MINISTRY OF COMMERCE AND INDUSTRY, EGYPT

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NOTES AND MEMOIRS No. 29

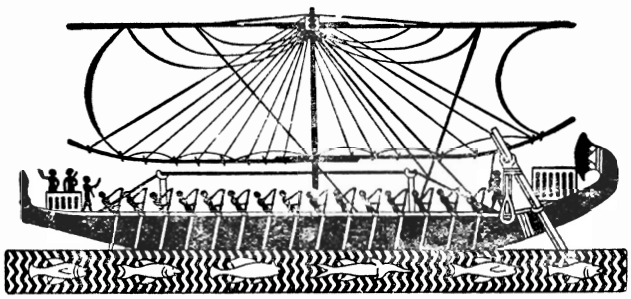
A CHEMICAL STUDY OF THE EGYPTIAN SARDINELLA

1.—VARIATION IN THE FAT CONTENT OF WHOLE FISH, FLESH, AND GONADS

BY

M. K. EL SABY, PH.D. (*Liverpool*)

Scientific Assistant, Hydrobiology and Fisheries Directorate, Alexandria



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A Chemical Study of the Egyptian Sardinella

1.—Variation in the fat content of whole fish, flesh, and gonads

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INTRODUCTION

Save what is recorded in the Fisheries reports issued since 1920 by the Fisheries Research of Egypt, there is no published account concerned with a description of the Egyptian Sardine Fishery, and for this reason it appears to me to be desirable to write a short note on this fishery as regards composition, locality, season, annual total production, importance, etc., before proceeding to discuss the chemical aspect of the subject.

Three species of the genus Sardinella compose our Sardine Fishery, of which the S. aurita (allache) constitutes about 80 per cent of the total production ; the remainder consists of S. eba save for the negligible percentage of less than 0·50 per cent of S. granigera.

S. aurita (Allache).

Migratory, travels in big shoals, appears in considerable quantities about two to five weeks time after the flow of the Nile flood reaches the Mediterranean. At the time of its first appearance the fish is lean and exhausted after spawning during the summer months. Some of the fish are still full, but these form a very small percentage of the total. The fish start to feed vigorously on the Nile mud contents of phytoplankton and on the swarms of the marine diatoms and perydinians and other phytoplanktonic forms, which flourish abundantly at that time due to the effect of the vast quantities of fresh water discharging into the sea.

The fish rapidly fatten and the catches increase in size until they reach a maximum by November.

With the fall of the Nile flood the fishery begins to slacken gradually until it practically ceases by the end of January. Thus the season, in some years, extends from mid-August to the end of January, while in others it fluctuates by starting a little later and ending a little earlier. The season seems to depend mostly on the height of the flood and also on the prevailing physical and chemical conditions.

After the season is ended, the fish leave the inshore waters and migrate into deeper waters probably in an easterly direction.

Average individual size of the fish during season 18 cms.

Average individual fresh weight of the fish during season 70 grams.

S. eba.

This species seems to be more local than S. aurita and lives along the shores in the shallower waters.

During season October–January it mixes up with S. aurita and travels in big shoals.

The fishermen's catch is often a mixture of the two species; sometimes composed entirely of S. aurita while at others it consists exclusively of S. eba.

Average individual size of this fish during season 14 cms.

Average individual weight of this fish during season 35 grams.

After the season is ended, this fish disappears for 3 to 4 months until it again re-appears during the very limited summer inshore Sardine Fishery, localised so far at Alexandria Eastern Harbour. The summer fishery ground extends only from Alexandria to Abou Kir in the inshore waters of not more than 20 fathoms.

The number of boats engaged in this fishery does not exceed 20.

The quality of the fish is poor and their gonads are approaching ripening and maturation and the fish are ready to move to deeper waters to spawn.

The quantities, produced from this summer fishery, are comparatively small and are consumed fresh locally. S. eba is generally the predominant fish in the catches, S. aurita being rather rare during this fishery.

Average individual size of S. eba during summer fishery 14·5 cms.

Average individual weight of S. eba during summer fishery 28 grms.

Average individual size of S. aurita during summer fishery 17 cms.

Average individual weight of S. aurita during summer fishery 52 grams.

S. granigera.

This is a rare fish, compared with the other two species and does not play any significant part in the economics of the Sardine fishery. It generally appears early during the summer fishery mentioned above. Its presence in the catches does not occur later than May–July. This fish is caught in small quantities at Alexandria Harbour in a westerly direction. It seems to prefer life in waters deeper than 20 fathoms. (*N.B.*—The deepest waters in which the fisherman can work on is bounded by the depth of his net, which in Egypt does not exceed 20 fathoms).

This species does not make more than 10 per cent of the summer fishery, which in its turn does not exceed 5 per cent of the total production of the Sardine fishery all the year round.

Average individual size of this fish during May–July 18 cms.

Average individual weight of this fish during May–July 48 grams.

The Sardine fishery is centered along the Northern coast of Egypt at Abou Kir, Rosetta, Broullos, Damietta and Port Said.

Table I shows that the average annual landing returns of this fishery during the last ten years are estimated at 4,880·3 metric tons, while in the same period the total production of our sea fisheries, practiced along the Mediterranean coast, Red Sea coast and along the Suez Canal with its lakes amounts to an annual average of 9,218·7 metric tons.

TABLE I.—AMOUNTS OF SARDINE CATCHES, COMPARED TO THE TOTAL PRODUCTION OF ALL THE SEA FISHERIES AND ESTIMATED VALUE OF THE SARDINE (1926–1935).

Year	Amounts of Sardines in Metric Tons	Total Production of Sea Fisheries in Metric Tons	Percentage of Sardine catches to total production of Sea-Fisheries	Annual Total Value of Sardine
				L.E.
1926	770	3,435	22·4	—
1927	1,700	4,770	35·6	—
1928	3,220	5,620	57·2	—
1929	2,938	6,626	44·3	—
1930	7,867	13,708	57·4	167,731
1931	3,826	10,152	37·6	52,003
1932	5,042	10,144	49·7	61,966
1933	6,190	11,407	54·2	107,579
1934	12,055	16,657	72·3	224,422
1935	5,195	9,668	53·7	67,527
Mean	4,880·3	9,218·7	48·4	113,538

The annual sardine catches exceed by far those taken of any other marine fish in Egypt and as shown above make up 48·4 per cent of the total landings of our Sea Fisheries. It is thus obvious that any attempt to develop the Sea Fisheries industry should deal first with the development of the sardine fishery.

