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THE ADULTERATION OF MILK

BY

HENRY A. MOTT, Jr., E.M., Ph.D.

MINING ENGINEER AND ANALYTICAL CHEMIST; MEMBER OF THE AMERICAN CHEMICAL SOCIETY; MEMBER OF THE NEW YORK ACADEMY OF SCIENCES; FELLOW OF THE GEOGRAPHICAL SOCIETY, ETC., ETC.

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THIS department of the subject of milk is, without doubt, the most important of all. Surely, every effort made to discover or point out the true method for detecting the adulteration of this most important fluid, which is so indispensable to the kitchen, the sick-room, and the nursery, cannot help but be received with interest. For this reason I shall endeavor in this paper to consider in detail:

1st.—The Adulterants of Milk.

2d.—The Instruments and Methods of Detecting Adulteration.

Before proceeding with the discussion of the first division of the subject, it will probably be well to consider very briefly some of the peculiarities of milk, of which undue advantage are taken by milkmen.

Milk contains two elements, water and fat, both of which possess a specific gravity less than that of pure milk itself; these two elements can vary, and do vary, between certain limits in pure or normal milk; but when the variations are too great the milk becomes abnormal. Between certain limits, then, a sample of pure milk may have a low specific gravity, owing to a large proportion of water, or it may have a low gravity, owing to a large proportion of fat. In the first case the milk would be poor and thin, in the latter rich and thick. The consistence of two such fluids, a thorough milkman (I mean one posted up to the tricks of his trade) could easily distinguish, and it is, I suppose, on the business principle, that you should only give a man for his money as little as possible, that the milkman, when he finds or receives a quantity of milk that is rich and thick, *partly* skims and dilutes it between certain limits, knowing that the fraud cannot be detected, owing to the fact that the constituents of milk (especially fat) are subject to variation. I am sorry to have to say that this fraud cannot be detected, but it is a fact, and we must grin and bear it, for science never has nor never can offer a method for the detection of such adulteration. Neither chemical analysis nor the various instruments used for detecting adulteration can offer any aid.

Happily, though, for the consumers of this most valuable fluid, the limits between which such adulteration can be carried on are very small, and consequently no very serious results could originate from such adulteration even to infants. If the milkmen would limit their adulteration to this point, we all might be thankful, but unfortunately for us they do not condescend to consult any other source but their pockets. Hence there is forced upon the consumers: "Milk diluted largely with water; skimmed milk; skimmed milk diluted largely with water, and various decoctions called milk, containing any number of adulterants." Fortunately science can interfere with such adulterations and frauds as these, and when they are detected then a severe and just penalty should be pronounced upon the perpetrator, who not only robs the consumers of their rights, but sends many an infant to its grave.

1.—The Adulterants of Milk.

The adulterants, said to be used by different writers for the adulteration of milk, are quite numerous. Although water and, sometimes, chalk, soda, and caramel are practically the only adulterants that are used, the proper treatment of the subject demands the consideration of all the other adulterants, no matter if the consideration extends to the brains of the sheep.

1. *Water.*—This fluid is the most prevalent adulterant of milk—it costs nothing, and possessing a speci-

fic gravity less than that of pure milk, the gravity of this fluid may be reduced at pleasure. The amount of water added by milkmen ranges between 10 and 50 per cent. Dr. Chandler,[1] from numerous and valuable investigations of the milk supply of New York, concluded that the average milk sold consisted of three-quarters milk and one-quarter added water. The 120,000,000 quarts of milk sent annually to New York receive an addition of 40,000,000 quarts of water, which, sold at 10 cents per quart, brings $4,000,000 per annum, or $12,000 per day.

There are a few persons who are disposed to make light of the adulteration of milk by water, but to an educated mind they only display their ignorance. The addition of water to milk or, worse, to skim milk greatly decreases the percentage of the milk solids (as proven in the following table), and consequently renders the milk not only unfit for the food of infants but in many cases dangerous.

If the water used to adulterate the milk is not pure, we have danger arising from another source. There is recorded a case[2] where an epidemic of typhoid fever occurred near Glasgow, Scotland, in 1872–3 by the milkman adulterating his milk with foul water, and allowing his cows to slake thirst from such water. Thirty-two out of thirty-nine families which were supplied with this milk, as also the family of the milkman, were attacked. Families supplied by other milkmen were not affected.

The fever germs were propagated through the adulterating of the milk with this foul water. Another case is reported: "In one of the healthiest suburban sections of London 500 cases of typhoid fever were found distributed in 104 families, 96 of which were supplied with milk from one dairy. The contagion

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[1] Johnson's Cyc., article Milk.

[2] See Willard's Practical Butter Book, p. 24.

Table of the quantities of milk solids contained in 100 parts of a mixture of water and pure milk, in different proportions.[1]

BY CÉSAIRE REYNARD.

Milk.	Water.	Milk solids.	Milk.	Water.	Milk solids.
100	0	12.9200	64	36	8.2688
99	1	12.7908	63	37	8.1396
98	2	12.6616	62	38	8.0104
97	3	12.5324	61	39	7.8812
96	4	12.4032	60	40	7.7520
95	5	12.2740	59	41	7.7308
94	6	12.1448	58	42	7.2016
93	7	12.0156	57	43	7.1724
92	8	11.8864	56	44	7.0432
91	9	11.7572	55	45	6.8140
90	10	11.6280	54	46	6.6848
89	11	11.4988	53	47	6.5556
88	12	11.3696	52	48	6.4264
87	13	11.2404	51	49	6.2972
86	14	11.1112	50	50	6.2600
85	15	10.9020	49	51	6.1308
84	16	10.8528	48	52	6.0016
83	17	10.7236	47	53	5.9724
82	18	10.5944	46	54	5.9432
81	19	10.4652	45	55	5.8140
80	20	10.3360	44	56	5.6848
79	21	10.2068	43	57	5.5556
78	22	10.0776	42	58	5.4264
77	23	9.9484	41	59	5.2972
76	24	9.8192	40	60	5.1680
75	25	9.6900	39	61	5.0388
74	26	9.5608	38	62	4 9096
73	27	9.4312	37	63	4.7384
72	28	9.3024	36	64	4.6532
71	29	9.1732	35	65	4 5220
70	30	9.0440	34	66	4.3928
69	31	8.9148	33	67	4.2636
68	32	8.7856	32	68	4.1344
67	33	8.6564	31	69	4.0522
66	34	8.5272	30	70	3.8760
65	35	8.3980			

[1] Journal de Chimie Méd., p. 358. 1856.

was traced directly to the water used for washing the milk cans and retained in the milk, the water being previously polluted by sewer drainage."

All stagnant water contains organisms either animal or vegetable, that renders it unsafe to use, or to allow cows to drink. In the case of pure spring water or running water, which likewise contains organisms, there is not sufficient organic matter in suspension to promote their development. In the case of stagnant water the organic matter in suspension or in solution creates in the water the proper mediums suitable for the development of living organisms. "It[1] is no longer mere water—it is a world of microscopic animals and plants which are born, live, and increase with bewildering rapidity. Drink a drop of this water and you swallow millions of minute beings." Use this water to adulterate milk and you furnish more nourishment to these little organisms, which continue to multiply, and then give the milk to an infant for food and you supply with it organisms which are capable of producing violent cramping and purging, as also capable of setting up putrefaction in the tissues.

2. *Chalk.*—This substance is sometimes used to produce a thickness and opacity to milk that has been diluted with water; it is also used to neutralize the acidity in sour milk.

3. *Starch, Flour, Decoction of Barley, Rice, and Emulsion of Almonds and Hempseed* are said to be used to thicken milk and to neutralize the blue color caused by dilution.

4. *Cane Sugar, Dextrine, Milk Sugar, Gum Tragacanth, Gum Arabic,* and *Borax* are sometimes used to increase the specific gravity of diluted milk and sweeten the same.

5. *Salt* (sodic chloride) is used to increase the specific gravity of diluted milk and to bring out the flavor.

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[1] Scientific Conversations by M. Porville. Paris.

6. *Turmeric, Annatto, Caramel, juice of certain roots,* such as *the Carrot* or the *different flowers, Marigold, Saffron,* and *Safflower,* are used to color the fluid so as to hide the blue color due to dilution.

7. *Carbonate or Bicarbonate of Soda* is used to prevent the milk from becoming sour, by neutralizing the acidity; also to increase the specific gravity of diluted milk.

8. *Gelatin* and *Isinglass* have been used to thicken diluted milk.

9. *Cerebral matter, Sheep's Brains, Calves' Brains,* or *Horses' Brains,* have been detected in milk. They were used to thicken the milk after first watering the same.

Having enumerated over the adulterants *said* to be used for the adulteration of milk, I will now proceed to the discussion of the second division of the subject, namely:

2.—The Instruments and Methods for Detecting Adulteration.

The first requisite, before proceeding to apply a rapid and practical test to the examination of milk, is to ascertain the nature of the adulterants used, so as to know what has to be coped with in the examination. If a given sample of milk, known to be adulterated with several of the adulterants mentioned above, is presented to a chemist to discover the nature of the adulterants, the only method for arriving at the required result is by chemical analysis. Knowing the adulterant or adulterants used, then a more rapid method may be adopted for their detection. It is well though, in large cities, from time to time, to make analyses of the adulterated fluid, to ascertain whether or no the adulterant or adulterants have been changed; for it might become necessary to change to a certain extent the method of examination. Experience has demonstrated that water is, in 99 cases out of

100, the only adulterant used for the adulteration of milk. This has been clearly demonstrated in this country, in England, Scotland, France, Belgium, Germany, and Switzerland. Let us now consider the instruments and methods for detecting its presence in commercial milk.

DETECTION OF THE ADULTERANT, WATER.

The detection of water, when employed as an adulterant of milk, is not always possible, for two reasons: 1st, because science does not offer any method for distinguishing the water naturally present in milk and the *added* water; 2d, because the percentage of water varies so much in pure milk, that it is only possible to detect added water when the quantity present exceeds the maximum quantity in pure milk. No matter what method we adopt to detect adulterated milk, whether it be chemical analysis, the lactometer, the microscope, or the various other instruments and methods to be described, a standard which shall represent the poorest pure milk has got to be adopted. When it is desired to use the specific gravity of milk as a test for its purity, the specific gravity adopted as a standard must represent the gravity of the whole pure milk.

To determine this gravity any number of experiments have been made: but, before proceeding to the consideration of the different experiments, let us glance for one moment at the various specific gravities stated by prominent writers which are given to represent the weight of milk:

SPECIFIC GRAVITY OF COW'S MILK.

1.030 to 1.039	Simon.[1]
1.0302—1.0396	Vernois & Becquerel.[2]
1.026—1.032	Scherer.[3]

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[1] Animal Chem., Eng. ed., p. 50.

[2] Anal. d'Hygiène Publ., Avril, 1857.

[3] Physiol., von Dr. Wagner, 1850, p. 450.

1.0295—1.0343 average 1.0317	Fleischman.[1]
1.0324 (average)	Brisson.[2]
1.0288—1.0364 1.0322 (average)	Quevenne.[3]
1.0284—1.0357 1.032 (average)	Macadam.[4]
1.032 (average)	Wiggin.[5]
1.029—1.040 1·032 (average)	Mott.
1.02958—1.0354 1.03184 (av'ge)	Jepson & Gardner.[6]
1.02958—1.03538 1.03219 (av'ge)	Waller.[7]
1.029—1.034 (whole milk)	Hassal.[8]
1.026—1.031	Hassal.[9]
1.028—1.032	Wilson.[10]
1.026—1.036	Atcherley.[11]
1.029	Gorup v. Besanez.[12]
1.030 (lowest)	Marchand.[13]
1.029—1.034	C. Müller.[14]
1.031494 (average)	J. Blake White.[15]
1.027—1.033 1.030 (average)	Sharples.[16]
1.026—1.035	Parkes.[17]
1.026—1.032	Klencke.[18]
1.0271 (average)	Orthman.
1.0248—1.0348	Pincus & Struckmann.
1.02958—1.0348	Chandler.[19]

[1] Jahresb. Th. Chem., XIII.-XV. (3), p. 237.
[2] Rees' Ency., 1819, article "Milk."
[3] Dict. Ency. des Sci. Méd., p. 130.
[4] Amer. Chem., 1875, May, p. 419.
[5] Report, 1870–71, Providence, R. I.
[6] City Record, July 29, Oct. 7, 1875.
[7] School of Mines, Columbia College.
[8] Adulteration of Food, new ed., p. 408.
[9] Adulteration of Food, old ed., p. 216.
[10] Handbook of Hygiene, p. 42.
[11] Adulteration of Food, p. 61.
[12] Physiol. Chemie, p. 332.
[13] Mémoires d'Agriculture, Paris, 1858, p. 305.
[14] Anleitung zur Prüfung der Kuhmilch, p. 47.
[15] City Record, Aug. 17–24, 1876.
[16] Proc. Amer. Acad. Arts & Sci., p. 149 (vii.).
[17] Practical Hygiene, p. 216, London, 1866.
[18] Die Verfälschung der Nahrungsmittel und Geträuke, von Herman Klencke, 1858.
[19] Johnson's Cyc., article "Milk."

In reviewing the above figures, quite a difference will be observed; but, fortunately, this difference can be readily explained. The object of most experimenters has been simply to determine the specific gravity of the particular samples they have had under examination, and their results are correct for those particular samples, but incorrect if they are meant to represent the specific gravity of *all the milk* from a milking thoroughly mixed together.

When I speak of the specific gravity of the milk of a cow, I mean the specific gravity of all the milk from the cow (in perfect health) thoroughly mixed together, obtained at her regular hour of milking, not the specific gravity of the first, middle, or last portion, for each of these portions give an entirely different specific gravity peculiar to themselves. The following are tests of the first and second drawn milk from eight different cows: [1]

First drawn milk.			Second drawn milk.		
Cows.	Specific Gravity.	Cream.	Cows.	Specific Gravity.	Cream.
1....	1.027	9	1....	1.023	25
2....	1.026	13	2....	1.023	22
3....	1.027	8	3....	1.025	10
4....	1.029	7	4....	1.024	15
5....	1.030	11	5....	1.024	32
6....	1.030	8	6....	1.022	25
7....	1.029	3½	7....	1.026	7½
8....	1.031	2	8....	1.030	5
Total...		61½	Total...		141½

Schübler found that, on fractioning the milk at a milking, the—

[1] London *Lancet*.

