Food Values of New Zealand Fish.

Part 5: The Fats of the Red Cod in relation to its Food.

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IT has been established by numerous observations and experiments that the fats stored by animals are to a large extent derived directly from the fat of their food: thus the feeding of pigs on fish-meal, &c., affects the flavour of the bacon, and it has been proved by direct experiment that the fat of a dog fed largely on mutton-fat acquires the characteristics of mutton-suet. Also, unusual fatty acids such as erucic acid can be detected in the fat of an animal fed on fat containing that acid. It has also been inferred that under natural conditions fats can pass with little change from the body of one animal to another. As was indicated in Part 4 of this series, if this holds good for fish we might obtain evidence as to their food from the study of their fat.

So far as we can find, there are no observations on the subject except those of Rosenfeld, who fed carp and goldfish on mutton-suet, and found that the fat laid on by the fishes was mutton-fat. He also compared the fat of some marine forms of life with the fat of their food where the latter was "tolerably well known," and found a fairly close agreement.

An opportunity for procuring suitable material for similar observations presents itself annually in Dunedin Harbour in the case of the red cod (*Lotella bacchus*), which in the late summer and autumn subsist almost entirely on the shoals of whale-feed (*Munida gregaria*) that frequent the harbour at that time. Later in the year red cod become scarce in the harbour, and are caught in deep water outside the Heads. At this time their stomachs are free from the debris characteristic of a whale-feed diet, and what their food then is is uncertain.

Through the kind co-operation of the Marine Biological Station at Portobello we obtained samples of whale-feed, and of red cod when their stomachs were quite full of partially digested whale-feed. These were all obtained early in March. Later in the year (end of September) we were supplied with two specimens of red cod caught outside the Heads, when the stomachs showed no sign of whale-feed and contained only some slimy mucus.

The composition of whale-feed has already been the subject of a paper by the Hon. G. M. Thomson and G. S. Thomson, but we decided to repeat the analysis on samples taken at the same time as the fish were caught, and analysed by the same methods as were used for the fish.

Since the fat, or oil, of the liver in vertebrates differs from that of the other organs and depots of the body, we examined the liver-fat separately from that of the flesh.

METHODS.

Except in the case of the livers, the minced and weighed material was first extracted twice in succession with double its bulk of alcohol (approximately 90 per cent.) at room-temperature, and the residue was dried in the sun, extracted with ether (Soxhlet), and the fat so obtained was weighed separately. The alcohol of the alcoholic extract was distilled off, and the residue, after drying, was also extracted with ether, and so we obtained the fat that was soluble in both alcohol and ether, as well as the fat soluble in ether only. In all the operations we avoided exposure of the fats to heat and oxidation as far as was practicable in our circumstances.

The fish-livers were so fatty that we found it best to extract some of the fat with ether by shaking up and drawing off the ethereal layer before attempting to dry completely. The usual extraction method then followed, and all ether-soluble material was combined and weighed.

The fatty acids and "unsaponifiable" material were obtained from 8 to 10 grammes of fat thoroughly saponified with alcoholic potash. After diluting the soaps and driving off the alcohol, ether was used in separating funnels to remove the "unsaponifiable" part. The fatty acids were then obtained by acidifying the residue.

The iodine values of the fatty acids and oils were estimated by Wijs's method, and the mean molecular weight by titration with one-fiftieth normal alkali.

The results are given in the table.

—	Whale-feed.	Red Cod (A) feeding on Whale-feed.		Red Cod (B) feeding in Deep Water.	
		Flesh.	Liver.	Flesh.	Liver.
Water percentage	..	79·0	44·3	81·0	46·0
Solids by difference.. ..	..	21·0	55·7	19·0	54·0
Fat percentage	1·3	0·8	47·3	0·9	40·4
Nature of the fat*	Brown pasty mass	Brown pasty mass	Dark-red oil	Pasty mass	Red oil.
Percentage of the fat soluble in alcohol and in ether	80·0	77·0	..	68·0	..
Percentage of "unsaponifiable" matter	6·9	5†	10·8	5†	9·6
Nature of fatty acid—Solid at	15° C.	15° C.	15° C.	15° C.	15° C.
Iodine value of the fatty acids (Wijs)	138·8	139·2	113·1	135·5	111·3
Iodine value of the liver-oils..	..	..	85·0	..	72·0
Mean molecular weight of fatty acids	309·0	334·0	282·0	335·8	283·0

* All these fats contained appreciable amounts of lecithin, as shown by the development of trimethylamine during the saponification. The liver-oils gave black resinous pitch-like acids denser than water. † Approximate.

Discussion of Results.

Our analyses indicate that there is a very close agreement between the nature of the fat of whale-feed and the body-fat of red cod (A) at a time when it was undoubtedly feeding on whale-feed: thus the iodine values (approx. 139) agree, also the physical appearances and the percentage of the fat soluble in both alcohol and ether. The mean molecular weights of the fatty acids in the two cases differ by 26—a figure which corresponds approximately to two carbon atoms with attached hydrogens. This is interesting when one remembers that, according to modern views, fats in the body are split up or synthesized by removal or addition of two carbon atoms at a time.

