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THE COMPOSITION AND ANALYSIS OF MILK.

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(Read at the Meeting, June 7, 1905.)

Average Composition of Milk.—Of the 38,297 samples analysed in the laboratory of the Aylesbury Dairy Company during 1904, 33,747 were samples of milk. The average composition of 15,910 samples taken from the milk on arrival at the depots from the farms is given in the subjoined table :

Average Composition of Milk during 1904.

MONTH.	MORNING MILK.				EVENING MILK.				AVERAGE.			
	Specific Gravity.	Total Solids.	Fat.	Solids-not-Fat.	Specific Gravity.	Total Solids.	Fat.	Solids-not-Fat.	Specific Gravity.	Total Solids.	Fat.	Solids-not-Fat.
January	1·0324	12·58	3·61	8·97	1·0322	12·96	3·98	8·98	1·0323	12·77	3·80	8·97
February	1·0327	12·54	3·57	8·97	1·0322	12·86	3·89	8·96	1·0325	12·70	3·73	8·97
March	1·0325	12·52	3·55	8·97	1·0322	12·82	3·86	8·96	1·0323	12·67	3·71	8·96
April	1·0323	12·36	3·45	8·91	1·0320	12·81	3·91	8·90	1·0321	12·58	3·68	8·90
May	1·0327	12·24	3·28	8·96	1·0323	12·85	3·87	8·98	1·0325	12·54	3·57	8·97
June	1·0327	12·28	3·29	8·96	1·0322	12·75	3·81	8·94	1·0323	12·50	3·55	8·95
July	1·0321	12·26	3·42	8·84	1·0314	12·64	3·87	8·77	1·0317	12·45	3·64	8·81
August	1·0321	12·33	3·48	8·85	1·0315	12·77	3·96	8·81	1·0318	12·55	3·72	8·83
September	1·0324	12·50	3·53	8·96	1·0320	12·96	4·03	8·93	1·0322	12·73	3·79	8·94
October	1·0324	12·60	3·63	8·97	1·0320	13·07	4·11	8·96	1·0322	12·84	3·87	8·97
November	1·0326	12·72	3·70	9·02	1·0321	13·09	4·11	8·98	1·0324	12·90	3·90	9·00
December	1·0327	12·76	3·71	9·05	1·0323	13·08	4·07	9·01	1·0325	12·92	3·89	9·03
Average	1·0325	12·47	3·52	8·96	1·0320	12·89	3·96	8·93	1·0322	12·68	3·74	8·94

The morning and evening meals have been kept separate, and, as usual, there is a difference of about 0·4 per cent. of fat between them. As in former years, May and June are the poorest months, and October, November, and December the richest.

The yearly average percentage of fat (3·74) is less than that found last year; it may be suggested that the very wet season of 1903 affected the soil, and the fodder grown on the farms in 1904 was not of the same quality as in the years immediately preceding, and that this had some effect on the percentage of fat in the milk.

THE ANALYST.

Human Milk.—A sample of human milk gave the following figures :

	Per Cent.
Total solids	10.39
Fat	1.98
Sugar	6.40
Proteids	1.75
Ash	0.26
Solids-not-fat	8.41

The fat in this sample is very distinctly below the average.

Chlorine in Ash.—In order to see whether much chlorine was lost on burning milk, as has been shown by J. O'Sullivan to be the case in vegetable ash, a sample giving 0.092 per cent. chlorine in the ash was burnt with lime ; 0.100 per cent. was found, showing that 0.008 per cent. had been lost.

Buttermilk.—Three methods of preparing buttermilk may be used :

Churning soured cream ;
Churning sweet cream ;
Churning soured milk.

A preparation much resembling buttermilk may be also made by churning sour separated milk till the curd is broken up into very fine particles.

The composition of each of these is :

	Sour Cream.	Sweet Cream.	Milk.	Separated Milk.
Specific gravity	1.0314	1.0331	1.0329	1.0355
Total solids	8.39	9.02	8.87	9.23
Fat	0.50	0.35	0.70	0.10
Sugar	3.40	4.42	3.65	3.93
Proteids	3.30	3.51	3.28	3.65
Ash	0.65	0.73	0.68	0.79
Lactic acid	0.50	0.01	0.76	0.56

A slight addition of water for churning purposes was made to the three buttermilks.

A New Milk Preservative.—Quite recently a new preservative came into my hands ; it consisted of a liquid of specific gravity 1.027 containing 5.6 per cent. of hydrogen peroxide, some sodium chloride, and a little sodium phosphate, and pellets chiefly consisting of potassium carbonate (with another potassium salt which, owing to the sample being accidentally destroyed before the analysis was finished, was not identified). Organic matter was also present.

