depot fat contained considerable amounts of *trans*, little or none was found in the placental fat from the same individual (Table II). *Trans* fatty acids were also found to be absent in fetal and newborn baby tissues.

TABLE II

Percentage of *Trans* Fatty Acids in Six Samples of Placental and Maternal Fat from Same Individual (20)

Placental fat % *trans*	Maternal depot fat % *trans*
0	6.4
<0.5	6.8
0	6.1
0	1.5
<0.5	1.8
0	5.2

Summary

Extensive positional and geometrical isomerization occurs during the catalytic hydrogenation of edible oils and fats. The extent of this isomerization can be controlled by varying the conditions of hydrogenation.

Studies on the nutritional and metabolic aspects of the geometric isomers formed during the hydrogenation of edible fats indicate that the animal organism appears to be capable of metabolizing *trans* isomers. However there is some evidence to indicate that the deposition of *trans* fatty acids in animal tissues may worsen a pre-existing essential fatty acid deficiency. The possible effects of *trans* fatty acids on other metabolites remains unclear.

REFERENCES

1. Moore, C. W., J. Soc. Chem. Ind., *38*, 320 (1919).
2. Hilditch, T. P., and Vidyarthi, N. L., Proc. Roy. Soc. London, *A122*, 552, 563 (1929).
3. Sinclair, H. M., Lancet, *270*, 381 (1956).
4. Boelhouwer, C., Gerckens, J., Ong Tian Lie, and Waterman, H. I., J. Am. Oil Chemists' Soc., *30*, 59 (1953).
5. Allen, R. R., and Kiess, A. A., J. Am. Oil Chemists' Soc., *32*, 400 (1955).
6. Knegtel, J. T., Boelhouwer, C., Tels, M., and Waterman, H. I., J. Am. Oil Chemists' Soc., *34*, 336 (1957).
7. Allen, R. R., and Kiess, A. A., J. Am. Oil Chemists' Soc., *33*, 355 (1956).
8. Cousins, E. R., Guice, Wilma A., and Feuge, R. O., J. Am. Oil Chemists' Soc., *36*, 24 (1959).
9. Chahine, M. H., Cousins, E. R., and Feuge, R. O., J. Am. Oil Chemists' Soc., *35*, 396 (1958).
10. Allen, R. R., J. Am. Oil Chemists' Soc., *33*, 301 (1956).
11. Sinclair, R. G., J. Biol. Chem., *115*, 211 (1936); *ibid. 118*, 123 (1937); *ibid.*, *111*, 515 (1935).
12. Holman, R. T., and Aaes-Jorgensen, E., Proc. Soc. Exp. Biol. Med., *93*, 175 (1956).
13. Privett, O. S., Pusch, F. J., and Holman, R. T., Arch. Biochem, and Biophys., *57*, 156 (1955).
14. Alfin-Slater, Roslyn B., Wells, A. F., Aftergood, L., and Deuel, H. J. Jr., J. Nutrition, *63*, 241 (1957).
15. Johnston,, Patricia V., Johnson, O. C., and Kummerow, F. A., J. Nutrition, *65*, 13 (1958).
16. Allen, R. R., Kiess, A. A., Johnston, Patricia V., and Kummerow, F. A., J. Am. Oil Chemists' Soc., *35*, 203 (1958).
17. Hartman, L., J. Am. Oil Chemists' Soc., *34*, 129 (1957).
18. Johnston, Patricia V., Johnson, O. C., and Kummerow, F. A., Proc. Soc. Exp. Biol. and Med., *96*, 760 (1957).
19. Johnston, Patricia V., Johnson, O. C., and Kummerow, F. A., Science, *126*, 698 (1957).
20. Johnston, Patricia V., Walton, C. H., and Kummerow, F. A., Proc. Soc. Exp. Biol. and Med., *99*, 735 (1958).

[Received June 18, 1959]

Calculation of the Distribution of the Saturated and Unsaturated Acyl Groups in Fats, from Pancreatic Lipase Hydrolysis Data[1]

R. J. VANDER WAL, Armour and Company, Chicago, Illinois

THE RESULTS of a series of analyses of natural fats by means of the pancreatic lipase hydrolysis technique of Mattson and Beck (1) were published recently by Mattson and Lutton (2). By the Mattson and Beck procedure, fatty acyl groups in the 1- and 3-positions of triglyceride molecules may be preferentially and nonspecifically removed with little displacement of those in the 2-position.

The data include a) the percentage of saturated acyl groups among the acyl groups in the whole fat and b) the percentage of saturated acyl groups among the acyl groups in the 2-monoglycerides which would be produced if all groups in the 1- and 3-positions were removed by hydrolysis. From these data and on the basis of two simple and plausible assumptions, the proportions in some of the fats of the four triglyceride types, GS_3, GS_2U, GSU_2, and GU_3, and those of the symmetrical and unsymmetrical isomers which comprise the GS_2U and the GSU_2 molecules were calculated in a manner to be described.

