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FATTY ACIDS IN DEPOT FATS OF GREEN TURTLES *CHELONIA MYDAS* FROM THE HAWAIIAN ISLANDS AND JOHNSTON ATOLL

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Abstract—1. Depot fat samples from thirteen individual mid-Pacific turtles *Chelonia mydas* were examined for overall fatty acid composition.

2. It can be concluded from analysis of fatty acids that the mid-Pacific green turtles generally synthesize their triglyceride depot fats with at least one, but not more than two, positions occupied by 12:0 and 14:0, possibly with 16:0 and 16:1 as well.

3. These two fatty acids are probably utilized as temporary energy storage and are synthesized from acetate originating in the gut from dietary carbohydrates.

4. The most probable source of dietary carbohydrate is benthic algae. These, their epiphytes, and gut bacteria also contribute numerous minor and trace unsaturated fatty acids.

5. A select group of four oils of high iodine value (> 100) are shown to have a higher than common concentration of 22:6n-3–22:5n-3. This suggests a particular dietary source of fatty acids different from the other samples, possibly including jellyfish or other animal matter.

INTRODUCTION

The marine turtles are a fascinating group of animals in some danger of disappearing (Thompson, 1988; Davenport *et al.*, 1990). Through energy conservation practices (Naito *et al.*, 1990; Sakamoto *et al.*, 1990) they are capable of extended migration over thousands of miles, presumably without food *en route* (Bustard, 1972). The fact that the bodies are therefore rich in oil has long been known but relatively little work on the composition of their oils (Hilditch and Williams, 1964) was possible until the development of gas–liquid chromatography. In the last three decades details on the fatty acids of depot fats for a considerable number of species have been published (Ackman *et al.*, 1971; Joseph *et al.*, 1985; Holland *et al.*, 1990).

In the western Atlantic, turtle grass *Thalassia testudinum* is a basic food of the green turtle *Chelonia mydas* (Bjorndal, 1980; Williams, 1988). The range of the green turtle includes the Pacific Ocean, where several sea-grasses are found (Nichols and Johns, 1985). However, in mid-Pacific these grasses are often scarce and alternative diets must be the norm. In an attempt to continue the *C. mydas* food chain observations published for Caribbean samples (Joseph *et al.*, 1985) we have examined green turtle depot fat samples from thirteen animals of the Hawaiian Islands and Johnston Atoll mid-Pacific region.

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MATERIALS AND METHODS

Samples of freshly biopsied depot fats from field studies of *C. mydas* were tightly packed in glass vials and flown to Halifax, and stored frozen at −30°C until analyzed. The fat was dissolved in petroleum ether and the triglycerides purified by thin-layer chromatography on silica gel. Conversion of triglycerides to methyl esters with 7% BF3-MeOH was followed by gas–liquid chromatography in a PE-8420 apparatus on a column of flexible fused silica with a bonded Carbowax-20M coating (SUPELCOWAX-10, 30 m × 0.25 mm i.d.). Operating conditions were: hold at 185°C for 8 min, program to 220°C at 1°/min, and hold, as described and illustrated by Ackman (1987). Peak areas were converted to weight per cent fatty acids by a program (Ackman and Eaton, 1978) incorporating flame ionization correction factors (Craske and Bannon, 1988) and simultaneously providing a calculated iodine value.

RESULTS

The fourteen analyses of triglycerides included one duplicate analysis (Table 1). Basically, all had four important saturated acids ranging in total from 37 (w/w)% to just over 50 (w/w)%. Similarly, monoethylenic acid totals ranged from 35 (w/w)% to 45 (w/w)%. There were few distinctive characteristics among the polyunsaturated fatty acids, but the calculation of (w/w)% fatty acids by the computer program also provided the calculated iodine value. This is a fair summation of the numbers of ethylenic bonds in all types of fats (Hilditch and Williams, 1964), including marine oils of fish and mammal origin (Ackman, 1982). Accordingly the samples of Table 1 are organized in descending order of calculated iodine

Table 1. Fatty acids (w/w%) of depot fats of mid-Pacific green turtles with group designations and origins from Hawaii or Johnston Atoll