	Specific Gravity.	Cream.
First portion showed	1.0340	5 per cent.
Second " "	1.0334	8 " "
Third " "	1.0327	11.5 " "
Fourth " "	1.0315	13.5 " "
Fifth " "	1.0290	17.5 " "
Average	1.0321	11.0 " "

Jepson & Gardner, Milk Inspectors for New York, found the milk and strippings of two cows:

		Entire Milk.	Strippings.
First cow	Specific gravity	1.0348	1.02610 lact. 90
Second cow.	" "	1.0319	1.02668 lact. 92

What, then, is the specific gravity of cow's milk? Or what is the range of the specific gravity? I have already stated that a number of experiments have been made to determine this important point, and we will now proceed to consider them:

Dr. Fleischman,[1] of Germany, personally inspected the milk of thirteen different dairies in the vicinity of Linden, containing in the aggregate one hundred and twenty-three cows. He noted the specific gravity of the milk of each cow separately and upon each day, in bulk, with the following results:

"The mean specific gravity from the 123 cows is 1.0316908." "The maximum specific gravity of any one of the 123 cows is 1.034300, and the minimum specific gravity from any one of the 123 cows is 1.029500." "The milk of 9 per cent. of the cows exceed 1.033 in specific gravity." "The milk of 89 per cent. of the cows ranged from 1.033 to 1.030 in specific gravity, and the milk of 2 per cent. of the cows was below 1.030 in specific gravity." "The mean specific gravity of the milk from the 13 dairies ranged between 1.03065 and 1.03285, or, in round numbers, between 1.031 and 1.030."

Quevenne[2] tested the milk from 103 cows, his ex-

[1] Jahresb. Th. Chem., XIII.-XV. (3), p. 237.

[2] Dic. Ency. Sci. Méd., p. 130.

periments extending over a period of eleven years. He found the average specific gravity 1.0322, and for the range 1.0288 to 1.0364. He only found *one* sample of specific gravity 1.0288; he found six samples between 1.029 and 1.030, five samples above 1.035, and ninety-one samples between 1.030 and 1.035.

Dr. Steven Macadam[1] made a number of tests at three large dairies in the neighborhood of Edinburgh. He found the specific gravity to range from 1.0284 to 1.0357; the average of forty-four trials of different milks being 1.03220. The milk was taken direct from the udders of the cows.

He found only one sample of specific gravity 1.0284, one of 1.0294, and one of 1.0296. All the other samples had a specific gravity between 1.0304 and 1.0357.

Jepson & Gardner[2] tested the milk of 109 cows (45 Harlem and 65 Orange Co., N. Y.); they found, for the average, the special gravity 1.03184, for the range 1.02958 and 1.0354.

Dr. Waller tested the milk of 86 cows and obtained the average specfic gravity 1.0321, and for the range 1.02958–1.0353.

Dr. J. Blake White[3] tested the milk of 129 cows at six dairies, making 142 examinations, and found the total average specific gravity 1.031494.

Lastly, Dr. Christian Müller[4] had made, under his control, "in the newly-erected manufactory of condensed milk of the Swiss Company, Moléson," a large number of milk tests. Out of the first 280 weighings in the month of March, 1872, only two cases were found under 1.030, namely, 1.0286 and 1.0298. Over 1.033 to and with 1.034 there were twenty cases; over 1.034 only two, the highest being 1.0344. Two hun-

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[1] Amer. Chem., May, 1875, 419.

[2] City Record, July 29, and Oct. 7, 1875.

[3] City Record, Aug. 17 and 24, 1876.

[4] Anleitung zur Prüfung der Kuhmilch, p. 55.

dred and fifty-seven weighings varied between 1.029 and 1.033. "As the average of all the tests," he says, "I obtain a figure which is only a very little larger than 1.031. With respect to the milk which gave the specific gravity 1.0286, it came from a spayed cow, which was already fattening and gave daily two quarts of milk that had, moreover, a bitter taste."

From the above most elaborate experiments an unprejudiced mind will not hesitate to say that the specific gravity of the *whole milk* from cows in perfect health will never fall below 1.029. And if we see stated the *specific gravity of a cow's milk below* 1.029, *we may be sure that either the milk is abnormal, the sample tested not a fair average of all the milk that could be obtained from the cow at her regular hour of milking, the sample has been tampered with, the instrument used to obtain the specific gravity incorrect, or that the temperature at which the specific gravity was obtained could not have been the conventional temperature* 15.5, *C.* (60° *F.*). With respect to the two samples recorded, one by Quevenne and the other by Macadam, which gave a gravity slightly below 1.029 within 6 ten thousandths, it is evident that some of the above-mentioned conditions were overlooked.

No better proof is necessary to my mind than the fact that it took the examination of the milk from over 850 cows to produce two such samples.

The minute we find a property of milk that is constant, or, if it varies, does so between certain limits that can be definitely fixed, that minute this property becomes a standard and test for the purity of milk. And it is for this reason that an instrument can be constructed, based on the fluctuating gravity of pure healthy cow's milk, the indications of which will be infallible.

The original galactometer discovered by Cadet de Vaux, in 1817; the Centesimal Galactometers; the Lactodensimeter, discovered by Quevenne, in 1842;

the first instrument called Lactometer, by Mr. Dicas;[1] the Lactometer, discovered by Edm. Davy, in 1821; the Milk Tester, discovered by Greiner, in Berlin, in 1834; the Milk Weigher of Mollenkopf, Dörssel, and Geissler, in Stuttgart; and the various other lactometers are such instruments, which are all hydrometers, and differ from each other in the graduation of their scales.

The Centesimal Galactometer was invented by Dinocourt: it is shown in fig. 1. The stem of the instrument has two scales: one for pure milk, the other for skimmed milk; the scale A, *in part colored yellow*, serves to weigh the milk with its cream; the first degree on the top of the scale is marked 50, which corresponds to the sp. gr. 1.014. The following marks extend from 50 to 100 (sp. gr. 1.029), and over. Each degree starting from one hundred in mounting up to 50, represents a hundredth of pure milk; the degrees formed by a *line* are equal, as 50, 52, 54, etc.; the degrees formed by a dot are unequal, as 81, 83, 85, etc. To illustrate by an example: If the galactometer is sunk to the 85th degree, that will indicate 85 hundredths of pure milk, and consequently that 15 hundredths of water has been added to this milk; if sunk to 60 degrees, that will indicate 40 hundredths of

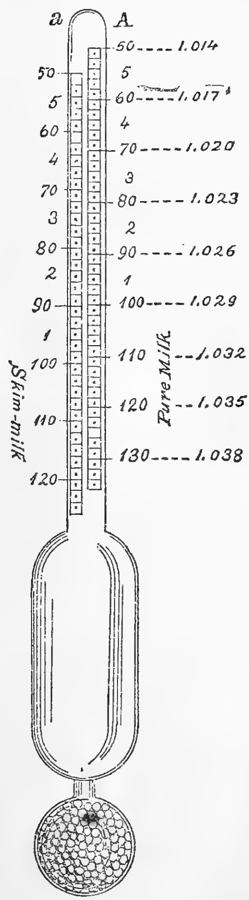

Fig. 1.

* Agric. Survey of Lancashire, 1815, p. 550.

water, or four-tenths of water added. If it is desired to count by tenths, it is only necessary to notice that the first tenth is white, that the second is colored yellow, the third white, the fourth yellow, and that the fifth is also white; towards the middle of each tenth the figures 1, 2, 3, 4, 5 are placed to indicate their order.

The scale, *a*, is in part colored blue, and is destined to weigh skim milk; it is, like the first, divided into hundredths (100 degrees), of which the first 50 have been cut off as useless, as in the case of the other scale, each degree commencing from 100 to 50 and mounting upwards represents a hundredth of pure skimmed milk, consequently the manner of estimating the quantity of water added to skim milk is absolutely the same as for pure milk with cream. The degree 130 corresponds to a specific gravity 1.038, the degree 120 to 1.035, the degree 110 to 1.032, *the degree* 100, *which is the standard, to* 1.029, the degree 80 to 1.023, the degree 70 to 1.020, the degree 60 to 1.017, and the degree 50 to 1.014.

Another Centesimal Galactometer[1] was invented by Chevallier; it is similar to the above instrument. It serves to determine the specific gravity of cream, milk, and skimmed milk. This instrument is used in connection with the creamometer. The specific gravity of the milk not skimmed is first determined, noting the temperature, then the volume of cream is ascertained by means of the creamometer, and finally the specific gravity of the skimmed milk is determined, noting the temperature.

From the data obtained, by referring to tables compiled by Chevallier, the additional water contents of the milk is ascertained.

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[1] Jour. Pharm. et Chim., 3d series, 1844, t. v. p. 137; Jour. Chem. Medic., 4th series, 1856, t. 11, p. 342–401.

THE LACTODENSIMETER.

The lactodensimeter [1] is an instrument differing from the galactometer just described only in the division of its scale. It is the production of Bourchardat and Quevenne, and is represented in fig. 2. This instrument, like all the densimeters, gives immediately and without calculation the density of the liquid in which it is plunged; its scale comprises only the densities which may be presented by pure or adulterated milk. The shaft bears three distinct graduations. The first, which is the middle one in the figures, contains the whole numbers intermediate between 14 and 42. In reality, the whole numbers comprised between 1.014 and 1.042 ought to be inscribed; but on account of the small size of the shaft the two first figures have been suppressed which do not change. If, consequently, the instrument is sunk in a liquid up to the figure 29, this signifies that a litre of this milk weighs 1.029 grams, and that its density is consequently 1.029. The instrument has been graduated for the temperature of + 15° C. It is necessary, therefore, for obtaining an *exact* indication, to be assured the liquid under examination is at this temperature. In the contrary case, it may be brought back to this degree by plunging the gauge containing the milk in water that is cold, or in lukewarm water, according as the thermometer is above or below + 15°. The table given on p. 19 may also be employed, which is easily comprehended on inspection, and which is extracted from the memoir of Bouchardat and Quevenne.[2]

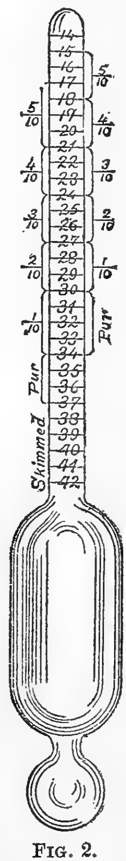

FIG. 2.

[1] See Dic. Ency. Sci. Med., p. 144—Lait.
[2] Répertoire de Pharmacie, juillet, 1856.

The scale on the right is employed when it is certain that the milk acted on is not skimmed. This scale shows what are the variations of the density of milk in proportion as water is added, and the figures $\frac{1}{10}$, $\frac{2}{10}$, etc., indicates that the liquid operated upon has been mixed with this proportion of water. The scale on the left contains the same indications relative to skimmed milk. Milk is marked pure on this instrument between the specific gravities 1.030 and 1.034, skimmed milk is marked pure between the gravities 1.034 and 1.037.

LACTOMETER.

The original instrument that was called a "Lactometer" was discovered by Mr. Dicas in 1815. The following is a description of the instrument by the inventor:

"It is constructed with ten divisions on the stem, which is similar to the patent brewing hydrometer, and with eight weights, which are to be applied only one at a time upon the top, to obtain the weight of the milk; an iron sliding rule accompanies this instrument, upon the middle or sliding part of which is laid down the lactometer weight of the milk, going from 0 to 80; and opposite thereto are placed the various strengths of milk, from water to 160, 100 having previously been fixed upon, from a number of experiments, as the standard of good new milk, and each of the other numbers bearing a proportionate reference thereto.

"At one end of the slide-rule, the degrees of heat from 40 to 100 are placed with a star opposite as an index to fix the slide to the temperature of the milk.

"The whole being graduated to show the exact strength of the milk, as it would appear in temperature 55 degrees of heat, although tried in any inferior or superior temperature between 40° and 100°; thus the great inconvenience which would attend bringing

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
14	12.9	12.9	12.9	13.0	13.0	13.1	13.1	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	14.0	14.1	14.2	14.4	14.6	14.8	15.0	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	16.8
15	13.9	13.9	13.9	14.0	14.0	14.1	14.1	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	15.0	15.1	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	16.8	17.0	17.2	17.4	17.6	17.8
16	14.9	14.9	14.9	15.0	15.0	15.1	15.1	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	16.0	16.1	16.3	16.5	16.7	16.9	17.1	17.3	17.5	17.7	17.9	18.1	18.3	18.5	18.7	18.9
17	15.9	15.9	15.9	16.0	16.0	16.1	16.1	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	17.0	17.1	17.3	17.5	17.7	17.9	18.1	18.3	18.5	18.7	18.9	19.1	19.3	19.5	19.7	20.0
8	16.9	16.9	16.9	17.0	17.0	17.1	17.1	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	18.0	18.1	18.3	18.5	18.7	18.9	19.1	19.3	19.5	19.7	19.9	20.1	20.3	20.5	20.7	21.0
19	17.8	17.8	17.8	17.9	17.9	18.0	18.1	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	19.0	19.1	19.3	19.5	19.7	19.9	20.1	20.3	20.5	20.7	20.9	21.1	21.3	21.5	21.7	22.0
20	18.7	18.7	18.7	18.8	18.8	18.9	19.0	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.8	20.0	20.1	20.3	20.5	20.7	20.9	21.1	21.3	21.5	21.7	21.9	22.1	22.3	22.5	22.7	23.0
21	19.6	19.6	19.7	19.7	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.1
22	20.6	20.6	20.7	20.7	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.1	24.3	24.5	24.7	24.9	25.2
23	21.5	21.5	21.6	21.7	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.1	25.3	25.5	25.7	26.0	26.3
24	22.4	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.0	25.2	25.4	25.6	25.8	26.1	26.3	26.5	26.7	27.0	27.3
25	23.3	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.5	24.6	24.8	25.0	25.2	25.4	25.6	25.8	26.0	26.2	26.4	26.6	26.8	27.1	27.3	27.5	27.7	28.0	28.3
26	24.3	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1	25.2	25.3	25.5	25.6	25.8	26.0	26.2	26.4	26.6	26.9	27.1	27.3	27.5	27.7	27.9	28.2	28.4	28.6	28.9	29.2	29.5
27	25.2	25.3	25.4	25.5	25.6	25.7	25.8	25.9	26.0	26.1	26.2	26.3	26.5	26.6	26.8	27.0	27.2	27.4	27.6	27.9	28.2	28.4	28.6	28.8	29.0	29.3	29.5	29.7	30.0	30.3	30.6
28	26.1	26.2	26.3	26.4	26.5	26.6	26.7	26.8	26.9	27.0	27.1	27.2	27.4	27.6	27.8	28.0	28.2	28.4	28.6	28.9	29.2	29.4	29.6	29.9	30.1	30.4	30.6	30.8	31.1	31.4	31.7
29	27.0	27.1	27.0	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28.1	28.2	28.4	28.6	28.8	29.0	29.2	29.4	29.6	29.9	30.2	30.4	30.6	30.9	31.2	31.5	31.7	31.9	32.2	32.5	32.8
30	27.9	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	29.0	29.2	29.4	29.6	29.8	30.0	30.2	30.4	30.6	30.9	31.2	31.4	31.6	31.9	32.2	32.5	32.7	33.0	33.3	33.6	33.9
31	28.8	28.9	29.0	29.1	29.2	29.3	29.5	29.6	29.7	29.8	30.0	30.2	30.4	30.6	30.8	31.0	31.2	31.4	31.7	32.0	32.3	32.5	32.7	33.0	33.3	33.6	33.8	34.1	34.4	34.7	35.1
32	29.7	29.8	29.9	30.0	30.1	30.3	30.4	30.5	30.6	30.8	31.0	31.2	31.4	31.6	31.8	32.0	32.2	32.4	32.7	33.0	33.3	33.6	33.8	34.1	34.4	34.7	34.9	35.2	35.5	35.8	36.2
33	30.6	30.7	30.8	30.9	31.0	31.2	31.3	31.4	31.6	31.8	32.0	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.7	34.0	34.3	34.6	34.9	35.2	35.5	35.8	36.0	36.3	36.6	36.9	37.3
34	31.5	31.6	31.7	31.8	31.9	32.1	32.2	32.3	32.5	32.7	32.9	33.1	33.3	33.5	33.8	34.0	34.2	34.4	34.7	35.0	35.3	35.6	35.9	36.2	36.5	36.8	37.1	37.4	37.7	38.0	38.4
35	32.4	32.5	32.6	32.7	32.8	33.0	33.1	33.2	33.4	33.6	33.8	34.0	34.2	34.4	34.7	35.0	35.2	35.4	35.7	36.0	36.3	36.6	36.9	37.2	37.5	37.8	38.1	38.4	38.7	39.1	39.5

the milk at all times to one temperature is avoided, and a simple mechanical method of allowing for the contraction and expansion substituted."

