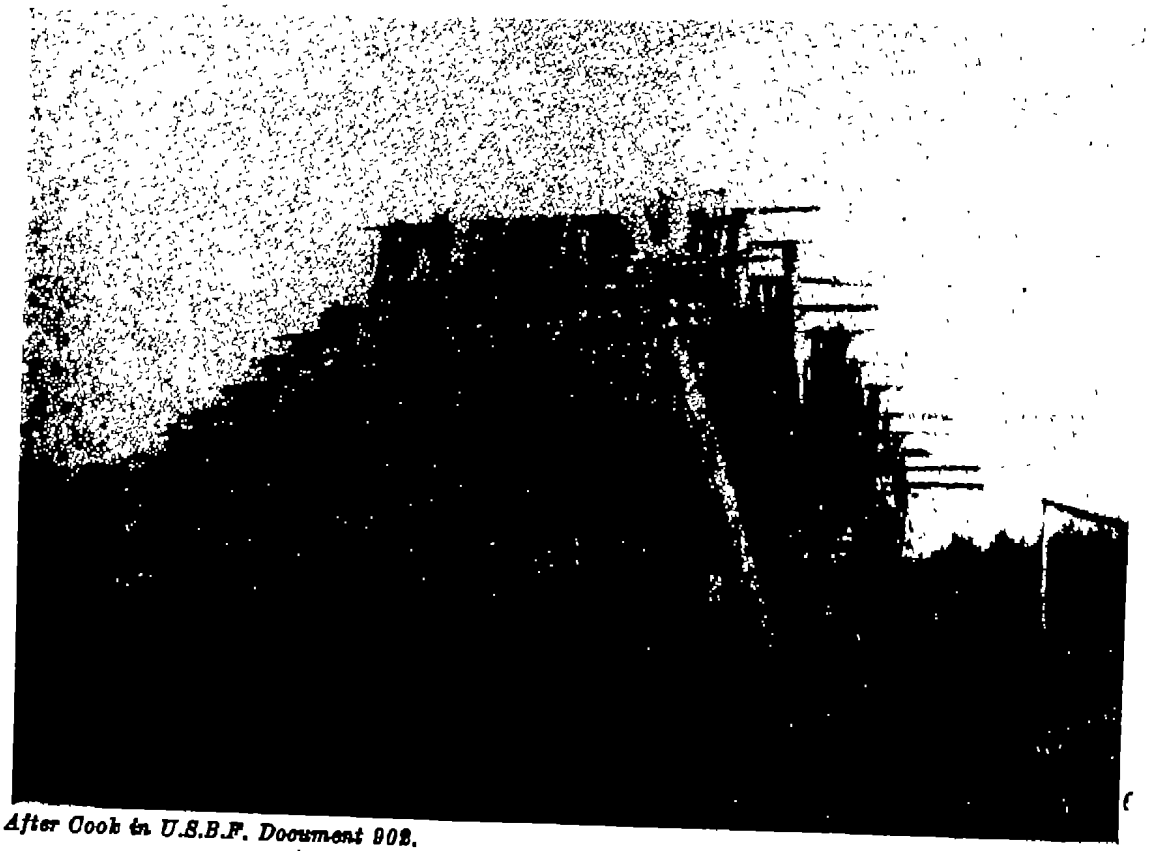
"Fatbacks—Cut the fat backs into suitable pieces for curing and pack them in a container. Make up a mixture, as follows, for each 100 pounds of meat:

10 pounds salt
2 ounces saltpeter
4 gallons water.

"Pour this mixture over the meat, adding enough more water if necessary to cover it completely.

"Smoking helps to preserve the meat. If properly done it gives a desirable flavor.

"The smokehouse can be made any size and of the kind of material suitable to the demands of the owner. If a very small quantity of meat is to be smoked once a year, a barrel or a box will answer. On the other hand, if a considerable quantity of meat is smoked and the house is to be permanent, it should be built of brick, concrete,



After Cook in U.S.B.F. Document 902.

FIG. 38.—An Indian salmon-drying rack, Bering Sea, Alaska.

or stone, to be fireproof. A small outdwelling can be used, if care is taken to confine the fire to the center of the room in an iron kettle. The safest method is to construct a fire pit outside of the house and pipe the smoke into the house. The pipe running from the pit to the house should be buried to prevent crushing.

"A smokehouse 6 by 8 ft. 10 ft. high, will give best results for general farm use. Ventilation should be provided to carry off the warm air and prevent overheating of the meat. Small openings under the eaves or a chimney in the roof will control ventilation. If arrangements can not be made to have a fire pit outside the house it can be built on the floor and a metal sheet constructed to shield the meat. If the meat can be hung 6 to 7 feet above the fire, this shield will not

be necessary. At this height the meat will get the benefit of the thick smoke and still hang below the ventilator.

"Green hickory or maple wood is the best fuel for smoking. Hard wood is preferable to soft wood. Resinous woods should never be used, as they give an objectionable flavor to the meat. Corn cobs may be used, but they deposit carbon on the meat, giving it a dirty appearance.

"Allow the meat to hang in the smokehouse twenty-four hours before beginning to smoke. Space between the pieces of meat is necessary to insure good circulation of smoke. A slow fire should be started, so that the meat will warm up gradually. Do not get the house too hot. The fire can be kept going continuously until the smoking is complete, holding the temperature as even as possible (120 degrees F.). Thirty-six to forty-eight hours is the time required to smoke a lot of meat, but slower and longer smoking is desirable if the meat is to be kept any length of time. During warm weather it is better to start the fire every other day rather than heat up the meat too much. In the winter, however, if the fire is not kept going the meat may cool and the smoke will not penetrate properly. As soon as the meat is thoroughly smoked, open the doors and ventilator, so that the meat can cool.

"Smoked meat, after it is hard and firm, should be wrapped in heavy paper and put into muslin sacks."

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Chapter 18.

The Canning Industry.

A Frenchman, Nichols Appert, has been styled "The Father of Canning." He invented in 1795 a process of heating foods sealed in glass cans, which caused them to keep indefinitely. He said: "It is obvious that this new method of preserving animal and vegetable substances proceeds from the simple principle of applying heat in a due degree to the several substances, after having deprived them as much as possible of all contact with the external air. It might, on the first view of the subject, be thought that a substance, either raw or previously acted on by fire, and afterwards put into bottles, might, if a vacuum were made in those bottles and they were completely corked, be preserved equally well as with the application of heat in the water bath. This would be an error, for all trials I have made convince me that the absolute privation of the contact of external air (the internal air being rendered of no effect by the action of heat) and the application of heat by means of the water bath, are both indispensable to the complete preservation of alimentary substances." Dr. McBryde says: "While Appert had no conception of the rôle played by micro-organisms in the spoilage of foods, his experiments clearly showed that a vacuum alone was not sufficient for the preservation of foodstuffs, and that the application of heat and the subsequent exclusion of the outside air were essential to their successful preservation. We now know that the air contains microörganisms or germs which are responsible for the fermentation and putrefaction of foods.

"The stimulus which prompted Appert's investigations was a prize offered by the French Government for a method of preserving foods for the use of the navy, and in 1809 the inventor was awarded the prize of 12,000 francs. The process was given to manufacturing firms in France and was soon carried to England.

"At first the secret of the process was carefully guarded, but in time the employees of the different establishments became more or less familiar with the details of the process and in this way the method was carried from England to America about 1815 or 1818.

"Ezra Daggett, originally in the employ of an English firm, is said to have first brought the secret to America, and as early as 1819, in partnership with his son-in-law, Thomas Kensett, was engaged in the packing of hermetically sealed food in New York City. Lobster, salmon and oysters were among the first goods packed in America, but by 1825 fruits and vegetables were also canned.

"In the case of meats which are 'processed' or heated in the can, it is customary to subject the meat to a preliminary cooking or par-boiling before placing it in the cans. This is done in order to partly cook and at the same time to shrink the product.

"The cooking is carried on in large iron tanks, fitted with iron tops, usually hinged, which may be raised or lowered. Sufficient water is used to cover the meat, and the water is heated by means of perforated steam coils in the bottom of the tank.

"When the meat has been sufficiently cooked it is removed from the boiling water by means of large metal forks and transferred to the 'trimming bench,' where the gristle, surplus fat, and bone are trimmed off. The meat then goes to the cutting machine, which cuts it into pieces, according to the size of the cans to be filled. After it is cut to the proper size the meat is passed down through a chute to a lower floor to be packed in the cans.

Filling and Capping the Cans.

"In the case of products like tongue and Vienna style sausage where the form of the product is to be preserved, it is necessary to fill or 'stuff' the cans by hand.

"In the case of corned beef and potted or deviled meat the cans are filled by machinery. The stuffing machines, which usually work on the rotary principle, consist of a series of pistons and cylinders. The cans are placed beneath the cylinders, and the meat is fed into the cylinders from above and is forced down into the cans by the pistons.

"The meat is fed into the stuffing machine with scoops in which the proper amount of meat for each is weighed approximately. When the can leaves the stuffing machine, it is weighed and adjusted to the proper weight by adding to or taking out a little of the meat.

"After the can has been weighed and the necessary adjustment made in the weight, the top is wiped and any projecting particles of meat are shoved down into the can so as not to interfere with the cap. The cap is next put in place and soldered under a rotary soldering machine.

"The capping machines consist of a series of small revolving tables upon which the cans are placed with the tops laid loosely in position. The caps are then clamped down from above and are soldered either by hand or by automatic soldering irons. When the cans leave the capping machine they have been completely sealed except for the small vent holes in the top, through which the air within the cans is to be later exhausted.

"The cans are next inspected for cap leaks (i.e. leaks in the solder holding the cap), and these are repaired by hand.

Sealing the Cans Under Vacuum.

"The next step in the canning process consists in exhausting the air from the interior of the can, and this is usually effected by means

of vacuum machines. The usual form of vacuum machine consists of a large circular iron box with air-tight doors and a small glass window through which the vents are sealed by means of an electric soldering iron. The machine is filled with cans and closed, the vacuum is then applied, and the vents are sealed as the cans are brought beneath the window on the movable bottom of the machine.

"From the vacuum machine the cans are run out on tables and again inspected for leaks. Any leaks that are found are at once repaired by hand, the vents of these cans are then reopened, the cans replaced in the vacuum machine, and the vents resealed under vacuum. The cans are now ready to be processed.

Processing the Cans.

"Processing consists in heating the cans to a sufficiently high temperature to insure the preservation of their contents, and constitutes one of the most important steps in the whole canning process. Two general methods of processing are followed, known as the 'retort process' and the 'water process.'

"In the retort method of processing, the cans are placed in large iron or steel boilers, known as retorts, which can be securely closed by means of bolts. In these retorts the cans are subjected to the action of steam under pressure and in this way high temperatures can be secured. The length of time the cans remain in the retorts and the temperatures employed depend upon the nature of the product and the size of the cans.

"In the water method of processing, the cans are placed in large open kettles or tanks filled with water, which is raised to and maintained at the boiling temperature by means of steam pipes. The cans remain in the boiling water for varying lengths of time, depending upon the size of the can and the nature of the product."

Along with the great growth which the canning industry has made during the last quarter of a century there has been also a great increase in the number of difficulties which have arisen. Many of these problems of canning have been only partly solved. Within the last few years the National Canners' Association (formed in 1907) and the Experiment Stations have been attacking these problems, some of which at times threatened the industry as a whole.

The study of the necessary heat treatment in ideal canning methods has occupied considerable attention. This subject has been found to be important not only from the standpoint of killing ordinary spoilage organisms but because of the necessity of killing very resistant organisms which are found to produce extremely poisonous toxins if allowed to grow at all in canned goods. It is well recognized that a few deaths due to the eating of any kind of canned goods results temporarily in almost complete elimination of the particular kind of canned goods from the human diet. So this subject is being studied

from two standpoints, that is, efficiency in food preservation and its relation to public health.

Concerning the amount of heat treatment required by different food in being canned, Bitting says: "Sterilization may be accomplished by heat below, at, or above the boiling temperature, depending upon the length of time the heat is applied and the number of applications made. It is not practicable to sterilize all foods in the same way because of injury to quality or prohibitive expense. Sterilizing below the boiling point is feasible only for a few products, principally fruits, and then is advisable only when it is desired to preserve a very fine appearance. This may be accomplished above 165 degrees F. by maintaining the temperature for a longer time than when boiling, or by repeating the operation on two or more successive days. The object is to prevent breaking the tissue and loss of juices from the fruits by excessive heat. This method of sterilization has been applied experimentally and in private canning with gratifying results, but it involved so much time and labor that it is not used commercially except in a limited way. Sufficient work has not been done to say definitely what products can best be treated in this way nor what temperatures are best suited for different foods. It has been used chiefly with foods in glass, though equally satisfactory results are obtained with foods in tins.

"Cooking at boiling temperature is practiced with nearly all fruits, as the germs present are easily destroyed. Most of the fruits are processed for from 12 to 25 minutes. The tomato is the most important vegetable processed at boiling temperature, which is usually maintained for 50 minutes.

"Among the vegetables requiring a high temperature in processing are corn, peas, beans, both green and dry, pumpkin, beets, and sweet potatoes. Corn is one of the difficult products to can, requiring a temperature of from 245 degrees to 250 degrees F. for from 75 to 80 minutes, depending to a considerable extent upon how dry it is packed. If very dry, the heat will penetrate to the center of the can very slowly, the actual time required to raise the center to the temperature of the bath being from 55 to 65 minutes. In a can of peas this is accomplished in 6 or 7 minutes, the difference being due to the fact that heat currents are set up in the liquid portion of the peas, while they are absent in the corn. The necessity for a high temperature is therefore dependent upon the ease with which the heat can penetrate the product, as well as the resistance of the organisms. Some products which were formerly processed by boiling for a long time are now given a higher temperature for a few minutes, as the product has a much better appearance when it is not overcooked.

"The penetration of heat in the can is dependent almost wholly upon the ease with which convection currents are set up, occurring most rapidly in products which permit the free circulation of water, weak brine, or sirup between the solids, as in peas, and least rapidly in the absence of free liquid, as in dry-packed sweet potatoes. Products

having a heavy though uniform consistency like pumpkin and squash, require a long time for heat to penetrate to the center of the can. Heavy tomato pulp takes a much longer time to reach the boiling point than canned tomatoes, and soft ripe fruits, as apricots and peaches, need more time to become sterilized than green fruit, not because the germs are more resistant but because the heat can not penetrate as readily as when the liquid circulates freely between the solid pieces. Failure to recognize this principle of the movement of heat in liquid, semi-liquid, and solid substances has caused the loss of thousands of cases of foods. Mechanical agitation shortens the period of cooking, especially in foods of heavy body; at the same time it places a greater strain upon the can, with a tendency to increase the number of leakers."

Springers.

The Bittings discuss abnormal conditions in cans as follows: "A springer is a can the contents of which are sterile but which has one or both ends more or less convex. This condition is due to overfilling, to generation of gas due to the action of the contents upon the container, to packing the cans cold, or to packing without a vacuum. The condition may be so mild that the ends may be returned by moderate pressure from the fingers or so severe as to cause bursting.

"A flipper is the incipient stage of a springer. The term is usually applied to such cans as permit the ends to be returned to the normal by pressure from the fingers or by striking the end of the can on some firm object.

"Springers and flippers are almost wholly confined to open top cans, and are most frequent in cans filled cold, as hand-packed tomatoes. The fruit has more or less air or gases incorporated in the interstices of the tissues, and this is retained in the can if sealed cold or given only a light exhaust. The subsequent rise in temperature will cause expansion, which produces the convex end on the can. Springers due to this cause tend to become more tense when subjected to moderate heat, as in an incubator, and to disappear on being subjected to a low temperature, as in a refrigerator. It has been a frequent occurrence that foods packed in the North, especially in the fall, and shipped South to a warmer climate have developed the trouble, and when returned to the factory, are found in perfect condition. Likewise the same goods which are perfect in appearance in the winter present the appearance of springers the following summer. If the materials packed were inert toward the can, the springers would remain practically quiescent subject only to temperature variations.

"The effect of the retention of the air in the unexhausted or very poorly exhausted can, is to increase the activity of the attack by the content upon the metal of the container, and thus liberate hydrogen gas, which further increases the pressure and causes springers of more marked character which will not return to normal by a moderate

reduction of temperature or by pressure. It was assumed for a time that because there is always head space in a soldered can the springer was in reality due to overfilling and that the condition could be corrected by leaving head space. Head space, unless the air be exhausted, only aggravates the condition. In the case of the soldered can, the sealing heats the air above the food to a higher degree than is done by exhausting, causing it to be driven out through the vent, which materially corrects the condition.

"Springers are also caused by the action of the food material upon the container, a condition independent of the fill or of the exhaust, though slack filling and poor exhausting increase the rate and the amount of activity. (One cubic centimeter of hydrogen is liberated by each 4.8 mg. of tin or 2.2 mg. of iron when dissolved in acid at ordinary temperature.)

"In the case of springers there will be no vacuum, the gas given off is hydrogen which will burn, and is emitted with one sudden spurt; the contents are normal and fit for food unless they have been subjected to prolonged heating, as those which have become stack-burned. The cans may show a marked galvanized-like effect or etching, depending upon the kind of product."

Swells and Flat Sours.

A. W. Bitting and K. G. Bitting have the following to say by way of describing what is meant by swells and flat sours: "Defects from lack of sterilization are designated in the trade as swells or puffs and flat sours, though this classification is not strictly correct. A food may not be sterile and spoilage may be very pronounced without the production of gas or the development of a sour taste.

"A swell is a can having one or both ends or some part of the body distended by pressure generated by gas-producing organisms.

"A flat sour is a can in which the contents have been changed, usually with an increase in acidity, but without the production of gas or of only a very small quantity. The exterior of the can presents a normal appearance.

"The flat sour gets its name from the fact that the can shows no distention and the food develops a very sour taste due to the formation of acid. This condition is not recognized nearly so early as the swell, due to the fact that there is no external evidence of trouble to attract attention. Furthermore, the breaking down of tissue and the formation of acid is a slower process than that of the gas formation. Flat sours are rarely recognized under two weeks and frequently not until after a month. If the trouble be due to thermophilic forms, then storage of only partially cooled cans in a warm warehouse will favor the development.

"Flat sours are generally associated with delays in handling foods through the factory, as cut peas or jerked corn permitted to stand in the yard or under the shed over night and to become more or less

heated. It is possible to have corn and peas sour so slightly before packing as to be unnoticed, but later the heat of the process develops a distinctly acid taste. This is not a real flat sour, as the number of organisms are relatively small and are killed during processing, and a flat or an acid taste is present from the start. In flat sours the number of organisms is always high though they may not retain their vitality for a very long time. Lack of cooling and stacking cans while hot are the chief causes of flat sours. The cans which might be sterile if cooled may not be sterile if not cooled, and this is true particularly if the process is close to the minimum line. This corresponds with making media in a laboratory, where experience has shown that tubes or flasks left in the sterilizer and which cool slowly are prone to spoil, while those taken out and cooled remain perfect. A method of testing for flat sours without opening the cans is to submerge them in hot water until the ends spring out and then lay them on a table to cool. The ends of the normal cans will collapse in a short time while the defective will not collapse or will do so more slowly."

A. W. Bitting says: "A proper sirup is a necessity in the packing of most fruits, and has become as much an essential of the grade as the size and quality of the pieces. The sirup may vary from very light to very heavy, or between 10 degrees and 60 degrees on the Balling scale. By common consent the sirups are generally made to be 10, 20, 30, 40, 50 or 60 degrees Balling."

Condition of Fruit to Be Canned.

In the canning of fruit Bitting says: "The first essential is that the fruits be harvested when in prime condition, handled with care to prevent injury or bruising and conveyed with speed from the tree or vine to the factory. For canning purposes it is not necessary, and may not be desirable, that all fruits be as far advanced or as soft as for eating, but they should be ripe, with the flavor characteristic of the ripe fruit. They should not be so far advanced that they will not withstand the ordinary cooking necessary for sterilization without breaking to pieces. The prime condition for canning is that state of maturity in which the flavor and other characteristic qualities have been developed to the maximum and may be retained during sterilization.

"Bruised or damaged fruit can not be made attractive, and its use involves heavy waste. The proper handling of the fruit is therefore very important. Apricots, peaches, pears, etc., should be handled in shallow boxes which will not hold more than a bushel and will not admit of more than three or four layers of fruit. The top should be protected with cleats, so that one box can be set upon another without touching the fruit, thus insuring some ventilation. The small fruits—strawberries, raspberries, blackberries, and loganberries—are handled almost exclusively in chests, which are illustrated in detail in Plate II. The California packers have developed this part of the business to a

higher degree of perfection than those in any other section of the country. The conical basket used in handling tomatoes in the East should be abolished. The depth is too great and the shape such that the weight of superimposed fruit wedges the lower layers tightly together, causing crushing, rotting, and excessive waste. The baskets are weak, do not stack without bruising or cutting the fruit, and easily become disarranged or broken in shipping.

"Rapid transfer of the fruit to the factory after it has been picked is very essential. Deterioration in flavor and weight begins early; conditions favor the growth of organisms, and bacteria, yeast, and mold may develop wherever the fruits press together or the skins are broken. Delicate fruits, such as berries, if picked in the morning should be at the factory in the afternoon, or if picked in the evening should be delivered in the morning. Fruits with hard skins will last much longer, but the rule with all should be quick action. One of the disadvantages of a factory located in the city is the delay in receiving fruit promptly; dependence upon the surplus of the fresh fruit market is hazardous.

"One source of trouble and a cause of spoilage of much fruit is contamination from sour and moldy boxes. When a box is used several times it becomes permanently infected and a cause of infection by spoilage organisms. This can be controlled without much difficulty by having a tight room in which the worst boxes are placed after they are emptied, with steam turned on to saturate the atmosphere and sulphur burned or sulphurous acid gas liberated to act as a disinfectant. This does not require a large place, much time, or expense."

Spoilage may be a rapid or a slow process. Bitting says: "Spoilage may result from insufficient processing, defective containers, or the use of unfit material. These losses are generally classed under the heads of swells, flat sours, and leaks. Formerly losses were heavy at many factories, but these are becoming less each year, owing to a better knowledge of what is necessary in material, handling and improved appliances. More attention is paid to testing for bacteria, and greater care is taken in obtaining accurate thermometers and gauges, automatic temperature-regulating devices and time recorders, so that little is left to the judgment of the processor or helper.

"Spoilage due to insufficient processing is generally divided into two classes—swells and flat sours. In the former there is generation of gas, causing the ends of the can to become distended; in the latter the content of the can is sour, but there is nothing in the appearance of the can to enable the customer to determine the condition until the can is opened. Swells are generally due to the underprocessing good material, while flat sours most often result from giving the regular process to material which has been allowed to stand for some time, such as peas remaining in a load over night or corn left in a car or in a pile until it begins to heat. The raw material may show no evidence of fermentation on superficial examination, but this condition frequently exists under the conditions just cited. Swells are therefore

more likely to be associated with rush operations and flat sours with an overstock or delay in getting at the raw material. It is not intended to give the impression that swells and sours may not occur under other conditions, such as changes in the consistency of the corn, nor that swells may not occur in material which has stood, and sours result from underprocessing, but only to state a general rule.

"Swelling or souring may take place shortly after processing or the spoilage may be delayed for weeks or even months. Swelling is more likely to occur and be detected early, while souring is apt to be delayed, though it may occur early. The heat used in processing may have been insufficient to kill the vegetative forms or spores, but may have injured them to such an extent that time was necessary for recovery, and subsequent development. A microscopic examination of the material a few days after processing, or of the incubating cans during a short period, might not show anything wrong. It is only by incubating samples for a number of days that early recognition can be made of some cases of spoilage or possible spoilage. The canner often sends his goods from the factory with full confidence in their condition, and it is not until after they have been in the broker's warehouse or upon the grocer's shelves many weeks or even months that he becomes aware that anything is wrong. The spoilage may amount to only one can to the case, or the percentage may be high; but in either event the goods are rejected with loss.

"Spoilage from the use of improper material—i.e., material which has been allowed to stand until fermentation has begun—is generally more or less sour to the smell and taste, but is sterile, the heat of processing having killed the bacteria.

"Can leaks may occur along the side, 'seam leaks'; at either end, 'end leaks'; at the cap, 'cap leaks'; at the tip, 'tip leaks'; or may be due to defective tin plate. Can making has reached such a point of perfection that manufacturers guarantee all above two to the thousand. These imperfect cans are usually due to the solder not making a perfect union or to defects in crimping or double seaming. With the use of the automatic capping and tipping machines there are fewer leaks than formerly occurred when the work was done by hand; leaks in sanitary cans are generally due to poor adjustment of the rollers. Leakers are recognized, as a rule, by inspection in the hot bath, few getting into the wareroom. Leaks may be very small, even microscopic in size, and, therefore, difficult to detect."

In *U.S.D.A. Bulletin* No. 196 (1915), A. W. Bitting describes the commercial canning of corn as follows: "A modern corn-canning plant is a large establishment, equipped with valuable automatic machinery to do the work in a rapid, cleanly manner. When the corn arrives at the factory it is dumped from the wagon onto a conveyer, which carries the ears to different parts of the husking shed as they are needed. Most of the husking is done by hand, but this practice will undoubtedly give way to machine methods, as the husking machines have been almost perfected in recent years. As rapidly as a

bushel measure is husked it is put upon a conveyer, and while on the way to the silking machine is sorted for quality. A high grade may be secured only by selecting ears with grains which are uniformly tender. Corn which is too old or too young to make a fancy grade of goods is taken out and held until a sufficient quantity accumulates to make a run on low grade. The silking is done by means of rolls and brushes. As the ear revolves on its axis and at the same time is carried forward, it is gently wiped by rapidly revolving brushes, which pick up any silk that may be attached. This work is done with remarkable rapidity and by machinery so carefully adjusted for any irregularity in the size of the ears or even in a single ear that there is no chafing or bruising of the tenderest grains. This process is immediately followed at some factories by a thorough spraying with water, while at others this is omitted, the claim being made that a certain flavor is lost.

"The corn is cut by machinery, and from the time the ear is fed into the cutter until the corn is sealed in the can it is not again touched by hand. The ear is forced through a series of curved knives, mounted in an adjustable circular frame, so that they will accommodate themselves to the varying size of the cob. Scrapers complete the work by removing the grain and soft bits of kernel at the base. The corn again passes through a machine to remove bits of silk, husk, or cob, so that the final product is as clean as machinery can make it. This cleaner consists of a series of wire combs, which intermesh as the corn passes through, and wire cylinders which act as sitters.

"The corn is next mixed and cooked, and in this operation it is necessary to add some water, otherwise it would become a dry tough mass in the can. The quantity of water used will depend upon the consistency desired and the condition of the corn. Some varieties require more than others but the average quantity used in cream corn is about 5 ounces per can. It is also usual to add both salt and sugar to the corn to give the desired flavor. This is used in all grades, though more carefully in the high grades than in the low. The eastern packers, as a rule, use more sugar than the western.

"The care with which the cooking is done before the corn enters the can determines in a large measure its appearance. Too much brine will give a sloppy can, while too little gives a dry can. Insufficient cooking will leave the brine and corn separated; the quantity of brine may be right but the corn may be dry in the bottom of the can and most of the brine on top, or they may be mixed but not blended. The preliminary heating is done by steam, using automatic machinery, which heats and evenly mixes the corn and brine and at the same time fills the cans. The corn enters the cans at about 180 degrees F. and the capping is done in the usual manner.

"Corn is one of the most difficult products to process. It requires a temperature of about 250 degrees F. for 75 minutes to insure sterilization. There are packers who process at from 240 degrees to 245 degrees for 90 minutes, and others who process their corn twice to

insure keeping. The higher the temperature the browner the corn and the more pronounced the cooked taste. The consistency of the corn makes a great difference in the heat which must be used; the drier the corn the slower the heat penetration."

In studying the heat resistant organisms of cold packed canned peas Ruth Normington gives the following conclusions in *Michigan Agr. Experiment Station Tech. Bul.* No. 47:

"The spoilage in cold packed canned peas is largely due to the presence of resistant spore-forming organisms which are not killed by the temperature attained in the prescribed method for processing. Therefore, before canning peas or other vegetables, the product should be very carefully washed to remove all soil or dust and thus remove the greater percentage of organisms.

"The time for processing of vegetables should be lengthened so that the center of the can may be at a high temperature sufficiently long to kill the more resistant organisms.

"The processing of all cold packed canned vegetables should be carried out by the steam pressure method to insure the greatest probability of success.

"The results obtained in the chemical analysis of spoiled peas suggest that the determination of creatinin and ammonia, especially the former, may serve to detect bacterial decomposition in this canned food product."

Magoon and Culpépper summarize their work on temperature changes in the container during canning operations as follows:

"(1) In tin cans containing various quantities of water, changes in pressure vary somewhat from the calculated values, owing to the distortion of the can under the changed conditions.

"(2) With water the rate of change of pressure and the rate of change of temperature at the center of the can agree closely and are very rapid where the external medium is water and very slow where the external medium is air.

"(3) With food materials in which a free liquid fills the interspaces the rate of change of pressure and of temperature is very rapid; but while the maximum temperature is reached promptly, the maximum pressure, on the other hand, is never reached during the ordinary processing periods, the pressure continuing to rise slowly as long as the high retort temperatures are maintained.

"(4) In cans filled with material of heavy consistency, the rate of change of temperature at the center of the can is very slow. In contrast with this, the rate of change of pressure is very rapid at first and then becomes slower after the first few minutes. An equilibrium of pressure apparently is never reached, since in experiments where processing was continued for several hours the pressure continued to rise as the retort temperature was maintained.

"(5) The continued increase in pressure long after an equilibrium of temperature is reached has been explained as due to the decomposition of the food material with the consequent liberation of gases.

The setting free of hydrogen as a result of the action of the a of the material upon the metal of the can would give this result, doubtless it does with some acid fruits, but experiments with v tables seem to indicate that this is not the sole cause of the increas pressure.

"(6) In the heat exhausting of cans the vacuum may not be p portional to the average temperature of the material at the time sealing, but is determined largely by the temperature of the h space. Thus, a short exhaust results in a comparatively high vacu if the sealing is done immediately. On the other hand, a long exha may be very ineffective if the sealing is delayed so that the head sp cools.

"(7) The vacuum developed in tin cans is generally below theoretical, the causes contributing to the variation from theoreti values being the distortion of the can, the swelling of colloidal s stances, and the liberation of gases during processing. Lower vacuu are obtained where long processing periods are used and the hig retort temperatures are employed.

"(8) The resistance of the can to internal pressure is very mu greater than its resistance to external pressure; hence, the vacuum a the pressure cannot safely be made numerically equal when process much above 100 degrees C. In order to reduce the strain due to ternal pressure during processing, the sealing temperature is made high as is possible without danger of collapse of the can in handl when subsequently cooled to normal temperature. The strain up the can during processing is found by subtracting the pressure in t retort from that in the can. When the pressure in the retort is leased the strain upon the can is increased by an amount somewh less than the pressure in the retort, owing to the cooling which occu during the release and to the further distortion of the can. T greatest strain upon the can occurs at the time the pressure in t retort reaches zero. The strain due to internal pressure is grea the lower the sealing temperature and the higher the processi temperature.

"(9) The experimental work herein reported indicates that most vegetables the optimum temperature for the sealing of No. cans is 80 degrees to 85 degrees, and for No. 3 cans 75 degrees to degrees C. This would be different, obviously, for fruits and oth substances having high acidity and where the processing temperatu are low."

Concerning the intermittent method of processing Magoon a Culpepper have stated the case as follows: "Since sterilization the intermittent process depends not only upon the maximum te perature attained, but also upon the length of the interval betwe processing periods and upon the temperature during this interval, becomes of very great importance to understand thoroughly the tim temperature relations throughout the entire process. The first pr cessing is supposed to destroy all vegetative forms of bacteria, a

during the following interval any spores which may be present germinate and are killed during the second processing period. Any spores failing to germinate during the first interval are expected to germinate during the second interval and so are destroyed in the vegetative form during the third process. If the temperature during these intervals should be either too high or too low for the germination of any spores, then the whole process might fail. It is also known that spores of certain bacteria under optimum conditions germinate very quickly, multiply, and again form spores in a period of less than 24 hours. These facts make it highly important to understand the entire time-temperature relations."

In *U.S.D.A. Bul.* No. 956 (1921), C. A. Magoon and C. W. Culpepper give the results of an extensive "Study of the factors affecting temperature changes in the container during the canning of fruits and vegetables." They summarize their studies as follows:

"(1) The mercury thermometer is sufficiently accurate for practical work in the determination of temperature changes in the canning of food materials if it is properly calibrated and standardized.

"(2) A satisfactory apparatus has been devised for measuring the temperature changes at the center of the can during the processing period and the subsequent cooling, which permits the use of the mercury thermometer both in the water bath and in the steam retort.

"(3) In a can packed with material having an interspace filled with a free liquid, as in string beans, the rate of change of temperature at the center of the can is very rapid, and in materials of a heavy or pasty nature, as in sweet corn, the rate is very slow unless mechanical agitation is employed.

"(4) In canned materials the character of the pack and the composition of the material very largely determine the rate of change of temperature in the can. The fineness of division and compactness of the material and the amount and viscosity of the free liquid are the factors which influence the rate of change of temperature. Variations in the composition of the material, however, have very little effect if the consistency of the material is such that no convection can occur.

"(5) Sodium chlorid has very little direct effect upon the rate of change of temperature in the can. Dilute sugar solutions have only a small effect, but the concentrated solutions have a considerable effect in retarding the rate of change. Solutions of starch have a very marked retarding effect upon the rate of change of temperature at the center of the can. The retarding effect increases very rapidly from 2 to 5 per cent. In 5 per cent starch the consistency becomes such that all convection is stopped and the rate of change is very slow. Increasing the percentage of starch further has very little effect upon the temperature changes. Also, any other material of a viscous nature, such as protein or pectin, retards the rate of change of temperature.

"(6) The glass container has a marked retarding effect upon the rate of rise in temperature in those materials in which there is a free

liquid, as in string beans, but is of little importance in materials of a heavy consistency, such as sweet corn. On the other hand, glass cools faster in the air than tin, owing to its greater power of radiation.

"(7) Differences in the diameter of the container are of much less importance in those materials in which there is a free liquid than in materials of heavy consistency. Thus there need be little difference in the processing period of No. 2 and No. 3 tin cans of string beans, but there must be considerable difference in the processing period of No. 2 and No. 3 tin cans of sweet corn.

"(8) The temperature of the bath or retort is reached in the container in approximately the same time, whether the processing temperature is 100 degrees, 109 degrees, 116 degrees or 121 degrees C. Tomatoes are a striking exception to this rule, because the higher temperatures break down the tissues of the fruit.

"(9) The difference in the rate of cooling in the air and water is very marked. In materials having a free liquid the cooling is exceedingly rapid, as in string beans, but is considerably slower in materials having a heavy consistency, as in sweet potatoes. Cooling in air is always very much slower than cooling in water.

"(10) Since a steam-tight closure in glass containers can not be made, any temperature above 100 degrees falls to 100 degrees as rapidly as the temperature of the retort, so that the temperature is always 100 degrees or below when removed from the retort.

"(11) In the intermittent process, the first processing period may or may not affect the rate of temperature change in the second processing period, depending upon the composition and nature of the material. Any change during the first processing period which interferes with convection retards the rate of change of temperature during the second processing period. This change may be the simple compacting of the material, the going into solution of starch, protein, pectin, or any other mucilaginous material. If the material at the outset is such that no convection occurs, then the gelatinization of starch or other such change has very little effect upon the rate of change of temperature in the can.

"(12) The fruits and vegetables as processed in these tests fall roughly into two groups, with reference to time-temperature relations. The first group consists of those fruits and vegetables packed so that there is a free liquid filling the interspaces between the pieces of material. The rate of change of temperature in this group is very rapid. The second group consists of those materials that are packed in such a way that little or no convection can occur. The rate of change of temperature in this group is very slow."

Botulism.

Until a few years ago there was no association made between meat poisoning known as botulism and poisoning in other foods. Sausage poisoning was known to be a very definite poisoning several

TABLE XI.

STANDARD CAN SIZES.

Number of Can	*Diameter in Inches*	*Height in Inches*	*Capacity in Ounces*
1	2 11/16	4	11.6
1 tall	2 11/16	4 1/4	12.3
2	3 3/8	4 9/16	21.3
2 1/2	4	4 1/4	31.2
3	4 1/16	4 7/8	35.
3 tall	4 1/16	5 1/2	39
8	6 1/16	6 7/8	104
10	6 1/32	6 9/16	107.

centuries ago. By some, this disease was thought to be caused by alternate freezing and thawing of sausages. Information concerning the real nature of botulism was furnished by Van Ermengem, while studying an epidemic in Belgium in 1894. The organism which he found to be the cause of this food poisoning he named Bacillus botulinus.

In 1913 an outbreak of food poisoning caused by eating canned stringed beans occurred at Stanford University. A little later food poisoning due to eating ripe olives attracted much attention. It was at this time that the organism and its prevalence attracted general notice. Since this time many outbreaks of food poisoning have occurred due to the growth of this organism in canned foods.

An extensive study of the distribution of Bacillus Botulinus in soil has shown that this organism is a natural inhabitant of the soils of many localities. The fact that the organism often exists in soils explains how it finds its way into foods and at the same time emphasizes the necessity of cleanliness of foods to be canned and cleanliness of factories and methods.

In a study of soils of California, Meyer and Duforsky report that out of 78 samples of virgin soil taken from areas free from animal excreta, 45 contained toxic cultures of B. botulinus (mainly type A). From 226 samples of soil from gardens, orchards, and cultivated fields, 59 samples furnished cultures of B. botulinus. Of 122 samples of garden vegetables and fruits 33 furnished the organism. The leaves and fruit of olive trees furnished cultures of B. botulinus readily. Hay, straw and animal feeds were contaminated with B. botulinus in 10 out of 52 samples. Only 3 out of 45 samples of manure were positive. Soil samples from Alaska and Canada were found to contain B. botulinus spores. Also soil samples from Hawaiian Islands and China contained spores of this organism. In the examination of European soils, it was emphasized that type A is quite well eliminated in well cultivated soils.

They say "B. botulinus is a common soil anaërobe of the Western States of the Cordilleran system. It is less frequently encountered in the Atlantic States and is relatively rare in the Middle States, the Great Plains, and the Mississippi Valley. The soil of the Western

States, inclusive of the Great Plains, yields mainly B. botulinus, type A, while the Mississippi Valley and Great Lakes region is characterized by a striking predominance of type B. Similarly prevalent is this latter type in the Atlantic States of Maryland, Delaware, New Jersey, Georgia, and South Carolina, while scattered findings of type A in Maine, New York, and Pennsylvania indicate the existence of breeding places in virgin forests and mountains. Soils which are subjected to intensive cultivation and fertilization contain, as a rule, B. botulinus, type B."

Some good advice given by different authorities on botulism is as follows: (1) Clean raw vegetables well before canning as the more botulinus organisms present the greater time is required to make the goods sterile.

(2) Use only good, sound material as B. botulinus develops in decayed material.

(3) Little delays should be practiced between gathering products and canning them.

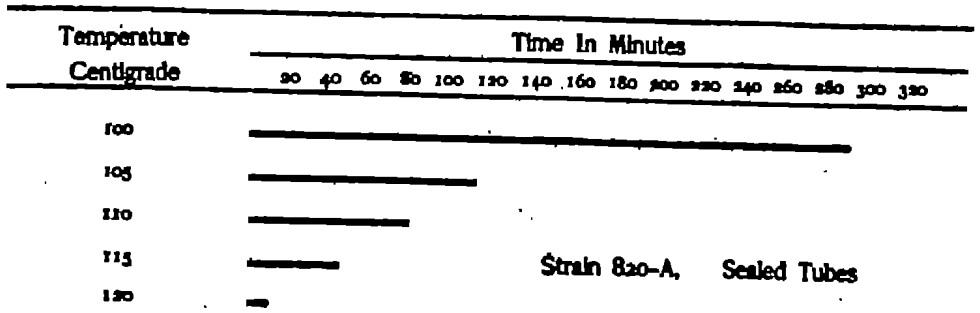
(4) Low acid fruit and vegetable products form especially suitable media for the development of B. botulinus.

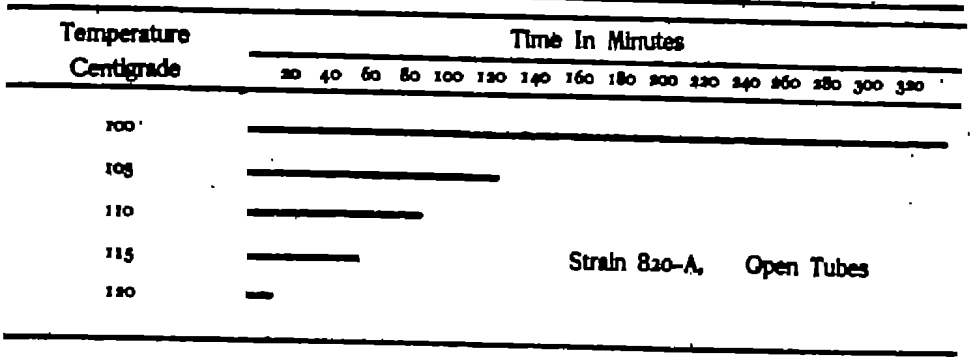
Work done for the American Canners Association has shown that the amount of processing required depends largely upon the pH value. For instance, rhubarb, cherries, tomatoes, and such rather high acid foods require less processing than corn, beans, etc., which have a pH value above 4.5. The greatest danger of botulism is in the canning of foods which naturally have a pH value above 4.5.

"When canning foods with a pH value above 4.5 it is good practice to take representative cans from each batch and incubate them for five days at 30 to 37 degrees C. to see if spoilage develops in any case."

Concerning the pathogenicity of B. botulinus in the human body, Coleman and Meyer say: "The study of this particular problem may properly be divided into three parts: (1) The injection or ingestion of detoxified B. botulinus spores or bacilli, (2) the injection or ingestion of the spores or bacilli together with a minute dose of B. botulinus toxin (or other substances) insufficient by themselves to produce symptoms of botulism, and (3) the latency of injected or ingested spores of B. botulinus in the animal body where such spores, due to various causes, may later germinate, multiply, or be freed of their toxin and produce symptoms of the disease." They show that five doses of toxin-free spores of B. botulinus are pathogenic when introduced into the animal body. These spores and the vegetative forms arising from them are rapidly disseminated throughout the tissues of the body. Toxin-free spores of B. botulinus germinate, and the vegetative forms arising from this germination multiply and liberate toxin in the animal body.

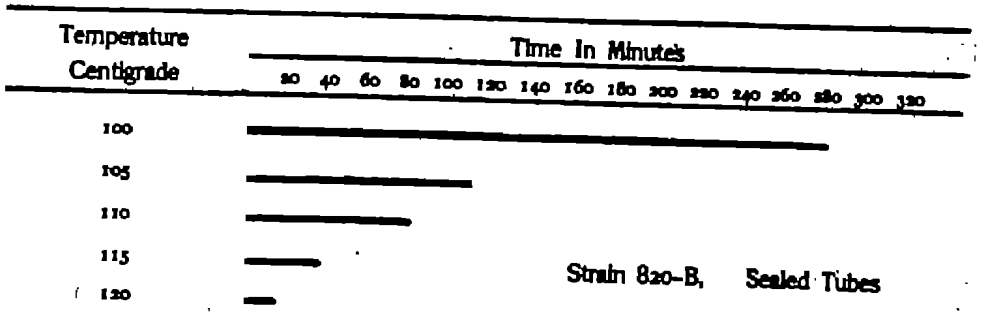
Extensive experimentation is now being carried on to determine temperature penetration of different foods during the canning process. Other very important phases of canning now being investigated are

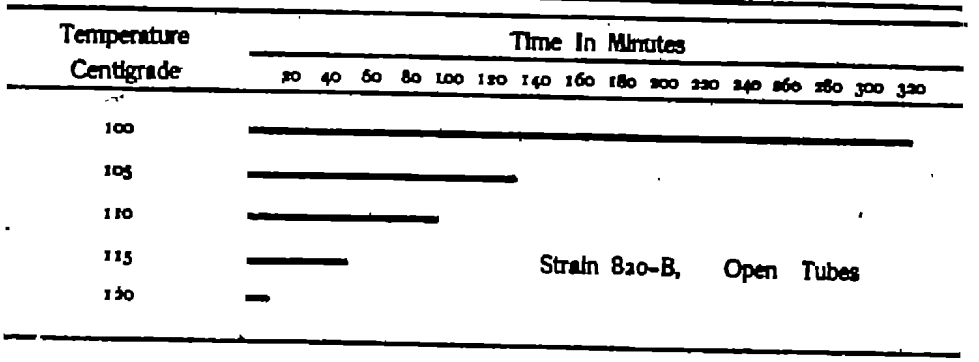




STRAIN 820-A

Showing the time required in minutes for destroying the spores of *Clostridium botulinum* by moist heat.





STRAIN 820-B

Moist heat destruction of C. botulinum.

the natural acidity of different fruits and the resistance of botulinus spores to different periods and types of heat treatment.

The poisoning produced by B. botulinus is the result of action of this organism on food. This poison is called the B. botulinus toxin.

When one considers that there are 400,000,000 cans of canned food placed on the market in the U. S. annually, it is remarkable how little poisoning there is. However, the ideal to be reached is the elimination of this poisoning. Great strides have already been taken in this direction. The American canners are wide awake to the great importance of reaching a point where they can say that commercially canned foods cause no outbreaks of food poisoning.

In a study of the resistance of the spores of Clostridium botulinum to moist heat, Tanner gives the following summary and conclusions:

"1. The spores of Clostridium botulinum in sealed tubes exhausted to 17 mm. vacuum are destroyed within a period of five hours at 100 degrees C.; within two hours at 105 degrees C.; within one and one-half hours at 110 degrees C.; within forty minutes at 115 degrees C.; and within ten minutes at 120 degrees C.

"2. A longer heating period was required to destroy spores of the same age in open tubes than in tubes exhausted and sealed, under the conditions that obtained in this investigation.

"3. The death of spores is probably a gradual process. Surviving spores may have their internal mechanism so injured that weak toxins are formed."

The above work of Tanner largely confirms that of Weiss who concluded that the spores were killed within 5 hours by a temperature of 100° C., 40 minutes at 105° C. and by 6 minutes exposure to a temperature of 120° C.

