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THE FATS AND FATTY ACIDS
OF THE GRAIN SORGHUMS

A TECHNICAL BULLETIN

BY C. K. FRANCIS AND W. G. FRIEDEMANN

DEPARTMENT OF CHEMISTRY

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THE FATS AND FATTY ACIDS OF THE GRAIN SORGHUMS

BY C. K. FRANCIS AND W. G. FRIEDEMANN

Other publications of this Station have described related work on the grain sorghums as follows: "The Chemical Composition of Kafir Corn",* "Foods From the Grain Sorghums",** "The Poisoning of Livestock While Feeding on Plants of the Sorghum Group",*** and "The Starches of the Grain Sorghums".****

As indicated in a previous bulletin on the starches, the botanical characteristics of the grain sorghums are quite similar and the relationship is even more pronounced in the microscopical and chemical properties of the different starches. The object of the work described in this bulletin was to ascertain the nature of the substances making up the fat in the grains of the grain sorghums, and to obtain additional evidence of the close relationship of the plants.

The composition of the best known grain sorghums, kafir, feterita and milo, is similar, as indicated by the analyses***** shown in Tables I and II.

TABLE I
The Composition of Kafir, Feterita and Milo Grains

	Kafir	Feterita	Milo
Water	10.57	10.67	10.42
Ash	1.13	1.31	1.37
Protein	13.88	14.00	14.38
Fiber	1.84	2.04	2.10
Nitrogen-free extract	70.02	69.61	69.43
Ether extract (fat)	2.56	2.37	2.30

TABLE II
Proximate Analysis of the Ether Extract (Fat) of Kafir, Feterita and Milo

	Kafir	Feterita	Milo
Liquid (unsaturated) fatty acids	2.20	1.92	1.84
Solid (saturated) fatty acids20	.35	.23
Volatile fatty acids02	.02	.01
Unsaponifiable residue14	.08	.22
Ether extract (fat)	2.56	2.37	2.30

*Oklahoma Agricultural Experiment Station Bulletin No. 89, 1910.

**Oklahoma Agricultural Experiment Station Circular No. 27, 1914.

***Oklahoma Agricultural Experiment Station Circular of Information No. 38, 1915.

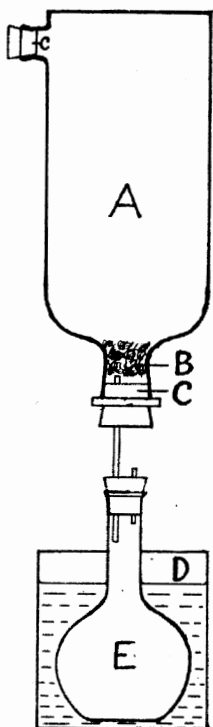
****Oklahoma Agricultural Experiment Station Bulletin No. 110, 1916.

*****A. O. A. C. Methods, U. S. Department of Agriculture, Bureau of Chemistry, Bulletin No. 107 (revised). Fiber was determined by the one filtration method through asbestos. Crops grown on Oklahoma Agricultural Experiment Station farm.

EXPERIMENTAL

THE FATS

Extraction of Fat.—Large quantities of crude fat were necessary for the investigation, and a special apparatus, Figure 1, was designed which would permit a comparatively large amount of the raw material to be treated at one time. Four kilograms of finely ground grain were put in an 8-liter aspirator bottle and covered with 1600 cc. of ether. After standing for twenty-four hours, having shaken the treated meals at intervals, the bottle was inverted and the ethereal solution percolated in the manner shown in illustration. When all of the extract had passed through, 1000 cc. of ether were added, and percolated after standing twenty-four hours. This extraction process was repeated seven or eight times until the extract was colorless.



A, the 8-liter aspirator bottle with meal inverted to percolate off the ether solution. B, absorbent cotton. C, cork. D, a bucket containing cold water. E, receiving flask

The first ether extraction of kafir yielded 0.8433% fat and the last extraction 0.0449%, showing that practically all the fat had been removed by eight extractions. The percentage of fat obtained by the above method agreed closely to that obtained by the A. O. A. C. (indirect) method, as shown by the following results:

Fat from 4 kilograms feterita by above method	2.80%
Fat from 2 grams feterita by A. O. A. C. method	2.72%
Fat from 4 kilograms milo by above method	2.53%
Fat from 2 grams milo by A. O. A. C. method	2.61%

The ether was recovered by distillation and the residue filtered through hardened filter paper in a hot water funnel. The fat, nearly free from ether, was heated in a water oven, while dry carbon dioxide passed through it. The fat was considered dry after heating for eight hours, or when the loss in weight in one hour was no more than 1 or 2 milligrams.

