XV. THE DISTRIBUTION OF THE FATTY ACIDS IN THE MILK FAT OF THE COW AND SHEEP.

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The variation in the character of the fat of cow's milk with advance of lactation, change of diet and other factors has received probably more attention at the hands of the investigator than any other aspect of the composition of milk. A careful examination of the formidable mass of literature in which this work is recorded reveals, however, that very little guidance has yet been obtained as to the fundamental causes underlying the changes observed. The prime reason for this comparative sterility of the work has undoubtedly been the difficulty of carrying out more than a superficial examination of the milk fat. No problem presents greater difficulties to the analyst than the quantitative separation and determination of a mixture of fatty acids, and the acme of difficulty is reached in the case of the most complicated mixture of fatty acids which is found in butter fat. For this reason investigators have mostly been content to limit their attention to the determination of various more or less well-defined groups of acids, such as steam-volatile, or water-soluble or unsaturated acids, etc., whereby naturally only a very imperfect record of the variations in composition has been obtained.

Efforts have not been lacking, however, to obtain a complete expression of the composition of the fat by the determination of each individual acid present, but in most cases the methods employed have been admittedly very imperfect, and in some cases assumptions have been made which subsequent research has proved to be incorrect. There is even a doubt whether the qualitative composition of butter fat has yet been fully explored, but there is clear evidence that the only acids present in more than minimal proportions are the unsaturated acid, oleic acid, and the eight saturated acids of the acetic series, representing the members with an even number of carbon atoms from C_4 to C_{18} , viz. butyric, caproic, caprylic, capric, lauric, myristic, palmitic, and stearic acids.

In the work reported in the present communication an attempt has been made to devise a method more precise than any previously used for the analysis of this complex mixture of acids.

Up to the present, most of the methods advanced for the quantitative analysis of this mixture have been based upon the difference in solubility of the several salts in certain solvents at given temperatures. Since these methods have proved more or less unreliable and have given discordant results in the hands of different workers we decided to examine the possibilities of a separation of the mixed methyl esters obtainable from butter fat. A detailed account of the method eventually devised will be found in the Experimental Part of this communication, and may be briefly summarised here.

A weighed amount of dry butter fat is converted to methyl esters by heating in ethereal solution with excess of methyl alcohol containing a small percentage of hydrogen chloride. The mixed esters are carefully separated from the reaction mixture and then fractionally distilled three or four times, in each case the distillation being made under atmospheric pressure until a temperature of 150°–160° is reached, and the fractionation subsequently completed under a pressure of about 15 mm.

The mixture of esters is thereby resolved into a series of fractions each assumed to contain only two saturated esters and one unsaturated ester, the latter being further assumed to be methyl oleate. Evidence in support of these assumptions will be found on a later page. From the iodine absorption value and the saponification value of each fraction it is then possible to calculate the weight of each ester contained in it (see later). Finally in summing up these results for the individual fractions the weight of each acid in the original weight of butter fat is arrived at.

In carrying out the fractional distillation under the conditions described in the Experimental Part it will be found that distinct fractions tend to collect round about the following temperatures:

Fraction	Boiling point	Fraction composed of	
(a)	120°/760 mm.	Butyrate + Caproate	} + a small proportion of oleate
(b)	150°/760 mm.	" "	
(c)	70°/15 mm.	" "	
(d)	105°/15 mm.	Caproate + Caprylate	
(e)	135°/15 mm.	Caprylate + Caprate	} + a large proportion of oleate
(f)	150°/15 mm.	Caprate + Laurate	
(g)	175°/15 mm.	Laurate + Myristate + considerable oleate	
(h)	202°/15 mm.	Myristate + Palmitate	
(i)	210°/15 mm.	Palmitate + Stearate	}
(j)	over 212°/15 mm.	Stearate + Dihydroxystearate	

The temperature registered by the thermometer during the distillation of the final fraction (*j*) varies considerably in different experiments, owing to the fact that this fraction is usually a small one, and that slight decomposition occurs during its distillation. If the esterification has been carried out successfully, however, no difficulty will be experienced in the distillation, and the decomposition involved will be so slight that no appreciable loss of ester will result. On an average, the *total* loss of esters incurred during an experiment amounts to less than 1 % of the weight of fat taken for analysis.

Haller [1906, 1907, 1908] states that the fractional separation by this method proceeds satisfactorily up to methyl laurate, but it was found impossible to obtain even the earlier fractions free from unsaturated material. Similar results have been recorded by Miss Smedley [1912] who concluded from a study of the iodine values of the various fractions, that unsaturated acids other than oleic acid exist in butter fat. In several instances she found that the iodine value of the fraction containing methyl caprate was appreciably greater than those of the fractions immediately preceding or following it, and accordingly the presence of a decylenic acid seemed probable, though she failed to isolate the compound. As we also repeatedly observed a local maximum iodine value for the fraction boiling at 120°/15 mm. (cf. p. 142) experiments were carried out with the object of identifying the unsaturated body present in this fraction. These, unfortunately, were inconclusive, the only positive result obtained being the isolation, from the product of an oxidation experiment with the fraction, of a small quantity of material, which from its crystalline appearance and melting point (130°) was regarded as dihydroxystearic acid.

Some indirect evidence of the possibility of methyl oleate being present in the lower boiling fractions, however, was obtained from the following experiment. Pure specimens of butyric, caproic, caprylic, capric, lauric, myristic, palmitic and stearic acids were obtained, and, before use, proved to be free from unsaturated material by the fact that no iodine absorption resulted when they were treated with Wijs' reagent. Weighed amounts of the above acids were then mixed with a known weight of pure oleic acid, so as to give a mixture of acids approximately the same as that occurring in butter fat. The acid mixture was then esterified in the usual way, the esters fractionated in the same manner as those prepared from butter fat, and after three fractionations the iodine value of each fraction was determined. In the following table are given details of

the final fractionation and the weights and iodine values of the individual fractions:

Fraction	Temperature ° C.	Pressure mm.	Weight g.	Iodine value g.
1	65-130	760	0.29	1.867
2	-150	760	0.33	2.523
3	75- ?	15	1.27	1.730
4	-120	15	0.90	4.324
5	-140	15	1.18	5.823
6	-147	15	1.70	2.320
7	-155	15	2.90	2.840
8	165-170	15	8.61	3.630
9	-185	15	14.12	8.250
10	-200	12	14.77	39.12
11	-202	12	16.72	57.51
12	197-199	9	18.14	68.00
13	-205	9	6.80	72.61
14	Residue	—	1.80	71.50

As methyl oleate is the only unsaturated compound which can possibly be present, it is evident from the above results that it distils over with the lower esters. Further, a distinct local maximum iodine value is indicated corresponding to the fraction boiling between 120°-140° at 15 mm., so that the results, though at a lower level, are perfectly analogous to those obtained from an examination of butter fat. Accordingly it is reasonable to conclude that oleic acid is the only unsaturated acid present in the butter fat, and support is given to this view by the fact that so far all attempts to isolate or identify any other unsaturated body have proved unsuccessful.