In an earlier piece of work Thom et al. working with a strain of Clostridium botulinum obtained from a food poisoning outbreak at Boise, Idaho, found that the spores withstood a steam pressure of 10 lbs. for 15 minutes while 15 lbs. steam pressure for 15 minutes destroyed them.

G. S. Burke found that the spores could survive boiling water for three hours and more, and that when grown in certain kinds of media had increased resistance to heat exposure.

Weiss found that the spores die gradually due to heat exposure and that young spores are more resistant than old ones. Further he found that the spores are killed more readily in certain fruit juices than in other food juices as lima bean juice.

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Chapter 19.

Cane and Beet Sugar.

The cane sugar industry is very old. Cane sugar making was practiced in India in about 400 A.D. The beet sugar industry first became important in Germany when in 1785 the King of Prussia erected beet sugar factories to develop the industry. However, it was the sugar shortage in France in 1805 which gave the beet sugar industry the opportunity of greatest development. The importation of cane sugar into France was temporarily cut off by England's blockade of French shipping which resulted in a severe sugar famine in France. Napoleon emphasized the production of sugar from beets after many other sources had been tried without much commercial success.

Cane Sugar Manufacture.

In the manufacture of cane sugar, the cane is passed through preliminary shredders and then between smooth steel rolls which press out the juice much as a wringer removes water from clothes. About 90 per cent of the juice is obtained in this way while the remainder may be obtained by extracting the residual sugar from the bagasse by using water.

As the can juice comes from the rollers it is heavily contaminated with germ life. Due to the warm climate of sugar cane countries a vigorous fermentation starts as soon as the juice is separated from the cane. The light sugar liquors in a few hours will become sour and the destruction of sugar will result. To prevent this the sugar liquor is concentrated to a point where germs can no longer grow, that is to about 40 degrees Baumé. The heat required to concentrate the liquors kills off the germ life present and the high concentration prevents the growth of organisms which later gain entrance. In heating the liquors for concentration, lime is added to cause the nitrogenous constituents of the liquors to "break" or coagulate and rise to the top. This is a purifying operation. In the evaporation of the sugar liquors, crystals begin to form when a certain concentration is reached. When the crystallization in the heavy liquors has reached a certain point, it is sent to the centrifugals where the crystals are separated from the molasses by the copper screen of the centrifugal machines. The sugar which is first removed from a liquor is called centrifugal or raw sugar and is not white. This process of separation is repeated several times

until most of the saccharose of the heavy sugar liquor is obtained as moist crystals of raw sugar.

The refining of the raw sugar is not generally carried on where the cane is produced but is sent to refineries in the country where the sugar is to be marketed.

Beet Sugar Manufacture.

The manufacture of beet sugar differs somewhat, in principle, from raw cane sugar manufacture. The beets are scrubbed and then sliced into very thin slices. The sliced beets are placed in diffusion tanks set up in batteries so that the flow of liquors through them can be controlled as to concentration of sugar. The heaviest liquors are taken from one end of the battery and the new diffusion water is applied to the most thoroughly extracted beet pulp. The sugar liquor leaving the diffusion battery is treated from this point on, in the same manner as light cane sugar liquor in the cane sugar process.

Moore says, "The juice is extracted from the cane by means of heavy steel horizontal crushers and rollers driven by powerful steam engines. The cane passes first between two crushers, which are rollers with interlocking teeth of various designs on their faces. Here the cane is pressed into a mat of even thickness. It passes by means of an endless carrier to the first set of rollers which are arranged in a group of three—two below and one above. In most modern mills there are three to four such groups of rollers arranged in tandem. As the mat of cane passes in a horizontal direction from one set to the next, it is sprayed with hot water to dilute the remaining juice and facilitate a more complete extraction. After passing the last roller the mat of extracted cane fiber, or bagasse, is carried on another endless conveyer to driers or directly to the furnace, where it is used for fuel to operate the mill.

"The juice flowing downward from the sets of rollers is first strained to remove suspended matter. It passes through a juice heater, where the temperature is raised to 190-200 degrees F., thence into settling tanks. After about one-half hour the fairly clear juice is drawn off, leaving a deposit of dirt in the bottom of the tank. The juice is further clarified by the addition of lime. Sulphurous acid or other chemicals may also be used, depending on the methods followed in individual mills. All methods have for their purpose the precipitation of impurities, which are afterwards filtered out, or the decomposition of reducing sugars into organic acids. The settlings and scums from juice heaters and settling tanks are treated separately, and the clear liquor recovered from them is added to the main body of clear juice, which is evaporated to sirup under partial vacuum in the so-called 'effects.' The sirup may or may not be further clarified and filtered at this point, depending on details of the process used. It now passes into the vacuum pans where it is boiled at low temperatures under greatly reduced atmospheric pressure. After long-continued boiling

the sirup becomes very thick and concentrated, due to evaporation of water, and small crystals of sugar begin to appear in the heavy viscous liquid. These crystals grow in size with the introduction from time to time of fresh sirup. When the crystals are of proper size the magma of crystals and mother liquor known as 'massecuite' is passed on to the centrifugals, where the next operation of separating crystals from the mother liquor (molasses) takes place. Usually the molasses is not entirely exhausted of sugar and is returned and boiled again in the vacuum pan, either alone or with the addition of fresh sirup. The process may be repeated several times.

"The centrifugal machines, of which there are usually a large number, known technically as a 'battery,' consist of vertical cylindrical baskets inclosed in jackets. The sides of the baskets are perforated and in addition are lined with fine-mesh wire-gauze strainers. The baskets are revolved at high speed and the molasses is thrown out against the sides of the outer jacket and drops into a gutter below. The crystals are retained in the baskets and are washed quickly with water while revolving to remove the film of molasses. The sugar is scraped with paddles from the sides of the baskets as they revolve and is carried through tubes to driers, then to a spout where it is bagged or barreled."

Brandes, et al., are of the opinion that cane syrup may have a future of greater importance. They say: "Extension of the market for cane sirup has been retarded by the fact that, as it is produced by a large number of individuals on a relatively small scale, the sirup has varied greatly in quality. Furthermore, cane sirup evaporated to fairly high density will crystallize, while on the other hand sirup of sufficiently low density to prevent crystallization inevitably ferments unless heated and preserved in air-tight containers. Correction of these difficulties will materially assist in increasing the market for cane sirup.

"Crystallization of cane sirup is due to the presence of too great a proportion of sucrose or cane sugar and may be prevented by a process recently developed in the Department of Agriculture. This consists of using invertase, an enzyme obtained from yeast, in such manner as partially to invert cane sugar, thereby producing a mixture of cane sugar and invert sugar of increased solubility. By partially inverting the cane sugar in cane sirup by this method it is also possible to produce a noncrystallizing sirup of such high density as to greatly minimize the danger of fermentation. This last procedure is recommended for sirup shipped in barrels or held in bulk during warm weather. The process is also advantageous for preventing crystallization of sirup of moderate density packed in cans. The value of the method has been demonstrated in commercial practice. The cost for invertase is approximately one-half cent per gallon of sirup."

Brandes, et al., give the following description of beet sugar manufacture: "Sugar beets, like sugar cane, are transported for manufacture into sugar to large factories which, for the reasons given in the discussion of cane, should be centrally located with reference to the

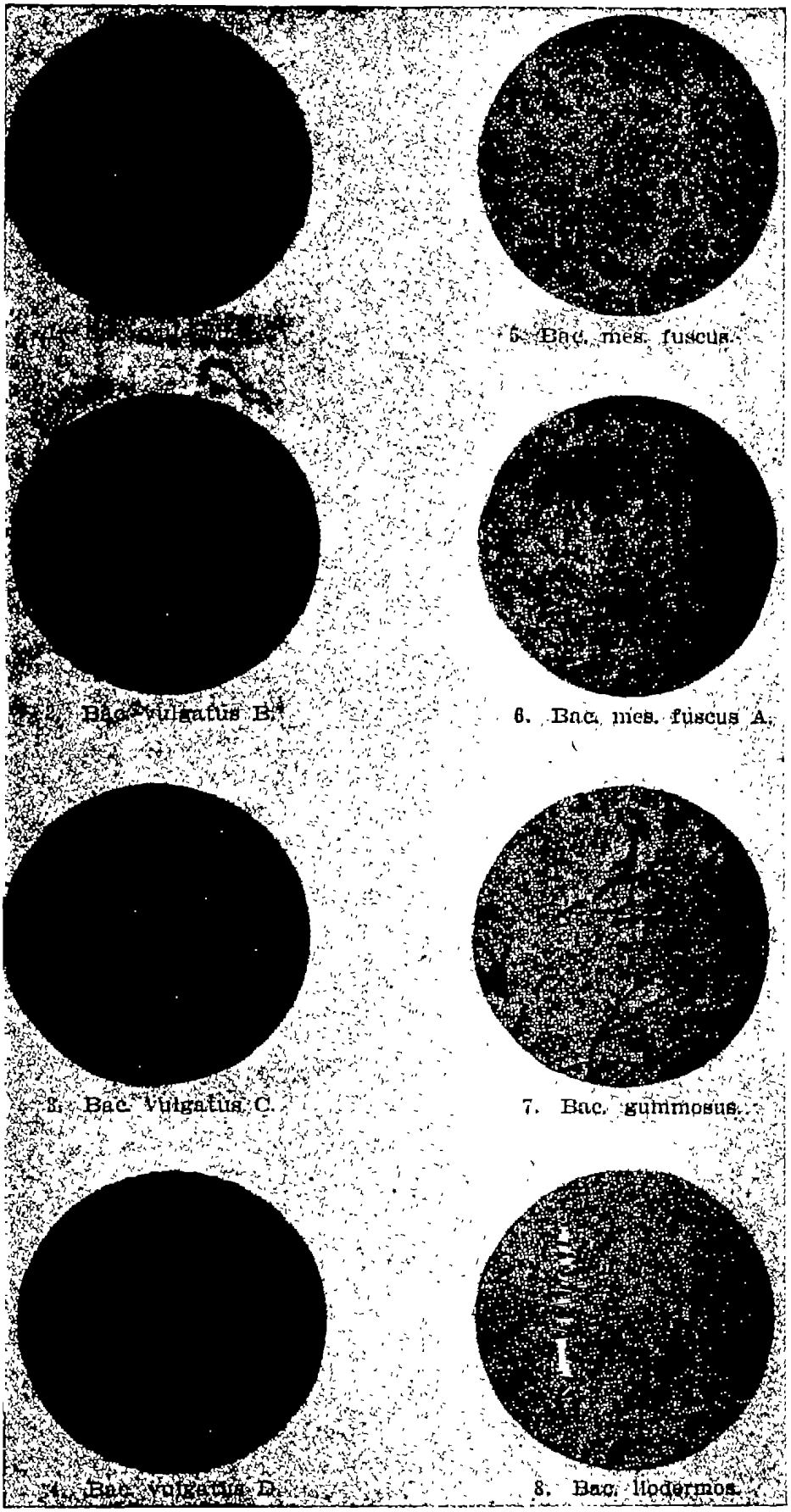
beet-growing area. Private railways are in almost universal use on cane plantations, but this is not the case with beets, which are grown mostly on small independent farms, and hauled in wagons to the mill or to loading stations on the main railway. At the factory the beets are dumped into V-shaped bins at the bottom of which is a flume covered with removable boards. As needed, the beets are carried into the factory by the swift current of the flume.

"Briefly, the process of manufacture consists of cleaning and slicing the beets, placing the slices in large cylinders and extracting the sugar by diffusion. This is accomplished by successive treatments with hot water. Here is where the process differs essentially from extraction from cane. The extract is clarified by treatment with suitable chemicals, the sludgelike precipitated material removed by filtering, and the clean juice evaporated under reduced pressure until a mass of sugar crystals has been formed. The sugar is finally separated from the other liquor or molasses. After several strikes of sugar have been obtained, the molasses is further desugarized by other processes. The Steffen process is generally used in this country.

"Owing to variations in the composition of beets, due largely to storage and variation in degree of maturity, it has been necessary to discard molasses from time to time in operating the Steffen process, the net result being that only 65 per cent of the beet molasses produced has been treated for recovery of sugar. The remaining 35 per cent has been used in the past largely for feeding purposes, a relatively small amount having been used for manufacture of alcohol. Owing to the recent drop in price of this discard molasses, the question of increased efficiency in desugarization has become very important. The Department of Agriculture is investigating this problem at the present time and also devising improved analytical methods, which will make it possible to determine more accurately the amounts of sugar entering the factory and the losses which occur during the process of operation. More accurate chemical control makes possible further reduction of sugar losses."

W. L. Owen in *Louisiana Experiment Station Bulletin* No. 125 (1911), says: "The question of the deterioration of sugars in storage has formed the subject of many investigations both in the cane and beet sugar industries in recent years, and has also occupied the attention of the sugar planter since it has come to be generally appreciated as a source of considerable loss. It is probable that the loss to the industry through this source was suspected long before scientific investigation had established it as an actual fact, and probably before the nature of the causes of this change in sugars had been apprehended. For a long time the popular idea regarding the deterioration of sugars was that this action was due to certain changes which might be termed autogenous—that is, those changes independent of outside influences. As an example of this theory, we might take the idea that the slow deterioration of sugars is caused by the hydrolytic action of the organic acids which they contain. Later, however, this view was

PLATE 10



After Owen in Louisiana Bulletin 125.

Microphotographs of sugar cane bacteria.

Species	Reaction to Gram's Stain	Formation of Spores	Liquefaction of Gelatine	Fermentation of Lævulose: Acid	Fermentation of Lævulose: Gas	Fermentation of Dextrose: Acid	Fermentation of Dextrose: Gas	Gum Fermentation of Sucrose: Dextran	Gum Fermentation of Sucrose: Lævan	Production of Indol	Production of Hydrogen Sulphide	Growth in Albumen (Free Medium)	Source	Size in Microns	Presence of Flagella	Film on Bouillon	Growth in Closed Arm
Bac. vulgatus (A)	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. vulgatus (B)	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. vulgatus (C)	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. vulgatus (D)	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. mes. ruber	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. mes. fuscus	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. mes. fuscus (A)	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. mes. fuscus (B)	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. mes. niger	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. liodermos	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. mes. granulatus	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. gummosus	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. megatherium	+	+	L	+	−	+	−	−	+	+		+	Sugar	L 1 B 2	+	+	−
Bac. mycoïdes	+	+	L	+	−	+	−	−	+	+		+	Cane Juice	L 1 B 2	+	+	−

modified and the theory of the indirect inversion of sugar by bacteria became a popular one. By this indirect inversion is meant that which is due to the action of the acids developed by the microörganisms occurring in sugars.

Owen remarks: "In view of the many conditions lacking in sugar to fulfill the requirements of the great majority of bacterial species, the discovery of certain species which have adapted themselves to these unusual conditions for bacterial development is of interest even considered apart from the economic importance of the changes that they induce. For with the knowledge of this adaptation of bacteria to environments highly unfavorable to their development, as viewed from the standpoint of what we have hitherto regarded as essential to it, we are compelled to believe that the range of bacterial activities is far wider than we have thought them."

This subject of the development of tolerance to substances, by bacteria, is a very important one as is shown in the practice of methods of preservation by salting, sugar curing, etc.

Brain and Deerr, and also Owen considered that no organisms could grow in sugars containing less than 1% of moisture. This means that sugars of so low a water content do not deteriorate on storage.

In the above table Owen gives the cultural characteristics of some of the most important bacteria found on sugars. He says that these organisms are divided into three groups upon the basis of their morphology and physiology. The groups which he mentions are:

(a) Mesentericus vulgatus type.
(b) Mesentericus fuscus type.
(c) Megatherium type.

In the table on opposite page Owen gives the characteristic of belonging to the above types.

The following table taken from Louisiana Bul. 125, by Owen, illustrates very well the bacterial condition of sugar refinery liquors, washings, and sugars:

BACTERIOLOGICAL ANALYSES OF SAMPLES FROM A SUGAR REFINERY.

Name of Sample	*Dilution Employed*	*No. of Organisms per Gram or cc.*	*Presence of Species of Economic Importance*
Raw sugar	1:100	1,000	+
Raw washings	1:1000	5,000	+
Washed sugar	1:100	2,000	+
Melted washed sugar			
Def. wash. sugar and liquor	1:200	800	+
Bag filtered wash. sugar and liquor	1:1000	3,000	Moulds & Bacteria
Light sweet water			
Clear filtered liquor	1:1000	1,000	+
Defecated washings	1:000	6,000	+
Bag filtered washings	1:000	5,000	+

BACTERIOLOGICAL ANALYSES OF SAMPLES FROM A SUGAR REFINERY—*Continued.*

Name of Sample	*Dilution Employed*	*No. of Organisms per Gram or cc.*	*Presence of Species of Economic Importance.*
Dark sweet water	1:2000	8,000	+
Char. filt. washings	1:400	8,000	+
Mud water	1:2000	400,000	+
Press cake	1:2000	No development	
Press water			
Conc. sweet water	1:1000	20,000	+
Granulated magma	1:100	300	+
Granulated syrup	1:1000	5,000	+
Wet granulated sugar	1:50	150	+
Dry granulated sugar	1:50	150	+
Remelted magma	1:50	200	+
Remelted syrup	1:1000	25,000	+
Undefecated liquor	1:500	10,000	+
Remelted sugar	1:500	500	+
Car sugar	1:500	3,000	+
Barrel syrup	1:100	8,000	+
Car syrup, two weeks in hot room	1:100	400	+

At the end of an investigation of the bacterial deterioration of sugars Owen gives the following summary of his conclusions:

"1. The deterioration of sugars is caused by a group of bacteria comprising the well-known potato group of bacilli.

"2. The destruction of sucrose induced by these organisms is by means of an enzyme which we have termed levanase. This enzyme is extracellular in its action and breaks down sucrose as follows:

$$C_{12}H_{22}O_{11} = C_6H_{12}O_6 + C_6H_{10}O_5$$

"3. The formation of levan in sugars introduces an error in both the single polarization and Clerget methods of determination of sucrose. This error causes a decrease in the single polarization of .6V for every 1 per cent of levan, and an increase of .67V for Clerget in the presence of 1 per cent of gum. Owing to this factor of error, a sugar in which gum formation has taken place would show an increase in sucrose by the Clerget method of determination.

"4. The spores of the species causing deterioration of sugar are highly resistant to heat and survive different processes of manufacture, thus forming in part the contamination of the final products.

"5. The gum formation of sucrose is favored by slightly alkaline reaction of the medium."

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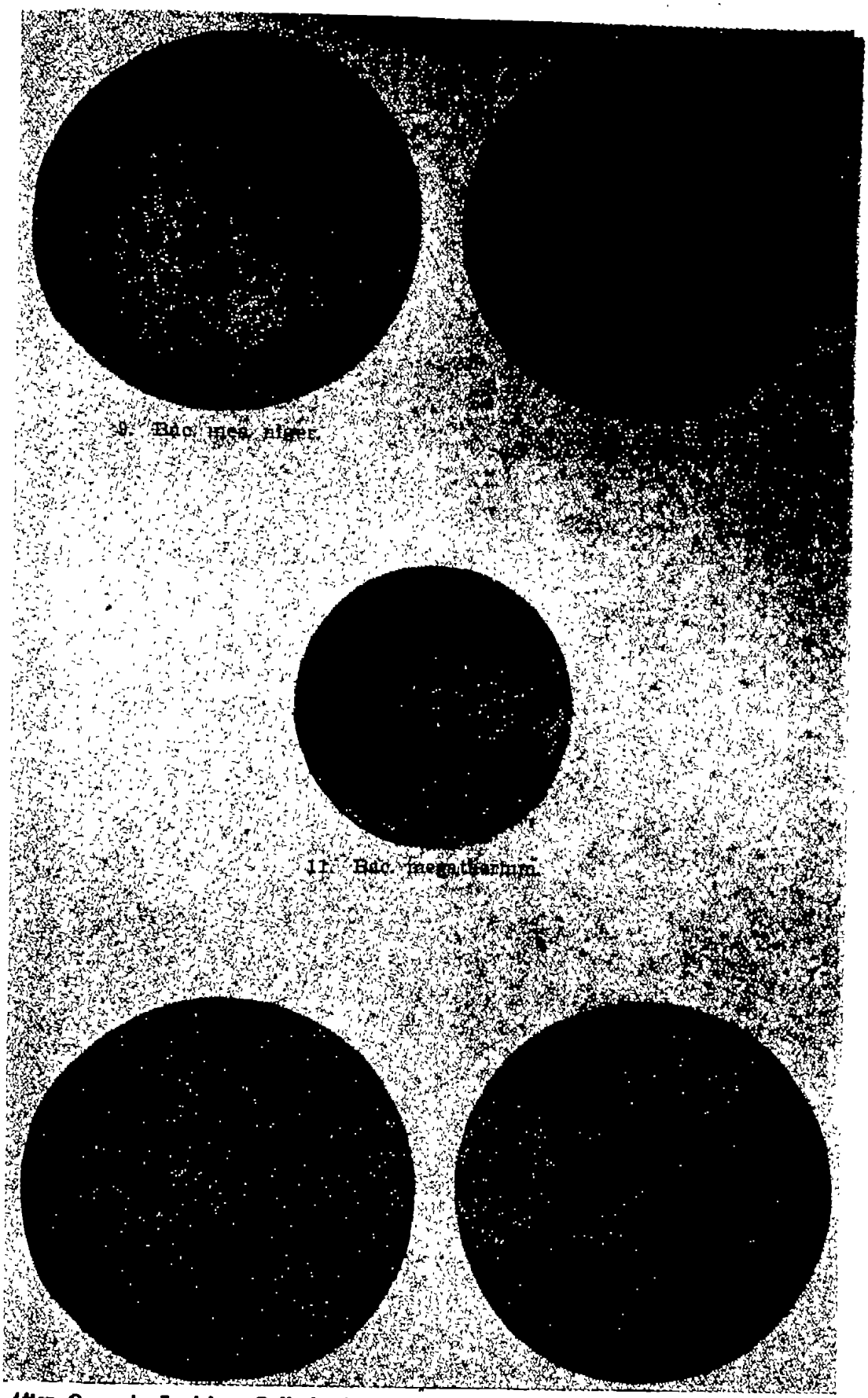
PLATE 11



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Microphotographs of sugar cane bacteria.

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Chapter 20.

Meat Products.

The activities of bacteria, yeasts, and molds are a continuous danger to meat at almost every step in its production, preparation, manufacture, and handling. Some of the products formed when microörganisms grow in meat are very detrimental to health.

The growth of miscellaneous bacteria in meat may be very dangerous not only because disease producing organisms may be present but because of the toxins and poisonous by-products which often result when certain common bacteria attack meat proteins.

Meat producing animals are in more or less danger of becoming infected with one or more of a long list of infectious diseases, and part of these are transmittible to man. For this reason the eating of meat or meat products has caused much disease in humans. However, since the establishment of meat inspection in the United States in about 1885 by the Bureau of Animal Industry, the use of infected meat has been cut down to a point where the meat passed by such inspection can be considered safe. It is still true, however, that some infectious meat reaches our markets. This comes from animals killed on the farm, or in makeshift slaughter houses, by persons who are not in the meat business, but who nevertheless do occasionally kill an animal and sell the uninspected meat.

There is not much agreement concerning the relation of the presence of miscellaneous bacteria in meat to its healthfulness. Some authorities hold that meat containing more than 1,000,000 bacteria per gram is not fit for human food while others believe that 10,000,000 bacteria per gram of meat would be as strict a standard as should be inforced. On the other hand there are some who do not think that the number of miscellaneous bacteria in meat has anything to do with its healthfulness whatever. On this point it seems logical to some to consider that in general, meat is in danger of developing toxicity or even pathogenicity in proportion as the miscellaneous bacterial content rises. They consider meat of high bacterial content to be dirty, stale, or improperly handled as to refrigeration or cleanliness.

E. O. Jordan in an address before the American Association for the Advancement of Science, Dec., 1917, in discussing food poisoning said:

"Gastro-intestinal disturbance traceable to some food eaten shortly before is a common occurrence and is indeed part of the experience of many persons. Not long since, the majority of such attacks were

declared due to 'ptomain poisoning,' and were deemed to be sufficiently explained by this designation. It was believed, though never, it must be confessed, on very good evidence, that the foods responsible for the trouble had been kept too long or under improper conditions and had undergone bacterial decomposition or spoiling. This decomposition was supposed to have resulted in the formation of ptomains, a name given by Selmi to certain basic compounds formed in the later stages of protein disintegration. Interest in ptomains was especially stimulated by the work of Brieger, who isolated and studied (1882-1883) the properties of many of these bodies.

"Confidence in the sanitary significance of ptomains has been shaken by many facts. For one thing, ptomains are formed in the later stages of protein decomposition, and by the time they are present, the organoleptic evidences of decomposition have become pronounced. There is little doubt that food containing ptomains would be almost invariably condemned by the senses as nauseating and unfit for use. On technical grounds numerous criticisms have been made with respect to the methods used for isolating and extracting ptomains and for determining their clinical effect. Perhaps the principal reason, however, for the decline in the belief that ptomains have any important share in the production of food poisoning has been the discovery that in many instances the responsibility can be placed definitely upon other factors."

It is the consensus of opinion that normally the flesh of healthy animals is free from bacteria. Fresh meat from healthy animals, then, if properly handled should be low in germ content. Some authorities believe that there should be bacterial standards for meat while on the other hand there are people who prefer meat in which there are visible signs of protein liquefaction. This subject of the relation of miscellaneous microörganisms to meat needs much further investigation.

In the large packing establishments meat is inspected by the Bureau of Animal Industry Inspectors and meat infected with pathogenic microörganisms is eliminated. Ante-mortem inspection removes many diseased animals but rigid inspection of the carcasses immediately after slaughter detects the remainder. Nevertheless 25 to 40% of the meat consumed in the U. S. is said to escape inspection due to the fact that it is marketed through channels in which there is no inspection.

Some of the more important infections, pathogenic to man, sometimes found in meat but usually detected by inspection, are tuberculosis, anthrax, trichinosis, actinomycosis, botrymycosis, pseudotuberculosis, rabies, septicemia, foot and mouth disease, pyemia, etc.

Meat Preservation.

In meat preservation several different methods are employed as follows:

(a) Sterilization and sealing as is the case in the meat canning industry.
(b) Partial sterilization by heating as in the preparation of cooked meats.
(c) Freezing of meat as is the case in storage and shipment of fresh meat.
(d) Drying of meat, an old custom used by all peoples more or less for the preservation of many different kinds of meats including fish.
(e) Pickling.
(f) Preservation of meat products by concentration as in the case of the preparation and preservation of meat extract.

The sterilization of meat by canning is an industry which takes in almost every type of meat. Corned beef, potted meats, canned chicken, canned roast meats, sardines in oil, and meat soups are some of the most important canned meats.

Some meats as sausages are partially sterilized by cooking and keep for days or weeks if kept cold. These sausages are not sterile but have a very slight germ life in them as the cooking has killed all bacterial life except perhaps a few spore-bearers. Such sausage, if kept cold, remains a safe food, while, if allowed to become warm for any length of time becomes dangerous.

Sausage, according to Edelmann, is a mixture of meat and other products placed in a sausage covering. Some of the products often used in sausage making are blood, fat, flesh, heart, liver, tongue, salt, sugar, spices, pepper, paprika, etc.

The object of making meat into sausages is to preserve it, to make it more appetizing and to more easily market it. In the preparation of sausages one of the main objectives to be reached is the reduction of bacteria and of bacterial growth in the sausage. This is more or less accomplished by cooking, sealing, smoking, and the use of ingredients which are somewhat germicidal.

The shipping of meat in the frozen state is widely practiced where meat is shipped long distances by boat. The meat is frozen before being taken aboard. Frozen meat has been found to keep indefinitely.

The drying of meat such as strips of beef, venison, etc., is the earliest method of meat preservation. Many different kinds of meat are marketed in the dried state, as dried beef, dried haddock, mixed fish flakes, codfish, dried herring, etc.

Dried beef is prepared from beef which is pickled in a "brine—saltpeter—cane sugar" pickle for fifty or sixty days. After pickling, the beef is smoked and dried, which requires from one to two weeks.

In the preparation of dried beef, there is a weight gain in the meat of several per cent.

Edelmann gives the following beef pickling formula:

90% brine	100 gal.
Saltpeter	5 lbs.
Cane sugar	20 lbs.

Preservation of meat by curing is well illustrated in the curing of pork. The curing pickle is made according to Edelmann as follows:

Salt	2½ lbs. to 1 gal. water
Cane sugar	5 oz. to 1 gal. water
Saltpeter	4 oz. to 1 gal. water

Use 5½ to 5¾ gallons of pickle to each 100 lbs. of hams or shoulder.

The pork cuts are submerged in the pickle in vats after having been pumped full of pickle with a pump and needle outfit. The object of pumping the pickle into the pork is to shorten the time of curing and reduce the loss from sours.

A very important point in curing pork is that the pork be handled under sanitary conditions and that the pickle be sterile. The packing vats should be sweet, clean and sterile.

Dry, salt pork, according to Edelmann, is made by rubbing in 14 lbs. of salt to each 100 lbs. of pork after pumping with pickle.

The preservation of meat products by concentration is best illustrated by the preservation of beef extract. It is the evaporated filtrate obtained from new, clean beef, treated to high steam pressure. This extract according to Stutzer contains:

20% water
60% organic matter
20% meat salts

The preservation of smoked meats is due in part to the germicidal property of the creosotic compounds of smoke which penetrate the meat. Hard woods of different kinds are used in smoking meats. Edelmann says Juniper wood is best. He says that smoking can be done in a short time even a few hours by forced smoking in a smoking room held at or near 100 degrees C. Slow smoking at 20 degrees C. requires several days or even weeks.

Disease Organisms in Meat.

B. enteritidis, when it infects meat, has been found to grow even during cold storage. The fact that the toxin produced by this organism is not destroyed by boiling or roasting makes B. enteritidis infected meat a very dangerous food. The best protection from B. enteritidis infection of meat is cleanliness in all the operations of production and preparation. The number of deaths from B. enteritidis poisoning is not great but the number of cases followed by slow recovery is considerable.

B. coli and B. proteus, in meat not refrigerated properly, flourish and sometimes cause food poisoning in those who consume the meat.

Trichina infection of pork usually results when hogs eat trichina

infected rats or foods contaminated with trichina. When humans eat trichina infected pork, the parasite reaches the circulation by way of the intestines and the lymph glands. The parasites reach the striated muscles by way of the circulation. Here the embryos develop. Pains in these muscles are the first symptoms of the disease.

Detection of trichina infected pork is usually successful by the microscopic examination of muscles at the base of the tongue and the pillars of the diaphragm.

When pork is cooked and the central part reaches 80 degrees C. the parasite is killed. However, pickling or salting does not necessarily kill the parasite.

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Chapter 21.

Marine Products.

Shellfish.

The bacteriological aspects of the shellfish industry are very closely associated with the sewage pollution of the waters of bays and river mouths. The study of this subject is rapidly increasing in importance because of the greater amounts of sewage entering coastal waters where oysters are planted. The direct connection of many epidemics of typhoid fever and dysentery with sewage pollution of oysters has emphasized the great need of protecting the public, and also the oyster and clam industries, from such calamities.

Sewage disposal is a problem which only a few large cities have wrestled with successfully. Many large and small sea-coast towns from the time of their first settlement have taken advantage of the opportunity of disposing of sewage in the ocean. This method of sewage disposal is practiced too largely at present. Also steamships and sailing vessels have the custom of disposing of sewage and garbage in waters wherever they happen to be. Thus as population increases, and ocean and river commerce grows, the menace of pollution of navigable waters increases, and the shellfish industries are more and more threatened. As a result there are fewer places to-day where oysters can be planted and grown free from contamination with disease germs than ever before.

It is estimated that more than $30,000,000 worth of oysters are marketed in the U. S. each year. There is no question but that this industry should be protected and that this great food product should be increased rather than diminished in total output. According to G. W. Stiles an extensive industry is also being developed in maturing seed oysters taken from the Atlantic coast and transplanted in the colder waters of Puget Sound where the water is too cold for spawning and development.

The custom of "floating oysters" is largely practiced in the shellfish industry because of certain advantages. The practice is to take oysters from the beds where they have grown and remove them to "floats" which are large, partly submerged boxes with slatted bottoms usually 20 to 50 feet by 2 feet deep. In these floats the oysters are allowed to "fatten." The oysters are taken from salt water and are floated in fresh water. In fresh water the oyster takes in more water than in salt water due to the fact that fluids inside of the oyster's body are

quite concentrated. This concentration is the natural development of life in salt water. Upon change to fresh water osmosis causes a swelling of the oyster with fresh water. The advantages of this are that the oysters weigh more, are more bulky, and also become lighter in appearance.

Stiles says that the proper control and location of oyster beds in relation to public health should be a matter of great concern to those engaged in the industry. He adds that because of unsanitary methods of sewage disposal large areas of once valuable oyster grounds are at the present time subjected to conditions which render the shellfish taken from them wholly unfit for food purposes. He says that many extensive oyster layings may be free from contamination at one

After Stiles in U. S. Bureau of Chemistry Bulletin 136.

FIG. 39.—Indian Creek, where upon investigation nine oyster dealers were found to be floating oysters in the cellars of their houses. Such practices were stopped.

time but due to the springing up of summer cottages and the increase in size of small towns the oyster beds are threatened.

George W. Stiles of U. S. Dept. of Agr. Bur. of Chem. gives the following conclusions as the result of his studies concerning the contamination of shellfish:

"(1) There is undisputed evidence to show that infected oysters, clams, mussels, scallops, and other shellfish may cause typhoid fever and other gastro-intestinal disturbances when consumed by susceptible individuals.

"(2) The epidemics of typhoid fever, due to ingestion of polluted sea food, have in most instances been traced to shellfish floated in polluted water, although there is also evidence that oysters and other shellfish, grown in polluted waters and directly consumed without transplanting for a time in pure waters, may be the source of typhoid infection.

"(3) The investigations pertaining to the Minisink banquet, held at Goshen, N. Y., on October 5, 1911, show conclusively that the 'Rockaway' oysters served on this occasion were wholly responsible for the typhoid and gastro-enteritis cases following this banquet.

"(4) There were 17 well-defined cases of typhoid fever, with one death, and 83 cases of gastro-enteritis (diarrhœa) traced directly to eating 'Rockaway' oysters from Jamaica Bay, floated at Indian Creek, near Canarsie, Long Island, N. Y.

"(5) In addition to the typhoid and other intestinal disorders following the consumption of 'Rockaway' oysters at the Minisink Banquet, there were also 10 other cases of typhoid and 16 of diarrhœa traced to eating 'Rockaway' oysters, some of which came from the same lot furnished for the Minisink banquet.

"(6) The bacteriological examination of water and shellfish collected from Jamaica Bay shows that this body of water is dangerously polluted; the laboratory data are substantiated by the sanitary inspection, which shows that millions of gallons of raw sewage discharge daily into this bay, and, in many instances, in close proximity to or directly over oyster beds.

"(7) Typhoid bacilli were isolated in pure culture after 7 and 21 days from oysters which had been floated at Inwood, Long Island, N. Y., on October 12, 1911, and kept out of water in storage at 39 degrees F. Organisms of the B. coli and B. paratyphosus groups were also isolated from oysters floated at Indian Creek, near Canarsie, Long Island. They were probably the cause of the gastro-enteritis cases following the Minisink banquet.

"(8) This investigation comprises a complete study of all the factors which would materially contribute to typhoid infection. Each item of the menu served at the Minisink banquet was carefully considered, and the 'Rockaway' oysters served were the only articles of food consumed by all of those who had typhoid or gastro-enteritis following this banquet."

Stiles in an investigation, "Shellfish Contamination from Sewage Polluted Waters and from Other Sources," gives the following conclusions:

"(1) There is undisputed evidence to show that shellfish become contaminated when placed in sewage-polluted water, and that B. coli and B. typhosus will survive for variable lengths of time in the liquor and the body contents of such shellfish after their removal from infected water.

"(2) The presence of sewage organisms in oysters and other shellfish, even in small numbers, may be indicative of great danger; for, where such organisms exist, the specific cause of enteric fever and allied disorders may also be found.

"(3) The results of many investigators show that sewage-polluted shellfish have been responsible for the production of typhoid fever and other intestinal diseases. The most noteworthy cases appear to have occurred from eating oysters which had been floated in sewage-polluted

water, although instances are cited where shellfish infected by polluted water, either in their natural or artificial beds, have also been the vehicle of disease transmission.

"(4) The shellfish industries of this country are extensive and important, comparing favorably with other industries concerned with the production of food materials. A valuable article of food is furnished to millions of people by these industries, and thousands of individuals find profitable employment in developing and carrying on this business in all its phases.

"(5) The indiscriminate introduction of sewage into our natural bodies of water is now the greatest enemy to the shellfish industries. In order to correct this evil it will be necessary to prevent further pollution of our waters, or else to remove the shellfish industries from the grounds subject to pollution.

"(6) Oyster beds should be protected from every possible source of contamination, and they should be located in water proven to be pure by repeated examinations. These examinations should consist of careful bacteriological and chemical analyses of both the water and oysters from oyster layings. The laboratory findings should also be supplemented by systematic inspection of all the territory which could in any wise affect the condition of the water flowing over the oyster beds.

"(7) The practice of floating oysters in water of questionable purity should be absolutely prohibited because of the probability of sewage contamination. When it is desired to remove the gross filth from the exterior of the shell, oysters may be floated and allowed 'to cleanse themselves' in suitably constructed devices in waters free from pollution, and containing no less salt than the water in which they will grow to maturity.

"(8) Like other perishable food products, oysters may become unfit for use if stored or kept under unsanitary conditions. This spoilage, however, may take place wholly from the length of time out of water.

"(9) Oysters removed from pure beds may become contaminated during the process of shucking or preparation for the market in insanitary shucking establishments. These places should be constructed in a sanitary manner and provided with satisfactory appliances for the proper cleansing and sterilization of utensils used for shipping oysters. Without such devices it is almost impossible to prepare packages in a sanitary manner. This is particularly true when cans, barrels or containers of any kind are used a second time without proper cleansing and sterilization. When contaminated these unsterile vessels may become active agents for the dissemination of disease-producing organisms.

"(10) The liquor in the shell surrounding the oysters contains more bacteria than does an equal volume of meat from the same oyster. This liquor, together with any sand in the gills of the oyster, can be removed and the meat chilled at the same time by the use of pure

ice and water. This washing process can be done efficiently within 3 to 10 minutes, depending upon the method employed. Oysters should not be allowed to soak in fresh water, as they increase in volume, change in appearance and flavor, and decompose more rapidly than those not soaked."

The Canning of Marine Products.

C. H. Stevenson classifies canned marine products into five classes as follows:

"(1) Plain boiled, steamed, or otherwise cooked.
"(2) Preserved in oil.
"(3) Prepared with vinegar, sauces, spices, jellies, etc.
"(4) Cooked with vegetables, etc.
"(5) Preserved by some other process but placed in cans for convenience in marketing.

"The first class includes salmon, mackerel, herring, menhaden, cod, halibut, smelt, oysters, clams, lobsters, crabs, shrimp, green turtle, etc.; sardines almost exclusively make up the second class.

"The third class includes various forms of herring prepared as 'brook trout,' 'ocean trout,' etc., mackerel, eels, sturgeon, oysters, lobsters, crabs, etc.

"The fourth class includes fish chowder, clam chowder, codfish balls, green turtle stew, terrapin stew, and deviled crabs.

"The fifth class is made up of smoked herring, halibut, haddock, carp, pickerel, lake trout, salmon, eels, sturgeon, etc., and brine salted mackerel, cod and caviar."

Bitting describes the oyster canning industry as follows: "In 1858 Louis McMurray, of Baltimore, found that by scalding the oysters in boiling water the shells would partially open and the labor of shucking could be lessened. Two years later the system of steaming them instead of scalding was developed, and no material change in method has taken place since that time. McMurray is said to have had a most excellent reputation as an oyster packer. His method was to save all the liquor and condensed steam from the steam boxes, filter it, and use it in filling the cans. He used neither salt nor water. There is probably no packer in the business at the present time following this method.

"Oysters are obtained by dredging and by tonging, the former upon the reefs and in the deeper water, and the latter in the shallow bayous where planting has been done. The usual equipment consists of a schooner of about 48-foot keel, 55 feet over all, and 16-foot beam. When loaded, this will carry about 275 barrels of oysters. The crew consists of a captain and four men. A dredge is carried on each side of the boat and operated by two men. The dredge consists of a heavy iron rake about 3 feet wide, to which is attached a chain or heavy cord purse, the mouth of which is held open by an iron bar just above the rake. The dredge is lowered to the ground and dragged along by

the movement of the boat. The rake loosens the rock or ground and they are collected in the purse.

"At short intervals the dredge is drawn on board by means of a windlass, the purse is emptied, and the operation repeated. The oysters are culled in some places, the small ones being returned. The catch is put in the hold if the boat is out in warm weather or is to be gone for more than a day. The trips are generally limited to from three to five days in order to insure delivery in a fresh condition at the cannery. Other varieties of smaller boats are also used, though power boats are generally barred. The Gulf-coast factories pay about 60 cents per barrel for oysters used in canning and 80 cents per barrel for those used in the fresh trade, owing to the difference in size. The barrel is rated by measure and not by weight. On the eastern coast the measurement is by the bushel.

"The oysters are rated by size. If there are from 800 to 1,000 to a barrel they are known as standard, from 600 to 800 per barrel as selects, and from 450 to 600 per barrel as extra selects. The largest oysters, known as 'counts' on the east coast or as 'plants' on the Gulf coast, run less than 450 per barrel and are always sold raw. The larger oysters are found on certain reefs on which work has been prohibited for given periods or in certain water where planting has been done. The term 'plants' when applied to eastern oysters refers to those taken from deep water, transplanted in shallow water, and cultivated until they have attained a desired size.

"When the oysters are brought in, they are hoisted directly from the boat to the steaming car. These iron cars or crates are 28 inches wide, 19 inches deep, and 8 feet long. They will hold 5 barrels of 2½ bushels each. As soon as the car is filled the oysters should be given a thorough washing with clean water to remove the dirt and mud attached to the shell before it goes to the steam box, otherwise there is contamination during the shucking. The cars are wheeled from the dock to the steam box, which accommodates 3 cars. The steamer is a rectangular iron box, just large enough to admit the cars, and is 25 feet in length. There are a few variations from these sizes, but these are standard. The doors are closed at both ends; steam is turned on until a pressure of 10 pounds is reached, and this is maintained for 5 minutes. The doors are then opened and the oysters allowed to cool quickly in the air. It is important that the oysters be steamed well so that there will be no shrinkage in the can, but not long enough to cause them to become crummy. Both the time and the temperature at which the steaming is done seem to have been fixed by experience, as none of the superintendents seemed to know what the effect would be if a lower temperature and longer time or higher temperature and shorter time were given.

"The car of steamed oysters is pushed into the shucking shed, the shuckers standing around the car and working until it is emptied. The usual number of shuckers is from five to eight, and they are generally women and children.

"The steamed oyster has the shell partly opened, the meat being easily removed by means of a short, heavy-bladed knife. The oysters are deposited in pans which are hooked to the oyster car. The shucker receives 5 cents for 3½ pounds of selects or 3 pounds of standards. The oysters are weighed as received from the shuckers, washed and placed in cans by weight according to the grade and order. The cans are filled with a weak hot brine (2 pounds of salt to 10 gallons of water), frequently by passing the cans through a dip box. This method was used at one time in other lines of canning, but has been superseded by more sanitary methods, and should be in this case.

"The cans are capped in the usual manner, either by hand or machine, and are then processed in the retort at 240 degrees F., the No. 1 cans for 12 minutes and the No. 2 for 15 minutes. The different packers vary the time a few minutes, but practically all use the same temperature.

"The oysters are cooled as soon as sterilized, and when dry are ready to pack. The oyster is easily sterilized, it is not hard on the can, and there is little loss from spoilage.

"The term 'cove' is applied to any canned oyster. It originally meant only the oysters obtained on the western shores of Chesapeake Bay and was distinctive of quality. Gradually any oyster became a cove oyster and now the term refers to canned oysters irrespective of where they are obtained."

The Preparation and Canning of Shrimps.

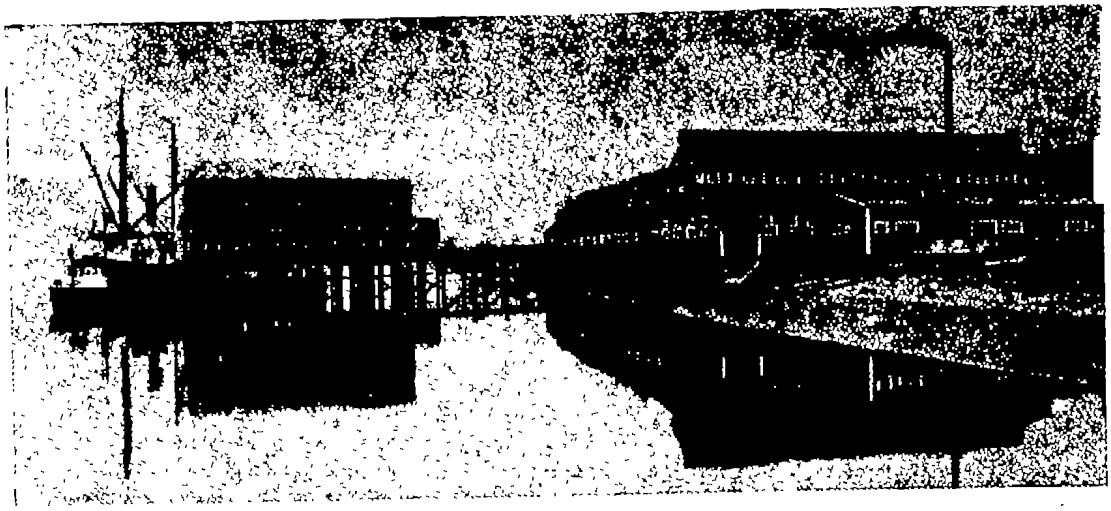
Bitting describes the process as follows: "The peeled shrimps are thoroughly washed in two or more changes of water and are then ready for blanching. The blanching consists in boiling the shrimp in salt water, which is done by suspending them in a wire basket in the boiling brine. The time of the blanch is usually about four minutes for the wet pack and five minutes for the dry pack. The salt in the brine is in the proportion of about 1 pound per gallon of water. Up to the time the shrimps go into the blanch they are white or slightly gray in color; the boiling in the brine causes them to become bright pink or red.