"And as skimmed milk, being divested of the particles of butter which existed before skimming, appears to have a less degree of affinity with that than the new milk has, one side of the ivory sliding-rule is adapted to skimmed, and the other to new milk."

"General Rule.—First find the temperature of the milk with the thermometer, and fix the sliding-rule so that the star shall be facing the degree of heat the mercury rises or falls to; then put in the lactometer and try which of the weights, applied to the top, will sink it to some one division on the stem; add the number of the weights upon the top, and that of the division together, and opposite to the same formed upon the side, will be shown the strength of the milk."

"Examples of New Milk.—If in the temperature of 72°, the lactometer with the weight 40 sinks to 9 upon the stem, fix the slide so that the star shall be facing 72°; then opposite 49 will be found 100°, the strength of the milk. Again if in 60° the lactometer with 50 on the top sinks to 6 upon the stem, the slide being fixed for new milk so that the star shall be at 60° of heat, then facing 56 will be found 110°, the strength of this milk in proportion towards the other, provided it is equally replete with cream."

"To discover which, it becomes requisite these two samples should stand a certain time, that the cream may rise, which being taken off, they are to be tried with the lactometer again, and as the cream is evidently the lighter part, the milk will appear by its denser or better in quality than before. Supposing the milk in the first sample to be 57 by the lactometer, in 60° of heat, the strength by the skimmed milk side of the rule will be 112°. And admit the second sample of new milk to be 58, in 64° when skimmed, the strength would be 116°.

"As a comparison:

Say Number 1, New Milk	100
" Skimmed Milk	112
Difference	12
Number 2, New Milk	110
When skimmed	116
Difference	6

"From which it appears that Number 1 has produced a larger quantity of cream than Number 2, and consequently may be deemed the better milk."

The next instrument receiving the name of lactometer was invented by Prof. Edmund Davy[1] in 1821. It is represented in Fig. 3. It is made of brass, and consists of a pear-shaped bulb, at the top of which is a graduated stem, and at the bottom a brass wire, to the end of which a weight is screwed. This instrument is only intended for skimmed milk, and the 0 mark corresponds to the sp. gr. 1.035, which, according to Davy's experiments, represents the lightest genuine skimmed milk. The dots in the figures, which extend from 0 to 35, indicate parts of water in 100 parts skimmed milk at 60°.

Of the various lactometers that have been in use, the only difference was the specific gravity represented by the 100 degree of the scale. The specific gravity corresponding to the 100 degree on the centesimal galactometer invented by Dinocourt, as I have already stated, was 1.029, which was intended to represent the proper minimum. This sp. gr. has been adopted by the Board of Health of New York as the standard for their lactometers.

The old standard adopted by the milk dealer was 1.030; this was changed by Dr. Chilton to 1.034, and

[1] Tilloch's Philosophical Magazine, Nos. 57, 58, p. 241.

has gradually dropped to 1.033. So that the standard now employed by the milk dealers to *secure for themselves* pure milk is 0.004 higher than that adopted by the Board of Health.

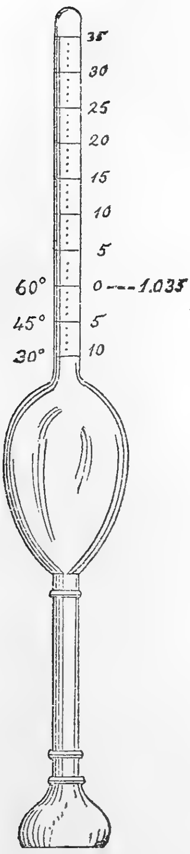

Fig. 3.

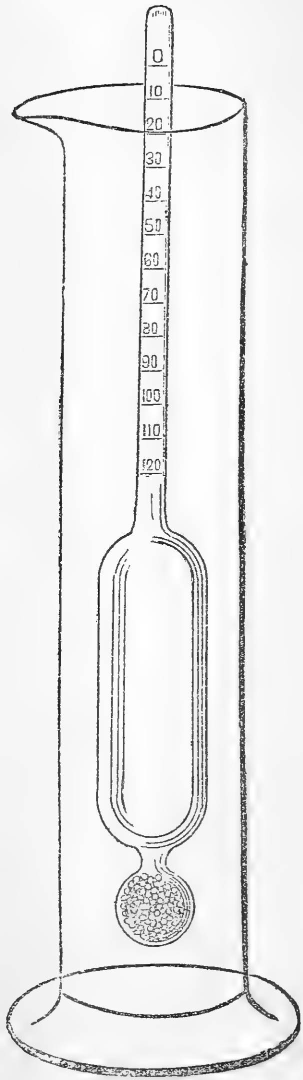

Fig. 4.

In graduating the Board of Health lactometer shown in Fig. 4, the 100° is placed at the standard 1.029, and 0 at 1.000 ; the gravity of water, the intermediate spaces being divided into 100 divisions. Great care should be taken to determine with absolute accuracy the 0 degree and the 100 degree; other points may also be determined, but they are not absolutely necessary if the space is properly divided. The point to which the lactometer sinks in the milk under examination indicates the percentage of milk in 100 parts. Thus, if the lactometer sinks to 80, the milk must consist of, at least, 20 per cent. of water and 80 of milk. This assumes the original milk to have had a specific gravity of 1.029; but, if the milk had originally a gravity of 1.034, it would require 16.67 per cent. of water to bring it down to 1.029, and 20 per cent. more water to lower it to 80° on the lactometer. The temperature at which examinations are made with the lactometer should be 60° F., for *exact* determinations, as the instrument is graduated for that temperature. If it is only necessary to establish the *fact* of an adulteration by water, the milk may be cooled to a temperature below 60° F., which an expert can easily ascertain by the sense of taste, etc. The lower the milk is cooled the more dense it becomes; consequently, if the lactometer should sink below 100 in a sample of milk known to be below 60° F., sufficient evidence to establish the *fact* of its adulteration is indicated. A sample of milk tested by Dr. Chandler,[1] which stood at 100 by the lactometer at 60° F., was found to stand at 106 at 44° F., at 98 at 66° F., at 90 at 80° F., and at 74 at 100° F.

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[1] Johnson's Cyclopædia, article "Milk."

Value of the Degrees of the Board of Health Lactometer in Specific Gravity.—By Dr. Waller.

Lactometer.	Gravity.	Lactometer.	Gravity.
0	1.00000	45	1.01305
1	1.00029	46	1.01334
2	1.00058	47	1.01363
3	1.00087	48	1.01392
4	1.00116	49	1.01421
5	1.00145	50	1.01450
6	1.00174	51	1.01479
7	1.00203	52	1.01508
8	1.00232	53	1.01537
9	1.00261	54	1.01566
10	1.00290	55	1.01595
11	1.00319	56	1.01624
12	1.00348	57	1.01653
13	1.00377	58	1.01682
14	1.00406	59	1.01711
15	1.00435	60	1.01740
16	1.00464	61	1.01769
17	1.00493	62	1.01798
18	1.00522	63	1.01827
19	1.00551	64	1.01856
20	1.00580	65	1.01885
21	1.00609	66	1.01914
22	1.00638	67	1.01943
23	1.00667	68	1.01972
24	1.00696	69	1.02001
25	1.00725	70	1.02030
26	1.00754	71	1.02059
27	1.00783	72	1.02088
28	1.00812	73	1.02117
29	1.00841	74	1.02146
30	1.00870	75	1.02175
31	1.00899	76	1.02204
32	1.00928	77	1.02233
33	1.00957	78	1.02262
34	1.00986	79	1.02291
35	1.01015	80	1.02320
36	1.01044	81	1.02349
37	1.01073	82	1.02378
38	1.01102	83	1.02407
39	1.01131	84	1.02436
40	1.01160	85	1.02465
41	1.01189	86	1.02494
42	1.01218	87	1.02523
43	1.01247	88	1.02552
44	1.01276	89	1.02581

Lactometer.	Gravity.	Lactometer.	Gravity.
90	1.02610	106	1.03074
91	1.02639	107	1.03103
92	1.02668	108	1.03132
93	1.02697	109	1.03161
94	1.02726	110	1.03190
95	1.02755	111	1.03219
96	1.02784	112	1.03248
97	1.02813	113	1.03277
98	1.02842	114	1.03306
99	1.02871	115	1.03335
100	1.02900	116	1.03364
101	1.02929	117	1.03393
102	1.02958	118	1.03422
103	1 02987	119	1.03451
104	1.03016	120	1.03480
105	1.03045		

The following table by Dr. Voelcker, with an addition by Dr. Chandler, illustrates the effects of watering and skimming:

	UNSKIMMED.		SKIMMED.	
	Sp. Gr.	Lact.	Sp. Gr.	Lact.
Pure milk	1.0314	108	1.0337	117
10 per cent. water added..	1.0295	102	1.0308	106
20 " " " ..	1.0257	88	1.0265	91
30 " " " ..	1.0233	80	1.0248	86
40 " " " ..	1.0190	66	1.0208	72
50 " " " ..	1.0163	56	1.0175	60

Thus it is seen that with a sample of pure milk of sp. gr. 1.0314 more than 10 per cent. of water could be added before the gravity is reduced to 1.029 or 100 on the lactometer; and, after skimming, considerable more.

That the specific gravity 1.029 is the true minimum standard for *pure whole cow's milk,* I think I have already fully demonstrated; yet it is interesting to bear in mind that it has been confirmed by Müller,[1] Fleischmann, Goppelsröder, Krämer, and other *specialists.*"

[1] Anleitung zur Prüfung der Kuhmilch, p. 42.

Müller[1] says: "From more than 6,000 notes by Quevenne and Bouchardat, the minimum is 1.029, and the maximum 1.033. For the hospitals and public institutions in Paris, the minimum is 1.030." He further says: "If" . . . "we go through all Europe, from country to country, from place to place, from dairy to dairy, from Alp to Alp, with the lactodensimeter in hand, and mix at times the milk of several cows together which have been milked under conditions sufficiently touched upon, we shall find that the milk which is divided as a trade commodity from the physiological milk weighs between 1.029 and 1.033."

Let us consider, now, if there are any objections to the use of the standard lactometers for the detection of adulteration. I have already stated that a sample of perfectly pure cow's milk, possessing a high specific gravity, can be considerably additioned with water, and the lactometer is unable to detect the fraud. The question naturally arises, is there any method by which the fraud can be detected? The answer comes unfortunately, *no*—owing to the variation in the proportion of each constituent, a proper margin has to be left for the maximum and minimum proportions, and between these limits the fraud can be perpetrated, and defy all Science to detect it.

Milk may be skimmed, which will increase the specific gravity of the fluid; it may then be watered, and the sp. gr. reduced to the standard of the lactometer, or the sp. gr. may be still further reduced, and by the addition of some solid substance, such as sugar or salts, increased to the standard specific gravity. The question naturally arises here, can the lactometer detect such adulteration? To answer this question, we must first inquire into the method adopted where the lactometer is used to detect adulteration. It is to be

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[1] Correspondenz-Blatt des Niederrheinischen Vereins für oeffentliche Gesundheitspflege. Band vi., p. 82. Dr. Heusner.

supposed that an expert commissioned to examine milk for adulteration, using, as a means, the lactometer, will perform the test which is to be made, in connection with the senses—that is to say, the sample under examination should be examined as to its opaqueness and color, its taste and odor, etc. If, on the contrary, he performs the test automatically, simply taking the degree of the instrument, noting the temperature, without examining the sample otherwise—the lactometer itself will not detect such adulteration; but such an experimenter is not fit or competent to make such investigations, for, no matter what the method of examination may be, the common sense is always required to accomplish the object in view. I say it *without fear of successful contradiction*, that if the lactometer is used in connection with the senses, that is to say, regarding the flow of milk from the bulb of the instrument, observing its opacity and color, as also examining as to flavor and odor of the sample under examination, that the lactometer will detect all the *practical frauds* perpetrated *by milkmen*. In my opinion there is not one unprejudiced person, with the experience and education that a milk expert should have, that cannot distinguish a fair sample of pure milk from a fair sample of skimmed milk or cream; and, if such is the case, how readily could be detected an adulterated sample.

In the first part of this paper I stated that the indications of the lactometer are infallible; this is the case, for if a sample of milk should indicate a degree less than the standard, there is indisputable evidence that the sample has been tampered with.

METHOD OF DETERMINING THE CREAM.