The two assumptions are: a) that whatever proportions of saturated acyl groups (S) and unsaturated acyl groups (U) are dispersed among the 1-positions, the 2-positions, and the 3-positions, respectively, of the triglycerides, they are distributed therein at random;[2] and b) that the 1- and 3-positions are occupied by identical proportions of S and U.[3]

The method of calculation is as follows:[4]

a = % S among the acyl groups in the whole sample as found by analysis
b = % S in the acyl groups in the 2-positions. It is equal to the % S among the acyl groups in the 2-monoglycerides, found by analysis
c = % of the total S in the sample present therein as S2 = $\frac{(b)\,(100)}{3a}$ (See Table II, Mattson and Lutton)
d = % of the total S in the sample present therein as S1,3 = 100 − c

---

[1] Presented in part at the 50th Annual Spring Meeting, American Oil Chemists' Society, New Orleans, La., April, 1959.

[2] The individual acyl groups constituting the S and U are not under consideration except as members of the two classes.

[3] In correspondence with the author in 1957 A. S. Richardson suggested the possibility that there may be a random distribution involving the 1- and 3-positions but not the 2-position in fats. Speaking of plant triglycerides, he emphasized these predictions: "Even distribution, to the extent that it really occurs, will some day be found to be in large measure the result of preferential attachment of unsaturated acid at the 2-position of the glyceryl residue. Chance distribution, to the extent that it really prevails, will be found to be confined mainly to the 1- and 3-positions." One suggested possibility was that the first step in the triglyceride synthesis is selective esterification at the 2-position. Random distribution, he said, if it thereafter occurred, would be calculated by analogy with esterification of glycol, not glycerol. In that case the pattern of distribution outlined in the present paper would result, but the bare assumption of random distribution involving only the 1- and 3-positions would not necessarily lead to this pattern.

[4] The following symbols will be used in the calculations:

S = Saturated acyl groups in general.
U = Unsaturated acyl groups in general.
S2 = Saturated acyl groups in the 2-positions.
S1,3 = Saturated acyl groups in the 1-positions and those in the 3-positions. Positions 1 and 3 are considered identical.
U1,3 = Unsaturated acyl groups in the 1-positions, also those in the 3-positions. Positions 1 and 3 are considered identical.

e = % of the total acyl groups in the sample present therein as $S1,3 = \frac{(d)\,(a)}{100}$

f = % of the total acyl groups in positions 1 and 3, present therein as $S1,3 = 1.5\,e$

g = % of the total acyl groups in positions 1 and 3, present therein as $U1,3 = 100 - f$

h = % of the sample containing saturated acyl groups in both 1- and 3-positions $= \frac{f^2}{100}$

i = % of the sample containing unsaturated acyl groups in both 1- and 3-positions $= \frac{g^2}{100}$

j = % of the sample containing one saturated and one unsaturated group in the 1- and 3-positions, respectively, plus that containing one unsaturated and one saturated acyl group in the 1- and 3-positions, respectively, $= 100 - (h + i)$.

The values for h, i, and j represent the proportions of S–S, U–U, and U–S, respectively. (U–S and S–U are here represented as U–S since they are identical.) The value representing the percentage of saturated acyl groups among the groups in the 2-positions (b) is now distributed at random among the values representing the percentages of S–S, U–U, and U–S, as follows:

$$k = \%\ SSS = \frac{(b)\,(h)}{100}$$

$$l = \%\ USU = \frac{(b)\,(i)}{100}$$

$$m = \%\ USS = \frac{(b)\,(j)}{100}$$

In the same way the value representing the percentage of unsaturated acyl groups among the groups in the 2-positions (100-b) is distributed among the values representing the percentages of S–S, U–U, and U–S as follows:

$$n = \%\ SUS = \frac{(100\text{-}b)\,(h)}{100}$$

$$o = \%\ UUU = \frac{(100\text{-}b)\,(i)}{100}$$

$$p = \%\ UUS = \frac{(100\text{-}b)\,(j)}{100}$$

Finally—

$k = \%\ GS_3$
$m + n = \%\ GS_2U$
$l + p = \%\ GSU_2$
$o = \%\ GU_3$

The proportions of the glyceride types and isomers in two hypothetical fats and eight of the fats analyzed by Mattson and Lutton have been determined by this method of calculation. The results of these calculations, the data from which they were derived, and theoretical and experimental data for comparison are presented in Table I.