"The shrimps are turned out upon trays having wire netting. As soon as cool they are filled into cans by hand, each can being weighed. The shrimps are all packed in either No. 1 or No. 1½ cans, the former having 4½ ounces and the latter 9 ounces. There is no attempt at grading.

"Shrimps are put up in what are known as dry and wet packs. In the dry pack no liquor is added, while in the wet pack brine is used. The process for dry shrimps is 1 hour at 240 degrees F. or 4 hours at 212 degrees F. for No. 1 cans, and 75 minutes at 240 degrees F. and 4 hours at 212 degrees F. for No. 1½ cans. The process for wet shrimps is 11 minutes for No. 1 and 12 minutes at 240 degrees F. for No. 1½ cans.

"The fill of 4½ and 9 ounces in the No. 1 and No. 1½ cans has the appearance of being light weight or slack filled. Experience has shown, however, that close filling causes matting of the shrimp and an unsightly appearance. The wet-packed shrimps are preferred by those who are familiar with the fresh article. They have better texture, odor, and taste than the dry packed. A barrel of good shrimps will pack 190 No. 1 cans or 100 cans of No. 1½.

"Formerly shrimps were put up in bulk with a preservative. These were headless (only the head and thorax removed, the shell left on), and since that method of preservation is no longer approved, very few shrimps are obtained upon the market other than canned. Some pickled headless shrimps are put up in 1 to 5 gallon cans for hotels. These are boiled in strong brine for several minutes and put up in a saturated salt solution. They keep, but are very salty, and as it takes



After Cook in U.S.B.F. Document 902.

FIG. 40.—Salmon cannery at Hoonah, Alaska.

a long time to freshen them they are not available for immediate use.

"Shrimps are difficult to keep." Put up in the ordinary tin can they will blacken in a short time and will attack the tin, making minute holes. Success in canning shrimps was dependent upon lining the can. This was first done by Mr. G. W. Dunbar of New Orleans, in 1875. The method consisted in inserting a sack in the can and filling it with the shrimps to prevent their coming in direct contact with the tin. Later a thin veneering of wood, corn husks, parchment paper, asphaltum, and enamels were used. Parchment paper is used by all packers, with possibly one exception, at this time; in this case wood veneer is used."

According to Bitting: "Salmon canning on the Pacific coast is one of the large canning industries, and is of so much importance that Government aid is extended in maintaining fish hatcheries in order to keep up the supply. The first salmon canning was done on the Sacramento River in 1864, later on the Columbia River in 1866,

in British Columbia in 1874, and in Alaska in 1882. The value of the salmon pack on the Pacific coast is more than $10,000,000 annually.

"There are four species of salmon which have large commercial importance—Oncorhynchus tschawytscha, the chinook, quinnat, red spring, or King Alaska; O. nerka, the sockeye, Blueblack or redfish; O. kisutch, cohoe, silver or silver sides; and O. gorbuscha, humpbacks or pink Alaska. Preference is given to the bright pink color by the consumer, but for real quality the paler cohoe excels some of the others, the fresh being less dry and containing more oil and a better flavor.

"The salmon are caught in the rivers as soon as practicable after they leave the sea on the way to the spawning grounds. They are caught by nets, seines, traps, and fish wheels. The catching of the fish is done on an elaborate scale, an idea of which may be gained from a brief description of a trap. This consists of a steel-wire netting, starting at the shore and carried out into the stream at an upward angle for a distance of about 2,500 feet. This netting is supported by piles placed about 15 feet apart. At the outer end is a large square compartment known as the pot. This is usually about 40 by 40 feet and in water as deep as 65 feet. This pot contains a dip net equal to its area. Just previous to reaching the pot the trap is made to zigzag or assume a heart shape, so that the fish in trying to pass up the stream will be directed into the pot."

The Canning of Salmon.

Turrentine describes the process of canning salmon as follows:

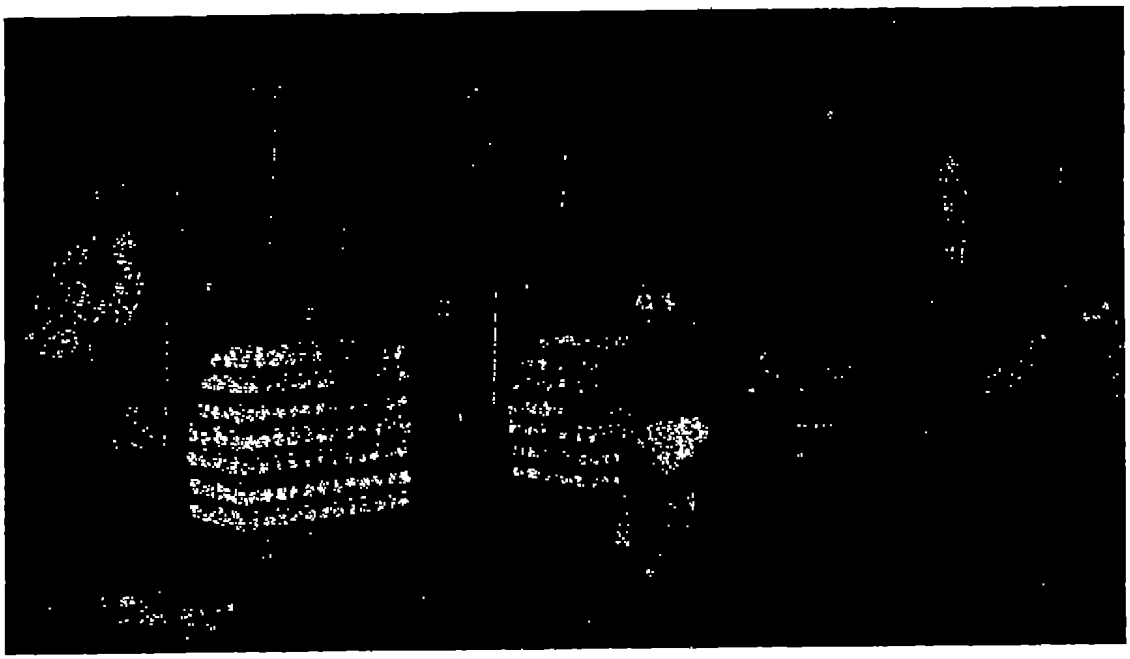
"Formerly the cleaning or butchering was done by Chinamen, and in some canneries this practice is continued. In most instances, however, cleaning by hand has been supplanted by machine cleaning.

"The mechanical cleaner is spoken of in the parlance of the cannery as the 'iron chink,' a name which originated from the pseudo name of its human predecessor. Without entering into a detailed description of this machine, it is sufficient to say that it essentially is a revolving disk or wheel about 2 feet in diameter, around which knives and stiff brushes are arranged. These work together to split the fish along its belly, to remove its viscera, and to sever its fins, and finally its tail.

"The machine is fed by two laborers, the first of whom places a fish under a stationary knife, against which it is lifted mechanically. The second laborer thrusts the beheaded fish into a slot, of which there are a number on the peripheral rim of the wheel, tail first, so that it becomes wedged and is held firmly. It thus is lifted and carried around, belly outward, by the wheel, and is brought successively against the knives and brushes. Abundant jets of water are made to play upon the fish as it passes through the machine.

"This contrivance works rapidly and fairly successfully, with a

rated capacity of 50 fish per minute and an actual output of 36 dressed fish per minute. It thus is possible to do away with the large force of skilled and high-waged dressers. Fish are by no means uniform nor rigid objects; therefore no machine can be expected to adapt itself to the variation in size and the manner in which they pass through the machine. As the fish are not dressed uniformly by the machine, they subsequently must be passed under the knives of the 'slimers,' laborers whose duty it is to finish the work left incomplete by the machine. As the number of these about equals the number of 'butchers' which would be required if the dressing were done altogether by hand, there is not the economy in labor resulting from the use of the mechanical cleaner that would be expected. The fact that much



After Cook in U.S.B.F. Document 902.

FIG. 41.—Cooking the salmon in retorts.

less skill is required of 'slimers' than of 'butchers,' however, is an item greatly in favor of the use of the mechanical cleaner.

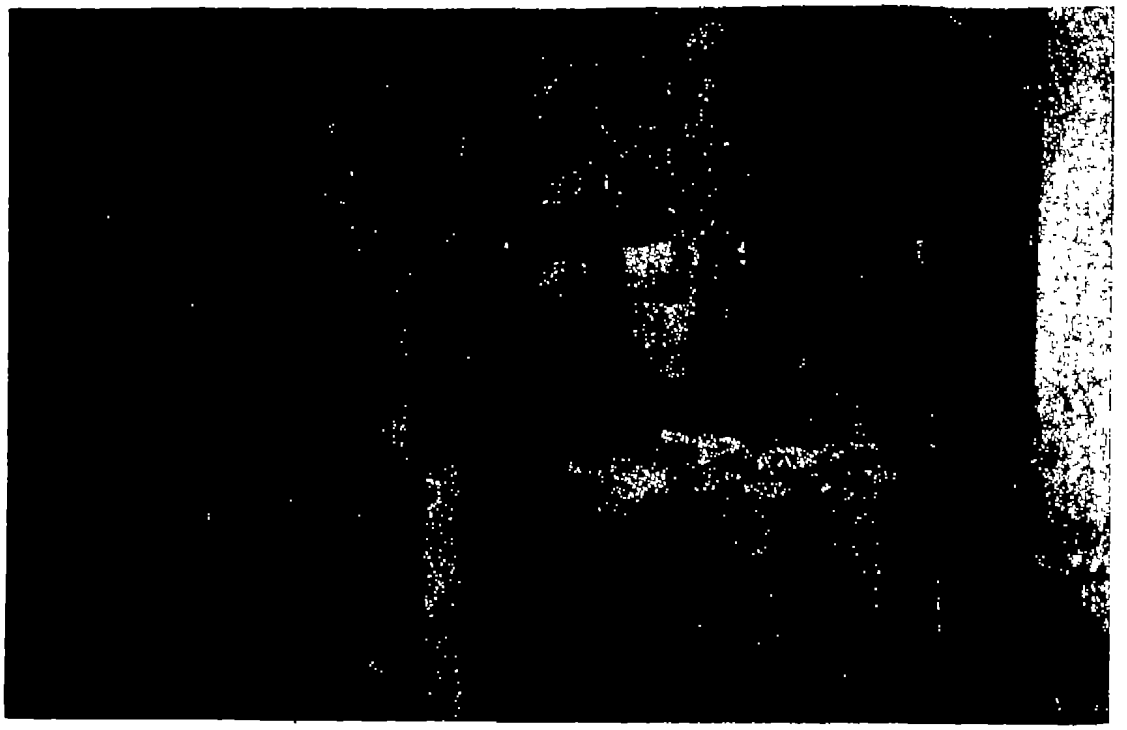
The Cutting Process.

"After being thoroughly cleaned, the fish are cut into pieces of convenient size for filling the cans. A mechanical cutter of simple design has been adopted for this purpose. It consists essentially of a short conveyor which is made to revolve over bearings in such a way as to describe an ellipse. Blocks of wood are placed at intervals to carry the fish. At the apex of the ellipse revolving knives are place. These revolve in horizontal slits in the conveyor and blocks. As the blocks start on their upward course the fish are placed upon them by hand and are carried through the knives. The distance be-

tween the knives is such that the fish are cut into sections of the proper length to fill cans of the size for which they are intended.

The Filling of the Cans.

"Cans designed to hold a pound of fish are filled usually by a machine which, by means of a plunger, thrusts into the can pieces of salmon already cut to the right length and trims off that which projects. As the thrust of the plunger is uniform, the machine is able to load the cans with a nearly exactly uniform weight of fish, and works rapidly. Less than a second is required in filling a can. From



After Cook in U.S.B.F. Document 908.

FIG. 42.—Cutting salmon into pieces of a size to fit the can.

the filler the cans are passed along a table, where they are inspected for short weight. Smaller cans are filled by hand. Their shallowness makes them less adapted to the filling machine, as they do not retain their charge of fish so readily.

"After filling, it remains to cap the cans or put the lids on, cook the contained fish, seal, clean, and label. The canning process involving the use of soldered cans has been supplanted almost entirely by that based on the use of the solderless or so-called 'sanitary' can. The latter process, being almost entirely automatic, effects a great saving in labor as well as floor space, and is commendable from both a mechanical and a sanitary point of view.

"The modern cannery is equipped with machinery in units. A unit is spoken of as a 'line.' The one-line cannery is equipped with

a mechanical cleaner, or 'iron chink,' a cutter, a filling machine, a capping machine, followed by a steam box for the preliminary cooking before sealing, two crimping machines for fastening the caps to render the can air-tight, and the requisite steam autoclave capacity for the final cooking. Such an equipment gives a daily capacity of 900 cases of canned salmon, each case containing 4 dozen 1-pound cans or 48 pounds of canned salmon. This estimate is based on a day of about 12 hours. During the canning season a 'one-line' cannery, or one with a single unit, is expected to pack about 40,000 cases. The season's pack is determined by the skill of the management, the condition of the market, and the fortune of the fishermen."

Kippered Salmon.

J. N. Cobb discusses the kippering of salmon as follows: "On the Pacific coast practically all of the kippered salmon is prepared from frozen white-meated king salmon, which on account of the color of the flesh is not in much demand. It is, however, fully the equal, in both flavor and food value, of the red-meated kinds. It is not absolutely essential that the fish be first frozen, as the fresh fish may be kippered after dressing, but the latter is always a little soft when so prepared owing to an excess of moisture, which is largely removed in freezing. Fresh salmon is available only part of the year, so it is found most convenient to freeze and store the stock and work it up when needed throughout the year.

"Before freezing the fish have been dressed, so when thawed in cold, running water, it is only necessary to split and cut them into pieces of a pound or less, these being about 6 inches long, or perhaps 3 inches broad, depending upon the part of the fish the piece is taken from, and place them in a tank of strong brine to season for several hours. They are then dipped in a harmless vegetable coloring, similar to that used by the butchers for coloring sausage; this gives the outside of the product a red color, a concession to popular prejudice.

"From the coloring tank, the pieces are placed on a tray with wood frame and bottom of one-half inch square meshed wire; care is taken that the pieces do not touch each other.

"The tray is then slipped into a rack which will hold a number of these, placed one above the other, and this rack is then run on a track into the smokehouse.

"A medium fire is then kindled which dries and slightly smokes the pieces from 16 to 18 hours.

"When they reach a proper stage the fire is enlarged but great care must be exercised in order to prevent their being overheated, and this is done by means of the damper at the bottom of the smokehouse and the ventilator at the top. The fish are baked in this manner from 25 to 35 minutes, the thermometer showing from 250 to 275 degrees of heat.

"When the cooking is completed the cars are pulled out and the

fish allowed to cool, after which each piece is wrapped in a square of parchment paper and packed in a box or basket which holds 10 pounds."

J. N. Cobb says, "The process of preserving fish by freezing was first introduced in 1888.

"There are four important features in packing and using frozen salmon: (1) To get fresh fish; (2) to keep them cold (about 15 degrees above zero) after they are frozen; (3) to keep a coat of ice on them; and (4) to allow them to thaw slowly in cold water or in the air before cooking.

"In selecting salmon for freezing, only the finest and freshest of each species are used. The current belief that freezing destroys the flavor of the fish is erroneous, the flavor depending entirely upon the condition before freezing, and the quicker they are frozen after being caught the better will the natural flavor of the fish be preserved. Frozen salmon are just as wholesome as fresh, and their chemical constituents are almost identical. The danger lies in the temptation to freeze the fish after decomposition has set in but, fortunately, this is now very rarely practiced in the salmon industry.

"The cohoe or silver, and the chum, or dog, salmon are the choicest of the salmons for freezing. The other species, except the red, or sockeye, which is too oily and rarely frozen, are also frozen in varying quantities. The steelhead trout, which is ranked by the Pacific coast dealers among the salmon, is considered the choicest fish of all for freezing.

"Some of the most modern plants in the country are on this coast. These have numerous freezers, generally, in which a temperature of from 25 degrees to 30 degrees F. below zero can be maintained if desired, although a temperature of more than 10 degrees below zero is rarely ever required. All freezing is by direct expansion and each freezer is piped with about 2 feet of 1¼-inch pipe per cubic foot of freezing space. The bunkers in the freezers are in pairs, generally nine pipes wide, spaced 10 inches apart. This leaves about 3½-foot passage through the center of each freezer opposite the swing doors. The salmon are laid on metal sheets, which are placed on the tiers of pipes.

"After freezing the salmon are passed through openings in the rear of the freezers into the glazing room, which has a temperature of about 20 degrees F., where they are dipped into water, and when removed are covered with a thin glaze of ice, which may be thickened by repeated dippings. This is an extra precaution to exclude the air from the fish.

"After being thoroughly frozen and glazed, each fish is covered first with a parchment, like rolls of butter, and then with a piece of heavy brown paper. They are then packed in boxes holding about 250 pounds each, placed in cold-storage cars and shipped.

"The method of freezing fish in brine is now under serious consideration by a number of fishermen and dealers. A brine freezer may

be of small capacity and carried on a fishing boat or it may be a freezer of large capacity at some central point convenient for receiving the catches. In this method a strong brine solution, cooled by circulation through crushed ice is used for freezing the fish. By this method large fish may be frozen in from 1 to 3 hours, a great saving in time as compared with the method at present in use."

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Chapter 22.

Vinegar Manufacture.

There are two fermentations involved in vinegar making, the alcoholic, and the acetic fermentation. The alcoholic fermentation may be represented as follows:

$$\underset{\text{dextrose}}{C_6H_{12}O_6} + \text{yeast alcoholase} = \underset{\text{ethyl alcohol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2}$$

This reaction is the result of the action of alcoholic yeasts on dextrose sugar.

The acetic fermentation may be represented by the following reaction:

$$\underset{\text{ethyl alcohol}}{2C_2H_5OH} + O_2 + \text{bacterial oxidase} = \underset{\text{acetic aldehyde}}{2CH_3CHO} + 2H_2O$$

$$\underset{\text{acetic aldehyde}}{2CH_3CHO} + O_2 + \text{bacterial oxidase} = \underset{\text{acetic acid}}{2CH_3COOH}$$

Raw Materials of Vinegar Making.

Vinegar can be made from a wide variety of products, however the most common sources of vinegar are cider, grape juice, and malt extracts of grains. Other products which have been used as sources of vinegar are honey, beets, oranges, sugar cane, peaches, berries, pears, watermelons, maple syrup, sorghum, glucose, molasses, etc. Some of the sources of starches which may be treated with diastase or otherwise converted into sugars for vinegar making are starches of corn, potatoes, wheat, arrowroot, etc.

Composition of Vinegar.

Vinegar as it usually comes on the market contains 3 to 6 per cent acetic acid, 2.5 per cent total solids and .3 per cent ash (mainly potassium salts). In addition there are other important chemical substances which give to vinegar its desirable flavor and aroma. These substances differ according to the methods and care of manufacture, also according to the source of the sugary extract which has been fermented. Chemically, acetic acid is the oxidation product of ethyl alcohol and is the second member of the fatty acid series.

Acetic acid is not only a fermentation product but can also be produced by the destructive distillation of wood.

Spontaneous Fermentations.

The fermentations in vinegar-making are best carried out by the use of "starters," but the custom of using pure cultures is not very well established in home or commercial vinegar-making. When fruit juices are left exposed to the atmosphere, alcoholic fermentation usually sets in, followed some weeks later by acetic acid fermentation. This means that alcoholic yeasts and acetic acid bacteria are normally present almost everywhere. Under certain conditions, however, vinegar-making does not proceed spontaneously. This has been found by the author to be the case where vinegar-making is attempted with apples grown under irrigation conditions and sprayed with certain arsenic sprays.

The Alcoholic Fermentation.

The alcoholic yeast, Saccharomyces ellipsoideus, is well suited to carry on the alcoholic fermentation in vinegar-making. Jörgensen describes this species as a bottom-fermentation yeast, producing mostly oval and round cells in wort, seldom producing sausage-shaped cells. It ferments dextrose, lævulose, and saccharose but does not ferment lactose. Further Jörgensen says, "At temperatures above 13° C. the film of S. ellipsoideus II develops so rapidly and vigorously that flasks containing this yeast can be recognized by this feature alone. Thus, at 22°-23° C. the film had completely covered the surface in six to twelve days." He says that when streak cultures of S. ellipsoideus are grown for eleven to fourteen days at 25° C. in wort containing 5.5 per cent of gelatin, it produces a characteristic net-like structure which differentiates it from other species.

LaFar (1910) gives the following description of S. ellipsoideus: "Saccharomyces ellipsoideus, E. C. Hansen. Synonyms: Sacch. ellipsoideus I., E. C. Hansen = Sacch. ellipsoideus, E. C. Hansen = Sacch. ellipsoideus, Rees. The cells are ellipsoidal, though they may also be sausage-shaped. The limits of budding temperature in wort are 40°-41° C. and 0.5° C. The spores are 3-4 μ, seldom 3.5-4 μ in diameter. Limits of sporulation temperature on gypsum blocks, 30.5°-32.5° C. and 6°-7° C. The cells of the young film, grown at 13°-15° C. differ from those of Sacch. turbidans (which are round and oval) by consisting largely of long, sausage-shaped forms. At the end of eleven to fourteen days the streak cultures on wort gelatin at 25° C. exhibit a peculiar reticulated structure, differentiating them from the preceding species and Sacch. turbidans. This species is generally a bottom yeast. It was discovered on the surface of ripe grapes in the Vosges district and is one of the numerous species that play an active part in the fermentation of wine."

The temperature for best work with many strains of this organism is between 75° and 80° F.

The place of Saccharomyces in the classification of the true yeasts is given in the following key by Hansen after Buchanan:

Family I. Vegetative reproduction by budding—Saccharomycetaceæ.
- A. Cells do not form a surface membrane at once on sugar media, i.e., do not grow exclusively at the top of the medium.
  - 1. Spores having a single membrane.
    - a. Cells fusing in pairs before spore formation—zygosaccharomycete.
    - b. Cells not fusing in pairs before spore formation.
      - (1). Spores germinate by ordinary budding—Saccharomyces.
      - (2). Spores germinate by means of promycelium—Saccharomycodes.
  - 3. Spores having two membranes—Saccharomycopsis.
- B. Cells forming a surface membrane at once by sugar media.
  - 1. Spores spherical, hemispherical, or irregular—Pichia.
  - 2. Spores lemon-shaped with pointed ends—Willia.

Family II. Vegetative reproduction by fission—Schizosaccharomycetes

Wyant of Michigan Agr. Experiment Station says that in the alcoholic fermentation there should result about 50% as much alcohol as there was sugar in the unfermented solution. She says, "100 parts of sugar in the juice should produce theoretically about 51 parts of alcohol, that is, about half as much alcohol by weight should be obtained as there was sugar in the juice. In actual practice only from 45 to 47 per cent is obtained because some of the sugar is used by Saccharomyces ellipsoideus and other microörganisms for purposes other than alcohol production.

"In the conversion of alcohol into acetic acid 100 parts of alcohol should yield theoretically 130 parts of acetic acid, but less than 120 parts are actually obtained because certain other yeasts and bacteria, which are quite sure to be present, also use alcohol as food.

"Thus for every 100 parts of sugar present in the original sugary solution, under favorable conditions, 50 to 55 parts of acetic acid should be obtained. So if a vinegar containing 5 per cent acetic acid is desired, the fermentation should be started with at least a 10 per cent sugar solution, while for a 4 per cent. acetic acid content (Michigan standard) the sugar solution (fruit juice, etc.) must contain at least 8 per cent sugar."

In the manufacture of vinegar from alcoholic solutions produced from fruit or grain extracts, there is sufficient nitrogenous material and phosphate salts so that the acetic acid bacteria do not lack for these fundamental elements of nutrition.

If an alcoholic liquor has been produced from fruit or grain extracts which have been the seat of growth of foreign bacteria, neither the alcoholic fermentation nor the acetic acid fermentation can be normal and a satisfactory vinegar cannot be made because of the off-flavors produced by abnormal fermentation.

The importance of the use of pure cultures as "starters" in making

vinegar is very evident from the large number of abnormal fermentations which are possible.

The alcoholic fermentation of a single sugar as dextrose, naturally results in ethyl alcohol and carbon dioxide, however, there is a large number of bacterial fermentations which may go on along with the yeast fermentation and use up enough of the sugars so that the final vinegar is low in acid. Some of these bacterial fermentations which may attack dextrose, according to Kruse, are as follows:

(1). $C_6H_{12}O_6 = 2C_3H_6O_3$
lactic acid

(2). $C_6H_{12}O_6 = 3C_2H_4O_2$
acetic acid

(3). $C_6H_{12}O_6 = C_4H_8O_2 + 2CO_2 + 2H_2$
butyric acid

(4). $C_6H_{12}O_6 = C_4H_{10}O + 2CO_2 + H_2O$
butyl alcohol

(5). $7C_6H_{12}O_6 + 6H_2O = 12C_3H_8O_3 + 6CO_2$
glycerin

(6). $7C_6H_{12}O_6 + 6H_2O = 12C_4H_6O_4 + 6H_2O$
succinic acid

(7). $C_6H_{12}O_6 + 6H_2O = 6CO_2 + 12H_2$

Use of Sulphurous Acid and Pure Cultures.

Cruess, Zion and Sefredi investigated the value of the use of sulphurous acid and pure cultures in vinegar making and found that a large loss was being suffered due to the presence of foreign organisms which could be largely eliminated by the proper use of sulphurous acid and a pure culture system. They describe the conditions in a typical vinegar factory as follows: "In one of the largest factories, the cull apples and peels and cores from apple driers are ground or 'grated' in an Ohio apple grater as soon as received. The juice is pressed out with heavy screw presses driven by a motor and cog gearing with a capacity of 60 tons per day. The juice goes to 20,000 gallon tanks. The first tank of the season is started with a large starter of compressed yeast. When this tank is in fermentation, about one third of its contents is used to start the next tank. The third tank is started from the second, and so on through the whole series of tanks. Over 500,000 gallons are made in this way during a season. Examination of the fermented juice showed it to be 'dry,' that is practically free from unfermented sugar, but it was shown by microscopical examination to contain large numbers of lactic acid bacteria and the large tanks soon developed a heavy growth of mycoderma (wine flowers) often alcoholic fermentation. The lactic acid bacteria develop a 'mousey' flavor and the mycoderma rapidly oxidizes alcohol to CO_2 and H_2O without forming any corresponding amount of acetic acid. Laboratory tests demonstrated that mycoderma isolated from cider was capable of

destroying all of the alcohol of a fermented orange juice containing 4.5 per cent alcohol in three weeks. The gravity of heavy mycoderma growth may be seen from these figures."

They say, "The use of pure yeast and sulphurous acid in barrel fermentations gave increased yield of alcohol, more complete fermentation of the sugar, a better flavor, more rapid clearing, a fermented liquid practically free from lactic bacteria and mycoderma vini, and a more rapid change of alcohol to acetic acid after alcoholic fermentation. This indicates the disappearance of practically all of the active sulphur dioxide because acetic bacteria have been shown to be very sensitive to it. Large scale fermentations with pure yeast and sulphurous acid gave an increased yield of alcohol and a cleaner fermentation. Examination of several factories shows the extreme need of some method of control of alcoholic fermentation, and to supply this need, the use of small amounts of sulphurous acid to eliminate wild yeast and the addition of pure selected yeast to give a rapid and complete fermentation seems the most practical means of producing the desired results."

The Acetic Acid Fermentation.

It was shown by Hansen that the organisms causing acetic acid fermentation of alcoholic solutions consist of several species as follows:

Bacterium aceti (Kutzing)
Bacterium pasteurianum (Hansen)
Bacterium kutzingianum (Hansen)
Bacterium xylinum (Brown)
Bacterium acetigenus
Bacterium oxydans
Bacterium industrius

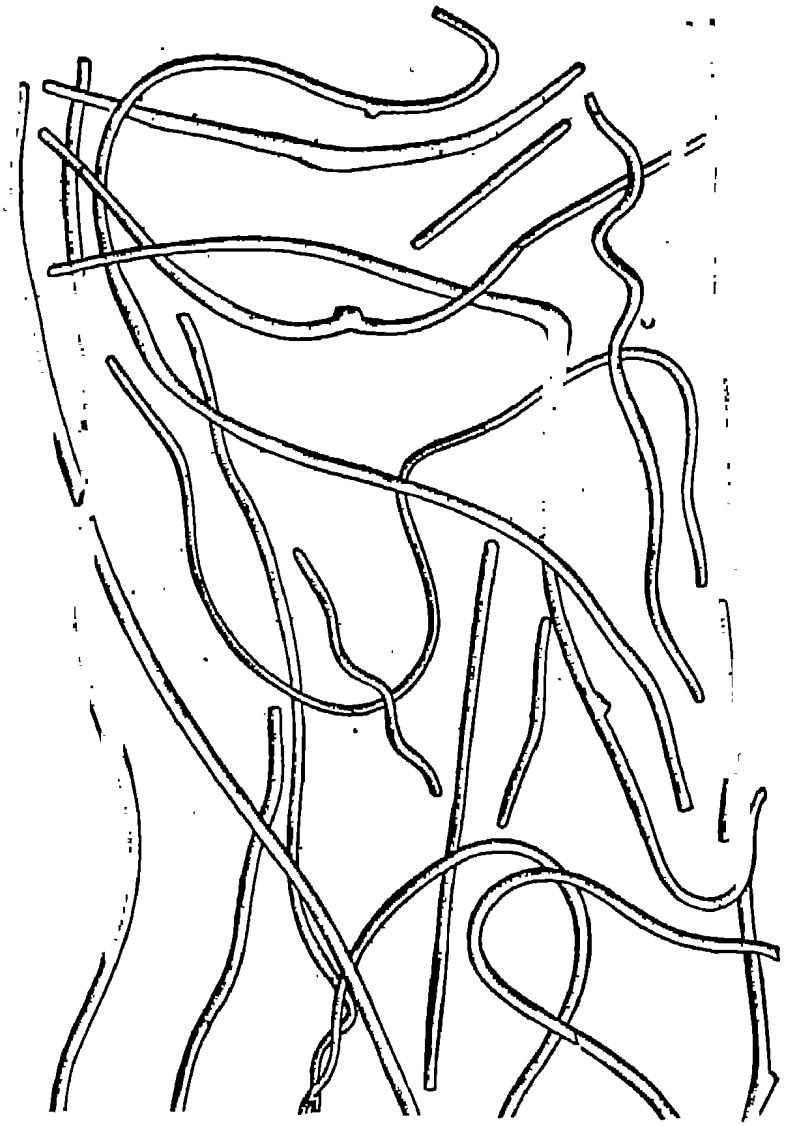
The vinegar bacteria if undisturbed form a film on the surface of alcoholic solutions. This is often called "Mother of vinegar." As the conversion of alcohol into acetic acid is purely an oxidation, it is obvious that the organisms causing this oxidation must remain on the surface and have a liberal supply of oxygen. When Pasteur investigated the troubles of the vinegar makers of Orleans, he found that they did not appreciate the great importance of supplying their fermenting vats with plenty of air and of the prevention of the submergence of the film of acetic bacteria. He devised a method of using a raft of slats on the surface of the alcoholic solutions to prevent the film of acetic acid bacteria from sinking.

In the manufacture of vinegar in barrels, the barrels are left partly full, with vents open so that there will be a considerable surface of liquid exposed to the air.

It has been calculated that one vinegar bacterium is capable in a single fermentation, of forming hundreds of times its own weight of

acetic acid. The organism causes this oxidation reaction because it needs the energy thus obtained for its life processes.

Because of the limited amount of sugar in fruit juices and the limits of alcoholic fermentation by yeasts, the amount of acetic acid in ordinary vinegar is kept down to from four to seven per cent.



After Hansen.

FIG. 43.—Bacterium aceti. × 1000. 24-hour-old culture in "dopple-bier" at 40°-40.5° C.

However, acetic acid fermentation has its limits also. When the concentration of acetic acid in fermenting liquor has reached eight per cent the activity of the acetic acid forming organisms becomes slower and slower and ceases almost altogether when 12 to 14 per cent acid content is reached.

The amounts of different sugar and the total amount of sugar in the juice of some common apples are given by Goff as follows:

ANALYSES OF APPLE JUICE.

	Sucrose	*Lævulose*		*Dextrose*		*Total*
	(c)	(d)	(e)	(d)	(e)	(d)
Mother	2.3	5.8	6.4	1.7	2.2	9.7
Grimes	3.9	5.8	6.4	0.5	1.2	9.9
Arkansas	1.5	5.8	6.2	2.6	3.0	9.9
Limbertwig	0.7	5.0	5.4	3.5	2.3	9.3
York Imperial.....	1.3	6.3	6.6	2.5	2.7	9.9
Lankford	2.6	..	6.8	..	2.2	..
Gano	1.8	5.9	6.0	3.2	2.6	10.4
Peck	..	6.3	6.2	3.3	2.3	12.0
Northern Spy.....	3.7	6.2	7.1	1.7	1.7	10.4
White Pippin.....	2.7	5.9	6.8	2.2	1.8	10.5
Plumb Cider.....	0.6	5.9	6.7	1.4	1.6	7.9
Rome (Beauty)....	1.9	6.1	6.8	1.4	1.9	9.7
Yellow Neuton....	3.1	5.9	6.8	1.8	2.4	11.2
Stayman Winesap..	3.1	6.3	6.8	2.1	2.4	11.6
Ben Davis	1.0	5.9	6.5	2.5	2.7	9.6

(c) Acid inversion, cu reduction.
(d) Optically.
(e) Broune.

He remarks concerning figures in above table that in every case the amount of lævulose exceeds the combined amounts of the other sugars present.

Acetic fermentation is carried on at different temperatures depending upon the particular organism employed and the process of manufacture. The English vinegar makers hold their acetic acid fermentation at between 40° and 43° C. while American manufacturers use a much lower temperature usually about 32° C.

Care must be taken that the alcoholic content of the solution being fermented to vinegar does not drop below two per cent alcohol as at this point the vinegar bacteria begin to respire and destroy some of the acetic acid already formed according to the following reaction:

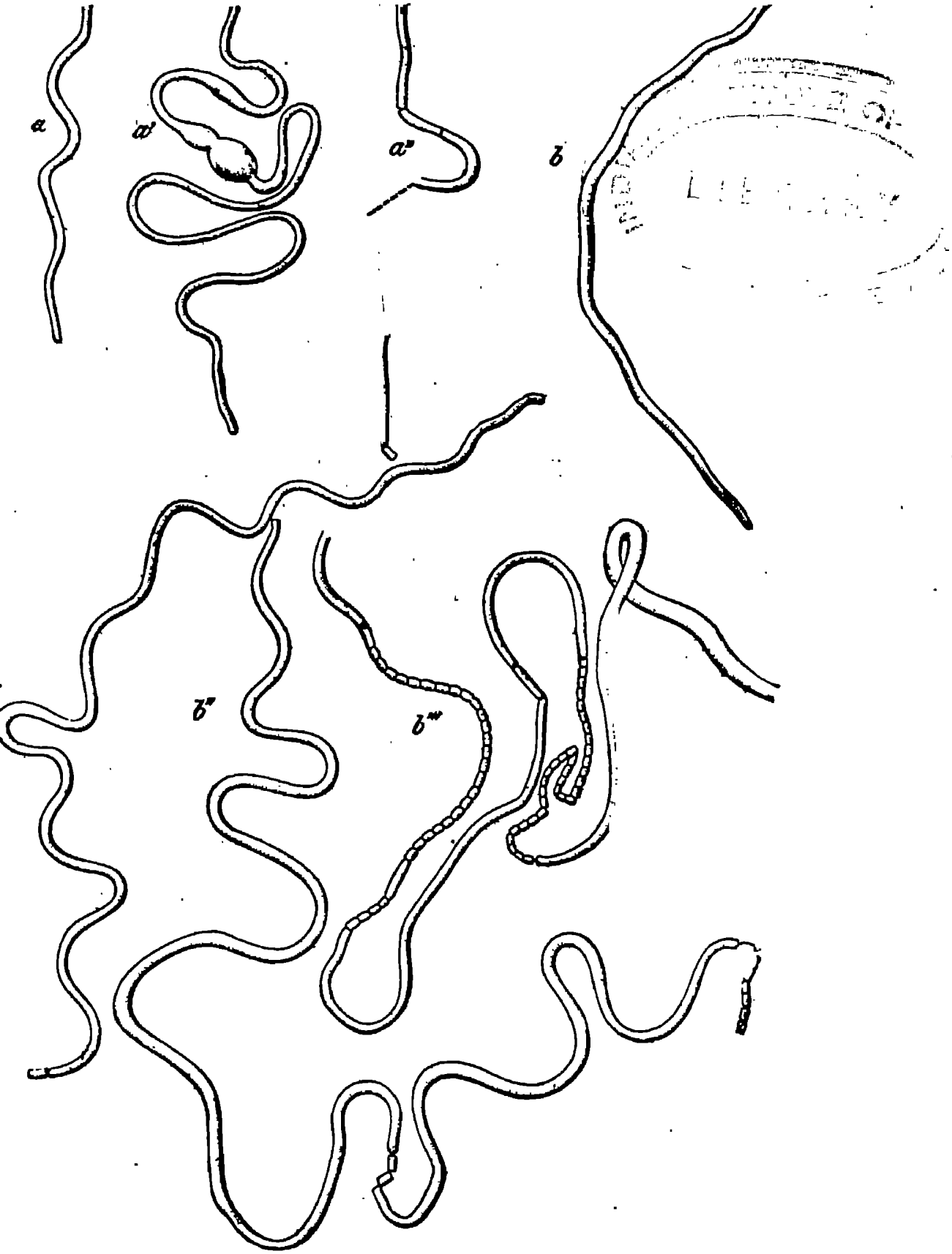
$$CH_3COOH + 4O = 2CO_2 + 2H_2O$$

Not only is this oxidation of acetic acid accompanied by commercial loss of strength but also loss of flavor and aroma.

Before the acetic acid bacteria are allowed to start their fermentation of the alcoholic solutions, it is important that the yeasts should have nearly completed their alcoholic fermentation as yeasts do not work so well in the presence of acetic acid. This is because of the poisonous effect which acetic acid has on alcoholic yeasts.

In starting the acetic acid fermentation it is usual to add a certain amount of "starter," that is, a culture of acetic acid bacteria. This insures a rapid film production on the surface of the liquid.

Concerning the subject LeFevre says, "Sometimes failure occurs during the acetic fermentation. Acetification may be slow in starting or may stop entirely, owing to the fact that the acetic bacteria are present only in small numbers or that those present are of a weak



After Hansen.

FIG. 44.—Bacterium pasteurianum. × 1000. Culture on "doppel-bier" agar a Böttcher chamber at 34° C.

(a) Long thread of early culture.
(a') After five and a half hours' culture.
(a'') After seven hours' culture.
(b) Long thread showing bends.
(b') Long thread after four hours' culture.
(b'') Long thread after six hours' culture.

strain or of an objectionable type, like the Bacterium xylinum. In most cases failure is due to the fact that the medium is unfavorable to the growth of the acetic bacteria or that the temperature and air conditions are not favorable. As a rule acetic bacteria will grow in a medium which is only weakly acid or even slightly alkaline, but a more prompt and vigorous growth can usually be obtained in a decidedly acid medium. For this reason the addition of vinegar is always advisable, especially in the case of juices or solutions which are normally low in acid. The addition of vinegar also is a protection against the growth of undesirable organisms until enough acid is formed by oxidation of the alcohol present."

Pasteur Method.

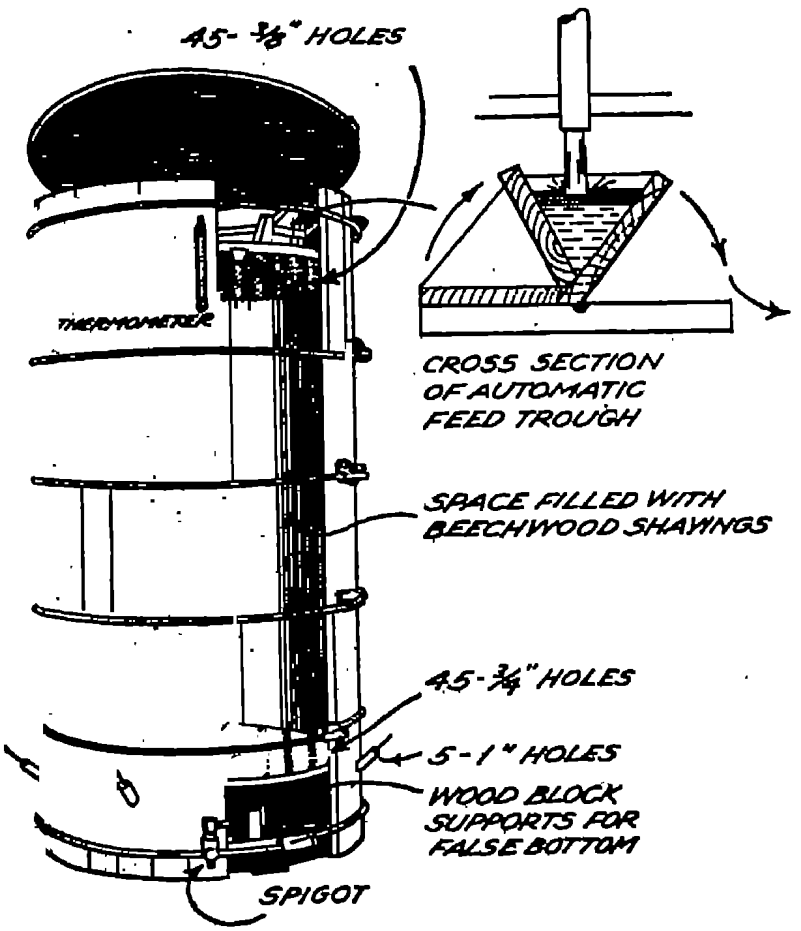
Pasteur used a shallow vat with regulated air vents near top for alcoholic fermentation. Four parts of high grade vinegar from a previous fermentation and six parts of filtered pasteurized wine was placed in the vat. A film of acetic acid bacteria was added to the top of the vat and a perforated wooden float was placed on the top of the liquor to keep the film from sinking. Each day a definite amount of vinegar was withdrawn and an equal amount of wine was added. The vinegar was filtered, pasteurized, and then stored. Some of the advantages of this method over the Orleans method is that it makes vinegar faster and therefore at less cost.

The "Quick Vinegar Process."

The rapidity with which vinegar is made from alcoholic solutions depends very largely upon the amount of film exposed to the air. Working on this principle, it became the custom in Europe to build a tall wooden tank (vinegar generator), with false head and false bottom. The tank was filled with washed beech-wood shavings over which the wine or alcohol containing liquor, was allowed to trickle. Air forced its way up through the porous mass of beech shavings while the alcoholic liquor traveled down through the shavings. Due to the great surface thus exposed, vinegar making took place very rapidly in these generators. Small amounts of wine were added intermittently. The vinegar was too weak as it came through the first time and had to be repassed several times through one tank or through several, lined up as a battery. The temperature was not allowed to go above 30 degrees C. because of considerable loss due to volatilization of alcohol and acetic acid. There is enough heat of fermentation generated by the acetic acid bacteria on the shavings to insure air circulation from the vents, in the lower false head, upward. The disadvantages of the "quick vinegar process" are the high loss of acetic acid due to volatilization, and the loss of other volatile products related to the flavor and aroma.

The Orleans Method of Vinegar Making.

This is an old method much used for making vinegar from wine. The wine is first filtered until it is clear then is slowly added to large casks which are ⅓ filled with "starter," that is, a fine vinegar from a previous fermentation. Then a small amount of wine is added and this is repeated each week until the cask is half full. When the cask is full, an amount of vinegar is drawn from the lower part of the cask each week and the same amount of wine is added. By this



From U.S.D.A.

FIG. 45.—Vinegar generator for quick or generator process.

process the casks are kept in continuous fermentation. While much can be said concerning the disadvantages of the Orleans method still it makes vinegar of the highest quality.

According to Mitchell, the following results were obtained in the analysis of white wine vinegars by the Municipal Laboratory of Paris:

	Specific Gravity	*Total Solids*	*Sugar*	*Potassium Bitartrate*	*Ash*	*Acetic Acid*
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Maximum	1.0213	3.19	0.46	0.36	0.69	7.38
Minimum	1.0129	1.38	0.56	0.07	0.16	4.44
Mean	1.0175	1.93	0.22	0.17	0.32	6.55

The following description of the Orleans method of vinegar-making is taken from *Gray's Operative Chemist* adapted to use in the United States by Carey and Lea in 1830:

"Almost all the vinegar of the north of France being prepared at Orleans, the manufactory of that place has acquired such celebrity as to render their process worthy of a separate consideration.

"The Orleans casks formerly contained nearly 200 gallons of wine, but at present only about half that quantity. Those which have been already used are preferred. They are placed in three rows one over another, and in the top have an opening of two inches diameter, which has a bung fitting close; there is another spill hole on the side to admit the air. Wine a year old is preferred for making vinegar, and is kept in adjoining casks, containing beech shavings, to which the lees adhere.

"The wine thus clarified is drawn off to make vinegar. At the first setting up of a manufactory, so much good vinegar, boiling hot, is first poured into each cask, as to fill it up one third of its height, and left there for eight days. Two gallons and a half of wine are mixed in every eight days, till the vessels are two thirds filled. Eight days afterwards, ten gallons of vinegar are drawn off for sale, and the cask is again gradually filled. Thus each cask or Mother yields twice its own admeasurement of vinegar in a year.

"It is necessary that a third part of the cask should always be left empty.

"In order to judge if the Mothers work well, the vinegar makers plunge a spatula into the liquid, and if it brings up a white froth, the making of the vinegar is judged to succeed well; if red, they add more or less wine, or increase the temperature.

"In summer the atmospheric heat is sufficient. In winter stoves to about 75° Fahrenheit maintain the requisite temperature in the manufactory.

"The casks get filled with lees in about ten years, and require to be cleansed; and fresh casks must be mounted every twenty-five years.

"If the vinegar is not clear it is clarified by being put for some time in a cask filled with shavings of beech wood."

Rotating Generator Process.