	Group I				Group II				Group III					
Sample nos.	6	11	2	10	13	5*	4*	9	15	7	3	8	12	14
Geographical origin	HI	JA	HI	JA	JA	HI	HI	JA	JA	HI	HI	JA	JA	JA
Fatty acid														
10:0	tr	1.34	0.71	2.64	2.03	0.85	0.99	0.91	1.58	0.53	0.33	0.67	0.57	1.56
12:0	6.60	6.56	10.93	10.09	13.17	16.78	18.05	16.02	16.04	13.18	11.17	20.32	20.67	17.54
13:0	0.33	0.36	0.22	0.41	0.49	0.29	0.32	0.26	0.40	0.13	0.20	0.22	0.19	0.38
14:0	6.98	5.86	7.83	6.87	9.26	9.25	9.51	10.17	10.74	9.75	11.06	11.45	11.97	11.55
15:0	0.59	0.75	0.54	0.52	0.48	0.25	0.24	0.29	0.32	0.20	0.25	0.33	0.20	0.11
116:0	0.36	0.21	0.17	0.19	0.20	0.09	0.08	0.12	0.10	0.08	0.07	0.08	0.07	tr
16:0	13.90	13.12	14.11	14.50	14.59	15.79	15.63	15.83	16.11	19.14	16.36	14.96	15.89	16.70
17:0	1.11	0.95	0.65	0.65	0.54	0.28	0.26	0.36	0.30	0.11	0.82	0.23	0.20	0.24
18:0	4.86	5.79	5.04	5.38	4.59	4.83	4.78	4.70	4.89	5.49	6.67	4.12	4.18	4.95
20:0	1.87	0.54	0.50	0.70	0.37	0.09	0.09	0.31	0.17	0.10	0.21	0.08	0.09	0.09
22:0	0.39	0.29	0.23	0.19	0.17	0.02	0.14	0.12	0.09	0.16	0.13	0.08	0.08	0.07
Σ Saturates	36.99	35.77	40.93	42.14	45.89	48.52	50.09	49.09	50.74	48.87	47.27	52.54	54.11	53.19
14:1n-5	0.38	0.39	0.49	0.46	0.60	0.56	0.57	0.72	0.69	0.62	0.61	0.75	0.77	0.69
16:1n-7†	4.96	5.85	6.08	7.05	7.15	6.50	6.35	8.85	8.25	8.42	5.90	8.28	9.23	8.99
16:1n-5	0.10	0.17	0.24	0.13	0.15	0.14	0.13	0.14	0.19	0.11	0.10	0.15	0.14	0.14
18:1n-9	20.84	26.94	22.79	24.99	24.85	25.43	24.34	26.31	26.29	30.46	33.92	28.07	25.71	27.42
18:1n-7	2.31	2.80	2.99	2.97	3.18	3.99	4.04	3.50	3.77	2.48	2.95	3.56	3.81	3.69
18:1n-5	0.18	0.25	0.24	0.20	0.24	0.29	0.27	0.31	0.35	0.17	0.15	0.33	0.32	0.30
20:1n-11	0.51	0.30	0.32	0.36	0.18	0.13	0.11	0.09	0.08	0.06	0.17	0.12	0.09	0.11
20:1n-9	1.04	1.24	0.96	0.59	0.60	0.40	0.28	0.35	0.42	0.35	0.82	0.29	0.26	0.28
20:1n-7	0.37	0.27	0.27	0.18	0.14	0.10	0.09	0.12	0.14	0.08	0.18	0.11	0.10	0.10
22:1n-11, n-13	1.80	0.17	0.69	0.54	0.40	0.11	0.15	0.29	0.16	0.21	0.21	0.11	0.11	0.11
22:1n-9	0.65	0.59	0.33	0.23	0.22	0.19	tr	0.16	0.09	0.38	0.12	0.07	0.09	0.06
24:1	2.61	0.73	0.98	0.82	0.57	0.32	0.49	0.30	0.20	0.57	0.38	0.15	0.17	0.14
Σ Monoenes	35.75	39.70	36.38	38.52	38.28	38.16	36.82	41.14	40.63	43.91	45.51	41.99	40.80	42.03
16:2n-7	1.02	0.67	0.53	0.68	0.44	0.08	0.15	0.29	0.15	0.15	0.08	0.20	0.08	0.09
18:2n-6	0.54	0.61	0.63	0.54	0.37	0.97	0.90	0.24	0.26	0.39	0.24	0.16	0.14	0.14
18:2n-4	0.23	0.37	0.25	0.23	0.23	0.34	0.30	0.15	0.18	0.24	0.03	0.21	0.11	0.18
20:2NMID	0.10	0.06	0.10	0.04	0.08	0.13	0.12	0.07	0.08	0.20	0.73	0.06	0.08	0.05
20:2n-9	0.05	0.07	0.09	0.11	0.10	0.02	tr	0.13	0.16	0.02	0.14	0.05	0.20	0.17
20:2n-6	0.33	0.38	0.32	0.25	0.20	0.21	0.19	0.19	0.18	0.20	0.16	0.19	0.20	0.18
Σ Dienes	2.27	2.16	1.92	1.85	1.42	1.75	1.66	1.07	1.01	1.20	1.38	0.87	0.81	0.81