The fat extracted from milo, separated at ordinary temperature, into two parts which we have termed liquid fat and sediment fat. A thorough separation was accomplished by centrifuging at 1500 r. p. m. for 15 minutes; the quantity of sediment fat obtained in this way was equivalent to 10% of the total volume. The sediment fat was filtered through a hardened filter paper at 70° C., and there was practically no residue left on the filter. The filtered fat was dried at 100° C. in an atmosphere of CO₂ to a constant weight. The solid milo fat differed only in melting point from the liquid milo fat.

The fat of kafir and feterita extracted in this manner was a greenish-yellow, vaseline-like substance having a pleasant nut-like odor and a vegetable oily taste, soluble in ether, chloroform, carbon disulphide, and to some extent in alcohol. The ether extract of milo is a liquid at room temperature, containing a small amount of solid fat, but similar to the other fats in appearance, taste and solubility.

Specific Gravity* was determined at 40° C. by the use of a pycnometer and the specific gravity calculated to 15.5° C. by the following formula:

$$G = G' \text{ plus } 0.00064 (T - 15.5^\circ \text{ C.})$$

G = specific gravity at 15.5° C.
 G' = specific gravity at (T)
0.00064 = mean correction for 1° C.

When the fat was liquid at room temperature, as in the case of milo fat, the determination was made at 15.5° C.

Solidifying Point or Titer Test.—The titer** test was made according to Dalican. One hundred grams of the fat were saponified with 80 cc. caustic potash solution, specific gravity 1.4 and 80 cc. of alcohol, and stirred in a porcelain dish on a water bath until the mass had reached a pasty consistency. The soap was then dissolved in 1000 cc. of water, and the solution boiled to remove the alcohol, replacing the water as necessary. The soap was decomposed with 20% sulfuric acid. After continued boiling the fatty acids separated as a clear, oily layer on the aqueous liquid; the latter was drawn off by means of a siphon, and the fatty acids washed several times with hot distilled water until the mineral acids had been removed. The fatty acids were then warmed and filtered into a porcelain dish through a dry plaited filter, fitted into a hot water funnel. The material was tested for traces of fat by dissolving a small quantity (about 2 cc.) in 15 cc. of alcohol and then adding 15 cc. of ammonium hydroxide. When an appreciable amount of fat had escaped saponification the mixture became turbid.

The fatty acids were stored in a desiccator over night. The solid substance was carefully melted in an air bath, and enough poured into a test tube 16 cm. long and 3.5 cm. wide, to fill the tube more than half full. This was fastened by means of a cork into a wide-mouthed bottle, 10 cm. wide and 13 cm. high, and a thermometer indicating tenths of a degree inserted in the fatty acids so that the bulb reached the center of the mass. When a few crystals appeared at the bottom of the tube the mass was stirred with the thermometer without allowing it to touch the sides of the vessel, but taking care that all solidified portions were well stirred into the mass. The mass gradually became cloudy throughout. Under the conditions of this test the temperature slowly fell, but suddenly began to rise until it reached a maximum, where it remained for some time before falling again. This maximum temperature is known as the titer or solidifying point.

Iodin Value, Wij's*** (modification Huebl's process).—Wij's iodine solution was prepared by dissolving approximately 13 grams of iodine in a liter of glacial acetic acid and the exact amount of iodine determined by titration with standard sodium thiosulphate. Washed, dry chlorine gas was then passed through the solution until the titration value of the original iodine solution was doubled. About one-fourth gram of the fat, accurately weighed on an aluminum boat, was transferred to a glass-stoppered bottle with 10 cc. carbon tetrachloride, 50 cc. Wij's iodine solution added, and the tightly stoppered bottle placed in a dark place for exactly one hour. Ten cc. of a 10% potassium iodide solution were added and the unabsorbed iodine titrated with

*U. S. Bureau of Chemistry, Bulletin No. 107 (revised), p. 129.