With the importance of the sardine fishery in view, the writer started the biological and chemical investigations on the sardine in the hope that these investigations might help its economic development.

The complexity of the problem has become increasingly apparent and has necessitated careful consideration from different aspects. As a result it was found convenient to deal with the chemical and biological aspects separately.

In a previous paper by the writer on the " Dietetic Value of certain Egyptian Food Fishes " 22 species including the sardine were considered. The chemical analyses for the determination of the percentages of Protein, Fat, Ash, and Water in the flesh of 21 species were carried out, while in one further species the Karous (*Morone Labrax*) a study of the gross chemical changes, which occur in the different tissues during the process of maturation and reproduction was made.

As the protein constitutes to a large extent the protoplasm of the living tissue, its percentage in the flesh of fishes does not greatly vary between individual fish, between different species, or between fish from different localities.

In contrast with the protein-content, the fat-content in the so called fat-rich-fishes such as herring, pilchard, sardine, makerel, etc., varies greatly between individual fish, between species in different localities and at different seasons of the year.

Fish fats and oils are of great value as foodstuffs because of their high caloric value. They have also further importance as foods because of their more lor less intimate association with three very, valuable accessory food substances, namely, Vitamins A, D and E. The presence of the three vitamins in the diet is of prime importance for the proper economy of the body.

The industrial importance of fish oils, extracted from whole fishes or from the offal of the canneries in the case of herring, pilchard, sardines, salmon, etc., is increasing as their particular properties

are becoming known. Fish oils are now-a-days considered a relatively valuable raw material in the general factory consumption of fats and oils, required by various industries.

From a table, given by the U.S. Department of Commerce for the year 1929 and recorded by *Brocklesby and Denstedt* (1933), the total consumption by factories of fish oils is estimated at 188,102 thousand pounds, consumed in the various industries as follows :—

U.S.A. Factory Consumption of Fish Oils by all Industries for the Year 1929 (Quantities in Thousands of Pounds).

Total of all industries	Shortenings	Soap	Paint and Varnish	Printers' Ink	Linoleum and oil-cloth	Textiles	Miscellaneous Industries
188,102	14,921	130,634	10,602	50	10,141	—	21,753

The oil of the miscellaneous industries are mainly consumed in the leather tanning industry, of which the annual consumption is estimated at 8,000 tons and also in the manufacture of greases and lubricants ; and sometimes for general purposes one class of mineral oils is blended with another class of fish oils.

Besides the importance of fish oils and fats in the foods and in the different industries mentioned above, the success of canned sardine as regards quality and flavour depends to a certain extent on the degree of its oiliness. Rich fatty sardines generally make a good quality canned food stuff, while the poor weak fish produce a low grade of canned sardine.

As the economic value of the sardine increases with the increase of the degree of its fatness, the study of the fat-content of sardine and its properties throughout the year in order to establish the difference between individual fish ; between different sexes ; between species ; between localities, and above all between the different seasons of the year, is essential for the development of the Sardine. Fishing Industry on sound and scientific basis. This paper is a preliminary survey of the fat metabolism of our sardine.

COLLECTION OF SAMPLES

Biological and chemical investigations on sardinella were carried on during the seasons of 1933–1934 and 1935–1936. The reason of the break in 1934–1935 season was due to the absence of the writer on board R.R.S. " Mabahiss " on her trip to the Red Sea (December 1934 to February 1935) for biological and hydrographical investigations.

Samples of fish were, whenever possible, collected from the marketable catches, landed at various fishing centres. After the count of the sample and its analysis into the three species of sardinella—S. aurita, S. eba and S. granigera—the biometrical and biological investigations of length ; sex : age ; state of maturity ; condition of intestinal fat and examination of the food-contents of stomach were recorded on every individual fish. These observations will be published later on.

Length was measured from the tip of the snout to the end of the longest caudal fin ray in the dorsal fluke of the tail.

Several scales from the anterior region near the tip of the pectoral fin were removed and prepared in the same way described by *Channon and Saby* (1932) for the count of winter rings under a projector or a binocular microscope according to the method of *Lea* (1910).

It was found convenient to record the state of maturity, according to the classification of Hjort's scale. The adopted classes of this scale actually encountered were :—

I.—Immature virgin or spent fish not yet recovered ;

II.—Maturing virgins or recovering spents ;

III.- Gonads filling one-half of the body-cavity ;

IV.—Gonads filling more than two-thirds of the cavity ;

V.—Gonads full, filling the body cavity.

The quantity of fat round the alimentary tract was observed and is recorded as the " mesenteric " fat in the terms, " no fat " ; " little fat "; " some fat "; " very fat."

Throughout this work on the biological and the biometrical data on the three species of sardinella, samples of a few fishes for the chemical analyses were selected to represent as far as possible a fair average of these factors.

As the fat content of the whole fish and that of the muscle are the most important from the dietetic and industrial point of view, it was decided in the first place to carry out estimations on samples from this point of view.

Later on and during the summer fishery of 1935, when the fish were poor and lean and of little importance for canning or production of oil, attention was given to the study of the chemical changes which occur during the process of maturation and investigations made as to any possible difference between males and females in this respect.

The selected fish were weighed in grams and treated as follows :—

(*a*) After the careful removal of the scales, the fish were taken for the determination of the fat content and were finely cut into small pieces.

(*b*) In the case of the estimation of the fat-content of flesh, the sample was taken by cutting a narrow fillet of the flesh, from behind the head to the tail region after careful removal of the skin.

(*c*) Gonads were readily obtained by dissecting the selected fish.

The selected samples were then stored in stoppered jars under excess of acetone until they were later worked up, as time allowed. Table II gives the history of all the samples taken for analyses.

TABLE II.—HISTORY OF SAMPLES.

