LXIV. NEW ZEALAND FISH OILS

II. SEASONAL VARIATIONS IN THE VITAMIN A CONTENT OF LING (*GENYPTERUS BLACODES*) LIVER OIL

By F. B. SHORLAND

*From the Department of Industrial Chemistry, University of Liverpool, and
the Agricultural Chemical Laboratory, Wellington, New Zealand*

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PREVIOUS studies [Shorland, 1935; 1937] have shown that the ling, in contrast to the fish examined by other workers, exhibits no major seasonal variations in the vitamin A potency of the liver oil, although the data so far obtained are insufficient to detect minor fluctuations. The object of this work is to study further the variations in the liver oil potency of vitamin A and to ascertain its distribution both in the tissues and in the food.

The livers from each batch of fish caught in Cook Straits, within 7–18 miles of Island Bay, Wellington, were placed in a number of cloth bags and autoclaved with low pressure steam [cf. Shorland, 1935]. The additional extract obtained by pressing was mixed with the “steamed” oil and the combined yield was recorded. Some of the residues from the pressing process were dried and extracted with ether to assess the total oil content.

Calculation of the vitamin A content was made on the basis of values obtained with the richest vitamin A distillates [Carr & Jewell, 1933], $E_{1\text{ cm}}^{1\%} 328 \text{ m}\mu = 1600$, Carr-Price value = 78,000, the latter being mainly used, though wherever possible the intensity of absorption at $328 \text{ m}\mu$ has been taken as the final criterion. The figures recorded here refer to the content of $\text{C}_{20}\text{H}_{29}\text{OH}$ only and other substances [cf. Morgan *et al.* 1935] possessing possible vitamin A activity were ignored. Fish livers yielding by extraction with solvents oils of high vitamin A potency sometimes gave “steamed” oils of much lower potency [cf. Schmidt-Nielsen & Schmidt-Nielsen, 1929]. The “steamed”, “pressed” or petrol-extracted [cf. Denz & Shorland, 1934] preparations from any given batch of ling livers showed, however, little variation in vitamin A content. In this work, therefore, the vitamin A figures recorded in Table I are conveniently based on the combined “pressed” and “steamed” extracts.

Although nearly 3000 livers have been used, the minor monthly fluctuations (cf. Table I) may not be significant but may be due to errors in sampling. In Fig. 1, therefore, the effect of this error has been minimized by taking the mean bi-monthly values. These show a progressive decrease in vitamin A content from 0.7% in January–February to 0.5% in July–August. The slightly diminished vitamin A content towards the end of the season, which lasts from April to September, is in accordance with the previous data [Shorland, 1935] and with measurements made on bulk samples. The latter showed a mean Carr-Price value of 490 during the earlier part of the 1936 season, but for the later samples the lower value of 450 was obtained, according to data kindly supplied by British Drug Houses, Ltd. Detailed data were not available for the period October to December, but the few samples analysed both in this and the