In the circular accompanying the sample it was claimed that this preservative was harmless, contained nothing but constituents of milk, and could not be detected. As hydrogen peroxide is not immediately destroyed when added to milk, but remains for some time, it would probably be found in samples to which this preservative had been added. The test with para-phenylenediamine or "ortol" will detect very minute quantities.

The Gerber Method.—There appears to be some doubt as to the correct volume of one division of the neck of the Gerber bottle, and not only do the bottles of different makers vary slightly in the volume of the divisions, but the English and German standardizing authorities are not quite in accord as to the value. I have found that the value 0.126 c.c. for each division, indicating 1 per cent. of fat, gives the most

accurate results, and that when bottles graduated with a smaller value were used the readings required to be corrected to this volume.

As values of from 0.124 to 0.126 appear to be used by the makers of bottles, I have made some fresh experiments with a view to determine (*a*) the most nearly correct value, (*b*) the errors inherent to the process, and (*c*) the influence of diameter of the neck on the results.

A series of milks were prepared by weighing out quantities of cream and separated milk and mixing them, and the fat in each of these was determined by the Gerber process and the results compared with the percentage of fat deduced from the composition of the cream and separated milk. The mean of four Gerber readings by Messrs. Goodson and Ashby and myself was taken, and only in one milk did the extreme readings differ by as much as 0.1 per cent. A set of bottles graduated, using the value 0.124 c.c., was used, and in order to minimize errors due to imperfect graduation each milk was read in four different bottles.

A series of determinations of the weight of milk delivered by an 11 c.c. pipette, the three observers agreeing very closely, gave the value as 11.276 grams – 0.017 F.; with ordinary milks (3 to 4 per cent. fat) 11.22 grams is very nearly correct.

I estimate the volume of the fat between the upper and lower layers of the meniscus as equal to 0.08 per cent., and this, which is always neglected in reading the percentage of fat, must be added on in calculating the actual volumes.

The volumes of fat are calculated by multiplying the percentage of fat by the weight of milk calculated from the formula given above, and dividing by 100×0.8865 (the mean apparent density of fat in glass at 70° C.).

The following table shows the results obtained:

Percentage of Fat.	Mean Gerber Reading.	Mean Gerber Reading $\times \frac{1.26}{1.24}$.	Weight of Milk delivered. Grams.	Volume of Fat at 70° C.c.	Volume of Fat in Gerber. C.c.	Ratio.
1.37	1.38	1.36	11.253	0.174	0.181	1.04
1.84	1.88	1.85	11.245	0.233	0.243	1.04
2.76	2.79	2.74	11.229	0.347	0.356	1.03
3.23	3.29	3.23	11.221	0.409	0.418	1.02
3.66	3.74	4.68	11.217	0.463	0.474	1.02
4.45	4.54	3.46	11.200	0.562	0.573	1.02
4.92	5.04	4.96	11.192	0.621	0.635	1.02

It is seen that the value 0.126 c.c. for one scale division represents very closely the percentage of fat in milk, and that the volume of the Gerber fat is greater than the actual fat present, the mean ratio being 1.025.

There are several reasons which might explain the increased volume: (*a*) There is a layer of acid liquid formed round the fat; (*b*) amyl alcohol, or a derivative, dissolves in the fat; and (*c*) the acid and amyl alcohol produce amyl esters, with elimination of glycerol, or other changes.

If (*a*) is the reason, a marked difference in the volume should be observed in bottles with necks of different diameters; a bottle of diameter 0.312 cm. gave a volume 0.177 c.c., a bottle of diameter 0.334 cm. gave a volume 0.176 c.c., and a bottle of diameter 0.496 cm. gave a volume 0.175 c.c.; the differences represent about 0.01 in the reading, which is within the limits of experimental error.

As surface energy to which a layer would be due varies greatly with temperature, the apparent expansion of the fat should be markedly different from the true expansion in the presence of a layer; on cooling a fat column 7.45 divisions from 76° to 34.5°, it contracted to 7.20, a difference of 0.25 divisions, and on cooling a fat column 7.19 divisions from 74° to 30° it contracted to 6.96, a difference of 0.23 divisions. A contraction of 0.24 division should have taken place in each case. These results show that if any layer is formed it is of infinitesimal thickness, and the increase in volume cannot be due to this cause.

If (b) is the reason, a variation of the amount of amyl alcohol should affect the results; using quantities from 0.8 c.c. to 2.0 c.c. in place of the usual 1.0 c.c. produced no appreciable variation in results. Therefore the increase in volume cannot be due to amyl alcohol or a derivative dissolving in the fat.

An examination of the fat showed that the real cause is a change in the composition of the fat. The same milk was treated forty-eight times, and the combined fat separated. Some of the fat was churned from the cream obtained direct from the milk.