If this be granted, it is possible, as indicated later (p. 151), to determine the mean molecular weight of the saturated esters present in each fraction: and these results, taken in conjunction with the observed boiling points for the respective fractions, point to each fraction containing, in addition to the proportion of methyl oleate, two saturated esters, one of these being present in large excess. Thus, for example, the saturated portion of the first fraction is largely methyl butyrate, a little methyl caproate being also present: the second fraction is largely caproate with a little butyrate or caprylate: and so on. Working on this principle, that there are present in each fraction, besides a proportion of methyl oleate, two saturated esters, one of which largely predominates, the amount of each ester present can be estimated from the mean molecular weight of the saturated esters by use of the following formulae:

$$x_1 = \frac{m_1}{m} \cdot \frac{m_2 - m}{m_2 - m_1} \cdot w \text{ and } x_2 = w - x_1,$$

,, w is the weight of the saturated esters in the fraction,

„ x_1 „ „ „ ester, whose mol. wt. is m_1 ,

" x_2 " " " " " "

Although the above method for arriving at the composition of the fat is liable to many sources of error, it has been found to yield consistent results when duplicate analyses of the same sample were carried out (see p. 145). This, of course, is no guarantee that the percentage of any particular acid found in a fat by this method is the correct one, but such was found to be the case when a more rigorous test was applied. When the artificial mixture of acids mentioned in the preceding pages was subjected to this method of analysis, the results obtained showed a remarkably close agreement with the theoretical values.

These are tabulated below for comparison:

	Wt. of acid taken	Wt. of esters cal. from wt. of acid taken	Wt. of esters found by analysis
Acid	g.	g.	g.
Butyric	4.34	5.03	5.026
Caproic	1.69	1.89	1.854
Caprylic	1.10	1.21	1.240
Capric	1.30	1.41	1.467
Lauric	3.80	4.06	3.994
Myristic	20.50	21.76	22.108
Palmitic	14.50	15.30	14.950
Stearic	1.26	1.32	1.416
Dihydroxystearic	—	—	0.210*
Oleic	40.00	41.98	41.675
	Total weight	93.96 g.	93.940 g.

It would appear, from the above results, that the method is sufficiently reliable for all practical purposes for the detection of significant differences in composition between different fats. We have indeed already applied it for the comparison of the fat obtained from "first runnings" of milk with that from "last runnings" or "strippings" from the same cows. Reference to the summary on p. 145 will show that these two fats showed differences that were much larger than those obtained with duplicates of the same fat. The greatest differences noted are in the amounts of myristic, palmitic and

stearic esters, there being nearly 9 % less myristate in fat of "first runnings," but 6 % more palmitate, and nearly 3 % more stearate. The "first runnings" fat also yielded a larger proportion of methyl oleate, as was indicated by the iodine values.

Duplicate complete analyses of the fat obtained from ewe's milk gave quite a good agreement throughout (cf. p. 145), but the mean composition of ewe's milk fat thus arrived at showed marked differences from the average analysis of cow's milk fat, especially with regard to the percentages of the lower fatty acids. The amount of methyl butyrate was considerably higher than in cow's milk fat, the caproate somewhat lower, while the caprylate and caprate were between four and four and a half times as great. Without further evidence it is impossible to say whether these differences are characteristic or purely accidental.

With regard to the actual percentages of the several acids present in cow's milk fat, the results obtained by different observers vary within wide limits. Although this is only to be expected with a mixture such as butter fat, where so many factors contribute to the variation, still the great differences in the amounts, for example, of lauric acid, or stearic acid, reported as being present in butter fat, must be due mainly to the method of analysis employed. The following table (p. 145) gives a summary of results obtained by several workers, and there is added for comparison the results of the analyses, which are detailed in the present communication (pp. 147-162).

As far as the lower fatty acids are concerned the percentages found by us are about a mean of those hitherto published. The values for the butyrate tend to be a little high, and this is probably accounted for by the special precautions taken to secure efficient condensation when working with the lowest boiling fractions. The amounts of lauric acid found are considerably higher than was found by Browne, whose results are commonly quoted as authoritative. That butter fat does contain a considerable proportion of lauric acid was demonstrated by the following experiment. A fraction of methyl esters, obtained from butter fat, was found by the above method to consist of methyl caprate, methyl laurate, and methyl oleate approximately in the ratio 13 : 100 : 8. Three grams of this were hydrolysed, and the resulting acids isolated. The semi-solid mass obtained on cooling was spread on a porous plate, which soon absorbed the liquid oleic and capric acids, leaving behind fully two grams of a pure white solid acid. This weight agrees closely with the estimated amount of lauric acid present, and the solid after recrystallisation from spirit was identified by its melting point (43°) as lauric

Composition of Butter Fat.

Observer		Butyric acid	Caproic acid	Caprylic acid	Capric acid	Lauric acid	Myristic acid	Palmitic acid	Stearic acid	Dihydroxy- stearic acid	Oleic acid
		%	%	%	%	%	%	%	%	%	%
Molt [1907, p. 281]	...	...	7.40			—	—	20.00	40.93	—	26.53
Koefoed [1891]	...	1.37	1.83	0.46	1.83	7.32	20.13	25.62	1.83	—	31.11
Bell [1890, p. 48]	...	6.13	2.09			—	49.46			—	36.10
Duclaux [1886]	...	3.38	2.0—	—	—	—	—	—	—	—	—
		3.65	2.26	0.80			47.50			—	40.40
Blyth [1903, p. 340]	...	3.49	2.40	0.80			—	47.50			40.40
Browne [1899]	...	5.45	2.09	0.49	0.32	2.57	9.89	38.61	1.83	1.00	32.50
Fleischmann	Sample 1	5.00	2.00	0.15	—	—	—	52.12	—	—	35.36
and	" 2	5.00	2.00	0.15	—	—	—	51.10	3.35	—	33.30
Warmbold	" 3	4.32	2.16	0.67	—	—	4.46	48.94	5.54	—	28.81
[1907]	" 4	4.32	2.16	0.67	—	—	10.00	42.75	2.00	—	33.00
Siegfeld	Sample 1	3.53	2.50	1.03	—	—	25.35	17.18	—	—	42.75
[1907]	" 2	3.58	1.26	2.87	—	—	22.94	20.84	—	—	40.53
	" 3	3.27	1.73	1.89	—	—	30.70	16.89	—	—	37.98
	" 4	3.35	1.68	2.21	—	—	26.00	20.96	—	—	38.09
Jensen [1905, 1, 2]	...	3.92	1.88	—	—	—	—	—	—	—	—
Richmond [1914, p. 42]	...	3.43	3.25	0.51	1.77	6.94	19.14	24.48	1.72	—	33.60
Crowther and Hynd	Cow's Dairy butter	4.45	1.45	0.99	1.10	3.55	20.13	15.24	1.08	0.68	45.47
	milk First runnings	4.30	1.98	1.11	1.51	5.08	10.38	17.47	5.93	0.30	46.49
	fat Last runnings	4.06	1.48	1.37	0.96	6.40	18.78	11.78	3.19	0.16	41.31
	Average	4.27	1.64	1.16	1.19	5.01	16.43	14.83	3.40	0.38	44.42
Hynd	Sheep's 1st analysis	6.60	1.06	4.18	4.72	4.73	13.20	13.87	4.56	0.36	40.61
	milk 2nd analysis	6.48	1.29	4.27	4.86	4.67	14.28	12.81	4.22	0.18	40.72
	fat Mean	6.54	1.18	4.23	4.79	4.70	13.74	13.34	4.39	0.27	40.67