The proportions of the glyceride types and isomeric forms in a fat in which the saturated and unsaturated acyl groups are distributed at random, such as Hypothetical Fat No. 1, can be calculated from the proportions of S and U therein. The fact that the values calculated for this fat by the present method are identical with the true values shows that the method of calculation gives the correct results when, as in this case, the assumptions apply correctly.

The calculated values for the glyceride types in kokum butter, pig fat, and peanut oil agree closely with those found by other methods in fats containing about the same proportions of S. Those for beef fat are in approximate agreement, but the samples are less similar. The divergences in the values for the glyceride types are as would be expected. The values for the glyceride types in cacao butter do not agree well with the analogous data even though the samples seem closely similar. They are however of the same order of magnitude. The discrepancies may of course be due to analytical error.

Discussion

The close agreement between the values for the glyceride types found in kokum butter, pig fat, and peanut oil by the present method and those found by the dissimilar methods of Hilditch and Murti (4) and Kartha (3, 5) constitutes good evidence that all

TABLE I

Triglyceride Types and Isomeric Forms in Some Hypothetical and Natural Fats

Fat		Composition: Types (% wt.)				Composition: Isomers (% wt.)			
		GS_3	GS_2U	GSU_2	GU_3	SUS	SSU	USU	UUS
Hypothetical, No. 1 a = 50: b = 50 Distribution, random	Calc., present method	12.5	37.5	37.5	12.5	12.5	25.0	12.5	25.0
	Calc., random distribution	12.5	37.5	37.5	12.5	12.5	25.0	12.5	25.0
Hypothetical, No. 2 a = 50; b = 0 Positional distribution random	Calc., present method	0	56.25	37.5	6.25	56.25	0	0	37.5
	Calc., restricted random dist'n	0	58.4	33.3	8.3	19.5	39.0	11.1	22.2
Kokum butter (2) a = 59.3; b = 3.7	Calc., present method	2.8	73.9	21.6	1.6	73.1	0.8	0	21.6
	Found, (58.9% S in sample) (4)	1.5	76.1	20.8	1.6	......	......	......	......
	Calc., restricted random dist'n (58.9% S in sample)	2[a]	75.4[a]	20.6[a]	2[a]	25.1	50.3	6.9	13.7
Pig fat (2) a = 36.0; b = 70.7	Calc., present method	2.5	22.4	55.7	19.4	1.0	21.4	46.9	8.8
	Found, (37.8% S in sample) (5)	2.9[a]	25.3[a]	53.3[a]	18.5[a]	......	......	......	......
Peanut oil (2) a = 20.9; b = 1.4	Calc., present method	0.1	9.9	42.5	47.5	9.3	0.6	0.7	41.8
	Found, (19.5% S in sample) (3)	0[a]	9[a]	42[a]	49[a]	......	......	......	......
	Calc., random dist'n, (20% S in sample)	0.8	9.6	38.4	51.2	3.2	6.4	12.8	25.6
Beef fat (2) a = 53.5; b = 29.2	Calc., present method	12.6	43.7	35.3	8.4	30.6	13.1	3.4	31.9
	Found, (59.4% S in sample) (5)	18.2[a]	46.6[a]	30.3[a]	4.9[a]	......	......	......	......
Cocoa butter (2) a = 59.9; b = 9.8	Calc., present method	7.1	67.5	23.3	2.1	65.0	2.5	0.2	23.1
	Found, (59.8% S in sample) (6)	2[a]	77[a]	21[a]	......	......	......	......	......
Pig fat, safflower oil diet (2) a = 22.3; b = 44.0	Calc., present method	0.6	9.6	45.8	44.0	0.7	8.9	34.5	11.3
	Calc., random distribution	1.1	11.6	40.4	46.9	3.9	7.8	13.5	27.0
Rat fat, fat-free diet (2) a = 14.8; b = 17.2	Calc., present method	0.3	5.7	32.3	61.7	1.6	4.1	12.8	19.5
	Calc., random distribution	0.3	5.6	32.2	61.8	1.9	3.7	10.7	21.5
Soybean oil (2) a = 12.8; b = 0.0	Calc., present method	0	3.7	31.0	65.3	3.7	0	0	31.0
	Calc., random distribution	0.2	4.3	29.2	66.3	1.4	2.9	9.7	19.5

[a] % Mol. In these fats the differences between % mol and % wt. are negligible.

three methods gave the correct values. These fats have widely divergent physical characteristics, and one is an animal fat and two are vegetable fats. It is therefore not unlikely that the method can be successfully applied to all natural fats such as these, in which C_{16}–C_{18} acyl groups are in great excess. Whether it can be applied to others of greater or lesser chain length remains to be seen.

