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HYDROGENATED MARINE FAT, ITS INFLUENCE ON RAT TISSUE LIPIDS, COMPARED TO FISH OIL, RAPE SEED OIL AND LARD

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ABSTRACT

A feeding experiment on rats has been performed, comparing fish oil and partially hydrogenated fish oil (HMF) with rape seed oil and lard. After a two week preliminary period during which the percentage of lard in the diet was increased from 7% to 20%, four groups of rats were fed diets containing 20% of the four fats for 12 weeks. Growth was controlled, and samples of liver, heart, thigh muscle and brown adipose tissue taken after 1, 2, 6 and 12 weeks. Lipids of these tissues were separated into neutral and polar fractions, and the fatty acids prepared and analyzed on GLC. Results are given and discussed. The following conclusions are given:

A deposition combining endogenous and exogenous fat was reached already after one week of feeding and remained fairly constant throughout the feeding period. The content of docosenoic acid (22 : 1[1]) in heart and brown adipose tissue was an exception.

Dietary ω-6 and ω-3 polyenoic acids were easily deposited in all tissues, the highly unsaturated ω-3 acids from the fish oil were found in phospholipids at levels well above those in the dietary fat. HMF, which contained only low levels of polyenoic acids, gave increased tissue levels of the short chain acids 14 : 0 and 16 : 1.

Relative to the dietary levels, 20 : 1 was found in higher concentrations than 22 : 1 in all tissues in the groups given HMF, fish oil and rape seed oil. The group given HMF showed lower relative levels of both 20 : 1 and 22 : 1 than the groups on fish oil and rape seed oil.

On feeding fish oil and rape seed oil, 22 : 1 was found in the heart triglycerides after one week at levels nearly up to that in the dietary fat. During the next weeks the levels fell to about half the dietary level. Similar values were found in the brown adipose tissue triglycerides.

In the group fed rape seed oil, the neutral lipid of the heart tissue was about twice that in the other groups during the first two weeks, corresponding to a ten-fold increased 22 : 1 content in the lipids.

[1]22 : 1) notation for fatty acid of 22 carbon atoms in chain, one double bond.

INTRODUCTION

The use of hydrogenated marine fat (HMF) in margarine production warrants nutrition studies on its uptake and metabolism. In two earlier studies we have reported on the effect of HMF on the composition of tissue lipids of rats on a low-fat diet (BRAEKKAN et al., 1968) and on the effect of growth and liver weight in rats on a high-fat, low protein diet (NJAA et al., 1971).

Studies on the uptake and metabolism of rapeseed oil (ABDULLATIF & VLEES, 1970, BEARE-ROGERS et al., 1971) have focussed interest on the accumulation of fat in heart tissue of young rats. This accumulation and the subsequent histological changes have been ascribed to the content of erucic acid (22 : 1 ω 9). BEARE-ROGERS et al. (1971) and ODENSE et al. (1971) included hydrogenated herring oil in similar studies because of its known content of monoenes of chain length 20 and 22.

This report is concerned with detailed fatty acid analyses of liver, heart, thigh muscle and brown adipose tissue lipids of young rats fed during 12 weeks diets containing 20% of hydrogenated marine fat (HMF), fish oil (capelin oil, CO), rapeseed oil (RO) and lard (L).

METHODS

EXPERIMENTAL PROCEDURES

Male Wistar-Möll rats weighing about 50 g on arrival, were housed in separate cages and given a basal fat free diet with 7% added lard for 4 days. The amount of lard was increased to 14% for the next 5 days and to 20% for the last 5 days of a 14 day pre-experimental period. The rats were then weighed and divided into 4 main experimental groups of 21 rats each. Care was taken to equalize the mean body weights in the four groups. The experimental diets and water were given ad. lib. One rat from each group was killed at the start of the experiment, and five rats from each group were killed after 1, 2, 6 and 12 weeks on the diets, and samples of liver, heart, thigh muscle and the brown adipose tissue located under the skin between the shoulder blades, taken for lipid analysis. Food intakes for each of the surviving rats were recorded during the sixth and twelfth week of the experiment.

Details of the composition of the experimental diets are given in Table 1, analytical data on the four fats used in the experiment are given in Table 2.

Table 1. *Composition of the experimental diet.*

Partly dextrinized potato starch	29.4 %	
Sucrose	20.0 %	
Casein	20.0 %	
Minerals (Sure 1941)	4.0 %	
Vitamin mix (see below)	1.0 %	
Cellulose powder	5.6 %	
Fat (see table 2)	20.0 %	
	100.0 %	
Vitamin-mix:		
Thiamine–HCl	10	mg/kg diet
Riboflavin	10	»
Pyridoxine–HCl	10	»
Ca-panthotenate	30	»
Nicotinic acid	50	»
p-Aminobenzoic acid	100	»
Inositol	500	»
Cholin-*H*-tartrate	2000	»
Folic acid	2	»
Biotin	0.2	»
Cobalamine	0.02	»
Menadione	5	»
A/D conc. (750.000 IE A/g – 150.000 IE D/g)	6.7	»
25 % α-tocopherol-acetate	400	»
Cellulose powder q.s. ad	10	g/kg diet

Table 2. *Fatty acid composition of the dietary fats, extracted from the complete diets.*

Fatty acid designation	Lard L	Hydrogenated capelin oil 1) 2) HMF	Capelin oil 2) CO	Rapeseed oil RO
14:0	2.2	6.9	6.2	0.1
16:0	21.8	14.0	12.3	4.0
16:1	2.6	7.0	11.3	0.3
18:0	17.4	5.2	0.6	1.6
18:1	41.3	16.2	17.0	12.9
18:2	10.3	9.0	8.4	16.0
18:3	–	–	–	9.9
18:4	–	–	3.0	–
20:0	0.2	2.1	–	–
20:1	2.4	16.4	16.4	7.9
20:2–3	–	2.8	–	–
20:4	0.3	–	–	0.3
20:5	–	–	7.8	–
22:0	–	2.0	–	–
22:1	0.2	14.4	10.6	44.2
22:2–4	–	3.0	0.8	0.1
22:5	0.3	–	0.3	0.3
22:6	–	–	4.3	1.4

1) Further information regarding fatty acid isomers in this type of fat: LAMBERTSEN & al. (1966, 1971).

2) 5 % soybean oil added to the fat.

ANALYTICAL PROCEDURES

Frozen tissues from the five rats in each group were weighed, cut in small pieces and ground in a mortar with quartz sand and warm chloroform/methanol (70/30), filtered and reextracted twice. Collected extracts were evaporated in vacuum (40°C), transferred to columns (12 mm i. d.) of 20 g silica gel (Woelms, for partition chromatography) and eluted with chloroform followed by methanol. Non-lipid material was not eluted. The eluate was evaporated in vacuum, weighed and transferred with hexane to a new silica gel column as above. Neutral lipids were eluted with ethyl ether hexane mixtures containing up to 40% (v) ethyl ether. Polar lipids were then eluted with chloroform/methanol (70/30) followed by methanol. The two eluates were evaporated, weighed and taken up in methanol for saponification.

Up to 1 g sample of the lipid fractions were saponified in methanol/60% KOH (30/2) with pyrogallol and ascorbic acid added for protection. After ether-extraction of the unsaponifiable constituents, the soap solution was treated with 2 N HCl, and extracted with ethyl ether, washed with diluted HCl, evaporated in vacuum and taken up in 10 ml 12% BF_3 in methanol. After boiling for 10 min., the methyl esters were extracted into ethyl ether, the extract washed with water, evaporated, purified by column chromatography on SiO_2 and dissolved in methyl hexanoate to give a 5% solution. The solutions were stored in the freezer in small vials.

Gas-liquid chromatography. Instrument: Perkin-Elmer 900, temperature-programmed, dual flame ionization detectors. Column: 1/8″ stainless steel, 1200 mm length filled with a) 6% EGSS-X on 80/100 mesh silanized kieselguhr (Merck), b) 4% OV-1 on the same support. Temperatures: injector: 240°, manifold 210°, oven 170–200° for column a), 200° isothermal for column b). 2 μl samples were injected, N_2 flow rate was 25 ml/min.