During a period of two years, Hartman and Tolman carried on an investigation at Medina, N. Y., of the manufacture of vinegar by the rotating generator process. In this work, they made many analyses which furnish much information concerning commercial vinegar manufacture. The apples used were mainly Baldwins and Greenings.

They describe the process as follows: "The fruit was grated and the finely ground pulp subjected to hydraulic pressure in the customary manner. The juice running from the presses had a temperature of

about 50° F. and had a pleasant, clean taste. The yield was about 170 gallons per ton of apples. The solids at the various pressures did not vary much; if anything, there was a slight decrease in the solids as the pressure increase, but this was not consistent. The juice was pumped into fermenters of 20,000 gallons capacity and allowed to ferment spontaneously. The pomace remaining after the juice had been removed was firm and dry. This pomace was stored in heaps for about three days and then repressed without the addition of water under the same conditions as the first pressings. During the storing period the pomace showed signs of fermentation, evidenced by a rise in temperature in the center of the heap. The second pressing juice which amounted to about one-ninth of the total available juice of the apple, was fermented spontaneously. Both the first and second pressing juices after completing fermentation were aged for about one year in the original fermenters. After this time the fermented first and second pressings were mixed in a ratio of about 9.1 respectively; i.e., 8,947 gallons of each of the first pressings, and 2,105 gallons of the second pressings. This mixture constituted the cider vinegar stock, being the starting material for the subsequent operations. The stock was aged for one month, and was divided into two parts. One part was cleared on beech wood shavings and the other part was filtered through paper pulp. The time occupied for clearing was about twelve days. The cleared and filtered stocks were then pumped into the generators, ten generators for each portion. The generators were of the rotating type. They consisted of a rectangular tank of about 480 gallons capacity, for holding the stock, and a cylindrical drum filled with beech wood shavings. The drum dipped into the cider to the depth of about one-third of its diameter, and revolved very slowly through the stock in the tank, about 1½ turns in 24 hours. The heat of acetification caused sufficient circulation of air to furnish the oxygen required for the life of the acetic bacteria. In this mode of generating it is not necessary to prepare a feed, the stock being generated without the addition of vinegar."

In the table given on following page Hartman and Tolman give a summary of the results of their work.

Malt Vinegar.

In discussing the manufacture of malt vinegar by the English, Cary and Lee say, "In this country vinegar is usually made from malt. By mashing with hot water 100 gallons of wort are extracted in less than two hours, from six bushels of malt. When the liquor has fallen to the temperature of 75° F. four gallons of yeast are added. After thirty-six hours it is racked off into pairs of casks placed upright, having a false bottom pierced with holes, fixed a foot from their bottoms. On this a considerable quantity of rape or the refuse from the makers of British wine, or otherwise a quantity of low priced raisins, is laid. The liquor is pumped into the other barrel every 24 hours, in which time it has begun to grow warm. Sometimes,

TABLE XII.

COMPOSITION OF JUICES, FINISHED VINEGARS, AND INTERMEDIARY PRODUCTS.

Summary of Analyses by Hartman and Tolman.

Results in Grams per 100 cc.

	Sp. Gr. $\frac{15.6\,C.}{15.6\,C.}$	Alcohol per cent by Volume	Solids by Weighing	Sugars as Invert Sugar: Before Inversion	Sugars as Invert Sugar: After Inversion	Sugars as Invert Sugar: After Evaporation	Sucrose by Copper	Non Sugar Solids	Volatile Reducing Substances as Invert Sugar	Acid as Malic as Acetic (a)	Volatile Acids as Acetic	Fixed Acids as Malic (a)	Ash	Alkalinity (b) of Water Soluble Ash	Total P_2O_5 Mg. per 100 cc.	Glycerin	Pentosans	Proteins (N × 6.25)	Date Sampled
Juice, composite—																			
1st pressing	1.0592	0.07	14.98	...	...	...	...	2.82	....	0.59	0.02	0.57	0.33	34.0	27.4	...	....	....	10/24/13
2nd pressing	1.0334	2.25	8.74	...	...	...	...	5.19	....	1.03	0.26	0.74	0.37	37.0	32.7	...	....	....	10/27/13
Juice, fermented—																			
1st pressing	0.9982	7.40	1.53	...	...	0.03	...	1.55	none	0.88	0.47	0.31	0.33	35.4	26.5	0.26	0.028	0.046	11/28/14
2nd pressing	1.0053	5.45	2.13	...	...	0.09	...	2.04	none	1.47	1.02	0.34	0.39	38.0	31.7	0.25	0.193	0.074	11/28/14
Vinegar stock—																			
Theoretical	.....	7.20	1.62	...	...	0.04	...	1.58	none	0.89	0.53	0.31	0.34	35.2	27.6	0.25	0.041	0.035	.....
Proper	0.99849	7.00	1.51	...	...	0.03	...	1.48	none	0.78	0.49	0.24	0.33	35.0	25.8	0.25	0.041	0.044	12/ 7/14
Vinegar—																			
Filtered stock	1.0150	0.13	1.34	...	...	0.07	...	1.27	0.27	6.45*	6.37	0.07	0.32	31.6	22.0	0.25	0.078	0.035	1/30/15
Cleared vinegar	1.0159	0.17	1.43	...	...	0.03	...	1.35	0.28	6.47*	6.41	0.07	0.32	33.2	23.6	0.25	0.076	0.035	3/ 1/15
Vinegar stored—																			
Filtered stock	1.0159	0.04	1.32	0.45	...	0.12	...	1.20	0.33	6.47*	6.44	0.03	0.30	34.4	23.7	0.24	0.033	0.033	10/ 3/15

* Determined in distillate.

(a) On all juices and stocks determined indirectly, in all vinegars determined directly.

(b) Cc. N/10 acid per 100 cc.

indeed, the vinegar is fully fermented without the rape, which is added toward the end to communicate flavor.

"Vinegar is made at Ghent, in Flanders, from beer; in which the following proportions of grain are found to be most advantageous: 1,880 pounds of malted barley; 700 of wheat; and 500 of buckwheat. These grains are ground, mixed, and boiled, along with 27 barrels of river water, for three hours. Eighteen barrels of good beer for vinegar making are thus obtained. By a subsequent decoction more fermentable liquid is extracted which is mixed with the former. The whole brewing yields about 750 gallons, English measure, of vinegar."

Vinegar from Oranges.

The manufacture of vinegar from oranges in California has been studied by Poor. He concludes that at the low price of apple cider vinegar there is little chance for vinegar made from oranges to compete. He says that orange juice contains 8 to 11 per cent sugar with an average of 9.5 per cent while apple juice contains 10 to 16 per cent sugar with an average of 12 per cent. He calls attention, however, to the fact that while this difference in sugar content of 2.5 per cent means 1.15 per cent less acetic acid still the greater fixed acid content of orange juice will bring the total acidity up to about the same per cent as apple cider vinegar. Poor in his work used the "quick vinegar" process.

Pasteurization of Vinegar.

LeFevre says: "Pasteurization is always to be considered as one of the measures for preserving vinegar and maintaining its strength. The deterioration is usually the result of the combined activity of the acetic acid organisms. Even after filtration or clarification, vinegar contains bacteria which upon being exposed to the air, grow and multiply, making the vinegar 'mothery' and perhaps cloudy. This condition may be prevented by pasteurization which is sometimes done as soon as acetification is completed. Also the same end may be accomplished by storage in air-tight containers which are completely filled, however, pasteurization is usually deferred until the vinegar is transferred to its final containers.

"The proper temperatures for the pasteurization of vinegar range from 140° to 160° F. Experience has shown that if properly carried out a temperature of 140° F. is effectual for this purpose, but it is the minimum—no lower temperature can be depended upon to produce the desired result. On the other hand, a temperature of 160° F. should not be exceeded, for the reason that it is not required and may cause an unnecessary loss of acetic acid by evaporation.

"Under commercial conditions vinegars are usually pasteurized by the continuous method. The vinegar is heated to the required temperature by being passed through coils of pipe surrounded by steam

and then to other coils covered by cold water, which again cools it to about 70° F. Under the usual factory procedure, vinegar that has been poorly aged is first filtered, then pasteurized, and poured at once into the final containers.

"Pasteurization is believed also to assist the maturing of vinegar, giving it a softer and more pleasing taste and aroma. This it probably does by hastening the combination of the residual alcohol in the vinegar with the acetic acid, thereby favoring the formation of esters."

Vinegar Diseases.

Pasteur in 1868 first called the attention of the Orleans vinegar manufacturers to the fact that the organism which forms a pellicle on fermenting wine is different from the one which causes a surface growth on souring wine. He named the former Mycoderma vini and the latter Mycoderma aceti. Concerning the troubles caused by these organisms which Pasteur grouped under the name Mycoderma vini LeFevre says, "Malfermentations may be caused by false yeasts, molds, or undesirable bacteria. The mycodermæ, yeastlike organisms, which nearly always accompany fruits and fruit juices, often develop upon exposure to the air, forming a scum on the surface of the juice. These organisms which are known as Mycoderma vini, often called wine flowers, like the true yeasts, multiply by budding, but unlike the true yeasts, grow only in the presence of oxygen, for which reason they are called aërobic, and have no fermenting value. They live on the medium on which they grow, being destructive to both fixed acids and alcohol. The presence of mycodermæ is objectionable in all of the fermentation industries and the scum formed by them should be removed whenever possible. This scum which at first is thin, whitish, and smooth, grows rapidly, soon becoming thick, rough, and heavily wrinkled. It should not be confused with the acetic film which at first usually occurs as greasy looking spots on the surface and gradually spreads, becoming a grayish veil-like covering over the entire surface. As a rule the acetic film later becomes a smooth, leathery membrane, which eventually sinks by its own weight, only to be succeeded by another similar formation. This membrane is made up of acetic bacteria and a gelatinous material given off by them."

This trouble can be checked by the addition of a large amount of pure culture of acetic bacteria. Steam and hot water sterilization of equipment is also practiced as a preventive measure.

The infection of vinegar with vinegar eels and vinegar flies are also dreaded troubles of the vinegar maker. LeFevre says, "Vinegar may become infected with small worms (Anguillula acti (Muel.) Muel.), commonly called vinegar eels. Although very small they can be seen with the unaided eye by holding the vinegar in a small glass before a strong light. They are harmless when taken internally, but very objectionable from an æsthetic standpoint. As these eels are apparently found only in vinegar or in connection with fruits or other

substances which are undergoing acetic fermentation, they undoubtedly spread from such sources. They usually occur around the edge of lactic liquids and in the surface of the film. When sufficiently numerous they may destroy the film, causing it to sink, thus interfering with acetification. When very numerous they may give rise to a putrid decomposition which makes the vinegar unfit for use.

"Vinegar eels are rapidly killed by heat, a temperature of 130° F. being sufficient for their destruction. Heat, therefore in some form is

After Howard in U.S.D.A. Year Book 1911.

FIG. 46.—Vinegar eels.

the best means of getting rid of them. They are easily removed from finished vinegar by filtration, followed by pasteurization. Barrels, tanks, and generators which contain them should be sterilized by steam."

It has been suggested that to get rid of vinegar eels, the closing of the vinegar generator shuts off the air supply of the worms and kills them all in a few days.

Vinegar mites sometimes spoil vinegar according to LeFevre. He says, "Unless great care and cleanliness are observed in connection with vinegar production, mites (Tyroglyphus longior L. and Tyroglyphus siro Gerv.) may appear in large numbers and prove very troublesome. They are undoubtedly identical with the mites often present in cheese and other food products. Under favorable conditions of warmth and moisture, these mites breed with great rapidity and

unless proper precautions are taken they may enter vinegar casks and generators, spoiling the contents.

"Mites are readily destroyed by the use of hot water or steam. If a room becomes badly infested, it should be cleaned, fumigated with sulphur, and thoroughly washed with kerosene emulsion. The entrance of mites into vinegar casks may be prevented by painting a ring of turpentine or kerosene oil around the openings."

Concerning vinegar flies LeFevre says, "Several species of light brown flies (Drosophila spp.) breed in the juices of decaying fruits

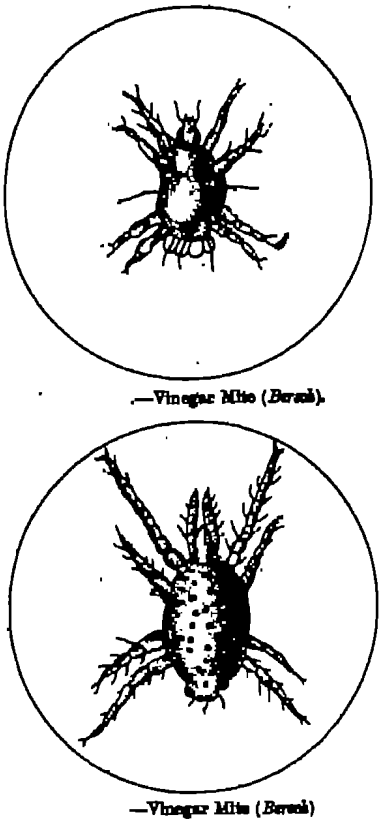


FIG. 47.—Vinegar Mites.

and also around the openings of vinegar containers or wherever they find vinegar exposed to the air. These are known as fruit or vinegar flies. If very numerous, the larvæ of these flies may get into the vinegar and cause its deterioration. They may also be responsible for the introduction of the Bacterium xylinum, an undesirable member of the acetic group.

"The presence of these flies may be prevented to a great extent by cleanliness and by avoiding the spilling of vinegar and the leakage from casks. The importance of keeping all openings in casks well screened has already been mentioned."

TABLE XIII.

COMPARATIVE READINGS ON THE BRIX (OR BALLING *) AND BAUME SACCHARIMETERS, WITH THE APPROXIMATE PERCENTAGES OF ALCOHOL AND ACETIC ACID WHICH MAY BE OBTAINED THEORETICALLY IN THE VINEGAR FERMENTATION.

Per cent cane sugar by wt. or degrees Brix or Balling	Degrees Baumé	Theoretical percentage of		Per cent cane sugar by wt. or degrees Brix or Balling	Degrees Baumé	Theoretical percentage of		Per cent cane sugar by wt. or degrees Brix or Balling	Degrees Baumé	Theoretical percentage of	
		Alcohol	Acetic acid			Alcohol	Acetic acid			Alcohol	Acetic acid
0.0	0.0	0.00	0.00	5.0	2.8	2.69	3.50	10.0	5.7	5.38	7.00
0.1	0.1	.....	.....	5.1	2.9	.....	.....	10.1	5.7	.....	.....
0.2	0.1	.....	.....	5.2	2.95	.....	.....	10.2	5.8	.....	.....
0.3	0.2	.....	.....	5.3	3.0	.....	.....	10.3	5.8	.....	.....
0.4	0.2	.....	.....	5.4	3.1	.....	.....	10.4	5.9	.....	.....
0.5	0.3	0.27	0.35	5.5	3.1	2.96	3.85	10.5	5.9	5.65	7.35
0.6	0.3	.....	.....	5.6	3.2	.....	.....	10.6	6.0	.....	.....
0.7	0.4	.....	.....	5.7	3.2	.....	.....	10.7	6.1	.....	.....
0.8	0.45	.....	.....	5.8	3.3	.....	.....	10.8	6.1	.....	.....
0.9	0.5	.....	.....	5.9	3.35	.....	.....	10.9	6.2	.....	.....
1.0	0.6	0.54	0.70	6.0	3.4	3.23	4.20	11.0	6.2	5.92	7.70
1.1	0.6	.....	.....	6.1	3.5	.....	.....	11.1	6.3	.....	.....
1.2	0.7	.....	.....	6.2	3.5	.....	.....	11.2	6.3	.....	.....
1.3	0.7	.....	.....	6.3	3.6	.....	.....	11.3	6.4	.....	.....
1.4	0.8	.....	.....	6.4	3.6	.....	.....	11.4	6.5	.....	.....
1.5	0.85	0.81	1.05	6.5	3.7	3.50	4.55	11.5	6.5	6.19	8.05
1.6	0.9	.....	.....	6.6	3.7	.....	.....	11.6	6.6	.....	.....
1.7	1.0	.....	.....	6.7	3.8	.....	.....	11.7	6.6	.....	.....
1.8	1.0	.....	.....	6.8	3.9	.....	.....	11.8	6.7	.....	.....
1.9	1.1	.....	.....	6.9	3.9	.....	.....	11.9	6.7	.....	.....
2.0	1.1	1.08	1.40	7.0	4.0	3.77	4.90	12.0	6.8	6.46	8.40
2.1	1.2	.....	.....	7.1	4.0	.....	.....	12.1	6.8	.....	.....
2.2	1.2	.....	.....	7.2	4.1	.....	.....	12.2	6.9	.....	.....
2.3	1.3	.....	.....	7.3	4.1	.....	.....	12.3	7.0	.....	.....
2.4	1.4	.....	.....	7.4	4.2	.....	.....	12.4	7.0	.....	.....
2.5	1.4	1.35	1.75	7.5	4.25	4.04	5.25	12.5	7.1	6.88	8.75
2.6	1.5	.....	.....	7.6	4.3	.....	.....	12.6	7.1	.....	.....
2.7	1.5	.....	.....	7.7	4.4	.....	.....	12.7	7.2	.....	.....
2.8	1.6	.....	.....	7.8	4.4	.....	.....	12.8	7.2	.....	.....
2.9	1.6	.....	.....	7.9	4.5	.....	.....	12.9	7.3	.....	.....
3.0	1.7	1.62	2.10	8.0	4.5	4.31	5.60	13.0	7.4	7.10	9.10
3.1	1.8	.....	.....	8.1	4.6	.....	.....	13.1	7.4	.....	.....
3.2	1.8	.....	.....	8.2	4.6	.....	.....	13.2	7.5	.....	.....
3.3	1.9	.....	.....	8.3	4.7	.....	.....	13.3	7.5	.....	.....
3.4	1.9	.....	.....	8.4	4.8	.....	.....	13.4	7.6	.....	.....
3.5	2.0	1.88	245.	8.5	4.8	4.58	5.95	13.5	7.6	7.37	9.45
3.6	2.0	.....	.....	8.6	4.9	.....	.....	13.6	7.7	.....	.....
3.7	2.1	.....	.....	8.7	4.9	.....	.....	13.7	7.75	.....	.....
3.8	2.2	.....	.....	8.8	5.0	.....	.....	13.8	7.8	.....	.....
3.9	2.2	.....	.....	8.9	5.0	.....	.....	13.9	7.9	.....	.....
4.0	2.3	2.15	2.80	9.0	5.1	4.85	6.30	14.0	7.9	7.64	9.80
4.1	2.3	.....	.....	9.1	5.2	.....	.....	14.1	8.0	.....	.....
4.2	2.4	.....	.....	9.2	5.2	.....	.....	14.2	8.0	.....	.....
4.3	2.4	.....	.....	9.3	5.3	.....	.....	14.3	8.1	.....	.....
4.4	2.5	.....	.....	9.4	5.3	.....	.....	14.4	8.1	.....	.....
4.5	2.55	2.42	3.15	9.5	5.4	5.11	6.65	14.5	8.2	7.91	10.15
4.6	2.6	.....	.....	9.6	5.4	.....	.....	14.6	8.3	.....	.....
4.7	2.7	.....	.....	9.7	5.5	.....	.....	14.7	8.3	.....	.....
4.8	2.7	.....	.....	9.8	5.55	.....	.....	14.8	8.4	.....	.....
4.9	2.8	.....	.....	9.9	5.6	.....	.....	14.9	8.4	.....	.....
5.0	2.8	2.69	3.50	10.0	5.7	5.38	7.00	15.0	8.5	8.18	10.50

* The Brix and Balling saccharimeters both read directly in percentages of cane sugar. They may differ, however, in the temperature at which they are to be read.

Adapted from Table 8, Appendix, of O. A. Browne's Handbook of Sugar Analysis (1912). The above table is taken from Michigan Experiment Station Special Bulletin 98.

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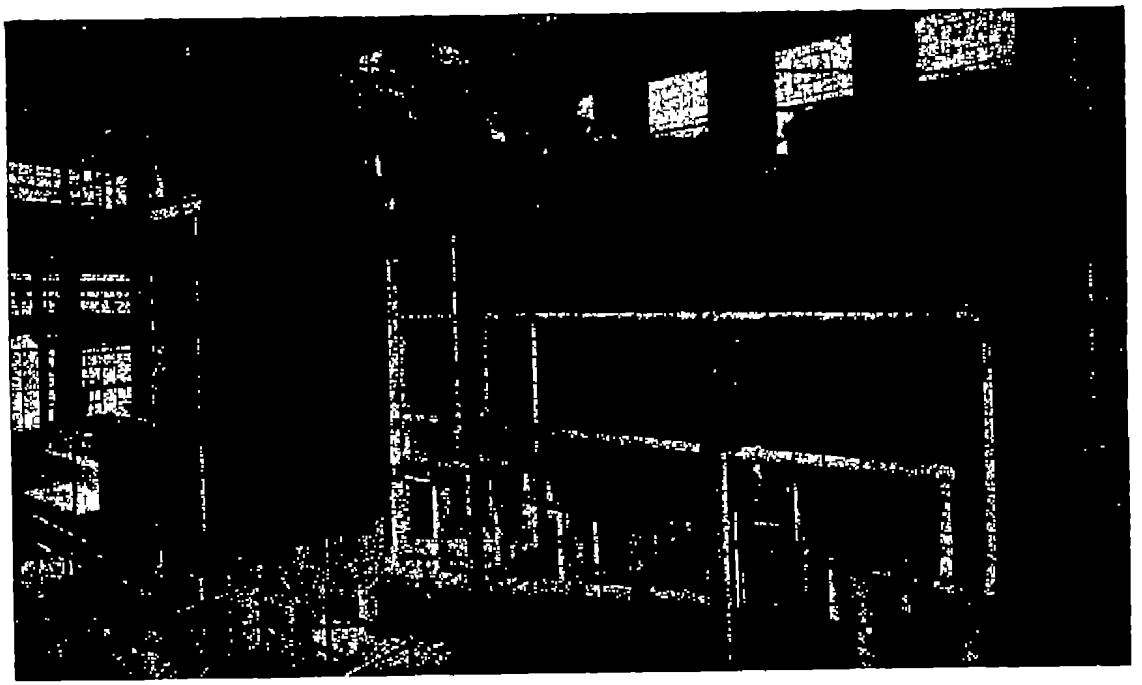
TABLE XIV.—*Continued.*

Asparaginic acid	3.5%
Glutaminic acid	6 %
Tyrosin	2 %
Tryptophan	.5%
Cystin and other sulphur compounds	2 %
Oxyprolin	4.5%
Cholin	.5%
Glucosamin	.5%

ANALYSIS OF THE ASH.

Phosphorus pentoxid	P_2O_5	54.5
Potassium oxid	K_2O	36.5
Magnesium oxid	MgO	5.2
Calcium oxid	CaO	1.4
Silica	SiO_2	1.2
Sodium oxid	Na_2O	.7
Sulphur trioxid	So_3	.5
Chlorin	Cl	trace
Iron	Fe	trace
		100.00



Courtesy of Fleischmann Company.

FIG. 50.—Side view of yeast fermentors.

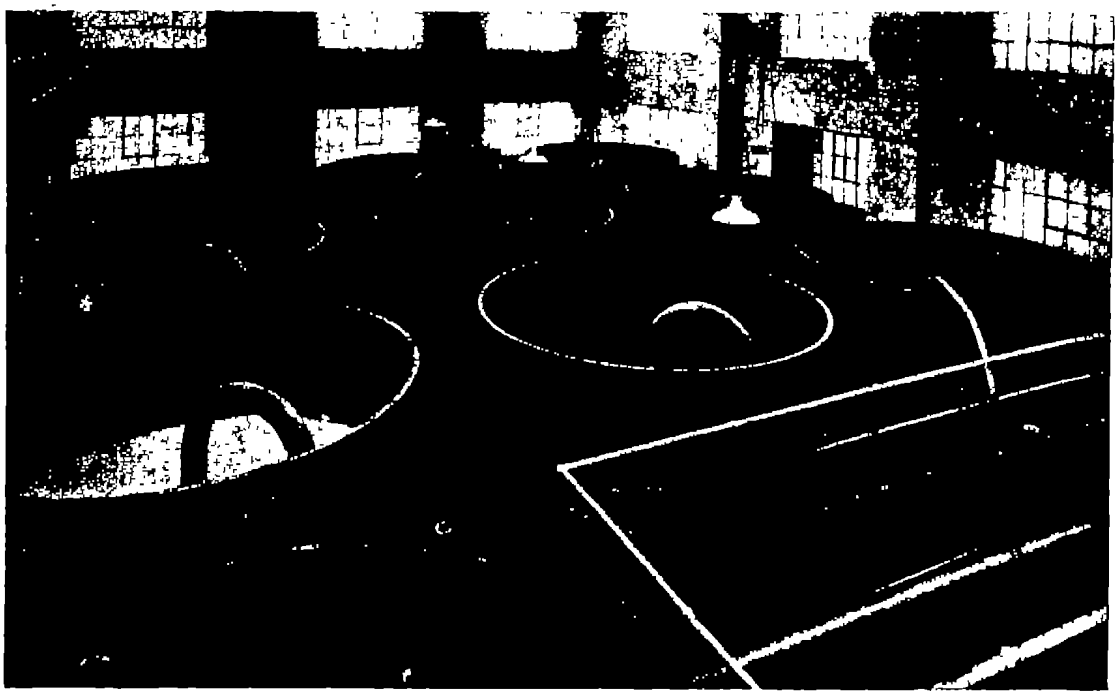
Preparation of Nutrient Solution.

In the preparation of nutrient wort in yeast manufacture the following raw materials are brought together in the mash tub: barley malt, corn, malt sprouts, occasionally rye, and water. The barley malt should be high in diastatic power and also rich in pro-

teolytic enzymes. It should be finely ground before going to the mash tub. The corn is prepared for the mash tub by first grinding and then cooking under steam pressure. Finally malt sprouts and the water are added to the tub.

The water used in the mashing operation is of high purity and is free from bacteria. Salts of calcium and magnesium in the water make the addition of sulphuric acid necessary as these salts may reduce the acidity of the mash. By adding sulphuric acid, magnesium and calcium sulphates are formed which are valuable as stimulants of yeast growth.

The object of the mashing operation is to bring the proteins of



Courtesy of Fleischmann Company.

FIG. 51.—Top view of yeast fermentors.

the grains into solution and to hydrolyze the starches into sugars. The mash at first is held at 50 to 55° C. for an hour so that the proteolytic enzymes of the malt can change the proteins to peptones. After this period which favors proteolytic action the temperature of the mash is raised to 65° C. and held for several hours at this temperature so that all liquefied starch may be hydrolyzed into fermentable sugars by the diastase.

Next the mash is cooled to about 55° and acidified by inoculation with pure cultures of lactic acid bacteria. The purpose of this acidification is to protect the mash from the action of putrefactive bacteria and at the same time to create a condition in the mash which hastens peptonization of the proteins. When the acidification of the mash has reached about 1.5% acid it is sterilized, filtered, cooled and passed into the yeast fermentation tank.

Addition of Culture.

To the filtered wort in the fermentator is added, from a generator, a pure culture of yeast. The amount of this stock yeast added is usually about 2.3% of the grain used. The concentration of the wort may be 10% to 11% Balling. The temperature in the fermentor at the start of fermentation is about 22° C. and during fermentation rises to 30° C. at which temperature it is held. Higher temperatures have been used but the yield of yeast is reduced. Aeration by means

Courtesy of Fleischmann Company.

FIG. 52.—Plate presses for expelling moisture from yeast.

of an air compressor is maintained for 10 to 12 hours when the yeast growth is completed.

Separation of Yeast.

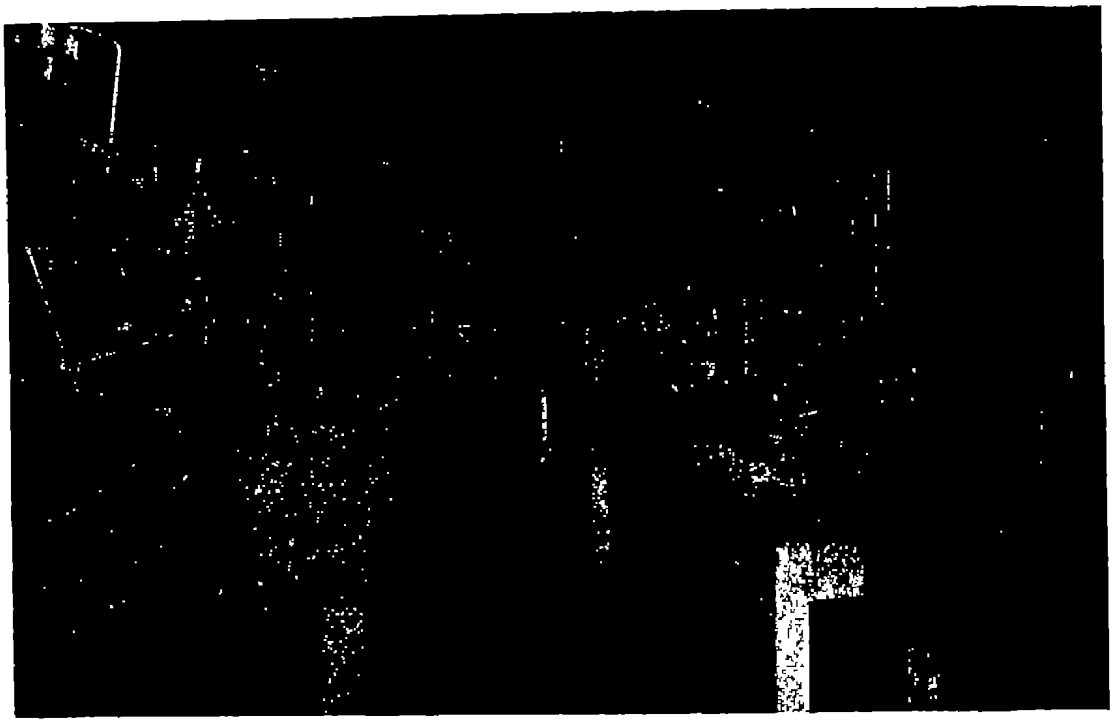
At the end of the fermentation the yeast is separated from the wort by use of centrifugal machines. In producing compressed yeast of about 75% moisture from separator yeast, square iron filter presses are used. Finally the yeast is passed through cake cutting and wrapping machines. The one pound package is largely used by commercial bakeries while the small cakes are sold for use in the home.

The most important uses of yeast in bread-making are as:

A leavening agent.
An agent to help mature the gluten.
An additional nutritive substance.
A source of vitamines.
A source of the enzymes, maltase, invertase, endotryptase, etc.

Courtesy of Fleischmann Company.

FIG. 53.—Filter tanks.



Courtesy of Fleischmann Company.

FIG. 54.—Yeast laboratory.

Yeast considered separately from the bread industry has come to be widely used as a therapeutic agent because of its vitamines, enzymes and nucleic acid.

One value ascribed to yeast nucleic acid is said to be its ability when injected subcutaneously to increase the white corpuscle content of the human blood.

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Chapter 24.

Tomato Products.

Bacteriological Control of Tomato Products.

The Bureau of Chemistry of the U. S. Department of Agriculture considers tomato products unfit for food:

(1) When mold filaments are found in more than 66% of the fields examined according to the Howard method.
(2) When yeasts and spores are present in excess of 125 per 1/60 cmm. according to the Howard method.
(3) When bacteria are present in excess of 100,000,000 per cc. according to the Howard method.

It has been found that tomato products made from fermented and mouldy tomatoes cannot pass the above requirements. In other words microscopic control methods are practical in eliminating the use of unfit tomatoes in the manufacture of products. Laxity in picking and sorting of tomatoes is detected later in the finished product by microscopic methods.

An excessive number of bacteria, yeasts, mold filaments, and spores is evidence of the use of partly decayed tomatoes, improper storage or dirty utensils. According to B. J. Howard there is a definite relation existing between the mold count and the percentage of rot by weight used in making the product. He says that bacteria per cc. up to 15,000,000 does not indicate per cent of rot but that for every 20,000,000 bacteria per cc. above the first 15,000,000 indicates one per cent of rot used.

Cruess says that canned tomatoes and chili sauce usually run low in microörganisms because they are made from peeled stock. However when considerable numbers of yeasts, molds, and bacteria are found in these products it indicates the use of decomposed material or careless methods.

Howard and Stephenson (1917) in Bulletin 581 of U. S. Dept. of Agriculture give the following summary of their microscopical studies on tomato products.

"Tomato products promptly made from stock judged acceptable by visual inspection never show high counts of microörganisms. Similarly, products made from stock obviously not good or from stock improperly handled usually show high counts. It may therefore be

assumed that high counts of organisms in such products indicate unmistakably that the stock used was in bad condition or was handled in an insanitary manner during manufacture.

"It was found that tomato pulp stored in barrels usually gave high microscopical counts; hence it would seem inadvisable to use barrels for storing the product.

"Field work performed during the past three seasons has proved that with proper equipment and factory management there is no reason for stock ready for the cyclone to contain over 1 per cent of decayed material.

"In factories where the stock is properly handled the mold count is of greater importance than the counts on the other organisms in judging the condition of the raw stock. High counts of yeasts and spores, and bacteria are more frequently an indication of secondary than of primary spoilage. A low mold, yeast and spore, or bacterial count does not necessarily indicate sound stock, but a high count in any of these organisms always indicates bad stock or improper handling.

"It was found that of the samples made in the laboratory none with less than 5.5 per cent of rot gave a mold count of more than 50. In the case of the factory samples the mold count rises sharply from 0 to ½ per cent of rot. Beyond ½ per cent the rate of rise gradually decreases, until after 20 per cent of rot the rate of increase is slow. A mold count of 40 may be obtained in samples having any amount of rot between 2.2 and 100 per cent.

"A yeast and spore count of 20 represents about one per cent of decay. From this point the rate of increase is slow.

"A bacterial count below 15,000,000 indicates little as to the amount of decay. Beyond this point, however, up to 20 per cent of rot the rate of increase is about 20,000,000 for each per cent of rot.

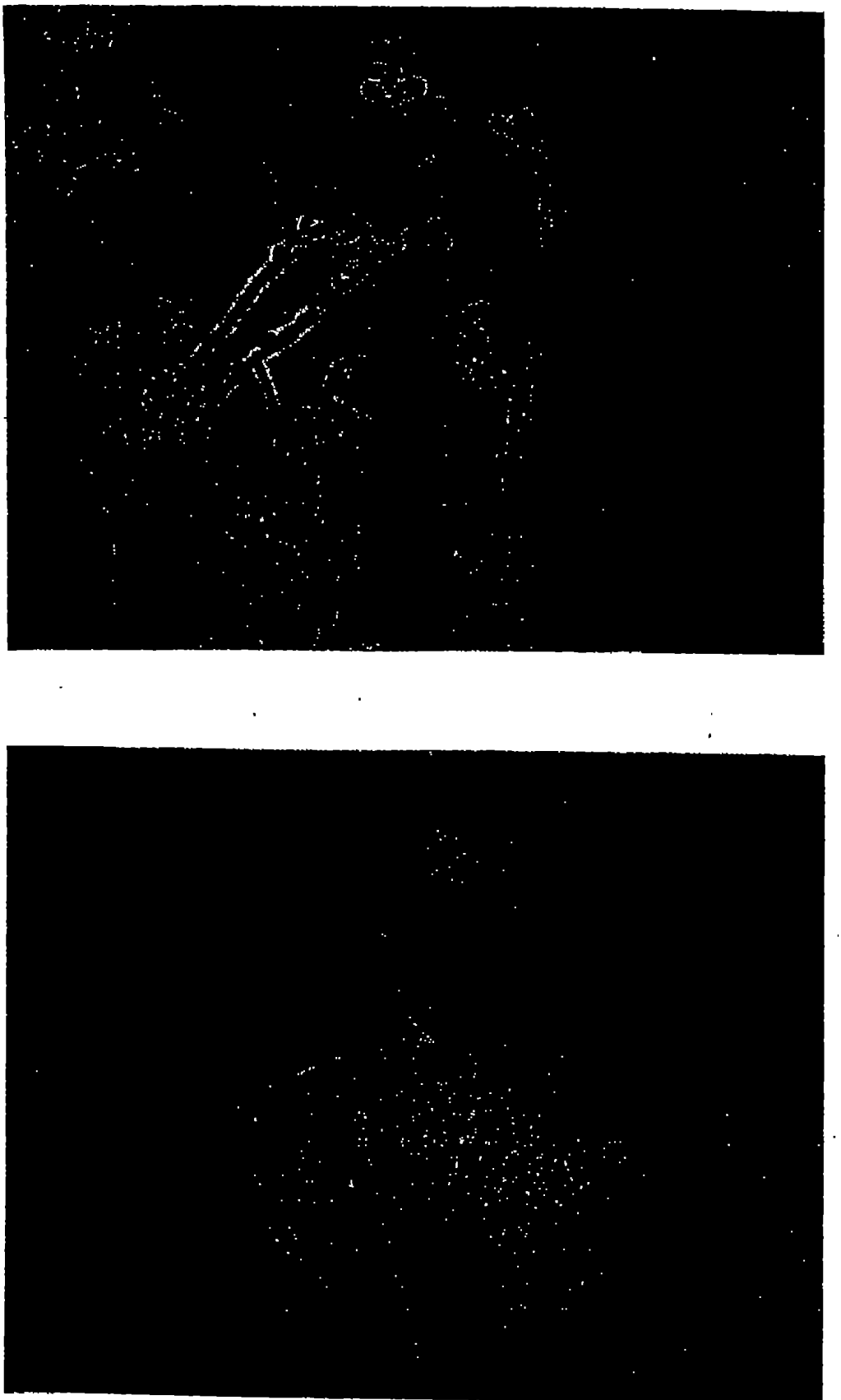
"An investigation of the manufacture of tomato sauces and pastes in Italy showed that Italian products should be equal to American products made under similar conditions. The mold count for the concentrated products was found to be about the same as that for pulp, and the yeast and spore and bacterial counts to be proportional to the degree of concentration. Sauces and pastes made from objectionable material run particularly high in yeasts, spores, and bacteria. High counts on this class of products, then, indicate bad stock or insanitary handling."

The following explanation and description of microanalytical methods is taken from "Microscopical Studies on Tomato Products," by Howard and Stephenson, United States Department of Agriculture Bulletin No. 581.

Method for Microanalysis of Tomato Products.

"Since the publication of Bureau of Chemistry Circular 68, no statement of the microscopical method used by the department has

PLATE 12



After Howard in U.S.D.A. Year Book 1911.

Molds, mold spores, and bacteria found in decaying tomatoes.

been issued. The bureau has received repeated requests for a restatement of the method including more definite details of manipulation than were given in the circular. In 1915, after the method incorporating the most important of these details had been rewritten, the Association of Official Agricultural Chemists adopted it as a tentative method and published it November 1916, in the *Journal of the Association of Official Agricultural Chemists*. At the meeting of the same association in November, 1916, a few minor changes were authorized. As it is uncertain when the association will publish the method in its amended form, permission has been granted by the chairman of the Board of Editors of the Association of Official Agricultural Chemists to incorporate it here.

Apparatus.

"(a) Compound microscope.—Equipped with apochromatic objectives and compensating oculars, giving magnifications of approximately 90,180 and 500 diameters. These magnifications can be obtained by the use of 16 and 8 mm. Zeiss apochromatic objectives with X6 and X18 Zeiss compensating oculars, or their equivalents, such as the Spencer 16 and 8 mm. apochromatic objectives with Spencer X10 and X20 compensating oculars, the drawtube of the microscope being adjusted as directed below.

"(b) Thoma-Zeiss Blood counting cell.

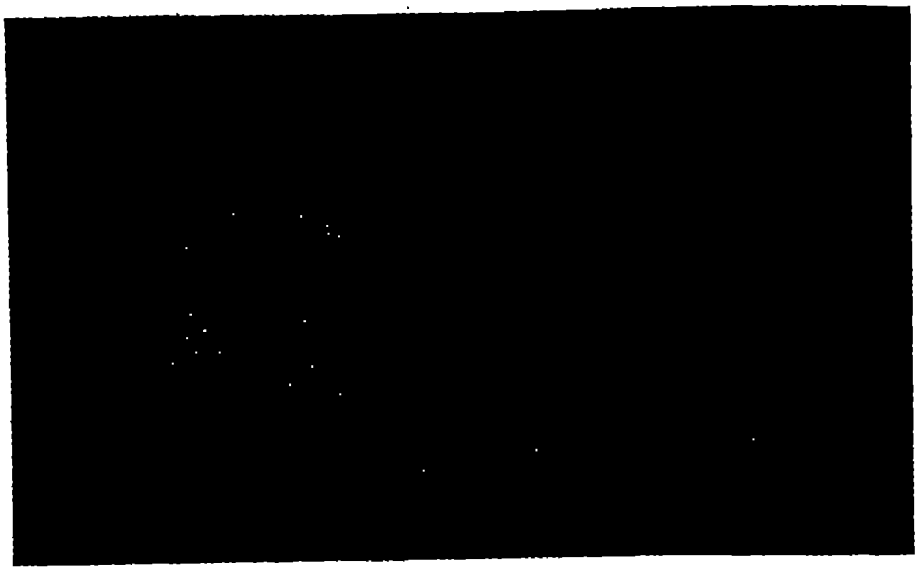
"(c) Howard mold counting cell.—Constructed like a blood-counting cell but with the inner disk (which need not be ruled) about 19 mm. in diameter.

Molds (Tentative).

"Clean the special Howard cell so that Newton's rings are produced between the slide and the cover glass. Remove the cover and place, by means of a knife blade or scalpel, a small drop of the sample upon the central disk; spread the drop evenly over the disk and cover with the cover glass so as to give an even spread to the material. It is of the utmost importance that the drop be mixed thoroughly and spread evenly; otherwise the insoluble matter and consequently the molds are most abundant at the center of the drop. Squeezing out of the more liquid portions around the margin must be avoided. In a satisfactory mount Newton's rings should be apparent when finally mounted and none of the liquid should be drawn across the moat and under the cover glass.

"Place the slide under the microscope and examine with a magnification of about 90 diameters and with such adjustment that each field of view represents approximately 1.5 sq. mm. of area on the mount. This area is of vital importance and may be obtained by adjusting the drawtube to the proper length as determined by actual measurement of the field, a 16 mm. Zeiss apochromatic objective with a Zeiss X6 compensating ocular or a Spencer 16 mm. apochromatic objective with a Spencer X10 compensating ocular, or their equivalents, being used to obtain the proper magnification.

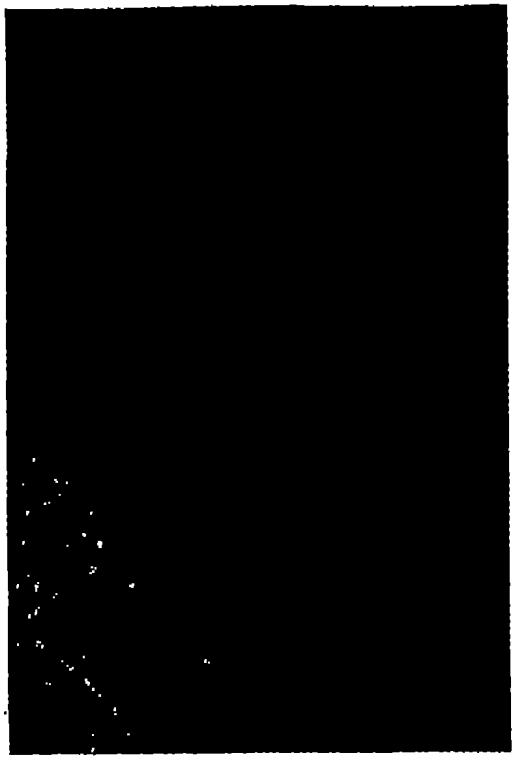
PLATE 13



(A)—Spores and fragments of filaments of mold from decaying sweet pepper.

After Howard in U.S.D.A. Year Book 1911.

(B)—Yeasts and bacteria from decaying tomatoes.



(C)—Rod-shaped bacteria from tomato pulp.

"Observe each field as to the presence or absence of mold filaments and note the result as positive or negative. Examine at least 50 fields, prepared from 2 or more mounts. No field should be considered positive unless the aggregate length of the filaments present exceeds approximately one-sixth of the diameter of the field. Calculate the proportion of positive fields from the results of the examination of all the observed fields and report as percentage of fields containing mold filaments.

Yeasts and Spores (Tentative).

"Fill a graduated cylinder with water to the 20 cc. mark, and then add the sample till the level of the mixture reaches the 30 cc. mark. Close the graduate, or pour the contents into an Erlenmeyer flask, and shake the mixture vigorously 15 to 20 seconds. To facilitate thorough mixing the mixture should not fill more than three-fourths of the container in which the shaking is performed. For tomato sauce or pastes or products running very high in the number of organisms, or of heavy consistency, 80 cc. of water should be used with 10 cc. or 10 grams of the sample. In the case of exceptionally thick or dry pastes it may be necessary to make an even greater dilution.

"Pour the mixture into a beaker. Thoroughly clean the Thoma-Zeiss counting cell so as to give good Newton's rings. Stir thoroughly the contents of the beaker with a scalpel or knife blade, and then, after allowing to stand 3 to 5 seconds, remove a small drop and place upon the central disk of the Thoma-Zeiss counting cell and cover immediately with the cover glass, observing the same precautions in mounting the sample as before. Allow the slide to stand not less than 10 minutes before beginning to make the count. Make the count with a magnification of about 180 to obtain which the following combinations, or their equivalents, should be employed; 8 mm. Zeiss apochromatic objectives with X6 Zeiss compensating ocular, or an 8 mm. Spencer apochromatic objective with X10 Spencer compensating ocular with draw tube not extended.

"Count the number of yeasts and spores on one-half of the ruled squares on the disk (this amounts to counting the number in 8 of the blocks, each of which contains 25 of the small ruled squares. The total number thus obtained equals the number of organisms in 1/60 cmm. if a dilution of 1 part of the sample with 2 parts of water is used. If a dilution of 1 part of the sample with 8 parts of water is used the number must be multiplied by 3. In making the counts the analyst should avoid counting an organism twice when it rests on a boundary line between 2 adjacent squares.

Bacteria (Tentative).