Sir Joseph Banks was the inventor of an instrument by means of which the cream in milk may be determined; this instrument was called by him the Lactometer, but it afterwards received the more appropriate name—Creamometer. It consists of a graduated tube, usually eleven inches long and half an inch in diameter; ten inches of this are graduated in tenths of an inch—that is, in hundredths of the whole. To make the examination the tube is filled with milk up to the 100 mark, and set aside for twelve hours; the cream rises to the surface, and its volume is determined by the thickness of the stratum formed, and which is ascertained by noting the number of degrees or tenths through which it extends.

This method is based on the assumption that all milk, under the same circumstances, would deposit its cream with the same facility, and that the cream so deposited would always have the same proportion of fat in it. As to all milk depositing its cream with the same facility, is evidently a mistake, for experiments have demonstrated that the larger the milk globules the more rapid will they rise, and the more perfect will be the separation of the cream from the milk. Valuable investigations by Dr. Sturtevant[1] have shown that the milk of a butter-cow consists mostly of large globules, whilst the milk of a cheese-cow contains very small globules. So that if two samples of milk, one from a butter-cow and the other from a cheese-cow, were placed in a Creamometer and allowed to rest for 12 hours, the cream from the butter-cow's milk would be far greater than that from the other, owing to the fact that the globules rise more rapidly.

Careful trials of this test, made with different samples of milk, whose composition was determined by chemical analysis, have shown that it is untrustworthy. Baumhauer examined 20 different samples of milk in this manner. His results are recorded in the following table:[2]

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[1] Ayrshire Cow, p. 239.

[2] See Amer. Chem., Nov., 1876, p. 199.

Table I.

	On 1000 c.c. of Milk.						On 100 Parts by Weight of Non-volatile Matter Deprived of Fat.				Determination of Density by Direct Weighing.		Lact-ometer.		Galacto-meter.		Cream-ometer.
	Non-volatile substances.	Substances soluble in ether.	Sugar.	Other substances soluble in water.	Substances insoluble in water.	Mineral constituents.	Milk-sugar.	Other substances soluble in water.	Substances insoluble in water.	Mineral constituents.	In its natural state.	Skimmed.	In its natural state.	Skimmed.	In its natural state.	Skimmed.	
1. 11 March, near Amsterdam..	123.8	26.8	45.8	12.0	39.2	7.9	47	12	41	8.1	1.0343	1.0360	16.3	17.0	120	113	10 0
2. 11 March. near Leyden.......	111.4	25.7	47.0	11.6	27.1	7.6	54	14	32	8.9	1.0320	1.0328	15.2	15.6	110	106	7.7
3. 4 February, near Hague.....	133.6	35.3	39.1	14.4	44.8	7.7	40	13	46	7.8	1.0353.	1.0369	16.7	17.5	124	116	10.0
4. 25 March, at Papendrecht...	108.4	19.7	47.4	11.3	30.0	7.0	53	13	34	7.9	1.0310	1.0320	14.7	15.2	111	102	8.7
5. 25 March, at Dubbeldam....	123.9	33.1	35.5	20.3	35.0	6.8	39	22	39	7.5	1.0303	—	14.4	—	106	—	8.5
6. 15 April, near Utrecht.......	121.6	23 7	40.9	14.9	42.1	8.0	42	15	43	8.1	1.0319	1.0340	15.0	16.0	111	109	9.5
7. 15 April, near Utrecht.......	112.1	23.3	45.5	12.0	31.3	7.2	51	13	36	8.0	1.0307	1.0330	14.5	15.6	106	105	10.7
8. 9 January, near Arnhem.....	125.5	32.3	52.8		40.4	7.5	56		44	8.0	1.0338	1.0340	—	—	124	—	4.7
9. 7 January, near Tiel.........	110.4	27.7	59.3		23.4	7.0	71		29	8.4	1.0309	1.0329	—	—	—	—	9.2
10. 7 January, near Tiel.........	105.0	29.8	52.0		23.2	6.4	69		31	8.5	1.0280	1.0290	—	—	—	—	8.5
11. 7 January, near Doesburg....	124.9	20.8	54.8		49.3	6.7	53		47	6.4	1.0318	1.0326	—	—	—	—	12.5
12. 9 January, near Zutphen.....	123.6	37.1	51.1		35.4	7.9	59		41	9.1	1.0335	1.0341	—	—	119	—	8.0
13. 9 January, near Zutphen.....	107.1	25.5	51.3		30.3	7.1	63		37	8.6	1.0307	1.0312	—	—	112	—	7.2
14. 7 January, near Niméguen...	137.4	43.4	60.7		33.3	7.4	64		36	7.9	1.0341	1.0363	—	—	—	—	—
15. 7 January, near Niméguen...	125.8	39.9	57.8		28.1	7.5	67		33	8.7	1.0326	1.0348	—	—	—	—	8.5
16. 7 January, near Niméguen...	104.4	20.9	59.4		24.1	7.3	71		29	8.7	1.0321	1.0333	—	—	—	—	7.7
17. 28 April, near Leeuwarden...	112.6	27.6	41.4	19.5	24.1	7.0	48	22	30	8.2	1.0303	—	—	—	—	—	8.7
18. 28 April, near Leeuwarden...	116.4	22.8	39.5	16.3	37.8	7.2	42	17	41	7.6	1.0300	—	—	—	—	—	8.5
19. 28 April, near Leeuwarden...	118.8	27.7	40.9	20.8	29.4	7.1	45	22	33	7.8	1.0301	—	—	—	—	—	—
20. 28 April, near Leeuwarden...	122.4	27.7	43.0	20.3	31.4	7.3	45	21	34	7.7	1.0318	—	—	—	—	—	3.5
Mean.......	118.5	28.5	57.0		33.0	7.3	63.2		36.8	8.1	1.0318	1.0334	—	—	—	—	—

On examining this table we find that experiments Nos. 1 and 3 were found by chemical analysis to have respectively 2.7 and 3.5 per cent. of fat, while the creamometer indicated no difference between them. Nos. 5, 10, 15, 18, and 20 were found to contain 3.3, 3.0, 3.9, 2.3, and 2.7 per cent. of fat, but the thickness of the layer of cream formed by all of them was the same.

The addition of water to milk facilitates and hastens the separation of its cream, but, of course, does not

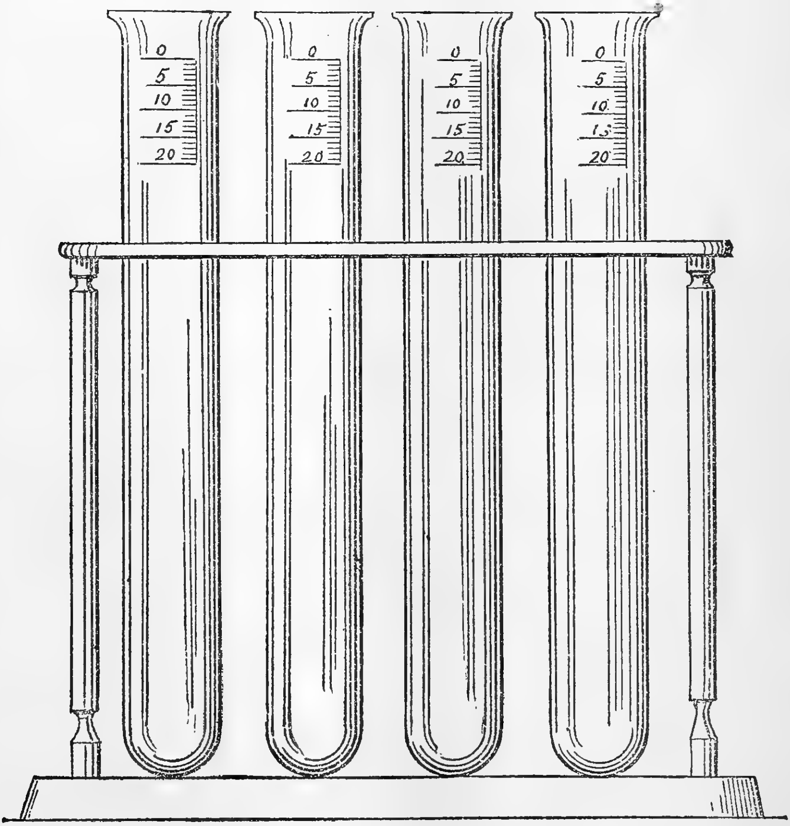

FIG. 5.

increase the amount, as has been erroneously stated. Some creamometers resemble test-tubes in shape, and like them, are supported in racks (see Fig. 5); they are usually graduated only in the upper two inches; others are provided with feet, and are graduated throughout their whole length. A great deal has been said about combining the indications of the lactometer with those of the creamometer—it is very certain that, if the indications of the creamometer cannot be relied upon, no benefit can be derived by combining them with those of the lactometer.

KROCKER'S[1] APPARATUS.

Krocker made an apparatus for collecting the quantity of cream a given sample would furnish, which is somewhat of an improvement on the old creamometer. The milk is set in shallow vessels, but two or three inches deep, from which the cream was afterwards transferred to a slender glass cylinder with a graduated scale on its side, in which graduated cylinder the amount of cream produced by each sample of milk could be accurately measured. "In Krocker's simple form of apparatus devised for this purpose (see Fig. 6) the dishes in which the milk is set for cream to rise

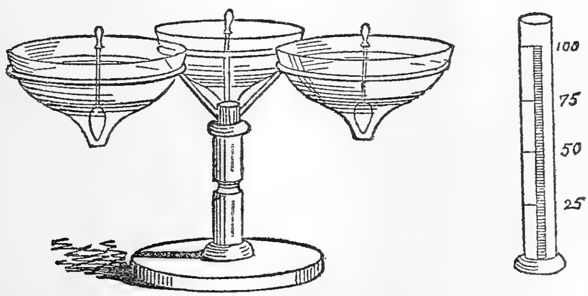

FIG. 6. KROCKER'S CREAMOMETER.

are supported in iron rings attached to an upright stand, they taper down to a narrow orifice at the bottom, closed by a ground glass stopper, the long handle of which reaches up through the milk; on lifting this

[1] Die Milch von Benno Martinez. Also Am. D. Ass. 1871, p. 45.

stopper, the milk under the cream flows off, and it is easy to mark the precise moment at which the cream begins to flow out, when the stopper is put into its place and the opening closed till the graduated cylinder can be placed to receive the cream."

To define the utility of his creamometer, Krocker, in 1855 and 1856, undertook two series of experiments. In the first of them the mid-day milk of 12 different cows was put during twenty-four hours at 10° to 12° R., on the one hand, into one or two of his creamometer globes 1½ to 2 inches high, on the other hand, into one or two cylinders 18 inches high, and the contents of the milk of each cow in fat and dry substance were determined by Haidlen's method. In the second series there were three divisions of experiments each made with one sort of milk, the first was to show the duration of the skimming in the globes by itself at an even temperature, the second the same in comparison with the cylinders, and the third the skimming in the globes at different temperatures. The per cents of cream are ascertained according to the volume.

1*st Experiment.*

No. of Expr.	Per cent. of Cream.				Per cent. obtained from milk.		Remarks.
	In the Globes.		In the Cylinder.				
	A	B	A	B	Fat.	Milk, Solid	
1	12.5	12.25	11.0	11.75	2.30	12.70	
2	9.5	9.3	6.9	6.9	2.50	11.64	
3	10.0	10.3	8.75	7.80	2.73	12.02	
4	10.75	10.5	8.9	8.4	2.81	12.31	
5	12.50	.....	12.0	.....	3.18	13.24	
6	11.20	.....	10.75	.....	2.75	13.04	
7	12.40	.....	12.0	.....	3.43	13.12	In the original paper for A 1.40 was given instead of 12.40 (Ex. 7).
8	13.25	.....	13.0	.....	3.15	13.20	
9	10.0	.....	18.*0	.....	2.30	11.85	Milk fresh, acid reaction.
10	12.4	.....	8.5	.....	3.14	13.13	
11	12.4	.....	16.*0	.....	3.23	13.20	Very acid reaction.
12	10.0	.....	15.5	.....	2.63	12.25	Strongly acid reaction.
13	13.2	.....	.....	.....	2.63	12.25	Milk No, 12, with 1% of soda added.

2d Experiment.

Divisions.	Temperature. Degrees. R.	Vessels.	Per cent. of cream deposits after standing in hours.					Remarks.
			6	12	18	24	40	
I	10 to 12	Globe No. 1...	12.2	....	....	....	....	
		" " 2...	....	11.6	....	....	....	
		" " 3...	....	...	11.9	....	....	
		" " 4...	....	....	....	11.9	....	
		" " 5...	....	....	....	14.8	....	With addition of 1% of soda.
II	10 to 12	Globe No. 1...	11 2	....	....	....	....	
		Cylinder No. 1	10.0	....	....	....	....	
		Globe No. 2...	....	....	11.8	....	...	
		Cylinder No. 2	....	....	10.5	....	....	
		Globe No. 3...	....	....	....	12.0	....	
		Cylinder No. 3	....	....	....	11.0	....	
		Globe No. 4...	....	....	....	....	12.0	With beginning decomposition.
		Cylinder No. 4	....	...	....	....	11.5	Also with decomposition.
		Globe No. 5...	....	....	15.2	....	....	With addition of 1% of soda.
III	16 to 18	Globe No. 1...	....	....	....	....	....	Indistinct.
		" " 2...	....	....	11.6	....	....	Cream layer with slightly sharp border,
		" " 3...	....	....	....	11.5	....	Milk already thickening and very acid.
	10 to 12	" " 4...	....	....	12..	....	....	

On examining the above tables, it will at once be seen that the measurement of the cream even by means of the globe is very uncertain as well as of little value for ascertaining the fatty contents of milk, although its results are much more accurate than those obtained where cylinders are employed. The deposit of cream of the same milk differed in different globes up to 0.3 per cent. (Experiment No. 3), in the cylinders up to 0.75 per cent. (Experiment No. 1); the same per cents of cream in the globes of different milk, namely, 10 per cent., came from milk with 2.31, 2.63 and 2.73 per cent. of fat, (Experiment Nos. 9, 12, 3,) and 12.4 per cent. of cream from milk with 3.14, 3.23 and 3.43 per cent. of fat, (Ex. Nos. 10, 11, 7,) while milk with nearly the same fatty contents, namely, 3.14, 3.15, 3.18, 3.23 per cent. (Ex. Nos. 10, 8, 5, 11) furnished in cream in the globes 12.4, 13.25, 12.50, 12.4 per cent., in the cylinders 8.5, 13, 12, 16 per cent.