Identifications of peaks were ascertained by «semilog plots» and by standard runs of saturated and unsaturated series. The tabulated values are given as percentage peak areas of total peaks calculated, with no corrections. Peak areas were peak heights times width at half height, the peaks being corrected by hand for base line deviations and over-lapping. The tables were totalled to 99%, giving 1% non-calculated peaks. These comprise fatty acids of chainlengths below C_{14} and above C_{22}, oddnumbered and branched chained acids. This value is probably somewhat low, but as the fatty acid composition is discussed on a relative basis, this is of minor significance. The mixed isomers of C_{20} – and C_{22} – acids with 2, 3 and 4 double bonds are given as sum values. The OV-1-runs (Column b) were used to ensure correct values for acids which partly overlapped in EGSS-X-runs, i. e. 22 : 1 and 20 : 5, and correspondingly 20 : 1 and 18 : 4.

RESULTS

No deaths or visible diseases occurred among the animals during the experiment. The rats appeared to eat and grow normally. Fig. 1 gives the growth curves for the four groups, and shows that the RO-group had a slower weight gain than the three other groups. The food intakes, controlled in weeks 6 and 12, showed that groups L, HMF and RO had very similar average food intakes, whereas the CO-group had an average intake 5% less than that of the other groups.

The tissue lipid weights showed that the brown adipose tissue contained 50% lipid material whereas the lipid content averaged 4.3% for the liver, heart and thigh muscle tissues. Insignificant differences were found between the three latter tissues, and between the groups L, CO, and RO, with the exception of the heart one- and two-week samples on the RO-diet. The

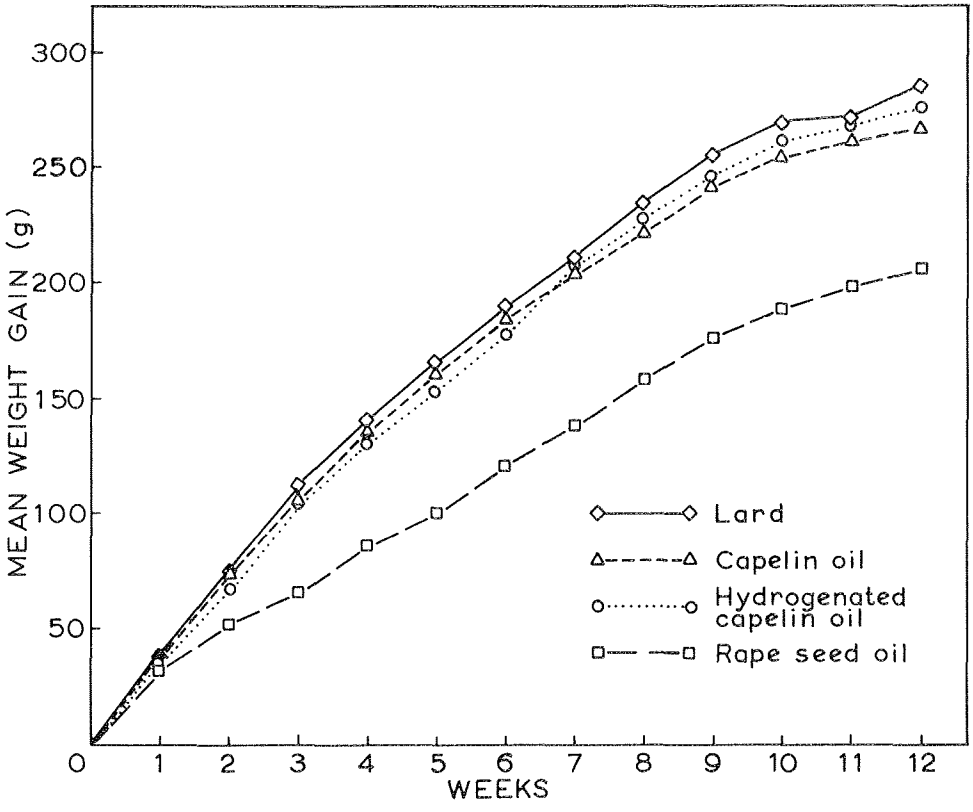

Fig. 1. *Average growth of four groups of rats fed during 12 weeks on 20 % fat diets.*

HMF-group tissues had somewhat lower average lipid contents. The lipid contents of these three tissues decreased, however, with time, from a mean of 5.5% at the one week sampling to 3.5% at the twelve week sampling. Separation of the lipids into neutral and polar material showed a 1 : 1 relation for the liver and heart samples, a 3 : 1 relation for the thigh muscle lipids, while the brown adipose tissue lipids contained 95% neutral and 5% polar material.

From each gas chromatogram 17 fatty acid values (including the combined 20 : 2—3 and 22 : 2—4) were calculated. The total data from the fatty acid determinations of all lipid fractions are in the order of 2300 values (Appendix Tables 1 and 2). This material was reduced to simplify the discussion. Generally the time factor showed least variation and it appeared practical to average the values for 1, 2, 6 and 12 week samples. The fatty acids may be discussed as 5 «natural» pairs plus stearic acid and a few particular dietary acids, such as linolenic acid from the rapessed oil. Table 3 gives the resulting concentrate of the analyses, ca. 280 values. The fatty acids in this table add up to 95 ± 3% of the total.

14 : 0 AND 16 : 1

Myristic and palmitoleic acids are characteristic components in fish lipids, whereas their concentrations in vegetable lipids are negligible. Northern fish oils, such as herring and capelin oils, contain 5—8% of myristic acid and 5—12% of palmitoleic acid, and Table 2 shows values in this order. They are evidently synthesized by the rat, as they were present in all lipids in the zero time control group as well as in the RO-group. Table 3 shows levels in neutral lipids of 12 to 18% in the HMF-group and 8 to 15% in the CO-group, compared to levels of 2—8% in the RO- and L-groups. Highest levels were found in the thigh muscle samples for all groups. The 16 : 1 values in the HMF-group increased through the experimental period in all tissue samples. The polar lipid fractions generally showed low contents of the 14 : 0—16 : 1 pair, and highest in the thigh muscle and the adipose tissue, particularly for the HMF-group. No obvious time effects were seen.

16 : 0 AND 18 : 1

Palmitic and oleic acids were the major fatty acids present in the triglycerides of rat tissues, representing 30—70% of the total in neutral lipids.

These acids are major end products of fatty acid biosynthesis in the rat, and therefore decreased relative levels resulting from the dietary intake of other fatty acids are of interest.

The dietary levels of 30% in the HMF and the fish oil and 17% in the rapeseed oil for this pair are well below the control rat values of 56—70% in

Table 3. *Condensed fatty acid compositions of neutral (N) and polar (P) lipids in four rat tissues. Averages over four sampling times.*