"Estimate the bacteria from the mounted sample but allow the sample to stand not less than 15 minutes after mounting, before counting. Employ a magnification of about 500, which may be obtained by the use of an 8 mm. Zeiss apochromatic objective with an X18 Zeiss

compensation ocular with draw tube not extended or an 8 mm. Spencer apochromatic objective with an X20 Spencer compensating ocular with a tube length of 190, or their equivalents. Count and record the number of bacteria in a small area consisting of 5 of the small sized squares. Move the slide to another portion of the field and count the number on another similar area. Count 5 such areas, preferably 1 from near each corner of the ruled portion of the slide and 1 from near the center. Determine the average number of bacteria per area and multiply by 2,400,000, which gives the number of bacteria per cc. If a dilution of 1 part of the sample with 8 parts of water instead of 1 part of the sample with 2 parts of water is used in making up the sample, then the total count obtained as above must be multiplied by 7,200,000. Omit the micrococci type of bacteria in making the count."

The importance of sorting in the manufacture of tomato products has been emphasized by Howard and Stephenson: They say: "A careful consideration of the causes of failure in making clean, sound, sanitary tomato products shows clearly that more difficulty is experienced in effecting satisfactory washing, prompt handling, and efficient sorting than in any of the other phases of the manufacturing process. Sorting is the most important of these operations, in which the judgment of the workman plays a considerable part. Satisfactory washing is largely a question of proper operation of a mechanical device. This may be said of many of the other operations about the factory, but so far no mechanical contrivance for separating the decayed from the good parts of the tomatoes has been placed upon the market. This operation must still be performed principally by hand. Although some washers, if properly constructed and operated, will assist in removing the badly soft-rotted tomatoes, efficient hand sorting must be employed if a uniformly good, sound product is to be obtained.

"Experience has shown that in factories where the tomatoes are used only for peeling stock and where all the trimmings are thrown away sorting is an unnecessary expense. In the making of pulp of any kind, however, efficient sorting is absolutely necessary. Otherwise there can be no assurance of producing a uniformly sound product with low counts of microörganisms.

"The conditions observed and the results obtained in various factories show that there is little, if any, choice between sorting the tomatoes before and after washing. Some of the best, as well as some of the poorest, results were obtained in factories where one or the other of these methods was employed. Approximately two-thirds of the plants visited during the seasons of 1915 and 1916 that did any sorting at all were using the wet method, and one-third the dry method. In order to remove clinging pieces of partially decayed tomatoes, the tomatoes always should be subjected to a washing or rinsing after sorting, even though the principal washing has been done before sorting."

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Chapter 25.

Fruit Juices and Beverages.

The science of the preservation of fruit juices is only in its infancy. The great value of fruit juices in any diet is only partly appreciated. Great quantities of valuable fruit juices go to waste each year while at the same time few people are free from injury to health due to too little fruit or fruit products in the diet.

The slowness with which comparatively cheap fruit juices have come into use is due largely to the lack of satisfactory methods of preserving fruit juices without alteration in flavors.

Grape juice is one of the most important fruit juices of commerce. According to Munson, Concord grape juice must contain 20.37% total solids, .663% acids as tartaric acid, 18.54% grape sugar, .027% phosphoric acid and .55% cream of tartar, and no alcohol. In the pressing out of the juice of the grape, many of the organisms existing on the skins and stems find their way into the expressed juice and if allowed to remain will ferment it. While refrigeration retards this fermentation still it cannot be depended on to prevent it.

Grape juice is usually preserved by holding for a short period of time at the temperature of 175° F. A temperature higher than 175° F. begins to affect the flavor giving it a slightly cooked taste. Pasteurization of the grape juice is effected in vat pasteurizers or in continuous types.

Loganberry juice is a product which has come into the market recently but the industry is growing rapidly. It is said that the juices of loganberries grown in Oregon and Washington differ from that of the loganberries of California in that the northern berries have a higher acid content. Because of the naturally high acid content, loganberry juice has to be diluted and sweetened for consumption, however this high acid content is very important in aiding the sterilization of the juice.

Because of the love of molds for high acid berry juices, loganberries must be crushed and expressed as soon as possible after picking.

Apple juice or cider is often considered as only vinegar making material but is in reality one of our most valuable fruit juices and there is increasing activity shown in marketing it as a summer drink. However, there are certain difficulties in its preservation. It is hard to sterilize and preserve cider without preservatives. Heating cider to the temperature which would insure preservation in containers is inclined to give a cooked taste.

Sour apples contain .5% or more of malic acid while sweet apple juice contains but half this amount. The chief constituents of apple and pear juices are sugar, tannin and malic acid.

H. C. Gore says: "It is possible to sterilize apple juice in wooden containers, the product remaining sound for at least six months under actual observation. The precautions which must be taken to insure this are as follows: First paraffin the containers on the outside, then sterilize, and fill with juices heated to between 149 degrees and 158 degrees F. (65 degrees to 70 degrees C.); seal, taking measures to relieve the vacuum produced by the contraction of the juice on cooling by filtering the air through cotton. Twenty-four ten-gallon kegs successfully stood a severe shipping test, showing no loss due to fermentation of the juice. The juice so prepared was found to be palatable, and acceptable as a summer drink. (2) It is demonstrated that apple juice can be successfully sterilized in tin containers, using the type of tin can sealed by the mechanical process, excluding all metals from contact with the juice except the tin of the can. Where lacquered cans are used the contamination with tin was reduced about one-half. Apple juices were canned and sterilized by heating in a hot water bath, up to the temperature of 149 degrees F. (65 degrees C.) for a half hour, and then were allowed to cool. These juices possessed only a slight cooked taste due to the heating and retained much of their distinctive apple flavor. It was found that from finely flavored apple juice a first-class sterile product could be made, while a poorly flavored apple juice yielded an inferior product. The process conditions mentioned were not quite thorough enough to sterilize all of the varieties canned. A slight increase in the temperature or time of processing, or both, should be made, the temperature not to exceed 70 degrees C. (158 degrees F.) in any case. (3) The best treatment for sterilizing in glass was found to consist in heating for one hour at 149 degrees F. or for one-half hour at 158 degrees F. Heating for one hour at 158 degrees did not produce marked deterioration in flavor, a half hour being allowed in all cases for the juice to obtain the temperature of the water bath. (4) It was shown that the great bulk of the insoluble material naturally contained in apple juice can be removed by means of a milk separator. (5) It is possible to carbonate the juice slightly before canning or bottling, thus adding a sparkle to the product. A flavor foreign to fresh apple juice is also added, however, and uncarbonated sterile juice will resemble fresh apple juice more closely. Carbonating by the addition of water charged with carbon dioxide was considered by some to injure the flavor, lessening the characteristic fruit flavor by dilution. In the opinion of others a heavy, rich juice was improved both by the charge of carbon dioxide and by the consequent dilution. Experiments indicated that the danger of contamination by mold growths was lessened by maintaining an atmosphere of carbon dioxide above the surface of the juice after opening. (6) It is demonstrated that benzoate of soda in quantities varying from 0.03 to 0.15% (0.1% being the maximum temporarily permitted by the food

regulations), while it checks the alcoholic fermentation, allows other organisms to develop (notably the acetic acid ferment), whereby the palatability of the product as a beverage is destroyed."

It is the acid content of fruit that most aids their preservation by heat. Generally speaking the greater the acid content the less the exposure to heat required to sterilize. Biglow and Dunbar designate the kind of acid in fruit juices as follows:

Apple	Malic alone
Cherry	Malic alone
Plum	Malic alone
Banana	Malic alone
Peach	Malic alone
Persimmon	Malic alone
Cantaloupe	Citric alone
Cranberry	Citric and malic
Currant	Citric and malic
Gooseberry	Citric and malic
Pear	Malic alone
Quince	Malic alone
Watermelon	Malic alone

Kayser reports that pineapple contains citric acid alone.

Very delicious fruit juices are prepared from blueberries, cherries, and gooseberries by expelling the juice from the fruit and pasteurizing it on two or three consecutive days at 155° F. for 30 minutes. In the preparation of these fruit juices it is important that the fruit be washed well before pressing and that the utensils used in bottling and the bottle be sterile.

The Preparation and Preservation of Fruit Juices.

In a study of the possibilities of preparing and preserving the juices of such fruits as the orange, lemon, pineapple, strawberry and blackberry, H. C. Gore in the *U.S.D.A. Bulletin*, says:

"The experiments developed the fact that ordinary methods of sterilizing fruit juices by heat could be successfully applied to but a limited number of the special fruits such as the black raspberry, blackberry, black currant, sour cherry, and peach. In the case of the juices of the strawberry, red raspberry, red currant, pineapple, and the citrus fruits, as well as apple cider, sterilization by heat caused loss in flavor, and where kept after heat sterilization the juices of these fruits tended to lose color or flavor or both.

"In the case of strawberry, apple, and other juices which are greatly injured in distinctive flavor by being heated, it is possible to retain the flavor satisfactorily by keeping the juice in freezing storage at a temperature of 14 degrees F. Although certain juices, as pineapple and orange, are not greatly injured in flavor by sterilization, they change in flavor and color upon being kept at ordinary temperatures after sterilization. Keeping such juices in cold storage at from 32 degrees to 36 degrees F. causes satisfactory retention of the

color and flavor. Another cold-storage method of general application to fruit juices, and one particularly valuable for fruit juices, the distinctive characters of which are injured by heat, is the method of concentrating by freezing.

"Juices of oranges, lemons, and pineapples darken greatly in color if sterilized and subsequently kept in contact with atmospheric oxygen. Satisfactory color retention can here be had by sterilizing and keeping the juices free from atmospheric oxygen, which is most conveniently effected by carbonating slightly and sterilizing them in carbon dioxid.

"Juices of red and black currants, blackberries, black raspberries, sour cherries, and peaches may easily be successfully prepared on the large scale by the methods used for the preparation of grape juice, as they retain their characteristic properties well on being sterilized and stored away. Strawberry juice and red raspberry juice are not suited for preparation on the large scale because of the readiness with which the distinctive colors and flavors change. Huckleberry juice is somewhat characterless. Pineapple juice requires special methods for its successful preparation not necessary in case of other juices. Its preparation on the commercial scale, however, is of marked promise.

"Satisfactory methods for the preparation of lemon and orange juices have not been developed. The peculiar change in flavor of lemon juice stored after sterilization, even at low temperatures, is an obstacle to be overcome before the preparation of the juice on the large scale can be considered advisable. The problem of preparing orange juice is not without promise. It is not unlikely that highly specialized methods in which cold storage will play a prominent, if not dominating part, will be required."

Gore says concerning cold storage of fruit juices: "Apple juice, cooled quickly after pressing to 32 degrees F. and stored at this temperature, will keep for from 6 weeks to three months before it ferments sufficiently to be considered hard or sour. Unpublished experiments on the keeping of raw orange juice at from 32 degrees to 35 degrees F. show that its flavor deteriorates quite rapidly. An unfavorable feature of storage of raw fruit juices at from 32 to 35 degrees F. is the development of molds at juice surfaces. It is not improbable that simple measures for the suppression of the mold growths could be successfully used, as for example, keeping the containers entirely filled, or keeping the juice surfaces well blanketed with a layer of carbon dioxid, or possibly using ultraviolet light. It seems probable, however, that cold storage of freshly expressed juices at from 32 degrees to thirty-five degrees F. is of but limited application, as the activities of microörganisms are not sufficiently held in check."

Gore studied the retention of colors and flavors during preparatory heating and storage of fruit juices. He says:

"The extent to which color and flavor were retained on keeping the

juice after sterilization varied greatly in the juices from the various fruits.

"In strawberry juice the brilliant red color of the freshly sterilized juices in all cases faded greatly and further flavor losses occurred. Sterilization and subsequent keeping in carbon dioxid were not effective in securing color retention.

"Red currant juice very gradually lost in distinctive color and flavor on being kept at room temperatures after sterilization and keeping in carbon dioxid was not effective in securing either color or flavor retention. Cold storage at from 32 to 35 degrees F. was found to be a very satisfactory means of controlling color and flavor changes.

"The distinctive colors and flavors of black currant, blackberry, and black raspberry juices were satisfactorily retained during prolonged periods at common storage. The flavor of blackberries was, however, distinctly less well retained than that of black currants or black raspberries, though it did not undergo a perceptible change during a storage period of six months.

"In the case of red raspberries the distinctive color and flavor were poorly retained, even on keeping the juice in carbon dioxid in cold storage at from 32 to 35 degrees F.

"When sterilized and subsequently kept in carbon dioxid the distinctive color of pineapple juice remained practically unchanged. When exposed to atmospheric oxygen at juice surfaces during and after sterilization, marked darkening occurred. Change in color was also found to be greatly, though not wholly, retarded by keeping the juice in cold storage at from 32 to 35 degrees F. On keeping the juice at ordinary temperatures the distinctive pineapple flavor gradually lessened, though the juices remained recognizable as pineapple. By keeping in cold storage at from 32 to 35 degrees F. flavor change was almost wholly prevented.

"The distinctive colors and flavors of peach and cherry juices were quite well retained while kept at room temperatures. Huckleberry juice, hot pressed, lost in flavor on keeping.

"Lemon juice darkened in color if sterilized and kept in the presence of atmospheric oxygen, though the color was satisfactorily retained when the juice was sterilized and kept in carbon dioxid or in vacuum. In all cases an off-flavor, designated as a 'bottled lime-juice' flavor, appeared in the lemon juice after it had been kept for a time after sterilization, even though in cold storage at from 32 to 35 degrees F."

Beverages are generally thought of as belonging to several different classes as alcoholic and non-alcoholic, carbonated and non-carbonated, fermented and unfermented, etc.

Some of the most popular of summer beverages are called pops. Pops are defined by J. O. La Back as "non-alcoholic, artificially carbonated beverages sold in the original bottles and intended to be consumed as soon as opened."

Pops are made with different flavors as, strawberry, orange, pine-

apple, lemon, raspberry, cream, and cherry. The rootbeers and ginger ales are kinds of pops. La Back speaks of beverages of the coca cola type containing caffeine and flavoring from the cola plant as pops. According to W. R. Pumell the bacteriological content of pops is generally small due to the germicidal condition. In summing up his investigation of the bacteriological condition of pops he gives the following conclusions:

"1. The bacterial count of the finished products, put out by soft drink manufacturers, does not give a correct index into the sanitary conditions existing.

"2. That carbonic acid gas is antiseptic and germicidal to a decided extent, but since all microörganisms are not inhibited or killed, it cannot be relied upon as a sanitary safeguard.

"3. That most of the waters used in making the product are contaminated and unfit for use.

"4. That the bottles, when ready for filling, show a lack of sterilization and proper methods of cleaning.

"5. That were it not for carbonation the bacterial count apparently would be enormously high."

Cereal beverages have been brought into prominence by the prohibition laws. Sippel in *American Food Journal* says that cereal beverages can be divided into three groups:

Group I.—This group comprises cereal beverages prepared from fermented beers by means of de-alcoholizing devices.

Group II.—Cereal beverages prepared by the use of malt but unfermented.

Group III.—Cereal beverages prepared by the use of malt and unfermented.

Carbonated beverages are made from many different fruit juices as follows:

Fruit Juice	*Quarts Juice*	*Quarts Water*	*Lbs. Sugar*
Grape juice	1	1	..
Elderberry juice	1	1	2
Blackberry juice	1	1	1
Raspberry juice	1	1.5	1.5
Currant juice	1	2.5	2
Blueberry juice	1	2	1.5
Gooseberry juice	1	5	1.5
Strawberry juice	1	5	1
Cranberry juice	1	3	2
Cherry juice	1	2	1
Plum juice	1	1.5	1
Pear juice	1	0	⅓
Mulberry juice	1	2	3
Peach juice	1	1	1
Apricot juice	1	1	1
Loganberry juice	..	..	..
Rhubarb juice	1	4	2
Apple juice	1	0	⅓
Tomato juice	1	0	1
Orange juice	1	0	1

NOTE: The above juices should be pasteurized before carbonation.

Pumell says further in the same article that by far the greater number of de-alcoholizing processes on the market to-day employ a vacuum. The beer is boiled under a vacuum at a temperature of from 90° F. to 120° F., and in this way the loss of these aromatic substances is reduced to a minimum. De-alcoholized beers prepared in vacuo do not possess the "cooked" tastes noticeable in some beverages de-alcoholized by boiling at atmospheric pressure. The esters and oils escaping with the alcohol do not all volatilize at the same temperature. Advantage has been taken of this fact in certain processes which employ reflux condensers and fractionating devices to collect the various oils and esters and when de-alcoholization is complete, these are returned to the beverage.

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Chapter 26.

Coffee and Cocoa.

Coffee.

Coffee is produced in Brazil, Central America, Hayti, West Indies, Mexico, Jamaica, Arabia, Abyssinia, Liberia, and Dutch West Indies. The quality of the product depends largely upon the planter's skill, the soil, the climate, and the preparation.

It is the opinion of many that some of the world's finest coffee is produced in Brazil. The explanation given by E. L. Wright for the superiority of Brazilian coffee is a combination of adaptable soil and climate with a high order of intelligence on the part of the planters.

In the preparation of coffee the matured cherries are picked, placed in bags and sent to the factory where preparation for market is completed. At the factory the fruit part, the outer parchment and the silver lining are all removed either by the old dry method or the new wet method. The wet method is used most. The first step is the pulping process, after which the pulp and the seeds are separated by flotation. Fermentation sets in amid the depulped seeds after several days standing and separates the parchment and silver lining from the seeds. At the completion of fermentation the seeds are dried and passed through a peeling machine which removes the parchments and lining tissues.

The bacteria involved in the process of fermenting the parchment coatings of coffee seeds are similar to those of the fermentation which goes on in flax retting.

Cocoa.

Cocoa beans are produced in Central America, South America, Dutch East Indies, British West Indies, and West Africa. However, Ecuador is the home of the cocoa tree which was discovered by the Spaniards.

Cocoa beans have a bitter principle which is somewhat reduced by a fermentation process. The quality of the cocoa made from the beans depends to a considerable extent upon the success of this fermentation. The cocoa beans grow in bunches of thirty to forty, surrounded by a soft husk or shell. The beans are collected and placed in fermentation boxes with proper air vents. The sweet outer covering of the beans begins to ferment immediately. This mucous lining of

the beans is liquefied and drips from the boxes. Heat of fermentation develops in the boxes and the fermentation is controlled by observing the temperature. When the fermentation has progressed to a proper point the beans are removed, thoroughly scrubbed and dried.

Loew says, "the process of fermentation depends especially on yeast cells which increase rapidly in the syrup of the cocoa bean, with the formation of alcohol and CO_2. Also bacteria take part in the fermentation, oxidizing the alcohol to AcOH. A rise in temperature takes place and the slimy tissue surrounding the seeds comes off and collects on the bottom of the vat. The removal of this tissue is the chief end of the fermentation. It causes the seeds to be more easily dried. An oxidation of the tannin takes place which causes the brown color of the bean. The taste and the aroma depend on the fermentation as well as on the roasting."

Chapter 27.

Drinking Water.

The Bacteriology of Drinking Water.

In supplying drinking water for use in cities, towns, railway coaches, and steamboats, the object is that it shall be palatable and at the same time safe, that is, free from disease germs. The task of supplying potable water to cities grows harder as population increases, and as previously safe sources of drinking water become polluted. The importance of methods of water purification becomes more and more emphasized. Also methods of determining the sanitary condition of water becomes more vital to public welfare.

Where a few years ago the water of our larger cities was grossly polluted much of the time, now most cities have safe drinking water. It was formerly considered that the drinking water of rural districts was usually very good whereas now the amount of typhoid fever and dysentery spread by drinking water in rural districts is one of our great sanitary problems. City physicians have now come to expect considerable typhoid fever in the fall when people return from their vacations, "vacation typhoid."

There are more or less bacteria in all natural waters but the great majority of these have no special health significance. For this reason there is no attempt to obtain drinking water absolutely free from bacteria. Water free from contamination by man or animals is considered safe as far as bacteria are concerned, but there is very little such water.

Man is his own worst enemy as far as bacterial contamination of water is concerned and practically all bacteriologically unsafe water is made so by contamination by human beings.

As it is impossible to ascertain the actual bacteriological condition of large amounts of water it has become a custom to depend upon indications and to condemn drinking water which according to bacteriological tests is dangerous. The presence of B. coli of human origin in water is quite generally accepted as a serious indication that the water is not safe to drink. The B. coli test was first advocated by Theobald Smith, who considered that in so far as B. coli accompany the feces of all warm blooded animals, water containing it in abundance may logically be considered to be contaminated with feces. Later it was found that B. coli or coli-like bacteria exist even in uncontaminated fields of grain. This fact led to a very intensive study of this

group of bacteria. Winslow described B. coli as aërobic non-spore-forming bacilli producing acid and gas in dextrose and lactose media. While a great amount of work has been done concerning the colon group of bacteria there is still much confusion as to the identification of fecal and non-fecal strains of B. coli. Grossly polluted water is easily identified by the presumptive test but waters on the margin of allowed contamination give trouble.

Lactose bile broth thought to be favorable to B. coli but not to other organisms was advocated as a test for B. coli but it was found that the sodium taurocholate of bile inhibited nearly ½ of the typical coli organisms as well as miscellaneous water organisms and it is generally accepted that the use of lactose is more satisfactory in making the presumptive test.

Work in the direction of identification of fecal and non-fecal B. coli has been done by Rogers, Clark and Lubs. They found that the carbon dioxide hydrogen ratio differs for fecal and non-fecal B. coli, the non-fecal coli producing carbon dioxide and hydrogen in the ratio of 2 to 1.

In using methyl red to distinguish fecal and non-fecal B. coli it was found that the fecal organisms give an acid (red) color, while the non-fecal B. coli give an alkaline (yellow).

According to Levine, the methyl red test checks with the Voges-Proskauer reaction. The test for B. coli of fecal origin is the development of a red coloration in the medium after twelve hours incubation.

Methyl red medium is made by adding methyl red to a phosphate broth and Voges-Proskauer medium is made by adding 10% KOH solution to the phosphate broth.

Many different devices and treatments for the purification of drinking water have been tried out during the last thirty-five years. Some of the more important processes used in America for reduction of bacterial content are:

Screening.
Sedimentation.
Filtration.
Coagulation.
Chlorination.
Use of ozone.
Use of violet ray.

Screening through fine wire cloth removes much objectionable material which carries bacterial life or furnishes food for bacteria.

Sedimentation is the adoption of a natural method of water purification. By reducing the rate of flow of water sediment is allowed to settle out of water. With the removal of sediment large numbers of bacteria are carried down.

The use of filtration of water in modern water plants is another illustration of the adoption of one of nature's methods of purifying water. When water passes through a considerable thickness of fine

sand it becomes purified, because microörganisms adhere to the sand particles or are caught between them. In the operation of rapid mechanical filters in water purification plants, the filter beds are so arranged that when they have become clogged with material removed from the water they can be washed and scrubbed by rapid reverse currents which polish the sand and gravel vigorously.

Slow sand filters are large beds of sand through which the water passes slowly. These beds are cleaned occasionally by draining and removing the upper surface of slime and dirt.

Coagulation as a method of bacterial water purification may be very efficient. The material most generally used in producing the "flock" is either iron sulphate or alum. Many different kinds of mechanisms have been used for adding the chemical to the water in definite amounts so that no excess of chemical will remain after the flock has been formed and has precipitated.

The destruction of bacteria in water by the use of chlorine has become very important in recent years. Bacteria are very sensitive to chlorine and are killed by very small amounts. The chlorine is added to the water in different ways as in the form of calcium hypochlorite or as a liquid chlorine. By carefully controlling the amount of chlorine added to water a large percentage of the bacteria are killed and still very little or no free chlorine remains in the water. This result is due to the fact that chlorine unites with organic matter whenever it comes in contact with it.

The use of ozone, violet rays, etc., has not become extensively used because of the expense of these methods. However, these methods have been used on board vessels with considerable success.

Methods * of the American Public Health Associations for testing for the presence of members of the B. coli group in water are as follows:

It is recommended that the B. coli group be considered as including all non-spore-forming bacilli which ferment lactose with gas formation and grow aërobically on standard solid media.

The formation of 10 per cent or more of gas in a standard lactose broth fermentation tube within 24 hours at 37 degrees C. is presumptive evidence of the presence of members of the B. coli group, since the majority of the bacteria which give such a reaction belong to this group.

The appearance of aërobic lactose-splitting colonies on Endo or eosin methylene blue plates made from a lactose broth fermentation tube in which gas has formed, confirms to a considerable extent the presumption that gas-formation in the fermentation tube was due to the presence of members of the B. coli group.

To complete the demonstration of the presence of B. coli as above

* The methods for water analysis given here are taken from the Standard methods of American Public Health Association, Fifth Edition, 1923, and I wish to give acknowledgement here of their splendid work which means so much to the public health.

defined, it is necessary to show that one or more of these aërobic plate colonies consists of non-spore-forming bacilli which, when inoculated into a lactose-broth fermentation tube, form gas. It is recommended that the standard tests for the B. coli group be either (a) the Presumptive, (b) the Partially Confirmed, or (c) the Completed test as hereafter defined, each test being applicable under the circumstances specified.

A. Presumptive Test.

1. Inoculate a series of fermentation tubes with appropriate graduated quantities of the water to be tested. In every fermentation tube there must always be at least three times as much medium as the amount of water to be tested. When necessary to examine larger amounts than 10 cc. as many tubes as necessary shall be inoculated with 10 cc. each.

2. Incubate these tubes at 37° C. for 48 hrs. Examine each tube at 24 and 48 hours and record gas-formation. The records should be such as to distinguish between:

(a) Absence of gas-formation.

(b) Formation of gas occupying less than ten per cent (10%) of the closed arm.

(c) Formation of gas occupying more than ten per cent (10%) of the closed arm.

More detailed records of the amount of gas formed, though desirable for purposes of study, are not necessary for carrying out the standard tests prescribed.

3. The formation within 24 hours of gas occupying more than 10 per cent (10%) of the closed arm of fermentation tube constitutes a positive presumptive test.

4. If no gas is formed in 24 hours, or if the gas formed is less than ten per cent (10%), the incubation shall be continued to 48 hours. The presence of gas in any amount in such a tube at 48 hours constitutes a doubtful test, which in all cases requires confirmation.

5. The absence of gas formation after 48 hours incubation constitutes a negative test. (An arbitrary limit of 48 hours' observation doubtless excludes from consideration occasional members of the B. coli group which form gas very slowly, but for the purposes of a standard test the exclusion of these occasional slow gas forming organisms is considered immaterial.)

B. Partially Confirmed Test.

1. Make one or more Endo or eosin methylene blue plates from the tube which, after 48 hours' incubation, shows gas formation from the smallest amount of water tested. (For example, if the water has been tested in amounts to 10 cc., 1 cc., and 0.1 cc,, and gas is formed in 10 cc. and 1 cc. not in 0.1 cc., the test need be confirmed only in the 1 cc. amount.)

2. Incubate the plates at 37 degrees C., 18 to 24 hrs.

3. If typical colon-like colonies have developed upon the plate within this period, the confirmed test may be considered positive.

4. If, however, no typical colonies have developed within 24 hours, the test cannot yet be considered definitely negative, since it not infrequently happens that members of the B. coli group fail to form typical colonies on Endo or eosin methylene blue plates, or that the colonies develop slowly. In such case, it is always necessary to complete the test as directed, under "C" 2 and 3.

C. Completed Test.

1. From the Endo or eosin methylene plates made as prescribed under "B," fish at least two typical colonies, transferring each to an agar slant and a lactose broth fermentation tube.

2. If no typical colonies appear upon the plate within 24 hours, the plate should be reincubated another 24 hours, after which at least two of the colonies considered to be most likely B. coli, whether typical or not, shall be transferred to agar slants and lactose broth fermentation tubes.

3. The lactose broth fermentation tubes thus inoculated shall be incubated until gas formation is noted; the incubation not to exceed 48 hours. The agar slants shall be incubated at 37° C. for 48 hours, when a microscopic examination shall be made of at least one culture, selecting one which corresponds to one of the lactose broth fermentation tubes which has shown gas-formation.

The formation of gas in lactose broth and the demonstration of non-spore-forming bacilli in the agar culture shall be considered a satisfactory completed test, demonstrating the presence of a member of the B. coli group.

The absence of gas-formation in lactose broth or failure to demonstrate non-spore-forming bacilli in a gas-forming culture constitutes a negative test.

In order that tests for B. coli may have quantitative significance, the following general principles and rules should be observed:

Ordinarily not less than three portions of each sample should be tested, the portions being even decimal multiples or fractions of a cubic centimeter; for example, 10 cc., 1 cc., 0.1 cc., .01 cc., etc. It is essential that the dilutions should be such that the largest amount gives a positive test (unless the water is such as to give negative tests in 10 cc.) and the smallest dilution, a negative result. To insure this result, it is often necessary to plant four or five dilutions, especially in the examination of a sample of entirely unknown quality. The quantitative value of a series of tests is lost, unless all or at least a large proportion of the smallest dilutions tested have given negative results.

In reporting a single test, it is preferable merely to record results as observed, indicating the amounts tested and the result in each, rather than to attempt expression of the result in numbers of B. coli

per cc. In summarizing the results of a series of tests, however, it is desirable, for the sake of simplicity, to express the results in terms of the numbers of B. coli per cc. or per 100 cc. To convert results of fermentation tests to this form, the result of each test is recorded as indicating a number of B. coli per cc. equal to the reciprocal of the smallest decimal or multiple fraction of a cubic centimeter giving a positive result. For example, the result: 10 cc. plus; 1 cc. plus; 0.1 cc. minus; would be recorded as indicating one B. coli per cc. An exception should be made in the case where a negative result is obtained in an amount larger than the smallest portion giving a positive result. For example, in a result such as: 10 cc. plus; 1 cc. minus; 0.1 cc. plus. In such case, the result should be recorded as indicating a number of B. coli per cc. equal to the reciprocal of the dilution next larger than the smallest one giving a positive test, this being a more probable result.

Where tests are made in amounts larger than 1 cc. giving average results less than one B. coli per cc. it is more convenient to express results in terms of the numbers of B. coli per 100 cc.

The following table illustrates the method of recording and averaging results of B. coli tests:

Result of Tests in Amounts Designated				*Indicated Number of B. coli*	
10 cc.	1 cc.	0.1 cc.	.01 cc.	per cc.	per 100 cc.
plus	negative	negative	negative	0.1	10.
plus	plus	negative	negative	1.0	100.
plus	plus	plus	negative	10.0	1,000.
plus	plus	plus	plus	100.0	10,000.
plus	plus	negative	plus	10.0	1,000.
Total (for estimating averages)				121.1	12,110.
Average of 5 tests				24.0	2,422.

The above method of expressing results is not mathematically altogether correct. The average number of B. coli per cc. as thus estimated is not precisely the most probable number calculated by application of the theory of probability. To apply this theory to a correct mathematical solution of any considerable series of results involves, however, mathematical calculations so complex as to be impracticable of application in general practice. The simpler method given is therefore considered preferable, since it is easily applied, and the results so expressed are readily comprehensible.

In order that results as reported may be checked and carefully valuated, it is necessary that the report should show not only the average number of B. coli per cc. but also the number of samples examined; and, for each dilution, the total number of tests made, and the number (or per cent) positive.

Methods of the American Public Health Association for differentiating fecal from non-fecal members of the B. coli group.

(1) At least 10 cultures should be used. If possible these should be subcultures from plates made direct from the water since all of

the cultures obtained by plating from fermentation tubes may be descendants of a single cell in the water. If cultures from water plates are not available those obtained from plates made as prescribed under B. above may be used.

(2) Inoculate each culture into dextrose potassium phosphate broth, adonite broth, and gelatin. For additional confirmatory evidence inoculation may be made into tryptophane broth, and saccharose broth. The dextrose broth must be incubated at 30 degrees. Other sugar broths may be incubated at 30 degrees or 37 degrees as convenient. Gelatin should be incubated at 20 degrees.

(3) After 48 hours record gas formation in adonite and saccharose broths. Determine indol formation in tryptophane broth by adding drop by drop, to avoid mixing with the medium, about 1 cc. of a two per cent alcoholic solution of p-dimethyl amido-benzaldehyd, then a few drops of concentrated hydrochloric acid. The presence of indol is indicated by a red color which is soluble in chloroform. There may be some unconverted tryptophane still present which will give a distinctly blue color which is insoluble in chloroform. A mixture of the two will be either blue or violet. If from such a mixture of colors the red of indol be extracted with chloroform, proof of the presence of indol will be complete.

(4) After 5 days apply methyl red test and Voges-Proskauer test to dextrose broth.

Methyl Red Test.*

Indicator solution—Dissolve 0.1 gram methyl red in 300 cc. alcohol and dilute to 500 cc. with distilled water.

Procedure in test—1. To 5 cc. of each culture add 5 drops of methyl red solution.

2. Record distinct red color as methyl red +, distinct yellow color as methyl red —, and intermediate colors as ?.

Voges-Proskauer Test.

To the remaining 5 cc. of medium add 5 cc. of a ten per cent solution of potassium hydroxide. Allow to stand over night. A positive test is indicated by an eosin pink color.

(5) Gelatin tubes should not be pronounced negative until they have been incubated at least 15 days.

The following group reactions indicate the source of the culture with a high degree of probability:

Methyl red + ... Voges-Proskauer — ..... Gelatin — ..... Adonite — ..... Indol, usually + ... Saccharose, usually —	B. coli of fecal origin.

* NOTE: See A. P. H. A. Standard Methods of Water Analysis (1923), p. 107, for preparation of media.

Methyl red —	B. aerogenes of fecal origin.
Voges-Proskauer + ...	
Gelatin —	
Adonite + ...	
Indol, usually —	
Saccharose + ...	
Methyl red —	B. aerogenes, probably not of fecal origin.
Voges-Proskauer + ...	
Gelatin —	
Adonite —	
Indol, usually —	
Saccharose + ...	
Methyl red —	B. cloacæ, may or may not be of fecal origin.
Voges-Proskauer + ...	
Gelatin + ...	
Adonite + ...	
Indol, usually —	
Saccharose + ...	

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Chapter 28.

The Egg Industry.

Interest in the bacteriology of eggs arose from the fact that the spoiling of eggs was found to be due to bacterial attack. Further, some of the diseases of poultry are caused by the bacterial infection of eggs and are disseminated in this way.

Considerable literature has been published on the subject, and interest is still growing due to the rapid rise of the poultry industry. Mauer (1911) examined 600 fresh eggs bacteriologically and found that over 18% contained bacterial infection. In 1914, Bushnell and Mauer found that 23.7% of 2,759 fresh eggs were infected with bacteria. Rettger concluded from a study of about 4,000 fresh eggs that normal fresh eggs are generally sterile. Only 9% of the fresh eggs which he examined contained bacteria.

It has been well demonstrated by Mauer (1911), Pernot (1908), and Cao (1908), that bacteria can pass through the normal egg shell. Mauer (1911) found that out of 100 infected eggs 82% had infected yolks, 25.9% had infected whites, and 7.9% had both the egg white and yolk infected. In 1912, Stiles and Bates found 87% of 613 yolks and 70% of 616 whites of fresh eggs to be infected. Bushnel and Mauer (1914) arrived at the following results:

Per cent	infected	in	yolk	at	20	degrees	C.....	19.3
"	"	"	"	"	38	"	"	4.3
"	"	"	white	"	20	"	"	2.6
"	"	"	"	"	38	"	"	0.8

In explanation of the fact that egg white of infected eggs usually has less bacteria than egg yolk, Rettger and Sperry (1912) reported that egg white has an antiseptic property. They say that this antiseptic effect is more active at 37 degrees C. than at 20 degrees C.

The first method used in the bacteriological examination of eggs was a direct microscopic method. Later Cao used a method of enrichment followed by planting on agar. He washed the egg carefully in soap and water, then placed it in 1:1,000 mercuric chloride solution for 10 minutes followed by drying in alcohol and ether. The egg was then punctured at both ends with a sterile needle so that the egg white could be run out into 80 cc. of sterile broth in a flask. After the white had run out the yolk was added to 80 cc. of sterile broth in another flask. The egg broth mixtures were thoroughly shaken and incubated for 24 hours at 37 degrees C. At the end of incubation the egg broths were plated on agar using several dilutions.

Some of the results obtained by Hadley and Caldwell (1916) are as follows:

"Of 2,520 fresh eggs examined by the direct method 8.7% showed bacterial infection in the yolk. The percentage of infection obtained for individual hens per year varied between 2.8 and 15, the average being 9. No hen laid all sterile eggs during any full year. No correlation was observed between percentage of infection and hatchability. No correlation was observed between percentage of infection and fecundity, age of the hens, or the season of the year. The percentage of infection for infertile and for fertilized eggs was essentially the same."

Hadley and Caldwell came to the conclusion that the most probable source of primary egg infection is the ovaries of the fowl, which become infected by bacteria escaping through the intestinal wall into the portal circulation. They say that the nature of the bacterial species occurring in the primary infection of eggs makes clear the fact that primary infection plays no rôle in bringing about the decomposition of eggs, and that this decomposition is due to secondary infection.

T. E. Rush gives a very satisfactory method of bacteriological examination of eggs as follows: "A simple technique for the bacteriological examination of shell eggs. . . . The eggs are first immersed in a strong soap solution (the standard soap solution used in water analysis has been found to be very satisfactory) and scrubbed with a small brush to remove any adherent dirt and hen feces; then they are thoroughly dried in a clean towel and immersed in a mercuric chloride solution (1: 1,000) and allowed to remain about five minutes.

"The egg is now removed from the mercuric chloride solution, care being taken to handle it by the small end, and without drying, it is put into 60-70 per cent alcohol, where it is allowed to remain a few minutes.

"Again handling the egg by the small end it is placed upon a three-inch clay triangle (which has been previously flamed to insure sterility) large end down and the alcohol ignited by quickly passing a flame under the egg. The success of the method from this point on depends upon the formation of a drop of water from the alcohol (60-70 per cent alcohol has been found most satisfactory) on the bottom (large end) of the egg.

"When the alcohol has burned off, a very hot flame (Tirrell burner) is directed at the drop of water on the under side of the egg and after sufficient heating a piece of the egg shell from 1 to 2 cm. in diameter snaps off. In some cases the vitelline membrane is broken at this point and the contents of the egg run out, so it is necessary to have a container ready for use.

"If the vitelline membrane does not break at this point or all the contents do not run out, it is only necessary to apply the flame gently to the top (small) end of the egg when the expansion of the air will

totally empty the shell. Care must be taken at this point not to burn the egg shell or coagulate the contents. This heating should be done with a nearly luminous flame.

"The most satisfactory type of receiver is a large Phillips beaker, which has been previously sterilized with a sufficient quantity of broken glass in it to cover the bottom of the flask. This broken glass serves to cut up both the yolk and white and make a homogeneous mixture from which an average sample can be withdrawn and plated, using the usual precautions."

Decay in Eggs.

Pennington, Jenkins and Betts, say: "Mold may penetrate a wet, broken shell and attach itself to the inner surface in the form of irregular patches. If the growth takes place at low temperatures, the affected portions of the white are gelatinized. These mold spots appear as dark areas before the candle, and are seen easily if not covered with the fingers.

"The condition of the yolk is one of the most important factors to be determined when judging the quality of eggs by candling. When a fresh egg is twirled before the candle the yolk is dimly seen as a dark and shadowy object moving slowly in the white. The more transparent the shell the more distinctly is the yolk seen. The yolk sac is so strong and the white so firm that the spherical form of the yolk is altered very little when the contents of the egg are set in motion by the turning during candling.

"Because of the thinner condition of the white, the yolk of a stale egg is seen much more plainly on candling than that of a fresh egg. As the egg ages the yolk sac weakens, and since the white becomes thinner at the same time the outline of the yolk is seen to change when the egg is rotated. When such an egg is opened the yolk flattens out and often breaks. The differences in the strength of the yolk sac of eggs of varying degrees of freshness are indicated clearly. If eggs which have weak yolks before the candle show whole yolks when opened, they are graded as good if no other cause for rejection is observed.

"When the yolk of an egg is so weak that a shake in the hand causes it to break and mix with the white, the egg should be graded as unmarketable, for during shipment it is very likely to become unfit for food. These eggs are difficult to grade accurately by candling. They are of such inferior quality, however, that in case of doubt they should be classed as inedible.

"The yolk sac may so weaken that the yolk seeps or strains through into the white. In these eggs the yolk would appear whole before the candle, but it would be weak, and the white would have a cloudy yellow color. Out of the shell the yolk will be seen to be flattened and sometimes mottled and the white to be streaked with yolk. Very close candling is required to detect these eggs, and since they are

border-line eggs, in which further deterioration is very rapid, they should not be graded as marketable.

"The more common form of disintegration of the yolk takes place through the rupture in one or more places of the yolk sac and the mingling of the white and yolk. This mixing is commonly known as 'addling.' All degrees of addling may be found, from the egg in which the yolk is just beginning to mix with the white to the egg in which no vestige of white is seen. The eggs representing the early stage of mixing are called 'mixed rots,' and those representing the later stage, 'white rots.' Both are inedible.

"Mixed rots are characterized on candling and out of the shell by the irregular mixture of white and yolk. Often one portion of the yolk shows more deterioration than another, a condition shown by a darkened area on candling and by whitish streaks out of the shell.

"The characteristics noted for mixed rots are even more marked in the white rots. In these eggs the white assumes a general yellow appearance on candling and out of the shell.

"The incrusting of the yolk is a characteristic form of deterioration among eggs with soiled shells which have been held in cold storage. Under certain conditions the bacteria enter the shell, liquefy the white, making it watery, and produce a coating or crust on the yolk. Before the candle the yolk appears to have dark, mottled areas. Such eggs are unfit for food.

"The position of the yolk also must be taken into consideration when grading eggs by candling. In a fresh egg the yolk is slightly above the center in the large end of the egg. Although lighter than the white, it does not float against the shell because the chalazæ tend to hold it in a central position in the egg. As the egg becomes stale with age, and especially from exposure to heat, the white is weakened, thereby making it possible for the yolk to float near the shell. This condition indicates staleness if the egg shows shrinkage.

"As ageing continues, the yolk may adhere slightly to the shell, but a quick twist of the egg may set the yolk free without breaking it. In such a case the egg is edible, but a very low grade. With further ageing the yolk will stick to the shell so that it can not be separated without breaking the yolk sac, in which case the egg is classed as bad. When the yolk is thus broken, as may happen when the egg is turned quickly, the appearance of the egg before the candle is the same as that of the mixed rot. Again, the yolk may be adherent at one point and broken at another. These eggs deteriorate quickly into mixed or white rots.

"Dampness may be another factor causing the yolk to stick to the shell. In this case molds penetrate the shells as far as the yolk, which becomes very heavily attached to the shell."

The preparation of the frozen and dried eggs is an industry which has sprung up in the Middle West. Pennington says: "The frozen-egg industry, hardly 15 years old, is permanent, because it has developed as the direct result of an economic need. Many eggs, such as

cracked, small, dirty, shrunken and slightly heated eggs, commercially termed seconds, reach the first concentration center in a wholesome condition, but if shipped in the shell to a distant consuming center they would markedly decompose and be entirely unfit for food purposes. The new industry believed that cracked eggs and seconds could be conserved by freezing out of the shell, and the baker thereby supplied with wholesome eggs at a reasonable price during the whole year.

"As was to be expected, the new industry had to face many problems. The general public had its usual prejudice against any food coming from cold storage. The industry was ignorant of the general principles of bacterial cleanliness in the commercial preparation of a perishable foodstuff. Unprincipled persons, thinking they could conceal the inferiority of low-grade eggs by freezing them en masse, brought the industry into disrepute. Food officials were groping in the dark in their efforts to protect the public against decomposed eggs. These contending forces were fast making the investment of money in the preparation of frozen and dried eggs a hazardous business proposition."

In their bulletin on the preparation of frozen and dried eggs, Pennington et al., say: "If good organization was important in the candling room, it was even more so in the breaking room; here the product (good eggs being furnished) gained or lost in quality, depending upon the mode of handling. Here, also, the cost of preparation increased or decreased with the efficiency of the working force. First in importance was the foreman, for upon him should rest the responsibility of the work of the breaking force and the condition of the ultimate product. He should be able to command the respect of his subordinates, be conversant with the fundamental principles of bacterial cleanliness and be familiar with the different types of eggs occurring in breaking stock.

"Owing to the decided changes made in equipment and methods, the routine work in the breaking room in 1912 was quite different from that of 1911. The duties of the foreman the second season included the enforcement of the following: Clean manipulation of the egg during breaking, the proper method of grading, the changing of apparatus and the cleaning of hands after breaking a bad egg, the correct speed for breaking, the thorough washing and sterilization of utensils, and the maintenance of discipline in the breaking force.

"Since the presence of one infected egg would contribute myriads of bacteria to the liquid product, the study of the grading of eggs out of the shell became a very important part of the work. As has been stated, the candling of eggs is a very efficient means of eliminating bad eggs from breaking stock, but it is by no means accurate. It is also generally understood by those familiar with eggs before the candle and out of the shell that there are some types of objectionable eggs, such as musty or sour eggs, which can only be detected when broken. The laboratory findings on composite samples of eggs graded

to definite types and broken under clean commercial conditions showed as given in Bulletin 51 of the U. S. Department of Agriculture, the following facts:

"The majority of the samples of white rots, eggs with yolk lightly adherent to the shell, and all of the samples of sour eggs, black rots, eggs with green albumens, eggs with yolk heavily adherent to the shell, and all other eggs with bad odors, were infested with bacteria. B. coli were present in most of these eggs and constituted the predominating organism in sour eggs.

"The eggs with yolk lightly adherent to the shell were slightly lower in quality than the regular breaking stock eggs, whereas the sour eggs, white rots, eggs with green whites, and eggs with yolk heavily adherent to the shell showed considerably more deterioration. Eggs with bloody whites or eggs with blood rings, should not be used. The cause of the musty egg, the odor of which increases on heating, thereby creating disaster in the bakery, has not been determined.

"Eggs with shell and inner membranes broken are termed 'leakers' by the trade. There are all gradations, from the egg which has lost very little of its contents to the egg which has practically nothing left in its shell but the yolk.

"During periods of the year when receipts are low and the number of leakers consequently few, they are commonly sold in the shell to the near-by consumers and employees of the packing house. In the season of heavy receipts, when there are more leakers than can be used locally, they are either thrown with the rots or broken out and frozen. The second method of disposal is the one concerned in this investigation.

"Formerly if the leakers were to be conserved for food purposes the candlers sorted these eggs from receipts as they worked and either broke them immediately into a container near by or placed them in pans or pails to be opened in another room."

