mal's liver alone exceeds the amount he ingested, and if whole body calculation were possible it might be at least one order of magnitude larger still. Therefore, it seems unlikely that the odd-chain acids detected in the animal arose only from the lipids of the starch ingested. The starch diet caused diarrhea in the rats, suggesting a change in intestinal flora. One explanation for the increased content of odd-chain fatty acids (8.5%) in the livers of these animals may thus be an increased bacterial synthesis of odd-chain acids in the intestinal lumen. Another might be alteration of lipid synthesis by the kind of carbohydrate fed. However, the mechanism of increased synthesis of odd-chain fatty acids is not known or suggested.

In conclusion, the kind of dietary carbohydrate has been shown to influence the fatty acid composition of liver lipids. Dietary sucrose, maltose and glucose produce minor differences, but starch causes a larger proportion of the liver fatty acids to be odd-chain fatty acids. All of the carbohydrate diets permitted induction of fatty acid compositions characteristic of essential fatty acid deficiency, indicating that the development of essential fatty acid deficiency on the traditional high sucrose diets has not been an artifact related to sucrose, but that it is a deficiency observable irrespective of type of dietary carbohydrate. Although the metabolism of carbohydrate and the metabolism of fatty acids are interrelated, high levels of different dietary sugars caused only minor differences in fatty acid composition in both linoleate-supplemented and linoleate-deficient rats. On the other hand, dietary starch induced higher levels of odd-chain fatty acids than did the dietary sugars in both deficient and supplemented rats.

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Competitive Inhibitions in the Metabolism of Polyunsaturated Fatty Acids Studied via the Composition of Phospholipids, Triglycerides and Cholesteryl Esters of Rat Tissues[1]

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Abstract

Male rats which had been kept on fat-free diet and which were deficient in essential fatty acids were divided into ten groups. All ten groups received 0.8% of calories of linolenate, and nine received one of three levels of either linoleate, γ-linolenate or arachidonate for a period of six days. The rats were sacrificed, the livers, kidneys and testes were extracted, and the phospholipids, triglycerides and cholesteryl esters were separated by thin-layer chromatography. The fatty acid composition of each was determined by gas-liquid chromatography. The inhibition of the metabolism of linolenic acid by linoleate, γ-linolenate and arachidonate was evidenced in all three lipid classes and in all tissues. The activities in suppressing linolenate metabolism were in the order 20:4 > 18:3 > 18:2.

Introduction

SEVERAL STUDIES in this laboratory have confirmed conclusively that there is no metabolic crossover between the different families of polyunsaturated fatty acids. The studies were made with rats which had been maintained on fat-free diets supplemented with highly unsaturated fatty acids of different families (1–4). These conclusions are in accord with those of Mead et al. (5) and Klenk and Mohrhauer (6) who also found via tracer experiments no interconversion between fatty acids from different families in mammalian tissue. But although no conversion takes place between families of fatty acids, inhibitions and competitions between fatty acids from different families have been amply demonstrated (7,8). The decrease of the trienoic acid content of tissues of rats fed a fat-free diet plus linoleic and linolenic acids was observed by Rieckehoff et al. (7). Fulco et al. (9) proved that the triene was 5,8,11-eicosatrienoic acid and the inhibition of the synthesis of the oleic family (ω9) by linoleate (ω6) and linolenate (ω3) was clear.

The decreased proportion of tissue oleic acid with increasing amounts of dietary linoleic acid was observed by Dopeshwarkar and Mead (10) and they suggested that oleate and linoleate compete as substrate for the enzymes involved in the linoleic ⟶ arachidonic acid conversion when dietary oleate is abundant compared with dietary linoleate. These suggestions are supported by the work of Tinsley (11), Bozian