Table I. *Cook Strait ling liver oils*

Date of catch	Approx. total wt. livers kg.	Mean wt. liver g.	Yield of oil %	Iodine value (Wijs 1 hr.)	Carr-Price B.U.	Vit. A content of oil from B.U. %	$E_{1\text{cm}}^{1\%}$ 328 m μ	Vit. A content of oil from u.v. %	Mean liver wt. for month g.	Mean % vit. A for month
16. i. 35	10.4	612	20.4	141.1	360	0.46	7.5	0.47	627	0.56
24. i.	44.4	661	17.5	135.6	440	0.56	8.0	0.50		
31. i.	7.7	453	—	142.9	780	1.00	15.8	0.99		
4. ii.	3.62	453	40.6	144.8	300	0.38	6.7	0.42	652	0.85
13. ii.	11.3	494	20.8	139.0	660	0.85	15.4	0.96		
14. ii.	45.3	721	32.0	134.6	790	1.01	14.6	0.91		
24. ii.	8.6	576	19.5	149.1	440	0.56	8.7	0.54		
1. iii.	27.2	796	24.7	138.0	650	0.83	11.9	0.74	651	0.55
6. iii.	11.3	540	22.0 (39.4)*	143.4	430	0.55	7.8	0.49		
11. iii.	27.6	553	28.6	139.9	630	0.81	12.4	0.78		
23. iii.	57.1	—	19.8	144.8	230	0.29	5.3	0.33		
7. iv.	25.3	793	23.0 (37.4)	142.3	460	0.59	11.4	0.71	707	0.74
25. iv.	11.3	812	18.8	149.1	480	0.62	7.9	0.49		
25. iv.	22.7	—	—	153.2	480	0.62	8.6	0.54		
26. iv.	11.3	630	20.0	143.6	560	0.72	11.5	0.72		
27. iv.	18.1	566	23.2	131.5	940	1.21	18.8	1.18	798	0.60
10. v.	24.9	998	22.9	139.0	430	0.55	10.4	0.65		
22. v.	17.7	503	—	148.1	240	0.31	5.65	0.35		
25. v.	81.6	730	—	149.1	390	0.50	9.3	0.58		
26. v.	117.9	892	16.4 (32.8)	140.6	530	0.68	10.1	0.63		
27. v.	20.4	417	23.5	143.3	500	0.64	11.1	0.69		
27. v.	24.4	906	—	143.3	470	0.60	8.9	0.56		
2. vi.	43.0	—	22.4	—	430	0.55	8.1	0.51	630	0.68
20. vi.	36.2	—	28.5	143.2	450	0.58	8.95	0.56		
21. vi.	27.2	—	22.2	135.8	760	0.98	15.4	0.96		
24. vi.	33.1	621	21.9 (33.8)	141.6	490	0.63	11.4	0.71		
28. vi.	12.7	634	27.0 (43.9)	146.7	520	0.67	10.6	0.66		
— vi. 36	13.6	648	—	140.6	760	0.98	14.0	0.88	679†	0.57
2. vii. 35	4.1	2034	—	136.4	410	0.53	8.3	0.52		
3. vii.	163.4	—	—	146.2	430	0.55	8.8	0.55		
6. vii.	54.4	—	—	147.5	470	0.60	8.5	0.53		
9. vii.	23.5	739	21.9 (39.6)	148.7	230	0.29	5.2	0.33		
15. vii.	489.5	—	—	145.2	410	0.53	9.5	0.59		
18. vii.	6.8	1700	—	138.9	220	0.28	5.2	0.33		
22. vii.	20.85	771	18.0	139.0	410	0.53	9.25	0.58	810	0.43
2. viii.	18.1	648	19.2	142.2	230	0.29	4.0	0.25		
22. viii.	23.6	942	16.4	139.8	320	0.41	7.1	0.44		
18. viii. 36	22.2	671	15.3	150.8	470	0.60	9.0	0.56		
— viii.	24.9	925	18.2	139.3	410	0.53	7.0	0.44	—	0.56
4. ix. 35	145.0	—	—	142.6	420	0.54	8.9	0.56		
28. ix.	2.7	—	—	146.4	330	0.42	5.9	0.37		
— xi. 36	—	—	—	149.4	690	0.89	15.0	0.94	—	—
5. xii.	3.6	—	—	141.8	370	0.47	8.10	0.51		

* Figures in brackets refer to total oil content.

† The data for the liver weights are not representative, the figures given in the table are therefore calculated from 308 lb. of livers collected during July 1934 and July 1935.

preceding investigations suggest that the vitamin A content does not vary greatly from the mean monthly value of 0.615% (Carr-Price value, 486; $E_{1\text{cm}}^{1\%}$ 328 m μ =9.84). The mean amount of vitamin A in ling liver was 215 mg./100 g. tissue or 1494 mg./liver, as compared with 316.5 mg. vitamin A/100 g. tissue or 1434 mg./liver for Aberdeen samples of halibut calculated on the basis of a 1 lb. liver containing 20% oil from data given by Lovern *et al.* [1933].