acid. It seems from the above result that the usually accepted idea that only traces of lauric acid are present in butter fat must be modified. At any rate one cannot accept Caldwell and Hurtley's statement [1909], that the amount of lauric acid in butter fat is so small that none can be isolated from a pound. At the same time their observation, that palmitic acid is present in much smaller proportions than usually assumed, while myristic acid is more abundant, is borne out by our results, which in this particular also agree well with those of Siegfeld [1907]. It is with regard to stearic acid, however, that the greatest discrepancies have been reported. Many observers state that this acid either does not occur in butter fat, or is present only in very small amount. Thus Lewkowitsch [1913, p. 558] found only 0.49 % stearic acid in the insoluble fatty acids of butter fat, and Hehner and Mitchell [1896] also found very small proportions of stearic acid, varying from 1.3 to 3.6 %, and in some cases none at all. Koefoed [1891] and Browne [1899] both quote 1.83 % stearic acid, and the latter author writes:

"A noteworthy fact is the low percentage of stearic acid in butter fat.

This is somewhat contradictory to the statements which we find given by many authorities on the subject, who regard stearic acid as one of the principal acids in butter fat, it being placed by some writers as high even as 40 %. We believe that these statements should be modified somewhat; when we consider that oleic acid of molecular weight 282 constitutes over one-third of the insoluble acids from butter fat, it is self-evident that the percentage of stearic acid (mol. wt. 284) must be small in comparison with that of its lower homologues to give a mean molecular weight of 261 to the whole mixture....The low percentage of stearic acid should rank with the high percentage of soluble fatty acids, as one of the characteristic differences between butter and other animal fats."

In view of the above, it is surprising to find later evidence, which shows that the percentage of stearic acid in butter fat is considerable. Thus, Miss Smedley [1912] concluded that, of the total fatty acids from 10 to 15 % was stearic, and quite recently Holland, Reed and Buckley [1916] estimated that the proportion of stearic acid in the insoluble fatty acids from butter varied from 6.93 to 22.33 %, according to the type of fodder, and probably also to the individuality and period of lactation. Though the factors mentioned would, no doubt, influence the amount of stearic acid present, the variation seems extraordinarily well marked, and one feels inclined to doubt the applicability of Hehner and Mitchell's method to this particular analysis, especially as Lewkowitsch has pointed out that this method yields entirely unreliable or at best capricious results in a large number of cases where mixtures of stearic acid with acids other than palmitic and oleic are involved. Even if only palmitic and oleic acids be present, the results are still very uncertain; for example in the case of the fatty acids of cotton seed oil it was impossible to detect stearic acid by this method, even if 5 or 8 % of pure stearic acid had been added to the mixed fatty acids.

The average proportion of stearic acid obtained by us is 3.4 % for cow's butter fat, and 4.39 % for sheep's butter fat. The small amounts of dihydroxystearic acid found are regarded as oxidation products of a portion of the oleic acid, and not present originally. If these amounts be converted to oleic acid, the total oleic acid thus found agrees with that calculated from the iodine value of the original fat.

In the literature several references are found relating to the presence in butter fat of traces of acids other than those tabulated here. If such exist, they will probably be found amongst the higher fractions, the investigation of which we hope will form the subject of a future communication. In the

meantime, however, we intend to apply the method now described for a comparative study of fats obtained from different sources, and of milk fats produced under different conditions.

EXPERIMENTAL.

In the following pages full details are given of the method employed for the analysis of a sample of butter fat prepared from butter purchased at a local dairy. The general procedure followed was the same for the other materials analysed for which, therefore, only a condensed account is given.

I. *Analysis of Cow's Butter Fat.*

Preparation of the fat for analysis.

The butter was placed in a beaker, and melted by warming at a temperature not above 50°. As soon as the water and curd had separated, leaving the upper layer of fat perfectly clear, it was decanted through a folded filter paper, which had previously been thoroughly dried in the steam oven. The filtered fat was then ready for analysis. If not required at once it should be preserved in the cold away from light and air. In melting the butter a high temperature must be avoided, but at the same time the duration of heating should be reduced to a minimum.

Preparation of the methyl esters from butter fat.

From preliminary experiments it was found that Haller's [1906, 1907, 1908] acid method of esterification was preferable to that employed by Bull [1900, 1906], but to render the process quantitative, several precautions must be taken. These will be mentioned in the account which follows.

136.11 g. clarified fat were weighed off accurately into a round-bottomed litre flask and mixed with 214 cc. absolute methyl alcohol containing 2.5 % hydrogen chloride, and 323 cc. pure dry ether. The flask used was fitted to a fairly long double-surface condenser by means of a ground-glass joint, and the condenser carried a delivery tube, which was bent twice at right angles, and led into a series of U-tubes, surrounded by a freezing mixture of ice and salt. The esterification mixture was then heated for twelve hours on a water-bath at a temperature just sufficient to keep the liquid refluxing gently. After allowing to cool thoroughly, the U-tubes were detached, and the small quantity of liquid (10 to 15 cc.), which had collected, transferred to a litre graduated flask (A). The tubes were washed out with a little pure dry ether, and the washings also added to flask (A). The liquid, which had collected

in these tubes, was mainly ether, but at the same time an appreciable quantity of methyl ester (methyl butyrate) was always found to be present. Consequently, if this precaution was not taken, loss of this ester resulted.