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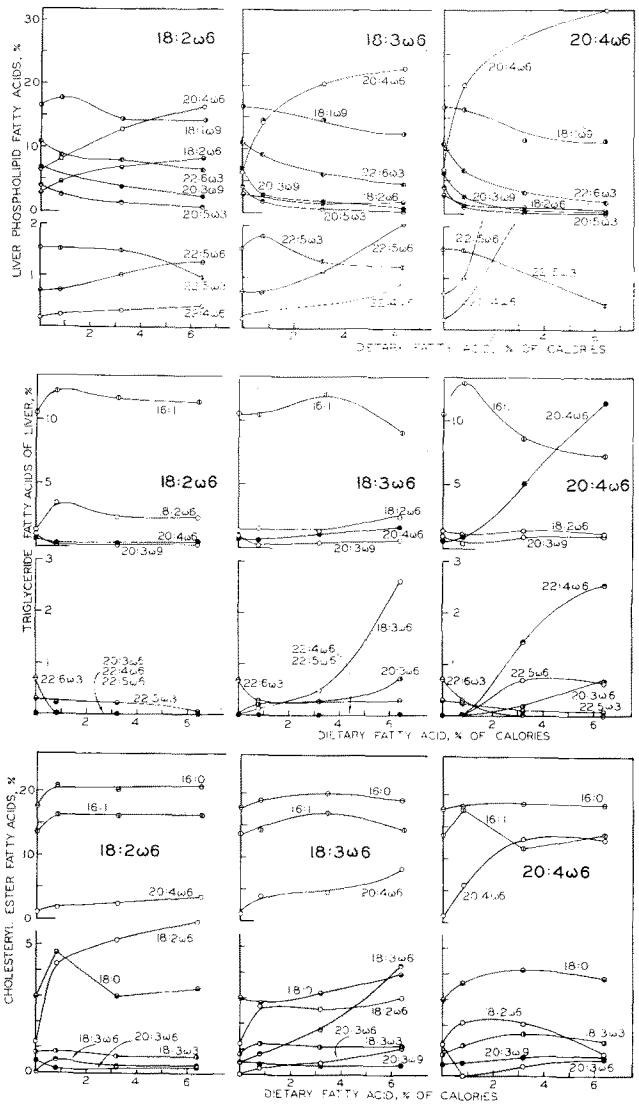

FIG. 1. The effects of different levels of dietary supplementation of linoleate, γ-linolenate and arachidonate upon the fatty acid composition of phospholipids, triglycerides and cholesteryl esters of rat liver. The fatty acid supplement is indicated by large lettering. Fatty acids which were not affected by the dietary supplements or which are not pertinent to the discussion are deleted.

et al. (12) and Holman and co-workers (1,4,13). Holman and Mohrhauer (14) have confirmed and extended the observations of earlier workers (15–18) that the metabolism of linoleate is inhibited by linolenate. The inhibition of linolenate metabolism by dietary linoleate was recently shown by Rahm and Holman (19). The competitive equilibrium between linoleate and linolenate can be displaced in either direction, and the fatty acid favored in this competition depends upon the relative levels of these acids in the diet (13,19).

Previously the effects of inhibition were observed in the total fatty acids of tissue lipids. It is our purpose in the present experiment to study the inhibition of linolenate metabolism by three members of the linoleate family, 18:2, 18:3 and 20:4, in phospholipids, triglycerides and cholesteryl esters in several rat tissues at three different dietary levels of these fatty acids. All of the groups were fed the same amount of linolenate to provide a constant amount of this precursor of its family of fatty acids. The studies were performed in short-term experiments, for the same metabolic conversions have been demonstrated in mature fat-deficient rats within 5 days as had previously been observed in 90-day experiments beginning with normal weanling rats (20).

Experimental

Weanling male rats of the Sprague-Dawley strain were conditioned by maintaining them for 7 months with fat-free purified diet (1) prior to administration of fatty acid supplements. Sucrose, cellulose, vitamin-free casein and required salts and vitamins are the essential constituents of the fat-free diet. The rats were divided into 10 groups of 4 animals each which all received linolenate as daily oral supplement at the level of 0.8% of total calories to provide a minimal constant level of this acid. In addition, linoleate, γ-linolenate or arachidonate was fed as daily oral doses at one of three levels to nine of the groups. The intake of fatty acid supplements was calculated as percent of total calories measured by food consumption.

The dietary methyl esters of linoleic, linolenic and arachidonic acids were obtained from The Hormel Institute. They were analyzed by gas-liquid chromatography (GLC) and their purity was found to be greater than 99%. The methyl γ-linolenate was prepared from the seed oil of *Oenothera lamarckiana* (21) and analyzed by GLC and infrared spectrophotometry. Its content of γ-linolenate determined by GLC was greater than 99%, and it contained 10.4% of *trans* isomers.