To study the distribution of fat and vitamin A in the tissues two specimens were used (length 5 ft. 1 in., 5 ft. 1½ in.; weight 51 lb. 7½ oz., 53 lb. 1½ oz., respectively) taken at 150 fathoms on 2. vii. 35. The liver oils were prepared in the usual way, but the remaining tissues were steam-cooked and then pressed to remove surplus water prior to continuous extraction with light petroleum (B.P. 50–70°).

Fig. 1. Seasonal variations in the vitamin A content of Cook Strait ling liver oil.

○ — ○ Mean monthly values. △ — △ Mean bi-monthly values.

Table II. *Distribution of vitamin A in the tissues of the ling*

	% wt. of total fish	Oil content as % total oil in fish	Oil content of tissues %	Carr-Price value	% vitamin A	% vitamin A of total vitamin A in fish
Liver,	8.3	98.9	ca. 35	410	0.53	ca. 97.9
Viscera,	5.1	1.0	0.6	820	1.05	2.1
(excluding liver)						
Body,	67.2	0.1	0.04	No test	—	—
Head,	19.4	Trace	0.004	No test	—	—

The higher values of 0.11 and 0.18% for the fat content of two specimens of ling flesh examined by Johnson [1921] were probably partly due to more efficient extraction by means of ether and partly to the fact that the present results have been expressed as a percentage of the whole body including both flesh and bones. In contrast to the viscera of the halibut [Lovern *et al.* 1937] which may contain as much vitamin A as the liver, the viscera of the ling yielded only traces of vitamin A, 97.9% of the total vitamin being found in the liver.

The low yield, calculated as 2% of the total oil in the fish, and the negative Carr-Price test of the oil obtained from four typical mature roes (av. wt. 566 g., 0.9% fat) taken on 28. ix. 35, suggest that spawning has very little effect on the oil and vitamin reserves of the liver.

Table III summarizes the data on the vitamin A potency of some ether-extracted oils prepared from whiptail (*Macruronus novae zelandiae*) which is the chief food of the ling [cf. Phillipps, 1926].

Table III. *Vitamin A content of Cook Strait whiptail*

	Wt. g.	% oil (ether extract)	Carr- Price value	% vit. A	Total vit. A mg.	Remarks
W_1 (whole fish)	1246	0.72	75	0.10	90	Taken practically undigested from one of the ling described in Table II
W_2 (body and head)	1132	0.17	23.6	ca. 0.03	ca. 0.6	} Taken by line from the ling fishing grounds, 23. vii. 35
W_2 (viscera excluding liver)	46	1.51	280	0.36	2.7	
W_2 (liver)	8.6	15.7	370	0.47	6.3	
W_3 (liver)	—	—	68	0.10*	—	—
Ling liver	694	35	490	0.615	1494	—

* $E_{1\text{ cm.}}^{1\%}$ 328 m μ , 1.6.

DISCUSSION

The results of previous investigations suggest that diet and changes in oil content are important factors in determining seasonal variations in the vitamin potency of fish oils [cf. Drummond & Hilditch, 1930; Lovern *et al.* 1933].

Changes in the oil content of the liver are frequently connected with spawning. The cod, for example, which has been studied in detail by Drummond & Hilditch [1930], ceases to feed at such times and a considerable proportion of oil is transferred to the gonads [cf. Hjort, 1914], leaving the vitamin reserves practically unimpaired. The residual liver oil, therefore, contains a higher concentration of vitamin A than when the fish is feeding normally. The reverse process may take place during intensive feeding on a diet relatively deficient in vitamin A. Thus the intensive feeding of the groper during October and November is associated with an infiltration of fat into the liver which reduces the vitamin A potency of the oil [Shorland, 1937]. Bills *et al.* [1934] noted that the potency of halibut liver oil was related to the oil content of the liver, but the decrease in vitamin A content from January to August was disproportionately greater than the increase in oil content, suggesting that other factors in addition to dilution controlled the potency of the oil.