Fatty acid designations	Dietary fat	Liver		Heart		Thigh muscle		Brown adipose tissue	
		N	P	N	P	N	P	N	P
Control rats at start									
14:0 – 16:1		2.5	*0.6*	7.1	*1.8*	11.9	*3.6*	7.0	*3.4*
16:0 – 18:1		69.0	*27.6*	56.0	*23.7*	68.2	*33.8*	70.0	*44.0*
18:2 – 20:4		14.9	*32.1*	25.5	*38.1*	12.2	*29.6*	10.9	*30.6*
20:5 – 22.6		1.3	*13.5*	0.6	*11.9*	0.2	*11.9*	0.1	*1.4*
20:1 – 22:1		1.1	*0.4*	1.6	*0.9*	1.2	*0.5*	1.6	*1.0*
18:0		7.1	*21.2*	5.2	*17.6*	3.7	*15.2*	7.7	*16.3*
Hydrogenated marine fat									
14:0 – 16:1	13.9	12.5	*4.6*	14.6	*4.6*	17.9	*8.5*	14.9	*10.8*
16:0 – 18:1	30.2	59.9	*30.8*	47.5	*23.7*	55.7	*31.9*	49.4	*38.4*
18:2 – 20:4	9.0	10.0	*32.0*	10.3	*42.6*	8.8	*29.8*	9.2	*27.5*
20:5 – 22:6	–	0.4	*5.8*	0.7	*5.3*	0.3	*1.6*	0.5	*1.0*
20:1 – 22:1	30.8	7.7	*2.1*	14.0	*5.8*	7.8	*3.9*	13.9	*8.0*
18:0	5.2	4.6	*16.3*	5.1	*11.3*	4.9	*12.4*	5.0	*8.7*
20:0 – 22:0	4.1	1.1	–	3.0	–	1.3	–	3.4	–
Fish oil (capelin)									
14:0 – 16:1	17.5	8.6	*3.6*	11.4	*4.8*	15.2	*6.6*	10.8	*7.5*
16:0 – 18:1	29.3	43.7	*28.1*	40.5	*23.7*	49.7	*29.3*	42.7	*32.5*
18:2 – 20:4	8.4	8.6	*14.2*	11.2	*23.5*	7.9	*15.4*	8.6	*15.1*
20:5 – 22:6	12.1	17.8	*28.7*	6.6	*23.6*	3.4	*23.9*	4.1	*16.0*
20:1 – 22:1	27.0	9.5	*4.5*	21.7	*7.4*	18.2	*6.7*	24.8	*11.3*
18:0	0.6	2.0	*13.9*	4.4	*11.3*	2.4	*10.9*	4.6	*12.4*
22:5	0.3	5.8	*4.2*	–	–	–	–	–	–
Rape seed oil									
14:0 – 16:1	0.4	5.1	*2.7*	3.2	*1.8*	5.6	*3.6*	2.5	*2.4*
16:0 – 18:1	16.9	55.7	*32.5*	30.6	*24.0*	45.8	*27.8*	30.7	*27.5*
18:2 – 20:4	16.3	15.8	*29.1*	13.8	*36.1*	16.4	*28.2*	16.4	*29.4*
20:5 – 22:6	1.4	2.4	*11.1*	1.2	*6.6*	0.4	*11.4*	0.9	*4.3*
20:1 – 22:1	52.1	11.6	*4.6*	40.1	*15.1*	20.3	*7.3*	37.9	*19.5*
18:0	1.6	1.6	*13.0*	2.5	*8.7*	2.3	*11.2*	2.0	*7.2*
18:3	9.9	3.7	*1.9*	3.7	*2.5*	6.4	*2.8*	5.6	*5.5*
Lard									
14:0 – 16:1	4.8	4.2	*1.1*	7.3	*2.2*	7.7	*2.3*	6.9	*4.3*
16:0 – 18:1	63.1	69.4	*27.7*	65.7	*26.2*	70.2	*30.7*	67.1	*45.8*
18:2 – 20:4	10.6	14.0	*35.5*	11.6	*33.2*	10.8	*27.2*	9.9	*28.0*
20:5 – 22:6	–	1.5	*10.0*	0.5	*13.2*	0.3	*14.7*	0.1	*1.4*
20:1 – 22:1	2.6	1.8	*0.5*	2.1	*1.5*	1.5	*1.0*	1.8	*1.4*
18:0	17.4	5.2	*21.2*	9.9	*17.4*	7.2	*16.7*	11.9	*15.8*

the four tissues. Decreased levels are seen in all tissue samples for the groups CO, HMF and RO, most pronounced for heart and adipose tissues, with values of 31% in the RO-group, 40—43% in the CO-group and 47—49% in the HMF-group, compared to 66—67% in the L-group. Both 16 : 0 and 18 : 1 decreased proportionally, with the exception of rather high levels of oleic acid in the livers of the RO-group. The low levels of 16 : 0+18 : 1 corresponded mainly to increased levels of the 20 : 1+22 : 1-acids, and the two pairs varied with time in inverse proportions.

The polar lipids showed very constant levels of this fatty acid pair, with only minor changes from those in the control rats. The one exception to this was decreased levels in the brown adipose tissue of the HMF-, CO- and RO-group, corresponding to increases in 20 : 1+22 :1.

18 : 2 AND 20 : 4

A sufficient dietary intake of the essential linoleic acid was ensured for all groups. Soybean oil was added to the HMF and the capelin oil, and Table 2 shows 9% of 18 : 2 in HMF and 8.4% in CO, the former value may include other isomers resulting from the hydrogenation process. Lard and rapeseed oil had higher values, 10 and 16% respectively.

From Table 3 can be seen that all neutral lipids contained levels of the essential pair 18 : 2+20 : 4 similar to the dietary intake. The high start value of 24.5% 18 : 2 in heart neutral lipid did not influence this trend. Arachidonic acid levels were generally low. Increased values were found in hearts from the HMF- and CO-group in the one-week samples. The contents were constant during the experiment with the exception of a linoleic acid increase after 6 and 12 weeks in thigh muscle and heart of the RO-group.

The 18 : 2+20 : 4-pair was among the major fatty acids in the polar lipids. The levels were fairly constant through the experiment and little influenced by the dietary fats, with the exception of the CO-group. The values in this group averaged 17% compared to 32% for the other groups. The decrease corresponded remarkably well with the increased values for 20 : 5+22 : 6. The content of arachidonic acid was particularly low in the CO-group, and decreased with time of experiment. Other time effects were not obvious. The heart values were about 20% higher than those of the three other tissues.

20 : 5 + 22 : 6

These highly unsaturated ω-3-acids are major components in fish oils, and the capelin oil used contained 12%. This pair was found in the neutral lipids in all tissues in the CO-group, mainly in the liver (18%) balanced by

lowered 16 : 0/18 : 1 content, less in the three other tissues (3—7%). The polar lipids of the rat tissues showed as expected high values for the 20 : 5+22 : 6-acids. Again, capelin oil in the diet had a pronounced effect, the values in this group being nearly 3 times those in the other three groups. (Ave: 24% against 9%). Time of experiment gave only small changes in the concentration of these acids, with one noteworthy exception. The 22 - :6-concentration in the polar lipids of the HMF-group fell steadily. A corresponding increase was seen for both palmitic and linoleic acids. After 12 weeks, the values for 22 : 6 was only 21% of the one-week value (Fig. 2).

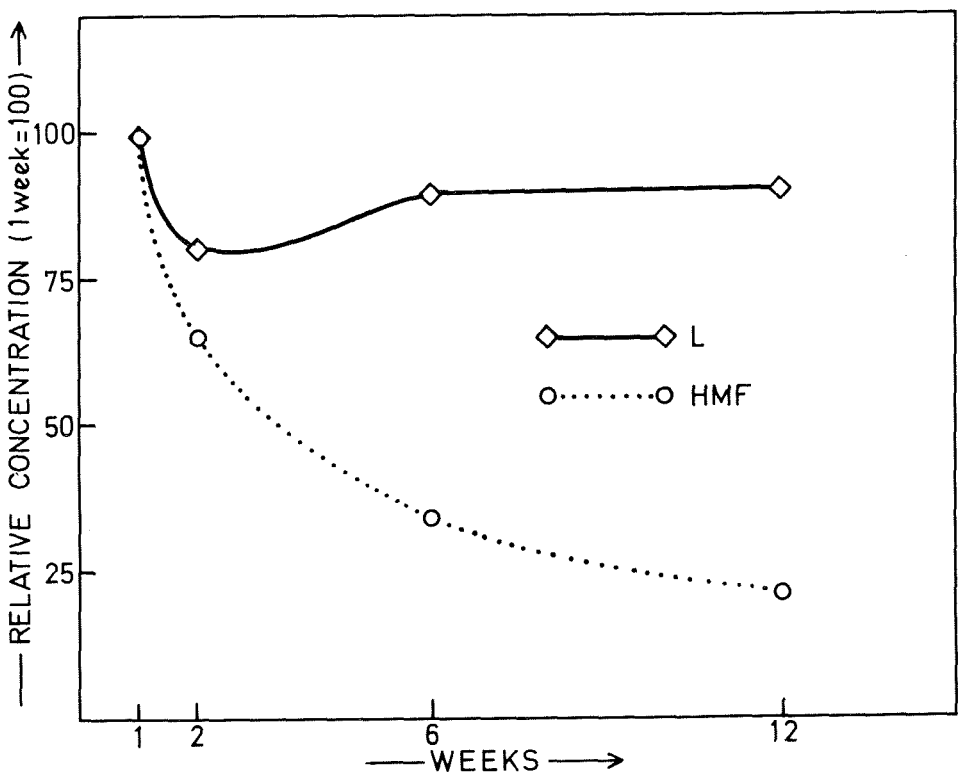

Fig. 2. *Percentage of 22:6 in the fatty acids of the polar lipids (phospholipids) of livers of rats fed during 12 weeks on 20 % fat diets. Values are given relative to the one-week values.*

SOME FATTY ACIDS CHARACTERISTIC FOR THE DIETARY FATS

Stearic acid, 18 : 0, represents 17.4% of the lard, compared to 0.5—5% in the other fats. Neutral lipids from the L-group tissues showed higher levels than those of the other groups. Polar lipids in the L-group remained at the start level, whereas those of the HMF-, LO- and RO-group fell to about 2/3 of that level. Only small variations were seen with time of sampling.

Linolenic acid, 18 : 3 ω 3, represented 9.9% of the rapeseed oil. It was present in all lipids samples from the RO-group, up to 6% in thigh muscle and adipose tissue neutral lipids, less in liver and heart lipids.

