Clinical Reports

Effects of the Composition of Dietary Fat upon Composition of Adipose Tissue

D. M. HEGSTED, PH.D.,* C. WHYMAN, M.S.,† A. GOTSIS‡ AND S. A. ANDRUS, M.D.§

THERE is abundant evidence to show that the fatty acid composition of the fat in various tissues, at least in some animals, can be influenced markedly by the composition of the dietary fat. Several reviews[1-3] have summarized the older literature. This area of investigation has received relatively little study in recent years although there has been a great deal of interest in fatty acid metabolism and the effects of dietary fat. Improvements in the alkaline isomerization method[4] for the measurement of polyunsaturated fatty acids and particularly the perfection of gas-liquid chromatography for the separation and measurement of fatty acids[5,6] will undoubtedly stimulate work in this field. Some of the recent studies have shown that the composition of the fat of human milk[7] reflects the composition of the dietary fat to a considerable extent. *Trans* fatty acids of dietary origin are apparently readily deposited in body fat of both man[8] and the rat[9] and polyunsaturated fatty acid content of the diet is reflected in the fat of eggs[10] and in the tissues of pigs, rats, chicks[11-13] and fish.[14]

From the Department of Nutrition, Harvard School of Public Health, Boston, Massachusetts.

* Associate Professor of Nutrition; † Research Assistant; ‡ Senior Research Assistant; § Assistant Professor of Pathology.

This study was supported in part by grants-in-aid from the John A. Hartford Memorial Fund; the Albert and Mary Lasker Foundation, New York; the National Heart Institute (Grant H 2200), Bethesda, Maryland; the Nutrition Foundation, New York; the Fund for Research and Teaching, Department of Nutrition; and the Life Insurance Medical Research Fund, New York.

We have had occasion to analyze the abdominal fat of hens fed diets containing different dietary fats. In spite of the evidence in the literature, we were surprised to find how accurately the fatty acid composition of the adipose tissue reflected the composition of the fat included in the diet. These findings may be of interest in view of the extensive studies now underway in all parts of the world upon the nutritional role of fat and fats of different composition, especially in coronary heart disease and atherosclerosis.

EXPERIMENTAL METHOD

Pullets were obtained from a commercial source when they were between three and four months of age. They were placed in individual cages and six received each of the experimental diets. The basic diet, similar to that used by Fisher et al.,[10] consisted of the following mixture: corn meal, 27.7 pounds; soybean meal (solvent extracted), 30 pounds; Solka-floc (Brown Company, Berlin, New Hampshire), 10 pounds; butyl fermentation solubles, 2 pounds; corn distillers solubles, 2 pounds; dried whey, 2 pounds; alfalfa leaf meal, 3 pounds; dicalcium phosphate, 4 pounds; trace mineral mixture (Limestone Corporation of America, Newton, New Jersey), 3 pounds; salt, 0.5 pound; vitamin B_{12} supplement, 0.5 pound; DL-methionine, 0.2 pound; vitamins A and D (10,000 A–600 D), 0.1 pound; choline chloride, 25 grams. Nine parts of this basal diet and one part of the appropriate oil were mixed to form the various rations fed. The oils used were coconut oil, safflower oil, olive oil, corn oil and

TABLE I

Survival, Production of Eggs, Mean Serum Cholesterol and Vascular Sudanophilia in the Various Groups

Category of Measurement	Group No. and Oil Fed				
	1 (Safflower)	2 (Coconut)	3 (Safflower-Coconut)	4 (Corn)	5 (Olive)
Survival to 15 weeks	6	6	4	6	6
Eggs per hen per week, 15 weeks*	2.79	3.59	4.41	4.13	4.48
Survival to 33 weeks	4	5	2	5	5
Eggs per hen per week, 33 weeks*	1.54	3.15	2.78	2.96	3.20
Mean serum cholesterol, mg. %	137	179	157	117	135
Degree of vascular sudanophilia	0–1+	2–3+	2–3+	2–3+	1–2+

* Calculated on the number of weeks each bird was alive.

