The Nutritive Properties of Monoglycerides

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The fat of natural food in practically all cases occurs as triglycerides (5). Synthetic mono- and diglycerides were first prepared by Berthelot (2) in 1854 by heating fatty acids with an excess of glycerin at 200° C. Other methods for the preparation of mono- and diglycerides are described by Grün (3).

The work presented here was designed to study the comparative utilization and metabolism of synthetic and natural glycerides by the rat. Under the conditions of the experiment, mono- and triglycerides were found to be utilized in a similar manner and to have approximately equal value in the nutrition of the rat.

Usually the chemical composition of the food fat is reflected in the chemical composition of the fat stored in the animal body. However, when the food fat is insufficient, the animal converts carbohydrate material into fat and this fat is different in character from the ordinary fat occurring in feeds in that it contains a higher percentage of solid acids.

The rate of glyceride digestion *in vitro* was studied by Balls (1) who found that mono- and diglycerides were digested more rapidly than triglycerides by pancreatic lipase. Rosenthal and Trautwein (10) studied glyceride absorption with pancreas-extirpated dogs. They reported that monoglycerides were utilized much better than triglycerides. They suggested this might be due to the ease with which monoglycerides form emulsions or to their greater solubility in water.

Experimental

Monostearin and monolinolein were secured * and incorporated in a purified diet for rats. The *a* monostearin used had a melting point of 81° C. and a mixed melting point with known *a* monostearin of 81°-81.5° C. The sample of monolinolein was not pure, but contained about 20 per cent of monoolein. Neither sample contained diglycerides. A ration containing lard was used as a control. The composition of the rations is given in Table I. The rations containing the three types of glycerides were fed to groups of albino rats. Two male and two female rats constituted a group. The feeding of the rations extended over a period of eight weeks during which time the animals were confined to individual cages. Growth and feed consumption were measured at weekly intervals. It was the plan to feed rations having equivalent percentages of fatty acids in all cases. This entailed the incorporation of 24 per cent of monoglycerides in the ration, which was not well tolerated by the animals. Therefore, at the end of four weeks feeding the amount of monoglycerides was reduced to eight per cent. At the end of the feeding trial the animals were killed and their gastrointestinal tracts removed. Care was exercised not to lose any of the abdominal and organ fat. The remaining carcasses were frozen and ground in a food chopper, after which they were extracted three times with redistilled acetone, followed by extraction with peroxide-free ether. The combined extracts were concentrated in vacuo and reextracted with ether. The ether solution was washed and made up to volume. The extracted fat was of a reddish color. This color was removed by treating the fat with an aluminum silicate adsorbent (13). This absorbent has been shown to remove most of the phospholipids in the fat without affecting the neutral glycerides. The fats, after partial separation into solid and liquid fractions by the Twitchell lead salt method, as modified by Hilditch (4), were esterified with methyl alcohol and the methyl esters distilled and fractionated with a 36 inch rectifying column of the Podbielniak type packed with glass helices.

TABLE I

Percentage Composition of Rations

Constituent	Lard Control No. 1	Monostearin		Monolinolein	
		No. 2	No. 2A	No. 3	No. 3A
Casein [1]	20.0	20.0	20.0	20.0	20.0
Sucrose	62.2	46.2	62.2	46.2	62.2
Salts [2]	4.8	4.8	4.8	4.8	4.8
Cod Liver Oil	1.0	1.0	1.0	1.0	1.0
Dried Yeast	4.0	4.0	4.0	4.0	4.0
Lard	8.0	.....	.....	.....	.....
Monostearin	.....	24.0	8.0	.....	.....
Monolinolein	.....	.....	.....	24.0	8.0

[1] Extracted with alcohol and ether.
[2] Osborne and Mendel. J. Biol. Chem. *37*, 572, 1919.

* These materials were furnished by Dr. A. W. Ralston, Research Division, Armour and Company, Chicago, Illinois.

Results

The results of the feeding trial are given in Table II. During the first four weeks' feeding period when equivalent amounts of fatty acids were fed in the diet the growth produced on the monoglyceride diets was markedly slower than on the lard diet. The mechanical state of the rations containing the synthetic fats was thought to be responsible. These rations were very oily and produced large fatty excreta. Accordingly the amount of monoglycerides was reduced from 24 to eight per cent. This change brought about an immediate increase in food consumption, and growth during the second four weeks' feeding period was satisfactory and approximately equal on all of the rations. Growth over the entire eight weeks' period was slower on the ration containing monostearin than on the lard or monolinolein ration.

TABLE II

Growth of Rats on Natural and Synthetic Glycerides

Ration	Average Total Gain			Food Required Per Gram of Gain		
	1st Period 4 wks.	2nd Period 4 wks.	8 wks.	1st Period	2nd Period	8 wks. Period
	grams	*grams*	*grams*	*grams*	*grams*	*grams*
Lard	28.80	18.60	23.14	2.39	5.58	4.12
Monostearin	14.34	19.02	16.70	3.17	5.33	4.85
Monolinolein	14.88	22.40	19.60	3.04	4.20	3.63

The experiments demonstrate that synthetic monoglycerides are utilized practically as well for the growth of rats as natural triglycerides, when fed at a level of eight per cent.