**Lewkowitsch, Chem. Tech. and Anal. Oils, Fats and Waxes, Vol. I, p. 178. (Third Edition, 1904.)

***Lewkowitsch, Chem. Tech. and Anal. Oils, Fats and Waxes, Vol. I, p. 250. (1904 Edition.)

standard sodium thiosulphate, using starch solution as indicator. The total iodine added was determined similarly in a blank test; the difference between the two amounts is the quantity of iodine absorbed. The iodine value was calculated from these figures.

Index of Refraction was determined at 40° C. by means of an Abbe refractometer.

Melting Point.—The Wiley method was used.

All other determinations were made by the official methods of the Association of Official Agricultural Chemists, as published in Bulletin No. 107 (Rev.), U. S. Bureau of Chemistry, and the Journal of the Association of Official Agricultural Chemists.

TABLE III
Constants of Kafir, Feterita and Milo Fat

	Kafir	Feterita	Milo	
			Liquid rat	Sediment Fat
Specific gravity	0.9398	0.926	0.9275	*
Melting point (Wiley)	42.70	44.70	42.90	55.45
Titer test	34.45	30.60	29.75	*
Iodin value	108.40	111.04	112.95	111.15
Soluble acids, as butyric	0.66	0.56	0.53	2.14
Insoluble acids	93.22	95.10	91.63	94.24
Saponification value	193.58	187.30	189.51	191.61
Reichert-Meissl number	4.35	3.00	1.30	*
Liquid acids	86.02	81.10	80.10	*
Solid acids	7.92	14.82	10.08	*
Free fatty acids, as oleic	27.01	6.47	7.72	*
Acetyl value	42.23	6.10	20.46	*
Maumene number	68.10	*	*	*
Unsaponifiable residue	1.71	.835	0.05	*
Refractive index at 40° C.	1.4669	1.4651	1.4675	1.4669
Non-volatile acids	93.78	93.91	89.39	*
Total volatile acids	0.85	0.82	0.59	*

*Sufficient quantity not available for the determinations.

The similarity of the fats from kafir, feterita and mило is shown in their physical and chemical constants, as is evident from above table.

THE FATTY ACIDS

The same acids were found to be present in kafir, feterita and mило fats, therefore a description of the methods used in each case for their separation would be a needless repetition.

Saponification of the Fat

Approximately fifty grams of the fat were accurately weighed into a 750 cc. Erlenmeyer flask, 40 cc. potassium hydroxide solution (specific gravity 1.4), and 40 cc. purified alcohol* added, and the flask heated for eleven hours on the water bath under an air condenser until the fat was saponified, and then without the condenser until

*The alcohol was freed from aldehydes, etc., by treating three liters of 95% alcohol with 1 gram of silver nitrate. After standing two days it was distilled over potassium hydroxide.

nearly free from alcohol, the last traces of alcohol being removed by blowing carbon dioxide-free air into the flask.

Separating the Volatile from the Non-Volatile Fatty Acids

The saponified material was dissolved in 450 cc. of (recently boiled) distilled water, the flask fitted to a condenser, a few pieces of recently heated pumice stone and 100 cc. of 20% sulphuric acid added and the mixture heated over a low flame until the non-volatile acids had completely fused. The heat was gradually increased until the rate of distillation was 100 cc. per hour. Boiling, distilled carbon-dioxide-free water was added to the flask when necessary. The distillate containing the volatile acids was filtered through an extraction thimble into a receiving flask. Very few solid particles came over. The still and the extraction cone were washed with hot water and the washings added to the non-volatile acids remaining in the flask. An excess of barium hydroxide was added to the distillate, concentrated to below 100 cc., transferred to a 300 cc. side-neck distillation flask, and the volume made up to 120 cc. One cc. of concentrated sulphuric acid was added and 110 cc. distilled, regulating the flame so that 100 cc. distilled in forty-five minutes. Treatment of the residue (residue A) is explained below.