As we had expected, the liver-fat of the red cod differs from that of the flesh, and here also there are interesting relationships, for the mean molecular weight of the liver fatty acids differs from that of the flesh by 52—which corresponds to four carbons; also the amount of unsaturation is proportionate to the molecular weight: thus the ratio of 334 (mean molecular weight) to 139 (the iodine value) is practically the same as 282 to 113. It has been shown by Leathes and others that in mammals the liver-oils are always less saturated—*i.e.*, have a higher iodine value—than the body-fats. Here there seems to be the opposite condition; but the figures may be accounted for by assuming that the unsaturated fatty acids of the body-fats had had four carbon atoms split off, and that in the process of splitting some of the unsaturation had disappeared; otherwise, owing to the smaller size of the fatty-acid molecule in the liver-oil, the iodine value would have been higher than it is.

In the examples of simultaneous analyses of fat of food and fat of consumer of the food given by Rosenfeld none is in such close agreement as are our figures. We would have been glad, however, if he had examined the "consumers" at another season of the year, when the nature of their food was less obvious, or even different, for it would have been interesting in comparison with our results in the case of red cod B. These, as already stated, were caught six months earlier, or later, in the life of the cod—unfortunately we cannot say which with certainty, for the scales were not examined, but from the weight of flesh it is probable that the red cod B were either younger fish or fish of the same age as A but in poorer condition.

In these "winter" fish the main characteristics of the fats remain very much the same as in the "summer" fish—*e.g.*, the iodine values and mean molecular weights of the fatty acids are similar. The percentage of fat in the flesh is 0·1 higher in the winter fish, but this is within the experimental error, and there may have been wastage of the protein part of the flesh. Incidentally, our analyses confirm those of Mrs. Johnson (Part 2 of this series) in finding that red cod is poor in fat.

There are, however, certain differences to be noted:—

(1.) The fraction of the total fat that is soluble in both alcohol and ether is 77 per cent. in A, 68 per cent. in B.

(2.) The livers of the winter fish were smaller relatively to the weight of flesh (ratio of weights respectively 1 : 15) than those of the summer fish, where the same ratio was 1 : 10.

(3.) The percentage of liver-oil was also less—40·4 for winter fish, 47·3 for summer fish.

(4.) The iodine values of both liver-oil itself and the fatty acids of the liver-oil were less in the winter fish.

Although these points of difference are small when looked at singly, they all indicate a certain degree of depletion of the reserves, and, taken in conjunction with the empty state of the stomach, point to a condition of semi-starvation.

The explanation which we think best fits in with the data we have obtained is that the main food of this fish for the whole year consists of whale-feed. During the summer and autumn the red cod gorges itself on this food, and fattens so far as its liver is concerned. In winter it retires to deep and colder water. Here, owing to lessened metabolism, and possibly lessened food-supply, it lives largely on its reserves till the whale-feed season again occurs. During the time of plenty the character of the fat acquired has a direct relationship to the fat of the food.

Unsaponifiable Material.

We paid special attention to the nature of the unsaponifiable matter in these marine oils, for the following reason: One of us (C. L. C.) has already demonstrated that "mutton-bird oil" consists mostly of cetyl-oleate and other esters of cetyl alcohol. For some time we have been investigating the fate of cetyl alcohol in the body, and, incidentally, its origin in the mutton-bird. One possibility that presented itself to our minds is that the oil may be an indigestible (*i.e.*, unsaponifiable) residue of the fat present in the food of the bird. The finding of cetyl alcohol in whale-feed or other shell-fish, or in the fats of any form of marine life, would lend support to such a view, but, in spite of much time and labour spent in crystallizing out the unsaponifiable constituents, no trace of cetyl alcohol was found; on the other hand, there was clear evidence that the great mass of it consisted of cholesterol in more or less pure form.

In conclusion, we beg to thank the University of Otago for facilities given us for carrying on this work, and to acknowledge financial assistance received from the New Zealand Institute Research Fund.

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Food Values of New Zealand Fish.

Part 6: The Vitamin-A Content of Mutton-bird Oil and of some Fish-oils.

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Since the beginning of the present century two great advances have been made in our knowledge of dietetics. One, originating in a better knowledge of the chemical constitution of the protein molecule, has led to the recognition of the importance of the quality as contrasted with the mere quantity of protein in diet; the other is the discovery of the need for accessory factors, or vitamins, in addition to the protein, salts, carbohydrate, and fat.

Of late years a large amount of work has been done on the presence of vitamins in various foodstuffs, and it seemed desirable to carry out similar investigations in New Zealand. This paper relates to the estimation of vitamin A in some marine products.

Method.

The mode of procedure commonly adopted in this kind of work is now so well established that it is unnecessary to set it out in detail, except so far as local conditions are concerned. Litters of young albino rats, weaned about the thirtieth day, were fed on a diet consisting of—Casein, 19·3 per