Saturated acids of chain length 20 and 22 were present in the hydrogenated marine fat (sum 4.1%), and could be seen in the neutral lipids from the HMF-group samples. Heart and adipose tissue levels reached 3% of these two acids.

Lastly, a raised level of 22 : 5 was seen in liver lipids in the CO-group. An average of 6% in neutral, and 4% in polar lipids were well above the content of 0.3% in the capelin oil.

20 : 1 AND 22 : 1

These long chain monoene acids were of particular interest in the present study. Table 2 shows the concentrations of these fatty acids in the dietary fats. The HMF and CO-fats both held 16% 20 : 1, and respectively 14% and 11% 22 : 1. The rapeseed oil had 8% 20 : 1 and 44 % 22 : 1. Table 3 shows that these acids were prominent in neutral lipids of the groups HMF, CO and RO, and that heart and brown adipose tissue showed the highest levels. The 20 : 1/22 : 1-pair was, in fact, the major fatty acid pair in heart and adipose tissue of the RO-group, with values of 40 and 38% respectively. Liver values were generally low, ranging from 8—12%.

Polar lipid concentrations of these acids were much lower, about a third to a half of those in neutral lipids. Again, heart and adipose tissue of the RO-group gave the highest values, 15% and 20% respectively, and liver of all groups the lowest values, 2—5%. With the exception of some values from the RO-group, all 20 : 1-values were higher than the 22 : 1-values. No obvious time effects were seen in the polar lipids.

Fig. 3 shows the effect of time on the concentrations of 20 : 1 and 22 : 1 in neutral lipids of the four tissues. As the concentration of these acids varied greatly in the dietary fats, it was found practical to give the tissue concentration values relative to the dietary intakes. The figure shows the difference in the fatty acid pattern between heart and thigh muscle, and the

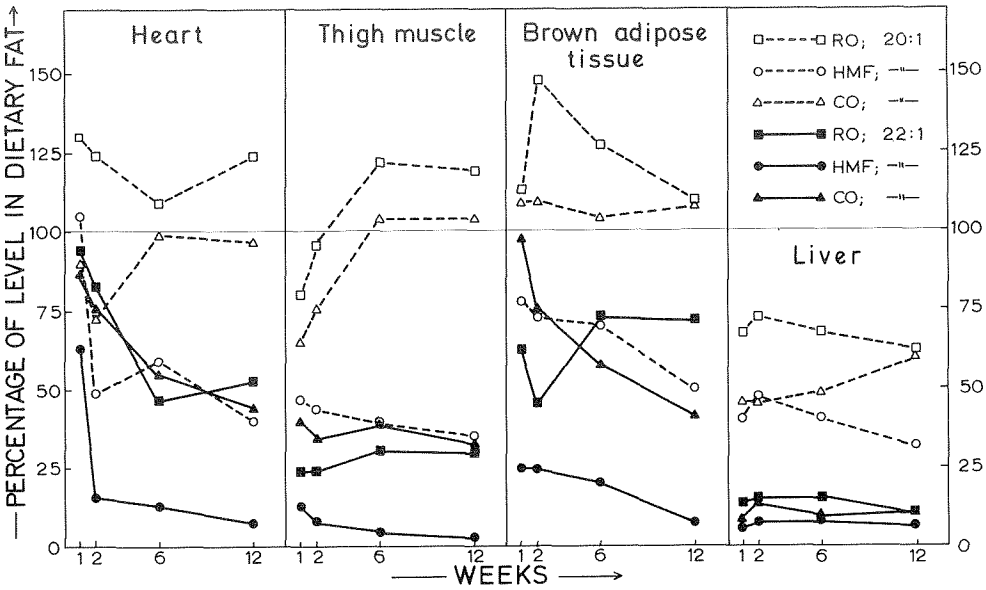

Fig. 3. *Percentages of 20:1 and 22:1 in the fatty acids of neutral lipids from four tissues of rats fed during 12 weeks on 20 % fat diets. Values are given relative to those in the dietary fats.*

corresponding similarity between heart and adipose tissue, pointing to the heart as a primarily fat metabolizing organ. Decreasing levels of 22 : 1 during the 12 weeks of experiment were seen mainly in the heart, (HMF-, CO- and RO-groups) and in brown adipose tissue (HMF- and CO-groups). Of further interest in Fig. 3 are the relative higher levels of 20 : 1 compared to the 22 : 1 in all groups and tissues. Lastly, it can be seen that the HMF-groups of all four tissues show the lowest relative levels of both 20 : 1 and 22 : 1. Absolute values of the contents of neutral lipid and 22 : 1 in the heart of the four groups are given in Table 4 and fig. 4. These values, based on small weights, are somewhat inaccurate, but show that a doubling of the levels of neutral lipid were found in the one- and two-week samples in the RO-groups. These values corresponded to a 10-fold increase of the concentration of 22 : 1 over the CO-group.

Table 4. *Neutral lipid (N. L.) and docosenoic acid (22:1) in heart tissue (mg per g of wet tissue).*

Fat group	1 week		2 weeks		6 weeks		12 weeks	
	N. L.	22:1	N. L.	22:1	N. L.	22:1	N. L.	22:1
HMF	25.7	2.31	4.9	0.11	20.6	0.39	29.5	0.35
CO	25.9	2.38	16.2	1.31	11.1	0.64	31.9	1.50
RO	56.0	23.18	32.9	12.01	12.6	2.60	24.1	5.62
L	26.6	tr.	8.1	0.04	15.0	0.06	23.4	0.07

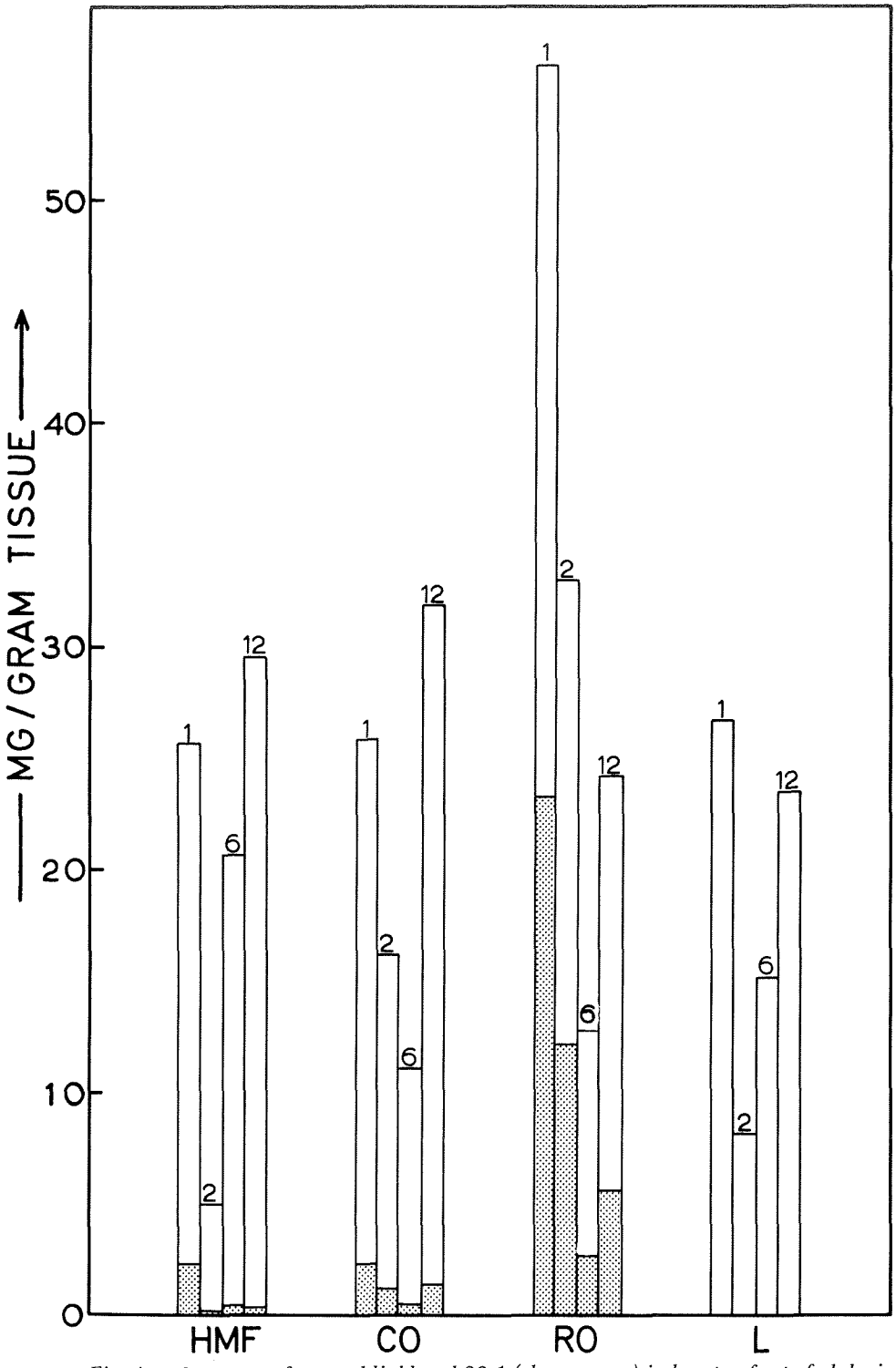

Fig. 4. *Contents of neutral lipid and 22:1 (shown grey) in hearts of rats fed during 12 weeks (figures on top of each column) on 20 % fat diets.*