The volatile fatty acids were then estimated in the distillate by the Duclaux* method as follows: The 110 cc. distillate, containing 0.1037% acid, calculated as butyric acid, was placed in a 300 cc. side-neck distillation flask and 100 cc. distilled in 45 minutes, collecting the distillate in 10 cc. portions and titrating each portion with N-100 barium hydroxide, using phenolphthalein as indicator. The amount of acid remaining in the 10 cc. residue (residue B) was also determined by titration.

(A) Acidity of 10 cc. Distillates from Kafir Fat (Duclaux Method)

Fraction	1	2	3	4	5	6	7	8	9	10
cc. N-100 Ba (OH) ₂ required	10.35	8.80	7.40	6.65	6.65	6.50	6.70	7.40	8.80	11.45
Sum	10.35	19.15	26.55	33.20	39.85	46.35	53.05	60.45	69.25	80.70
Actual per- centage of acid distil- ling over into any given 10 cc. fraction	12.82	23.72	32.89	41.10	49.38	57.43	65.73	74.90	85.81	100.00

A total of 80.7 cc. of N-100 Ba (OH)₂ was required for the 100 cc. of distillate and 35.25 cc. for the 10 cc. residue (B) in the flask. In other words, 69.6% of the acids, as expressed in terms of cubic centimeters of N-100 Ba(OH)₂, were volatile and 30.4% non-volatile under the conditions of the test.

For a duplicate determination the neutralized distillate from above (the 10-10 cc. fractions or distillates), the 10 cc. remaining in the flask from the first determination (residue A) and the 10 cc. residue from the Duclaux determination (residue B) were washed into an

*Recherches Sur Les Vins, Deuxieme Memoire, Sur Les Acides Volatiles Du Vin—Ann. Chem. Phys. (5), II, 289.

evaporating dish, an excess of barium hydroxide added and the solution evaporated to about 50 cc., then acidified with 1 cc. sulphuric acid, diluted to 120 cc., and 110 cc. distilled. The volatile acids in this 110 cc. distillate were determined by the Duclaux method, as described above.

(B) Acidity of 10 cc. Distillates from Kafir Fat (Duclaux Method)

Fraction	1	2	3	4	5	6	7	8	9	10
cc. N-100 Ba (OH) ₂ required	10.40	8.80	7.40	6.85	6.25	6.50	6.90	7.80	9.20	11.95
Sum	10.40	19.20	26.60	33.45	39.70	46.20	53.10	60.90	70.10	82.05
Actual per- centage of acid distil- ling over into any given 10 cc. fraction	12.68	23.40	32.41	40.76	48.39	56.31	64.71	74.22	85.43	100.00

The second distillate checks up with the former one.

A total of 82.05 cc. of N-100 Ba(OH)₂ was required for the 100 cc. of the distillate and 35.5 cc. for the 10 cc. residue. The total quantity of volatile acids obtained in this manner was 69.8% and 30.2% of the acids remained in the residue. The high percent (30.2) of acid in the residue indicates the presence of either formic or acetic acid, or possibly both. If acetic acid alone was present, the residue would contain 20% of the total acid, and 41% of the total acid if formic alone was present.

Formic acid was indicated in kafir, feterita and milo fats by the reducing action of the neutral potassium salts of the volatile acid distillate on silver nitrate and mercuric chloride (calomel test).

The presence or absence of acetic acid in kafir fat was not indicated by the ethyl acetate test, due probably to the small amount of acid that was present in the residue. Propionic acid was not indicated by the lead propionate test in any of the fats.

Butyric acid was identified in kafir, feterita and milo fats by the ethyl butyrate test.

The presence of other higher volatile acids in kafir fat was indicated by the milky appearance of the first two or three cc. of the distillate. This condition disappeared as the volume of the distillate increased.

The above method, devised by Duclaux, is an indirect method and is based upon the behavior of the acids during distillation from dilute aqueous solution. Duclaux states that if three or more acids are present it is difficult to calculate the ratio in which the acids are present from the titration values of the different fractions. In such cases he recommends the partial neutralization of the volatile acids with KOH whereby the higher acids can be distilled off, while the lower acids remain behind as salts. This was not done on account of the small amounts of material available (0.1 gram calculated as butyric in 110 cc.) and therefore the ratio of the volatile acids in kafir fat could not be calculated.