The following conclusions concerning the frozen and dried egg industry and also the Glossary are from Pennington, et al., in *U.S.D.A. Bul.* 224.

"1. Eggs commonly used for breaking stock by reputable firms are small and oversized eggs, dirty and cracked eggs, and shrunken eggs.

"2. In order to check deterioration, the eggs should be held in chilled surroundings before and during the process of candling, breaking, and mixing preparatory to freezing and drying.

"3. All eggs, even during the spring months, should be candled previous to breaking.

"4. In order to insure well-candled eggs going to the breaking room, the system of candling should be such that the work of the individual candlers is checked.

"5. In order to prevent waste, the eggs difficult to grade should be set aside by the regular candlers to be recandled by an expert.

"6. All eggs used in the preparation of frozen and dried eggs should be graded out of the shell as well as by the candle, because certain

heavily infected eggs, such as sour eggs and eggs with green whites, can only be detected when broken.

"7. In order to insure a good product, bacterial cleanliness and careful grading must be obtained during the process of preparation.

"8. The fingers of the breakers should be kept dry and clean.

"9. In order to prevent waste and to insure good grading not more than three eggs should be broken into a cup before emptying.

"10. Good eggs should not be saved when a bad egg has been broken in a cup with them.

"11. White and yolk are contaminated less by the mechanical than the shell method of separation. Only clean eggs should be separated by the latter process.

"12. The percentage of 'rots' rejected on candling and the organisms in the liquid egg saved increases as the season advances.

"13. Canned eggs with the majority of samples having counts of less than 5,000,000 bacteria per gram, and with 100,000 B. coli or less can be prepared in the producing section from regular breaking stock, provided strict cleanliness and careful grading have been observed. The ammoniacal nitrogen will very seldom be over 0.0024 on the wet basis or 0.0087 on the dry basis.

"14. A second-grade frozen product prepared from eggs showing incipient decomposition to the senses, such as 'beginning sours' and eggs with green whites, are not only heavily infected but chemically decomposed. These eggs are unfit for food purposes.

"15. Only two grades of canned eggs should be prepared when grading eggs out of the shell, namely, food eggs and tanners' eggs.

"16. Leaking eggs handled on special trays between candling and breaking room and graded carefully are as fit for breaking as regular breaking stock.

"17. Tanners' egg contains markedly larger numbers of bacteria and larger amounts of ammoniacal nitrogen than does food egg.

"18. The control of the supply of the air to drying belts to prevent saturation from the liquid egg is an important factor in preventing multiplication of bacteria in the product during the process of desiccation.

"19. The amount of ammoniacal nitrogen in desiccated egg is not a reliable index to the quality of the raw material from which it is prepared, because this substance is volatilized unevenly during the process of desiccation.

"20. The following eggs should be discarded during grading: Black, white mixed and sour rots, eggs with green whites, eggs with stuck yolks, musty eggs, moldy eggs, "blood rings,' eggs containing diffuse blood, and eggs abnormal in odor.

Glossary.

" 'Seconds' are small and oversized eggs, dirty eggs, and shrunken eggs.

" 'Leakers' are eggs with shell and inner membrane broken.

"A 'blood ring' is a fertile egg in which the embryo has developed sufficiently to show blood.

"A soft egg is an egg the yolk of which appears whole before the candle, but breaks when opened.

"A 'strong odor' egg is an egg which has an eggy odor.

"An 'off' egg is an egg which has a slightly abnormal odor.

"A 'beginning sour' is an egg showing the first signs of the odor characteristic of sour eggs.

" 'Mixed egg' is a product prepared by adding yolks to whole egg.

" 'Drip' is the liquid egg, mostly white, which collects in the bottom of the breaking tray while eggs are being broken.

" 'Second-grade egg' is a product prepared from 'drip' and incipient forms of deteriorated eggs, such as 'beginning sours,' eggs with light-green whites, etc.

" 'Tanners' eggs' are a product made from the rejects of the candling and breaking rooms, minus eggs of bad odor. It is used as the name implies, for tanning leather.

" 'Flaky egg' as opposed to 'wet lumps' is the more thoroughly dried portion of egg coming from the drying belts.

"A 'churn' is a device for breaking yolks and for mixing yolk and whole egg."

Method of Egg Preservation.

Of the methods of food preservation three are commercially applied to the preservation of eggs, namely, preservation of eggs by cold storage, preservation by antiseptics, and preservation by sealing.

The cold storage of eggs is widely practiced and is of great economic importance in leveling the price of eggs throughout the year. The condition of eggs in cold storage is determined by the amount of bacterial contamination of egg shell and egg before going into storage. The action of the low temperature of storage simply retards bacterial action, which is another name for spoilage. The generation time of normal egg spoilage organism at summer temperatures may be as short as thirty minutes or lengthened by low temperature to a period of several days.

The storage of eggs in antiseptic solutions, although practiced by some, is not very successful according to experiments carried on by the U. S. Dept. of Agriculture. By this investigation it was found that eggs stored in salt water were not edible because of salt penetration. Also the following information was obtained:

Treatment	*Percentage Bad*
Packed in solution of water glass	00%
Solution of salicylic acid and glycerine	80
Rubbed with salt	70
Packed in bran	70
Sterilized in boiling water 12-15 sec.	50
Solution of alum	50
Packed in peat dust	20
Packed in wood ashes	20
Boric acid and water glass	20

The method of preserving eggs by packing them in water glass has been successfully used for many years. The water glass sterilizes the surface of the egg and hermetically seals the egg so that bacteria cannot reach the interior of the egg.

Some other sealing methods have been employed in egg preservation as wrapping eggs in waxed paper, coating with paraffin, varnishing with collodion, etc., and coating with vaseline.

Of the methods tried out the use of a vaseline coating, packing in lime water or water glass were the only ones which caused eggs to remain unfermented according to the U. S. Dept. of Agriculture. The use of vaseline was found to be too laborious and storage in lime water gave a slight taste of lime water. It was found that the use of water glass (solution of water glass in water 1:9) was most efficient and practical; especially where a fairly low temperature of storage is maintained and eggs are kept well covered with the solution.

The most satisfactory results are obtained when only the cleanest eggs are used. Eggs which have been washed do not store well because in washing the bacteria on the surface of the egg are carried into the egg pores and readily find entrance into the egg. Eggs which are cracked or have spots should also be eliminated as they have internal contamination. Such eggs can be identified by candling. Infertile eggs are better for storage than fertile ones.

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Chapter 29.

Maple Sugar and Maple Syrup.

sugar and syrup made from the maple tree are foods which nous for their delicacy of flavor. There are two members of ple family (aceraceæ), the hard maple and the soft maple. Both e produce considerable amounts of maple syrup and maple The hard maple or sugar maple produces the largest amount h the soft maple also yields well. Early in the spring, in the before the buds become green, the trees are tapped by boring

on in Vermont. Bulletin, 151.

FIG. 55.—A sugar orchard.

f-inch holes about two feet from the ground. These holes are wo inches deep and three inches apart and spiles or spouts are into them to carry the sap to buckets. The sap is boiled o a definite Sp. G. depending on the product to be made. The for sugar-making is boiled down further than that for maple naking. The sap from a single tree may yield from 4 to 12 lbs. e sugar per season. The most favorable weather is characterized freezing nights followed by rather warm days.

ording to Edson, the composition of average maple sap is

about 3% saccharose with traces of other sugars as invert sugar. The distinctive flavor of maple sap and the products made from it is due no doubt to the small but important protein content. Maple sap also contains some malic acid and salts of calcium and potassium.

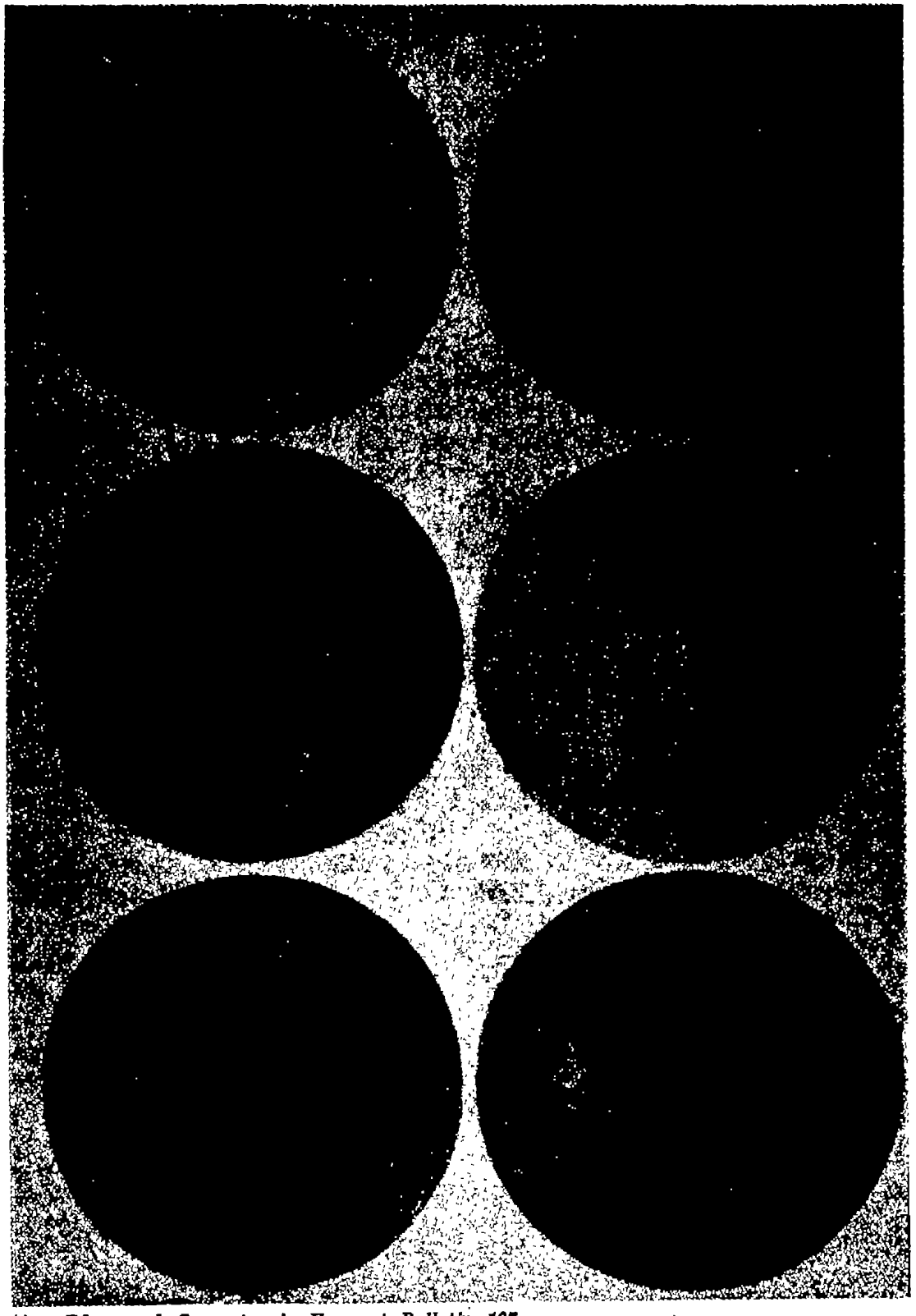
The Department of Agriculture has defined maple syrup as a food product containing not more than 35% water and weighing not less than 11 lbs. to the gallon. Sucrose constitutes 95 to 97.5% of maple syrup on dry basis.

Since the sap contains elements well suited for bacterial nutrition, we readily conclude that as soon as the weather becomes warm enough for the rapid growth of germs in the sap, some change must normally take place. Edson says that the appearance of the sap undergoes a marked change as the sugar season progresses. The first sap is clear and transparent and possesses a delicious sweet flavor but with the advance of the season, as the days become warmer and the freezing nights less severe and less frequent, the sap often becomes cloudy, and discolored, while at the same time certain unpleasant flavors develop. Such sap, while usually free from acid, is popularly termed sour. Several types of this sour sap are recognized by sugar makers. Milky sap, stringy sap, red sap, and particularly so-called "green sap" are among the more common kinds. "Green sap" is almost always observed just before the close of the season when the leaf buds are ready to open. These occurrences are observed by all maple sugar makers and this occurrence of "buddy" sap is often thought to be directly connected with the appearance of buds on the trees. It is always the case that the earlier "runs" of sap make the best syrup and sugar. The later the "run," the poorer the flavor becomes as a usual thing.

With the above facts in mind, Edson conducted a set of experiments to determine whether or not microörganisms are the real cause of "buddy" sap, poor flavor and poor quality of the finished syrup and sugar as the season develops. He showed that the sap within the vascular bundles of the tree is free from microörganisms and that when sap is drawn under aseptic conditions it keeps sweet without being sterilized or chemically preserved, while sap drawn under the ordinary conditions of tapped trees soon sours and becomes cloudy. He found that such sap contains enormous numbers of bacteria yeasts and molds, and that extensive decomposition changes have taken place.

A table from Edson's work shows clearly the effect of microorganisms in maple sap. In one series, samples of sap were inoculated with green fluorescent bacteria isolated from green sour sap and this trouble was reproduced. In another series samples of sap were inoculated with material obtained from cloudy sour sap and the organism which caused this trouble was established. In a third series sap was inoculated with an organism believed to be a new species obtained from a milky type of stringy sap. Stringiness and sourness developed in these samples. A fourth series was inoculated with

PLATE 14



After Edson and Carpenter in Vermont Bulletin 167.

FLAGELLA STAINS OF MAPLE SAP ORGANISMS.

Flagella preparations from 24-hour agar slants (Loeffler's stain). Figs 1-4 show capsulation.

FIG. 1.—*B. aceris*
FIG. 2.—*B. parallelus*
FIG. 3.—*B. parallelus*
FIG. 4.—*B. parallelus*
FIG. 5.—*Ps. fluorescens*
FIG. 6.—*Ps. fluorescens*

easts and molds obtained from red sap and resulted in the reproduc-
on of this trouble.

As in the production of other foods, quality here depends con-
derably upon the amount of cleanliness practiced in manufacturing
ie product. Clean, boiled sap buckets mean much in producing
iaple syrup and sugar of highest quality. New tap holes in the
itter part of the sap season improves the quality also.

The kind of organisms found by Edson in the sap coming from
ifferent trees were yeasts and bacteria. The number of organisms
ncreased in general as the sap season progressed. Late run sap was
ften sour. It was found that whereas late in the season the sap
owing from old holes and through old spiles was "bitter," "buddy"
nd cloudy, by boring new holes and using sterile spiles and utensils,
ap could be obtained which was clear and free from "buddy" and off
astes. This fact indicates that late-made syrup and maple sugar is
ften faulty due to bacterial infection of the sap.

Edson gives the following summary of the conclusions reached as
result of his investigations:

"Maple sap as it occurs within the tree is free from bacteria and
ther microörganisms.

"As the sap flows from the tree it becomes infected in the taphole,
pouts and buckets, with wild yeasts, spores of molds, and countless
umbers of bacteria. This infection becomes increasingly heavy with
he advance of the sugar season and is the cause of the 'souring' of
ap.

"Some of the types of hurt sap are caused by the action of specific
groups of organisms, others may be caused by the collective action of
many of the common forms.

"Green sap and the resulting red syrup are not to be attributed
to the swelling of the buds, but are caused by the development of a
particular group of bacteria characterized by green fluorescence.

"The dark color of the late run syrup is due entirely to the action
of microörganisms. If these are eliminated, as light colored syrup
may be made from the last run as from the first run.

"The flavor of the syrups is also seriously impaired by these
agents. This injury often becomes pronounced before marked change
in color is produced. 'Buddy' flavors also appear to be due, at least
in part, to the action of microörganisms.

"The quality of the product may be improved by: (1) keeping the
spouts and buckets thoroughly clean; (2) using metal utensils in lieu
of wooden ones; (3) gathering the sap at short intervals and boiling
it at once.

"In the canning, storage, and marketing of syrups, Langlade em-
phasizes the great importance of using sterile bottles and containers
thereby preventing molds and bacteria."

Jones gives the following remedial measures concerning the difficul-
ties in the manufacturing of high grade maple syrup and maple
sugar:

"Practical remedial measures must be based upon efforts to minimize the contamination with microörganisms and to restrict the period of their action to the shortest possible time. The lower their content and the shorter their period of growth, the better the product. As in dairying, cleanliness must be the watchword of the producer of superior goods. Clean spouts, clean covered buckets and clean holders are necessities. The use of metal utensils is to be preferred to the employment of wooden ones, because the latter material affords organic matter upon which organisms may develop. Moreover, wooden utensils are less readily cleaned. Covered buckets are preferable to open ones, not only because they keep out rain and snow, but because they prevent the entrance of bits of falling bark, decayed wood, and other inert matter. Such material is always heavily charged with bacteria and other organisms, so that in addition to the coloring matter carried in the refuse itself, agents are introduced which further discolor the product through their vital activities.

"The practice of storing sap is one to be avoided whenever possible. Modern evaporators not only make long periods of boiling unnecessary, but they make it possible to concentrate the runs day by day as they occur. They are doubtless important factors contributing to the improved quality of evaporator syrup as compared with that produced by older methods. When storage is resorted to, the temperature of the tank should be kept as low as possible, because the lower the temperature the slower the microörganic development. Holders should be located without rather than within the boiling house, where the heat of the pans will not influence their temperature.

"The evidence obtained indicates that the sugar-maker cannot expect to produce a high quality of syrup at the close of the season in average years, because there is no known means by which the physiologically induced 'buddy' flavor may be avoided. So long as the depreciation is caused solely by bacteria, cleanly methods will enable the producer to maintain a high standard of excellency in his product; but if the physiological activity of the tree begins to be manifest, the producer will find himself unable to manufacture an article of high excellency as regards flavor. The light color can be maintained indefinitely, but the 'buddy' flavor is so objectionable that the market value of the syrup is insufficient to render its production profitable."

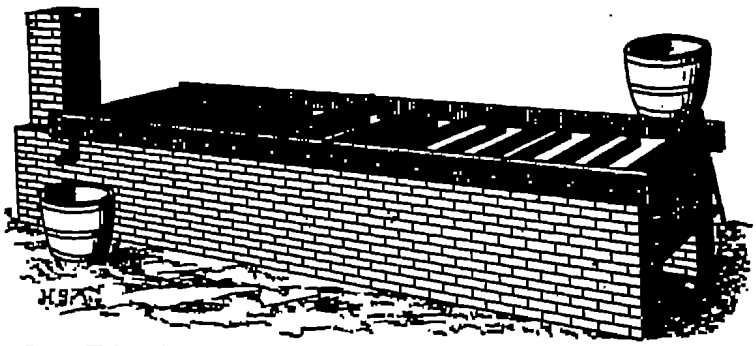
C. H. Jones says: "The conditions are more favorable to bacterial, yeast and mold contamination in the sap toward the close of the sugar season than earlier because of the higher temperatures, bare ground, rain, interrupted runs, less cleanly utensils, etc., which then obtain."

Jones describes standard maple syrup as follows: "Standard maple syrup should weigh 11 pounds to the gallon, should carry between 34 and 35% of water, should give a Baumé reading of 35½ to 36 at 60 degrees F., and should contain calculated to a moisture-free basis, a total (maple syrup) ash of 0.77%, an insoluble ash of 0.23% and a malic acid value of 0.60%. These figures constitute the standard

now in use for determining purity. They are none too low, should be considered collectively, and when properly interpreted, should enable certain differentiation between pure and adulterated maple products."

The following conclusions were given by Edson and Carpenter concerning the strains of fluorescent bacteria which they found as factors in maple syrup and maple sugar making:

"Among the 42 strains of green fluorescent bacteria, selected from several hundred strains which had been isolated from maple sap, there were 32 strains of the liquefaciens and 9 strains of the non-liquefaciens varieties of Ps. fluorescens. The studies included one strain which was never more than doubtfully fluorescent, which, for this and other reasons, should not properly be regarded as a member of the fluorescent group. The 9 strains of the non-liquefaciens variety showed a delayed liquefaction of gelatin in from 50 days to 5 months when cultivated in a moist chamber at 20 degrees C. Peptonization of milk by these strains was also long delayed commencing in from 30 days to 3 months.



From U.S.D.A. Bulletin 1389.

FIG. 56.—Pan evaporator.

"Critical comparative studies of 7 representative strains of green fluorescent sap bacteria and 6 so-called species Ps. alba, Ps. fluorescens, Ps. longa, Ps. mesenterica, Ps. tenuis, and Ps. putrida show that no sharp line of differentiation can be drawn between these forms. Of the known 'species,' Ps. alba, Ps. longa, and Ps. putrida fail to liquefy gelatin in 6 months time, while in the case of Ps. mesenterica and Ps. tenuis a delayed liquefaction occurs. In the latter named strain liquefaction first appears 4 months after inoculation.

"It is believed that the fluorescent sap bacteria as well as the so-called species, Ps. alba, Ps. longa, Ps. mesenterica, Ps. tenuis, and Ps. putrida should properly be recognized as strains of the liquefaciens and non-liquefaciens varieties of Ps. fluorescens."

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Chapter 30.

Dairy Products.

The original dairy products were milk, butter and chees production, manufacture and marketing of these products up or even 1890 was very simple. At about this time, however, t fessional dairyman appeared, ideas of sanitation in towns grew the family or neighborhood cow disappeared. About this sar the results of bacteriological study of milk and dairy produ taken seriously by the public. There was a wave of interest foods, and milk and dairy products of higher quality were der In 1893, Dr. Henry L. Coit initiated the idea of certified milk, idea of having milk that had been certified by a medical mi mission spread. Sedgwick and Batchelder, early in the devel of market milk, made a bacteriological and quality survey milk of the city of Boston.. Conn at Connecticut Experiment and Russell at Wisconsin made reports on milk quality. The of pure cultures as starters in the manufacture of butter and was also extensively studied.

Market Milk.

Milk is such an important food, especially for infants, t quality should be the highest of all foods. Still the nature and its production are such that it may be the dirtiest of al Not only is this true but it also happens that milk is a food v difficult to keep or transport in good condition.

Quality in market milk is hard to define. Many attemp been made to tell what is meant by quality in market milk, bu has been much difference of opinion. Dr. E. O. Jordan says, the exhaustively studied and relatively simple water standa subject to such exceptions and reservations, it is certainly no expected that bacterial standards for food will be any mor factory." H. A. Harding says, "Many factors combine to de the quality of milk, apparently thus far, no one has succeede fully analyzing the city milk situation as to formulate a c expression for milk quality."

There are certain methods which have been used in gaining of the sanitary quality of the milk produced by a dairyman. cards as illustrated on opposite page for scoring the dairy ha used quite extensively. The score card was used on the bas

SCORE CARD.

Equipment.	Score. Perfect.	Score. Allowed.
COWS.		
Health	6	....
Apparently in good health	1	
If tested with tuberculin within a year and no tuberculosis is found, or if tested within six months and all reacting animals removed	5	
(If tested within a year and reacting animals are found and removed, 3.)		
Food (clean and wholesome)	1	....
Water (clean and fresh)	1	....
STABLES.		
Location of stable	2	....
Well drained	1	
Free from contaminating surroundings	1	
Construction of stable	4	....
Tight, sound floor and proper gutter	2	
Smooth, tight walls and ceiling	1	
Proper stall, tie, and manger	1	
Provision for light: Four sq. ft. of glass per cow	4	....
(Three sq. ft., 3; 2 sq. ft., 2; 1 sq. ft., 1. Deduct for uneven distribution.)		
Bedding	1	....
Ventilation	7	....
Provision for fresh air, controllable flue system	3	
(Windows hinged at bottom, 1.5; sliding windows, 1; other openings, 0.5.)		
Cubic feet of space per cow, 500 ft.	3	
(Less than 500 ft., 2; less than 400 ft., 1; less than 300 ft., 0.)		
Provision for controlling temperature	1	
UTENSILS.		
Construction and condition of utensils	1	....
Water for cleaning	1	....
(Clean, convenient, and abundant.)		
Small-top milking pail	5	....
Milk cooler	1	....
Clean milking suits	1	....
MILK ROOM OR MILK HOUSE.		
Location: Free from contaminating surroundings	1	....
Construction of milk room	2	....
Floor, walls, and ceiling	1	
Light, ventilation, screens	1	
Separate rooms for washing utensils and handling milk	1	....
Facilities for steam	1	....
(Hot water, 0.5.)		
Total	40	....

Methods.	Score. Perfect.	Score. Allowed.
COWS.		
Clean	8	....
(Free from visible dirt, 6.)		
STABLES.		
Cleanliness of stables	6	....
Floor	2	
Walls	1	
Ceiling and ledges	1	
Mangers and partitions	1	
Windows	1	
Stable air at milking time	5	....
Freedom from dust	3	
Freedom from odors	2	
Cleanliness of bedding	1	....
Barnyard	2	....
Clean	1	
Well drained	1	
Removal of manure daily to 50 feet from stable	2	....
MILK ROOM OR MILK HOUSE.		
Cleanliness of milk room	3	....
UTENSILS AND MILKING.		
Care and cleanliness of utensils	8	....
Thoroughly washed		
Sterilized in steam for 15 minutes	2	
(Placed over steam jet or scalded with boiling water, 2.)		
Protected from contamination	3	
Cleanliness of milking	9	....
Clean, dry hands	3	
Udders washed and wiped	6	
(Udders cleaned with moist cloth, 4; cleaned with dry cloth or brush at least 15 minutes before milking, 1.)		
HANDLING THE MILK.		
Cleanliness of attendants in milk room	2	....
Milk removed immediately from stable without pouring from pail	2	....
Cooled immediately after milking each cow	2	....
Cooled below 50° F.	5	....
(51° to 55°, 4; 56° to 60°, 2.)		
Stored below 50° F.	3	....
(51° to 55°, 2; 56° to 60°, 1.)		
Transportation below 50° F.	2	....
(51° to 55°, 1.5; 56° to 60°, 1.)		
(If delivered twice a day, allow perfect score for storage and transportation.)		
Total	60	....

Equiment ..... + Methods ..... = ... Final Score.

NOTE 1.—If any exceptionally filthy condition is found, particularly dirty utensils, the total score may be further limited.

NOTE 2.—If the water is exposed to dangerous contamination, or there is evidence of the presence of a dangerous disease in animals or attendants, the score shall be 0.

Above Score Card is from U.S.D.A. Farmers' Bul. 502.

knowing the farm conditions under which milk is produced, one can tell much about what the quality of the milk will be. It is true to some extent, however, that there is a large factor which is almost impossible to bring into the score card: this is the factor of human nature. In other words two men each with similar dairy equipment, cows and all conditions the same, will produce very different milk. However, this does not mean that the score card has no value, but that it should be correlated with other tests.

Another method of controlling the quality of milk is the establishment of certified milk commissions throughout the country. These commissions at stated periods of time inspect the dairy, the conditions of production, and the milk produced. When they find the herd free from disease and all their rules for producing milk obeyed, they allow the use of the word "certified" to be applied to the milk.

A further method of obtaining an idea of the quality of milk is to grade it according to its bacterial content. This is done on the basis that milk produced under slovenly conditions has a high bacterial content and such milk stands a good chance of containing pathogenic organisms. Objections to the use of bacterial standards alone for milk quality are that infections may exist in the cleanest of herds and that attendants may be scrupulously clean and still be carriers of disease. As E. O. Jordan has said, "A clean but diseased cow is more dangerous than an ill kept healthy one." However, it still remains true that high germ content in milk signifies lack of care, that is, dirtiness, or staleness, or both. Jordan sums up the value of the bacteriological examination of milk by saying, "Evidently the most that can be claimed for the bacterial examination of milk is that it offers indications, more or less precise possibilities of danger. The numbers of bacteria in milk have little meaning unless the sanitary history of milk is known; when this is the case they often become useful in controlling procedures and detecting possible sources of danger; they can never be used as absolute and rigid standards for condemnation or approval; they are guides to investigation, they are not, taken alone, a basis for final judgment."

The above discussion of quality of milk has to do with raw milk; the question of pasteurization is taken up later.

The bacteria which find their way into milk are either pathogenic or non-pathogenic bacteria. Disease producing bacteria which may come from the dairy cow are mainly those which cause tuberculosis, mastitis, and organisms which cause intestinal disturbances. Other disease producing microörganisms which may find their way into milk but do not come from the cow are those which cause typhoid fever, diphtheria, scarlet fever, smallpox, etc.

The best means for the prevention of contamination of milk with Bact. tuberculosis is the frequent tuberculin testing of herds. Prevention of infection of milk with typhoid organisms, diphtheria organisms and the human pathogens in general is accomplished by constant care in making sure that attendants are not carriers of

disease organisms and that the utensils, wash water, and surrounding conditions are such that these organisms cannot reach the milk.

The sources of contamination of milk with non-pathogenic bacteria are the udder, feces of the cow, the utensils, and barn air. The average number of bacteria in milk as it comes from the cow's udder is about 500 per cubic centimeter. These are normally harmless chromogenic spherical forms. The bacteria carried into milk by the feces of the cow contain many proteolytic intestinal types and are often gas formers. These organisms or other closely allied organisms are sometimes blamed for intestinal troubles caused by dirty milk. When it is taken into consideration that the feces of cows often contain as high

PLATE 15

After Harding, Wilson, and Smith in (Geneva) N. Y. Bulletin 326.

Types of small-topped milk pails.

as a billion bacteria per gram, it is seen how greatly a small amount of feces may increase the bacterial content of milk. Utensils have been perhaps the greatest offenders in adding germs to milk. Sterilization of utensils has been so incomplete on the farm that they have been the source of much contamination. The milking machine is a piece of equipment which is very hard to keep sterile.

In a speech before the 20th Annual Convention of Dairy, Food, and Drug Officials, Geo. Taylor gives ideas of how high quality milk can be produced on the ordinary dairy farm. He shows that improper washing of cans alone may add from 100 to 235,000 bacteria per cubic centimeter to the milk. He says, "Although the importance of sterilization by steam has long been known, its practical application along simple dairy lines has been neglected. Boilers and pressure sterilizers are too high in cost for the small dairy. Consequently,

terilization of utensils by steam could be expected only from our argest and finest dairies. The milk supply of the country is largely urnished by the small dairy farms.

"There remained, therefore, the necessity of devising some apparatus which would be efficient and yet could be built so cheaply hat it could be used on the small dairy farm. *Farmers' Bulletin* 748, ntitled 'A Simple Steam Sterilizer for Farm Dairy Utensils,' describes n apparatus which will furnish to the small dairy farm the means f sterilizing milk utensils."

Prevention of a large germ content in fresh milk may be accomplished by the selection of cows with udders of low germ content, use f small topped milk pail, steam sterilization of all utensils, by cleaning f cows, and by the exercise of great care by attendants.

The study of the effect of temperature in the handling of milk has hown that a very clean milk with low germ content if not kept cold nay in a few hours become teaming with bacteria. So it is as important from the standpoint of the bacterial count to keep milk cool s it is to prevent its contamination during production and handling.

Pasteurization is the name given to the process first used by Pasteur, of heating liquids for a short time to kill off the greater part f the germ life. He first applied it to wine. Pasteurization of milk s a temperature which has become very important in recent years in hat milk properly pasteurized can be guaranteed free from disease germs. It is a process which is to some extent a cure rather than a prevention of contamination. It has been determined that if milk is eld for thirty minutes at a temperature of 145 degrees F. all disease acteria will be killed. The heating is followed by immediate cooling o 50 degrees F. so that the growth of saprophytic organisms which vere not killed by the heat treatment is checked. There are two general methods of pasteurizing milk; the flash method, and the tank r holding method. The flash method is a process in which milk is aised to a temperature of from 160 degrees F. to 185 degrees F., only or a fraction of a second. This process is not used much for the asteurization of market milk but is used considerably in the manufacure of butter. In the holding method of pasteurization, the milk is eld in a tank at a temperature of 145 degrees F. for twenty to thirty inutes. This method is superior to the flash method for market ilk in that it affects the flavor of the milk less, has less effect on the ream line, and at the same time is more sure in that the temperature s held over a longer period of time which allows of perfect control. n the case of the flash method, should the temperature drop even for n instant, considerable milk goes by without proper temperature reatment.

Bottle pasteurization is a variation of the holding method. In his process the milk is placed in bottles and sealed. The sealed ottles are placed in the pasteurization vat or chamber therefore inuring that each bottle of milk when pasteurized is free from disease erms as it is not opened until the consumer opens it.

Pasteurization of milk has the effect of destroying a certain power which fresh milk has, of holding the growth of bacteria in check from four to eight hours after milking. This power is called "germicidal power," but may be in reality a power to suppress the growth of bacteria rather than to actually kill germs to any extent. Milk sours rather more rapidly after pasteurization than before due to the more rapid growth of bacteria in it. This fact must be taken into consideration, and the milk must be kept cold to prevent rapid bacterial growth. Further, when pasteurized milk sours, it is liable to sour abnormally or to become very high in germ content before it clabbers. Pasteurization kills off a large percentage of the true milk souring bacteria (Streptococcus lacticus). While true lactic acid bacteria are healthful the bacteria which survive pasteurization may not be strictly of this type and for this reason stale pasteurized milk is undesirable.

In the handling of market milk the milk dealer has become a manufacturer as he modifies the milk by clarification, pasteurization, and packaging, and therefore has a manufacturers' obligation to fulfill, that is, he must guarantee quality. In order to do this he has to go back of the delivery of the milk at his plant and know the influence of all the factors above mentioned. He can only do this by studying the conditions in the territory from which his milk is shipped, in other words he must combine dairy inspection, control of conditions of handling milk in transit, and laboratory examination of the milk on arrival at the plant.

The U. S. Bureau of Animal Industry, Dairy Division, suggested the following guide for formulating milk ordinances for cities:

Form of Ordinance.

An Ordinance to Regulate the Production and Sale of Milk and Cream, and for Other Purposes.

'Be it ordained by the ——— of the city of ———, that for the purpose and within the meaning of this ordinance, (a) "milk" is the lacteal secretion obtained from the complete milking of cows: (b) "skimmed" milk is milk from which substantially all of the milk fat has been removed: (c) "certified milk" is milk produced and handled in conformity with the 'Methods and Standards for the Production and Distribution of Certified Milk,' adopted by the American Association of Medical Milk Commissions, May 1, 1912, and amendments thereto, in effect at the time of production, and certified to by a milk commission constituted in compliance therewith: (d) "grade A milk" is milk produced from healthy cows, as determined by the tuberculin test and physical examination within not exceeding one year previously by a qualified veterinarian, from dairies that score not less than ——— on the dairy-farm score card in current use at the time by the United States Department of Agriculture, which milk shall

not, at any time, contain more than ——— bacteria per cubic centimeter: (e) "grade B milk" is milk produced from healthy cows, as determined by physical examination within not exceeding one year previously by a qualified veterinarian, from dairies that score not less than ——— on the dairy-farm score card in current use at the time by the United States Department of Agriculture, which milk shall not at any time contain more than ——— bacteria per cubic centimeter: (f) "pasteurized milk" is milk which has been heated to, and for at least 30 minutes held at, a temperature of approximately 145, never less than 142, degrees F.; (g) "cream" is that portion of the milk, rich in milk fat, which rises to the surface of the milk on standing, or is separated from it by centrifugal force, and containing not less than ——— per cent of milk fat; (h) "homogenized" or "emulsified" milk or cream is milk or cream which has been subjected to the mechanical process of homogenization or of emulsification as the case may be; (i) "unsterilized containers" are containers which either have not been subjected to moist heat at a temperature as high as 205 degrees F. for two minutes or longer, or do not comply with such alternative requirements, to be prescribed by the regulations made pursuant to this ordinance, as may be necessary to effect sterilization thereof; and (j) "person" imports both the plural and the singular, as the case demands, and includes corporations, partnerships, societies, and associations.

When construing and enforcing the provisions of this ordinance, the act, omission, or failure of any officer, agent, or other person acting for or employed by any individual or by any corporation, partnership, society, or assoeiation, within the scope of his employment or office, shall in every case be also deemed to be the act, omission, or failure of such individual, corporation, partnership, society, or association, as well as that of such officer, agent, or other person.

Sec. 2. That no person shall sell or deliver for consumption as milk or cream or have in his possession with intent to sell or deliver for consumption as milk or cream either—

(a) Milk or cream to which water or any foreign substance has been added; or

(b) Milk containing less than ——— per cent of milk fat or less than ——— per cent of solids not fat, or cream containing less than ——— per cent of milk fat, unless such milk or cream is plainly and conspicuously labeled 'Subnormal' together with a statement showing the actual per cent of milk fat contained therein: or

(c) Skimmed milk which has not been pasteurized, or made from pasteurized milk, or which is not labeled 'Skimmed Milk'; or

(d) Milk or cream containing, or which has been exposed to, any disease producing bacteria; or

(e) Milk or cream the container of which is labeled or branded so as to mislead or deceive the purchaser; or

(f) Milk or cream produced from diseased cows, or from cows

during the period of 15 days preceding parturition, or within such time thereafter as the milk is abnormal, or from cows which have been fed unwholesome food or have had access to contaminated water; or

(g) Milk or cream which falls below the requirements of grade B, as defined herein, or milk or cream which has been produced, stored, handled, or transported in any unclean or insanitary manner: or

(h) Milk or cream the retail or the final container of which does not bear a plain and conspicuous statement showing the kind and grade as herein defined; or

(i) Milk or cream in unsterilized containers; or

(j) Milk or cream which such person has kept at a temperature higher than 50 degrees F.; or

(k) Grade B Milk, which has not been pasteurized; or

(l) Homogenized milk or cream, or emulsified milk or cream, unless it is plainly and conspicuously labeled 'Homogenized' or 'Emulsified,' as the case may be; or

(m) Milk which has had the cream line increased by any artificial means.

Sec. 3. That nothing in this ordinance shall be construed to prohibit the sale, when labeled so as to show its true character, of either (a) sour milk or sour cream; or (b) buttermilk or any similar product made from pasteurized milk or cream; or (c) modified milk if made from milk or cream equal at least to grade B.

Sec. 4. That no person shall sell or deliver, or have in his possession with intent to sell or deliver, for consumption as milk or cream, any milk or cream without a permit from the board of health of ———.

Sec. 5. That the board of health of ——— is authorized to make such regulations, from time to time, as are necessary for the efficient execution of the provisions of this ordinance, and to issue permits to sell and deliver milk or cream in ———. The board of health, after affording the permittee an opportunity for a hearing, may suspend or revoke any permit issued by it under this ordinance whenever it shall determine that the permittee has violated any of the provisions of this ordinance or of the regulations made hereunder, and without affording such opportunity, may suspend such a permit temporarily whenever it deems necessary.

Sec. 6. That the board of health of ———, its members, officers and agents, shall, at all reasonable times, have access to any dairy or any other place where milk or cream is produced for sale; to any wagon, truck, train, car, warehouse, or station in which milk or cream for sale is being transported or is being held for transportation or delivery; and to all establishments, plants, depots, or stores where milk or cream is kept or stored for sale. Any person who hinders or prevents such access shall be guilty of a violation of this ordinance.

Sec. 7. That any producer, handler, or seller of milk or cream, whether principal, agent, or employee, who, on demand, refuses to sell or deliver a sample, not to exceed one pint, of milk or cream in his

possession to any official designated by the board of health to collect samples, shall be guilty of a violation of this ordinance.

Sec. 8. That any person violating any of the provisions of this ordinance shall, on conviction by any court of competent jurisdiction, be punished by a fine of not more than ——— dollars, or by imprisonment of not more than ———, or by both such fine and imprisonment, in the discretion of the court; and for each subsequent offense, and conviction thereof, shall be punished by a fine of not more than ——— dollars, or by imprisonment of not more than ———, or by both such fine and imprisonment, in the discretion of the court.

There is no subject concerning which more different opinions have been expressed that this one of milk control. Nevertheless a sound science and practice of safe milk production has been built up. The following testing and inspection has been found to result in satisfactory milk control:

I. Testing and general inspection of animals. This eliminates from milk, disease germs which may be carried by the cow. The tuberculin test is the most important of these tests.

II. Physical examination of dairymen and helpers, and general inspection of the sanitary conditions of farm and methods. This eliminates from milk disease germs which may be carried by humans, flies, water, etc.

III. Laboratory examination of milk at time of its delivery to the consumer. This eliminates both filthy and stale milk from the market.

A number of different methods for the determination of bacteria in market milk have been devised. The oldest and most widely practiced is the plate method of Koch. This method is carried out by adding a known amount of milk to a medium which solidifies upon cooling on a plate. When this solidified medium is incubated each bacterium or clump of bacteria multiplies and becomes a colony visible to the naked eye. These colonies are counted and constitute the plate count when proper consideration is made for the amount of milk plated.

The following information concerning the plate count is in substance the method adopted by the A. P. H. A. For more detailed information the reader is referred to *Standard Methods of Milk Analysis*, published by American Public Health Association, New York City.

The Plate Method of Counting Bacteria in Milk.

The medium used has the following composition:

Agar	1.2% if oven dried, or 1.5% if market agar.
Beef extract	0.3%
Peptone	0.5%
Distilled water	

The reaction of the medium is to be between pH 6.2 and pH 7.0. If necessary to adjust the reaction, special attention is to be given to the H-ion concentration, making use of one of the indicators, brom thymol blue or brom cresol purple.

Three dilutions are to be made in plating; 1 to 100, 1 to 1,000 and 1 to 10,000—unless the quality of the milk is such that the highest or lowest of these is known to be superfluous. In no case are less than two plates to be made from each sample. Each sample bottle and dilution bottle is to be shaken 25 times with an up and down motion of about one foot, in not more than seven seconds. After dilution of the milk, the agar is to be poured into the plates within 15 minutes.

Incubation shall be at 37.5 degrees C. for 48 hours.

The plates used for counting are to have, if possible, between 30 and 300 colonies each. If there are no plates within these limits, the one having nearest to 300 is to be counted. Counting is to be done with a lens magnifying 2½ diameters. The exact counts from each plate are to be recorded, but not more than two significant left hand digits are to be used in making the final report.

Results are to be expressed, not as so many "bacteria per c.c. The practice of publishing counts from individual samples of milk as showing the quality of a given milk supply is not sanctioned, and it is required that a series of samples be examined before rendering judgment in regard to any milk supply."

The following descriptions of the "Breed Method" and the "Frost Method" of counting bacteria are taken directly from the A. P. H. A. "Standard Methods of Milk Analysis" Fourth Edition, 1923.

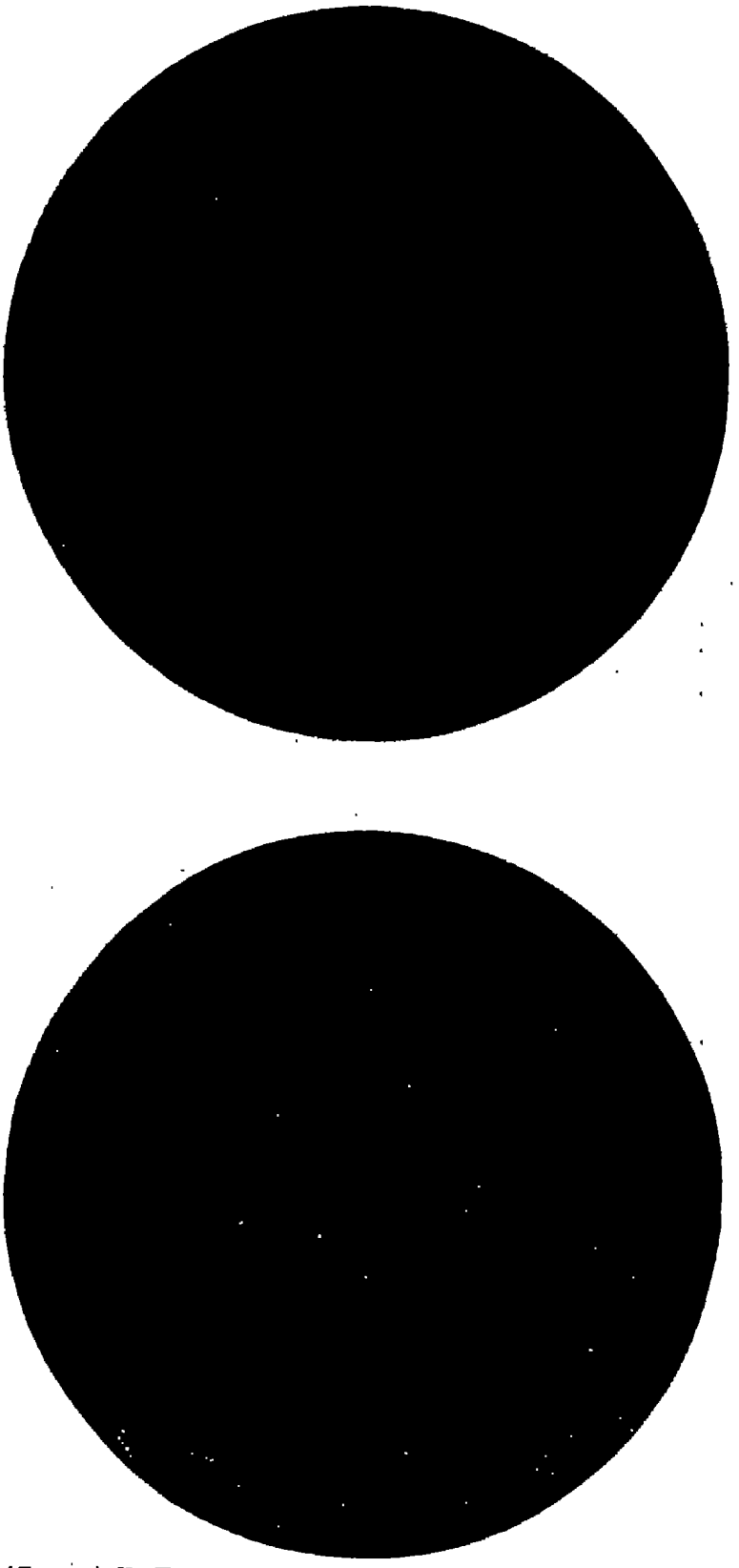
Microscopic Count of Bacteria (Breed Method) Official Method.

Various methods for counting bacteria in milk by microscopic examination have been described, but the method that is commonly described as a direct microscopic examination of a dried film of milk has been found to be the simplest and most reliable method of counting the bacteria as they exist in the milk itself. It is recognized in this report as a standard or official technique of equal standing with the colony count from agar plates where used for judging the quality of unpasteurized milk.