an equal mixture of coconut and safflower oil. The birds were weighed at two-week intervals, egg production was recorded and serum cholesterol determination[15] made at intervals during the study. The studies were terminated after thirty-three weeks. The heart and aorta were opened *in situ*, excised and fixed in formalin. Following staining with Sudan IV, an estimation of the extent of gross lipid deposition in the aorta and brachiocephalic arteries was made using a scale of 1 to 4+. A sample of abdominal fat was removed, the methyl esters of the fatty acids prepared[16] for analysis upon the chromatograph (Pye Argon Chromatograph, Jarrell-Ash Company, Newtonville, Massachusetts). The column contained 20 per cent polydiethylene glycol/pentaerythritol adipate as the stationary phase supported upon 100–120 mesh Celite. The area of the principal peaks was calculated as the height multiplied by the width at one-half the height. The area of each peak was recorded as percentage of the total area measured. No attempt was made to measure or, in some cases, identify the minor constituents.

RESULTS

Survival was poor in the group receiving the coconut-safflower oil mixture (Table I). Two died before the fifteenth week and only two of

TABLE II

Comparison of the Fatty Acid Composition of the Dietary Fat and the Adipose Tissue

Fatty Acid	Group 1 (Safflower)		Group 2 (Coconut)		Group 3 (Safflower-Coconut)		Group 4 (Corn Oil)		Group 5 (Olive Oil)	
	Dietary Fat	Adipose Fat	Dietary Fat	Adipose Fat	Dietary Fat	Adipose Fat	Dietary Fat	Adipose Fat	Dietary Fat	Adipose Fat
Capric	...	...	3.7	Trace	2.2	...	...	...	...	...
Lauric	...	Trace	29.9	18.0	15.3	7.8	...	...	...	...
Myristic	...	0.9	21.9	14.7	10.5	6.6	...	0.8	...	0.5
Myristoleic	...	Trace	...	3.2	...	Trace	...	...	...	Trace
Palmitic	11.9	14.4	15.7	17.4	9.6	16.4	15.1	15.4	17.2	16.3
Palmitoleic	...	2.0	...	3.5	...	2.2	...	1.8	2.3	3.0
Stearic	4.6	6.9	4.3	4.2	3.3	6.3	2.4	5.2	4.2	5.4
Oleic	17.6	27.7	18.4	26.9	15.1	25.8	34.0	33.4	63.6	53.8
Linoleic	64.5	45.8	6.1	12.1	43.5	34.6	46.8	41.5	11.0	19.3
Linolenic	1.4	1.9	...	Trace	0.6	Trace	1.7	1.6	1.7	1.3
Unknown	...	1.6	...	...	...	0.6	...	0.5	...	0.4
Unknown	...	...	...	...	...	...	...	1.6	...	1.2

NOTE: All figures shown are percentages.

the original six survived the entire thirty-three weeks. The cause of death was not determined and whether this mortality is related to the diet is unknown. During the time the hens were alive they laid about as well as any of the other groups. Egg production was poor in the first group which received safflower oil. Again the role of the diet is problematical.

The mean serum cholesterol values of the hens while they were alive are also shown in Table I, as well as the degree of vascular sudanophilia. It may be noted that the group receiving coconut oil had the highest serum levels and those receiving corn oil the lowest. It seems likely that these differences, if significant, may be related to the dietary fat. Since production of eggs was variable in each hen and in each group, the data do not allow definite conclusions.[16] The mean gross vascular sudanophilia in the group receiving safflower oil would appear to be less extensive than that in the other dietary groups. No distinct differences in the degree of vascular sudanophilia could be detected among these latter groups, with the possible exception of somewhat less involvement in the hens fed olive oil. The incidence of grossly elevated sudanophilic lesions paralleled the degree of vascular sudanophilia.