To the ether-alcoholic solution of esters in the reaction flask, slightly more than the calculated amount of barium carbonate was added to remove the free hydrogen chloride. Though the mixture was frequently shaken, neutralisation proceeded slowly, but finally all the mineral acid was removed as indicated by Congo paper. The flask was then fitted with a five-pear still head and the ether and methyl alcohol distilled off, using a long double-surface condenser, and collecting the distillate in a flask cooled in a freezing mixture. The distillate, which contained in addition to ether and alcohol the greater part of the butyric ester, was then transferred to flask (A), the collection flask being washed out with ether, and the washings also added to (A). The residue, which consisted of methyl esters, glycerol, barium chloride, the excess of barium carbonate used, and the traces of solvents, was transferred by means of ether to a separating funnel and shaken with brine. This caused the ethereal solution of esters to separate out on top free from glycerol which was held in the salt solution. The process was repeated three times, and the separated ethereal solution then dried over anhydrous freshly ignited magnesium sulphate. After standing over night the magnesium sulphate was filtered off through a large Gooch crucible prepared in the usual way, and washed well with dry ether.

Fractional distillation of esters.

A 250 cc. Claisen distilling flask was fitted with a dropping funnel and thermometer, a portion of the dried ethereal solution of esters introduced through the funnel, and the ether distilled off carefully on the water-bath, the distillate being again collected in a cooled receiver, so as to avoid any loss of esters. As the ether evaporated, more solution was added by means of the tap-funnel until the whole had been introduced, and finally the flask and funnel were washed with pure dry ether. When all the ether had been distilled off, the receiver was removed, its contents transferred to flask (A), and in its place was fitted a "Perkin fractionation triangle." The tap-funnel was removed from the straight neck of the Claisen flask, which was now fitted with a cork, carrying a tube drawn out to a *very* fine capillary, and reaching to the bottom of the flask. The distillation of the esters was then carried out, at first at ordinary pressure, and then *in vacuo*, the distilling flask being heated by means of an asbestos air-bath. After the fraction boiling

about 140°/15 mm. had been collected the condenser was dispensed with, and the residual esters transferred with ether to a smaller Claisen flask, the side limb of which was connected directly with the receiver.

The first fraction that distilled over consisted mainly of ether, and consequently was added to the litre flask (A), which contained all the solvent alcohol and ether recovered from the process. The volume of this was now made up to the mark with pure alcohol (or ether) and the amount of methyl ester in solution determined as described below.

It was found that, as a rule, the fractionation must be repeated three or four times before a sufficient separation was effected. Appended are the details of the final (third) fractionation in the experiment described:

Fraction	Temperature ° C.	Pressure mm.	Weight g.
1	65-130	atmospheric	1·6690
2	{ -150 53- 75 }	{ atmospheric 15 }	1·9662
3	-110	15	1·3396
4	-135	15	1·0886
5	-155	15	2·4600
6	-185	15	14·1852
7	{ -200 184-190 }	{ 15 13 }	18·3872
8	-197	13	18·1542
9	-202	13	18·1230
10	-202	12	16·7630
11	-206	12	18·6558
12	-211	12	10·0762
13 (residue)	—	—	6·7827
Total weight of fractions			129·6507

The temperatures quoted for the various fractions indicate the points at which the first and last drops contained in the respective fractions came over.

On comparison it will be seen that the boiling points given on p. 140 fall between these temperatures, and that it was about these points that the bulk of the fraction distilled. For example, in the above fractionation fraction 3 corresponds to (d) on p. 140, fraction 5 to (f), fractions 7 to 11 (inclusive) to (h). The collection of the last named in five fractions was necessitated simply by the relatively large volume of distillate obtained at this stage, collection-tubes of uniform size being used for general convenience.

Determination of methyl butyrate volatilised with solvents.

A 250 cc. conical flask was fitted with a cork carrying a dropping funnel and a delivery tube, the latter being connected with a condenser. 20 cc. of alcoholic KOH solution (roughly N/2) were transferred to the flask and

100 cc. of the ether-alcoholic solution from flask (A) placed in the funnel, the stem of which, drawn out to deliver small drops, reached almost to the surface of the potash solution. The flask was then heated on the water-bath, and the ether-alcoholic solution allowed to drop in slowly, so that the volume in the flask remained about the same. When all the solution had been added the distillate was transferred to the funnel, and the distillation repeated. All the ester in the original solution was thus hydrolysed, and after cooling the contents of the flask a few drops of phenolphthalein were added, and the excess of potash titrated with standard (roughly N/2) hydrochloric acid.

A blank experiment was carried out at the same time, using a mixture of 50 cc. pure ether and 50 cc. neutral alcohol in place of the ether-alcoholic solution of ester, and proceeding exactly as described above. From the difference between the two titres the amount of ester can be calculated if the reasonable assumption be made, that it consists solely of methyl butyrate. In all cases the mean of two closely agreeing determinations was used in calculating the results.

Appended are the details for the analysis here described:

	cc. HCl (N/1 $\times$ 0.497) required	
	<i>a</i>	<i>b</i>
Blank experiment	31.89	31.86
100 cc. ester solution	21.05	21.00
Difference	10.84	10.86
Mean titre	10.85 cc.	

Hence weight of methyl butyrate in solution (1000 cc.)

$$= 10.85 \times 10 \times 0.497 \times 0.1021 \text{ g.}$$

$$= 5.507 \text{ g.}$$

If this weight be now added to the 129.651 g. of esters obtained in the fractionation, a total of 135.158 g. of esters is arrived at as having been obtained from 136.11 g. of butter fat.

Examination of the individual fractions.

(1) *Iodine value.* The iodine value of each fraction was determined, using the method of Wijs. [Cf. Leathes 1910, pp. 67-69.]

The Wijs solution was always made up two or three days before being required for analysis, and before use its strength was determined by checking it against the thiosulphate solution, the latter being standardised by titration with weighed quantities of pure iodine.

From the iodine absorption of each fraction, the weight of methyl oleate present in it was then calculated, on the assumption that no other unsaturated compound was present.

The results obtained are summarised in the following table:

10 cc. Wijs reagent (= 21.92 cc. thiosulphate) were used in each case.

1 cc. thio. = 0.01257 g. iodine.

Fraction	Weight taken g.	Thio. used cc.	Δ cc.	Iodine value g.	Weight of methyl oleate in fraction g.
1	0.1775	21.76	0.16	01.13	0.022
2	0.2224	21.56	0.36	02.03	0.047
3	0.2642	20.59	0.33	06.33	0.106
4	0.2805	19.10	2.82	12.63	0.160
5	0.3017	19.35	2.57	10.70	0.307
6	0.2797	18.63	3.29	14.78	2.443
7	0.2564	15.81	6.11	30.07	6.294
8	0.2982	13.65	8.27	34.85	7.375
9	0.3257	9.56	12.36	47.70	10.080
10	0.2929	8.26	13.66	58.61	11.450
11	0.2559	8.83	13.09	64.26	13.970
12	0.2721	7.32	14.60	67.43	7.912
13	0.2904	9.25	12.67	54.84	4.335
Total weight of methyl oleate					64.501

(2) *The saponification value.* The usual method for determining the saponification value of a fat was followed, that is, a weighed portion of each fraction was heated with excess of approximately semi-normal alcoholic potash, and the excess then estimated by titration with standard (0.497 N/1) hydrochloric acid, using phenolphthalein as indicator.