No. of Sample	Date	Locality	Sample	Sex		Lengths (cms.)								Age No. of winter rings				Maturity Hjort's Scale					Fresh Wt. of sample (gms.)	Tissue Taken	Fresh Wt. of material used (gms.)
				♂	♀	13	14	15	16	17	18	19	20	1	2	3	4	I	II	III	IV	V			
1	15- 9-1933	Abou Kir	5 aurita...	3	2	—	—	1	1	3	—	—	—	—	4	1	—	2	3	—	—	—	335	Flesh	164
			7 eba ...	4	3	5	2	—	—	—	—	—	—	2	5	—	—	3	4	—	—	—			
2	10- 3-1933	Port Said	5 aurita...	2	3	—	1	2	2	—	—	—	—	3	2	—	—	5	—	—	—	—	230	Flesh	117
			5 eba ...	3	2	4	1	—	—	—	—	—	—	1	4	—	—	5	—	—	—	—			
3	13-10-1933	Port Said	4 aurita...	2	2	—	—	—	—	2	2	—	—	—	2	1	1	2	2	—	—	—	286	Whole fish	286
4	13-10-1933	Port Said	4 eba ...	2	2	—	2	2	—	—	—	—	—	1	3	—	—	3	1	—	—	—	144	,,	144
5	13-10-1933	Port Said	10 aurita	5	5	—	—	—	4	4	2	—	—	—	6	4	—	6	4	—	—	—	635	Flesh	102
6	20-10-1933	Port Said	2 aurita...	1	1	—	—	—	—	1	—	1	—	—	1	1	—	1	1	—	—	—	200	Whole fish	200
			1 eba ...	1	—	—	—	1	—	—	—	—	—	—	1	—	—	—	1	—	—	—			
7	20-10-1933	Port Said	5 aurita ...	3	2	—	—	—	2	1	1	1	—	2	1	2	—	2	3	—	—	—	335	Flesh	70
8	20-10-1933	Port Said	6 eba ...	3	3	3	2	1	—	—	—	—	—	3	3	—	—	3	3	—	—	—	185	,,	51
9	7-11-1933	Rosetta ...	4 aurita ...	2	2	—	—	—	1	2	1	—	—	1	3	—	—	1	3	—	—	—	230	Whole fish	230
10	7-11-1933	Rosetta ...	5 aurita ...	2	3	—	—	1	1	1	2	—	—	2	2	1	—	2	3	—	—	—	317	Flesh	105
11	10-11-1933	Damietta	4 eba ...	2	2	1	2	1	—	—	—	—	—	—	3	1	—	2	2	—	—	—	164	Whole fish	164
12	10-11-1933	Damietta	5 eba ...	3	2	2	2	—	1	—	—	—	—	1	3	1	—	2	3	—	—	—	182	Flesh	60

13	7-12-1933	Rosetta ...	4 aurita ...	2	2	—	1	—	2	1	—	—	—	2	2	—	—	2	2	—	—	—	182	Whole fish	182
14	7-12-1933	Rosetta ...	5 aurita ...	2	3	—	—	1	2	2	—	—	—	4	1	—	—	3	2	—	—	—	230	Flesh	32
15	3- 1-1934	Damietta	4 aurita ...	2	2	—	—	1	1	2	—	—	—	1	1	2	—	2	2	—	—	—	225	Whole fish	225
16	3- 1-1934	Damietta	5 aurita ...	2	3	—	—	2	2	1	—	—	—	2	2	1	—	2	3	—	—	—	220	Flesh	60
17	3- 1-1934	Damietta	4 eba ...	2	2	—	4	—	—	—	—	—	—	1	3	—	—	2	2	—	—	—	125	Whole fish	125
18	3- 1-1934	Damietta	8 eba ...	4	4	4	2	2	—	—	—	—	—	3	3	2	—	3	5	—	—	—	250	Flesh	30
19	25- 5-1935	Alexandria	4 aurita ...	2	2	—	—	—	—	—	—	—	4	—	—	—	4	—	—	—	1	3	260	Whole fish	260
20	25- 5-1935	Alexandria	4 aurita ...	2	2	—	—	—	—	—	—	—	4	—	—	1	3	—	—	—	1	3	275	Flesh	120
21	30- 6-1935	Alexandria	5 granigera	2	3	—	—	—	—	2	2	—	1	—	—	2	3	—	1	3	1	—	220	Whole fish	220
22	30- 6-1935	Alexandria	6 granigera	1	5	—	—	1	1	1	1	2	—	—	—	3	3	—	2	1	2	1	247	Flesh	102
23	1- 7-1935	Sidi Gaber	5 aurita ...	2	3	—	—	—	1	2	—	1	1	—	1	2	2	—	—	—	3	2	239	Whole fish	239
24	1- 7-1935	Sidi Gaber	5 aurita ...	2	3	—	—	—	—	3	—	1	1	—	2	1	2	—	—	—	1	4	240	Flesh	90
25	1- 7-1935	Sidi Gaber	5 aurita ...	5	—	—	—	—	—	—	1	2	2	—	1	2	2	—	—	—	2	3	295	Milt	12
26	1- 7-1935	Sidi Gaber	5 aurita ...	—	5	—	—	—	1	4	—	—	—	—	2	3	—	—	—	—	1	4	192	Gonads	8
27	25- 7-1935	Alexandria	4 eba ...	2	2	—	2	2	—	—	—	—	—	—	4	—	—	—	—	—	1	3	100	Whole fish	100
28	25- 7-1935	Alexandria	8 eba ...	4	4	—	1	4	3	—	—	—	—	1	4	3	—	—	—	—	3	5	223	Flesh	91
29	25- 7-1935	Alexandria	8 eba ...	4	4	—	1	4	3	—	—	—	—	1	5	2	—	—	—	—	3	5	223	Gonads	8
30	29- 7-1935	Alexandria	5 eba ...	5	—	—	1	2	1	—	1	—	—	—	4	1	—	—	—	—	4	1	145	Flesh	59
31	29- 7-1935	Alexandria	5 eba ...	5	—	—	1	2	1	—	1	—	—	—	4	1	—	—	—	—	4	1	145	Milt	4
32	29- 7-1935	Alexandria	5 eba ...	—	5	—	—	4	1	—	—	—	—	1	3	1	—	—	—	—	2	3	138	Flesh	59
33	29- 7-1935	Alexandria	5 eba ...	—	5	—	—	4	1	—	—	—	—	1	3	1	—	—	—	—	2	3	138	Gonads	6
34	29- 7-1935	Alexandria	23 eba ...	—	23	1	3	14	4	1	—	—	—	3	17	3	—	—	—	—	10	13	686	Gonads	24