Apparatus Required.

In addition to a microscope, microscopic slides, stains, etc., the only special apparatus required is a capillary pipette which discharges 1/100 cc. of milk. The most satisfactory form of pipette is made from a thick piece of thick walled capillary tubing with a bore of such a size that the single graduation mark is from 1½ to 2½ inches from the tip. The tip shall be blunt and of such a form that it will discharge the milk cleanly without running back on the side of the tip.

PLATE 16



After Brew in (Geneva) N. Y. Bulletin 373.

Breed milk smears as seen under the microscope.

Pipettes of this type are now listed by all of the usual supply houses. The pipettes shall be calibrated so as to deliver 1/100 cc., not to contain 1/100 cc. Because there are many inaccurately calibrated pipettes on the market, the calibration of all pipettes shall be tested by weighing the amount of milk discharged on chemical balances. The weight for milk should be .0103 gram.

Brew discusses the advantages and disadvantages of the microscopic and plate counts as follows:

DISADVANTAGES.

Direct Microscopic Method.

1. Difficult to measure so small a quantity of milk accurately.
2. The sample measured is too small to be representative.
3. Dead bacteria may be counted.
4. Error of count is great where bacteria are very few or many.
5. Cannot be used for quantitative work when the bacteria are few in number.
6. Many fields must be counted, because of the uneven distribution, if an accurate count is required.
7. Large, compact clumps cannot be counted.
8. Bacteria may be lost in process of preparing slides.

Plate Method.

1. All bacteria do not grow on the plates because of changes in food, temperature relations, or other conditions of environment.
2. The difficulty of breaking up the clumps in the milk affects the accuracy of the count.
3. Requires from 2 to 5 days' incubation period.
4. Different species require different incubation temperatures.
5. Gives no idea of the morphology of the organisms present.
6. More apparatus required, therefore more expensive. Technique complicated and difficult for trained bacteriologists to use in such a way as to secure consistent results.

ADVANTAGES.

Direct Microscopic Method.

1. Less apparatus required, therefore less expensive. Technique simple.
2. The results on a given sample can be reported within a few minutes.
3. Shows the cell content, the presence or absence of streptococci and other important things necessary in estimating the sanitary quality of milk.
4. Gives a better idea of the actual number of germs present.

Plate Method.

1. Is necessary for isolation of pure cultures.
2. Gelatin shows the liquefiers and, if litmus is used, the acid-producing bacteria.
3. Shows character of growth.
4. Shows living organisms only.

Only a single pipette is needed in making a series of tests provided this is kept clean while in use. In this kind of work cleanliness of glassware is more important than sterilization. Clean towels may be

used for wiping the exterior of the pipettes while making the microscopic preparations, and their bores may be kept clean by rinsing them in clean water between each sample. The small amount of water left in the bore may be rinsed out in the milk sample under examination. This method of procedure, while adding a small number of bacteria to each sample, introduces only a theoretical error, tests showing that such bacteria cannot subsequently be detected, and make no difference in the final result. After use, the pipettes should be kept in a glass-cleaning solution, such as the commonly used mixture of sulphuric acid and potassium bichromate.

Routine laboratories will find it convenient to use larger microscopic slides than the ordinary 1 by 3 inch slide. The largest slides that have been found to be conveniently examined with the use of a mechanical stage are cut 2 by 4½ inches. Such slides may be stored in ordinary card catalogue cases and may be very cheaply prepared from thin window glass or old photographic negatives. A margin of ground or etched glass on the longer edges of the slide about ¼ inch in width allows lead pencil labeling. The margins may be ground with an emery wheel, or they may be etched with hydrofluoric acid. The cost of these home-made slides ought not to exceed 2 to 3 cents each, whereas the similar slides listed by supply houses usually cost much more than this. A special guide plate (size 2 by 4¼ inches) marked off with 16 square centimeter areas is also needed. This can be obtained from regular supply houses. Only one of these is needed as it is used as a guide plate underneath the slides on which the milk preparations are made.

Preparation of Films of Dried Milk.

After a thorough shaking of the sample, 0.01 c.c. of milk or cream shall be deposited under a clean glass slide by means of the pipette above described. Spread the drop of milk uniformly over an area of one square centimeter by means of a clean, stiff needle. This may be most conveniently done by placing the slide upon the guide plate just described, or upon any other form of guide plate of glass or paper which is ruled in square centimeter areas. The marks showing through the glass serve as guides. After spreading the preparation shall be dried in a warm place upon a level surface protected from dust. In order to prevent noticeable growth, this drying must be accomplished within five to ten minutes; but excessive heat must be avoided or the dry films may crack and peel from the slide in later handling.

After drying, the slides are to be dipped in xylol, or any other suitable fat solvent, for a sufficient time to remove the fat (at least one minute), then drained and again dried. After this, the slides are to be immersed in 90 per cent grain or denatured alcohol for one or more minutes, and then transferred to a solution of Loeffler's methylene blue prepared as follows: Saturated alcoholic solution of

methylene blue, 30 c.c.; caustic potash in a 0.01 per cent solution 100 c.c.

Some of the methylene blue sold since the war has been found to be unsatisfactory in that solutions dissolve the milk films or wash them with an even blue color in which the bacteria fail to show distinctly. In some cases these troubles can be corrected by adding enough sodium carbonate to the liquid stain to make a .01 to .03 per cent solution; but it is better to secure a fresh supply of methylene blue from a satisfactory source. Old or unfiltered stains are to be avoided as they may contain troublesome precipitates.

The slides are to be left in the stain until overstained. They are then to be rinsed in water and decolorized in alcohol. The decolorization takes from several seconds to a minute or more, during which time the slide should be under observation, in order that the decolorization may not proceed too far. When properly decolorized the background of the film should show a faint blue tint. Poorly stained slides may be decolorized and restained without apparent injury. After drying, the slides may be examined at once, or they may be preserved indefinitely.

Standardization of the Microscope.

The microscope used must be so adjusted that each field covers a certain known fraction of the area of a square centimeter. This adjustment is simple if a micrometer slide, ruled in hundredths of a millimeter, is at hand (sometimes called a stage micrometer as it is used under the objective on the stage of the microscope). The microscope should have a 1.9 mm. (1/12 inch) oil immersion lens, and an ocular giving approximately the field desired (for example a 6.4 x ocular). It should also be fitted with a mechanical stage. If the large slides described above are used, this must be a special stage allowing a larger area of the slide to be examined than can be examined with the usual mechanical stage.

To standardize the microscope, place the stage micrometer on the stage of the microscope, and by selection of oculars or by adjustment of the draw tube, or both, bring the diameter of the whole microscopic field to .205 mm. When so adjusted, each field of the microscope covers an area of approximately 1/30000 cm. (actually 1/3028 cm.) This means that the dried milk solids from 1/300,000 part of a c.c of milk are visible in each field of the microscope. Therefore if the bacteria in one field only are counted, the number found should be multiplied by 300,000 to give the estimated number of bacteria per cubic centimeter. In practice, however, more than a single field is examined so that the number used for multiplication is smaller than this.

As the microscopic examinations must be made with greater care where the bacteria are relatively few in number, it is required that, in grading low count milk, a special ocular micrometer with a circular

ruling divided into quadrants shall be used. In using this micrometer, the microscope shall be so adjusted that the diameter of the circle on the eye piece micrometer shall be .146 mm. In this case the amount of dried milk solids examined in each field of the microscope is 1/600,000 part of a c.c. of milk. The limitation of the examination of the slide to the central portion of each field, avoids using the margins of the field where definition is hazy, and lessens the danger of overlooking bacteria. Likewise the magnification used is greater than that used where the whole field is examined.

Counting and Grading Milk.

The number of fields of the microscope to be examined varies with the character of the milk, and with the character of the data desired. Experience has shown that where the purpose is primarily to detect and eliminate the worst milk from ordinary market milk supplies, it is entirely permissible to use the entire field of the microscope for examination. At least thirty representative fields of the microscope should be examined for each sample of milk. Where the average number of individual bacteria (not groups of bacteria) is less than 24 bacteria per 30 fields (⅘ of a bacterium per field), it may be assumed that the milk will ordinarily give an official plate count of less than 60,000 per c.c. Where the number is less than 80 in 30 fields (average of less than 2⅔ per field) it may be assumed that the official plate count will be less than 200,000 per c.c. Where less than 800 per 30 fields (average of less than 26⅔ per field) it may be assumed that the official plate count will not exceed one to two million per c.c.

Where counts are made in order to enforce more stringent standards, as at Grade A plants or as a basis for premiums on milk giving an official plate count of less than 10,000 per c.c. the special eyepiece micrometer described above shall be used and the microscope so adjusted that only the central portion of each field is examined for counting. Where less than 4 bacteria are found in 60 fields (average of less than 1/15 of a bacterium per field) it may be assumed that the milk would ordinarily give an official plate count of less than 10,000 per c.c. The grading of milk of this type must be done with especial care as persons inexperienced with microscopic work have been found readily to confuse extraneous objects with bacteria, in milk containing very few organisms. Where the number is less than 24 per 60 fields (average of less than ⅖ a bacterium per field), it may be assumed that the official plate count will be less than 60,000 per c.c. Where the number is less than 80 per 60 field (average of less than 1⅓ bacteria per field), it may be assumed that the official plate count will be less than 200,000 per c.c. Where a number is less than 800 per 60 fields (average of less than 13⅓ bacteria per field), it may be assumed that the official plate count will be less than one or two million.

The standards given are computed (with the exception of the poorest grades) on the assumption that the official plate count will normally average ¼ of the total number of individual bacteria present. As many cases will be found which diverge markedly from the average, it is self-evident that this average represents only an approximation to the real conditions in any specific case, so that in some cases the microscopic grading will be more severe than that based on the plate counts, and vice versa. There is still a lack of sufficient data from which to judge fairly which system of grading is the more accurate. The indications are, however, that where the work is done with equal skill and care, and the allowances indicated are made, a reasonably close agreement in grade will be secured. This fact is highly reassuring as to the general accuracy of both systems of grading.

In the routine grading of milk by the microscopic method it is not expected that exact counts will be made. A high grade milk will show field after field on the microscope in which no bacteria are seen, while a poor grade of milk will show numerous bacteria in every field examined. It is only where the number of bacteria present is close to the border line between grades that counts need to be made. The examination, however, must be sufficiently thorough to make sure of the grade as specified above.

In order to insure careful work in grading, it is required that laboratories conforming to standard procedure shall preserve microscopic preparations until a reasonable period has elapsed after the reports are rendered to the person or persons whose milk has been examined. It is an excellent custom occasionally to have the grading done by one analyst repeated by a second analyst, particularly in those cases where punitive actions are to be based on the reports made.

Common Sources of Error in Counts.

Routine microscopic counts, like all bacterial counts, are to be regarded as estimates of numbers only. They cannot be made with absolute accuracy even with the most careful technique. Errors will arise from inaccuracies in measurement of the minute quantities of milk examined at any one time, from faulty staining or preparation of slides, from mistakes in observation and the like. These limitations, while important, are not difficult to overcome in sufficient measure to make microscopic grading a satisfactory method of controlling the quality of unpasteurized milk. As it is only in this way that counts of the bacteria themselves can be made, it must be recognized that accurately carried out microscopic counts of individual bacteria give the truest picture of the actual conditions of raw milk that can be obtained with any technique.

Where there is reason to expect the presence of large numbers of dead organisms, as for example in pasteurized milk, it is improper to place reliance upon microscopic counts. Valuable information may,

however, sometimes be obtained by making both plate and microscopic counts from samples of pasteurized milk.

Reports.

As only a few ordinances have yet been adopted in which both official and microscopic count standards have been given, the form of report used will need to be adapted to the circumstances under which each laboratory is working. Specific counts should not be given under normal circumstances, and care should be taken to avoid making finer distinctions in grade than are justified by the accuracy of the grading. A series of samples should be examined in all cases before rendering judgment as to the quality of any milk supply.

Microscopic Colony Count (Frost Method) Provisional Method.

Although this technique is not recommended at this time as a standard of official technique, it is described in this report because of the need for more extensive comparative investigations upon which to base judgment as to its real merits. The technique in question has been described by its author as follows:

"An area of four square centimeters is marked off on an ordinary microscopic slide with a wax pencil. The slide is sterilized in a flame, and then 0.05 (1/20) c.c. of the milk to be examined is placed on it with an accurately calibrated pipette. An equal amount of sterile nutrient liquefied agar, at 42-45 degrees C. is added and the two drops thoroughly mixed with a sterile loop and carefully spread over the area marked off. The mixture is allowed to harden and then a 'little plate' culture is formed.

"The bacteria in the milk are allowed to grow into colonies by keeping the preparation in a moist sterile chamber for a few hours. The period of incubation should be long enough to allow the bacteria to grow into distinct colonies although they may not be visible to the naked eye. In practice it seems best to allow eight hours at 37.5 degrees C. although good sized colonies are frequently formed in four hours. On the other hand, if more convenient, they may be allowed to grow 16 or more hours before they are counted. In order to count the colonies most readily the plates are thoroughly dried at a little less than 100 degrees C., treated with a 10 per cent solution of glacial acetic acid in 95 per cent alcohol, and stained with a methylene blue or carbolthionine solution about 1/4 its usual strength. In this way the colonies are deeply stained while the background is colorless.

"The colonies are counted under the microscope. Usually this can be done with the 16 mm. (2/3 inch) objective, although where the colonies are small or very numerous the higher powers may be used, e.g. the 4 mm. (1/6 inch) or the 1.9 mm. (1/12 inch) oil immersion lens. The factor needed to convert colonies per microscopic field into the number of colonies that would develop per c.c. of milk must be

determined for each microscope and each combination of lenses of the same; but roughly, when a 10 x eyepiece is used, one colony under a 16 mm. lens means 4,000 colonies per c.c. of milk, and the colonies in an average field of a 4 mm. lens should be multiplied by 100,000, and under a 1.9 mm. or oil immersion lens by 400,000. At least five representative fields should be counted and averaged.

"Dilutions may be avoided with milks expected to contain several million bacteria per c.c. by using 0.01 c.c. A drop of sterile milk should be added before mixing with the agar in order that the composition and consistency of the medium may not vary greatly from that used with the ordinary dilution. Some special apparatus has been found to be desirable."

This is essentially an agar plate technique in which the count of colonies can be secured within a shorter period than that used in the standard plating technique. This possibility makes it highly desirable that further studies be made with it. Some comparative counts have already been made by the author, and others who have used the method report to the Committee that they find counts similar to those obtained by the author. The fact that a microscope is used in making the counts has caused some to confuse this technique with that just described as the Breed method. The two are essentially different in that in the one case, the actual bacteria are counted as they exist in the milk, while in the other case the count is a count of colonies of bacteria which have grown either from isolated bacteria or from clumps of bacteria. The counts obtained by the Frost technique, like those from the standard technique ought not to be described as showing the number of individual bacteria originally present in the milk.

Because the counts obtained with the Frost technique do not agree exactly with standard counts, this technique cannot be recommended as a standard technique at present. This fact ought not, however, to be interpreted as expressing a view on the part of the Committee that the counts obtained by experienced workers are any less accurate than those obtained by the standard technique. Very little data have thus been gathered even in comparative studies, and none is of sufficient extent or accuracy to warrant making a mathematical analysis of it in order to establish the true accuracy of the counts.

Microscopic Count of Bacteria. (Allen.)

The Hydroxide Method of Counting Bacteria in Milk. A brass centrifuge tube of 23 mm. diameter with a flat removable screw bottom is used. Place 19 cc. of milk and 5 cc. of a water suspension of aluminum hydroxide in the tube and shake thoroughly. Then drop in a thick cover-glass of 22 mm. diameter and see that it settles to a position flat on the bottom of the tube. Centrifuge sufficiently to throw down the flock in a firm layer on the cover-glass. Immerse the hydroxide film in xylol to dissolve out the fat globules. Next immerse the film in alcohol to remove the xylol. Then dry the film

thoroughly to the cover-glass and stain with aqueous methylene blue or other suitable stain. An average of one organism in the usual 1.9 oil immersion field gives a count of 600 bacteria per cubic centimeter of milk. The centrifuging can be done in the Babcock tester along with butter fat tests.

The cover-glass preparations not only show bacteria but also are ideal for grading the milk as to insoluble dirt content.

Note: The aluminum hydroxide suspension should be of such a dilution that a film of ideal thickness for observation of bacteria in the microscope field is obtained. The flock should be made by bringing together very weak solutions of aluminum sulphate and sodium hydroxide both of which must be pure. The flock should be thoroughly washed by a number of decantations after dilutions with distilled water.

Butter.

Danish butter makers asked Dr. Storch in 1885 to aid them in certain flavor troubles which were current in butter making. He began a series of studies on the germ life in cream for butter making and found that the flavor of butter varies with the kind of germ life in the sour cream. Storch then experimented with a small amount of sour cream as a "starter" in making butter and tried to isolate the ideal cream ripening organism from the finest samples of butter. In this he failed, but later isolated the organism from the best ripened cream of the most successful creameries. The results of his investigations were published in 1890. Soon after this investigation the pure culture manufacture of butter in creameries in the United States began.

The next year Lunde showed that pasteurization at 185° F. in a flash pasteurizer was desirable in that it killed all tuberculosis organisms and at the same time reduced the bacterial life in the cream to a point at which the "butter starter" when added would dominate the fermentation.

H. W. Conn and H. Weigmann during 1890 to 1897 carried on much work which showed to the creamery men that the use of "butter-starters" for ripening cream reduced butter making to a scientific basis. It was this introduction of pasteurization and "butter-starters" combined with the Babcock test, which made it possible for creameries to be successfully established throughout dairy regions and to develop new dairy regions.

Conn held that the aroma of butter is due to the splitting up by bacteria of the nitrogenous portion of the butter, while Weigmann held that the aroma of butter is due to the esters formed during ripening of the cream.

Off flavors in butter have been studied extensively but this subject is found to be a very hard one to reduce to demonstrable facts. The chemist is inclined to hold that rancidity in butter is due to light and oxidation while the bacteriologist is inclined to ascribe rancidity to

bacterial action in butter. C. A. Brown defines rancidity as any chemical or physical change from the normal in the character of the butter fat.

The temperature of pasteurization of cream in Europe is 180° F. while lower temperatures are extensively used in this country. Rogers, Berg, and Davis say that in the continuous pasteurization of sweet cream for butter making, a temperature not lower than 165° F. nor higher than 175° F. should be used. Examination of the butter after storage indicates that pasteurization at 150° F. or lower leaves in the cream some factor causing a deterioration of the butter. The flavors of butter made from cream pasteurized at 180° F. is somewhat affected by heat.

E. S. Guthrie (1917) says as a summary to his experiments with butter that chemical changes in the butter were very slight when biological agents were held in check, that enzymic development produced no rancidity and that exposure of butter fat to high temperatures, light and air, did not cause rancidity. In this work rancidity in butter was considered as a butyric acid flavor.

One of the commonest of undesirable flavors is the fishy flavor. This trouble is thought by some to be due to high acidity and the presence of oxygen. Fishy flavor was attributed by O'Callaghan to Odium Lactis. Weigmann thought fishy flavor was due to overworking and from use of salt high in magnesium.

The production of butyric acid by fermentation was first observed by Marchand in 1840. Some twenty years later Pasteur explained the production of butyric acid from lactose sugar by the following reaction:

$$C_{12}H_{22}O_{11} + H_2O = 4C_3H_6O_3$$

Lactic acid

$$2C_3H_6O_3 = 2H_2 + 2CO_2 + C_4H_8O_2$$

Butyric acid

LaFar says B. Clostridium butyricum consists of a number of closely allied but nevertheless distinct species which produce butyric acid. He says that no sharply drawn line can be made between this group and the potato bacillus.

According to LaFar, Granulobacter, often called the true butyric acid bacillus or B. butylicus, possesses the faculty of storing up within its cells interior granulose. From glucose this organism produces butyl alcohol, carbon dioxide, hydrogen, and butyric acid.

Perdrin says that B. butyricus anaërobically causes with glucose the following reaction:

$$56C_6H_{12}O_6 + 42H_2O = 156H_2 + 114CO_2 + 39C_2H_4O_2 + 36C_4H_8O_2$$

followed by $46C_6H_{12}O_6 + 18H_2O = 112H_2 + 94CO_2 + 15C_2H_4O_2 + 38C_4H_8O_2$ and then simplification of the reaction as follows:

$$C_6H_{12}O_6 = 2H_2 + 2CO_2 + C_4H_8O_2$$

Ice Cream and Ices.

Back in the middle of the eighteenth century in Italy the art of making "sorbetto" was carried to a high point of perfection. The art loving Italians of that period were famed for their tastes for these delicacies. They were made in colors to imitate flowers, fruits, buildings, and statues. Wiley says these dishes were called "sorbetto" in Italy, "glacé" in France and "ices" in England. In this country most frozen dishes are called ice cream.

It is said that Dolly Madison invented American ice cream. Thyra Winslow writing in the *Illustrated World* says that while this is not true, it is no doubt true that the first ice cream served as part of a dinner was at the White House during the administration of President Madison. It is said that the guests were so delighted with the new dish that they all wished to imitate it in their own homes. Since this introduction of ice cream, it has increased in popularity and has grown in use steadily.

Thyra Winslow says that the first ice cream of the Philadelphia type was made in London in about 1800 by a confectioner named Gunton. She says that Gunton's methods of freezing were very crude. Some years later the method of making ice cream was greatly facilitated by the invention of the ice cream freezer by Nancy Johnson, the wife of an American Naval Officer.

Frandsen and Markham in their book on ice cream and ices mention the fact that a New York newspaper, *The Post Boy*, in 1786, contained an advertisement for ice cream. This no doubt was an advertisement for the Neapolitan type of custard cream which was made in the home for years before the introduction of the Philadelphia type.

For many years the Philadelphia type was popular as a delicacy only in the home and only on special occasions. It was perhaps little thought of as having food value. A little later caterers began to use it considerably and by 1850 the wholesale manufacture of ice cream was undertaken in Baltimore. Jacob Fussell, a milk dealer of Baltimore, began to practice using up his extra sweet cream by manufacturing it into ice cream. He succeeded to the extent that he later went out of the milk business entirely and became exclusively an ice cream manufacturer, establishing plants also in Washington, Boston, and New York City.

Brazelton, an employee of Fussell's, a little later, established ice cream plants in St. Louis, Cincinnati, and Chicago. It is interesting to note that J. M. Horton, who died in 1914, bought Fussell's New York ice cream plant. Horton was then a young man of 22. This same ice cream plant was estimated in 1910 at $600,000. Horton left an estate of $4,000,000. These facts give a clear idea of what the ice cream factory of to-day must be to compete in the large city trade.

This enormous ice cream business has been pretty largely developed by use of one type, the Philadelphia ice cream, although the increase

in dairy products has caused many new types to be developed. Ice cream manufacturers must make money and their opportunities for substituting cheap constituents for high priced ones are numerous. A good idea of the situation is obtained by reading the testimony at a Supreme Court Hearing of Dec. 4, 1916. It was testified that "The ice cream of commerce is not iced or frozen cream. It is a frozen confection, a compound. The ingredients of this compound may vary greatly in character, in the number used, and in the proportions in which they are used. These variations are dependent upon the ingenuity, skill, and judgment of the maker, the relative cost at a particular time, or at a particular place.

"Thus some Philadelphia ice cream is made of only cream, sugar and a vanilla flavor. In making other Philadelphia ice creams the whites of eggs are added, and according to some formulas vanilla ice cream may be made without any cream or milk whatever; for instance, by proper manipulation of the yolks of eggs, the whites of eggs, sugar syrup and vanilla bean. All of these different compounds are commonly sold as ice cream; and none of them is necessarily unwholesome. Thus ice cream is shown to be a generic term embracing a large number and variety of products and the use of the term does not necessarily imply dairy cream." However this testimony did not persuade the Supreme Court that there can be no ice cream standard.

The amount of ice cream consumed per year is said to be more than $175,000,000 worth or over 200,000,000 gallons or 40 to 50 dishes for each person per year. In the U. S. the consumption of ice cream has more than doubled during the last ten years. The Southern and Western States like ice cream especially in the summer but in the Northeastern States it has become a winter as well as a summer food.

It seems that the greatest weakness of the ice cream business is the lack of standardization but apparently that is being overcome. As yet no one satisfactory classification of ice cream has been accepted. If ice cream is to become a standard food, its composition must first become standardized.

The term ice cream is so indefinite and includes so many different products that the bacteriology of ice cream is also very indefinite. Some manufacturers take adventage of this fact at present as an excuse for an unsanitary product.

Only a comparatively few investigations concerning the numbers and kinds of bacteria in ice cream have been carried on. Some of these have been made under Dr. Wiley, one by Hammer of Iowa, and one by Ayres & Johnson of the Dairy Division of U. S. Dept. of Agr.

Most authorities agree that ice cream runs about 5 to 30 millions per gram. There is no doubt that if ice cream had a lower bacterial content it would be a better food.

Pennington and Walter in their investigations, reported that the number of bacteria in the commercial ice cream of Philadelphia ranged from 70,000 to 79,800,000 per cc. with an average of 17,833,000.

A report of the City Laboratory of Boston gives 23,000,000 bacteria per cc. as the average count for examinations made in 1906 and 1907. The highest count was 150,000,000 and the lowest was 1,000,000 bacteria per cc.

B. W. Hammer (1912) gives a summary of his investigations on ice cream as follows:

"1. At least some Iowa ice cream is in much the same condition bacteriologically as that studied elsewhere. Ten samples from Des Moines gave 19,920,000 organisms as an average per cubic centimeter. Twelve samples from the college creamery averaged 19,775,000 organisms per cubic centimeter.
"2. After pasteurization cream can be stored at 0 degrees C. for several days with no important increases in the number of bacteria developing on agar at 37 degrees C.
"3. Gelatin may carry enormous numbers of bacteria and some samples probably add large numbers of bacteria to the ice cream made with it.
"4. The vanilla has little effect upon the bacterial content of the ice cream in which it is used.
"5. Sugar properly cared for is usually low in bacteria.
"6. The freezer may be an important source of bacterial contamination of the ice cream made in it.
"7. It is possible to produce ice cream with a low bacterial content in quantities up to 20 gallons without employing expensive or time consuming methods.
"8. The bacteria which develops on agar at 37 degrees C. do not increase in ice cream during storage if the product is kept suitably hardened.
"9. Duplicate bacterial determinations made on ice cream in unbroken containers agree fairly well. With ice cream which has been transferred from one container to another wide variations may be encountered."

Bahlman (1914), from his studies on Cincinnati ice cream, concluded that cream is the source of the great majority of bacteria in ice cream. He says proper pasteurization of the cream and enforcement of regulations as to sanitary production of cream will reduce the bacterial content in ice cream. Pasteurization of the mix just before freezing would bring about a still greater reduction. He further says that the use of pasteurized cream does not affect the taste of the ice cream.

A. B. Gardner in *Ice Cream Trade Journal*, Vol. XI, No. 5, pp. 38-39, gives the following results of bacterial determinations on the mix during ice cream manufacture:

"About 200 gallons of cream, milk, and condensed milk were placed in the 500 gallon tank and agitated for 15 minutes:

"Sample 1. Front end of tank ..... 420,000 bacteria per cc.
2. Rear end of tank ..... 400,000 " " "
Milk and evaporated milk were then added and agitated.
3. Front end of tank ..... 700,000 bacteria per cc.
4. Rear end of tank ..... 650,000 " " "
Sugar was then added and mixed for 15 min.
5. Front end of tank ..... 1,600,000 bacteria per cc.
6. Rear end of tank ..... 410,000 " " "
A small amount of gelatin was added and the temperature was raised to 148° F. for 2 hrs. and 34 minutes.
7. Front end of tank ..... 40,000 bacteria per cc.
8. Rear end of tank ..... 50,000 " " "
From this tank the goods passed into a small tank feeding the homogenizer.
9. Front end of tank ..... 63,000 bacteria per cc.
10. Rear end of tank ..... 26,000 " " "
Samples were then taken from the pipe overflow feeding the homogenizer.
11. Overflow pipe ..... 47,000 bacteria per cc.
12. Tank half empty ..... 20,000 " " "
Pasteurization and homogenization completed ice cream was collected in a service tank from which it was fed by gravity into the ice cream making machines.
13. Front end of tank ..... 16,000 bacteria per cc.
14. Rear end of tank ..... 15,000 " " "
The batch was then cooled to 34° F. and held over night and the next morning samples taken.
15. Front end of tank ..... 10,000 bacteria per cc.
16. Rear end of tank ..... 9,000 " " "
Vanilla was then added.
17. Front end of tank ..... 9,000 bacteria per cc.
18. Rear end of tank ..... 10,000 " " "
Freezing was then begun and samples taken from machines as follows:

Machine 1. 25,000 bacteria per cc.
2. 20,000 " " "
3. ———
4. 10,000 " " "

Ayers and Johnson (1915) divide the bacteria of ice cream into groups as follows:

"Summer Ice Cream.
49.82% Acid Coagulating.
20.72% Acid Forming.
13.98% Inert Group.
1.86% Alkali Formers.
13.62% Peptonizers.

"Winter Ice Cream.
30.84% Acid Coagulating.
38.03% Acid Forming.
4.81% Inert Group.
5.42% Alkali Formers.
20.90% Peptonizers."

In Chicago some years ago the average bacterial count of commercial ice cream was 16,662,134 per cc., the highest count being 125,000,000 and the lowest being 20,000.

At Milwaukee over four-fifths of the ice cream had a germ content of more than 5,000,000 bact. per cc. The highest count was 8,000,000,000.

Wiley in his report states that it is a recognized fact that many cases of violent poisoning which arise from eating cream or ice cream are due to unsanitary conditions surrounding the dairy or ice cream factory, the storage for an improper length of time of these products, and the contamination which they suffer by reason of unsanitary conditions by infection from preëxisting poisonous bodies. The development of ptomain poisoning in cream and ice cream is entirely prevented by using a fresh sanitary raw product, manufacturing it in perfectly clean surroundings and disposing of it within a reasonable length of time after manufacture.

Conn says that instances of ice cream poisoning are common and are probably more easily avoided. They occur almost always in hot weather and are apparently most liable to occur in the hot days that follow a period of cool weather. That they are attributable to certain poisons in the ice cream produced by the growth of bacteria is beyond question. It has been shown that if the milk is kept cool for a number of days the lactic acid bacteria fail to grow; but at these low temperatures other kinds of bacteria do grow though somewhat slowly.

During a period of cool days when there is no demand for ice cream the cream accumulates in cold storage and bacteria which grow at low temperatures become active and increase in numbers. These organisms may produce a quantity of toxic products. If this cream is made into ice cream the toxic products may cause violent intestinal disturbance among those eating the cream. Little more is known concerning the trouble than the facts here stated. The cause is probably the development of toxic germs in cream kept at fairly low temperatures unchecked by the growth of lactic acid germs.

We have already seen that putrefactive bacteria frequently liquefy gelatin. Hence we should be led to suspect any milk that shows large numbers of liquefiers. It is the belief that the bacteria concerned belong to the putrefactive class. Evidently toxic poisoning and the diarrheal troubles are closely related.

Winslow says that in ice cream the germ count is often many times that of milk or cream. It has been found that the bacterial con-

tent of milk or cream will finally go higher at low temperatures than at incubation temperature.

A high bacterial content in ice cream indicates dirty methods or utensils or ice cream stored too long. It has been said that about 25% of the market ice cream contains the germs of tuberculosis. These are not killed in ice cream. Therefore ice cream should be made of cream from tuberculin tested cows or from freshly pasteurized cream.

Chapin writes that a remarkable outbreak of typhoid fever due to eating ice cream occurred in Manchester, England, in November, 1910. There were 108 cases. The makers and the sellers of the ice cream were Italians living in a tenement house in Manchester. Prof. Delephine, who investigated the outbreak, was of the opinion that the ice cream must have been so grossly infected as only to be explained by a multiplication of the bacteria in the materials used after they had been heated and before freezing. Of the 13 persons living in the house with the Italians there were six whose blood gave a positive Widal reaction.

Another typhoid outbreak due to ice cream was reported from Fort Sill, Okla. Here 20 cases were caused by eating ice cream from the neighboring town of Lauton.

Concerning the ability of Bacillus typhosus to live in ice cream, O. W. H. Mitchell says: "The reasons for undertaking the investigation were the occurrence of several epidemics of typhoid fever in which the evidence pointed strongly toward ice cream as the cause although conclusive proof was not secured. In his experiments six mixtures of ice cream were prepared according to common household receipts and typhoid bacilli added in quantities varying from 40,000 to 320,000 bacilli for each cubic centimeter of the mixture. After freezing, samples of 100 cc. of the inoculated ice cream were packed in ice and salt and stored at temperatures varying from — 3° C. to — 4° C. The length of time after which Bacillus typhosus was isolated from the various samples varied from 12 to 39 days."

Concerning the tubercle bacillus content of milk and milk products sold in Leipzig, A. Eber says that 19 out of 70 milk establishments supplied milk containing tubercle bacilli. Out of 210 samples of milk, 22 or 15% contained these organisms; of 150 samples of butter 12%; of 50 samples of cream 6%, and of 50 samples of curd 4%. No tubercle bacilli were found in 150 samples of margarin tested.

Newman says, "Some dozen outbreaks of disease have been attributed to the consumption of ice cream." He mentions three outbreaks of typhoid fever and a case of poisoning with symptoms of ice cream poisoning.

Sedgwick and Winslow collected records of four outbreaks of typhoid fever due to the use of ice cream and another has been reported by Barras.

Trask reports that ice cream was considered as the disease carrier in 3 out of 179 epidemics of typhoid fever investigated.

Buchan writing of epidemics in England describes four epidemics of typhoid fever, one of scarlet fever, three of ice cream poisoning and one of diarrhea as due to the eating of ice cream.

Condensed Milk and Milk Powder.

In 1856 the U. S. Patent Office granted to Gail Borden a patent for the manufacture of condensed milk by "concentrating sweet milk by evaporation in vacuo, having no sugar or other foreign matter mixed with it." While some condensed milk was manufactured on a small scale after 1856, still it was not until 1865 that the value of the new product, condensed milk, was demonstrated to any extent. During the civil war, however, the use of condensed milk in provisioning the army demonstrated the great value of the product. At this time sweetened and unsweetened condensed milk were manufactured but the unsweetened was sold in large cans while the sweetened was to some extent sold in sealed tins. The reputation gained by unsweetened condensed milk was built up on its superior keeping quality as compared with raw milk.

The condensed milk manufacturing business can be built up only in the best favored dairy sections. Hunziker says that where the milk supply drops below 15,000 pounds daily, the profitable manufacture of condensed milk becomes impossible. It is also necessary to have daily delivery of milk at the plant the same as in the market milk industry.

The quality of milk supplied to a condensed milk factory must be uniformly good. When it is considered that milk placed in cans is from several weeks to six months before arriving in the hands of the consumer, it is seen that any faults inherent in the product will have ample time to develop. Also the question of flavor of product becomes very important in marketing condensed milk in sealed cans. The bacterial condition of the milk determines to a large extent the final flavor of the product and also determines the percentage of spoiled cans.

The economic operation of a condensed milk business is of course seriously affected by any increase in loss due to spoiling of cans. Very bad milk will be detected at the condensery. In the hot-well or in the pan it may curdle, whey off, or develop granular material, but these are not the worst problems of the milk condensery. The most serious loss is experienced in the spoiling of condensed milk after it is shipped and has passed into the many channels of trade. The manufacturer must stand this loss and also the damage to the good name of his product.

Like the cheese maker, the manager of a milk condensing factory must go out and size up the conditions under which his milk is produced. He must apply milk quality tests along with the establishment of minimum standards for milk production. He must do this in order to insure uniformity in the quality of his milk supply. Such

rules are generally along the usual lines for the production of good quality milk.

When the milk arrives at the condensery, a man who has a trained sense of smell raises the cover of each can to get the collected odor. By this means much poor quality milk is easily detected. Next an acid test of the milk is made and milk above .2% acidity is thrown out as it would give trouble in the evaporating pan. Another test very often made is the "boiling test," which consists in simply boiling the sample of milk for a few minutes with close observation for slight acid formation. The "sediment test" so much used in the market milk business is sometimes made and in addition a fermentation test, or better the "Wisconsin curd test."

The two main types of condensed milk are: unsweetened and sweetened. The unsweetened condensed milk contains about twenty per cent of sugar due to concentration of milk constituents. Sweetened condensed milk contains about forty per cent of sugar, cane sugar having been added.

The sterilization of unsweetened condensed milk is a much harder problem than the sterilization of sweetened condensed milk. Also the danger of coagulation and caramelization during sterilization is much greater.

Gas-forming bacteria are especially important in the manufacture of condensed milk in that great losses of product after shipment are suffered due to "swelled heads" or cans in which gas-formers develop. When milk is produced under conditions such that it is contaminated with fecal organisms and certain soil organisms the condensed milk made from it is very likely to contain some spore-bearing gas-forming bacteria remaining alive in it. After this condensed milk is sealed up in cans, these gas-forming bacteria begin the production of gas and bulged cans due to gas pressure result. Also proteolytic anaërobes find splendid anaërobic conditions in canned milk and often produce very foul gases from the protein of the milk.

Curdling of condensed milk sold in cans is a frequent trouble. It is considered that this trouble is due to pin holes in the cans which allow the reinoculation of the milk rather than to be due to bacteria which have been carried through the process of condensing.

Bitter curd is another fault occasionally found in sealed condensed milk. The milk is generally curdled and the trouble is thought to be due to bacteria which produce rennet and split the protein of the milk into bitter products as peptones.

Another defect found in condensed milk is moldiness. This is due to improper sealing of the can or to pin holes, as ordinarily mold cannot thrive without the entrance of air into the can.

Powdered Milk.

The manufacture of powdered milk was first conceived in 1850 by Grunwade, an Englishman who patented a process of evaporating milk

in open steam jacketed pans, with continuous agitation. Many methods were devised later for the manufacture of milk powder for the next half century there was no great output of powdered by any method.

In 1899, W. B. Gere and I. S. Merrell invented a double roll which was not fully successful. Later Lewis Merrell, a brother Merrell applied the principle of spraying milk into hot dry a 1906, the Merrell-Soule Company built a powdered milk pl Arcade, New York, in which milk was evaporated in a vacuu and then sprayed into hot dry air.

L. C. Merrell in an address before the American Chemical S 1908, described a process of making powdered milk as follows:

"Fresh whole milk is drawn into a vacuum pan and a por its water removed. This condensation is halted while the r still in a fluid condition and before any of the milk albumen ha cooked on to the walls of the vacuum chamber. The milk i drawn from the vacuum pan and sprayed into a current of h The moisture in the milk is instantly absorbed by the air a particles of milk solids fall like snow. Upon examination, th found to contain less than 2 per cent, and sometimes not mor one-half of one per cent of moisture. The hotter the air the more the drying effect and the less danger there is of injuring th solids by heat."

In discussing the microscopic structure of powdered milk H and Dahle say that "a bubble of air is incorporated in the pa made by the spray method. The inferior keeping quality of process whole milk powder is ascribed to oxidation which is g because of the air inside as well as outside of the particles."

Supplee and Ashbaugh found that the bacteria in powdered decrease as the period of storage lengthens. They say that the scopic method of determining bacteria in powdered milk gives which are fully as uniform as those obtained by the plate metho

Cheese.

There are few subjects in biology or chemistry which hav as many investigations as cheese. In all parts of Europe and A the factors involved in the manufacture of cheese have been st Governments have realized the great value of the cheese indus develop regions remote from centers of population or to furnis high grade food where the land could be of little value exce pasture. Work on cheese has slackened in recent years becau the rapid development of the subject of market milk, ice cream drinks, and condensed and powdered milk.

The modern cheese factory system in this country began in when Jesse Williams of Oneida, N. Y., started the first cheese fa Transportation in country districts was poor in those days. manufacture of cheese fitted finely into our rural development as

is a dairy product which can be stored and marketed at the convenience of the distant cheese maker.

Generally speaking, there are two methods of making cheese, the acid-curd method (in which lactic acid formed by bacteria in the milk causes curd) and the rennet-curd method (in which rennet is used to throw down the curd). The latter method is the more important one in cheese manufacture and hundreds of different kinds of cheeses are made by this general method. These cheeses differ mainly because of the variation in the ripening process. The cheeses made by the rennet-curd method may be divided into two great classes; the hard and the soft cheeses. Hard cheeses are so-called because of the low moisture content as compared with soft cheeses. Cheese, like butter, is classified very largely by flavor and aroma which are derived from the biological and chemical actions taking place during ripening.

Woll in *Dairy Calendar* gives the following analysis of some of the different cheeses.

	Water	*Casein*	*Fat*	*Sugar*	*Ash*
Cheddar	34.38%	26.38%	32.17%	2.95%	3.58%
Cheshire	32.59	....	....	...	4.31
Stilton	30.35	....	....	...	3.83
Brie	50.35	....	....	...	5.41
Neufchatel	44.97	....	....	...	2.99
Roquefort	31.20	....	....	...	6.01
Edam	26.28	....	....	...	4.98
Swiss	35.80	24.44	37.40	...	2.36
Full Cream	38.60	25.25	30.25	2.03	4.07

The control of the quality of milk delivered at a cheese factory is as important as any part of the process of cheese making of the factory. Milk control at the cheese factory is even more important than at the creamery-creamery as pasteurization which has become so useful to the creamery-man has not been so satisfactorily applied to the making of cheese. This is on account of the off flavors caused by making cheese from heated milk and the effect of heat on curd-forming.

One of the most important tests made on milk at the cheese factory is the "Wisconsin Curd Test." In this test the sample of milk to be tested is curdled by rennet. The curd is then cut up so it can free itself from whey. It is then placed in a jar and held at blood heat and observed after several hours. The type of curd at the end of twelve hours tells much about the quality of the milk, as fecal bacteria, ruinous to cheese making, if present in considerable numbers in the milk will demonstrate the fact by gas formation in the curd. The curd in the case of clean milk will be free from gas pockets.

In the manufacture of cheddar cheese the milk is placed in large vats when delivered by the dairymen to the factory. It is then ripened to a proper extent in these vats by holding it at a temperature between 80° to 86° F. until a test shows that a proper acidity has developed. In some cheese factories the "starter" system is used.

A certain amount of pure culture of a desirable lactic acid organism (Bact. lactis acidi) is added directly to the milk after it is tempered in the ripening vats. Much time is saved and more uniform results are claimed for this pure culture method.

When the milk has reached a proper ripeness, that is acidity, rennet is added in amount such as to cause it to curdle in ten to fifteen minutes and to be in shape for cutting up in thirty minutes. In order to know how much rennet must be added to give this effect it is necessary to test out the rennet for strength. Rennet is an enzyme and varies greatly in strength. However, normally, three ounces of rennet is supposed to handle 1000 pounds of milk. Much care is exercised in diluting and in adding the rennet to the milk so that a uniform curd is obtained. After the rennet is thoroughly mixed with the milk, the milk is left perfectly still until a rather firm curd has developed.

The curd is now cut up into small pieces to aid the expulsion or running off of the whey and the contraction of the curd. After thoroughly cutting up the curd it is agitated until the particles are "healed over" as the cheese makers say, that is, the particles of curd have hardened somewhat and particles refuse to stick together.

Slight heat is now applied to the curd particles and the temperature is raised to 98° F., expelling further water and causing further hardening and contraction. In addition bacterial action goes on during this time. A rise of temperature to 98° F. increases this bacterial action greatly, causing greater production of lactic acid and other bacterial products. The heat, the bacterial action, and the increased lactic acid causes the curd to become only half its former size and also to become more tenacious.

The whey is now syphoned off and the curd becomes matted and is cut into blocks which are drained, turned over at frequent intervals, and piled up. Meanwhile bacteria and lactic acid are continuing to increase and the curd becomes more fibrous and elastic until the proper stage for grinding is reached. After grinding the curd, salt is added, which checks bacterial action somewhat. This curd is now pressed into a solid mass in a special press. The pressing takes at least twenty hours with frequent taking up of the press. After completion of pressing, the green cheeses are taken from the press and placed in the curing room, which is usually held at about 70° F.

The changes which go on during the ripening of cheese are not simple, and several different theories have been advanced as explanations.

Duclaux in 1882-1894 investigated the cheese ripening phenomena in French cheese factories making Cantal cheese. His investigation was carried on before the introduction of pure culture methods so that his work was not done with pure cultures. He found in cheese long spore-forming bacilli, Tyrothrix, which digested the casein. He explained cheese ripening by concluding that these bacilli caused the

chemical breaking down of the casein. The proteolytic enzyme secreted by Tyrothrix was named casease.

Adametz, an Austrian, published the results of his work on cheese in 1889. He was one of the first to work on cheese after the innovation of the plate method of obtaining pure cultures. This fact made his work very important at this time as he outlined the flora of cheese quite definitely. He found 90% of the organisms of cheese to be lactic acid forming organisms.

Freudenreich working at the same time as Adametz, 1889, studied Emmenthaler cheese near Berne, Switzerland. He reported that the peptonizing group of bacteria in cheese are checked by the lactic acid produced in cheese making, and that the flavor of cheese is due to the lactic acid group of organisms. He held that the lactic acid bacteria are unable to attack the casein in the presence of free lactic acid, but that a condition occurs in cheese in which the acid becomes bonded with other cheese constituents and then these lactic acid bacteria are able to break down the casein. Freudenreich no doubt was working with organisms similar to B. bulgaricus which he found could peptonize casein whenever he added chalk to the media and he considered this alkaline condition of the media to be similar to that condition existing in cheese during ripening.