The volatile acids vary from 0.59% to 0.85% of the fats. The foregoing tests prove the presence of formic and butyric acids in the fats of kafir, feterita and milo, and of some of the higher volatile fatty acids in kafir fat.

The Non-Volatile Acids

The non-volatile acids remaining in the Erlenmeyer flask after distilling off the volatile acids were washed with hot water until free from sulfuric acid. This required from six to eight washings. The acids were then filtered through a hot water funnel into a weighed Erlenmeyer flask and dried in a water oven in the presence of anhydrous carbon dioxide and then weighed.

Separating the Saturated from the Unsaturated Fatty Acids

The non-volatile acids were saponified with 600 cc. of half normal alcoholic potash, a slight excess of acetic acid added, and the solution neutralized with alcoholic potash, using phenolphthalein as indicator. The alcohol was removed by boiling in a water bath, the soap dissolved in 300 cc. of hot water and 360 cc. of hot 10% lead acetate solution added, rotating the flask while adding the latter. The precipitated lead soaps were placed in a hot water bath for 10 minutes and then cooled by immersing the flask in ice water, occasionally whirling it to cause the soaps to adhere to the sides of the flask. After cooling, the water and excess lead solution were poured off, the last trace of water being removed by means of pieces of filter paper. Then 700 cc. of anhydrous ether were added, the flask stoppered, and shaken at intervals until the lead salts disintegrated. The contents of the flask were heated under a reflux condenser on a steaming water bath until the insoluble lead salts were deposited on the bottom in the form of a fine powder; this required about 10 minutes heating. The ethereal solution was cooled to 0° C., filtered through a folded filter paper into a separatory funnel and the insoluble precipitate (the lead salts of the saturated acids) washed with ether several times. The filtrate contained the unsaturated acid lead salts.

Melting Point.—The capillary tube method* was used for the acids.

Molecular Weight.—The mean molecular weight was determined by dissolving the fatty acids in redistilled, neutral alcohol and titrating with a tenth-normal solution of potassium hydroxide, using phenolphthalein as an indicator. The weight of the fatty acids, expressed in milligrams, when divided by the number of cubic centimeters of N-10 KOH required and multiplied by ten gives the mean molecular weight. This determination served as a rapid method for obtaining further indications as to the purity and identity of the purified material.

Unsaturated Fatty Acids

The unsaturated fatty acids, obtained as the ether soluble lead salts, were liberated by the addition of hydrochloric acid (1:4) and the ethereal solution washed with water until the washings were free from acid.

The unsaturated fatty acids were separated as oxidation products by treatment with alkaline potassium permanganate at a temperature close to 0° C. (Hazura's Method).**

Thirty grams of the unsaturated acids were neutralized with 36 cc. caustic potash solution (specific gravity 1.27) and the resulting soap dissolved in 2 liters of water. The solution was cooled in a freezing mixture and 2 liters of a 1.5% potassium permanganate solu-

*Gattermann-Schober, *Practical Methods of Organic Chemistry*, p. 68 (1901).

**Leathes, *The Fats*, p. 82.

tion, also cooled to 0° C., added in a fine stream while the soap solution was agitated. The manganese peroxide was filtered off and the dihydroxystearic and sativic acids precipitated from the filtrate by acidifying with 20% sulfuric acid (Precipitate A). The dried precipitate was treated with a small amount of ether to remove any unaltered acids and the residue then treated with 3 liters of ether. After standing for some time the solution was filtered, sativic acid being insoluble in the ether.

The filtrate from precipitate (A) was neutralized with potassium hydroxide concentrated to 200 cc. and then acidified with sulfuric acid to precipitate linusic and isolinusic acids. A brownish liquid acid separated having the characteristic rancid odor of butyric acid. The mixture of acids was composed mainly of butyric and unoxidized liquid acids, and probably some oxidation products which may have been formed from the small amounts of palmitic* and stearic acid present in the unsaturated acids. Molecular weight determinations were not constant, indicating that a mixture was present. The mean molecular weight determined as above was about 198. No indications of linusic and isolinusic acid were observed in kafir, feterita and milo fats.

