XIII. THE COMPONENT FATTY ACIDS AND GLYCERIDES OF THE MILK-FAT OF INDIAN CAMELS.

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THE component fatty acids and glycerides of the milk-fat of the camel have been studied in detail, in order to compare them with those of the milk-fats of the cow [Hilditch *et al.*, 1929; 1930; 1931], buffalo [Bhattacharya and Hilditch, 1931], sheep and goat [Dhingra, 1933].

In north-western parts of India milk from camels is utilised as an article of diet by some tribes, but the fat is rarely extracted from the milk and used as a substitute for "ghee" (camel milk-fat is not included in the term "ghee" as defined in the Bombay "Adulteration of Ghee" Act).

The milk-fat used in the present investigation was prepared by churning fresh milk from the animals, and after separating water and caseinogen from the butter, the fat was stored *in vacuo* in sealed amber glass bottles. The milk-fat was obtained in the month of March 1933, when the temperature range was 50°–80° F., from Gujranwala (Panjab) camels, which had been fed partly on green grass but mainly on the tree leaves of *Zizyphus jujuba*, *Acacia speciosa* and *Acacia Arabica*. The yield of the fat from different samples of the milk varied from 2·0 to 2·5 %.

The general characteristics of the milk-fat are given in Table I.

Table I.

Colour	Almost white (cream tinge)
Odour	Buttery, with a slight tallowy odour
Sap. equiv.	259·0
Iodine value	40·8
Acid value	0·2
Reichert-Meissl value	16·4
Polenske value	1·6
Kirschner value	14·3
Setting-point	35·3
Refractive index $n_D^{40°}$	1·4555

The Reichert-Meissl and Kirschner values of camel butter-fat are lower and the saponification equivalent is higher than corresponding characteristics of cow, buffalo, goat and sheep butter-fats, but the Polenske value is considerably lower than that of the goat and sheep butter-fats and more nearly resembles that of cow and buffalo milk-fats.

Component fatty acids of camel milk-fat.

The method followed for the quantitative determination of the component fatty acids was that developed by Hilditch and Jones [1929]. On account of the small amount of the fat available, the mixed fatty acids from 200 g. of fat only

were employed for this purpose. The details of fractionation data are given in Table II, and the final results for the fat are summarised in Table III.

Table II.

(*a*) *Acids volatile in steam.*

No.	g.	B.P. (° C.)	Pressure	Mean equivalent	Acids: Butyric	Caproic	Caprylic	Capric	Oleic	N – S
1	In aqueous solution (4580 ml.)			—	0·90	—	—	—	—	—
2	In recovered ether (1535 ml.)			—	0·05	—	—	—	—	—
3	4·99	35–80	Atmospheric	—	0·13	—	—	—	—	—
4	1·55	80–140	,,	—	0·65	—	—	—	—	—
5	1·02	141–142	,,	—	0·91	—	—	—	—	—
6	1·22	140–141	,,	95·7	0·83	0·39	—	—	—	—
7	0·88	142–160	,,	101·0	0·42	0·46	—	—	—	—
8	0·57	100–110	Reduced	107·7	0·14	0·43	—	—	—	—
9	0·68	112–122	,,	126·4	—	0·40	0·28	—	—	—
10	1·48	Residue	,, (Iodine value 13·0)	183·2	—	—	0·94	0·14	0·21	0·19
					4·03	1·68	1·22	0·14	0·21	0·19

(*b*) *Acids non-volatile in steam.* 190 g.

(Sap. equiv. 261·9; Iod. val. 43·4.)

Lead salt separation.

	g.	%	Corresponding esters: S.E.	I.V.
"Solid" acids S	71·6	48·9	276·1	6·2
"Liquid" acids L	74·8	51·1	274·4	73·9

(*c*) *Fractionation of methyl esters.*

(i) Esters of "Solid" acids S.