The results of the analyses of the abdominal fat are shown in Table II together with analyses of the corresponding dietary fat. Typical chromatograms of the dietary and corresponding body fat are shown in Figures 1, 2 and 3. The similarity is such that any of the hens might be identified as to their dietary group by an inspection of the body fat analyses. In general, the analyses of fat from hens

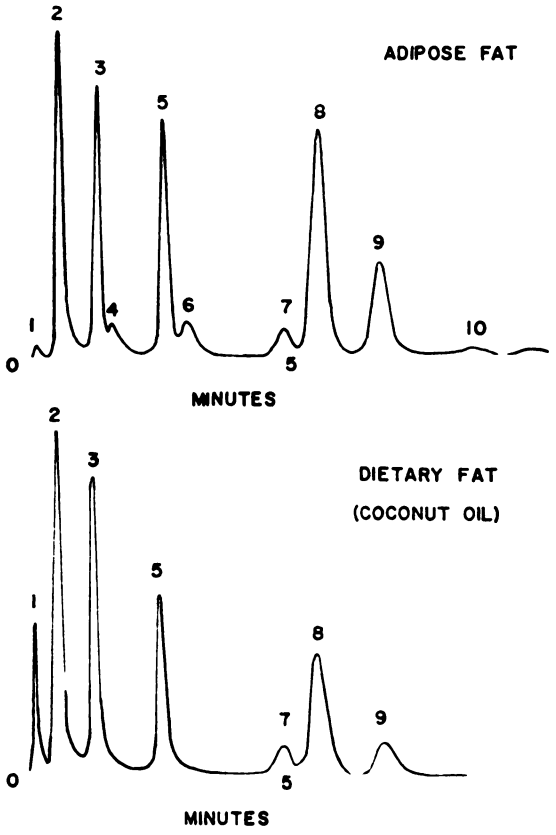

FIG. 1. A comparison of the chromatogram of coconut oil (bottom) and the adipose fat from a hen receiving 10 per cent coconut oil in the diet. The peaks are identified as the methyl esters of the following fatty acids: (1) capric, (2) lauric, (3) myristic, (4) myristoleic, (5) palmitic, (6) palmitoleic, (7) stearic, (8) oleic, (9) linoleic, (10) linolenic.

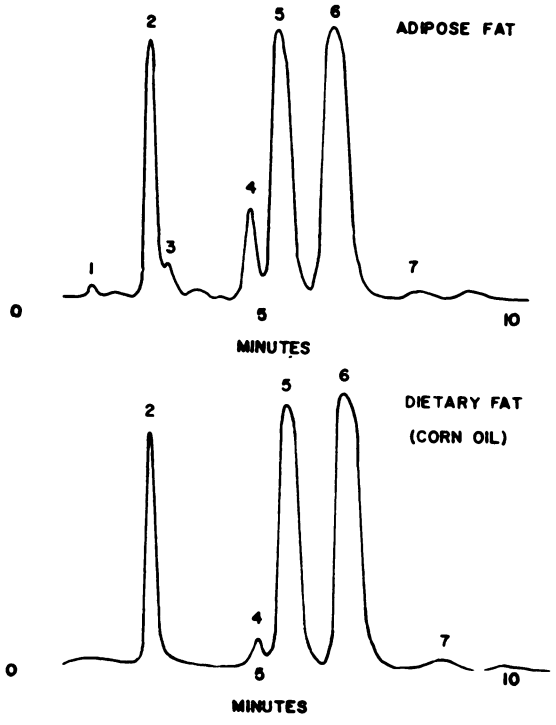

FIG. 2. Chromatograms obtained from corn oil and from the fat of hens fed 10 per cent corn oil. The peaks are identified as the methyl esters of the following fatty acids: (1) myristic, (2) palmitic, (3) palmitoleic, (4) stearic, (5) oleic, (6) linoleic, (7) linolenic. Several other minor constituents are present, particularly in the adipose fat.

within the same group did not vary more than ±5 per cent for the principal fatty acids although larger percentage variations were encountered for the fatty acids present in small amounts. Insufficient data are available to delineate the accuracy of the method for each fatty acid, particularly those present in small amounts, and the effects of variations in composition of the mixture upon the measurement of each constituent. The results are considered as semiquantitative only. The identity of a number of the minor constituents is inferred from the elution time since concentrates or pure samples were not available.