Table III describes the general characteristics of the body fat of the rats fed the natural and synthetic

glycerides. Table IV contains the fractionation data and Table V the distribution of fatty acids in the body fats calculated from the fractionation data. Reference to Table III will show that the monoglycerides were being utilized and their acids deposited in the body. The iodine numbers and percentages of solid and liquid esters show that the ration containing monostearin produced body fat that was less unsaturated, and the one containing monolinolein produced depot fat that was more unsaturated than the fat from animals consuming the lard ration. This in itself would constitute evidence that the monoglycerides were being utilized to good advantage by the experimental animals. The percentage of fat in the animals was higher in the group fed the lard ration, perhaps because a smaller amount of fatty acids was directly available for storage in the case of the groups fed the monoglycerides. The saponification values, which were similar, indicate that the monoglycerides were stored in the body as triglycerides.

TABLE III

Characteristics of Body Fat of Rats Fed Natural and Synthetic Glycerides

Kind of Fat in Ration	Iodine Number	Saponification Equiv.	Fatty Acids		Fat in Rat Bodies
			Solid	Liquid	
			per cent	*per cent*	*per cent*
Lard	70.6	289	23.5	76.5	18.7
Monostearin	61.7	286	25.5	74.5	14.3
Monolinolein	97.1	291	17.3	82.7	13.8

TABLE IV

Fractionation Data on Body Fat of Rats Fed Synthetic and Natural Glycerides

Fraction	Solid Esters			Liquid Esters		
	Weight of Fraction gms.	Saponification Equivalent	Iodine Number	Weight of Fraction gms.	Saponification Equivalent	Iodine Number
Lard Ration						
1	1.22	259.5	0.6	0.85	254.7	47.3
2	2.17	268.9	0.5	1.07	262.3	61.7
3	4.12	269.5	0.3	2.49	270.0	62.3
4	4.95	272.1	0.5	3.30	280.0	76.3
5	4.79	276.0	0.4	6.35	293.4	99.1
6	3.03	283.0	3.1	14.40	295.5	97.2
7	3.32	310.0	8.5	4.60	299.0	125.5
Monostearin Ration						
1	0.66	257.2	0.8	0.81	242.8	36.9
2	0.89	260.0	0.4	1.04	260.1	64.6
3	3.24	270.7	0.3	4.70	260.5	70.0
4	2.56	270.7	0.3	2.40	276.0	65.4
5	1.56	272.5	0.5	4.04	290.5	85.3
6	3.05	275.3	1.1	10.90	295.2	83.6
7	3.11	307.7	3.6	8.80	298.0	97.4
Monolinolein Ration						
1	0.59	257.4	0.7	1.09	250.4	45.3
2	0.86	268.7	0.8	1.24	263.7	56.7
3	3.40	271.8	0.4	3.06	264.5	58.4
4	2.73	272.9	0.3	3.64	288.6	112.1
5	1.81	273.4	0.6	8.57	294.7	126.9
6	1.83	282.2	3.8	10.15	294.8	124.2
7	2.08	313.0	11.5	8.90	295.3	116.9
				6.77	301.0	146.2

TABLE V

Molar Percentages of Fatty Acids in Body Fat of Rats Fed Synthetic and Natural Glycerides

Acid	Lard Ration	Monostearin Ration	Monolinolein Ration
Myristic	1.5	4.2	2.3
Palmitic	25.2	27.2	18.0
Stearic	3.6	4.3	2.8
Arachidic	1.4	1.5	1.1
Tetradecenoic	1.0	3.9	2.1
Hexadecenoic	5.8	9.0	4.8
Oleic	51.9	49.1	38.4
Linoleic	7.7	0.5	29.4
Arachidonic	1.6	0.3	1.3
Total Saturated Acids	31.7	37.2	24.2
Total C_{14} Acids	2.5	8.1	4.4
Total C_{16} Acids	31.0	36.2	22.8
Total C_{18} Acids	63.2	53.9	70.6
Total C_{20} Acids	3.0	1.8	2.4

Analyses of rat body fat, obtained from animals fed normal rations, have been reported by several workers (6, 7, 8, 12). These workers showed that rat fat contains low proportions of stearic acid and relatively high amounts of palmitic acid. The unsaturated acids were chiefly oleic with some hexadecenoic acids.

In the group fed the ration containing monostearin (Table V) there was little increase in the stearic acid content of the body fat. The increase in saturation of the fat was due to proportionate increase in most all of the other saturated acids found in the fat. This might have been accomplished by the interconversion between stearic, palmitic, and other saturated acids as suggested by Schoenheimer (11) and Rittenberg (9). The fat deposited by the rats on the monostearin ration could possibly have been derived from the carbohydrates in the ration. The percentage of C_{14} acids (especially the C_{14} unsaturated acids), however, is considerably higher than percentages of C_{14} acids reported for rats fed high carbohydrate diets (8). This would indicate appreciable metabolism of stearic acid in order to change it into an acid which can be stored by the rat. The total saturated fat content of 37.2 per cent is nearly the maximum value that can be obtained. Hilditch and Longenecker (6) and Longenecker (7) found that the percentage of saturated acids was rarely more than 35 to 37 per cent.

The fat from the animals fed the ration containing monolinolein was characterized by a high amount of linoleic acid which was apparently derived directly from the monolinolein of the ration. This indicates a high tolerance of linoleic acid by the rat.

Summary

1. Monostearin, monolinolein, and lard as compared in the rations studied were found to be practically equal for the growth of rats.

2. Stearic acid from monostearin was not stored to any appreciable degree in the body fat of rats.

3. Linoleic acid from monolinolein was apparently stored directly in the body fat of rats.

4. Fatty acids fed as monoglycerides appear in the depot fat of rats as triglycerides.

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