After 6 days of supplementation, the animals were killed by ether anesthesia. The tissues were immediately removed and stored frozen under chloroform. Chloroform was used rather than saline solution in order to avoid prolonged exposure of the tissues to room temperature while thawing out before the extraction, thereby minimizing lipolysis. The frozen tissue was homogenized with chloroform-methanol (2:1) according to the procedure of Folch et al. (22) in a mechanical blendor to extract the lipids. The total lipids from liver, testis and kidney were fractionated into lipid classes by thin-layer chromatography (TLC) on silica gel chromatoplates. The solvent for development was petroleum ether (BP<40C), anhydrous diethyl ether and formic acid (80:20:1). An indicator solution of 2,7-dichlorofluorescein, 0.2% in ethanol, was sprayed on the chromatoplates and the bands made visible under ultraviolet light. The fractions were scraped from the plates and the methanolysis was performed with 5% HCl in methanol under nitrogen without previous extraction of the lipids from the silica gel. The phospholipids, triglycerides, cholesteryl esters and free cholesterol were the only major fractions. The free fatty acid fraction was insignificant in all of the tissues, indicating minimal lipolysis. The epididymal fat consisted almost entirely of triglycerides, and fractionation was thus not necessary.

The methyl esters from phospholipids, triglycerides and cholesteryl esters were analyzed by GLC using a Research Specialties gas chromatograph with argon ionization detector. A 210 cm glass column of 5 mm I.D. packed with 20% ethylene glycol succinate polyester (EGS) plus 2% phosphoric acid coated on Gaschrom P, 80–100 mesh was used. The flow rate was 60 ml argon/minute at an inlet pressure of 10 psi. The inlet heater was kept at 250C and the detector cell at 235C. All of the esters were chromatographed at 195C column temperature using two parallel re-

TABLE I

Fatty Acid Composition of Phospholipids from Liver, Testis and Kidney of Rats in Percent of Total Fatty Acids

Supplement	Liver				Testis				Kidney			
	None[a]	18:2ω6[a]	18:3ω6[a]	20:4ω6[a]	None	18:2ω6	18:3ω6	20:4ω6	None	18:2ω6	18:3ω6	20:4ω6
14:0	0.2	0.2	0.2	0.3	1.9	0.8	1.7	0.7	—	—	—	—
16:0	23.0	22.4	24.8	22.1	36.2	35.1	36.0	36.8	20.9	23.6	21.9	21.0
18:0	20.4	18.4	19.3	21.2	6.7	7.3	6.8	6.6	16.9	16.9	21.6	19.3
Total sat.	43.6	41.0	44.3	43.5	44.9	43.2	44.5	44.1	37.8	40.5	43.5	40.4
16:1	4.7	3.9	3.7	3.4	1.7	1.1	1.2	1.0	3.0	2.5	2.5	2.0
18:1ω9(18.52)[b]	16.6	14.5	12.4	11.4	17.3	14.6	15.4	14.9	17.8	12.8	12.9	12.4
20:3ω9(21.47)	6.9	2.6	0.9	0.6	4.2	2.9	2.0	1.7	8.4	2.7	1.1	1.1
Total ω9	23.5	17.1	13.3	12.0	21.5	17.5	17.3	16.6	26.2	15.5	14.0	13.5
18:2ω6(19.28)	2.9	8.4	1.9	0.7	1.4	3.0	1.0	0.6	3.7	9.7	1.9	1.0
18:3ω6(19.67)	tr	0.2	0.8	0.0	—	—	—	—	—	—	0.4	—
20:3ω6(21.74)	0.8	2.4	3.6	0.6	0.9	1.5	1.5	0.7	1.5	1.8	3.0	0.9
20:4ω6(22.27)	6.3	16.4	22.7	31.4	10.5	13.0	14.9	16.0	17.8	23.9	30.3	36.8
22:4ω6(24.26)	0.2	0.4	0.9	2.7	0.7	1.1	1.2	1.8	1.2	1.1	1.0	1.9
22:5ω6(24.69)	0.7	1.3	2.0	2.6	13.8	15.3	16.5	16.2	—	0.4	0.6	0.9
Total ω6	11.0	29.1	32.0	38.1	27.3	34.0	35.1	35.3	24.1	36.8	37.1	41.5
18:3ω3(20.45)	0.4	0.3	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.2	0.1	0.4
20:5ω3(23.26)	4.2	0.8	0.4	0.2	1.4	1.3	0.8	1.0	3.7	0.7	0.3	—
22:5ω3(25.38)	1.7	1.0	1.2	0.5	1.0	0.8	tr	tr	0.3	0.2	0.2	—
22:6ω3(25.70)	10.9	6.6	4.7	2.0	1.8	1.8	0.9	1.7	2.0	1.7	1.1	1.0
Total ω3	17.0	8.8	6.6	3.0	4.6	4.1	1.8	3.0	6.4	2.8	1.6	1.4