As all the fractions, except the last, were perfectly colourless liquids, the solutions for titration were only faintly coloured, and hence it was possible to obtain a very sharp end-point, thus giving results of considerable accuracy. A blank experiment was always carried out at the same time, and under identical conditions, and the difference between the two titres thus obtained corresponded to the fatty acids contained in and liberated during the process from the weight of esters taken for analysis.

The actual saponification numbers of the several fractions were not calculated, as the real object of the experiment was the determination of the mean molecular weights of the *saturated esters* present in each fraction. This was arrived at in the following way.

Having found the iodine value of each fraction, the amount of methyl oleate (*b*)¹ contained in the weight of esters (*a*) taken for the analysis of each fraction can readily be calculated, and the number of cc. of the standard hydrochloric acid (*b'*) equivalent to these amounts of methyl oleate can then be obtained. If these titres for methyl oleate (*b'*) be subtracted from the titres found for the total esters (*a'*), titres corresponding to the amounts of

¹ The index letters refer to the first table on p. 152

saturated esters (*c'*) are arrived at, and hence the mean molecular weights of the saturated esters in each fraction can be determined, as the weights of the saturated esters (*c*) are also known. The complete results are tabulated below.

Fraction	(a) Weight taken g.	(b) Weight of oleate g.	(c) Weight of saturated esters g.	(a') Titre cc.	(b') Titre for oleate cc.	(c') Titre for saturated esters cc.	Mean molecular weight of saturated esters
1	0.5237	0.0069	0.5168	6.21	0.04	6.17	108.55
2	0.6023	0.0143	0.5880	9.22	0.09	9.13	129.6
3	0.6520	0.0517	0.6003	8.11	0.35	7.76	155.7
4	0.6701	0.0987	0.5714	7.23	0.67	6.56	175.3
5	0.7225	0.0901	0.6324	6.97	0.61	6.36	200.1
6	1.6495	0.2841	1.3654	13.80	1.93	11.87	231.45
7	1.7611	0.6028	1.1583	13.35	4.09	9.26	251.65
8	1.6410	0.6669	0.9741	12.32	4.53	7.79	251.7
9	1.6894	0.9392	0.7502	12.32	6.39	5.93	254.4
10	1.7109	1.1685	0.5424	12.11	7.94	4.17	262.05
11	1.6915	1.2520	0.4395	11.88	8.51	3.37	262.55
12	1.6942	1.3110	0.3832	11.88	9.05	2.83	270.4
13	1.6895	1.0800	0.6095	11.30	7.34	3.96	309.7

Fraction	Total weight g.	Weight of methyl oleate g.	Weight of saturated esters g.
1	1.6690	0.022	1.647
2	1.9662	0.047	1.920
3	1.3396	0.106	1.233
4	1.0886	0.160	0.928
5	2.4600	0.307	2.153
6	14.1852	2.443	11.742
7	18.3872	6.294	12.093
8	18.1542	7.375	10.779
9	18.1230	10.080	8.043
10	16.7630	11.450	5.313
11	18.6558	13.970	4.686
12	10.0762	7.912	2.164
13	6.7827	4.335	2.448
Totals	129.6507	64.501	65.149

Weights of Individual Esters in each Fraction.

Fraction	Butyric g.	Caproic g.	Caprylic g.	Capric g.	Lauric g.	Myristic g.	Palmitic g.	Stearic g.	Dihydroxy- stearic g.	Oleic g.
Volatile with solvents	5.507	—	—	—	—	—	—	—	—	—
1	1.194	0.453	—	—	—	—	—	—	—	0.022
2	0.270	1.650	—	—	—	—	—	—	—	0.047
3	—	0.090	1.143	—	—	—	—	—	—	0.106
4	—	—	0.320	0.608	—	—	—	—	—	0.160
5	—	—	—	0.993	1.160	—	—	—	—	0.307
6	—	—	—	—	4.072	7.670	—	—	—	2.443
7	—	—	—	—	—	7.640	4.453	—	—	6.294
8	—	—	—	—	—	6.774	4.005	—	—	7.375
9	—	—	—	—	—	4.382	3.661	—	—	10.080
10	—	—	—	—	—	1.389	3.924	—	—	11.450
11	—	—	—	—	—	1.149	3.537	—	—	13.970
12	—	—	—	—	—	—	2.130	0.034	—	7.912
13	—	—	—	—	—	—	—	1.493	0.955	4.335
Totals	6.971	2.193	1.463	1.601	5.232	29.004	21.710	1.527	0.955	64.501

Final Summary.

Acid	Weight of ester g.	Ester %	Acid* %
Butyric	6.971	5.16	4.45
Caproic	2.193	1.62	1.45
Caprylic	1.463	1.08	0.99
Capric	1.601	1.19	1.10
Lauric	5.232	3.80	3.55
Myristic	29.004	21.46	20.13
Palmitic	21.710	16.08	15.24
Stearic	1.527	1.13	1.08
Dihydroxystearic	0.955	0.71	0.68
Oleic	64.501	47.74	45.47

* Strictly speaking the numbers given represent the weights of the respective acids obtainable from 100 g. of the mixed methyl esters, but must approximate very closely to the percentages in the actual fat.

II. Analysis of Artificial Mixture of Fatty Acids.

Details of the final distillation, and the iodine value of each fraction have already been given (p. 142).

Estimation of methyl butyrate:

Total ester required for saponification $\text{KOH} = (86.9 \times 0.497) \text{ cc. N/1 HCl}$.

Therefore total weight of methyl butyrate $= 86.9 \times 0.497 \times 0.1021 = 4.41 \text{ g.}$

Total weight of esters obtained $= 89.53 + 4.41 = 93.94 \text{ g.}$

„ „ „ calculated $= 93.97 \text{ g.}$

Analysis of Fractions.