If experiments 7 and 8 in respect to the globes, and 10 and 12 in respect to the cylinders, be compared with each other, fatty contents of 3.66 per cent. may be calculated from 7 for 8, while the same actually amounted to only 3.15 per cent., and from 10 for 12 contents of 5.7 per cent. opposed to 2.63 per cent. actual contents (the indistinct separation of cream in No. 9 would have given a still greater difference) The experiments show further, that the skimming is to be considered as ended after 18 hours in the globes at 10° to 12° R., while it has lasted as long as 40 hours in the cylinders, and that a temperature of over 16° R., is less adapted for the determination of the cream layer than one of 10° to 12° R. Finally the experiments show that an addition of 1 per cent., of soda to the milk considerably thickened the layer of cream; whether in like measure the separation of fat from the milk was promoted is not demonstrated.

CHEMICAL ANALYSIS.

Every scientific man will admit that, by chemical analysis, the constituents of milk may be estimated and the nature of the adulterants in a given sample ascertained and determined, provided, the adulterants if they are one or more of the constituents of milk, the additional quantity exceeds the maximum amount present in pure milk. The great objection to chemical analysis as a practical means for detecting the adulteration of milk, is that such investigations require the practiced hand of a chemist, as also considerable time.

To practically establish the *fact* of an adulteration (which is all that is wished to be attained or is possible to attain) of the *numerous* samples that have to be examined daily in the large cities throughout the world, I consider that chemical analysis is perfectly useless, for it is very evident that the examination must occupy only a few minutes to be at all practical, or to admit of a general application.

That my opinion is not at variance with the opinions of those who have the most right to speak on this subject, I quote from Gomp Besanez,[1] who says, (speaking of the detection of water): "An exact chemical analysis of milk would certainly lead most surely to the end, but the applicability of this method to the sanitary-police control of milk in the larger cities, exactly where such control seems most necessary, is frustrated by two circumstances: the expense of time which every such analysis requires, rendering impossible the nearly simultaneous proof of many samples of milk, and the fact that such an analysis can only be performed by a skillful chemist."

Christian Müller[2] says: "Chemical analysis is called upon to prove milk and its nature physiologically, to characterize morbidly changed milk, and to discover the alterations it has suffered; further, to find out the changes which milk undergoes through the influences of food, time of day and seasons of the year, of the temperature, of the mode of life of the animal, etc. Also it furnishes alone the means of proving adulterations of milk by the addition of such substances as are not contained in the normal milk. It cannot, however, serve for the detection of adulterated milk, and leaves us completely in the lurch when it is wanted to confirm the ordinary adulteration of milk, addition of water and skimming, in no large measure. If the latter adulterations attain such a degree that the chemical expert may declare the adulteration by the existing scientific notes, there are other means which lead to the end far more quickly, with less expense of time and money, and with equal certainty. . . . . . . In accusations of the last mentioned ordinary adul-

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1 Physiol. Chemie, Band III., p. 459.

2 Anleitung zur Prüfung der Kuhmilch, p. 39.

terations, chemical analysis is of importance to the judge only when legally regulated figures are fixed, which the chemical expert has simply to seek and confirm."

He also says:[1] "I have learned with great regret, that recently the claims of chemical analysis have gained admission into the regulations of a few dairies. This is according to my conviction an ever-ending series of processes, which will precisely hinder that which it is desired to attain, and I consider it a duty to earnestly warn against it. Science itself summons us, therefore, imperiously before another tribunal, and it will be asked: Where do we find this? The answer is easy, and is the lactodensimeter[2] in the dairy."

Dr. Heusner[3] says: "Chemical analysis has the advantage that its conclusions are based on direct proof and not on indirect physical methods, but on the other hand, according to the statements of Müller, Goppelsröder, and Fleischmann, it is less adapted for the detection of minor adulterations than Müller's method. (Lactometer Method.) The reason of this is, that with regard to the percentage of solids and fat there are as yet no such reliable and extended observations as has been made with regard to the limit of specific gravity, and partly owing to the defectiveness of the chemical methods thus far employed."

"Complete analysis is only necessary where foreign substances are suspected in milk, and in such cases the microscopic investigation should not be omitted."

The reasoning just given by Dr. Heusner I can fully endorse. Surprising as it may seem, out of the thousands of analyses of cows' milk which have been reported in the various works, only a few can be selected, which are fairly stated to represent the analysis of an *average* sample of *whole* milk. I have frequently

[1] Loc. cit., p. 77.

[2] Lactometer.

[3] Deutscher Verein für oeffentliche Gesundheitspflege, 1877, p. 51.

seen stated that the milk examined was *believed to be* a fair average sample of the whole milk, but, of course, such statements go for nothing.

Unless the samples were obtained in the presence of the experimenter, or by his assistant in whom he has confidence, no great value can be attached to them.

Any number of analyses representing the whole milk from spayed cows or cows being dried off or in other abnormal conditions can be selected, but these would possess no value as regards a true standard for pure milk.

The following analyses given to me by Dr Waller, which he carefully made, are of the whole milk, and will serve as examples:

ANALYSIS NO. 1.		ANALYSIS NO. 2.	
Name of cow—"*Red.*" Age—5 years. Feed of cow—Fresh brewer's grain, Indian meal, brand with some salts. Quantity of milk (evening), 3½ qts. Whole quantity of milk said to be 10 qts. per day. Cow in perfect health. Sample obtained Jan. 15, 1877, in the presence of Dr. Waller.		Name of Cow—"*Strawberry.*" Age—6 years. Feed of cow—Fresh brewer's grain, Indian meal, brand with some salt. Quantity of milk (evening), 5 qts. Whole quantity of milk said to be 10 qts. per day. Sample obtained Jan. 15, 1877, in the presence of Dr. Waller.	
Lactometer	106°=1.03074	Lactometer	103°=1.02987
Cream 12½% by vol. (16 hours).		Cream by vol. 8.7% (16 hours).	
Whey	92°=1.02668	Whey	92°=1.02668
Average of two Analyses.		*Average of two Analyses.*	
Water	87.202	Water	87.240
Milk solids	12.798	Milk solids	12.760
	100.000		100.000
Fat	3.389	Fat	3.684
Milk sugar	4.743	Milk sugar	4.828
Casein	3.854	Casein	3.518
Inorganic salts	0.812	Inorganic salts	0.730
	12.798		12.760

The first of the following tables was compiled by Dr. Jos. C. Rowland, Assistant Sanitary Inspector of N. Y. All the milk from each cow, at the time of milking, was collected in the presence of Dr. Rowland, was thoroughly mixed together by him, a sample cooled to 60° F., then tested with the lactometer with the

I.—*Table showing the Record of each Cow.*

Name.	Age.	Where Bred.	Last Calving.	Time of Next Calving.	Average daily Quantity of Milk.	Evening Milking.		
						Yield.	Sp. Gr.	Lactometer at 60° F.
1. Fanchon.......	10	England, Alderney Islands	Dec. 8, 1876.	Not with calf.	14 quarts.	6 quarts.	1.0336	116
2. Eugenia.......	10	" " "	Aug. 14, "	Nov. 10, 1876.	5 "	2 "	1.0348	120
3. Eugenia 2d....	4	American breed from pure Alderney.	Feb. 25, "	March 1, 1877.	7 "	3 "	1.0348	120
4. Ruby..........	12	England, Alderney Islands	Nov. 17, "	Not served.	14 "	5½ "	1.0369	127½
5. Belle of Farmington........	10	" " "	May 4, "	April 5, 1877.	4 "	2 "	1.0330	114
6. Mag..........	12	" " "	Oct. 1, 1872.	Not with calf.	5 "	2 "	1.0353	122
7. Mabile........	10	" " "	April 15, 1876.	May 30, 1877.	4 "	2 "	1.0396	136
8. Frolic 3d......	6	American breed from pure Alderney.............	Sept. 25, "	Not served.	7 "	3½ "	1.0348	120
9. La Biche......	4	" "	June 19, "	Aug. 17, 1877.	7 "	3¼ "	1.0369	127½
10. Caprice........	10	England, Alderney Islands	Nov. 17, "	Not served.	9 "	4 "	1.0350	121
11. Rose 2d.......	7	American breed from pure Alderney.............	Nov. 1, "	Not served.	7 "	3 "	1.0350	121
12. Rose 4th......	4	" "	Oct. 11, "	Dec. 21, 1877.	14 "	6½ "	1.0330	114

TABLE II.— *Analyses of Milk from the above-mentioned Cows.* By DR. ELWYN WALLER.

Name.	Water.	Fat.	Milk Sugar.	Casein.	Inorganic Salts.	Cream by Volume.	Lactometer.	Whey by Lactometer.
1. Fanchon	84.642	5.550	5.020	3.807	0.981	10 per cent.	116	102
2. Eugenia	86.919	2.922	4.975	4.370	0.814	8 "	120	98
3. Eugenia 2d	85.476	4.379	4.963	4.407	0.775	18 "	120	99
4. Ruby	85.143	4.470	4.825	4 657	0.905	18 "	127½	102
5. Belle of Farmington	83.641	6.158	4.361	4.809	1.034	20 "	114	102
6. Mag	83.150	6.500	4.973	4.544	0.833	24 "	122	102
7. Mabille	81.914	5.909	4.667	6.428	1 082	25 "	136	104
8. Frolic 3d	85.939	4.256	4.914	4.105	0.786	9 "	120	99
9. La Biche	83.421	5.375	4.700	5.617	0.887	12 "	127½	100
10. Caprice	86.089	3.569	5.082	4.405	0.855	....	121	....
11. Rose 2d	85.489	4.218	4.966	4.390	0.937	....	121	....
12. Rose 4th	87.064	3.515	4.964	3.620	0.837	....	114	101
Average	84.907	4.735	4.867	4.596	0.893	16 per cent.	121½	101

tabulated results. The samples were then given to Dr. Waller for analysis, the results being tabulated in Table II.

Although these analyses possess a value, before a true standard can be established a large number more will be required.

With respect to the defectiveness of the methods for making analyses of milk, no better proof is necessary than that most every chemist has a method of his own. Gorup. Besanez says:[1] "Strictly speaking only those analyses are comparable that are made by the same method of analysis."

As I have already stated, no matter what method we adopt to detect adulteration, a standard that will represent the poorest pure milk has got to be adopted. For this reason the British Society of Public Analysts have determined upon the following as the *minimum* proportions of constituents in unadulterated milk:

Water	88.5
Milk solids	11.5
	100.0
Fat	2.5
Solids not fat	9
	11.5

The proportion of the fat in this analysis is, in my opinion, considerably too low for pure healthy *whole* milk, and it is my opinion, when a large number more of analyses are made of the whole milk from cows in perfect health, it will be found that the poorest milk will have more nearly the following composition:

[1] Physiol. Chemie, Band III., 1875.

Water	88.0
Milk solids	12.0
	100.0
Fat	3.0
Solids not fat	9.0
	12.0

If a sample of the whole milk of a cow is found, which gives less than 3 per cent. of fat, other samples from the same cow should be taken on some other occasions to verify the result; if the second and third analyses give a greater proportion of fat, sufficient proof is furnished, that when the first sample was obtained the cow was in a slightly abnormal condition. When we think how many simple circumstances will materially change the composition of the milk of a cow, such as even worrying or running the cow, etc., we will readily see how necessary it is to make duplicate analyses as we approach the limits of variation.

DONNÉ'S LACTOSCOPE.

An instrument was invented some years ago for determining the fat contents in milk by M. Donné, of Paris. The following observations are by the discoverer:[1]

"Milk owes its white dense color to the globules or fatty matter or butter which it contains; the more numerous these globules the more opaque is the milk, and the more, at the same time, is it rich in the fatty part, or in cream, the more or less opacity being in relation with its principal quality—its richness in cream; the measure of this opacity is capable of giving them, indirectly, the measure of the richness of the fluid, and of indicating its value.

[1] See Hassal—Adult. of Foods, p. 227 (1857).

"But the degree of opacity of milk cannot be appreciated upon a mass of the fluid; it is not possible to measure it but in very thin layers, and it is this which is done with our lactoscope. This instrument is constructed in such a way that the milk may be examined in it in layers of every thickness, from the thinnest, through which all objects may be distinguished, up to that which allows of nothing to be perceived; it gives at once the richness of milk, in indicating the degree of opacity to which the proportion of cream stands in relation.

"The instrument consists of a kind of eye-glass composed of two tubes sliding one within the other, furnished with two parallel glasses, which approach each other up to contact, and separate more or less the one from the other at will by means of a very fine screw; a little funnel destined to receive the milk is placed at the upper part, on the opposite side is fixed a handle, which serves to hold the instrument. The tube which screws within the other forms the anterior or ocular part, that to which the eye is applied; it is marked with divisions to the number of 50, and figures which indicate the richness of the milk.

"A few drops of the milk to be examined are poured into the funnel. It is necessary to take the sample of milk from the mass of the milk, and not the surface of the liquid only, where the layers of cream collect; if then the milk has been at rest for some time, it must be agitated a little in order to mix all the parts.

"The funnel being full, the ocular tube is turned from right to left until the liquid has penetrated between the plates of glass, and collected at the bottom; the ocular tube is then turned in the opposite direction, from left to right, and one looks through it until the flame of a taper or candle can be distinguished. At this point stop and impress a slight rotatory movement, until, by a little manipulation, the light is lost to view, without going beyond the moment, when it is distinguished, so to speak, and ceases to be perceived; that is the point, definitely, where it is necessary to stop; it is only then required to read the figure of the division to which the arrow corresponds: that, we suppose, will be 25. The annexed table shows to what degree of richness, or to what proportion of cream the figure corresponds.

"The light ought to be placed at about a metre (at least three feet) from the observer; a greater distance will not impair the accuracy of the operation, but it is not the same if one looks from too near.

"One may assure himself of the accuracy of the instrument by adding a very small quantity of water, or even gruel, to the milk. Twenty degrees of water are sufficient to change the transparency of the liquid, thus milk marking 25, will mark 28 or 30 on mixing with it a little water.

"At the moment when the milk is introduced between the two plates of glass, it commonly happens that bubbles of air are enclosed in the layer of liquid; it is necessary to drive them out, and this is easily done by impressing certain movements on the milk, by separating more or less the eye-piece so as to cause the two plates of glass to withdraw and approach each

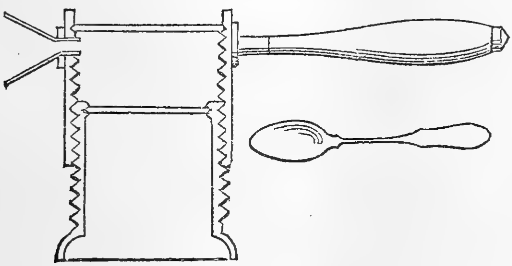

Fig. 7. Donné's Lactoscope.

other alternately. When the trial is terminated, the eye-piece is to be removed so as to clean the instrument perfectly, and to wipe the glasses; the glasses ought always to be very bright, and one ought to avoid, during the observation, to tarnish with the breath the glass of the eye-piece."