[a] All rats received a supplement of 0.8% of calories of 18:3ω3. A second supplement of 6.4% of calories of either 18:2ω6, 18:3ω6 or 20:4ω6 was given the groups except the control group indicated by none.
[b] Equivalent chain lengths (23) are indicated in parentheses.

corders of 1.0 and 10.0 mv full range to allow measurement of all fatty acids from one sample injection. The individual esters were identified by equivalent chain length (ECL) (23) and by internal standards, and the quantification was carried out by triangulation.

The abbreviated notation for unsaturated fatty acids indicates the chain length and number of double bonds. Thus, octadecadienoic acid is 18:2. When double bonds are methylene-interrupted and their positions are known, they can be indicated as a suffix indicating the position of the first double bond counting from the terminal (ω) methyl group. Thus, linoleic acid is 18:2ω6. The terminal counting and notation is used to indicate metabolic relationships in which the terminal structure remains unchanged.

Results and Discussion

The alterations in fatty acid composition of the phospholipids, triglycerides and cholesteryl esters from liver lipids of rats fed the same level of linolenate and three different levels of linoleate, γ-linolenate or arachidonate are shown in Figure 1.

Phospholipids

No consistent changes were observed in any group in the concentrations of the saturated fatty acids, myristic (14:0) and palmitic (16:0) (Table I and Figure 1) and stearic acid (18:0) was depressed only slightly when linoleate is increased. The data for acids which showed no significant change were therefore omitted from the figure. The level of palmitoleic acid (16:1) was depressed slightly by linoleate, γ-linolenate and the higher levels of arachidonate, and the amount of oleic acid (18:1) was depressed significantly by 18:3ω6 and 20:4ω6. When linoleate was the supplement, all of the metabolites of ω6 were increased. When γ-linolenate was fed, the levels of all of the higher ω6 fatty acids were increased, but 18:2ω6 was depressed. When the amount of dietary arachidonate was increased, the levels of 20:4ω6, 22:4ω6 and 22:5ω6 were increased, but 18:2ω6 and 20:3ω6 were lowered significantly. In other words, the metabolic precursors of the dietary supplement are suppressed but its metabolic products are increased under the conditions of this study.

Except for 18:3ω3, the amounts of ω3 fatty acids in liver phospholipids were depressed significantly by all three ω6 supplements. The total amount of ω3 acids was depressed from a level of 17.0% in the control group to 8.8%, 6.6% or 3.0% when linoleate, γ-linolenate or arachidonate were fed in the diet at a ratio of 8:1 with respect to the level of linolenate.

The accumulation of 5,8,11-eicosatrienoic acid (20:3ω9) in deficient animals was largely in the liver phospholipids. In animals fed ω6 acids, this fatty acid decreased sharply, but the suppression was in the order 20:4ω6 > 18:3ω6 > 18:2ω6. In this study of liver phospholipids the efficiency as inhibitor of metabolism of ω3 acids seems to be parallel to the efficiency of inhibition of formation of 20:3ω9, and to the known biopotencies (24) of the three ω6 acids. The amount of 18:3ω3 did not change significantly in phospholipids but all of its metabolites were decreased, as any of the ω6 acids were increased in the diet. The order of inhibition seems to be 20:4ω6 > 18:3ω6 > 18:2ω6 for all of the detectable steps in the metabolism of 18:3ω3.