Continued opposite

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Table 1. *Continued*

	Group I				Group II				Group III					
Sample Nos.	6	11	2	10	13	5*	4*	9	15	7	3	8	12	14
Geographical *origin*	HI	JA	HI	JA	JA	HI	HI	JA	JA	HI	HI	JA	JA	JA
Fatty acid														
16:3n-6	0.43	0.75	0.52	0.55	0.55	0.57	0.52	0.44	0.05	0.23	0.17	0.30	0.24	0.30
16:3n-3	0.46	0.52	0.28	0.30	0.21	0.20	0.21	0.11	0.14	0.28	tr	0.05	0.05	0.05
18:3n-6	0.12	0.14	0.11	0.12	0.07	0.10	0.09	0.04	0.03	0.05	0.02	0.02	0.03	0.02
18:3n-4	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
18:3n-3	0.19	0.28	0.34	0.21	0.19	1.37	1.29	0.14	0.21	0.36	tr	0.14	0.10	0.11
20:3n-9	0.02	tr	0.23	tr	0.18	tr	tr	0.03	0.02	tr	0.04	0.02	0.02	0.02
20:3n-6	0.09	0.17	0.11	0.16	0.32	0.35	0.31	0.13	0.13	0.26	0.31	0.14	0.10	0.10
20:3n-3	0.23	0.11	0.11	0.07	0.24	0.05	0.16	0.23	0.17	0.15	0.06	0.17	0.14	0.16
Σ Trienes	1.54	1.97	1.70	1.41	1.76	2.64	2.58	1.12	0.75	1.33	0.60	0.84	0.68	0.76
18:4n-3	0.22	0.19	0.21	0.24	0.14	0.50	0.51	0.11	0.10	0.09	0.04	0.07	0.07	0.06
18:4n-1	tr	tr	0.03	tr	0.01	0.01	tr	0.01	tr	tr	0.02	tr	0.01	tr
20:4n-6	0.74	1.68	1.47	1.35	0.98	1.16	1.11	0.71	0.80	1.08	0.42	0.52	0.40	0.37
20:4n-3	0.23	0.38	0.24	0.31	0.25	0.43	0.40	0.18	0.12	0.13	0.14	0.13	0.10	0.10
22:4n-6	1.66	1.60	2.02	1.16	1.07	0.60	0.70	0.38	0.39	0.38	0.93	0.28	0.26	0.20
22:4n-3	0.23	0.10	0.12	0.08	0.09	0.12	0.11	0.08	0.06	0.11	0.09	0.06	0.09	0.04
Σ Tetraenes	3.08	3.95	4.09	3.14	2.54	2.82	2.83	1.47	1.47	1.79	1.64	1.06	0.93	0.77
20:5n-3	0.39	1.24	1.04	1.48	1.17	1.60	1.63	1.20	1.05	0.92	0.27	0.73	0.51	0.49
21:5n-3	0.15	0.15	0.13	—	—	0.14	0.13	—	—	0.21	0.49	0.16	—	—
22:5n-6	1.96	1.60	1.61	0.89	0.68	0.19	0.22	0.32	0.43	0.18	0.10	0.10	0.15	0.11
22:5n-3	3.71	2.57	2.65	2.10	1.99	2.95	2.83	1.60	1.31	1.18	1.65	1.15	0.72	0.71
Σ Pentaenes	6.21	5.56	5.43	4.47	3.84	4.88	4.81	3.12	2.79	2.49	2.51	2.14	1.38	1.31
22:6n-3	13.63	10.24	9.07	7.91	4.79	0.77	0.81	2.29	1.56	0.50	0.37	0.30	0.47	0.35
Iodine value (Calc.)	131.49	122.54	112.72	102.74	86.88	74.31	72.72	68.60	63.11	61.17	59.57	53.44	50.58	50.52