TABLE II.—HISTORY OF SAMPLES (*contd.*)

No. of Sample	Date	Locality	Sample	Sex		Lengths (cms.)								Age No. of winter rings				Maturity Hjort's Scale					Fresh Wt. of sample (gms.)	Tissue Taken	Fresh Wt. of material used (gms.)
				♂	♀	13	14	15	16	17	18	19	20	1	2	3	4	I	II	III	IV	V			
35	3- 8-1935	Alexandria	5 eba ...	—	5	—	—	1	3	1	—	—	—	—	4	1	—	—	—	—	—	5	150	Flesh	50
36	3- 8-1935	Alexandria	5 eba ...	—	5	—	—	1	3	1	—	—	—	—	5	—	—	—	—	—	—	5	150	Gonads	5
37	3- 8-1935	Alexandria	5 eba ...	5	—	—	1	3	1	—	—	—	—	1	4	—	—	—	—	—	1	4	123	Flesh	34
38	3- 8-1935	Alexandria	5 eba ...	5	—	—	1	3	1	—	—	—	—	1	4	—	—	—	—	—	1	4	123	Milt	5
39	15- 8-1935	Rosetta ...	15 eba ...	15	—	—	2	11	2	—	—	—	—	3	10	2	—	—	—	—	—	15	438	Flesh	46
40	15- 8-1935	Rosetta ...	15 eba ...	15	—	—	2	11	2	—	—	—	—	4	10	1	—	—	—	—	—	15	438	Milt	27
41	15- 8-1935	Rosetta ...	15 eba ...	—	15	—	2	7	5	1	—	—	—	3	11	1	—	—	—	—	—	15	435	Flesh	54
42	15- 8-1935	Rosetta ...	15 eba ...	—	15	—	2	7	5	1	—	—	—	4	10	1	—	—	—	—	—	15	435	Gonads	22
43	30- 8-1935	Rosetta ...	2 aurita ...	2	—	—	—	—	1	1	—	—	—	—	2	—	—	—	—	—	—	2	69	Whole fish	69
44	30- 8-1935	Rosetta ...	6 aurita ...	6	—	—	—	—	2	2	1	1	—	—	4	1	1	—	—	—	—	6	241	Flesh	31
45	30- 8-1935	Rosetta ...	6 aurita ...	6	—	—	—	—	2	2	1	1	—	—	3	2	1	—	—	—	—	6	241	Milt	10
46	30- 8-1935	Rosetta ...	2 aurita ...	—	2	—	—	—	1	1	—	—	—	—	2	—	—	—	—	—	—	2	77	Whole fish	77
47	30- 8-1935	Rosetta ...	6 aurita ...	—	6	—	—	—	1	1	2	2	—	—	2	2	2	—	—	—	1	5	238	Flesh	40
48	30- 8-1935	Rosetta ...	6 aurita ...	—	6	—	—	—	1	1	2	2	—	—	3	2	1	—	—	—	1	5	238	Gonads	9
49	27-10-1935	Abou Kir	2 aurita ...	1	1	—	—	—	—	1	1	—	—	—	1	1	—	1	1	—	—	—	98	Whole fish	98
50	27-10-1935	Abou Kir	4 aurita ...	2	2	—	—	—	—	2	1	1	—	—	2	2	—	2	2	—	—	—	200	Flesh	90
51	18-11-1935	Port Said	3 aurita ...	3	—	—	—	—	—	2	1	—	—	—	2	1	—	2	1	—	—	—	181	Whole fish	181
52	18-11-1935	Port Said	4 aurita ...	2	2	—	—	—	—	2	2	—	—	—	1	2	1	4	—	—	—	—	235	Flesh	73

METHODS OF ANALYSES

The methods of analyses were very similar to those described by *Channon and Saby* (1932) in their preliminary study of "Fat Metabolism of the Herring." In all cases the acetone was removed from each sample by filtration through a Buchner funnel. The residue was repeatedly treated with warm fresh acetone and filtered. The final residue, after being finely ground in a mortar, was then extracted with ether in a Soxhlet apparatus for about 6 hours. The combined acetone extracts was evaporated to dryness *in vacuo* and the residue was dissolved in ether and filtered. The filtrate obtained was added to the ethereal extract from the Soxhlet extractor and the whole was then distilled and evaporated and dried *in vacuo* at 100°C. The fat-content of the tissue is expressed as the weight of this ethereal extract.

In some samples the amount of the ethereal extract was so small that only a few of the fat constants could be determined on account of lack of material. In these cases the fat was saponified and determinations of iodine number of the unsaponifiable fraction and of the fatty acids made.

Acid Value: 3 to 5 grams of the fat were dissolved in 40 cc. of neutral mixture of alcohol and ether (7 parts alcohol to 3 parts ether) and titrated with 0·1 N alcoholic sodium hydroxide solution, using phenolphthalein as indicator. The results were calculated as mg of potassium hydroxide required to neutralise the free fatty acids of one gram of the ethereal extract.

A portion of the fat was then saponified by boiling with excess of alcoholic potash until much of the alcohol was removed. This was followed by dilution with water in an extraction funnel and the ethereal extract of the unsaponifiable fraction was obtained by 5 to 6 extractions with ether. The ethereal extract, after washing with water to neutrality, was distilled and dried at 100° C *in vacuo* and the unsaponifiable fraction thus obtained. The combined soap solutions and aqueous washings were then acidified with conc. Hydrochloric acid, and similarly extracted with ether. After washing to neutrality the ethereal extract was evaporated and the residue dried *in vacuo* at 100° C. It was then dissolved in petroleum ether and allowed to stand over night. The light petroleum solution, after being filtered, was evaporated to dryness at 100° C *in vacuo*, and the fatty acids are obtained.