DISCUSSION

The endogenous (biosynthesized) fatty acids of rat tissue triglycerides consist of 75 to 80 percent of palmitic and oleic acids in a 1 : 2 relation, the rest being mainly the lower homologues 14 : 0+16 : 1 (1 : 10), and up to 5% of stearic acid (BOTTINO & al., 1970, ANDERSON & al., 1970, PRIVETT & al., 1965). This fatty acid composition is in normal feeding modified by the exogenous (dietary) fatty acids. Linoleic acid is the main additional fatty acid on «natural» foods or on laboratory chows. Our earlier experiments showed that rat milk contained 20% of the ω-6 fatty acid pair linoleic and arachidonic acids in the relation 9 : 1, and corresponding contents in rat tissues at weaning (BRAEKKAN & al., 1968). Table 3 shows similar values for the control rats. These were analyzed at the start of the feeding experiment, after a 2 week preliminary feeding on increasing quantities of lard. It is seen that lard was a useful reference fat in the experiment. The high stearic acid level of 17.4% in the lard did not greatly influence the rat tissue concentrations.

It is well known that tissue fatty acid composition is particularly sensible to dietary intakes of polyenoic fatty acids, and this is also evident from Table 3. The tissue triglyceride levels of ω-6 acids followed closely the intakes of linoleic acid, and the overall average found was 102.5% of the dietary levels in the four tissues. Further dietary intakes of ω-3 polyenes were also reflected in the tissues. Linolenic acid from rape seed oil was found in the tissue triglyceride and polar lipids at 30—50% of the level in the oil. The highly unsaturated fish oil fatty acids 20 : 5 and 22 : 6 strongly influenced the tissue levels, particularly in the polar lipids (phospholipids), were the ω-6 acids were depressed correspondingly. The liver triglyceride level of this pair averagee 147% of the concentration in the dietary fish oil.

Fish oils from North Atlantic fish species are characterized by their high levels of the fatty acids 14 : 0, 16 : 1, 20 : 1 and 22 : 1 and correspondingly low levels of palmitic and oleic acid. The capelin oil and the partially hardened marine fat used in our experiment both had a total of 45% of these acids. The four acids were found in the rat tissue triglycerides in different proportions, and with correspondingly decreased levels of 16 : 0+18 : 1. Table 3 shows values for the 16 : 0+18 : 1 pair midway between those of the dietary fats and the levels in the tissues of the control and lard groups.

It may be noted that the 14 : 0+16 : 1 pair was deposited in the HMF-group tissues up to the dietary level, as compared to only 35% of the 20 : 1+22 : 1 pair. This is an accordance with our earlier observations using a 7% fat diet (BRAEKKAN & al., 1968).

The uptake in the rat heart tissue of 22 : 1 as erucic acid (ω-9) from rape seed oil or «cetoleic» acid (mainly ω-11) from fish oils has been studied by

BEARE-ROGERS and coworkers in Canada (BEARE-ROGERS & al., 1971, 1972 a and b, CONACHER & al., 1973, TEIGE & al., 1973). The effect of erucic acid feeding on several rat tissues was studied by WALKER (1972). These studies show very high levels of 22 : 1 in the heart tissue triglycerides during the first experimental week, accompanied by an increased lipid content followed by a decrease to normal levels during the next few weeks. The present study confirms this as seen in Fig. 3 and 4. In fact, the observed decrease of the acid 22 : 1 in heart and brown adipose tissue with the time of sampling, was among the few exceptions to the rather constant tissue levels of all fatty acids generally observed. Fig. 3 shows the similarity of the heart and brown adipose tissue fatty acids as opposed to the thigh muscle fatty acids. It may be noted that the high one-week values of 22 : 1 did not increase above the dietary levels, whereas this was found for many of the 20 : 1 concentrations. Fish oils are used in foodstuffs after hydrogenation, and it is of particular interest that the HMF-group levels of 22 : 1 in all samples were much lower than those from the non-hydrogenated fat diets. On diets containing 7% HMF, BRAEKKAN & al. (1968) could not detect the presence of 22 : 1 in the rat tissues. The many different isomers of 22 : 1, present in the HMF fat (LAMBERTSEN & al., 1971) may well be a possible reason for the lower deposition of these acids, compared to those from non-hydrogenated fats.

The lipid contents of the heart tissues (Table 4, Fig. 4) showed increased values for the rape seed oil group at the one-week sampling and for the CO- and RO-groups at the two-weeks sampling. TEIGE & al. (1973) found similar high one-week levels (ca. 50 mg/g) on a diet of hydrogenated herring oil. The fat given in their study contained 23.5% 22 : 1 and a total of 27.9% of the fatty acids was in trans form. The HMF of the present study contained 14.3% 22 : 1 and more than 50% of the fatty acids in trans form. Table 4 suggests that a doubling of the heart lipids follows a ten-fold increase of the 22 : 1 contents in the lipids.

This feeding experiment, using diets containing 20% of four different fats for 12 weeks, may give the following conclusions:

1. A balanced deposition between endogenous and exogenous fat was reached already after one week of feeding and remained fairly constant throughout the feeding period. The content of docosenoic acid in heart and brown adipose tissue was an exception.
2. Dietary ω-6 and ω-3 polyenoic acids were easily deposited in all tissues, the highly unsaturated ω-3 acids from the fish oil were found in phospholipids at levels well above those in the dietary fat. Hydrogenated marine fat, which contained only low levels of polyenoic acids, gave increased tissue levels of the short chain acids 14 : 1 and 16 : 1.
3. Relative to the dietary level, the acid 20 : 1 was found in higher concentrations than 22 : 1 in all tissues in the groups given HMF, fish oil and rape

seed oil. The group given HMF showed lower relative levels of both 20 : 1 and 22 : 1 than the groups on fish oils and rape seed oil.

4. On feeding fish oil and rape seed oil, docosenoic acid (22 : 1) was found in the heart one-week triglycerides at levels nearly up to that in the dietary fat. During the next weeks the levels fell to about half the dietary level. Similar values were found in the brown adipose tissue triglycerides.
5. In the group fed rape seed oil, the heart tissue neutral lipid content was about twice that in the other groups during the first two weeks and this corresponded to a ten-fold increased 22 : 1 content in the lipids.

REFERENCES

ABDULLATIF, A. M M. and VLEES, R. O., 1970, Nutr. Metabol. *12*, 285—294.

ANDERSON, R. E., BOTTINO, N. R., COOK, L. J. and REISER, R., 1970, Lipids *5*, 171—179.

BEARE-ROGERS, J. L., NERA, E. A. and HEGGTVEIT, H. A., 1971, Can. Inst. Food Technol, J. *4*, 120—124.

BEARE-ROGERS, J. L., NERA, E. A. and CRAIG, B. M., 1972, Lipids *7*, 46—50.

BEARE-ROGERS, J. L., NERA, E. A. and CRAIG, B. M., 1972, Lipids *7*, 548—552.

BOTTINO, N. R., ANDERSON, R. E. and REISER, R., 1970, Lipids *5*, 165—170.

BRAEKKAN, O. R., LAMBERTSEN, G., UTNE, F. and NJAA, L. R., 1968, Nutr. Dieta *10*, 24—44.

CONACHER, H. B. S., PAGE, B. D. and BEARE-ROGERS, J. L., 1973, Lipids *8*, 256—258.

LAMBERTSEN, G., MYKLESTAD, H. and BRAEKKAN, O. R., 1966, J. Food Science *31*, 48—52.