Primary fractions: No.	g.	B.P./2 mm.	sap. eq.	I.V.	Refractionations: No.	g.	B.P./2 mm.	sap. eq.	I.V.
					S 11	3·73	120–156	261·0	2·3
					S 12	6·13	155–157	265·2	2·8
S 1	31·96	130–162	270·3	4·0	S 13	4·47	155–157	267·9	3·1
					S 14	4·27	156–158	273·0	4·0
					S 15	5·68	160–168	276·1	5·5
					S 16	2·40	Residue	283·9	8·7
S 2	4·81	160–164	283·4	8·2					
S 3	4·45	165–167	290·2	10·7					
S 4	3·71	Residue	297·8	15·3					

(ii) Esters of "Liquid" acids L.

					L 11	2·17	95–133	214·0	26·8
					L 12	4·10	135–148	250·7	47·4
					L 13	4·70	148–155	267·5	59·7
					L 14	5·12	152–159	270·3	64·4
L 1	38·94	95–180	270·1	70·2	L 15	5·13	158–160	281·9	78·2
					L 16	3·24	158–161	283·3	83·9
					L 17	4·80	158–160	295·8	88·9
					L 18	3·20	Residue	295·1	90·1
L 2	3·85	178–181	296·3	93·5					
L 3	2·00	181–182	295·9	94·2					
L 4	3·28	Residue	308·4	84·6					

The presence of the ordinary $\Delta^{9:10}$-oleic and $\Delta^{9:10,12:13}$-linoleic acids in the unsaturated components of the fat was shown by the identification of a dihydroxy-

Table III. *Summarised experimental data for fatty acids.*

Acid	Volatile acids 3·9 %	Acids non-volatile in steam: Solid acids S 47·0 %	Acids non-volatile in steam: Liquid acids L 49·1 %	Component fatty acids: including unsaponifiable % (wt.)	Component fatty acids: excluding unsaponifiable % (wt.)	Component fatty acids: excluding unsaponifiable % (mols.)
Butyric	2·10	—	—	2·10	2·1	5·9
Caproic	0·88	—	—	0·88	0·9	1·9
Caprylic	0·64	—	—	0·64	0·6	1·1
Capric	0·07	—	1·36	1·43	1·4	2·1
Lauric	—	—	4·56	4·56	4·6	5·7
Myristic	—	3·35	3·93	7·28	7·3	7·9
Palmitic	—	29·22	—	29·22	29·3	28·3
Stearic	—	11·08	—	11·08	11·1	9·7
Oleic	0·11	3·35	35·34	38·80	38·9	34·1
Linoleic	—	—	3·77	3·77	3·8	3·3
Unsaponifiable	0·10	—	0·14	0·24	—	—

stearic acid (M.P. 130°) and a tetrahydroxystearic acid (M.P. 172°) respectively from the products of oxidation of the dilute aqueous solution of the potassium salts of the acids from the penultimate fraction of the "liquid" esters. On hydrolysis of the residual fraction of the "solid" esters, stearic acid was identified.

For comparison, the molar percentages of the component fatty acids of one buffalo, two cow and one sheep milk-fats, along with those of the camel butter, are given in Table IV; while additional information may be gained from consideration of the combined amounts of the four groups of acids given at the foot of the Table.

Table IV. *Comparison of the molar distribution of the component acids of camel, cow, buffalo and sheep milk-fats.*