Relation of Degrees of the Lactoscope to vol. of Cream and Weight of Butter.

Degrees of the Lactoscope.	Approximate Weight of Butter per Litre.	Volume of Cream.	Degrees of the Lactoscope.	Approximate Weight of Butter per Litre.	Volume of Cream.
25	40		38	27.	
26	39	12	39	26.	8
27	38		40	25.50	
28	37		41	25.	
29	36	11	42	24.50	7
30	35		43	24.	
31	34		44	23.50	
32	33	10	45	23.	
33	32		46	22.25	
34	31		47	21.50	
35	30	9	48	21.	6
36	29		49	20.50	
37	28	8	50	20.	

Soubeiran,[1] speaking of Donné's lactoscope, says: "This instrument is founded on the supposition that the opacity of milk is proportional to the quantity of fatty matter and casein which it contains; but it depends also, probably, upon the diameter of the fatty globules, and on the state of more or less perfect suspension of the casein; it is therefore attached to variable natural causes, and consequently the appreciations based on the character of the opacity can have no precise character."

DR. HEUSNER'S LACTOSCOPE.

Dr. Heusner[2] has made an alteration in Donné's lactoscope, and says: "In my lactoscope (see Fig. 8) the two glass plates are fastened in a short brass ring, and

[1] Nouv. Dic., Falsifications et des Altérations, Aliments, etc., Paris, 1874, p. 309.

[2] Correspondenz-Blatt, etc., Band VI., p. 82.

one of them is covered with a grating of thick black lines (b b′). Between the plates a space remains of only 2 millimeters in width (d) that by a cross-piece (c) is divided into two halves, one (b′) of which is destined for the reception of the milk to be examined, the other (b) to receive the normal milk used in the comparison.

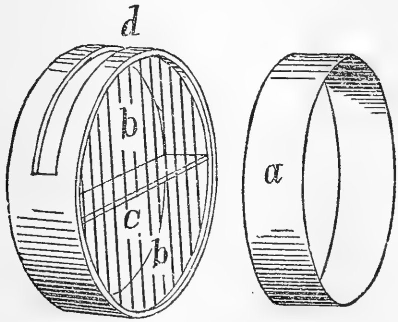

FIG. 8. DR. HEUSNER—APPARATUS.

"To be relieved of the trouble of procuring normal cow's milk before each investigation, I have had a small plate of milk-glass set into the half (b) of the apparatus, which possesses exactly the transparency of normal cow's milk in a layer of 2 millimeters thickness. The milk to be examined is put in through a slit-shaped opening of the brass case, by simply dipping the apparatus into the milk and a cover *a* is pushed over the slit to close it. After drying, the little instrument is held up to the bright light and examined to see through which half the black lines can be more distinctly perceived. If the milk appears more transparent than the milk-glass, we are justified in inferring one of those adulterations by which the fatty contents can be diminished. Besides the more simplified method of use, this lactoscope has this advantage, that it may be used in any light. I will observe that the apparatus was ready only a short time before my departure, and that consequently I could not find time to experiment on its exactness."

VOGEL'S OPTICAL MILK TEST.

Alfred Vogel's optical milk test is essentially only an alteration and simplification of Donné's lactoscope, differing from it chiefly in that, instead of measuring a milk-layer through which a flame of a candle-light is still visible, the quantity of milk is measured that is required to render water so opaque as to cause the candle light to disappear completely if looked at through a layer of milk of a certain thickness. The method depends on the principle that the richer a sample of milk is in fat the less of it will be required to make a thin layer of water so opaque that a light cannot be seen through it.

"The apparatus[1] required consists of a measuring flask, with a mark on the neck, indicating a capacity of 100 c.c., a test glass for holding a sample of the milk and water between the eye and the light, which should have parallel glass sides ½ c.m. apart so that the thickness of the layer of milk looked through will be exactly ½ c.m., a pipette graduated in ¼ cubic centimetres, and holding 4–5 c.c., and a box about 16 c.m., long and wide, with a slit in one side, in front of which, and 40 c.m. distant, the stearin candle is placed; the opposide side of this box is so cut out to fit the face that when the glass containing the milk is put in the box, all light can be excluded while an observation is made, except that coming through the slit from the candle; the inside of the box should be painted black.

"To perform the test, fill the 100 c.c. flask with distilled water up to the mark, add to 3 c.c. of the well-stirred sample of the cooled milk, and mix the two together thoroughly by vigorous agitation; fill the test-glass with this mixture, put it in the dark box, and make the observation, placing the eye close to the test-glass, and the candle against a dark background.

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[1] Agric. Chem., Caldwell, p. 265.

If the light can be seen, pour the test sample back into the flask, add ½ c.c. more milk, and make another observation; continue to operate in this manner, adding ½ or ¼ c.c. of milk each time, until the light is no longer visible." Add together the different quantities of milk, so as to find the total amount which has been added, and then ascertain from the following table the per cent. of butter the milk contains. The per cent. is calculated by the formula $\frac{23.2}{y}+0.23$, in which y = the number of cubic centimetres of milk required.

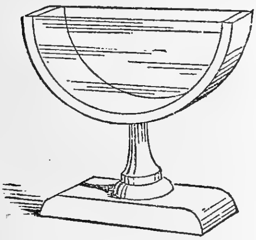

Fig. 9. Vogel's Optical Test.

Per cent. of Butter in Milk by Vogel's Optical Milk Test.

C.c. of Milk required.	Per cent. of Butter.	C.c. of Milk required.	Per cent. of Butter.	C.c. of Milk required.	Per cent. of Butter.
1.00	23.43	6.75	3.66	17.00	1.60
1.50	15.46	7.00	3.54	18.00	1.52
2.00	11.83	7.25	3.43	19.00	1.45
2.50	9.51	7.50	3.32	20.00	1.39
2.75	8.73	7.75	3.22	22.00	1.28
3.00	7.96	8.00	3.13	24.00	1.19
3.25	7.41	8.25	3.04	26.00	1.12
3.50	6.86	8.50	2.96	28.00	1.06
3.75	6.44	8.75	2.88	30.00	1.00
4.00	6.03	9.00	2.80	35.00	0.89
4.25	5.70	9.25	2.73	40.00	0.81
4.50	5.38	9.50	2.67	45.00	0.74
4.75	5.13	9.75	2.61	50.00	0.69
5.00	4.87	10.00	2.55	55.00	0.64
5.25	4.66	11.00	2.43	60.00	0.61
5.50	4.45	12.00	2.16	70.00	0.56
5.75	4.26	13.00	2.01	80.00	0.52
6.00	4.09	14.00	1.88	90.00	0.48
6.25	3.94	15.00	1.78	100.00	0.46
6.50	3.80	16.00	1.68		

Dr. Lauder Brunton[1] says: "Before applying this test, it must be ascertained by microscopical examination that the milk does not contain starch granules, or

[1] Physiol. Laboratory, Sanderson, p. 529.

any other impurity in suspension which might increase its opacity."

This method has been highly recommended for its accuracy by good authorities. Kuhn, in his prize essay on stock feeding, says that, as he has proved by his own experience, "this method enables one in a short time, and with but little trouble, to determine the fat in a large number of samples of milk with accuracy."

Caldwell[1] says: "After a little practice the whole analysis can be executed in three or four minutes, even to the cleaning of the apparatus to have it ready for another trial."

If cream is to be tested, only one cubic centimetre is to be added at first and a half c.c. at a time afterwards.

Vogel found that about 6 c.c. of pure cow's milk, or 3.7 of cream, added to 100 c.c. of water were sufficient to form a mixture which quite obscured a candle flame. When 8 c.c. are required, the milk contains about 30 per cent. more water than it ought, either from the addition of water, or of creamed milk. When 12 c.c. are necessary, the milk contains 50 per cent. too much water.

Hoppe-Seyler[2] alters this process so, that to a mixture of 5 c.c. of milk and 95 c.c. of water he keeps adding water until through a layer of 1 c.c. thickness the candle-light becomes visible.

Dr. Heeren[3] has very carefully examined into the merits of the optical test and says: "The four experiments performed by me with the most scrupulous care were the following:

"I. Pure milk from quite a fresh milking cow, milked in my presence, showed at 14° R., a spec. gravity of 1.0316. The chemical examination gave fatty con-

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[1] Report for 1871, Amer. Dairymen's Assoc., p. 50.

[2] Physiol. Chem., Band III., Milch, Gorup Besanez.

[3] Dingler's Polytechnisches Journ., Vol. 193, 1869, p. 403.

tents at 3.160 per cent. Examined with one of Vogel's galactoscopes, obtained from the mechanician Greiner in Munich, 8 cubic centimetres of milk were used, corresponding by the table to 3.14 per cent. The milk was divided into two parts; these were kept for 24 hours in a cellar and the milk of one part was taken away from under the cream by means of a siphon. This skimmed milk showed at 14° R. 1.0343 spec. gravity, and gave 0.701 per cent. by the chemical test; by the optical 22 K. C., corresponding to 1.28 per cent. The second unskimmed portion was now uniformly mixed by gently moving about, its specific gravity was sought for, which showed itself exactly the same as the day before=1.0316, and then by the addition of water it was diluted to a weight 4.508 times as much, by which its fatty contents became equal to those of the skimmed milk.

"This diluted milk of 0.701 per cent., fatty contents showed 0.690 per cent., by the optical test.

"II. Milk, not milked in my presence, but by the statement of the seller asserted to be still intact. Specific gravity = 1.0270. Fatty contents chemically determined = 5.018; optically 5.61 per cent. Skimmed, specific gravity = 1.0312; fatty contents chemically 1.670; optically 2.8 per cent. The unskimmed milk reduced by dilution to equal the fatty contents with the skimmed gave optically 14 K. C., corresponding to 1.88 per cent.

"III. Milk procured from a milkman, probably somewhat skimmed. Specific gravity = 1.0265; fatty contents chemically 4.225; optically 5.0. Skimmed, specific gravity=1.0312; fatty contents chemically 0.225; optically 1.0. The unskimmed portion diluted to 0.225 fatty contents, consequently now of equal fatty contents with the skimmed, gave optically over 2.00 K. C.

"IV. Milk from another milkman, without doubt partly skimmed. Specific gravity = 1.0260. Fatty contents chemically 2.312; optically 1.66 per cent. The unskimmed milk, reduced by dilution to the fatty contents of the skimmed, showed optically 24 K. C., corresponding to 1.19 per cent.

"A glance at these figures furnishes first of all a proof of the actually surprising exactness of the optical test, as long as we have to do with whole, intact milk, for the difference between the chemical and optical determination in No. I., 3.16 and 3.14, is certainly smaller than one might expect, when the gradual disappearance of the visibility of a candle-flame serves as the measure. In No. II. the agreement 5.018 and 5.61, or 100 : 112, is still less, but the possibility is by no means excluded, that the milk, in spite of the statement of the seller, may have suffered a slight addition of skimmed milk. In Nos. III. and IV., where more considerable differences presented themselves between the chemical and optical test, 4.225 and 5.0 (or 100 : 118) and 2.312 and 3.2 (or 100 : 139), probably, or indeed without doubt, a partial skimming had taken place.

"In all four investigations the deviations of the optical test showed themselves far more strongly in the skimmed than in the milk examined before the skimming, as the following table shows:

"Relation of the actual to the optically found fatty contents:

	Before Skimming.[1]	*After Skimming.*
In No. I.	1 : 0.997	1 : 1.82
" II.	1 : 1.12	1 : 1.73
" III.	1 : 1.18	1 : 4.44
" IV.	1 : 1.39	1 : 1.95

"By this, the above-made *à priori* assertion is confirmed, that the optical test will not prove right in skimmed milk, because, owing to the smallness of the

[1] That is, before the skimming performed by me, without any regard to a skimming perhaps previously performed by the producer.

fat-globules, it appears more transparent than it must be according to the actual contents. When in these experiments the unskimmed milk was diluted by addition of water, so far, that it possessed equal fatty contents with the skimmed, considerable differences were shown optically. There were here, consequently, two milks of fully equal fatty contents, which, however, were optically different, and must have been so naturally, as is shown by the following table:

	Actual contents of both milks.	Optical test showed. in the diluted.	in the skimmed.
No. I	0.701	0.690	1.28
" II	1.67	1.88	2.80
" III	0.225	0.268	1.00
" IV	0.85	1.19	1.66

"If the milks II., III, and IV. had not been already partially skimmed by the producer, the figures of the second column must have agreed with those of the first just as well as in the milk No. I., which was certainly not previously skimmed.

"If we go a step further, the possibility is shown of calculating approximately from the combination of the chemical with the optical examination, how much a milk has been skimmed. Without, however, going into this somewhat unfruitful calculation, I will only briefly remark that a difference of the optical from the chemical examination indicates in any case a skimming has taken place, and the greater this difference, the more extensive skimming is indicated. Thus it results from table A, that the milk No. I. was intact, next to it the milk No. II. on account of the difference, 1 : 1.12, indicates a slight skimming, while in III. and IV. the differences, 1 : 1.18 and 1 : 1.39, show that these milks, just as they were received from the milkmen, had been already skimmed in a very perceptible degree.

"*Recapitulation.*[1]—To facilitate a survey of the

[1] Loc. cit., p. 407.

somewhat complicated investigations the principal points may be again briefly recapitulated:

"1. Skimmed milk contains smaller fat globules than unskimmed milk.

"2. Smaller globules cause a greater cloudiness, in proportion to the existing quantity of fat, than larger ones.

"3. As the optical milk test is based upon the degree of untransparency, it can give no serviceable results for milk wholly or partially skimmed.

"4. Careful experiments have confirmed the great exactness of the optical test, of the galactoscope of Vogel, and of the table calculated by him, but only for intact, unskimmed milk.

"5. The more the milk has been skimmed, the more the optical statement differs from the true fatty contents.

"6. Two portions of the same milk, one by skimming, the other by dilution brought to exactly equal fatty contents, show considerable differences by the optical test, and this test gives the fatty contents correctly in the diluted milk, but too high in the skimmed.

"7. The possibility is given, of ascertaining, by combination of the chemical with the optical examination, what part of the fat of a milk was withdrawn by skimming.