*Same animal.
†Includes *trans*-6-hexadecenoic acid (Ackman *et al.*, 1971).

value and are divided arbitrarily into three groups for discussion purposes. Samples with numbers 8–14 were collected at Johnston Atoll but this does not bias the assignment by calculated iodine value, some falling into each group. The four turtle oils with iodine values of 131–103 (Group I) are in the low range for fish oils, but comparable to some herring oils (Ackman and Eaton, 1970). However, in many fish oils the "basic composition" of fish oils (Ackman *et al.*, 1988) is modified by two exogenous long-chain monoethylenic fatty acids, usually with 22:1 > 20:1. The Group I mid-Pacific turtle oils actually contained slightly more saturated fatty acids than marine fish oils which can often have up to 30% of such acids (Ackman, 1988). The four Group I oils have 16:0 (palmitic acid) and 14:0 (myristic acid) represented in about the same proportions, 13–14%, and 6–11% respectively, as are found in most fish oils (Ackman, 1982), but there is about 5% stearic acid in the turtle oils vs about 1% in most fish oils. A second and definitely a key factor differentiating the turtle total saturated acids from those of fish oils is the 12:0 (lauric acid) present in proportions as high as 11%. This acid is present only in traces in fish oils.

The monoethylenic fatty acids in the turtle oils are dominated by the ubiquitous 18:1n-9 (oleic) acid, accompanied by the 18:1n-7 isomer (*cis*-vaccenic acid) in a 10:1 proportion. In clupeid fish oils, which are rich in 22:1, the 22:1n-11 isomer (cetolic acid) is of exogenous origin (Ackman *et al.*, 1980) and dominant. In the turtle fats the 22:1n-9 (erucic acid) isomer is about as important, and is potentially of endogenous origin, as is the 16:1n-7 (palmitoleic acid). In this group the dienoic and trienoic polyunsaturated fatty acids are all minor, as is also not unusual in marine fish oils. The tetraenoic acids show enrichment in both 20:4n-6 (arachidonic acid) and the higher homologue 22:4n-6 (adrenic acid). The 20:4n-6 is about three to four times as important as in clupeid fish oils, and the equally obvious 22:4n-6 is about 10 times as important as in the fish oils. These two fatty acids are an indication of the tropical fatty acid systems which are notably richer in these two fatty acids than the northerly (or southerly) fish oil and lipid fatty acids (Ackman, 1989). This feature extends into the pentaenoic acids where 22:5n-6, also a minor fatty acid in clupeid oils, is almost as important as the other pentaenoic acid, the isomeric 22:5n-3. The latter is also the isomer found in high proportions in cold water seal oils (Ackman and Eaton, 1988). The surprising feature of the four Group I oils is however the high (8–14%) proportion of 22:6n-3 (docosahexaenoic acid or DHA). As this fatty acid has an iodine value of 464, it is clear that it is a major factor in the high iodine value of this group of turtle fats.

The second group (II) of four turtle fat analyses represents only three animals (see below). The iodine values ranging from 87 down to 69, have no exact parallel in commercial fish oils, although a crab triglyceride fraction of comparable iodine value has been described (Takeuchi and Ackman, 1987). This group of animals shows a moderate increase in total saturated fatty acids to 50% and this increase is mostly in 12:0, which approximately doubles to as much as 16%, and in 14:0 which increases by about 50%. Stearic acid (18:0) is, however, the same percentage of total fatty acids as in the fatty acids of the higher iodine value group.

The monoethylenic fatty acid totals change very little, but 20:1 and 22:1 are reduced overall. An unexpected change is in the proportion of 18:1n-7 to 18:1n-9, the former increasing from an average of 10.4% of total 18:1 for the first four oils to 12.7 for the second three animals with oils of lesser iodine values. This reflects an increase in the related 16:1n-7 from an average of 6% to 7.2%.