Iodine values of the unsaponifiable fraction and the fatty acids were determined according to the method of Rosenmund and Kuhnhenn (1923.)

RESULTS

PART I.

The Fat Content of Whole Fish Analyses

The amounts of the ethereal extract (gram per 100 g. of fresh sample) and the variation in the percentage yields of the fatty acids and unsaponifiable matter with the iodine values and the acid number of the fat of whole fish are recorded in Table III for S. aurita, and Table IV for S. eba.

TABLE III.—VARIATION IN THE PERCENTAGE YIELDS OF FAT IN S. AURITA (WHOLE FISH).

No. of Sample	Date	% yield of ethereal extract	% yield of fatty acids in the extract	Iodine value of fatty acids	% yield of unsap. matter in the extract	Iodine value of unsap. matter	Acid Number
3	13-10-1933	30·79	lost	—	lost	—	5·1
6	20-10-1933	30·29	87·50	110·6	0·95	82·0	5·9
9	7-11-1933	34·66	92·70	101·3	0·73	56·6	3·8
13	7-12-1933	30·60	89·54	105·6	0·68	62·7	5·7
15	3-1-1934	30·63	90·65	110·2	0·71	60·8	6·4
19	25-5-1935	3·37	86·20	144·1	4·20	70·4	28·5
23	1-7-1935	3·78	77·96	138·1	4·96	59·1	37·4
43	30-8-1935	7·32	79·66	117·3	2·96	74·5	25·6
46	30-8-1935	8·10	84·53	125·0	2·88	77·6	21·8
49	27-10-1935	23·76	83·24	107·1	0·91	60·9	11·6
51	18-11-1935	32·18	91·35	129·2	1·05	91·0	14·2
Mean Values		21·41	86·33	118·9	1·97	69·6	15·1

TABLE IV.—THE PERCENTAGE YIELDS OF THE FAT IN S. EBA (WHOLE FISH).

No. of Sample	Date	% yield of ethereal extract	% yield of fatty acids in the extract	Iodine value of fatty acids	% yield of unsap. matter in the extract	Iodine value of unsap. matter	Acid number
4	13-10-1933	42·47	89·60	—	0·35	65·4	7·8
11	10-11-1933	28·86	91·07	96·9	1·08	60·8	3·5
17	3-1-1934	24·12	86·92	103·0	1·03	55·2	6·7
27	25-7-1935	7·19	86·74	133·9	3·48	78·0	19·0
Mean Values		25·66	88·58	111·3	1·49	64·9	9·3

On account of the rarity of S. granigera and to the limited period of its appearance one sample only No. 21 of the whole fish was taken on May 30, 1935. The results of the analyses as follows :—

% yield of ether extract	% yield of fatty acids	Iodine value of acids	% yield of unsap. matter in the extract	Iodine value of unsap. matter
2·92	82·13	167·1	5·3	70·1

It should be noted that early in summer small quantities of poor fish are caught in the coastal waters from Alexandria to Abou Kir. These fish, being very lean and generally either unripe or immature start to feed on the zooplankton mainly Copepoda and in the meantime the reproductive organs mature. As the fish feed, the fat content increases up until it reaches its maximum for this period just before the fish go on the hunger migration to spawn.

This summer fishery or the spawning period is represented in Table III of S. aurita by 4 samples Nos. 19, 23, 43 and 46 : in Table IV of S. eba by one sample No. 27 ; and the one sample of S. granigera. while the rest of the samples of whole fish analyses of S. aurita and S. eba were taken during the fishing season or the extensive feeding period.

The results of the analyses of the spawning period show that in the case of S. aurita the percentage yield of fat of the whole fish was in May 3·37 when gonads were immature or unripe, slightly increased in July to 3·78, while it rose up by the end of August to 8·1 when the fish were full and about to spawn. The mean value for the four samples taken from this fish during summer period was 5·64 per cent of fat. In the case of the other two species the process of gradual increase of fat in the whole fish during this period could not be traced as one sample only was taken of each—Sample 21 of the whole fish of S. granigera, taken in May contained 2·92 per cent while sample 27 of S. eba taken in July contained 7·19 per cent of fat.

As the fish feed very vigorously during the fishing season on the abundant marine Phytoplanktonic forms, the amount of fat in the different tissues of the fish is continually enriched and the excess is deposited as the " Mesentric " fat round the alimentary tract. The results recorded in Table III for S. aurita show a striking rise in the fat content during this period as the percentage of fat in October varied from 23·76 in sample 49 to 30·79 in sample 3 and rose to a maximum 34·66 for sample 9 taken in November, with an average value for the season—October to January—of 30·42 as against 5·64, the mean value obtained during the spawning period.

Figures of Table IV of S. eba show great similarity as to the striking increase of the fat content in the whole fish during the period October to January, with a mean value of 31·82 per cent of fat as against 7·19 per cent in July.

To record the seasonal changes in the fat content of the two species S. aurita and S. eba, the results obtained in Table III and Table IV for the fat content of the whole fish are expressed graphically in Fig. I, assuming that samples of the two species were completed during the fishing months of one and continuous period (May–January). Whenever more than one sample were dealt with in any month, the mean value of their percentages of fat was taken to represent the percentage yield of the ethereal extract of the fish in that particular month.

