CCXXXV. FAT METABOLISM IN FISHES.
II. THE PERITONEAL, PANCREATIC AND LIVER FATS OF THE STURGEON (*ACIPENSER STURIO*).

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The data presented in the previous paper [1932] were all connected with fats which represented the main depôt fat of each species investigated, and, with the exception of the pike fats, the fat from only one depôt was used in each species. The quantity of any particular fat employed for a quantitative analysis of the component fatty acids should preferably be of the order of 200 g. and with less than 150 g. the accuracy will begin to fall off. This means that in many cases only the main fat depôts can be dealt with. However, with very large fish, there may be enough fat available from a number of sources. The writer was fortunate to obtain the whole of the viscera and a large piece of the peritoneal fat (the main fat store in the case of this fish) of a large sturgeon (*Acipenser sturio*) measuring over 11 ft. in length. The liver was not exceptionally rich in fat, but as it weighed 14 lbs., there was an ample supply of liver fat for analysis. The pancreas was loaded with fat, and a large sample was obtained. No opportunity was afforded for the examination of the flesh oil, but it was evident that the flesh itself was not of an oily nature, and the peritoneal fat may be taken as being the main deposit of stored fat.

The compositions of the fatty acids from these three oils are given in Tables I and II, and as before, the average unsaturation of each group is expressed in terms of deficiency in hydrogen.

Consideration of these figures reveals several interesting points. The writer was surprised to find that the liver fat was apparently no more unsaturated

Table I. *Composition of fatty acids in weight percentages.*

		Saturated			Unsaturated				
Oil from	Iodine value	C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
Peritoneal cavity	126·5	7·1	14·0	0·8	0·6	23·8	35·8 (−2·9 H)	12·1 (−7·4 H)	5·8 (−8·6 H)
Pancreas	119·6	4·5	16·4	1·1	Nil	21·4	36·7 (−2·9 H)	14·5 (−6·8 H)	5·4 (−9·1 H)
Liver	125	3·0	19·2	Nil	Nil	19·5	39·6 (−2·7 H)	11·8 (−7·1 H)	6·9 (−10·0 H)

Table II. *Composition of fatty acids in molar percentages.*

Oil from	Iodine value	Saturated			Unsaturated				
		C_{14}	C_{16}	C_{18}	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}
Peritoneal cavity	126·5	8·4	14·7	0·8	0·7	25·3	34·5 (−2·9 H)	10·8 (−7·4 H)	4·8 (−8·6 H)
Pancreas	119·6	5·3	17·4	1·1	Nil	22·9	35·7 (−2·9 H)	13·1 (−6·8 H)	4·5 (−9·1 H)
Liver	125	3·6	20·5	Nil	Nil	20·9	38·6 (−2·7 H)	10·6 (−7·1 H)	5·8 (−10·0 H)

than the main depôt fat, as indicated by the iodine values, and the more detailed analysis bears this out. This is contrary to what obtains with mammals, and from the figures given above it seems difficult to imagine a process of desaturation going on in the liver of the sturgeon. The degrees of average unsaturation of the various groups of acids in the three oils are indeed so much of the same order, that the differences might be considered as insignificant. If, however, they are taken into account, they seem to be against the theory that the liver fatty acids (it being remembered that throughout it is glyceride fatty acids that are referred to, and not phospholipin fatty acids) are more unsaturated than the fatty acids found in other fat depôts in the fish. The only grouping which is definitely more unsaturated in the liver fat than in the peritoneal fat is the C_{22} group, and for purposes of metabolism one would have thought that the acids in this group were unsaturated enough. It must not be forgotten, however, that associated with the highly unsaturated C_{22} acids there is usually some monoethylenic acid and it may be that this is further desaturated. The evidence of the other groups is against this supposition however. The C_{20} group is definitely most unsaturated of all in the storage fat, whilst the oleic-linoleic group is least unsaturated in the liver. But it is when we come to the palmitic and palmitoleic ratios that the figures seem more definite. Whilst the palmitic acid figure steadily rises from the peritoneal fat to the liver fat (*i.e.* from stored fat to fat probably taking part in active metabolism), the palmitoleic acid figure steadily falls. The total C_{16} grouping is remarkably constant, the figures being 40·0, 40·3 and 41·4 respectively for the peritoneal, pancreatic and liver fats. This steadiness between the main saturated component and its unsaturated derivative seems to the writer in full accordance with the results of Banks and Hilditch [1931; 1932] for pig fats, from which they conclude that there is inter-convertibility between saturated and unsaturated homologues. Their figures lead them to the opinion that the process is one of saturation to meet the normal body storage fat requirements, rather than one of desaturation. The present data throw no light on this interesting point, unfortunately, but they do support the argument that there is conversion of one acid into the other.