14.666 grams of the Gerber fat were steam-distilled, and a marked pear-drop odour was noticed in the distillate. The acidity was estimated both in the distillate and the aqueous residue in the distilling-flask, and the sulphuric acid was also estimated as barium sulphate in the aqueous residue. The aqueous residue was turbid, and after saponification and acidification some solid fatty acid separated. The distillate was saponified, and the alkaline solution steam-distilled; oily drops came over, which on oxidation with chromic acid gave a strong valeric acid odour. The Gerber fat, the fat which had been steam-distilled, and the original milk fat were examined. The results were:

	Gerber Fat.	Steam-distilled Fat.	Original Fat.
Total acidity (as c.c. N acid per 100 grams)	25.2	17.0	0.5
Volatile acidity (do.)	2.2	—	—
Water soluble acidity (do.)	5.9	—	—
Of which H ₂ SO ₄	4.1	—	—
Volatile acids (as butyric)	5.42%	4.98%	5.87%
KOH absorption	22.04%	21.92%	22.68%
Glycerol	10.49%	—	11.95%
Zeiss refraction figure at 35° C. ...	42.5°	45.1°	47.1°
Apparent density in glass at 70° ...	0.881	—	—
H ₂ SO ₄ in fat	—	0.20	—

From these results it appears that the fat has increased in weight about 3 per cent., and has lost 0.3 per cent. of butyric (or other soluble) acid; about 6 per cent. of the glycerides have been converted into free acid, about 18 per cent. into amyl esters, and about 40 per cent. into diglycerides or the equivalent of monoglyceride; the fat has taken up 0.39 per cent. of sulphuric acid, probably as sulpho-oleic acid; its volume has increased, owing, probably, to the amyl esters having a greater specific volume than glycerides, about 0.6 per cent. Altogether the total increase in volume is rather over 3 per cent., a figure which is in good agreement with the increase (2.5 per cent.) calculated above. Whether the difference is a real one, due

THE ANALYST.

329

to a slight solubility of fat in the sulphuric acid amyl alcohol solution (? as sulpho-oleic acid), or to the churned fat not being quite of the same composition as the ether-extracted fat, or due to experimental error, is a matter for speculation. The difference is not enough to affect the conclusion that the increased volume of the fat is due to a change in the composition of the fat.

I conclude, therefore—

(a) The best value for the scale division of a Gerber bottle is 0.126 c.c.

(b) The volume of the fat obtained in the Gerber process is about 1.025 the volume of the fat in the milk.

(c) The neglect of the volume of the fat between the upper and lower parts of the meniscus is partly compensated by the decrease of the weight of milk delivered by an 11 c.c. pipette with increasing quantities of fat.

(d) The exact diameter of the neck of the bottle is of no importance.

The results obtained show that the method devised by Rosier and myself (ANALYST, xxiv., 172) is accurate only to the extent of the compensation of two opposing factors—the increase in the weight of fat, and the decrease owing to solubility and volatility of some of the products formed. These two appear, however, to balance each other with fair accuracy.

DISCUSSION.

Mr. E. R. BOLTON inquired whether the iodine absorption of the fat obtained in the Gerber process had been determined.

Mr. RICHMOND replied in the negative, but said that he should expect the iodine absorption of the butter-fat to be lowered.

Mr. A. C. WILSON asked whether Mr. Richmond could give any information as to the difference in quantity between the morning and evening yields in these cases. In the North Riding of Yorkshire and the county of Durham, where the milking intervals were very uneven, the morning milk was practically speaking one-third more in quantity than the evening milk.

The PRESIDENT (Mr. Bevan) asked whether the decrease shown during 1904 in the average percentage of fat was due to any unusual circumstances connected with the process of analysis or to actual deterioration in the quality of the milk.

Mr. RICHMOND said that, according to an average which he had some time previously worked out for the samples which came under his observation, the interval between the morning and the evening milkings was 10.8 hours. The ratio between the quantities yielded in the morning and in the evening was approximately 100 : 85. With regard to the President's question, he thought that, seeing that the analyses were all made in the same manner and by the same operators, that the apparatus and reagents were constantly checked, and that the number of analyses was about 15,000 each year, the experimental error of the average could not be very large. He therefore considered that there must be some real difference in the milk itself. He believed that there was, and would be, a constant tendency for the percentage of fat in milk to fall, owing to the practice which prevailed among farmers of weeding out all cows giving small quantities of milk. This, in his experience, meant

THE ANALYST.

that those cows were being got rid of which gave the highest percentage of fat. The slight increase in the average percentage of fat shown during the three previous years he was inclined to attribute to increased attention to quality on the part of the farmers following the issue of the Sale of Milk Regulations. Probably the process of breeding for quantity was again coming to the fore. There was, however, one special circumstance in 1903, namely, the abnormal rainfall of that year. Possibly that had some influence which was reflected in the milk of 1904.