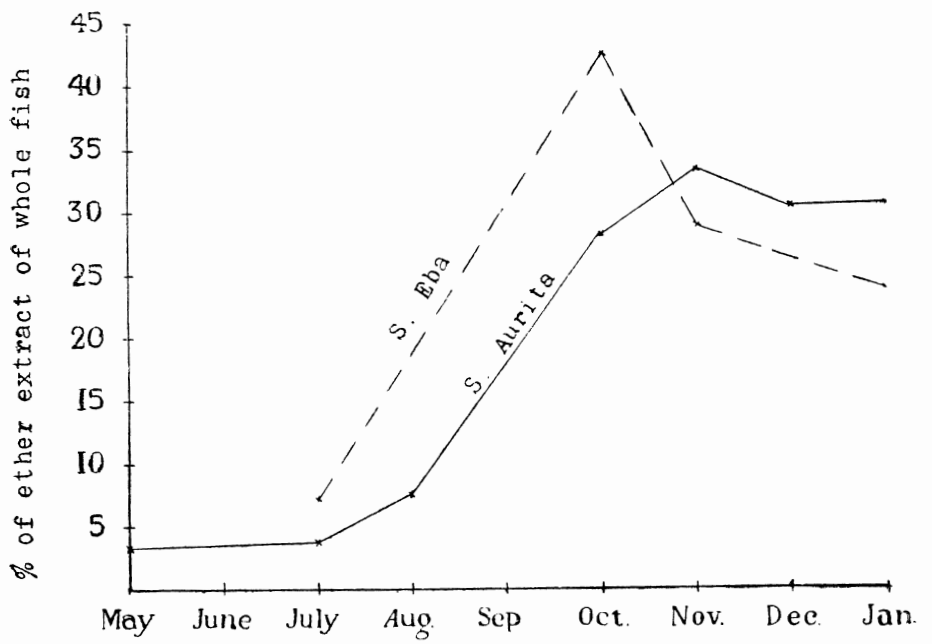

FIG. I.—Variation in the Fat-content of whole-fish analyses of S. aurita and S. eba during fishing months (May-Jan.)

Before the discussion of the figures concerned with the variation in the percentage yields of fatty acids and unsaponifiable matter with the iodine values and acid numbers, it is desirable to note that the ethereal extract in the manner obtained in this work contains a variety of substances :—

(*a*) *The unsaponifiable fraction.*—This consists largely of cholesterol.

(*b*) *Phosphatide.*—This consists largely of lecithin.

(*c*) *Triglyceride.*—This is the neutral fat "oil."

(*d*) *Extraneous material, which is not truly soluble in pure ether.*—The material appears in the extract because of the presence in them of phosphatide. If phosphatide is dissolved in ether, the ether solution of the phosphatide will dissolve many other things that are not soluble in pure ether.

The amount of (*a*), (*b*) and (*d*) will practically remain constant, irrespective of whether the fish is rich or poor in fat (*c*). When the fat content of the tissues increases, most if not all that is increasing in(*c*).

The next point to mention is that fatty acids which are present in the phosphatide are more unsaturated usually than are those in the triglyceride. Bearing these facts in mind the results recorded in Tables III and IV and in the case of the one sample of S. granigera, concerned with the variation of the yields of fatty acids and unsaponifiable matter with their iodine values are easy to explain.

During summer fishery the fish are lean and the ethereal extracts of samples contain very little triglyceride as against a high percentage of the other constituents– unsaponifiable matter, phosphatide, and extraneous materials—the properties of which would be most prevailing in the analyses of the extracts of this period. For example the extracts would be expected to contain a lower percentage yields of fatty acids with more unsaturated nature due to the concentration of phosphatide : a higher percentage of usnaponifiable material : and an increased acid number on account of the higher percentage of phosphatide and other extraneous material present in the extract.

When the fish fatten during the feeding season the amount of the fat content rapidly increases due to the striking increase of the amounts of the triglyceride or the neutral fat, the properties of which would be most prominent and dominating those of the other constituents in the analyses of the extracts of this period. For example the percentage yield of fatty acids in the extract shows a tendency to increase, while the fatty acids become less unsaturated ; a much lower percentage yields of unsaponifiable matter : and a sharp decrease in the acid number as phosphatide and other extraneous material being subsided by the neutral fat.

The results obtained from the analyses were :—

(1) From May to August, or the spawning period.—A comparatively lower percentage yields of fatty acids ranged in case of S. aurita Table III between 77·96 and 86·20 with a mean value 82·09, and in

Table IV of S. eba there was one sample only and its yield was 86·74 per cent while the sample of S. granigera gave a corresponding value of 82·13 per cent. The unsaponifiable matter in case of S. aurita Table III varied from 2·88 per cent in August to 4·96 per cent in July giving a mean value 3·75 per cent; the corresponding value in the sample of S. eba Table IV was 3·48 per cent while in the sample of S. granigera being 5·3 per cent.

The figures in Table III show that the iodine number of fatty acids varied from 117·3 when percentage of fat was 7·3 to 144·1 when percentage of fat was at its lowest 3·37, giving a mean value of 131·1 for this number during May to August, while the range of the variation in the iodine number of the unsaponifiable matter during the period was limited between 59·1 and 77·6 with a mean value of 70·4. The iodine number of fatty acids in the case of the sample of S. eba and that of S. granigera were 133·9 and 167·1 respectively while their corresponding values for the iodine number of the unsaponifiable matter were 78 and 70·1. In the case of S aurita Table III the acid number varied between 21·8 and 37·3 with a mean 28·3 and in the sample of S. eba Table IV its value was 19 but in the case of the sample of S. granigera no determination was made due to the lack of material.

(2) The feeding period October to January.—The yields of fatty acids showed a tendency for increase in Table III of S. aurita the percentage yields ranged between 83·24 and 92 7 with an average value of 89·16, while this range of variation in the case of S. eba Table IV was between 86·92 and 91·07 giving a mean value 89·2. The percentage yields of unsaponifiable matter in the extract definitely decreased—these varied from 0·59 to 1·05 giving an average yield for the whole season 0·78 per cent in the case of S. aurita Table III, while in the case of S. eba Table IV the corresponding variation was between 0·35 to 1·08 with a mean value of 0·83. During this period the fatty acids become less unsaturated and the iodine numbers obtained varied in the case of S. aurita Table III between the two extremes 101·3 and 129·2. giving an average iodine value 110·7, and in Table IV of S. eba two determinations only were made and gave the numbers 96·9 and 103·0. The iodine numbers of the unsaponifiable matter varied irregularly and insignificantly from a minimum of 56·6 to a maximum of 91·0 giving a mean of 69 in the case of S. aurita Table III, and from 55·2 to 65·4 with a mean 60·5 in the case of S. eba analyses. During this period the acid numbers strikingly decreased and their range of variation was from 3·8 to 14·2 with a mean 6·2 in the analyses of S. aurita Table III, and from 3·5 to 7·8 with an average value 6·0 in the analyses of S. eba Table IV.