Fraction	Iodine value g.	Mean molecular weight of saturated esters	Total weight of fraction g.	Weight of methyl oleate in fraction g.	Weight of saturated esters in fraction g.
1	1.87	102.0	0.29	0.004	0.286
2	2.52	103.55	0.33	0.007	0.323
3	1.73	129.3	1.27	0.025	1.245
4	4.32	136.9	0.90	0.045	0.855
5	5.82	160.2	1.18	0.080	1.100
6	2.32	190.4	1.70	0.046	1.654
7	2.84	214.9	2.90	0.096	2.804
8	3.63	238.2	8.61	0.365	8.245
9	8.25	243.3	14.12	1.361	12.759
10	39.12	260.0	14.77	6.747	8.023
11	57.51	270.9	16.72	11.230	5.490
12	68.00	270.9	18.14	14.400	3.740
13	72.61	297.1	6.80	5.766	1.034
14	71.50	319.9	1.80	1.503	0.297
Totals			89.53	41.675	47.855

Weights of Individual Esters in each Fraction.

Fraction	Butyric	Caproic	Caprylic	Capric	Lauric	Myristic	Palmitic	Stearic	Dihydroxy- stearic	Oleic
	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
Volatile with solvents	4.410	—	—	—	—	—	—	—	—	—
1	0.286	—	—	—	—	—	—	—	—	0.004
2	0.302	0.021	—	—	—	—	—	—	—	0.007
3	0.028	1.217	—	—	—	—	—	—	—	0.025
4	—	0.616	0.239	—	—	—	—	—	—	0.045
5	—	—	1.001	0.099	—	—	—	—	—	0.080
6	—	—	—	1.368	0.286	—	—	—	—	0.046
7	—	—	—	—	2.703	0.101	—	—	—	0.096
8	—	—	—	—	1.005	7.240	—	—	—	0.365
9	—	—	—	—	—	12.100	0.659	—	—	1.361
10	—	—	—	—	—	2.667	5.356	—	—	6.747
11	—	—	—	—	—	—	8.905	0.325	—	11.230
12	—	—	—	—	—	—			—	14.400
13	—	—	—	—	—	—	0.030	1.004	—	5.766
14	—	—	—	—	—	—	—	0.087	0.210	1.503
Totals	5.026	1.854	1.240	1.467	3.994	22.108	14.950	1.416	0.210	41.675
									equal to	0.188
										41.863
Theory	5.030	1.893	1.207	1.406	4.066	21.760	15.299	1.322	—	41.986

III. *Analysis of Butter Fat from "First Runnings" of Milk.*

July 27-31, 1914.

The sample was prepared from the mixed "first runnings" (*i.e.* first drawn milk) of several cows, the milk drawn representing about one-quarter of the total yield of the cows. The whole of the milk thus obtained was passed through a cream separator, the cream churned without delay, and the butter thus obtained used for the analysis.

The fat gave a Reichert-Wollny number of 28.37 and an iodine value of 45.65. The latter corresponds to 50.68 % of oleic acid in the fat.

Complete analysis:

Weight of fat taken 157.54 g.

Volume of methyl alcohol containing 2.5 % HCl 248 cc.

Volume of ether 375 cc.

Final (3rd) Fractionation.

Fractions from 2nd fractionation introduced	Fraction	Temperature ° C.	Pressure mm.	Weight g.
1, 2 →	1	65-130	760	2.3970
3 →	2	-150	760	1.4453
4 →	3	53-78	15	1.3808
	4	-110	16	1.6900
5, 6, 7 →	5	-133	14	2.6844
	6	-160	14	10.7606
	7	-180	13	13.3677
8, 9 →	8	-188	14	14.3442
	9	-196	14	18.3769
	10	-205	14	16.5646
10, 11 →	11	200-203.5	13	15.1847
	12	-205.5	13	16.1208
12, 13 →	13	-208	13	18.9202
	14	206.5-210	13	14.7388
		-280	13	
Total weight				147.976

Estimation of methyl butyrate:

Total ester required for saponification $\text{KOH} = 123.5 \times 0.523 \text{ cc. N/1 HCl.}$

Therefore total weight of methyl butyrate $= 123.5 \times 0.523 \times 0.1021 = 6.59 \text{ g.}$

Total weight of esters obtained $= 147.976 + 6.59 = 154.566 \text{ g.}$

Analysis of Fractions.

Fraction	Iodine value g.	Mean molecular weight of saturated esters	Weight of methyl oleate in fraction g.	Weight of saturated esters in fraction g.
1	0.24	117.8	0.007	2.390
2	1.08	125.15	0.018	1.427
3	3.28	141.6	0.053	1.328
4	8.06	166.7	0.159	1.530
5	12.73	182.0	0.408	2.276
6	13.89	221.0	1.746	9.015
7	19.20	236.45	2.997	10.370
8	28.06	257.2	4.701	9.643
9	37.59	264.35	8.067	10.310
10	48.01	271.6	9.289	7.276
11	55.95	272.2	9.920	5.265
12	60.34	286.5	11.360	4.761
13	68.03	289.1	15.040	3.880
14	65.26	302.2	11.235	3.504
		Totals	75.000	72.975

Weights of Individual Esters in each Fraction.

Fraction	Butyric	Caproic	Caprylic	Capric	Lauric	Myristic	Palmitic	Stearic	Dihydroxy- stearic	Oleic
	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
Volatile with solvents	6.590	—	—	—	—	—	—	—	—	—
1	0.909	1.481	—	—	—	—	—	—	—	0.007
2	0.206	1.221	—	—	—	—	—	—	—	0.018
3	—	0.721	0.607	—	—	—	—	—	—	0.053
4	—	—	1.001	0.530	—	—	—	—	—	0.159
5	—	—	0.283	1.993	—	—	—	—	—	0.408
6	—	—	—	—	6.546	2.469	—	—	—	1.746
7	—	—	—	—	1.860	8.510	—	—	—	2.997
8	—	—	—	—	—	4.148	5.495	—	—	4.701
9	—	—	—	—	—	1.904	8.406	—	—	8.067
10	—	—	—	—	—	—	6.823	0.453	—	9.289
11	—	—	—	—	—	—	4.812	0.453	—	9.920
12	—	—	—	—	—	—	1.843	2.918	—	11.360
13	—	—	—	—	—	—	1.100	2.780	—	15.040
14	—	—	—	—	—	—	—	3.011	0.492	11.235
Totals	7.705	3.423	1.891	2.523	8.406	17.031	28.479	9.615	0.492	75.000

Summary.

Ester	Wt. isolated	Ester	Acid
	g.	%	%
Butyric ...	7.705	4.99	4.30
Caproic ...	3.423	2.22	1.98
Caprylic ...	1.891	1.22	1.11
Capric ...	2.523	1.63	1.51
Lauric ...	8.406	5.44	5.08
Myristic ...	17.031	11.02	10.38
Palmitic ...	28.479	18.43	17.47
Stearic ...	9.615	6.22	5.93
Dihydroxystearic	0.492	0.32	0.30
Oleic ...	75.000	48.55	46.49
Total weight	154.565		

IV. *Analysis of Butter Fat from "Strippings" (July 27-31, 1914).*

The sample was prepared from the mixed "strippings" (last-drawn milk) of the same cows, and same milkings as furnished the sample of "first runnings," and was dealt with in precisely the same way.