The dienoic, trienoic and tetraenoic polyunsaturated fatty acid are reduced by about 50% in these three animals compared to the high iodine value group. This extends to all of the higher unsaturated acids but principally affects the 22:6n-3, which drops to less than the 22:5n-3 in the one animal providing two of the four oils analyzed. These two samples, 5 (carapace) and 4 (pelvis), came from one animal and provide convincing evidence of the stability of the samples, the accuracy of the GLC analysis, and the uniformity of distribution of depot fat composition in these large animals. This animal has less 22:6n-3 than the other two in the group, but this is compensated for by the higher total pentaene fatty acids.

The last six oils (Group III) have iodine values from 63 down to 51. There is, however, no further increase of note in the saturated fatty acids which stabilize at almost exactly 50% by weight of fatty acids. Of this as much as 21% by weight is 12:0 and 12% is 14:0. The two highest 12:0 numbers may be offset by less 18:0 and possibly also by less 16:0.

In the monoethylenic acids the totals for Group III are consistently just over 40% of all fatty acids. With the exception of oils 7, and 3, and 12, the percentages of 18:1n-7 in total 18:1 average 12.15, or about the same as in Group II. The further increase in 16:1n-7 to an average of 8.2% is thus not reflected in chain extension to 18:1n-7. The 20:1 and 22:1 fatty acids are still definite components but not of any importance. The less polyunsaturated fatty acids are again negligible in importance, and there is a further drop in 22:6n-3 to well under 1% (except for No. 15), a major difference since the total pentaenes, especially 22:5n-3, remain higher.

DISCUSSION

To consider the implications of the fatty acids in the low iodine marine value oils of green turtles one must consider the proportions of fatty acids in mole per cent and not weight per cent. The approximately 50% weight percent of saturated acids includes, in round (w/w%) figures, 20% of 12:0, and 10% of 14:0. The lower molecular weight of these acids means that they add up to higher percentage numbers in mole %, and if combined with 16:0 and 16:1 the total mole % is at least 55, approaching two-thirds of the fatty acids. Thus two out of three glycerol positions could be occupied by those shorter-chain saturated fatty acids (plus 16:1) which have no obvious dietary source and can be readily biosynthesized by the turtles themselves (Joseph *et al.*, 1985). Litchfield (1972) has discussed the rather scanty data for fatty

acid distribution of turtle oil fatty acids in triglycerides as part of a review of specific synthesis of triglycerides. The dearth of polyunsaturated fatty acids in the six particularly low iodine value oils of Group III, means that the turtles are forced to use freshly biosynthesized monoethylenic fatty acids to make up the balance of the triglyceride fatty acids since polyunsaturated fatty acids require at the least C_{18} precursors. The small increase in 16:1n-7 may be included in this process but both of the necessary 16:1n-7 and 18:1n-9 could be either dietary or biosynthesized *de novo*. Brockerhoff *et al.* (1968) clearly show the 16:1 and 18:1 concentrated in the 2-position for triglycerides of the leatherback *Dermochelys coriacea coriacea*. The saturated acids 12:0, 14:0, 16:0 and 18:0 in the same sample (Table 2) have a rather peculiar distribution. The two shorter chains are equitably distributed in the 1,3-positions, but the two longer chains favor the 1-position, over the 3-position, as in other higher animals. Litchfield did not clarify the status of the pentaenoic acids in the few turtle triglycerides examined.

The four high iodine value oils contain approximately one-third mole per cent for the three principal saturated fatty acids (12:0 + 14:0 + 16:0). It thus appears possible to speculate that the triglycerides of the green turtle depot fats always contain at least one-third freshly biosynthesized saturated acids in the 1- and 3-position (Table 2).

There are two possible reasons for this emphasis on shorter chain saturated fatty acids. One is the need for a low-melting depot fat which could be favored by a mixture of fatty acids rich in 12:0. The large marine turtle body temperatures may well be higher than that of the ambient sea-water as discussed elsewhere (Ackman *et al.*, 1971; Frair *et al.*, 1972; Davenport *et al.*, 1990; Holland *et al.*, 1990). The second is that this is a simple way of storing energy from dietary carbohydrate.