PART II.

The Fat Content of the Flesh and its Constants

The analytical data obtained for the amounts of the ethereal extract and the variation in the percentage yields of the fatty acids and unsaponifiable matter with the iodine values and acid numbers of the flesh are recorded in Table V for the flesh of S. aurita and Table VI for the flesh of S. eba.

TABLE V.—PERCENTAGE YIELDS OF FAT AND ITS CONSTANTS FROM THE FLESH OF S. AURITA.

No. of Sample	Date	% yield of ethereal extract	% yield of fatty acids in the extract	Iodine value of fatty acids	% yield of unsap.matter in the extract	Iodine value of unsap. matter	Acid number of the extract
5	13–10–1933	14·82	85·11	lost	0·90	68·8	no oil
7	20–10–1933	21·49	90·51	104·4	0·72	72·6	8·8
10	7–11–1933	24·50	90·01	96·2	1·31	48·2	6·8
14	7–12–1933	28·21	85·91	99·6	0·93	50·2	8·4
16	3–1–1934	24·46	lost	117·2	0·63	56·9	7·3
20	25–5–1935	2·92	lost	148·1	3·87	75·3	no oil
24	1–7–1935	2·65	lost	144·3	4·66	91·0	,,
44	30–8–1935	9·16	87·76	104·1	1·91	69·5	,,
47	30–8–1935	6·60	77·34	108·8	2·81	72·1	,,
50	27–10–1935	12·0	89·13	131·5	0·72	70·5	10·6
52	18–11–1935	24·1	88·76	124·1	0·92	58·9	7·1
Mean Values		15·54	86·81	118·8	1·76	66·8	8·2

TABLE VI.—PERCENTAGE YIELDS OF FAT AND ITS CONSTANTS FROM THE FLESH OF S. EBA.

No. of sample	Date	% yield of ethereal extract	% yield of fatty acids in the extract	Iodine value of fatty acids	% yield of unsap. matter in extract	Iodine value of unsap. matter	Acid number of the extract
8	20–10–1933	24·25	89·80	110·1	0·72	63·9	5·6
12	10–11–1933	23·85	86·90	80·5	0·88	56·5	4·5
18	3–1–1934	29·42	lost	—	lost	—	17·5
28	25–7–1935	4·23	78·34	133·9	3·71	78·8	no oil
30	29–7–1935	2·55	—	138·0	4·56	74·0	,,
32	29–7–1935	2·76	—	136·0	3·95	81·6	,,
35	3–8–1935	3·43	—	125·8	3·79	77·2	,,
37	3–8–1935	3·34	—	125·6	4·24	89·2	,,
39	15–8–1935	13·22	85·69	121·8	1·49	79·3	18·6
41	15–8–1935	11·41	86·64	126·3	1·61	90·6	20·7
Mean Values		11·05	83·88	124·4	2·79	76·8	13·4

From the figures recorded in Table V and in Table VI, it is clear that the fluctuations in the fat content of flesh are very similar to those previously described in the case of the estimations of that of the whole fish.

Here again it was found out that during the feeding season the fat content of the flesh from S. aurita Table V was lowest at 12 per cent in October ; rose to a maximum 28·21 per cent in December, and ended in January at a value 24·46 per cent giving a mean value for the whole fishing season 21·37 per cent of the fresh flesh In Table VI three samples only Nos. 8, 12 and 18 were taken during this period for the analyses of the flesh of S. eba—the fat content in them varied from 23·85 per cent to 29·42 per cent with a mean value 25·84 per cent.

On the other hand the fat content of the flesh during the summer fishery, May to August, is represented in Table V of S. aurita with four samples—its value varied between a minimum 2·65 per cent in July and a maximum 9·16 per cent in August, with an average value for this period of 5·33 per cent of the fresh tissue. In the case of the flesh of S. eba Table VI seven samples were taken during this period, the fat content in them varied between the two extremes 2·55 per cent in July and 13·22 per cent in August giving a mean value of 5·85 per cent.

In the case of S. aurita Table V the two samples 44 and 47 and in the case of S. eba samples 30 and 32 : 35 and 37 : 39 and 41 are of particular interest since each pair was taken on the same day under similar conditions and from the same catch to show the difference, if any, between the two sexes. The results obtained for the percentage yield of fat of the two sexes are tabulated in the following table :—

Date	Males		Females	
	Sample No.	% fat	Sample No.	% fat
29–7–1935	30	2·55	32	2·76
3–8–1935	37	3·34	35	3·43
15–8–1935	39	13·22	41	11·41
30–8–1935	44	9·16	47	6·16

These figures show a close similarity between the two sexes in the fat content. The apparent difference between the two samples 39 and 41 and the two samples 44 and 47 is probably attributed to individual variations rather than to a sexual difference.

The seasonal changes in the percentage yields of fat from the flesh of the two species S. aurita and S. eba are graphically expressed in Fig. II, assuming the continuity of sampling as was done in Fig. I.

Whenever more than one sample of flesh were taken from the same species in any month, the mean values of the percentages of fat were taken.