There is presently no way of testing the accuracy of the values for the isomeric forms. It is worthy of note however that the values for the glyceride types are the values, or the sums of values, derived by calculations based on the structures of the molecules. Thus the proportions of GS_2U are the sum of the proportions of SUS and SSU, the isomeric forms. If the value for GS_2U is correct, it is likely that the values for SUS and SSU from which it is derived are also correct.

Because no saturated acyl groups are present in the 2-positions in Hypothetical Fat No. 2, there can be no GS_3 in it. This fat therefore represents the extreme in "restriction" of GS_3. The values for the glyceride types calculated by the method of Kartha (3) for a fat in "restricted random" distribution with respect to the S and U are approximately, but not exactly, the same as those calculated by the present method. The values for the isomeric forms are grossly different; those calculated by the present method are obviously correct if it be assumed that those for the glyceride types are correct.

When a method of calculation gives correct results, the assumptions upon which it is based are presumably also correct. Therefore, in those fats to which the present method can be successfully applied, the saturated and unsaturated acyl groups in each of the three positions, no matter what their proportions, may very well be distributed therein at random. It is also quite possible that the proportions of S and U in the 1- and 3-positions are identical. If these characteristics were to prove common to natural fats generally, regardless of their origin, it would indicate a common synthetic pathway to the triglycerides. The present results suggest a mode of triglyceride synthesis common to both the animal and vegetable C_{16}–C_{18} fats.

The fat from the rat fed a fat-free diet is probably endogenous. The distribution of the saturated and unsaturated acyl groups therein is the most nearly random of all the fats investigated. Deviations from random distribution are largest in the proportions of the isomers, and the differences in these values are very small. It is of interest to note that the proportion of S in the 2-monoglycerides is slightly greater than that in the whole fat, which makes it resemble, in this respect, the distinctive pig fats more closely than the vegetable and other animal fats.

The calculated and observed values for the triglyceride types in kokum butter agree very well with those calculated for restricted random distribution. The calculated values for the isomeric forms are however greatly different. A similar relationship in cacao butter was pointed out recently by Vander Wal (7).

Summary

Evidence has been presented that the proportions of the glyceride types and isomeric forms in some fats in which C_{16}–C_{18} chains are greatly in excess can be determined by calculations based on a) the percentage of saturated acyl groups in the whole fat, b) the percentage of saturated groups in the 2-monoglycerides which can be derived from the fats by hydrolysis, c) the assumption that all the saturated and unsaturated acyl groups (S and U) present in each of the three positions in the molecules are dispersed therein at random, and d) the assumption that the proportions of S and U in the 1-positions are identical with those in the 3-positions. The method may apply to all predominantly C_{16}–C_{18} fats and to other fats as well.

REFERENCES

1. Mattson, F. H., and Beck, L. W., J. Biol. Chem., *219*, 735 (1956).
2. Mattson, F. H., and Lutton, E. S., J. Biol. Chem., *233*, 868 (1958).
3. Kartha, A. R. S., doctoral thesis, University of Madras, July 1949; J. Am. Oil Chemists' Soc., *30*, 326 (1953).
4. Hilditch, T. P., and Murti, K. S., J. Soc. Chem. Ind. (London), *60*, 16T (1941).
5. Luddy, F. E., Morris, S. G., Magidman, P., and Riemenschneider, R. W., J. Am. Oil Chemists' Soc., *32*, 522 (1955).
6. Hilditch, T. P., and Stainsby, W. J., J. Soc. Chem. Ind. (London), *55*, 95 T (1936).
7. Vander Wal, R. J., J. Am. Oil Chemists' Soc., *35*, 483 (1958).

[Received May 27, 1959]

Some Factors in the Measurement of the Suspending Power of Aqueous Detergent/Fabric Systems

A. S. WEATHERBURN [1] and C. H. BAYLEY, Textile Research Section, National Research Council, Ottawa, Canada

THE LABORATORY-SCALE measurement of detergency for the purpose of assessing the efficiency of detergent products or processes, used in aqueous systems for removing soil from textile fibers, has long remained an incompletely solved problem, and in spite of the large amount of work that has been devoted to the problem, no completely satisfactory test method has yet been evolved. Not only do variations in test conditions or types of soil give variations in data that may lead to entirely contradictory results, but even when the same test is carried out by different laboratories under supposedly identical conditions, surprisingly variable results have been obtained.

It is generally recognized that the "suspending power," *i.e.*, the ability of a solution of detergent to prevent the redeposition of suspended soil onto a washed fabric, is a major factor contributing to the over-all efficiency of a detergent. Laboratory measurements of suspending power have been of two general types: a) a piece of white fabric is washed along with soiled fabric in a solution of the detergent under test, or b) a piece of white fabric is

---

[1] Deceased.