The fat gave a Reichert-Wollny number of 29.38, and an iodine value of 44.02, the latter corresponding to 48.88 % of oleic acid in the fat. The fat was thus slightly richer in total volatile acids and slightly poorer in oleic acid than the fat of the "first runnings."

Complete analysis:

Weight of fat taken 158.10 g.

Volume of methyl alcohol containing 2.5 % HCl 248 cc.

Volume of ether 375 cc.

Final (3rd) Fractionation.

Fractions from 2nd fractionation introduced	Fraction	Temperature ° C.	Pressure mm.	Weight g.
1*	1	65-130	760	0.7170
2*	2	{ -150 53- 77	{ 760 17	1.5583
3*	3	-110	17	1.0808
4*	4	-130	17	1.7800
5*	5	-140	17	1.7644
6, 7, 8 →	6	-160	18	1.4912
	7	-185	18	15.1776
9, 10 →	8	189-193	18	12.0946
	9	-201	19	13.8648
11 →	10	199-203	17	13.3750
	11	-206	17	14.4274
12, 13, 14 →	12	-208	17	16.7288
	13	-213	17	14.0042
	14	211-213	17	17.1292
15 →	15	-220	17	18.0496
	16 (residue)	—	—	5.3868
Total weight				148.6297

* Fractions 1-5 of second fractionation were not redistilled.

Estimation of methyl butyrate:

Total ester required for saponification $\text{KOH} = (122.8 \times 0.523) \text{ cc. N/1 HCl}$.

Therefore total weight of methyl butyrate $= 122.8 \times 0.523 \times 0.1021 = 6.557 \text{ g.}$

Total weight of esters obtained $= 148.630 + 6.557 = 155.187 \text{ g.}$

Analysis of Fractions.

Fraction	Iodine value g.	Mean molecular weight of saturated esters	Weight of methyl oleate in fraction g.	Weight of saturated esters in fraction g.
1	0.15	112.9	0.001	0.716
2	0.55	122.6	0.010	1.548
3	1.63	135.0	0.021	1.060
4	4.90	153.9	0.102	1.678
5	12.16	172.9	0.250	1.514
6	11.65	196.8	0.203	1.288
7	11.41	223.8	2.022	13.156
8	19.16	235.7	2.704	9.390
9	24.64	246.1	3.990	9.875
10	30.33	251.9	4.848	8.527
11	40.94	252.35	6.898	7.529
12	56.74	268.7	11.090	5.639
13	63.73	269.0	10.420	3.584
14	68.21	285.4	13.650	3.479
15	68.91	288.1	14.620	3.430
16	66.86	304.8	4.208	1.179
Totals			75.037	73.592

Weights of Individual Esters in each Fraction.

Fraction	Butyric	Caproic	Caprylic	Capric	Lauric	Myristic	Palmitic	Stearic	Dihydroxy- stearic	Oleic
	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
Volatile with solvents	6.557	—	—	—	—	—	—	—	—	—
1	0.398	0.318	—	—	—	—	—	—	—	0.001
2	0.343	1.205	—	—	—	—	—	—	—	0.010
3	—	0.844	0.216	—	—	—	—	—	—	0.021
4	—	0.215	1.463	—	—	—	—	—	—	0.102
5	—	—	0.648	0.866	—	—	—	—	—	0.250
6	—	—	—	0.748	0.540	—	—	—	—	0.203
7	—	—	—	—	8.175	4.981	—	—	—	2.022
8	—	—	—	—	1.918	7.472	—	—	—	2.704
9	—	—	—	—	—	8.287	1.588	—	—	3.990
10	—	—	—	—	—	5.295	3.232	—	—	4.848
11	—	—	—	—	—	4.550	2.979	—	—	6.898
12	—	—	—	—	—	0.236	5.403	—	—	11.090
13	—	—	—	—	—	0.115	3.469	—	—	10.420
14	—	—	—	—	—	—	1.481	1.998	—	13.650
15	—	—	—	—	—	—	1.136	2.294	—	14.620
16	—	—	—	—	—	—	—	0.908	0.271	4.208
Totals	7.298	2.582	2.327	1.614	10.633	30.936	19.288	5.200	0.271	75.037

Summary.

Ester	Wt. isolated	Ester	Acid
	g.	%	%
Butyric ...	7.298	4.70	4.06
Caproic ...	2.582	1.66	1.48
Caprylic ...	2.327	1.50	1.37
Capric ...	1.614	1.04	0.96
Lauric ...	10.633	6.85	6.40
Myristic ...	30.936	19.93	18.78
Palmitic ...	19.288	12.43	11.78
Stearic ...	5.200	3.35	3.19
Dihydroxystearic	0.271	0.17	0.16
Oleic ...	75.037	48.36	41.31
Total weight	155.186		

V. Analysis of Butter Fat from Ewe's milk.

The sample was prepared from the mixed milk of several ewes of the flock at the Manor Farm, Garforth, in the spring of 1914.

The fat was separated by churning, and dealt with in precisely the same way as the samples of cow's butter fat.

The fat gave a Reichert-Wollny number of 29.41, and an iodine value of 41.41.

Complete analysis:

Weight of fat taken 162.16 g.

Volume of methyl alcohol containing 2.5 % HCl 280 cc.

Volume of ether 250 cc.

Final (4th) Fractionation.

Fraction	Temperature ° C.	Pressure mm.	Weight g.
1	-150	760	0.65
2	-160	760	2.30
3	55 - 77	16	1.25
4	-110	15	3.46
5	-130	15	8.15
6	-143	15	1.31
7	-155	15	4.97
8	-185	14	10.88
9	-190	13	16.83
10	-196	12	15.46
11	-201	12	17.14
12	-204	12	19.08
13	-207	12	15.72
14	-210	12	18.16
15	-220	12	9.10
16	-300	12	4.81
Total weight			149.27

Estimation of methyl butyrate:

Total ester required for saponification $\text{KOH} = (248.35 \times 0.523) \text{ cc. N/1 HCl}$.

Therefore total weight of methyl butyrate $= 248.35 \times 0.523 \times 0.1021 = 12.26 \text{ g.}$

Total weight of esters obtained $= 149.27 + 12.26 = 161.53 \text{ g.}$

Analysis of Fractions.