Fat	Camel butter	Cow butters [Hilditch and Sleightholme, 1931]: Autumn fed English I	Cow butters [Hilditch and Sleightholme, 1931]: Early summer pasture-fed English IV	Sheep butter [Dhingra, 1933]	Buffalo butter No. 2 [Bhattacharya and Hilditch, 1931]
Iodine value	40·8	41·3	41·6	32·1	33·5
Butyric	5·9	8·4	8·9	8·4	11·0
Caproic	1·9	3·5	2·7	5·4	2·8
Caprylic	1·1	2·7	2·0	5·8	1·5
Capric	2·1	2·9	3·0	10·1	2·3
Lauric	5·7	4·1	4·7	6·0	3·3
Myristic	7·9	7·2	10·9	11·8	10·4
Palmitic	28·3	27·1	24·3	20·4	28·7
Stearic	9·7	6·4	5·4	5·4	9·3
Arachidic	—	0·7	—	1·3	0·7
Oleic	34·1	33·9	34·6	22·2	27·8
Linoleic	3·3	3·1	3·5	3·2	2·2
Butyric-lauric	16·7	21·6	21·3	35·7	20·9
Myristic-palmitic	36·2	34·3	35·2	32·2	39·1
Stearic (-arachidic)	9·7	7·1	5·4	6·7	10·0
Oleic-linoleic	37·4	37·0	38·1	25·4	30·0

It is clear that camel milk-fat contains definitely less butyric acid than any of the other milk-fats in this Table. The caprylic and capric acid contents of camel milk-fat resemble those of the milk-fats of the cow and buffalo; sheep and goat

milk-fats, it may be recalled, stand apart in their relatively high proportions of these two acids and in corresponding reductions in their contents of oleic and palmitic acids. The differences between the fatty acids of the camel milk-fat and milk-fats of autumn-fed and early summer pasture-fed English cows is not so marked as between those of the former and the milk-fats of the buffalo, goat or sheep.

The low content of acids volatile in steam in camel milk-fat may partly be due to its xerophytic plant food, or as suggested by Dhingra [1933] in the case of goat and sheep butters, it may be mainly connected with the species of the animal. Possibly the amount of these acids decreases with the size and species of the animals in the decreasing order of sheep, goat, cow, buffalo and camel; but this conclusion requires further confirmation and for this purpose experiments are in progress.

Component glycerides of the camel milk-fat.

The glyceride structure of the fat was studied by separating quantitatively the fully-saturated glycerides present and by determining the component fatty acids in the latter, as described by Hilditch and Jones [1929]; from the combined data for the component fatty acids of the whole fat and of the fully-saturated glycerides, the components of the mixed saturated-unsaturated glycerides present were deduced.

The fat (250 g.) yielded after oxidation crude neutral products (69·9 g.), a portion of which (69·0 g.) was resolved by further purification into: (*a*) 56·2 g., acid value 0·3, (*b*) 4·5 g., acid value 16·1, and (*c*) acidic products, 8·3 g., acid value 90·3. From this, the amount of fully-saturated glycerides in the original fat was determined to be 24·2 % (wt.) or 25·6 % (mols.), corresponding to an "association ratio" of 0·98 mol. of saturated per mol. of unsaturated acids in the mixed saturated-unsaturated glycerides. The component acids of the fully-saturated glycerides are made up as follows:

Table V.

Acid	% (wt.) (Excluding unsaponifiable matter)	% (mol.) (Excluding unsaponifiable matter)
Butyric	3·4	8·9
Caproic	1·0	2·1
Caprylic	0·1	0·1
Capric	2·1	2·8
Lauric	2·2	2·6
Myristic	18·4	18·9
Palmitic	55·0	50·0
Stearic	17·8	14·6

As in cow, goat and sheep butter-fats, the proportion of fully-saturated components of camel milk-fat is a function of the relative amounts of saturated and unsaturated acids in the whole fat. The amount of the fully-saturated glycerides in the present case is somewhat less for a given ratio of saturated to unsaturated acids in the whole fat, than that in cow butters of somewhat similar iodine value. It will be noticed also that the ratio of saturated to unsaturated acids in the mixed saturated-unsaturated glycerides of camel milk-fat is somewhat higher than that of cow butters.

Distribution of the fatty acids in the camel butter glycerides.