LAMBERTSEN, G., MYKLESTAD, H. and BRAEKKAN, O. R., 1971, J. Amer. Oil Chem. Soc. *48*, 389—391.

NJAA, L. R., BRAEKKAN, O. R., LAMBERTSEN, G. and UTNE, F., 1971, Nutr. Metabol. *13*, 207—221.

ODENSE, P. H. and BROCKERHOFF, H., 1971, J. Fish. Res. Bd. Canada, *28*, 1793—1795.

PRIVETT, O. S., BLANK, M. L. and VERDINO, B., 1965, J. Nutr. *85*, 187—195.

TEIGE, B. and BEARE-ROGERS, J. L., 1973, Lipids *8*, 584—587.

WALKER, B. L., 1972, Nutr. Metabol. *14*, 8—16.

Appendix

Table 1. *Fatty acid composition of neutral lipids of male rats fed a diet containing 20 % fat for 1, 2, 6 and 12 weeks.*

Fatty acid designation	At start	Hydrogenated marine fat				Fish oil (capelin)				Rape seed oil				Lard			
		1 week	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w
Liver																	
14:0	0.7	1.4	2.2	3.5	3.4	1.6	1.4	1.5	2.3	0.5	0.6	0.7	0.8	1.0	0.9	0.9	1.5
16:0	22.3	20.2	17.6	19.1	20.2	14.3	12.9	13.8	14.5	12.3	12.2	16.3	14.6	22.5	22.0	23.6	24.0
16:1	1.8	6.9	10.7	10.9	10.9	5.8	6.3	7.2	8.1	4.2	4.5	4.3	4.8	2.8	2.4	2.7	4.4
18:0	7.1	4.5	4.9	4.5	4.4	3.2	2.2	1.4	1.3	2.6	1.0	1.0	1.6	5.4	4.5	3.9	6.9
18:1	46.7	43.4	39.8	39.0	40.4	31.5	27.7	29.6	30.4	41.3	42.5	41.5	42.0	46.6	48.8	47.9	42.2
18:2	12.5	10.7	8.7	8.8	7.9	7.6	8.4	7.9	7.7	15.0	14.7	13.5	15.5	13.1	12.8	12.2	12.1
18:3	0.1	–	0.2	0.8	1.4	0.7	0.7	0.6	0.8	2.9	3.9	4.1	3.7	0.5	0.2	0.5	0.6
20:0	0.1	0.7	1.1	1.3	0.9	–	–	–	–	0.3	0.3	0.3	0.4	0.1	0.1	0.1	0.2
20:1	1.0	6.7	7.8	6.8	5.2	7.6	7.6	8.0	9.9	5.4	5.8	5.4	5.0	1.5	1.5	1.4	1.6
20:2–3	1.2	1.6	1.9	2.0	1.9	1.3	0.9	1.0	0.9	1.6	1.2	0.8	0.8	1.1	1.2	0.9	0.9
20:4	2.4	0.9	1.9	0.2	0.7	1.0	1.0	0.2	0.4	1.6	1.0	0.9	1.0	1.3	1.4	1.5	1.6
20:5	–	–	0.2	0.3	0.1	7.1	8.6	6.3	6.3	1.2	0.7	0.6	1.1	0.1	0.1	0.1	0.1
22:0	0.1	0.1	0.2	0.1	0.1	0.4	0.2	0.1	0.6	–	0.1	0.2	0.4	–	–	–	0.1
22:1	0.1	0.8	1.2	1.1	1.0	1.0	1.5	1.1	1.2	6.1	6.6	7.2	5.0	0.1	0.1	0.1	0.8
22:2–4	1.3	0.6	0.4	0.5	0.2	1.2	1.0	1.1	1.0	0.5	0.5	0.4	0.4	1.1	1.0	0.9	0.7
22:5	0.3	0.1	–	–	0.1	5.2	7.4	6.7	3.8	1.5	1.6	0.8	0.9	0.5	0.6	0.5	0.3
22:6	1.3	0.4	0.2	0.1	0.2	9.5	11.2	12.5	9.8	2.0	1.8	1.0	1.0	1.3	1.4	1.8	1.0
Heart																	
14:0	2.9	4.9	5.0	6.3	5.0	3.6	2.7	5.0	5.4	0.4	0.9	1.4	1.2	2.6	2.5	2.5	2.4
16:0	21.9	13.9	19.5	17.2	19.1	13.7	11.9	14.4	15.2	5.4	7.2	11.5	10.0	19.7	24.0	21.1	22.4
16:1	4.2	5.4	8.9	11.5	11.2	6.5	4.7	8.4	9.1	1.4	2.1	3.0	2.5	4.5	4.9	4.8	4.8
18:0	5.2	5.5	5.2	4.9	4.8	4.4	7.2	3.1	2.8	2.5	1.9	3.0	2.4	7.7	7.6	10.8	11.4
18:1	34.1	21.6	29.5	32.1	36.9	25.5	21.2	30.2	29.7	17.0	18.4	25.3	27.6	33.5	41.9	45.3	42.4
18:2	24.5	6.4	10.1	8.2	8.3	7.2	10.0	8.1	8.3	9.9	11.3	16.1	14.1	11.0	12.0	9.6	10.1
18:3	0.8	–	0.7	0.6	0.3	–	0.4	0.4	0.5	2.4	3.1	5.3	4.0	2.1	0.8	0.5	0.6
20:0	0.3	2.5	1.9	2.0	2.1	–	–	0.1	–	0.8	0.6	0.6	0.6	0.5	0.2	0.2	0.3
20:1	1.3	17.2	8.0	9.7	6.6	14.8	11.9	16.3	15.9	10.3	9.8	8.6	9.8	3.9	1.4	1.4	2.3
20:2–3	0.6	3.3	1.6	2.5	1.9	0.8	1.0	1.2	1.1	0.6	0.8	0.5	0.7	0.3	0.4	0.4	0.6
20:4	1.0	5.1	1.8	0.7	0.7	3.8	6.6	0.6	0.3	1.6	0.9	0.5	0.7	3.6	1.1	1.1	0.8
20:5	–	0.5	0.2	0.2	0.2	2.7	3.7	1.3	1.5	0.6	0.6	0.3	0.2	0.1	0.1	–	–
22:0	0.1	2.0	0.8	0.5	0.3	–	–	–	–	1.0	1.5	0.4	0.2	0.3	0.1	–	0.1
22:1	0.3	9.0	2.3	1.9	1.2	9.2	8.1	5.8	4.7	41.4	36.5	20.6	23.3	7.7	0.5	0.4	0.3
22:2–4	0.9	0.4	2.5	0.5	0.4	0.5	0.9	0.7	0.6	1.3	1.4	1.0	1.2	0.4	0.6	0.4	0.2
22:5	0.3	0.3	0.3	0.1	–	1.5	1.8	0.8	1.2	1.2	1.0	0.4	0.2	0.4	0.2	0.1	0.1
22:6	0.6	1.0	0.7	0.1	–	4.8	6.9	2.6	2.7	1.2	1.0	0.5	0.3	0.7	0.7	0.4	0.2