Fraction	Iodine value g.	Mean molecular weight of saturated esters	Weight of methyl oleate in fraction g.	Weight of saturated esters in fraction g.
1	0.075	125.7	0.001	0.649
2	0.365	145.7	0.010	2.290
3	0.55	146.8	0.008	1.242
4	1.525	159.8	0.062	3.398
5	3.34	177.6	0.318	7.832
6	3.72	187.8	0.057	1.253
7	3.70	206.9	0.214	4.756
8	8.64	228.5	1.098	9.782
9	17.19	245.7	3.378	13.452
10	28.30	254.3	5.110	10.350
11	44.59	269.2	8.926	8.214
12	53.55	273.9	11.935	7.145
13	64.73	285.7	11.882	3.838
14	68.54	288.1	14.456	3.704
15	70.61	298.8	7.503	1.597
16	69.01	316.5	3.876	0.934
		Totals	68.834	80.436

Weights of Individual Esters in each Fraction.

Fraction	Butyric	Caproic	Caprylic	Capric	Lauric	Myristic	Palmitic	Stearic	Dihydroxy- stearic	Oleic
	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
Volatile with solvents	12.260	—	—	—	—	—	—	—	—	—
1	0.083	0.566	—	—	—	—	—	—	—	0.001
2	—	0.909	1.381	—	—	—	—	—	—	0.010
3	—	0.446	0.796	—	—	—	—	—	—	0.008
4	—	—	3.146	0.252	—	—	—	—	—	0.062
5	—	—	2.093	5.739	—	—	—	—	—	0.318
6	—	—	—	1.161	0.092	—	—	—	—	0.057
7	—	—	—	1.084	3.672	—	—	—	—	0.214
8	—	—	—	—	4.416	5.366	—	—	—	1.098
9	—	—	—	—	—	11.522	1.930	—	—	3.378
10	—	—	—	—	—	5.522	4.828	—	—	5.110
11	—	—	—	—	—	0.211	8.003	—	—	8.926
12	—	—	—	—	—	—	6.062	1.083	—	11.935
13	—	—	—	—	—	—	1.593	2.245	—	11.882
14	—	—	—	—	—	—	1.227	2.477	—	14.456
15	—	—	—	—	—	—	—	1.554	0.043	7.503
16	—	—	—	—	—	—	—	0.371	0.563	3.876
Totals	12.343	1.921	7.416	8.236	8.180	22.621	23.643	7.730	0.606	68.834

Summary.

Ester	Wt. isolated	Ester	Acid
	g.	%	%
Butyric	12.343	7.64	6.60
Caproic	1.921	1.19	1.06
Caprylic	7.416	4.59	4.18
Capric	8.236	5.10	4.72
Lauric	8.180	5.06	4.73
Myristic	22.621	14.01	13.20
Palmitic	23.643	14.64	13.87
Stearic	7.730	4.79	4.56
Dihydroxystearic	0.606	0.38	0.36
Oleic	68.834	42.63	40.61
Total weight	161.530		

VI. *Analysis of Butter Fat from Ewe's milk.*

Repetition of V with a further portion of same sample.

Complete analysis:

Weight of fat taken 164.35 g.

Volume of methyl alcohol containing 2.5 % HCl 273 cc.

Volume of ether 250 cc.

Final Fractionation.

Fraction	Temperature ° C.	Pressure mm.	Weight g.
1	-140	760	0.89
2	-155	760	2.82
	55 - 77	12	
3	- 80	12	3.72
4	-110	11	5.65
5	-140	11	7.12
6	-155	11	4.93
7	-185	11	17.56
8	184 -190	11	17.63
9	-192	11	17.54
10	-195	11	18.33
11	-199	11	17.71
12	-201	11	18.32
13	-215	11	12.45
14	Residue	—	6.94
Total weight			151.61

Estimation of methyl butyrate:

Total ester required for saponification $\text{KOH} = (227.9 \times 0.523) \text{ cc. N/1 HCl.}$

Therefore total weight of methylbutyrate $= 227.9 \times 0.523 \times 0.1021 = 12.17 \text{ g.}$

Total weight of esters obtained $= 151.61 + 12.17 = 163.78 \text{ g.}$

Analysis of Fractions.

Fraction	Iodine value g.	Mean molecular weight of saturated esters	Weight of methyl oleate in fraction g.	Weight of saturated esters in fraction g.
1	0.01	124.9	0.001	0.89
2	1.62	145.0	0.053	2.77
3	3.00	154.0	0.131	3.59
4	3.74	169.7	0.247	5.40
5	4.42	190.2	0.368	6.75
6	6.50	210.4	0.374	4.56
7	11.40	235.9	2.337	15.22
8	25.09	247.1	5.166	12.46
9	38.97	261.3	7.981	9.56
10	48.01	271.0	10.280	8.05
11	61.70	277.0	12.760	4.95
12	67.63	286.6	14.470	3.85
13	70.18	299.1	10.200	2.25
14	69.53	303.3	5.636	1.30
		Totals	70.004	81.60

Weights of Individual Esters in each Fraction.

Fraction	Butyric	Caproic	Caprylic	Capric	Lauric	Myristic	Palmitic	Stearic	Dihydroxy- stearic	Oleic
	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
Volatile with solvents	12-170	—	—	—	—	—	—	—	—	—
1	0-135	0-755	—	—	—	—	—	—	—	0-001
2	—	1-167	1-603	—	—	—	—	—	—	0-053
3	—	0-449	3-141	—	—	—	—	—	—	0-131
4	—	—	2-929	2-471	—	—	—	—	—	0-247
5	—	—	—	5-610	1-140	—	—	—	—	0-368
6	—	—	—	0-518	4-042	—	—	—	—	0-374
7	—	—	—	—	3-007	12-213	—	—	—	2-337
8	—	—	—	—	—	9-977	2-483	—	—	5-166
9	—	—	—	—	—	2-751	6-809	—	—	7-981
10	—	—	—	—	—	—	7-734	0-316	—	10-280
11	—	—	—	—	—	—	3-618	1-332	—	12-760
12	—	—	—	—	—	—	1-477	2-373	—	14-470
13	—	—	—	—	—	—	—	2-168	0-082	10-200
14	—	—	—	—	—	—	—	1-066	0-234	5-636
Totals	12-305	2-371	7-673	8-599	8-189	24-941	22-121	7-255	0-316	70-004

Summary.

Ester	Wt. isolated	Ester	Acid
	g.	%	%
Butyric ...	12-305	7-51	6-48
Caproic ...	2-371	1-45	1-29
Caprylic ...	7-673	4-69	4-27
Capric ...	8-599	5-25	4-86
Lauric ...	8-189	5-00	4-67
Myristic ...	24-941	15-23	14-28
Palmitic ...	22-121	13-51	12-81
Stearic ...	7-255	4-43	4-22
Dihydroxystearic	0-316	0-19	0-18
Oleic ...	70-004	42-75	40-72
Total weight	163-774		

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