It seems of value to determine whether this relative saturation of the liver fat of the sturgeon is paralleled in the marine mammals. The writer has secured a medium-sized porpoise, and hopes to be able to pursue this point by full

analyses of the fats from various organs as well as the blubber. It must be borne in mind, of course, that fish fats are of an essentially different, and more reactive, nature than the body fats of land mammals, and their metabolism may be more direct.

There is another remarkable constancy to be observed. The total saturated acid percentages (sum of myristic, palmitic and stearic acid figures) are 23·9, 23·8 and 24·1 % respectively for the peritoneal, pancreatic and liver fats, in spite of quite considerable variations in the constituent acids—myristic from 3·6 to 8·4 %, palmitic from 14·7 to 20·5 % and stearic from 0 to 1·1 %. This strongly suggests that the three saturated acids are of equal value to the fish, and that myristic acid can replace palmitic acid functionally to a considerable extent. The lower percentage of palmitic acid would be compensated for by conversion of the excess palmitic into palmitoleic acid, thus keeping the total C_{16} acid percentage approximately constant. The net result, therefore, is strikingly in agreement with the conclusions of Banks and Hilditch, and we may picture the scheme of things in the sturgeon as follows.

The fat in all deposits requires an approximately constant relationship between the amounts of saturated and unsaturated acids present, *viz.* 24 % of saturated and 76 % of unsaturated. The exact significance of the variations in the percentages of the respective components within the saturated group is not clear, but it seems not improbable that the greater reactivity of myristic acid as compared with palmitic, and the different conditions of oxidation, *etc.*, in the various organs may have something to do with it. At any rate, we may suppose that if myristic acid is being destroyed at an excessive rate, palmitoleic acid will be saturated to increase the palmitic percentage, and so keep the ratio between saturated and unsaturated acids constant. On the other hand, we must equally suppose that if myristic acid is entering a depôt in unusually large amounts, some palmitic acid will be desaturated to palmitoleic acid. Feeding experiments will be necessary to settle this point. The rôle of stearic acid may well be similar to that of palmitic acid, but in a minor degree. The writer would have been disinclined to draw such far-reaching conclusions from the data of one fish, had not the work of Banks and Hilditch afforded such strong support.

Naturally, such relationships would not be expected to hold amongst all the oils from various marine species, as there seems no reason why all gadoid fish, for instance, should require the same ratios. It may be fortuitous that for all the fresh-water fish oils given in the previous paper, the sum of the myristic, palmitic and stearic acid percentages approximates to 20.

Two further points of interest are the following:

(*a*) In respect of the high content of palmitoleic acid, and the constant proportion of total C_{16} acids, these oils resemble those of the fresh-water fish rather than those of marine species.

(*b*) The high content of oleic and linoleic acids, together with the reduced amounts of C_{20} and C_{22} acids, is also suggestive of a fresh-water fish.

Now the sturgeon is a fish which inhabits both fresh water and salt. The particular specimen from which these fats came had been caught in the North Sea, but all sturgeon ascend the large Continental rivers to spawn, and moreover do most of their feeding in fresh water. Thus it is hardly surprising to find that the fats are of the same type as those of a true fresh-water fish, and in fact the sturgeon figures are additional support for the genuineness of the differences pointed out in the previous paper between fats from marine species on the one hand and fresh-water species on the other.

Summary.

The fats from the peritoneal cavity (main storage fat), pancreas and liver of a large sturgeon have been analysed as regards their component fatty acids. The results do not support the theory of desaturation in the liver, in the case of this particular fish. It is hoped further to investigate this point in respect of a marine mammal.

The data do, however, agree with the view that there is an inter-relationship between the main saturated acid component which has an unsaturated derivative—stearic and oleic acids in the case of pigs, *etc.*, and palmitic and palmitoleic acids in the case of fish. There is no evidence, however, as to the seat of these transformations.

There is, moreover, distinct evidence that a definite relationship is maintained between the amount of total saturated acids present, and total unsaturated acids—in the case of the sturgeon the values being 24 % of saturated and 76 % of unsaturated acids. Thus the other main saturated component, myristic acid, must enter into the scheme, and a relationship is adduced between myristic, palmitic and palmitoleic acids.

The results support in every respect the provisional conclusions drawn in the previous paper as to the characteristic differences between the fats of marine fish and fresh-water fish.

REFERENCES.

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