In the case of North Sea halibut, the spawning effect is completely masked by pronounced seasonal variations which follow closely the normal rhythm of the diatom cycle, and as the abundance of diatoms is the only available measure of the carotene content of the sea, it is suggested [Lovern *et al.* 1933] that the great abundance of these organisms in the spring may be responsible for the increased potency observed during that period. A similar diatom rhythm has been found in the southern hemisphere [Dakin & Colefax, 1933] but the diatomaceous increase in the spring, so far as the ling is concerned, coincides with the period of minimum potency of the liver oil.

To judge from the time of appearance of mature roes it is probable that spawning takes place towards the end of August, when the potency of the liver oil is at a minimum. The present data suggest that spawning imposes an insignificant drain on the oil and vitamin A reserves of the liver, and, further, that the yield of oil remains constant for the greater part of the season. Observations over the past few years, however, show that during August and September, the cooked livers are not so firm as at other times and are therefore less amenable to pressing. If, therefore, the ling eats little or no food while spawning, and the vitamin A reserves are partially depleted during this period, the reduced potency observed at this season would be expected to occur.

Many fish, such as cod and halibut, appear to store large amounts of vitamin A in their liver although their food is relatively deficient in this vitamin [Drummond & Hilditch, 1930; Lovern *et al.* 1933; Macpherson, 1933], so that liver oils from older fish usually contain higher concentrations of vitamin A. Moreover, within a given species, as both the oil content and relative weight of the liver increase with age, the total vitamin A reserves become disproportionately greater. In the case of the ling, however, the food (cf. Table III) is shown to be relatively rich in vitamin A so that little storage is necessary to produce a liver rich in vitamin. In confirmation of this the larger livers from the older fish have not been found to yield more potent oils than the smaller livers of the younger fish (cf. Table IV). In instances where the total oil content is given, the vitamin A content may be calculated as 246 mg./100 g. tissue for livers of less than 700 g., whereas the heavier livers show 203 mg. The data given by Edisbury *et al.* [1937] for fresh water eel (*Anguilla australis* Rich.) also suggest that age has no marked influence on the vitamin A potency of the oil or tissues of the liver. In contrast to the ling, however, other tissues in the eel form a depot for vitamin A so that if the whole of the vitamin were stored in the liver, the liver oils would indeed show a well-marked progressive increase in potency with age.

Table IV. *Relation between weight of liver and vitamin A content of oil*

	Wt. of liver				
	400-500 g.	500-600 g.	600-700 g.	700-800 g.	Above 800 g.
No. samples	4	5	8	6	7
% vitamin A (mean value)	0.77	0.67	0.52	0.64	0.52

Accepting an average weight of 20 lb. for ling [*New Zealand Marine Dep. Rep.* 1933] the liver on the average comprises 7.5% of the headed and gutted fish as compared with 12.4% in the case of the larger specimens described in Table II. This increased proportion of liver in the larger fish has been generally established for most other species examined. Therefore it is probable that despite the slightly lowered potency of oil from the larger livers as compared with the smaller, the total vitamin A reserves increase proportionately with age, but the extent of the increase is very much less marked than in either cod or halibut.

SUMMARY

The vitamin A content of ling (*Genypterus blacodes*) liver oil slowly decreases from a maximum value of 0.7% during January-February to a minimum value of 0.5% during July-August. Changes in the vitamin potency of the oil are apparently related to spawning, when the vitamin reserves are used up to a much greater extent than the oil itself. In contrast to the fish hitherto studied by other workers the vitamin A content of ling liver oil does not increase with age, though, owing to the greater relative proportion of liver in the older fish, it is probable that there is a slight proportionate increase in the vitamin A content of the whole fish.

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