COMMENTS

The extent to which the fatty acid composition of the adipose tissue reflects the composition of the dietary fat is rather remarkable. Burr and Barnes[2] concluded, "It can hardly be said that any fat is typical of the species." On the other hand, it is clear that the animal is not entirely passive in the formation of tissue fat and some selection and modification of the dietary fatty acids is made. In the present studies the composition of corn oil and the fat from hens fed this oil were nearly identical in composition. One can deduce from the data from the other groups a tendency toward the formation of a fat of the corn oil type. Thus, the major constituents, palmitic, stearic, oleic and linoleic acid, when present in larger or smaller amounts in the dietary fat than occurred in the body fat of group 4 (fed corn oil), tend to be selectively retained or removed in the direction which would produce a fat of that composition. Thus, the body fat from group 1 (fed safflower oil) is lower in linoleic acid and higher in oleic acid than safflower oil itself, while the reverse relationship is seen in the group receiving olive oil. The extent to which the individual fatty acids are derived from the dietary source and from synthetic activities is, of course, unknown.

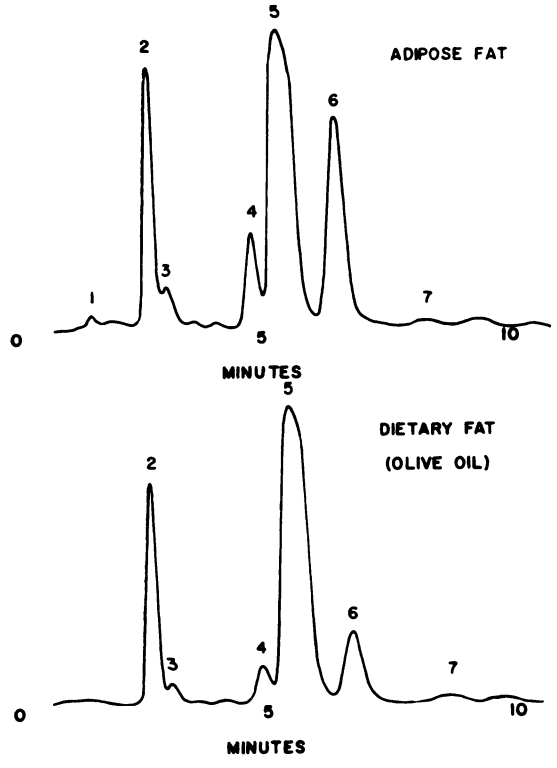

FIG. 3. Chromatograms obtained from olive oil and the fat of a hen fed 10 per cent olive oil. The peaks are identified as the methyl esters of the following fatty acids: (1) myristic, (2) palmitic, (3) palmitoleic, (4) stearic, (5) oleic, (6) linoleic, (7) linolenic. Several minor constituents are present in both samples.

The production and retention of some of the monounsaturated fatty acids, myristoleic and palmitoleic acids, is apparent in all groups. The dietary fat, with the exception of olive oil, contained very little of these fatty acids. It seems likely that these are derived in large part from the corresponding saturated acids since the content appears to be related partially to the intake of the fatty acids. This was particularly evident in the group fed coconut oil (group 2) which contained considerable myristic acid.

Undoubtedly, the changes in composition of body fat, as a result of changes in the diet, will be dependent upon both the composition of the dietary fat and the amount fed. The latter aspect has received relatively little study. The diets fed in this study contained 10 per cent fat, an amount higher than most common poultry rations, but relatively low in fat when compared to many diets consumed by man. The extent to which the kind and amount of dietary fat will be reflected in the tissue stores of various species, especially man, remains to be explored. It seems likely that analyses of the adipose tissue will reflect

the long term dietary pattern of the fatty acids consumed.

Those birds which received safflower oil in the diet had definitely less vascular sudanophilia than the other groups. It should be noted that none of the birds received cholesterol in the diet. The relationship of such differences in vascular sudanophilia to fat composition and serum cholesterol levels deserves further study.

SUMMARY

The fatty acid composition of the abdominal fat in hens was compared to the composition of the fat in the diet, the composition of the diets being otherwise identical. The proportion of fatty acids in the adipose tissue approximates that of the fat ingested. The findings, if applicable to man, suggest a method for estimating the dietary habits with regard to fat.

The hens consuming coconut oil had the highest serum cholesterol values. The amount of vascular sudanophilia was least in the group receiving safflower oil. Although it would appear that the kind of dietary fat influenced the serum cholesterol levels and the development of vascular sudanophilia, differences in production of eggs in this experiment limit the conclusions that can be drawn.

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