The molar percentages of the different groups of fatty acids in the whole fat, and its fully-saturated and non-fully-saturated glyceride components are collected in Table VI. As in Table IV, the data for the milk-fats of two cows, buffalo and sheep are also added for comparison with the camel milk-fat.

Table VI. *Molar distribution of fatty acids in camel, cow, buffalo and sheep milk-fats.*

Section	Acids	Camel butter	Cow butters [Hilditch and Sleightholme, 1931] Autumn fed English I	Cow butters [Hilditch and Sleightholme, 1931] Early summer pasture English IV	[Bhattacharya and Hilditch, 1931] Buffalo ghee, No. 2	[Dhingra, 1933] Sheep butter
Whole fat	Butyric-lauric	16·7	21·6	21·3	20·9	35·7
	Myristic	7·9	7·2	10·9	10·4	11·8
	Palmitic	28·3	27·1	24·3	28·7	20·4
	Stearic (-arachidic)	9·7	7·1	5·4	10·0	6·7
	Oleic-linoleic	37·4	37·0	38·1	30·0	25·4
Fully-saturated	Molar % F.S.G.	25·6	29·1	27·2	34·0	36·8
	Butyric-lauric	16·5	28·6	30·5	25·9	48·3
	Myristic	18·9	13·2	15·1	9·2	15·9
	Palmitic	50·0	43·1	39·5	47·1	26·9
	Stearic (-arachidic)	14·6	15·1	14·9	17·8	8·9
Mixed saturated-unsaturated	Molar % F.S.G.	74·4	70·9	72·8	66·0	67·2
	Butyric-lauric	16·6	19·0	18·3	18·5	28·4
	Myristic	4·2	5·0	9·4	11·1	9·4
	Palmitic	20·8	20·9	18·7	19·2	16·5
	Stearic (-arachidic)	8·0	4·1	2·2	5·8	5·5
	Oleic-linoleic	50·4	51·0	51·4	45·4	40·2

Hilditch and Sleightholme [1931] observed that the component acids of fully-saturated glycerides of six pasture-fed cow butter-fats, which differed widely in iodine value, were almost constant; but the corresponding data for camel milk-fat differ widely from all these, except that the percentage of stearic acid reaches a figure of about 15 % in camel and also in most of the cow milk-fat fully-saturated glycerides. The main differences between the two classes of fully-saturated glycerides are thus the lower percentage of the butyric-lauric acid group and the correspondingly higher proportions of myristic and palmitic acids in the case of the camel butter-fat. The differences between the components of the fully-saturated glycerides of the milk-fat of camels and those of goat, sheep and buffalo butter-fats are much more marked.

The percentages of the components of the mixed saturated-unsaturated glycerides of camel milk-fat are on the whole similar to those of the six pasture-fed cow butters and, to some extent, to those of buffalo ghee; but they differ from those of goat and sheep milk-fats in showing a lower percentage of the butyric-lauric group of acids and a correspondingly higher proportion of unsaturated acids.

SUMMARY.

The fatty acids of the milk-fat of the camel differ from those of cow, buffalo, goat and sheep milk-fats in a lower content of fatty acids volatile in steam. Camel milk-fat can to a great extent be distinguished from the milk-fats of other animals by its lower Kirschner and Reichert-Meissl values. The amount of the lower fatty acids is in decreasing order in the milk-fats of the sheep, goat, cow, buffalo and camel.

The content of the fully-saturated glycerides in camel milk-fat is a function of mean unsaturation, like that of the milk-fats of other animals. The component fatty acids of the fully-saturated glycerides of camel milk-fat are in somewhat different proportions to those in the milk-fats hitherto studied. The composition of the fatty acids of the mixed saturated-unsaturated glycerides of camel milk-fat is little different from that of most cow and buffalo butters, but more so from that of goat and sheep milk-fats.

From the point of view of general properties and of the component glycerides present, there seems no reason why camel milk-fat should not be used as a substitute for cow, buffalo, *etc.*, milk-fats.

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