The acid recovered from the ethereal extraction was recrystallized repeatedly with alcohol until, in case of the kafir fat, it gave a constant melting point of 131.3° C. and 132° C.; this compares to 131.5°-132° C. for the melting point of the dihydroxystearic acid obtained by Le Sueur.** A molecular weight of 316, determined by titrating with N-10 KOH, also indicates dihydroxystearic acid as tabulated below:

Dihydroxystearic Acid, $C_{18}H_{36}O_4$ in Kafir Fat

Weight Mgs.	cc. N-10 Alkali	Molecular Weight
131.5	4.16	316.1
156.7	4.95	316.6

The portion insoluble in ether was repeatedly extracted with hot water. On cooling the water extract a precipitate of fine, needle-like crystals formed. This was recrystallized until a constant melting point of 171-172° C. was observed. This agrees very closely to the melting point (173° C.), reported by Hazura*** for sativic acid. The theoretical molecular weight of sativic acid is 348, for the formula $C_{18}H_{36}O_6$. The molecular weight determinations are shown in the following table:

Sativic Acid, $C_{18}H_{36}O_6$ in Kafir Fat

Weight Mgs.	cc. N-10 Alkali	Molecular Weight
171.2	4.88	350.8
294.3	8.40	350.4
512.9	14.69	349.1
499.7	14.29	349.7

*Lewkowitsch, Chem. Tech. and Anal., Oils, Fats and Waxes, Vol. I. p. 93.

**Lewkowitsch, Chem. Tech., Oils, Fats and Waxes, Vol. I, p. 124.

***Lewkowitsch, Chem. Tech., Oils, Fats and Waxes, Vol. I, p. 126.

The constant melting point and the constant mean molecular weight, calculated from the neutralization value (titration with N-10 KOH) of this recrystallized substance, gave evidences that the substance was a definite, pure compound (sativic acid). The substance was burned in a combustion furnace to determine the percentage of carbon, hydrogen and oxygen. The empirical formula was calculated from the data obtained.

The percentage composition of the substance was found to be C=62.23, H=10.30, O=27.47.

Percentage Composition Found	Percentage Composition Calculated
(a) 0.2665 g. gave 0.6077 g. CO ₂ C=62.18 " gave 0.2412 g. H ₂ O H=10.13 O=27.69	C=62.03 H=10.42 O=27.55
(b) 0.4195 g. gave 0.9574 g. CO ₂ C=62.23 " gave 0.3863 g. H ₂ O H=10.30 O=27.47	

From the percentage composition the empirical formula was calculated as follows: Since an atom of carbon weighs 11.9097 times as much as an atom of hydrogen, and oxygen 15.873 times more than an atom of hydrogen, the ratio between the number of carbon atoms, the number of hydrogen atoms and the number of oxygen atoms is:

$$\frac{62.23}{12.005} : \frac{10.30}{1.008} : \frac{27.47}{16}$$

The formula C₁₈H₃₆O₆ is obtained from the above ratios by dividing the percentage of each element by its atomic weight, as shown in the following table:

Calculation of the Formula for Sativic Acid from the Analysis:

$$\begin{aligned} \text{C} \quad & \frac{62.23}{12.005} = 5.18 = 3.01 \text{ or } 3 \times 6 = \text{C}_{18} \\ \text{H} \quad & \frac{10.30}{1.008} = 10.22 = 5.94 \text{ or } 6 \times 6 = \text{H}_{36} \\ \text{O} \quad & \frac{27.47}{16} = 1.72 = 1.00 \text{ or } 1 \times 6 = \text{O}_6 \end{aligned}$$

TABLE IV

Oxyacid Derivatives of the Unsaturated Acids

Fat Obtained From	Dihydroxystearic Acid	Sativic Acid
Kafir—		
Melting point	131-132° C.	171-172° C.
Molecular weight found	317	350 and 348
Theoretical molecular weight	316	348
Feterita—		
Melting point	131.2° C.	170.8° C.
Molecular weight found	316.73	349.05
Theoretical molecular weight	316	348
Milo—		
Melting point	131.4° C.	172.0° C.
Molecular weight found	319.43	349.93
Theoretical molecular weight	316	348

The unsaturated acids are present in these fats in amounts varying from 80% to 86%. As dihydroxystearic and sativic acids are oxidation products of oleic and linoleic acids, these unsaturated (liquid) acids are present in the fats from kafir, feterita and milo.