Table 1. *(cont.)*

Fatty acid designation	At start	Hydrogenated marine fat				Fish oil (capelin)				Rape seed oil				Lard			
		1 week	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w
Thigh muscle																	
14:0	3.9	4.	5.5	6.6	5.4	4.2	4.6	5.4	5.3	2.1	2.3	1.2	0.8	2.7	2.6	1.9	1.6
16:0	23.4	18.6	19.1	19.6	18.4	18.2	17.4	14.7	14.9	15.2	14.9	11.9	9.7	21.1	22.3	21.6	21.0
16:1	8.0	9.6	12.2	13.4	14.3	9.8	10.1	10.5	10.7	5.3	5.1	3.1	2.5	7.2	5.9	4.6	4.1
18:0	3.7	6.0	5.2	3.9	4.5	3.2	3.3	1.4	1.8	3.6	2.7	1.3	1.7	6.9	7.1	8.1	6.7
18:1	44.8	37.0	35.1	37.4	37.4	33.1	34.2	32.2	33.9	35.0	33.3	30.7	32.6	46.0	46.0	49.6	53.2
18:2	11.9	8.9	8.9	7.6	8.7	7.6	7.2	7.7	7.8	13.4	14.2	17.2	18.9	10.5	11.4	10.0	9.6
18:3	0.6	–	0.6	0.6	1.0	0.5	0.5	0.4	0.3	4.9	5.9	7.1	7.7	0.7	0.7	0.6	0.6
20:0	0.2	1.2	1.1	0.8	1.1	0.1	–	–	–	0.4	0.6	0.6	0.4	0.2	0.1	0.1	0.1
20:1	1.1	7.7	7.2	6.4	5.8	10.6	12.4	17.0	17.1	6.3	7.6	9.6	9.4	1.5	1.3	1.5	1.0
20:2–3	0.5	2.3	1.7	1.5	1.4	1.5	1.0	0.8	0.7	0.3	0.3	0.6	0.7	0.5	0.2	0.5	0.4
20:4	0.3	0.5	0.4	0.1	0.2	0.7	0.2	0.2	0.1	0.5	0.4	0.3	0.5	0.6	0.5	0.3	0.3
20:5	–	0.2	0.2	0.1	0.1	2.0	1.7	1.7	0.9	0.3	0.1	0.1	0.1	0.1	0.1	–	–
22:0	–	0.3	0.3	0.2	0.2	0.1	–	–	–	–	0.2	0.2	0.1	–	–	–	–
22:1	0.1	1.9	1.1	0.7	0.5	4.2	3.7	4.1	3.5	10.8	10.6	13.9	13.0	0.3	0.2	0.1	–
22:2–4	0.2	0.2	0.2	0.1	–	0.3	0.2	0.3	0.3	0.3	0.4	0.8	0.6	0.2	0.2	–	0.2
22:5	0.1	–	–	–	–	0.7	0.6	0.7	0.5	0.2	0.2	0.2	0.1	0.1	0.1	–	0.1
22:6	0.2	0.2	0.2	–	–	2.2	1.9	1.9	1.2	0.4	0.2	0.2	0.2	0.4	0.3	0.1	0.1
Brown adipose tissue																	
14:0	2.5	6.0	5.0	6.0	6.2	3.8	4.0	4.9	4.4	0.9	1.2	0.8	0.4	2.3	2.5	3.3	3.1
16:0	24.0	18.2	20.1	17.3	19.5	13.5	15.3	15.7	15.9	9.2	9.8	8.7	8.3	21.7	23.1	20.8	22.6
16:1	4.5	7.6	8.7	9.6	10.4	6.4	6.4	6.4	6.7	1.8	2.1	1.2	1.5	3.9	3.4	4.4	4.8
18:0	7.7	5.3	5.0	5.4	4.2	3.8	5.2	5.1	4.4	2.4	2.0	1.5	2.0	13.7	12.6	10.9	10.4
18:1	46.0	28.0	28.1	30.7	35.7	24.0	26.2	28.2	32.0	22.2	22.6	20.2	21.9	41.5	45.1	47.8	45.9
18:2	10.6	10.0	7.3	8.1	7.2	9.3	7.9	7.5	8.1	15.3	17.3	15.4	15.4	11.9	8.4	9.1	9.3
18:3	0.6	–	–	–	1.0	0.6	0.5	0.4	0.2	5.9	6.6	5.6	4.2	0.6	0.3	0.4	0.4
20:0	0.2	2.6	3.2	2.6	1.7	–	0.2	0.1	0.2	0.7	0.7	0.4	0.6	0.4	0.3	0.2	0.2
20:1	1.5	12.8	11.9	11.4	8.2	17.8	17.8	17.0	17.7	8.9	11.7	10.0	8.6	2.0	2.0	1.5	1.2
20:2–3	0.5	1.9	2.4	2.3	1.8	1.8	1.3	1.2	1.4	0.8	0.8	0.3	0.7	0.2	0.4	0.3	0.4
20:4	0.3	1.1	1.5	0.9	0.5	0.5	0.2	0.2	0.2	0.6	0.7	0.3	0.6	–	0.4	0.2	0.4
20:5	–	0.5	0.8	0.3	0.2	2.1	1.3	1.4	0.8	0.4	0.5	0.5	0.6	–	–	–	–
22:0	–	1.1	0.9	0.7	0.8	0.1	0.1	–	–	0.7	0.5	0.2	0.3	–	0.1	–	–
22:1	0.1	3.6	3.6	2.9	1.2	10.4	8.1	6.1	4.4	27.7	20.5	32.1	31.9	0.2	0.2	0.1	–
22:2–4	0.3	0.3	0.5	0.7	0.4	0.7	0.7	0.3	0.3	1.0	1.3	1.1	1.3	0.3	0.1	–	0.2
22:5	0.1	–	–	0.1	–	0.9	1.0	1.2	0.7	0.2	0.3	0.3	0.3	0.1	–	–	–
22:6	0.1	–	–	–	–	3.3	2.5	3.3	1.6	0.3	0.4	0.4	0.4	0.2	0.1	–	0.1

Appendix
Table 2. *Fatty acid composition of polar lipids of male rats fed a diet containing 20 % fat for 1, 2, 6 and 12 weeks.*

Fatty acid designation	At start	Hydrogenated marine fat				Fish oil (capelin)				Rape seed oil				Lard			
		1 week	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w
Liver																	
14:0	0.1	0.4	0.4	0.5	0.7	0.6	0.6	0.4	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.1	0.3
16:0	14.0	11.4	11.6	11.2	11.2	14.3	11.9	12.8	15.3	11.8	11.7	12.2	11.5	14.0	14.3	13.2	13.5
16:1	0.5	4.7	4.0	3.6	4.0	2.9	2.8	3.5	3.0	2.6	3.3	1.8	1.8	1.1	0.7	0.7	1.2
18:0	21.2	15.4	15.4	17.2	17.3	14.3	12.4	14.1	14.7	12.3	9.5	14.8	15.4	20.6	21.2	21.3	21.6
18:1	13.8	19.6	19.6	19.2	19.3	12.9	13.3	15.2	16.5	18.1	27.4	18.2	19.1	13.5	13.4	14.9	14.1
18:2	10.0	12.8	13.8	13.1	13.0	6.5	5.7	7.0	7.4	12.5	15.0	13.0	11.9	10.7	10.4	10.9	8.6
18:3	–	–	–	0.1	0.2	0.1	0.3	0.2	0.2	2.1	2.4	1.4	1.5	–	–	–	–
20:0	0.1	0.2	0.1	0.2	0.1	–	–	–	–	0.4	0.4	0.3	0.2	0.1	0.1	0.1	0.2
20:1	0.2	1.8	1.8	1.7	1.8	3.5	3.4	4.5	4.5	2.8	4.0	2.9	3.3	0.3	0.3	0.4	0.5
20:2–3	1.4	4.1	4.2	5.3	5.3	1.0	9.8	1.4	1.6	1.6	0.9	1.8	1.7	1.3	1.3	2.0	1.9
20:4	22.1	16.5	18.3	20.2	20.3	9.1	6.8	6.7	7.4	16.3	12.0	17.6	18.2	24.0	24.2	25.6	27.6
20:5	0.1	0.2	0.1	0.1	0.1	10.7	13.4	11.9	10.4	4.0	2.6	2.7	2.7	0.3	0.3	0.3	0.2
22:0	0.1	0.1	–	–	–	0.1	0.1	–	–	–	0.1	0.1	0.2	0.1	0.1	–	–
22:1	0.2	0.4	0.4	0.2	0.3	0.5	0.5	0.5	0.6	0.8	1.9	1.2	1.3	0.1	0.2	0.1	–
22:2–4	1.2	1.6	1.6	3.1	3.1	0.5	0.6	0.5	0.5	0.4	0.5	0.2	0.2	0.6	0.6	0.7	0.5
22:5	0.6	0.3	0.1	0.1	0.1	4.0	6.5	4.3	2.1	2.6	1.8	1.8	1.4	0.7	0.9	0.6	0.4
22:6	13.4	9.5	7.6	3.2	2.2	18.0	19.9	16.0	14.3	10.3	5.1	8.7	8.3	11.4	10.8	8.1	8.4
Heart																	
14:0	0.8	1.0	1.3	1.3	1.9	0.8	1.3	2.0	2.1	0.3	0.3	0.7	0.5	0.4	0.7	1.1	0.7
16:0	10.7	8.7	8.3	8.0	8.6	10.1	9.3	9.2	10.1	9.2	5.0	8.2	6.5	10.6	11.4	10.9	10.6
16:1	1.0	2.2	3.1	3.3	4.4	2.4	2.8	4.5	3.2	1.5	1.3	1.6	1.0	1.1	1.5	2.4	1.0
18:0	17.6	14.1	10.9	11.0	9.3	12.8	12.5	6.5	13.3	11.4	7.5	5.4	10.4	17.7	19.2	15.3	17.4
18:1	13.0	15.4	14.9	14.4	16.5	13.0	13.7	14.5	14.9	22.7	14.4	16.3	13.7	14.0	17.9	15.1	14.4
18:2	23.2	22.5	23.4	24.4	24.8	15.1	12.2	20.3	16.0	18.3	19.5	35.0	23.4	17.5	16.6	15.8	14.4
18:3	0.3	–	–	–	–	–	0.4	0.2	0.3	1.8	2.7	3.3	2.2	0.2	0.1	0.2	0.2
20:0	0.1	0.2	0.6	0.4	0.6	–	0.1	–	–	0.5	0.4	0.2	0.3	0.1	0.1	–	–
20:1	0.5	3.1	6.3	4.6	4.3	3.0	4.5	6.0	8.1	3.0	6.7	3.2	4.6	0.2	0.9	2.1	0.9
20:2–3	1.2	0.5	2.6	3.0	3.0	0.5	1.2	1.6	1.4	0.7	1.3	1.1	1.3	0.5	0.9	1.5	1.1
20:4	14.9	18.3	17.1	21.0	19.0	11.5	8.9	5.7	4.3	11.4	12.7	9.6	14.4	18.3	15.6	15.8	18.7
20:5	–	–	0.5	0.2	0.1	4.1	5.5	5.0	3.6	0.3	1.0	0.5	0.6	–	0.1	1.0	1.0
22:0	0.2	0.2	0.5	0.3	0.1	–	0.2	–	–	0.2	0.4	0.2	0.2	–	0.1	0.2	–
22:1	0.4	0.6	1.9	1.3	1.0	0.1	2.0	2.3	3.4	6.0	19.1	7.0	10.9	0.2	0.5	0.8	0.2
22:2–4	2.0	1.6	1.8	2.6	3.1	0.6	0.5	0.6	1.1	0.5	0.5	0.2	1.0	2.1	1.8	1.4	2.5
22:5	1.2	0.8	0.5	0.1	0.1	2.8	3.0	2.1	2.6	2.2	1.8	1.6	2.2	1.8	2.3	1.8	2.3
22:6	11.9	9.8	5.3	3.1	2.2	22.2	20.9	18.5	14.6	9.0	4.4	4.9	5.8	14.3	9.3	13.6	13.6