The fatty acid composition of the phospholipids from liver, kidney and testis are shown in Table I for comparison. Because the changes induced by the two lower levels of supplementation were generally similar to but less than those induced by the highest level of supplements, only data from the latter have been included in the table. In kidney and liver phospholipids the amount of palmitic acid was only a little greater than stearic acid, but in testis it was almost six times more. The amount of palmitoleic acid was less in testis than in the phospholipids of the other two tissues. The oleic acid content of the phospholipids was quite similar in all of the tissues studied. In the group fed only linolenate as supplement, the most abundant fatty acid of the ω3 family was 22:6ω3 in liver and testis, but in kidney it was 20:5ω3. Arachidonic acid was the principal member of the ω6 family in liver and kidney, but in testis it was 22:5ω6. In the groups supplemented with the fatty acids of the ω6 family the most abundant fatty acid of the ω3 family was 22:6ω3 in the phospholipids of all tissues. Arachidonic acid was the most abundant ω6 acid in liver, testis and kidney phospholipids. The total amount of ω3 and ω9 families was depressed similarly by ω6 fatty acid in liver and kidney phospholipids. In the testis phospholipids the decrease was less noticeable. The total amount of ω6 fatty acids was usually greater in the phospholipids of kidney and testis than in the liver.

TABLE II

Fatty Acid Composition of Triglycerides from Liver, Testis, Kidney and Epididymal Fat of Rats

	Liver				Testis				Kidney				Epididymal Fat			
Supplement	None[a]	18:2ω6[a]	18:3ω6[a]	20:4ω6[a]	None	18:2ω6	18:3ω6	20:4ω6	None	18:2ω6	18:3ω6	20:4ω6	None	18:2ω6	18:3ω6	20:4ω6
14:0	1.2	1.4	1.2	1.1	1.8	1.8	2.0	1.6	2.4	2.1	2.5	2.2	2.3	2.8	2.5	2.9
16:0	29.8	35.2	31.6	29.9	31.4	31.5	31.0	28.8	34.8	29.9	29.4	38.0	31.8	30.8	29.4	30.0
16:1	10.5	11.9	9.0	7.7	14.6	15.6	16.5	14.3	11.2	12.1	16.1	10.8	16.7	17.4	16.1	15.6
18:0	2.4	2.8	2.6	2.6	2.5	2.8	2.5	2.6	4.6	3.5	3.1	4.4	2.4	3.2	3.1	3.3
18:1	50.8	45.3	45.9	39.3	40.2	40.3	41.4	42.2	44.2	51.2	46.3	45.2	44.9	40.8	46.3	45.3
20:3ω9	1.0	0.2	0.6	1.2	1.2	0.8	0.6	1.0	0.1	0.2	—	—	0.1	0.1	—	—
18:2ω6	1.4	2.3	2.4	1.2	1.4	2.2	1.4	1.6	0.5	3.0	1.3	0.5	1.2	3.2	1.3	1.1
18:3ω6	—	—	2.6	0.2	—	—	—	—	—	—	0.6	—	—	—	0.6	—
20:3ω6	—	—	0.7	0.6	0.1	0.2	0.2	0.2	—	—	—	—	—	—	—	—
20:4ω6	0.7	0.5	1.7	11.5	0.8	0.7	0.9	1.6	0.3	0.3	0.1	1.2	—	0.2	0.1	0.9
22:4ω6	—	—	—	2.6	0.6	0.5	tr	1.0	—	—	—	—	—	—	—	—
22:5ω6	—	—	—	0.6	3.1	2.3	2.8	4.5	—	—	—	—	—	—	—	—
18:3ω3	0.6	0.3	0.9	1.1	0.8	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.9	0.4	0.5
20:5ω3	0.7	—	0.2	0.3	1.6	0.6	0.4	0.4	0.5	0.2	—	—	—	—	—	—
22:5ω3	0.3	—	0.3	0.2	tr	tr	tr	tr	—	—	—	—	—	—	—	—
22:6ω3	0.7	—	0.3	—	tr	tr	tr	tr	—	—	—	—	—	—	—	—

[a] All rats received a supplement of 0.8% of calories of 18:3ω3. A second supplement of 6.4% of calories of either 18:2ω6, 18:3ω6 or 20:4ω6 was given the groups except the control group indicated by none. All values are % of total fatty acids.