Saturated Fatty Acids

The lead salts of the saturated fatty acids were transferred with the filter paper to an Erlenmeyer flask, the saturated acids liberated with hydrochloric acid (1:4) and the hydrochloric acid removed by repeated washings in a separatory funnel. The saturated acids were separated by the fractional precipitation method of Heintz.* Ten grams of saturated acids were dissolved in 1½ liters of alcohol which was sufficient to keep the acids in solution when cooled to 0° C. The alcoholic solution was heated to the boiling point, 20 cc. alcoholic magnesium acetate (18.835 grams magnesium acetate made up to 500 cc. with purified alcohol) added, cooled for several hours to 0° C. and then filtered. Ten precipitations were made in all, enough ammonia was added to the filtrate after each precipitation to neutralize the liberated acetic acid, and 20 cc. of the magnesium acetate solution added each time. Each magnesium salt precipitate was washed with alcohol, the acids liberated with hydrochloric acid (1:4), freed of chlorides by repeated washings with water, and dried. Melting point and mean molecular weight determinations were made on the liberated acid of the various precipitates. The precipitates from kafir fat showed a series of melting points varying from 53° to 79° C., and molecular weight determinations from 256 to 379, showing that the precipitates probably were mixtures of palmitic, stearic and some of the higher acids.

The precipitates having similar molecular weight and melting points were combined and recrystallized until the melting points were constant. The fatty acids or precipitates No. 3 and 4 thus combined from kafir fat had a melting point and molecular weight which indicated palmitic acid. These determinations, with an analysis by combustion, are given in the following table:

*W. Heintz, Ueber die Fette Journ. Prakt. Chemie, 1855, (66), 1-51.

Elementary Composition of Palmitic Acid With Those of the Precipitates from Kafir Fat Compared

Substance	Melting Point	Molecular Weight	Analysis		
			C	H	O
Palmitic acid C ₁₆ H ₃₂ O ₂	62.6	256	74.92	12.58	12.48
Precipitate No. 3 and 4	61.8	257	74.94	12.60	12.40

Empirical formula calculated from analysis of precipitates Nos. 3 and 4 for palmitic acid:

$$C = \frac{74.94}{12.005} = 6.24 = 8 \times 2 = C_{16}$$

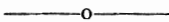
$$H = \frac{12.60}{1.008} = 12.55 = 16 \times 2 = H_{32}$$

$$O = \frac{12.40}{16} = 7.75 = 1 \times 2 = O_2$$

TABLE V
Saturated Acids

Substances	PRECIPITATES						
	I	II	III	IV	V	VI	VII
Kafir (fat)							
Melting point	56.0° C.	79.0° C.	61.8° C.	57.0° C.	76.0° C.	65.0° C.	56.0° C.
Mean molecular wt.	274.01	379.55 372.56	256.80	276.50	314.69 317.50	297.51	264.30
Milo (fat)							
Melting point	53.1° C.	57.2° C.	57.5° C.	58.3° C.	60.65° C.	59.8° C.	59.1° C.
Mean molecular wt.	289.57	268.28	266.09	267.25	266.27	271.34	262.85
Feterita (fat)							
Melting point	55.05° C.	56.50° C.	57.50° C.	57.55° C.			
Mean molecular wt.	277.02	282.39	273.04	280.73			
Palmitic Acid—							
Melting point	62.6° C.						
Mean molecular wt.	256.00						
Stearic Acid							
Melting point	69.00° C.						
Mean molecular wt.	284.00						

The saturated acids vary from 7% to 10% in these fats. The saturated (solid) acids of kafir, feterita and milo fat are a mixture of palmitic and stearic acid. Traces of higher saturated acids are present in kafir and milo fat. Stearic acid predominates in kafir and feterita fat and palmitic acid in milo fat.



SUMMARY

Six fatty acids have been shown to be present in kafir, feterita and milo fat—namely oleic and linoleic, stearic and palmitic, butyric and formic, predominating in the order given. Traces of saturated acids higher than stearic acid are present in kafir and milo fat. The above data shows that the physical and chemical constants of the fats and fatty acids of kafir, feterita and milo are similar.

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