Table 2. *(cont.)*

Fatty acid designation	At start	Hydrogenated marine fat				Fish oil (capelin)				Rape seed oil				Lard			
		1 week	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w	1 w	2 w	6 w	12 w
Thigh muscle																	
14:0	1.2	1.8	2.0	1.8	2.6	2.1	2.1	2.0	2.1	1.6	1.1	0.6	0.6	0.8	1.0	0.8	0.5
16:0	13.9	9.0	12.7	11.7	15.0	10.1	13.6	14.9	15.4	9.5	11.0	10.0	12.6	10.6	13.6	15.9	16.0
16:1	2.4	5.9	6.0	6.6	7.4	4.6	5.0	5.3	4.8	3.5	3.6	1.9	1.8	1.8	1.9	1.2	1.3
18:0	15.2	13.3	13.1	13.2	9.8	13.5	11.0	10.1	9.6	13.0	10.2	12.2	10.6	18.3	16.6	16.3	15.6
18:1	19.9	16.7	21.5	19.9	21.0	14.1	18.8	15.5	17.4	16.4	18.7	16.5	19.2	13.8	19.0	15.8	18.0
18:2	18.7	15.7	15.5	18.8	19.4	11.1	9.8	12.1	11.3	16.9	18.9	19.1	19.8	14.5	13.6	12.7	10.9
18:3	0.2	0.1	–	–	–	–	0.5	0.2	0.3	2.7	3.2	1.8	3.5	0.1	0.3	0.2	0.3
20:0	0.2	0.1	0.6	0.4	0.5	0.1	–	–	–	0.2	0.1	0.3	0.3	0.2	0.1	0.1	0.1
20:1	0.5	2.6	3.6	3.8	2.8	4.2	6.7	4.4	6.8	3.4	4.0	4.0	4.1	0.7	0.7	0.5	0.6
20:2–3	0.9	1.6	1.8	2.6	2.6	0.7	0.9	0.7	0.8	0.8	1.4	1.6	1.1	1.3	1.3	1.0	1.4
20:4	10.9	14.5	10.3	12.3	12.8	7.5	4.5	2.9	2.7	10.7	9.1	10.6	8.4	15.6	12.7	13.9	15.0
20:5	–	–	0.1	–	–	3.1	2.9	3.2	2.3	0.6	0.9	0.6	0.5	0.2	0.1	–	–
22:0	–	–	–	0.1	0.2	0.1	0.2	–	0.2	–	–	0.1	–	0.1	0.1	0.1	0.2
22:1	–	1.0	0.7	0.7	0.5	1.1	1.7	0.8	0.9	2.5	3.6	4.2	4.3	0.5	0.3	0.4	0.3
22:2–4	0.9	1.3	1.2	1.2	1.4	0.8	0.8	0.8	0.4	0.8	0.8	0.7	0.7	2.1	1.7	1.8	1.0
22:5	2.2	2.0	1.3	0.5	0.2	3.7	2.8	3.2	2.7	3.0	2.8	3.9	2.6	3.3	2.9	3.0	3.0
22:6	11.9	13.4	8.6	5.4	2.8	22.2	17.7	22.9	21.3	13.4	9.6	10.9	8.9	15.1	13.1	15.3	14.8
Brown adipose tissue																	
14:0	1.1	3.1	3.7	3.1	4.1	2.3	3.5	3.1	2.3	0.6	0.9	0.4	0.8	1.2	1.9	1.2	1.3
16:0	13.0	13.8	12.7	15.2	15.8	11.3	12.5	14.1	13.0	9.9	8.9	9.0	9.6	16.1	13.0	14.9	15.1
16:1	2.3	5.7	8.2	6.3	8.8	4.2	5.8	4.7	4.1	1.8	2.0	1.5	1.5	2.8	4.0	2.4	2.4
18:0	16.3	9.8	7.0	9.5	8.5	12.3	9.5	12.6	15.1	8.0	4.9	8.1	7.8	17.3	12.2	17.4	16.2
18:1	31.0	19.9	24.6	23.8	27.7	16.7	20.2	21.4	20.9	16.5	18.5	19.0	25.6	33.2	33.9	33.9	31.4
18:2	19.3	13.4	15.6	14.0	12.7	9.3	9.5	8.9	9.5	20.1	19.4	18.5	18.2	14.9	20.0	13.6	13.8
18:3	0.4	–	–	–	0.3	0.6	0.9	0.3	0.4	5.7	6.6	4.9	4.8	0.4	0.7	0.3	0.4
20:0	0.3	1.2	1.1	1.2	1.2	–	–	–	–	0.4	0.5	0.5	0.4	0.2	0.3	0.1	0.1
20:1	0.8	6.7	6.7	6.1	4.8	7.6	7.5	8.6	8.6	4.3	7.1	5.0	4.2	1.1	1.2	0.7	0.9
20–2–3	0.4	1.7	3.3	2.2	2.3	0.9	2.0	0.8	0.8	0.6	0.6	0.6	0.9	0.2	0.4	0.4	0.8
20:4	11.3	18.2	11.6	14.3	10.3	8.2	5.8	4.5	4.8	14.2	6.8	10.1	10.1	15.2	9.6	12.2	12.8
20:5	–	–	0.1	0.2	0.2	9.0	8.7	8.2	7.5	1.2	0.8	1.2	1.1	0.2	0.2	–	0.1
22:0	–	0.4	0.3	0.3	0.3	1.7	0.3	0.2	–	0.4	0.6	0.2	–	0.1	–	–	–
22:1	0.2	2.2	2.4	1.8	1.1	3.7	2.9	2.8	3.3	10.1	17.5	15.0	14.6	0.4	0.3	0.2	0.9
22:2–4	0.9	0.6	0.6	0.7	0.7	0.4	0.2	0.3	0.3	0.6	0.9	0.9	1.1	0.9	0.6	0.5	1.0
22:5	0.3	0.2	0.1	–	–	1.7	1.9	1.6	1.6	1.0	0.9	1.2	1.2	0.6	0.4	0.3	0.4
22:6	1.4	2.1	1.0	0.3	0.2	9.1	7.8	6.9	6.8	3.6	2.1	3.4	3.7	1.8	1.0	0.9	1.4