The ratio of product to precursor calculated for the conversion 18:3ω3 ⟶ 20:5ω3 in the liver phospholipids was decreased from 11.3 in rats fed linolenic acid alone to 6.3, 2.6 and 1.0, respectively, in the groups fed 3.2 calories % of 18:2ω6, 18:3ω6 and 20:4ω6, respectively. The product/precursor ratio for the conversion 20:5ω3 ⟶ 22:5ω3, which represents chain lengthening only, increased in the groups fed the three supplements probably because the precursor 20:5ω3 was depressed more drastically than was the product 22:5ω3. The ratio of 22:6ω3 to 22:5ω3, which represents a dehydrogenation step, was depressed by all ω6 supplements. If steady state concentrations of polyunsaturated fatty acids (PUFA) may be used as an index, these findings suggest that the competitive inhibition between families of PUFA is exerted primarily at the dehydrogenation steps (25). This was also suggested by the shape of dose-response curves in previous inhibition studies (13).

The trienoic/tetraenoic acid ratio has proven to be a convenient expression of essential fatty acid (EFA) status (26). When the ratios of triene/tetraene for each group were plotted against the linoleate, γ-linolenate and arachidonate contents of the diet expressed as percent of calories, three hyperbolas were obtained. The ratio of triene/tetraene in liver phospholipids was decreased from 1.1 in the control group to 0.15, 0.04 and 0.01, respectively, in the groups fed with the highest levels of 18:2ω6, 18:3ω6 and 20:4ω6. The hyperbola for γ-linolenate lay nearer to that for arachidonate than to that for linoleate. This suggests that EFA activity of γ-linolenate is more similar to arachidonate than to linoleate. When the ratios for 20:3ω9/18:1ω9 were calculated and plotted against dietary intake, the curves were very similar to those for 20:3ω9/20:4ω6.

Trigylcerides

The fatty acid composition of triglycerides from liver, testis, kidney and epididymal fat are shown in Table II. Because the changes elicited by the two lower levels of each supplement were similar to but less than those found in the animals fed the higher levels, only the latter data have been included in the table. In the liver triglycerides no important changes were observed in the content of myristic, palmitic and stearic acids. Myristic and palmitic acids were increased slightly in animals fed linoleate. These data have been omitted from Figure 1.

The level of palmitoleic acid was increased slightly by 18:2ω6, decreased slightly by 18:3ω6, but lowered significantly by higher levels of 20:4ω6. In liver triglycerides the ω9 family was depressed by all three members of the ω6 family, but only the 18:2ω6 inhibited the incorporation of both 18:1 and its metabolite 20:3ω9 into triglycerides. The 18:2ω6 was better able to compete with the ω9 family than its own higher metabolites were. This seems to be contrary to the conclusions reached by Peluffo et al. (27) that 20:3ω9 is depressed by arachidonate but not by linoleate per se.

In triglycerides, the only ω6 acid increased by feeding with linoleate was linoleate itself. When γ-linolenate was fed, the ω6 acids 18:2, 18:3, 20:3 and 20:4 were increased. When arachidonate was fed, 18:3ω6, 20:3ω6, 20:4ω6, 22:4ω6 and 22:5ω6 were increased but the 18:2ω6 was depressed slightly. In liver triglycerides the total amount of ω3 acids was rather small even in the control group fed only linolenic acid. γ-Linolenate or arachidonate increased the amount of

18:3ω3 in liver triglycerides, but dietary linoleate decreased the content of 18:3ω3. Perhaps the higher levels of dietary linoleate prevent the incorporation of linolenate into the liver triglycerides and divert it to oxidative processes, whereas γ-linolenate and arachidonate exert their competitive action principally in later steps of metabolism, causing an accumulation of linolenate. The other members of the linolenic acid family, 20:5ω3, 22:5ω3 and 22:6ω3, were depressed in all of the groups when ω6 acids were included in the diet.