"8. The observed increase of the specific gravity of the milk by skimming agrees exactly with the increase, calculated from the loss of fat, it being supposed that the specific gravity of the milk globules is assumed as equal to that of the pure butter-fat. If, on the other hand, on account of the supposed membranous covering, it be assumed as only a little greater, the experiments do not agree as well. In any case the covering must be supposed as of such immeasurable fineness that it can scarcely be imagined as existing.

"However excellent, indeed unsurpassed, the optical test, especially Vogel's galactoscope, and, perhaps, too, Feser's improvement on it, shows itself for farmers and all such persons as can examine the milk in a positively unskimmed condition, it cannot be recommended in the ordinary milk trade, where the milk offered for sale is so often, indeed usually, in a partially skimmed state, and in such cases I consider consequently the creamometer always as the most serviceable instrument, as the errors of its data do not go so far as those noted in the above table A, found by means of the optical test, which gave the fatty contents in unskimmed milk too high by 1.82, 1.73, 4.44, and 1.95 times the actually existing."

MARCHAND'S (de Fécamp) PROCESS.—This process is based on the determination of the butter by means of the *lacto-butyrometer* shown in Fig. 10. The instrument consists of a glass tube closed at one end, having an interior diameter of 0.010 m. to 0.012 m. It is divided into three equal parts of 0.10 m., the upper part being divided into hundredths. The operation is conducted as follows: A cubic decimetre of milk is introduced into the tube so as to be even with the first line of the graduation, and a drop of potassic hydrate is added to hold the casein in solution. Ether is then added in equal quantity to that of the milk, and the mixture is shaken, when a cubic decimetre of alcohol is added, and the mixture is again shaken, when the tube is put into a water-bath at 40° C., and there kept vertical, until the oleaginous layer rising to the surface no longer increases; but as this layer contains some ether, and as a small amount of butter may still be retained in the lower aqueous fluid, a correction of the results is necessary. The following table, compiled by Marchand, facilitates this correc-

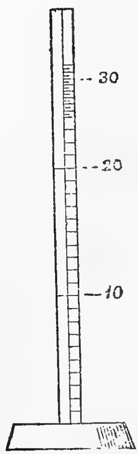

FIG. 10.
MARCHAND'S LACTO-BUTYROMETER.

Table of the Agreements of the Degrees of the Lacto-butyrometer with the Quantities of Butter contained in a Kilogramme of Milk.

Degrees.	Weight of the Butter.	Degrees.	Weight of the Butter.	Degrees.	Weight of the Butter.	Degrees.	Weight of the Butter.	Degrees.	Weight of the Butter.	Degrees.	Weight of the Butter.	Degrees.	Weight of the Butter.	Degrees.	Weight of the Butter.
	gr.		gr.		gr.		gr.		gr.		gr.		gr.		gr.
0.0	12.60	3.9	21.68	7.8	30.77	11.6	39.63	15.4	48.48	19.2	57.34	23.0	66.19	26.8	75.04
0.1	12.83	4.0	21.92	7.9	31.01	11.7	39.86	15.5	48.72	19.3	57.57	23.1	66.42	26.9	75.28
0.2	13.07	4.1	22.15	8.0	31.24	11.8	40.10	15.6	48.95	19.4	57.80	23.2	66.66	27.0	75.51
0.3	13.30	4.2	22 39	8.1	31.47	11.9	40.33	15.7	49.18	19.5	58.03	23.3	66.89	27.1	75.74
0.4	13.53	4.3	22.62	8.2	31.70	12.0	40.56	15.8	49.42	19.6	58.27	23.4	67.12	27.2	75.98
0.5	13.76	4.4	22.85	8.3	31.94	12.1	40.80	15.9	49.65	19.7	58.50	23.5	67.36	27.3	76.11
0.6	14.00	4.5	23.08	8.4	32.17	12.2	41.03	16.0	49.88	19.8	58.73	23.6	67.59	27.4	76.34
0.7	14.23	4.6	23.32	8.5	32.40	12.3	41.26	16.1	50.11	19.9	58.97	23.7	67.82	27.5	76.57
0.8	14.46	4.7	23.55	8.6	32.64	12.4	41.49	16.2	50.34	20.0	59.20	23.8	68.05	27.6	76.81
0.9	14.70	4.8	23.78	8.7	32.87	12.5	41.73	16.3	50.58	20.1	59 43	23.9	68.29	27.7	77.04
1.0	14.93	4.9	24.02	8.8	33.10	12.6	41.96	16.4	50.81	20.2	59.67	24.0	68.52	27.8	77.27
1.1	15.16	5.0	25.25	8.9	33.34	12.7	42.19	16.5	51.04	20.3	59.90	24.1	68.75	27.9	77.51
1.2	15.40	5.1	24.48	9.0	33.57	12.8	42.42	16.6	51.28	20 4	60.13	24.2	68.99	28.0	77.74
1.3	15.63	5.2	24.71	9.1	33.80	12.9	42.66	16.7	51.53	20.5	60.36	24.3	69.22	28.1	77.97
1.4	15.86	5.3	24.95	9.2	34.03	13.0	42.89	16.8	51.74	20.6	60.60	24.4	69.45	28.2	78 21
1.5	16.09	5.4	25.18	9.3	34.27	13.1	43.13	16.9	51.97	20.7	60.83	24.5	69.68	28.3	78.44
1.6	16.33	5.5	25.41	9.4	34.50	13.2	43.36	17.0	52.21	20.8	61.06	24.6	69.92	28.4	78.67

1.7	16.56	5.6	25.65	9.5	34.73	13.3	43.59	17.1	52.44	20.9	61.30	24.7	70.15	28.5	78.91
1.8	16.79	5.7	25.88	9.6	34.97	13.4	43.83	17.2	52.68	21.0	61.53	24.8	70.38	28.6	79.14
1.9	17.03	5.8	26.11	9.7	35.20	13.5	44.06	17.3	52.91	21.1	61.76	24.9	70.62	28.7	79.37
2.0	17.26	5.9	26.35	9.8	35.43	13.6	44.29	17.4	53.14	21.2	62.00	25.0	70.85	28.9	79.61
2.1	17.49	6.0	26.58	9.9	35.67	13.7	44.52	17.5	53.37	21.3	62.23	25.1	71.08	29.0	79.84
2.2	17.73	6.1	26.81	10.0	35.90	13.8	44.76	17.6	53.61	21.4	62.46	25.2	71.32	29.1	80.07
2.3	17.96	6.2	27.04	10.1	36.13	13.9	44.99	17.7	53.84	21.5	62.69	25.3	71.55	29.2	80.30
2.4	18.19	6.3	27.28	10.2	36.36	14.0	45.22	17.8	54.07	21.6	62.93	25.4	71.78	29.3	80.54
2.5	18.42	6.4	27.51	10.3	36.60	14.1	45.46	17 9	54.31	21.7	63.16	25.5	72.02	29.4	80.77
2.6	18.66	6.5	27.74	10.4	36.83	14.2	45.69	18.0	54.54	21.8	63.39	25.6	72.25	29.5	81.00
2.7	18.89	6.6	27.98	10.5	37.06	14.3	45.92	18.1	54.77	21.9	63.63	25.7	72.48	29.6	81.24
2.8	19.12	6.7	28.21	10.6	37.30	14.4	46.16	18.2	55.00	22.0	63.86	25.8	72.71	29.7	81.47
2.9	19.36	6.8	28.44	10.7	37.53	14.5	46.39	18.3	55.24	22.1	64.09	25.9	72.95	29.8	81.70
3.0	19.59	6.9	28.68	10.8	37.76	14.6	46.62	18.4	55.27	22.2	64.33	26.0	73.18	29.9	81.93
3.1	19 82	7.0	28.91	10.9	38.00	14.7	48.85	18.5	55.71	22.3	64.56	26.1	73.41	30.0	82.17
3.2	20.05	7.1	29.14	11.0	38.23	14.8	47.09	18.6	55.94	22.4	64.79	26.2	73.65	30.1	82.40
3.3	20.29	7.2	29.37	11.1	38.46	14.9	47.32	18.7	56.17	22.5	65.03	26.3	73.88	30.2	82.64
3.4	20.52	7.3	29.61	11.2	38.70	15.0	47.55	18.8	56.40	22.6	65.26	26.4	74.11	30.3	82.87
3.5	20.75	7.4	29.84	11.3	38.93	15.1	47.79	18.9	56.64	22.7	65.49	26.5	74.34	30.4	83.10
3.6	20.99	7.5	30.07	11.4	39.16	15.2	48.02	19.0	56.87	22.8	65.72	26.6	74.58	30.5	83.33
3.7	21.22	7.6	30.31	11.5	39.40	15.3	48.25	19.1	57.10	22.9	65.96	26.7	74.81	30.6	88.57
3.8	21.45	7.7	30.54												

tion. (The relation between the weight of the butter and degrees of the lacto-butyrometer are in the following table established according to the formula: $p = 12$ grms. $60 + n$ degrees $\times$ 2 grms. 33.)

According to Marchand a litre of pure milk must give from 30.55 gr. to 35.43 gr. of butter. These quantities were obtained from 126 analyses made by Marchand, and are nearly the same as those found by Quevenne: 34 grms. for the average, and 30 grms. for the minimum.

Chevallier and Henri give the average 31.3. Marchand states[1] that he agrees with Quevenne, "that all commercial milk, containing less than 30 grms. of butter a litre (kilogramme), does not have a normal proportion of cream, and that it has experienced a partial skimming. When the milk is obtained from a single cow, the minimum may be admitted at 27 grms."

"Milk containing 27 grms. of butter per kilogramme marks 6.2° on the lacto-butyrometer, and that containing 30 grms. indicates 7.5°.

"These figures are the smallest that can be admitted, and the last (7.5°) has constantly served me as a basis in the investigations with which I have been commissioned.

"For the authorized inspectors, therefore, the question will always be limited to determine whether the milk, which they may have to examine, indicates or does not indicate 7.5°. This is an easy verification to make; but when it conducts them to negative results, they should take care to have the suspected sample examined by an expert chemist. This is a measure of prudence from which they should never depart."

SALLERON'S PROCESS.—The *lacto-butyrometer* of Salleron[2] is shown in Fig. 11. It only differs from that of

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[1] Jour. de Pharm. et de Chimie, III. Série, Tome xxvi. Année, 1854, 2e Partée. Page 351.

[2] Nouveau Dict., Des Falsifications et des Alterations des Aliments et des Medicaments, par J. Léon Soubeiran, 1874, p. 107.

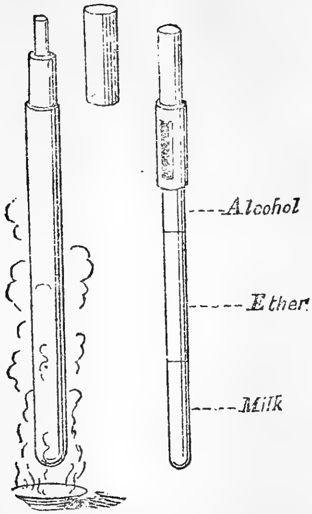

Fig. 11.—Salleron (Lacto-Butyrometer).

Marchand in having a graduated index, which gives directly the butter-contents of the milk; the first division of the index indicates, instead of 0, 12.6, and corresponds to 12.6 grms. of butter remaining in solution. The instrument has a tin tube for a case, which serves as a water-bath, and is supplied with a cup at its base, in which the alcohol is burned.

Leconte's Process.—This process consists in putting into a graduated tube (shown in Fig. 12) five cubic centimetres of milk, then twenty cubic centimetres of crystallized acetic acid and then closing the upper orifice of the tube, and shaking for several minutes. The casein that had been coagulated is dissolved little by little, and the butter floats rapidly on the liquid in the form of white flakes. The butter is liquefied by means of the flame of an alcohol lamp, and a liquid layer is thus obtained, whose volume is easily ascertained by means of the graduations on the tube. The apparatus is composed of a tube of about 0.025 m. in diameter, closed at one

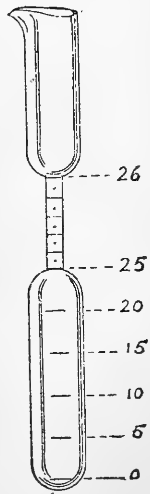

Fig. 12.
Leconte Apparatus.

of its extremities, and divided into five parts, each presenting a capacity of five cubic centimetres; to the upper part of this tube is joined another tube of much smaller diameter, and divided into twentieths of a cubic centimetre; then, to the upper part of this second tube a third tube of the same diameter as the first, but much shorter and not divided, serving as a funnel, is joined. This last tube receives the liquids which are dilated during the operation.

HORSELEY'S INSTRUMENT.

This instrument consists of a tube, which is divided so that every degree is one-hundredth of the whole. The milk to be tested is poured into the tube until it measures 250 grains, opposite which is a mark, *A*. Methylated ether is then added until the next mark, *B*, is reached, and the whole well shaken together for five minutes; methylated spirits is next poured in to 10° of the graduation, *C*, and again shaken for five minutes. On placing the tube in the stand the fat will rise to the top as a bright yellow oil, the measure of which will indicate the *weight*, because each graduation is equal to 4.15 grains of fat. The casein separates and falls to the bottom of the tube as a white mass, capable of being strained off, dried, and weighed. The remaining fluid after evaporation to dryness will give the amount of sugar and salts.

As an example: a rich sample of milk from an Alderney cow gave four graduations of fat from 250 grains of milk. Therefore,

$$\frac{4 \times 4 \times 4.15}{10} = 6.64 \text{ fat.}$$

The sediment equalled 10.8 grains; so that

$$\frac{10.8 \times 4}{10} = 4.32 \text{ casein.}$$

Residue after evaporation,

$$\frac{14.2 \times 4}{10} = 5.68 \text{ salts and sugar.}$$

Total solid contents = 16.64 per cent.

A sample of diluted milk.

No. 2 gave three gradations for fat,

$$\frac{3 \times 4 \times 4.15}{10} = 4.98 \text{ per cent.}$$

It has had 25 per cent. of water added.

No. 3 gave one gradation,

$$\frac{1 \times 4 \times 4.15}{10} = 1.66 \text{ per cent.}$$

It has had 50 per cent. of water added, and had 25 per cent. of fat removed.

No. 4 gave two gradations,

$$\frac{2 \times 4 \times 4.15}{10} \quad 3.32 \text{ per cent.}$$

This had had 50 per cent. of water added.

W. W. Stoddart, speaking of Horsley's instrument, says:[1] It "shows the fat or cream distinct and perfectly separated. By it you can calculate the weight per cent., and estimate the casein, the sugar and salts with great ease and rapidity. Indeed, the whole operation only takes ten minutes, or the quarter of an hour, and the results may be kept for observation for any length of time; an advantage of no mean importance when legal consequences are dependent on the analytical evidence.