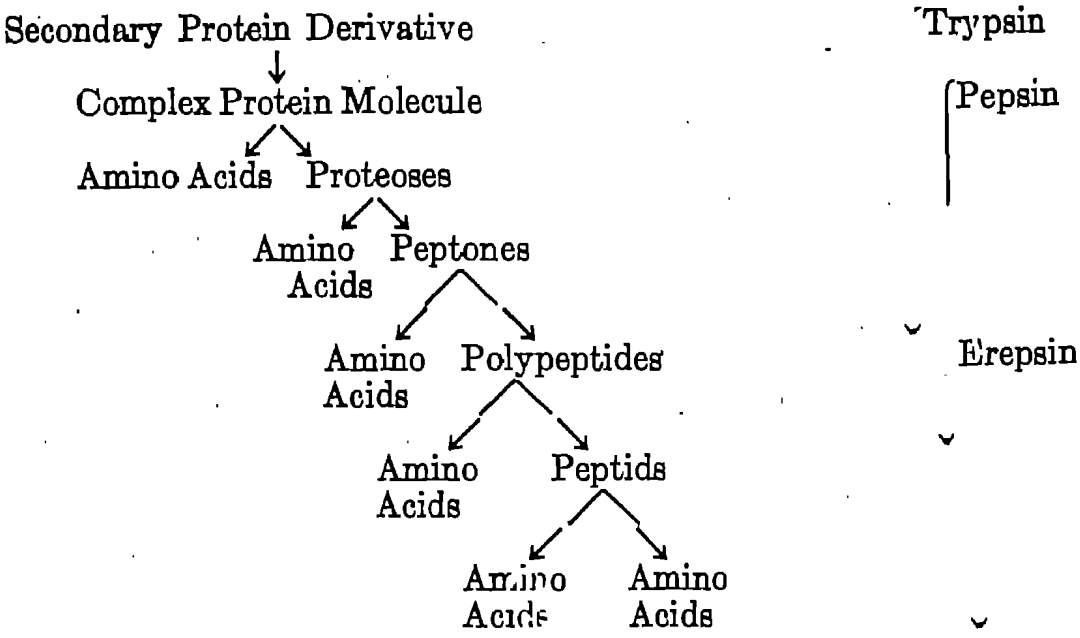
Babcock and Russell in 1897 published their work on cheese ripening. Enzymes exist in the milk of all mammals and in cow's milk they found an enzyme which they called galactase. They held that this enzyme is the cause of cheese ripening and showed that milk in which this enzyme has been destroyed by heat will not make satisfactory cheese. They also placed chloroform in milk thereby checking bacterial action but still found that casein was slowly digested. This fact showed enzymatic action instead of bacterial action on protein. According to Russell the bacterial flora of old ripened cheese is composed of about 99 per cent members of the Bacillus bulgaricus group.

Gorini, an Italian bacteriologist, published results on cheese in 1902 in which he held that the group of bacteria which form lactic acid and attack protein, form digesting enzymes which are the cause of cheese ripening. His work was done on Italian cheese at Milan.

Harding and Prucha worked on cheese ripening at Geneva, N. Y., 1900-1910, and concluded that the digestion of the casein of cheese during ripening is due to the collective action of native enzymes of milk, bacterial enzymes, and rennet action.

The protein decomposition in cheese ripening is in general a normal protein splitting. This splitting of the casein cheese is very valuable from the food standpoint as the protein products are far more digestible than the original protein. That rennet contains the enzyme pepsin and that this pepsin is a factor in cheese ripening is proven beyond a doubt by Babcock and Russell.

Kruse says that casein digestion may occur as follows:



The amino acids break up into hydroxy acids and NH_3.

The acid condition of cheese caused by the continual action of lactic bacteria on the residual milk sugar in the curd is an ideal condition for the action of the enzyme pepsin and natural proteolytic enzymes of the milk which Babcock and Russell have called galactase. That the ripening process in cheese follows along lines of natural protein splitting is shown by the increase of ammonia during cheese ripening and the increase in the higher fatty acids, propionic, butyric, and caproic acids. Flavor and aroma are considered to be due to the products of fermentation of the residual milk sugar. So delicate is the production of flavor and aroma that slight changes in condition of manufacture of cheese make distinct variations in flavor and aroma. The characteristic flavors and aromas of cheese do not occur until the ripening of the cheese is well along.

The most common trouble in cheese making is "floating" or "gassy curd" caused by an overwhelming number of gas forming bacteria belonging generally to the fecal group of bacteria. These bacteria get into the milk from filthy conditions in the cow stable. The most common type of bacteria found in such milk is B. coli aërogenes. The remedy is pains and cleanliness in milk production. To prevent continual trouble it is necessary for the cheese maker to keep in constant touch with the conditions under which his milk is being produced.

Occasionally chromogenic bacteria get into milk in such numbers that they dominate the flora. Such milk in cheese making will cause colored cheese or cheese with specks of color.

Bitter cheese has been found occasionally to be due to bacteria causing the formation of a bitter principle as peptone.

Cheese will become putrefactive if certain proteolytic anaërobes are favored by a low acidity in the curd.

Milk Beverages.

Milk beverages consist of fermented milk. They apparently are as old as the custom of herding. The reason for this early use of the custom of fermenting milk was to protect it from putrefaction. Milk well fermented by lactic acid organisms cannot be attacked immediately by proteolytic microörganisms. Also it was found that these fermented milks were healthful.

Yogurt is one of the well known milk drinks of the Bulgarians. The great length of life of many of the people of Bulgaria is attributed by Metchnikoff to the importance in their diet which they give to these fermented milk drinks. Metchnikoff made an intensive study of the people of Bulgaria, their use of this drink, and of the microorganisms found in it. From this study he formulated a very interesting theory of the cause of their longevity.

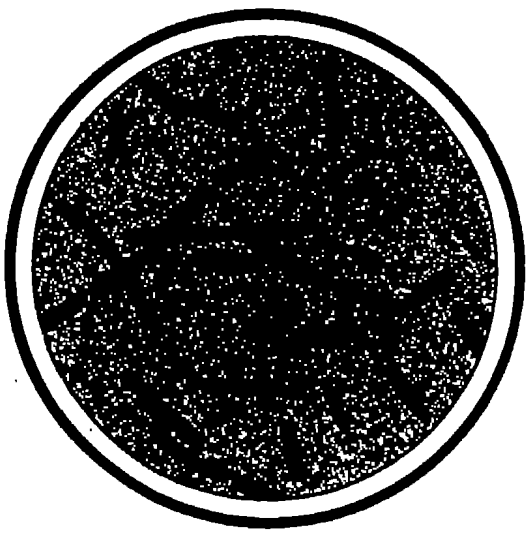


FIG. 57.—Microscopic appearance of culture buttermilk. The smaller organisms in chains are Str. lacticus. The rodlike organisms are Bacillus bulgaricus.

He found that Yogurt has a bacterial flora consisting mainly of a large microörganism called Bacillus bulgaricus. It has the ability to produce lactic acid in milk to the extent of 2% to 3%. When it is remembered that ordinary milk-souring bacteria are unable to raise the acidity of milk to more than .5% to .9% acidity it is seen how distinctly this fermented milk differs from ordinary sour milk.

It has been known by the medical profession for years that perhaps the greatest cause of shortening of life is autointoxication. The poisoning of the human system by the products of abnormal fermentation of protein in the intestines is thought to be more or less a common occurrence. From the fact that proteolytic decomposition is held in check by an overwhelming lactic acid flora, Metchnikoff reasoned that the Yogurt drinkers of Bulgaria benefit by the lactic acid bacteria and the lactic acid of Yogurt in that it keeps the in-

testines in somewhat of an unfavorable condition for the activities of proteolytic bacteria.

Along with B. bulgaricus and B. paralacticus there are also yeasts in the flora of Yogurt.

The inhabitants of the Caucasus Mountains make a fermented milk which they call Kefir. The drink is made by adding "Kefir Grains" to new goat's milk. According to the studies of Freudenreich, "Kefir Grains" consist of three species of bacteria and an alcoholic yeast. He found a streptococcus, a micrococcus, and a bacillus associated with the yeast. Kefir grains when not in use are taken from the milk and hung up to dry until they are used again. The origin of the Kefir grains is unknown but the natives of the mountains believe that they represent a gift from Mahomet.

Kern in his study of Kefir found the yeast to be Saccharomyces cerevisiæ. He says that, as for the bacteria, they form the principal mass of the bodies and occur in a zoogloea condition. The vegetative bacterial cells are 3.2 microns to 8 microns long and 0.8 of a micron broad. In preparations prepared through drying he was able to recognize a distinct cell membrane. When exposed to the influence of acids of high temperature, or of desiccation, the vegetative cells grow apparently through progressive cell division into long Leptothrix threads which ordinarily precede spore formation. The spores are round, appear in duplicate in each vegetative cell, and are always at the end. No division wall can be seen between the two spores. In the Leptothrix thread, series of spores are to be observed, which, however, are always so arranged that in each cell two spores occur. The spores which are still in the cell have a size of 0.8 micron, those lying free the size of 1 micron, and the germinating swollen spores up to a size of 1.6 micron. The germination of the spores takes place ordinarily in such a way that one can always recognize an exosporium and an endosporium. Out of the thicker exosporium there appears the thinner endosporium, first as a small wart, which gradually increases in size forming itself more and more to a long cylindrical tube and then begins to transform itself through cell division into vegetative cells.

Kefir is used by the mountaineers not only as a food, but is also applied as a medicine in connection with different diseases. As a ferment in the production of these drinks they use peculiar white bodies which have a spherical or elliptical form and reach a size between one millimeter and five centimeters.

Kumiss is a Russian drink which has been made for centuries by tribes living along the Kuma River. This drink is slightly alcoholic, containing about 1% alcohol. It is made from mare's milk by the action of lactic acid bacteria and a lactose fermenting yeast. The acidity of Kumiss is about the same as that of ordinary sour milk and the organism causing the lactic acid fermentation is thought to be the same as that of ordinary sour milk. However, it is considered by some that the acid and alcoholic fermentation in Kumiss is a

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symbiotic action, that is, the two different organisms are somewhat dependent upon each other. In investigating this milk, Freudenreich found that the yeast was not a beer yeast and could not attack lactose, but took the by-products of the lactic acid fermentation as a basis for the production of alcohol.

Leben is an Egyptian drink made from cow's milk or goat's milk, and sometimes from the milk of the buffalo. It does not differ greatly from Kumiss as its flora is made up of yeast and bacteria.

Country buttermilk has had quite a sale in some parts of the United States due to its recommendation by physicians. However, since Metchnikoff's work on Yogurt and similar fermented milks there has developed quite a consumption of "culture buttermilk" which is made by fermenting milk with either Bacillus bulgaricus or a combination of the Bulgarian bacillus and the lactic acid organism used in ripening cream in butter making. This product is easily made in the ordinary market milk plant or creamery by taking good pasteurized milk, inoculating it, and holding it at a constant temperature of 37° C. or below. In 12 to 24 hours the milk should become uniformly viscous, should have a pleasant, clean, sharp odor and should not have any whey standing on top of the curd. Many makers practice agitation during the fermentation.

Acidophilus Milk.

The study of the normal and the abnormal intestinal flora of human beings and of lower animals has been widely carried on for the last fifteen or twenty years. It now appears that some very important information is the result.

The relationship between diet, intestinal flora, and physical condition has been made the subject of many studies. Much has been written in the last few years by public health authorities concerning the elimination of disease germs. At the present time many authorities are coming to the conclusion that it is not only necessary that certain germs be prevented from entering the body but that certain other germs should always be present and in great numbers. Emphasis is being placed upon the fact that the maintenance of a fit physical condition in man or in the lower animals requires as much thought as the treatment of the sick.

While many scientists object to some of the evidence and many of the conclusions which Metchnikoff gave in his book, "The Prolongation of Life," still we have to admit that Metchnikoff set a high aim for himself when he undertook to find out how to make the average human life both longer and stronger. His studies certainly have inspired other men to greater efforts in this direction.

Metchnikoff's theory of longevity was unique in that it was a bold interpretation of a few well known facts. His theory was originally inspired by his observation of the large number of old people who were found among the inhabitants of the Balkan States. In searching for

an explanation of the presence in the Balkan States of numerous persons of great age his attention was drawn to their habitual diet of fermented milk. He was familiar with the high acid producing Lactobacillus bulgaricus later described by Massol but he knew nothing of the Lactobacillus acidophilus first described by Moro and later divided into types by Rahe (1918). Metchnikoff found that the fermented milk of the Bulgarians was teeming with an organism which has come to be known as Lactobacillus bulgaricus. Because of the enormous number of this organism in Bulgarian fermented milk which had constituted a considerable part of the lifetime diet of these centenarians, Metchnikoff concluded that their longevity had been due to the prevention of intestinal putrefaction which he believed resulted from the presence of Lactobacillus bulgaricus and the products of its activity.

The fact that the presence of organic acids preserves proteins has long been a familiar one, well illustrated in the keeping of silage, sauerkraut, pickles, etc. In the human intestines the conditions for the rapid growth of putrefactive bacteria are very favorable as to temperature, food, and reaction. Metchnikoff was of the opinion that the considerable length of the human intestines was primarily for the benefit of primitive man who because of the coarse foods which he ate, needed a large absorptive surface. He believed intestinal putrefaction in primitive man was to a considerable extent prevented by the very coarseness and low fermentability of his food. However, in the case of modern man with his ever increasing tendency to use more concentrated foods and at the same time to become more sedentary in his habits the long intestine becomes a grave factor in his life. The Federal statistics showing that organic break down due to systemic poisoning is on the increase seem to bear out Metchnikoff's reasoning.

Metchnikoff, in his work and in his thinking, seemed to take it for granted that the Lactobacillus bulgaricus established itself in the intestines of people using Bulgarian fermented milk as a part of their daily diet. However, the weight of evidence accumulated in the last ten years seems to indicate that this organism does not become the predominating intestinal flora even of people who use Bulgarian fermented milk as a part of each meal.

At the University of Illinois in 1915, the author carried on a series of experiments with the idea of determining to what extent the Lactobacillus bulgaricus is able to implant itself in the intestines of people who make a custom of using Bulgarian fermented milk in their daily diet. The feces of twelve students were plated for the presence of this organism at the beginning of the experiment with negative results. Following this test these men were each fed two quarts of Lactobacillus bulgaricus fermented milk daily for six days. At the end of this period, by plating in milk serum agar, it was possible to isolate the organism from the feces of only one man of this group. Many other experiments before and since have resulted in the same facts.

Following Metchnikoff's work and book there was much attention

called to the relation between intestinal flora and health. Douglas, an Englishman, wrote a book which he called "The Old Age Bacillus." He referred to Lactobacillus bulgaricus discussed by Metchnikoff. In America, Herter, Rettger, Cheplin, Torrey, Coleman, Kendall, Bass, and others have contributed largely to the subject of intestinal flora.

In a piece of work in which white rats were used as the experimental animals Rettger found that intestinal flora of these animals shifted as the type of diet changed. It was found that dextrin, lactose sugar, and starch when taken in sufficient amounts tended to help establish a flora of Lactobacillus acidophilus.

Concerning the natural flora of the human intestines it has been established that at birth they are sterile. But during breast feeding the intestinal flora becomes typically B. bifidus and B. acidophilus. When breast feeding is substituted by the use of cow's milk the flora of the intestines changes and members of the coli group and of putrefactive groups appear while B. bifidus and B. acidophilus tend to disappear. This change is thought to be due to the fact that in mother's milk the high milk sugar content causes undigested lactose to appear throughout the intestinal tract thus favoring the growth of L. acidophilus.

Kendall says, "The types of bacteria which constitute the normal fecal flora of the nurslings are few in number and definite in their chemical characters. The most prominent of these, B. bifidus, so-called because of its developmental peculiarities in artificial media, is a strict anaërobe. Other organisms, the so-called Kopfchen bacillus, B. coli, B. lactis aërogenes and Micrococcus ovalis, are as a rule, very much fewer in numbers than B. bifidus, and under normal conditions, appear less important. The question arises, why should an obligate anaërobe, as B. bifidus, dominate the nursling's intestinal flora? It must be remembered that breast milk, which is the normal diet of the nursling, consists monotonously of about 7 per cent of lactose, about 3 per cent of fat, and but 1.5 per cent of protein. Consequently the intestinal tract of the infant under ordinary conditions is practically continuously bathed in a nutrient medium containing at all times at least a minimal amount of sugar. The normal infantile feces is always slightly acid in reaction and this acid is lactic acid chiefly. It is a significant fact that the dominating organism, B. bifidus, is a lactic acid-producing microbe. It is also a significant fact that the reaction of the normal nursling's feces is acid enough to inhibit the growth of practically all putrefactive bacteria; there are few or no putrefactive bacteria in the normal infantile feces. This infantile flora, furthermore, appears to be a protective one in the sense that it inhibits the growth of bacteria which might produce either putrefaction or disease. These latter organisms are somewhat intolerant of lactic acid. It may be remarked parenthetically that one of the first indications of intestinal disturbance in infants is the temporary or even permanent disappearance of this lactic acid flora.

The following descriptions are from R. C. Fisher's work given in *Storrs Agr. Experiment Station Bulletin* 104, 1919:

Cultural Characteristics.

I. BACILLUS BIFIDUS.

1. *Source:*—
   Feces of breast-fed infants.
2. *Morphology:*—
   a. Cell form:
      Slender bacilli on lactose broth at 37° C.
   b. Characteristic cell grouping:—mostly as individuals or paired.
   c. Irregular form:—
      Quite frequently curved or bent in shape of comma. In lactose broth after 24 hours a bifid form was quite common.
   d. No flagella.
   e. Spores:—doubtful.
3. *Staining:*—
   Gram-positive.
4. *Physiology:*—
   a. Temperature best at 37° C.
   b. Anaërobic.
   c. No characteristic odor.
   d. Production of H_2S:—No definite indications after 4 days.
   e. Production of Indol:—No result after 4 days.
   f. Production of Pigment:—None—whitish gray colonies.
   g. Reduction of nitrates:—No definite result—mostly negative.
   h. Action on plain milk: Coagulates cow's milk, but does not coagulate human milk very readily. Has slight digestive properties.
   i. Action on litmus milk:—Acid reaction.
   j. Action on dextrose, lactose and sucrose broth:—In all three there was an acid reaction. Production of acid was most rapid in dextrose and lactose broth.
5. *Cultural characteristics:*—
   Bacillus bifidus grows best on dextrose or lactose agar of slightly acid reaction. It also made good growth in lactose bouillon. There was no surface growth.
   The colonies were very slow-growing, and only after three or four days could the tiny white lens-shaped smooth-edged growth be noticed when grown on an acid lactose agar.
   The study of the organism on plate cultures was very difficult because of their anaërobic properties. The morphology varied considerably from time to time. Sometimes difficulty was experienced in distinguishing *Bacillus bifidus* from another anaërobic form known as *Bacillus acidophilus*.

The two frequently occurred together in the various cultures.

To distinguish between the two, tests for production of acid in milk were usually used.

II. *BACILLUS BULGARICUS.*

1. *Sources:*—
   a. Fresh whole milk:—
      Milk directly from the cow was incubated for 18 hours at 21° C. and then for 48 hours at 37° C. This allowed at first the rapid development of the ordinary lactic acid organisms inhibiting the coli or other gas forming types. At the higher temperature and in the presence of the lactic acid already developed the *Bacillus bulgaricus*, if present, rapidly developed. With three to five consecutive inoculations practically pure cultures were obtained.

      Another method was to add about 0.75% lactic acid to the milk at the start and then incubate at once at 37° C.
   b. Commercial cultures:—
      Cultures were obtained from several commercial concerns.
2. *Morphology:*—
   a. Cell-form: Characteristic long slender bacilli after 48 hours incubation at 37° C. in lactose broth.
   b. Cell-grouping:—Mostly as individuals or as overlapping threads.
   c. No flagella.
   d. Capsules:—Doubtful.
   e. No spores.
3. *Staining:*—
      Gram positive: on staining with methylene blue they frequently show granules in the cell.
4. *Physiology:*—
   a. Temperature—Best at 37 to 45° C.
   b. Facultative anaërobes.
   c. Production of H_2S:—None.
   d. Production of Indol:—None.
   e. Production of Pigment:—None.
   f. Production of Nitrates:—Slight in milk.
   g. Enzymes:—Doubtful.
5. *Cultural characteristics:*—
   a. On broth:—Very meagre growth in medium after 36 hours.
   b. On plain agar:—As a rule colonies resemble typical *B. tetani* colonies.
   c. On dextrose or whey agar:——Slight growth deep in culture tube after about three days incubation. Colonies are almost microscopical in size and show radiating threads. They resemble *Bacillus bifidus* as tiny white lens-shaped colonies

except that they are rather saw-edged instead of smooth edged like the *Bacillus bifidus*.

d. Action on plain milk:—Forms a homogenous curd coagulating the milk in 4 to 24 hours.

e. Action on dextrose, lactose and sucrose broth was characteristic by formation of acid and no gas. Action is most rapid on dextrose and lactose broth.

Acidophilus milk in the last few years has come into use in at least two important ways: as a preventative or inhibiting agent of chronic intestinal putrefaction and as an aid in the treatment of typhoid fever to reduce tympanitis and diarrhea. Torrey and Coleman of Cornell Medical College both speak highly of its value in the treatment of typhoid fever.

It is thought by some that the acid product of L. acidophilus is not the only factor in the prevention of the activities of putrefactive bacteria in the intestinal tract. It has been suggested that some principle as that of bacteriophage, that is, specific lysis, is operative in the intestinal tract of breast-fed infants.

There are four types of Lactobacillus acidophilus as differentiated by their reaction in sugar broths as follows:

	Maltose	*Dextrose*	*Lactose*	*Sucrose*	*Raffinose*
Types A	+	+	+	+	+
B	+	+	+	+	—
C	+	+	—	+	—
D	+	+	—	—	—

The following is a description of B. acidophilus as given by Fisher:

BACILLUS ACIDOPHILUS:—

1. *Sources:—*
   a. Feces of breast-fed and bottle-fed infants.
   b. Patients on milk diets.
2. *Morphology* (very similar to B. bulgaricus):—
   a. Cell-form: long, slender bacilli in milk or acetic acid broth.
   b. Cell grouping: mostly as individuals or as overlapping threads.
   c. No flagella.
   d. Capsules:—Doubtful.
   e. No spores.
3. *Staining:* gram-positive.
   Old cultures may show several gram-negative bacilli.
4. *Physiology:—*
   a. Temperature best at 37-45° C.
   b. Anaërobic.
   c. Production of H_2S:—None.
   d. Production of Indol:—None.
   e. Production of Pigment:—None.

f. Production of Nitrate:—Doubtful.
g. Enzymes:—Doubtful.

5. *Cultural characteristics:*—
   a. On broth:—Little or no growth on ordinary broth but does well on acetic acid broth.
   b. On plain agar:—As a rule colonies resemble typical colonies of *B. tetani.*
   c. On dextrose or whey agar:—Slight growth deep in culture tube after about 3 days incubation.
   d. Action on plain milk:—Forms a homogenous curd coagulating the milk in 24 to 36 hours.
   e. Action on dextrose, lactose and sucrose was characterized by formation of acid and no gas. Action is most rapid on lactose and dextrose broth.
   f. Implanted organism can readily be recovered from feces where patient is fed on milk diet; in this it differs from the *Bacillus bulgaricus* which as a rule cannot be recovered from the feces.
   g. Amount of acid formed in milk:—The presence of free acid did not inhibit its development. Did not form acid as rapidly as *Bacillus bulgaricus* nor was its maximum acidity as high. Acidity varied from 0.6% to 1.9% in different cultures.

The cost of acidophilus milk has been very high, selling in some places for more than a dollar per quart. The preparation of the milk according to the method of Rettger and Cheplin is necessarily expensive because of the great care used. Bass, on the other hand, in the *Journal of the American Medical Association,* says: "The cost of acidophilus milk produced in this way and the difficulty of obtaining it may not be prohibitive when it is to be used for therapeutic purposes in the treatment of definite diseases, especially during the period of enthusiastic use of this therapeutic agent. However, if the drinking of acidophilus milk accomplishes the transformation of the intestinal flora, and greatly reduces or entirely prevents the growth of putrefactive bacteria in the intestinal canal, as we now believe it does then there is a great need for a much larger supply than is now available for general use. If it is beneficial as a remedy for diseases and conditions caused by harmful intestinal bacteria, it should be still more useful to maintain healthful conditions and to prevent the development of these diseases and abnormal conditions. Prevention of such diseases and abnormal conditions, is more important than cure."

"Acidophilus milk should cost little more than other kinds of 'buttermilk' if manufactured on a large scale. When produced, handled and distributed in a commercial way there is necessarily likely to be present a few other bacteria introduced in the handling and bottling but these are the same kind of bacteria that are present in hundreds of times greater numbers in other milk and milk supplies, and are

negligible so far as the present purpose is concerned. Stained preparations of such milk appear to be pure cultures of Bacillus acidophilus, but plate cultures usually show a few other bacteria."

Method of making acidophilus milk by Bass:

"(1) The temperature of a tank of skim milk is raised to from 190 to 195° F.
(2) It is held at about this temperature for one hour.
(3) It is cooled down to about 98° F.
(4) It is held at about this temperature for three to four hours.
(5) The temperature is again brought to from 190° to 195° F.
(6) It is held at about this temperature for one hour.
(7) It is cooled down to 98° F.
(8) It is inoculated with a pure culture of Bacillus acidophilus, in milk about 1 quart per hundred gallons of milk.
(9) It is held at about 98° F. until the milk is firmly coagulated and the desired acidity has developed.
(10) It is broken up by means of the mechanical agitator.
(11) It is cooled.
(12) It is bottled.
(13) It is distributed, or stored in the refrigerator room."

Bass says, "A pure culture of Bacillus acidophilus in milk is necessary for the inoculum. It must be a strain that grows well in milk. It is produced by inoculating quart bottles of milk sterilized in the autoclave, with 10 cc. of fresh culture, followed by incubating at 98° F. for twenty-four hours.

"In such inoculum there are from 700,000,000 to 1,000,000,000 bacilli per cubic centimeter, and it is good for a period of four or five days after which time the number of noble bacilli rapidly diminishes. Its keeping is not improved by refrigeration."

Rettger says, "Many dairies and milk producing concerns have undertaken to produce acidophilus milk and have failed." He says that successful production requires:

(1) A selected strain of acidophilus.
(2) Bacteriological laboratory facilities.
(3) Careful technique.
(4) A supply of fresh high grade milk.
(5) Proper equipment for incubation.
(6) Painstaking operator.
(7) Exact cooling equipment.
(8) And above all absolutely pure culture must be furnished for each package or batch.

Note: This pure culture must be continuously reisolated by plate media method.

It seems that the reasons for Rettger's exact requirements for making acidophilus milk is that the rate of multiplication of organisms

in milk other than L. acidophilus is so much more rapid that unless the acidophilus organism has a medium free from rapid growing germs it will be smothered out by its biological environment.

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Chapter 31.

The Microbiology of the Soil.

American agriculture has passed through several different phases in each of which different practices were required. W. J. Spillman in discussing the different steps in agricultural development in the U. S. says:

"In order clearly to comprehend our present position, it is necessary to review briefly the logical steps in agricultural development. In the settlement of a new region the pioneer farmer brings with him seeds of those crops he cultivated in his former home and the live stock he deems necessary in his new situation. In a few years he has learned which of these crops are best adapted to the new environment of soil, climate, and market facilities. Then follows the rapid development of a type of farming based on one or two crops for which there is a cash market. (In regions where transportation facilities are not favorable some form of livestock farming is usually followed until transportation lines are open, but in new regions the manure from the stock is ordinarily not made use of, so that the keeping of the live stock is of no importance from the standpoint of the maintenance of soil fertility. Where transportation facilities are available, the development of an exploitive type of grain farming is coincident with settlement.) The new soil is rich and for one or two generations is believed to be inexhaustible. It is therefore exploited of its fertility and a general change of system is instituted only when waning yields begin to bring failure to the less progressive element in the community. When this period is reached a new problem arises. Single-crop farming requires little capital. A dwelling, a few work stock and a modest shelter for them, a little fencing, and a moderate equipment of farm implements represent the necessary capital of the grain farmer in addition to his investment in land, and the last has usually been a gift from a generous nation.

"To change to a more conservative type of farming requires large expenditures for new equipment. Money must be invested in live stock, new buildings must be erected, fences built where none were needed before, and new types of machinery must be bought. Recent studies by this Department indicate that on well-organized stock farms in the Middle West the amount invested in farm buildings, exclusive of the farm dwelling, amounts on the average to $9.27 per acre for the whole farm, while the cost of fences represents $4.60 per acre. These two items alone, therefore, represent an outlay of about $2,220

on a 160-acre farm. The major part of this expenditure must be met when the farm changes from grain growing to stock farming. The investment in live stock itself on such a farm represents another sum nearly as large as the above. In addition, more labor is required, and this labor must be more intelligent and more reliable. Hence the change from an exploitive to a conservative type of farming is at best a gradual one, and requires unusual resourcefulness on the part of the farming population.

"It is not strange, therefore, that in many communities exploitive farming continues beyond it legitimate life. In fact, such a change could hardly proceed in the older settled States while the unbounded West offered the renter and the farm laborer the opportunity to acquire a home by gift from the Government, on soil fertile enough to permit, for one or two generations, profitable farming with little equipment other than energy and courage. At the same time, the nation as a whole did not suffer from the depletion of the soil in the older States, for the reason that increased production on the rich soils newly brought under cultivation in the West kept pace with the ever increasing demand for food. Hence it was that the decrease in the agricultural population and the abandonment of a large part of the land formerly tilled in the Eastern States attracted little attention.

"In addition to increasing the number of domestic animals on American farms our farmers must pay more attention to leguminous crops, and to other crops which provide a supply of humus for the soil. Legumes, such as clover, peas, alfalfa, etc., are especially important because of the fact that with the aid of certain soil bacteria they are able to draw their supply of nitrogen from the air. Having thus an unlimited supply of this valuable plant-food constituent, they become very rich in nitrogen. The stubble and roots of a leguminous crop frequently leave in the soil sufficient nitrogen for the needs of the crop that follows. Recent investigation by this Department in Kansas and Nebraska show that the average increase in the yield of corn grown after alfalfa, compared with corn grown after nonleguminous crops, is 75 per cent. A good crop of clover has a similar effect on the yield of crops which follow it. Instances are known where the practice of sowing bur clover in cotton fields in the fall of the year and turning it under in spring in time for another crop of cotton has, in three years, doubled the yield of cotton. Crimson clover sown in a similar manner between crops of corn has in a few years increased the yield of corn 50 per cent or more.

"The reason these leguminous crops have such a marked effect on fertility in many cases on depleted soils lies in the fact that nitrogen is not a constituent of the soil proper, but only of the decaying plant and animal matter in the soil. When soils are farmed for many years without any attention to their fertility this organic matter is rotted out and the nitrogen disappears. Hence nitrogen is nearly always the first plant-food constituent to become deficient in the soil."

The great problems of soil biology are: the accumulation of nitro-

gen, and the gradual liberation of phosphorus, potassium, calcium, magnesium, sulphur and iron from minerals normally abundant in average soils.

Nitrogen is accumulated in the soil by two methods, non-symbiotic nitrogen fixation and symbiotic fixation. The former may be of greater importance than we at present believe but the latter is of great importance in soil systems of permanent soil fertility. Liebig in 1840, advanced the theory that plants obtain their nitrogen by the assimilation of the NH_3 of the air: but this view was found to be incorrect by Laws and Gilbert of Rothamstead. They showed that elementary nitrogen cannot be assimilated by plants and that there is not enough ammonia in the air to go very far in fulfilling the nitrogen needs of plant. Berthelot showed that only plants grown in unsterilized soils are able to make nitrogen gains.

In 1893, Winogradsky demonstrated that certain anaërobic butyric acid bacteria as Bacillus chlostridium pasteurianum are able to form nitrogenous compounds from the elementary nitrogen of the air.

In 1901, Beyerinck showed that there is a large group of aërobic bacteria which are able to fix atmospheric nitrogen. He called this group of bacteria azotobacter. It has been enlarged by Lipman, Löhnis, and Westermann to contain the following members:

Azotobacter Chroococcum } Beyerinck and Van Delden
Azotobacter Agilis..... }

Azotobacter Vinelandii... }
Azotobacter Beyerincki... } Lipman
Azotobacter Woodstownii. }

Azotobacter Vitreum.....Lohnis and Westermann

Other organisms which have been reported as capable of fixing a small amount of atmospheric nitrogen are Radiobacter, Bacillus radicicola, B. pyocyaneus, B. pneumoniæ, B. lactis viscorum, B. prodigiosus, B. ruminatus, B. simplex, and B. mesentericus.

It is reported that the salts of iron and that approximately neutral reaction are important factors in the development of the azotobacter group. Some have estimated that members of the azotobacter group may fix from 15 to 60 lbs. of nitrogen per acre annually.

The existence of algæ in soil is supposed to be of benefit to azotobacter and some believe that azotobacter and algæ often live in a sort of a symbiotic fashion. The algæ are said to produce mannite sugars from cellulose material thereby furnishing azotobacter with a proper carbohydrate.

The amount of nitrogen fixed by the activity of azotobacter generally is not great as it is estimated that azotobacter requires 100 lbs. of carbohydrate for each pound of nitrogen fixed.

Gainey says that soils more acid than pH6 do not usually contain B. azotobacter. He says, "A definite and very close correlation was established between the absolute reaction of the soil and the presence

or absence of azotobacter in the soil." He further says that since a very limiting H ion concentration was found for pure cultures of azotobacter in laboratory media, it is believed that the very close correlation existing between the reaction and the presence of azotobacter indicated that the absolute reaction is of paramount importance if not the actual limiting factor in controlling the presence of this group of organisms in soils.

Symbiotic Nitrogen Fixation.

In ancient Roman times according to Columella, farmers considered that the growing of beans, alfalfa, lupines and vetches improved the soil and acted as manure. However more definite knowledge was not obtained until 1888 when Hellriegel and Wilfarth established the fact that certain plants and bacteria work together in the fixing of atmospheric nitrogen in the soil. Legumes were found to fix nitrogen by a symbiotic activity between the plant root and a bacillus which was called B. radicicola, the symbiosis resulting in tubercle formation on the plant roots. These tubercles had first been observed by Malpighi in 1687, who erroneously thought they were pathological processes. Marshall Ward studied these root tubercles and discovered that they were due to outside infection of the root, but it was left for Hellriegel and Wilfarth to interpret their true importance as atmospheric nitrogen fixers.

C. V. Piper in explaining how much nitrogen legumes may add to the soil by the practice of green manuring says:

"Attempts have been made to determine the quantities of nitrogen fixed by the action of the nodule bacteria, but no method has yet been found that will give more than an approximately correct answer. Analyses have been made of the quantities of nitrogen in various leguminous crops, both tops and roots, but the total nitrogen thus obtained includes some that was taken directly from the soil. Determinations have been made of the total nitrogen in soils before and after growing a leguminous crop, but the result represents merely the net difference between gain and loss resulting from the interplay of a number of factors, and even the net gain cannot be safely credited to the legume alone. Lastly, certain legumes have been grown with and without inoculation and the difference in the quantities of nitrogen in the crops determined.

"The Michigan Agricultural Experiment Station grew soy beans inoculating the soil on one field and leaving another uninoculated. Samples taken and analyzed showed that about two-thirds of the total nitrogen was taken from the soil and one-third from the air. The Illinois Agricultural Experiment Station grew alfalfa, both in pots and in field plats, some inoculated, others not. On the inoculated plats the alfalfa in the crops for a season contained nearly 160 pounds more nitrogen per acre than the crop from the uninoculated plats.

"At the Central Experimental Farm at Ottawa, experiments were

conducted with red clover by growing this crop year after year on specially prepared plats of sandy soil with a known nitrogen content. All the clover grown was turned back to the soil during nine years. At the end of this time the soil contained 472 pounds of nitrogen per acre more than at the beginning. As a result of a similar experiment carried on by the New Jersey Agricultural Experiment Station, the conclusion seems warranted that in this case the legumes took from the air and made available to the grain crops at least 54 pounds of nitrogen per acre each year.

"The Rhode Island Agricultural Experiment Station found that after growing legumes in pots for five years, removing the above-ground portions of the summer crops but turning under the hairy vetch grown in winter, there was a gain at the rate of a ton of nitrogen per acre, seven-tenths of which was removed in the crops. Many more examples might be given.

"On the other hand, workers in Kansas and in Wisconsin concluded that alfalfa took more nitrogen from the soil than from the air and that when the hay was removed there was a loss of nitrogen. In general, however, it has been accepted as an approximation to the truth that legumes get about two-thirds of their nitrogen from the air and one-third from the soil. If these crops are turned under, the soil will be richer in nitrogen; if they are removed, there will be in general little or no change in the nitrogen content of the soil so far as this is influenced by the fixation of nitrogen in the nodules and by the removal of the crop."

The inoculation of soils with B. radicicola may be accomplished in several different ways but the inoculation of the seed by some method before planting is perhaps most efficient. Commercial preparations for broadcasting over the field to be inoculated have been used considerably but are not considered very efficient. The transfer of inoculated soil from one field to another is quite successful but undesirable soil infection often results from the practice of this method.

B. radicicola was at first cultivated in the laboratory on a medium made of hard wood ashes, saccharose or maltose and agar devised by Harrison. The organism will remain alive for several years on media.

B. radicicola enters the plant through the root hairs or by way of a bruise. The bacteria produced in the nodule are said to be absorbed bodily by the plant tissue. With them the nitrogen which they have fixed is also assimilated by the plant. When the nodule becomes inactive it softens and disappears. As to how the plant utilizes the nitrogen fixed by the bacteria there are three theories:

(a) Winogradsky advanced the theory that the free (N) and nascent (H) form ammonia within the organism. (Reduction Theory.)

(b) Gerlack and Vogel believe the nitrogen is not reduced but is oxidized. (Oxidation Theory.)

(c) Hines thinks that the (N) combines directly with carbon compounds. (Direct Union Theory.)

It was reported at N. J. Agr. Exp. Station that 200 lbs. of nitrogen per acre was fixed by B. radicicola in one year.

The conservation of the fertility of the soil is principally the conservation of nitrogen. Whatever the form in which nitrogen exists in soil it is moving in the nitrogen cycle. Organic nitrogen is mainly in the form of protein or protein derivatives of animal or vegetable products. Nitrogen in protein exists in five different forms as:

1 amino nitrogen
2 diamino nitrogen
3 ammonia nitrogen
4 guanidin nitrogen
5 pigment forms

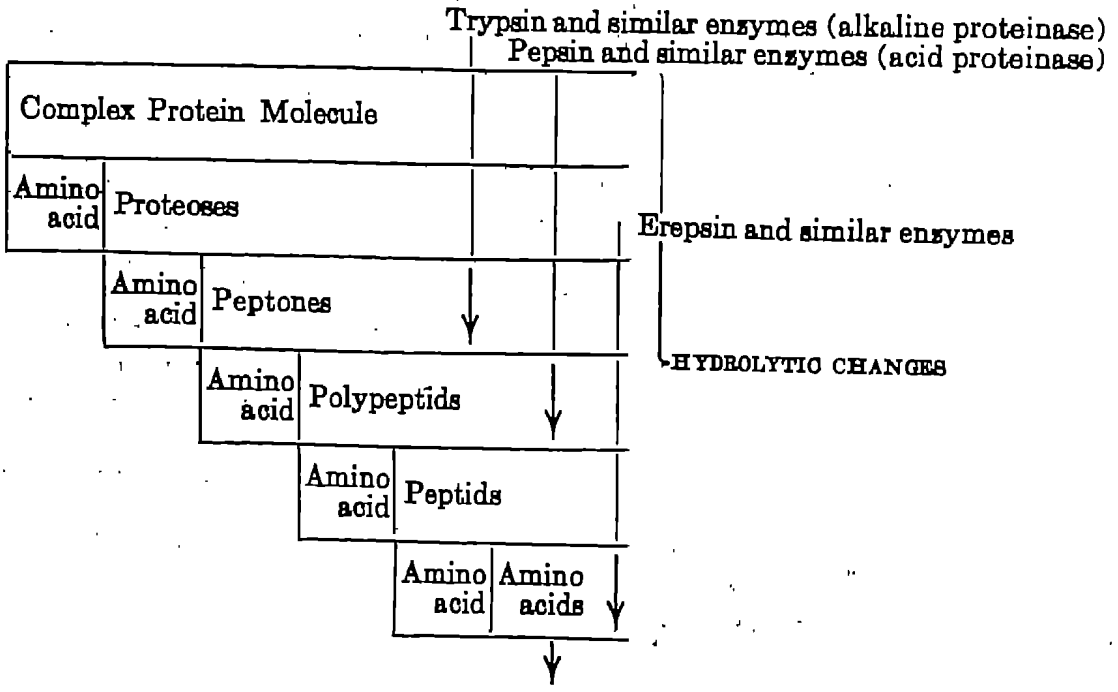
Whatever the form of the organic nitrogen product it is attacked in normal soil by bacteria.

Some of the organisms which split protein to ammonia are B. subtilis, B. mesentericus, B. mycoides, B. fluorescens liquefaciens, B. fluorescens putidus, Sarcena lutea, B. arborescens, B. proteus vulgatus, B. pyocyaneus, B. panthinus. All the above organisms are strong aërobes with the exception of B. proteus and B. fluorescens putidus.

In the breaking down of protein in soil the ammonifiers carry the simplication of the protein molecule to a point where the main derivatives are hydroxy acids and ammonia. Other products are formed in a lesser degree.

B. mycoides according to Kruse converts 46% of the nitrogen in protein into ammonia while B. pyocyaneus converts 70% of the nitro-

THE NITROGEN CYCLE FROM PROTEIN TO PROTEIN (A POSSIBLE CYCLE). KRUSE.



gen in protein into ammonia. No foul gases are formed in the aërobic decomposition of protein.

The secret of the conservation of the nitrogen in the soil is in the annual nitrogen return, the prevention of the denitrification and of the leeching away of the nitrates which are readily soluble in water. It is found that the greater the amount of humus in the soil the less the nitrate loss due to leaching. It appears that the humus material holds the nitrates by absorption or some kind of linking.

The amino acids anaërobically break up into hydroxy acids and NH_3 as

$C_6H_5.CHNH_2.COOH = C_6H_5.CH_2COOH + NH_3$ according to Kruse.
phenyl alanin phenyl propionic acid

The amino acids aërobically break up into simple products and NH_3 as

$C_6H_{13}NO_2 + 15O = 6CO_2 + NH_3 + 5H_2O$ according to Kruse.
leucine

NH_3 is absorbed by soil moisture as NH_3 H_2H NH_4OH.

Much CO_2 produced at the same time is absorbed as $CO_2 + H_2O = H_2CO_3 2NH_4OH + H_2CO_3 = 2H_2O + (NH_4)_2CO_3$

or

$CaCO_3$

Nitrosomonas oxidizes $(NH_4)_2CO_3 + 6O = 2HNO_2 + H_2CO_3 + 2H_2O$. Nitrosomonas is the only organism which can cause this reaction.

The strong acidity produced by nitrous acid must be neutralized if nitrification is to proceed as:

$$Ca_3(PO_4)_2 + 2HNO_2 = Ca_2H_2(PO_4)_2 + Ca(NO_2)_2 \text{ or}$$
$$Ca_3(PO_4)_2 + 4HNO_2 = CaH_4(PO_4)_2 + 2Ca(NO_2)_2$$

The oxidation of nitric to nitrate is caused by nitrobacter as:

$$Ca(NO_2)_2 + 2O = Ca(NO_3)_2$$

The calcium nitrate is utilized by plants and by them made into proteins again.

Denitrification.

In some very rich soils as those used for truck farming and gardening, there is considerable loss of nitrogen due to the activities of B. denitrificans. There are also twenty-eight different soil bacteria which are able to reduce nitrate to nitrite. Other forms reduce only nitrites. The biological reactions taking place in extremely rich soils may be grouped as follows:

Reduction of NO_3 to NO_2 or NO
Reduction of NO_2 to NH_3
Reduction of NO_3 to N
Liberation of N from organic compounds.

Carbohydrates as starch, sugars and other residues of crops may furnish the carbon for these reductions.

Denitrification in ordinary soils is not extensive and causes very little loss of nitrogen but in heavily manured and water logged soils it may be an important factor.

Phosphorus.

The slow but gradual liberation of phosphorus, potassium, sulphur and other essential mineral elements of plant growth is quite satisfactory in average soils. While no phosphorus fermenting organism has ever been found still Stoklasa found that P_2O_5 in phosphate was made soluble by bacteria as follows:

Uninoculated	3.8%
B. mycoides	23 %
B. megatherium	21 %
B. coli	20 %
B. mesentericus	15 %
B. butyricus	15 %
B. proteus	14 %
B. fluorescens	9.2%

It was found that acetic acid and formic acid are better solvents of phosphates than carbonic acid. Lipman thinks that sulphur makes phosphorus in phosphates available.

Potassium.

Some of the sources of potassium in soils are

Orthoclase
Feldspar (muscovite)
Mica (biotite)
Peroxines
Labradorite

There is evidence that potassium is made available to plants by the action of bacteria.

Soluble potassium may be made available to plants by the action of biological end products upon the zeolitic compounds of the soil. MacIntire has shown, however, that the economic additions of calcic and inorganic materials function to protect native soil potassium and give a repressive rather than a liberative chemical effect.

According to Kruse, urea is an important constituent of manured soils. Urea $CO(NH_2)_2$ the chief nitrogenous constituent of urine and the principal end point of tissue metamorphosis is attacked by the urea organisms and converted into ammonia and CO_2 as:

$$CO(NH_2)_2 + H_2O = CO_2 + 2NH_3 \quad \begin{matrix}\text{(Hydrolysis (enzyme)} \\ \text{(urease)}\end{matrix}$$

The bacteria concerned are mostly micrococci (M. ureae)

$$CO_2 + 2NH_3 + H_2O = (NH_4)_2CO_3 \text{ or}$$

$$\left.\begin{matrix}NH_2\\NH_2\end{matrix}\right\rangle CO_2 + 2H_2O = (NH_4)_2CO_3 + 14.3 \text{ Calories.}$$

Lentils and broad beans have much urease and perhaps this may act in the soil when the seeds decay.

Bassalik found that some of the intestinal bacteria of earthworms are able to make the potassium of orthoclase available to plants.

Many of the products of bacterial action in soils bring potassium of minerals into solution as acetic acid.

Sulphur.

There are several members of the non-filamentous sulphur bacteria which are important in liberating sulphur. Winogradsky found that these bacteria consume hydrogen rather than produce it. They oxidize hydrogen sulphide in their cells as:

$$2H_2S + O_2 = 2H_2O + S_2$$

They store free sulphur in their cells and later oxidize it to H_2SO_4, which is changed by contact with calcium compounds as $CaH_2(CO_3)_2$ and finally exists in the soil as sulphates. These bacteria are very important in nature as they furnish plants with available forms of sulphur. Some of these organisms producing bacterio-purpurin are Spirillum rubrum, Spirillum volutans, chromatium Okenii, etc.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