Stomach contents and observations of feeding behaviour of mid-Pacific green turtles (Balazs, 1985; Balazs *et al.*, 1987) have recently been published. If the diet of the Pacific green turtle is basically benthic algae but occasionally includes sea-grasses, coelenterates, or floating algae, or fish remains, then all of the polyunsaturated acids, including the 20:4n-6 and 22:4n-6 (Sipos and Ackman, 1968; Arai *et al.*, 1989; Holland *et al.*, 1990), are explained and the basic triglyceride simply incorporates these from the diet without modification. One piece of evidence suggesting a particular diet factor for this group is the ratio of 22:6n-3 to 22:5n-3. For samples 6, 11, 2 and 10 this figure is 3.7, 4.0, 3.4 and 3.8. In the other groups there is no such correlation, but the low levels preclude a definitive comparison. Bjorndal *et al.* (1991) discuss why green turtles may select a specific diet. Litchfield (1972) speculated that the position on the glycerol of the n-3 pentaenoic acid in the one marine turtle triglyceride examined would be similar to that of the 22:6n-3.

Table 2. Distribution of saturated and monounsaturated acids in mole% in the triglyceride of leatherback turtle fat†

Glycerol position	Fatty acid					
	12:0	14:0	16:0	18:0	16:1	18:1
1	7	18	24	12	7	12
2	2	10	4	2	13	45
3	9	14	10	5	8	19

†From Brockerhoff *et al.* (1968).

Whatever the origin, it is clear from the accumulations of long-chain fatty acids of both the n-6 and n-3 families (Table 1) that there is no Δ4,5 desaturase. This would be necessary to extend these fatty acids respectively to 22:5n-6 and 22:6n-3 (Chapkin and Miller, 1990; Cleland *et al.*, 1990; Garcia *et al.*, 1990). If operative on 22:5n-3 it should, according to current thinking, be equally operative in 22:4n-6, which is not the case. Depot fats need to be distinguished from meat lipids which contain phospholipids, but Alian *et al.* (1986) have observed that green turtle "meat contained less unsaturated fatty acid than loggerhead turtle meat". This could be the result of dietary preferences as much as of regional origin. Information on muscle and organ lipids in green turtles is limited (Holland *et al.*, 1990).

Marine algae are clearly the principal basis of the diets of mid-Pacific green turtles (Balazs *et al.*, 1987) and any carbohydrate could be quickly broken down to acetate in the turtle's digestive tract (Bjorndal, 1980; Bjorndal *et al.*, 1991) and then resynthesized to 12:0 and 14:0. The lipid content of marine algae is very low and the types of polyunsaturated fatty acids variable (Ackman, 1981). There are usually numerous algal epiphytes as well as the main seaweed body. The absence of significant 18:2n-6 and 18:3n-3 in the depot fat of any of these turtles is evidence that, unlike the Atlantic coast situation, sea-grasses (actually terrestrial plants adjusted to a marine milieu and with photosynthetic lipids containing 18:2n-6 and 18:3n-3) are not involved. The C_{20} and C_{22} polyunsaturated fatty acids found in small amounts in Groups II and III could have come from floating Pacific seaweeds. In most marine algae 22:6n-3 is much less obvious than 20:5n-3 (Nichols *et al.*, 1985; Takagi *et al.*, 1985; Volkman *et al.*, 1989). In animals 5 and in four out of five cases in Group III this proportion is observed. Large green turtles thus biosynthesize most of their depot fats *de novo* from acetate and other volatile fatty acids (Bjorndal *et al.*, 1991) to suit specific biochemical needs relating to energy storage and to confer physical properties matching their body temperatures. The addition of the C_{20} and C_{22} polyunsaturated fatty acids seems to be purely adventitious and based on dietary factors. These fatty acids therefore offer opportunities for food chain research in marine turtles similar to those recently observed in the blue-banded sea-snake *Laticauda colubrina* (Ackman *et al.*, 1991).

Little is known about the functions of the fats of most reptiles (Derickson, 1976). Recent dietary and analytical studies with the American alligator (*Alligator mississippiensi*) provide parallels in the conversion of carbohydrate to body mass (Staton *et al.*, 1990a), and in deposition of the longer-chain polyunsaturated fatty acids (Peplow *et al.*, 1990; Staton *et al.*, 1990b). The depot fats from one study include 12:0 from a dietary source, coconut fat. This fatty acid was *not* deposited when not in the diet (Staton *et al.*, 1990b). Otherwise the depot fats responded as expected to dietary fatty acids and bioconversion of C_{18} polyunsaturated fatty acids to

C_{20} and C_{22} fatty acids did not lead to important deposition in depot fats.

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