CHAMELEON TEST.

E. Monier[2] has founded a peculiar optical process for testing milk on the fact that potassic permanganate is equally discolored by casein and albumen. A

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[1] Pharm. Jour. and Trans., September, 1874, p. 188.

[2] See Die Milch, von Benno Martinez, Vol. I., p. 174; or Monier, Nouvelle méthode pour l'analyse du lait au moyen de liqueurs titrées, Compt. Rend., xlvi., 1858, p. 236.

two per cent. normal solution of casein is compared with the milk to be tested, and the volumes of a solution of potassic permanganate are determined, which must be added on one hand to the solution of casein, on the other to the milk, in order to obtain a lasting color of equal intensity in both. As these volumes are proportional to the existing quantities of casein and albumen, the contents of the milk in the two latter may be calculated from them. If the contents of casein and albumen are to be separately ascertained, the casein is first separated from a second portion of milk by means of a little acetic acid under warming to 40° to 50° C., and the albumen in the remaining liquid is determined as before. If the fatty contents of the milk are to be ascertained, the previously obtained precipitate is dried, and the already known casein contents are subtracted from it, the remainder giving the fatty contents. Experiments are wanting to show the utility of this method.

HALIMETRIC TEST.

Reichelt, of Ausbach,[1] has applied the halimetric test, proposed by Fuchs for the examination of beer, to the determination of the aqueous contents of milk. The method is grounded on the fact that 100 parts of water will dissolve 36 parts of pure salt. If we succeed, therefore, in finding how much salt comes to solution in a known fluid, whose entire water will dissolve the same, the water contents of this fluid may be calculated from it. Fuchs has constructed a halimeter for this determination of salt (see Fig. 13), which consists of a graduated spindle, open at the upper, thicker end, and closed at the lower, thinner end, whose divisions give in grains of the old Prussian apothecaries' weight the quantities of the residue of salt remaining undissolved in a liquid. Applied to milk the process is as follows:

[1] Die Milch, von Benno Martinez,

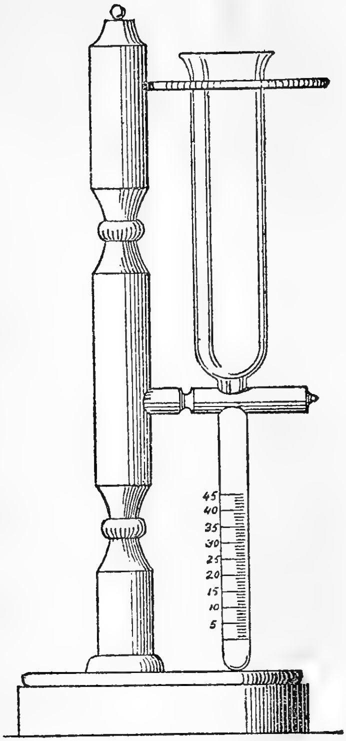

FIG. 13. REICHELT-HALIMETRIC TEST.

One thousand grains (= 62.5 grm.) of the milk to be tested are mixed in a flask with 324 grains (= 20. 25 grm.) of salt, and 240 grains (= 15 grm.) of tincture of litmus saturated with common salt, and repeatedly shaken at 25° to 30° R., then poured off into the halimeter, so that none of the undissolved salt remains behind in the flask; and after this has settled in the halimeter, and has been shaken close together, its quantity is read off, the water contents of the milk are then calculated from the grains of dissolved salt found. These = n, after the equation 36 : 100 = n : x, or the same by multiplication of n. 2.7778. The addition of the tincture of litmus is merely for the purpose of making the limit of the salt-residue more distinctly recognizable, partly by the coloring, partly by the dilution of the milk.[1]

In one experiment the salt-residue amounted to four grains. One thousand grains of milk, therefore, dissolved 320 grains of salt, corresponding to 888.89 gr. water, or 111.11 gr. dry substance. The determination of the dry substance of the same milk by evaporation with quartz-addition, and drying at 100° to 110° C., gave 11.033 per cent., consequently a difference of 0.078 per cent. In an examination of cream the halimetric test gave 14.306 per cent. dry substance; the evaporating test, 14.696 per cent. dry substance; difference, 0.390 per cent.

Another milk of 10 per cent. contents in dry substance was diluted with two per cent. in weight of water. The halimetric examination of this diluted milk gave 9.722 per cent. dry substance, while from calculation there should be 9.804 per cent.; difference, 0.082.

Benno Martinez[2] says: "The method furnishes quite exact results, and is besides easily and rapidly performed. From its nature, however, it can be of use only where one has to do with notoriously adulterated milk, and here of but slight use, as it can give no information on the relation of the parts of the dry substance to one another."

METHOD OF VERNOIS AND BECQUEREL.

Vernois and Becquerel proposed to determine the milk-sugar in milk, and thus to judge of its quality. This was accomplished by means of a polarimeter, which consists, according to Vogel [3] of a hollow tube

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Reichelt Wagner, Jahresbericht über die Fortschritte und Lustungen der chemischen Technologie für 1859, S. 443; aus Jahresber. üb. d. k. Landw. u. Gewerbeschule zu Ausbach, 1858–59, u. 1859–60, Ausbach, 1859 u. 1860.

[2] Loc. cit.

[3] Eine neue Milchprobe, Erlangen, 1862, p. 11.

0.3 metre long and 0.02 metre in diameter, both ends of which are provided with Nicol prisms. The rays of light fall in through the front prism or the polarizer; the second or analyzer is brought before the eye. If the entering light is examined in the empty tube, and with such a position of the prisms that their principal surfaces are parallel with one another, the rays of light are seen in their highest intensity. If the analyzer be turned about the axis of the tube and the parallelism of the prisms thus removed, every trace of light ceases, as soon as the principal surfaces stand at right angles with each other. If a fluid is now introduced into the tube which has an influence on the plane of polarization, the analyzer must be turned in a different way, sometimes more and sometimes less, in order to bring back darkness again.

METHOD PROPOSED BY POGGIALE.[1]

Poggiale proposed to ascertain the sugar in milk by means of the Soleil saccharometer, and thus to judge of its richness. He proceeded as follows:

The milk was coagulated with acetic acid at 40 to 50° C., a few drops of acetate of lead added to the serum, and again filtered, the filtrate poured into a tube 22 centimetres long and after closing up put into the apparatus. In this apparatus 201.9 grm. of sugar of milk dissolved in 1,000 cub. cent. (1 litre) of water indicate 100 degrees. If we denote by g the number of the degrees found in the testing of whey as to the sugar of milk, the sugar of milk contents in a litre are calculated according to the formula $100 : 201.9 = g : x$. The following table is founded on this formula:

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[1] Dosage du sucre de lait au moyen du sacharimètre de M. Soleil et determination de la rechesse du lait. Comptes Rendus, xxviii., 1849, p. 584.

Degree found.	Gramme Milk-Sugar.	Degree found.	Gramme Milk-Sugar.
18	36.34	26	52.49
19	38.36	27	54.51
20	40.38	28	56.53
21	42.39	29	58.55
22	44.41	30	60.57
23	46.43	31	62.58
24	48.45	32	64.60
25	50.57		

According to Poggiale the serum of pure milk should show 28°, corresponding to 56.5 gr. of sugar of milk in the litre of serum and 52.7 gr. in the litre of milk.

TEST OF MILK BY MEANS OF CENTRIFUGAL FORCE.

C. J. Fuchs, Professor of the Veterinary School in Karlsruhe, proposed (1859) the employment of a centrifugal apparatus. He states his process as follows: Common cylindrical test-glasses divided into centimetres are enclosed in paper, placed in correspondingly formed tin boxes, and the latter are so fastened on a centrifugal disk accelerated ten-fold by carrying over, that they can assume a horizontal position in swinging around. Fresh milk from a dealer showed $\frac{1}{15}$ of cream on the average after 300 turns or 3,000 rotations, and just as much was obtained from the same milk, when left in the same glass it had stood from twelve to twenty-four hours. Also, milk which had been diluted with a definite quantity of water showed a diminution of the cream corresponding to this quantity of water. If the milk was fatter than usual, a correspondingly greater quantity of cream was found by the centrifugal machine, as well as by spontaneous separation, namely, from 6 to 10 per cent. All the butter-globules were not, however, brought to the surface of the milk by the centrifugal machine.

The turning of the glass cylinders, instead of in the centrifugal machine, fastened on a rod seven to eight feet long with a wire four or five feet long on a loose ring, did not give the desired success, probably, as Fuchs says, because the rotations could not be effected quickly enough, and the greater length of the arch of rotation could not make up for the more rapid revolution of the centrifugal machine; besides, it was hard work, and much practice was necessary for an easy motion. Fuchs constructed therefore a particular small centrifugal machine especially for the test of milk. On a stand a disk lying horizontally 60 cm. in diameter is fastened and set in motion by a winch. Opposite to this disk stands a second, 6 cm. in diameter, which is moved ten times more rapidly by a cord running over both from the first disk. Through the smaller disk goes an angle projecting over it about one foot, on which there is an iron cross horizontally at the top, and on its ends the tin boxes for containing the milk vessels are hung by means of wires, so long that in turning round they describe a circle of two to three feet in diameter. This machine furnished the same result as the previously employed centrifugal apparatus; but after frequently repeated experiments, as it was made mostly of wood, its motion was irregularly distributed.[1]

REMARKS.

I must again call to mind the fact, that before we can adopt the method for determining the quality of milk, a standard must be recognized which will represent the poorest pure healthy milk. In the case of the specific gravity of milk, this standard has been accurately determined, and is recognized by those who have the most right to speak on this subject, but unfortunately, as yet, for the other methods I have

[1] Die Milch, von Benno Martinez, p. 176.

described, there is no recognized standard, and although many of them may be of great value until the true standard is obtained, they remain perfectly useless for the purposes they are intended for.

DETECTION OF CHALK.

When chalk is added to milk, it readily subsides if the sample is allowed to remain at rest for some time, particularly if a little water be added. So that, if in a tube a sample of milk is put, containing this adulterant, and allowed to remain at rest, we will have two layers formed, one on top and the other at the bottom; if to this bottom layer (which I suppose the milkman means us to consider an extra layer of cream), hydrochloric acid is added, effervescence takes place, and the chalk is dissolved to a solution, in which the characteristic properties of a lime-salt can be recognized.

STARCH, FLOUR, DECOCTION OF BARLEY, RICE, EMULSION OF ALMONDS AND HEMPSEED.

By boiling the sample of milk suspected to contain one or more of these adulterants, and adding tincture of iodine, the amylaceous substances, if present, will produce a blue coloration in the fluid.

For the detection of STARCH in milk and cream the microscope is much to be preferred. A little of the milk is spread out to a very thin stratum and then examined under the microscope. The examination is aided by tincture of iodine.

It is considered better to coagulate the milk with acetic acid, and search the fecula in the coagulated casein.

DEXTRINE.

Dextrine may be detected by adding to the suspected fluid iodine water, where a more or less violet-blue coloration appears. It is better to act on the milk coagulated by acetic acid.

The dextrine can also be inverted by means of sulphuric acid, and tested by means of the polarimeter. In this way Adrian has established for

Pure Milk.				Density.	Rotation to the Right.
0.10	of solution of dextrine.			1.0305	22.
0.20	of water,	0.10	"	1.032	32.25
0.15	"	0.10	"	1.0305	31.5

Laury found that if iodine be added to pure serum, it will be colored yellow, but, if the serum is mixed with 0.39 of dextrine, it will be colored dark blue; with 0.10, it is violet-blue, with 0.01, it is orange.

CANE-SUGAR.

To detect the presence of cane-sugar, the milk should be coagulated, and the serum evaporated at a *gentle* heat; if the residue is darker than usual, the presence of sugar may be suspected (as brown sugar is generally used). The residue may then be dissolved in distilled water, and a little yeast added, when the fluid should be exposed for some hours at a temperature of between 70° and 80° F. If fermentation ensues, "it is a sure sign of the presence of sugar, for milk sugar cannot ferment, at least in so short a time, as the fermentation is never brisk. But the smallest proportion of sugar, either GRAPE or CANE-SUGAR, very speedily gives rise to a tumultuous fermentation."—*Normandy.*

The carbonic acid may be collected, and the sugar calculated either from it or from the alcohol formed.

GUM ARABIC AND GUM TRAGACANTH.

To detect *gum arabic*, the serum of milk must be evaporated, and the residue boiled and digested with alcohol, which will take up the sugar and leave the gum. Or, the alcohol may be poured into the whey, when the gum will be precipitated in a white opaque flock, which, when collected and dried, may be identified by its appearance. To detect *gum tragacanth*, it has been "recommended to boil the milk, and leave it at rest for some hours, when a gelatinous translucid deposit will be formed, which, being washed with a small quantity of water and tested by a few drops of solution of iodine, produces a blue color because gum tragacanth contains starch. The starch is plentiful and is in the form of starch corpuscles; these are rather small, but vary much in size; many are irregular, some are rounded, others are somewhat polygonal, while a few are muller-shaped; in the more perfect grains a rounded hilum is distinctly visible."

SALT.

To detect the addition of salt, the most accurate method is to determine the percentage of chlorine. The ash may also be tasted, which, if strongly saline, indicates the addition of salt.

DETECTION OF CARBONATE AND BICARBONATE OF SODA.

When these salts are used the milk possesses a strong alkaline reaction, furnishes a serum having a sharp, bitter taste, and leaves a residue of the salt upon evaporation, which can be recognized by the usual tests.

DETECTION OF ANNATTO.

If the milk, when evaporated to a small volume, possesses a reddish or orange-red color, annatto may be suspected. If by the addition of an acid the color is rendered purplish, or by an alkali rendered brighter red, its presence is certain. The color may be extracted from the soft residue by means of alcohol, and tested with an acid and alkali as above. The color of the serum may also be observed.

DETECTION OF TURMERIC.

In some cases turmeric cells may be detected by the microscope. It is best to examine the fluid in the same manner as for annatto. The turmeric is rendered deep brown by alkalies, and may be thus distinguished.

DETECTION OF GELATIN.

Gelatin and isinglass have been detected in milk by Morin, at Rouen. It may be detected by treating the serum with tannin, when it will be precipitated. To the precipitate is then to be applied the usual tects.

DETECTION OF CEREBRAL MATTER.

When a sample of milk containing cerebral matter is examined under the microscope, portions of nerve tubules are readily discovered. Professor Queckett obtained a sample of milk adulterated by this substance.