The triglycerides from the three tissues analyzed show small differences among them. The triglycerides from liver and testis contained higher levels of higher PUFA than did the triglycerides from kidney and epididymal fat. The latter two tissues did not contain significant amounts of acids beyond 20:4ω6 and 20:5ω3. In testis triglycerides the amount of 22:5ω6 was unusually high, in agreement with recent findings that triglycerides of reproductive tissues of swine and cattle were very rich in polyunsaturated fatty acids (28). When 18:2 was fed, 18:2 occurred in triglycerides of kidney, testis, liver and epididymal fat, and it was very abundant in all. When 18:3ω6 was fed, it appeared in liver triglycerides only, in insignificant amounts. The incorporation of dietary arachidonate was significant in liver triglycerides only.

Cholesteryl Esters

The levels of palmitic and stearic acids in liver cholesteryl esters did not change consistently when 18:2ω6, 18:3ω6 or 20:4ω6 were fed. The amounts of palmitoleic and oleic acids did not change consistently when 18:2ω6, 18:3ω6 or 20:4ω6 were fed but 18:2ω6 seemed to increase the amount of palmitoleic acid. When linoleate was fed, 18:2ω6 and 20:4ω6 were increased significantly in cholesteryl esters. When γ-linolenate was fed, 18:2ω6, 18:3ω6, 20:3ω6 and 20:4ω6 increased significantly. When arachidonate was fed, 20:3ω6, 20:4ω6, 22:4ω6 and 22:5ω6 increased significantly, but 18:2ω6 and 18:3ω6 decreased. The liver cholesteryl esters had large amounts of ω9 and ω7 acids and the principal unsaturated fatty acids were monoenes (18:1) and (16:1). The total acids of the oleate family was almost unaffected by the concentration of ω6 in the diet. In the cholesteryl esters of 18:3ω3-fed animals there were not, at least in our short-term experiment (21), noticeable amounts of metabolites of the ω3 family. In a manner similar to that seen in the triglycerides, only dietary 18:2ω6 depressed the amount of 18:3ω3, but dietary γ-linolenate and arachidonate increased the amount of 18:3ω3 in the liver cholesteryl esters.

Conclusions

The fatty acid compositions of phospholipids, triglycerides and cholesteryl esters in rat liver lipids were quite different, and the chain extension and dehydrogenation of fatty acids seems to be reflected in the phospholipid fraction to a greater extent than in the triglycerides or cholesteryl esters. In the latter two fractions the deposition of PUFA was significant only in the groups fed arachidonate. The increase of the metabolites of ω6, as a consequence of feeding their precursors, was evident in all of the groups. If changes in the concentration of tissue fatty acids under the influence of varying amounts of single dietary fatty acids may be interpreted in terms of fatty acid metabolism, all steps in the pathway 18:2ω6 ⟶ 18:3ω6 ⟶ 20:3ω6 ⟶ 20:4ω6 ⟶ 22:4ω6 ⟶ 22:5ω6 are confirmed, including the first step which recently has been proved by Nugteren (29).

γ-Linolenate seems to be more similar to arachidonate than to linoleate in its efficiency of conversion, as well as its efficiency of inhibition of synthesis of 20:3ω9 and ω3 metabolites. The total percentage of saturated fatty acids from the different lipid classes remained fairly constant in all of the diet groups despite wide differences in the amounts of fatty acid supplement. The ratio 16:0/18:0 was nearly constant in liver phospholipids despite the different fatty acid supplements (11). The phospholipids contained the highest level of saturated fatty acids (40–44%), the triglycerides contained 32–36% and the cholesteryl esters contained 20–25%.

The effects of different levels of dietary PUFA upon the lipids of liver, testis and kidney have been resolved into their effects upon phospholipids, triglycerides and cholesteryl esters. When the compositions of the individual lipid classes are viewed singly, it becomes clear that individual polyunsaturated fatty acids respond differently in the three lipid classes. The responses are most dramatic in the phospholipids and the responses in cholesteryl esters and triglycerides are somewhat similar. The competitive inhibitions exerted by dietary linoleate, γ-linolenate and arachidonate upon the metabolism of 18:1 to 20:3ω9 and of 18:3ω3 to 22:6ω3 are most easily measurable in the phospholipids in which the higher PUFA are more abundant.

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