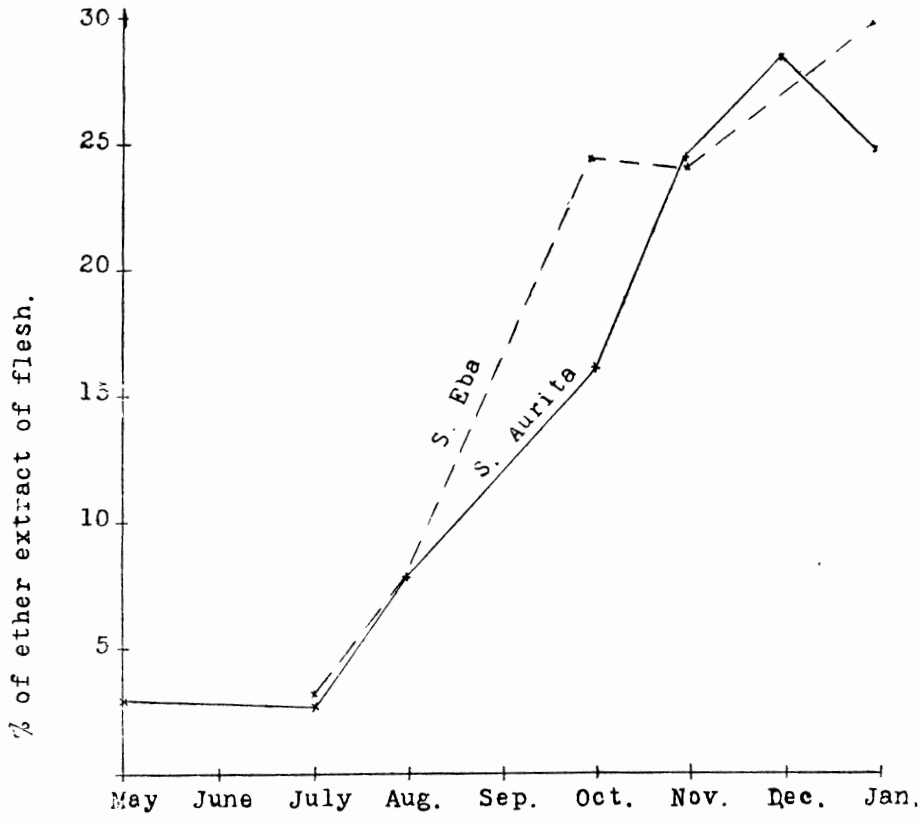

FIG. II.—Variation in the Fat-content of the flesh of S. aurita and S. eba during fishing months (May-Jan.)

Fig. II indicates a steady rise in the fat content of the flesh of both fishes from summer, when ripening and maturing fish were caught, to the autumn and early winter, when the fish were extensively feeding.

The maximum amounts of fat were apparently attained later on, at about the end of the fishing season. There was only one sample No. 22 taken on June 30, for the flesh of S. granigera. The ethereal extract of the flesh was 3·14 per cent of its fresh weight. The yield was insufficient for the analyses to be carried out.

The variations in the properties of the ethereal extracts of flesh from both fish S. aurita and S. eba show close similarities to those of the ethereal extracts of the whole fish previously explained.

The extracts of the spawning period gave comparatively lower percentage yields of fatty acids with more unsaturated nature ; higher percentage yields of unsaponifiable matter with increased iodine values ; and a definite rise in the acid number, while the properties of the extracts of the feeding period varied in a reverse sense. The mean values obtained for the properties of fat from the flesh of both species during the two periods of feeding and spawning are recorded in the following table :—

Species	Mean % Yield of fatty acids		Mean Iodine value of fatty acids		Mean % Yield of unsap. matter		Mean Iodine value of unsap. matter		Mean Acid number	
	Feeding	Spawning	Feeding	Spawning	Feeding	Spawning	Feeding	Spawning	Feeding	Spawning
S. aurita	88·24	82·55	112·2	126·3	0·88	3·31	60·9	77·0	8·2	—
S. eba	88·35	82·25	95·3	128·0	0·80	3·34	60·2	82·6	9·2	19·7

PART III.

The Fat-Content of the Gonads

During the months July and August 1935 maturing and ripening fish mainly of S. eba were caught with their gonads at the stages III, IV and V of Hjort's scale.

Samples of ovaries and testes of S. eba and S. aurita were taken and treated in the same way as in the case of the flesh of each species for the estimation of the fat content.

Due to the rarity of S. aurita in the summer catches, only 4 samples taken for the maturing reproductive organs of this fish—2 for each sex with their particulars as recorded in Table VII.

TABLE VII.—VARIATION IN THE PERCENTAGE YIELDS AND THE PROPERTIES OF THE ETHEREAL EXTRACTS OBTAINED FROM TESTES AND OVARIES OF S. AURITA.

Date	No of Sample	% Yield of ether extract		% Fatty acids in the extract		Iodine values of fatty acids		% Unsap. matter in the extract		Iodine value of unsap. matter	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1-7-1935 ...	25	4·95	—	—	—	147·1	—	12·57	—	76·1	—
	26	—	7·24	—	50·53	—	145·6	—	16·65	—	62·4
30-8-1935 ...	45	6·03	—	59·80	—	108·6	—	10·0	—	70·2	—
	48	—	6·88	—	52·38	—	103·4	—	11·79	—	63·2
Mean Values ...		5·49	7·06	59·80	51·45	127·8	124·5	11·28	14·22	73·1	62·8

These data show a difference in the mean value of the percentage yields of the fat content between testes and ovaries—the respective values being 5·49 and 7·06. There are also apparent differences between the percentage yields of fatty acids and between the yields of unsaponifiable substances in the extracts of testes and ovaries, but it is not safe to make any deductions from only two analyses of each sex. These differences are dealt with later when the results obtained for S. eba are discussed.

The variation in the amounts of fat content of the gonads of S. eba with their properties are recorded in Table VIII.

TABLE VIII.—VARIATION IN THE PERCENTAGE YIELDS AND THE PROPERTIES OF THE ETHEREAL EXTRACT OBTAINED FROM TESTES AND OVARIES OF S. EBA.

Date	No. of Sample	% Yield of ether extract		% Fatty acids in the extract		Iodine Value of fatty acids in the extract		% Unsap. matter in the extract		Iodine value of unsap. matter	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
29-7-1935 ...	31	4·12	—	38·69	—	—	—	18·13	—	79·5	—
	33	—	7·02	—	50·21	—	132·8	—	11·96	—	79·6
	34	—	6·90	—	68·32	—	139·5	—	11·10	—	85·9
5-8-1935 ...	36	—	7·72	—	56·69	—	116·9	—	12·12	—	75·1
	38	3·79	—	39·06	—	103·4	—	15·47	—	68·5	—
15-8-1935 ...	40	4·72	—	51·39	—	127·5	—	10.99	—	71·4	—
	32	—	5·95	—	60·39	—	116·6	—	9·79	—	72·0
Mean Values ...		4·16	6·9	43·05	58·90	115·5	126·5	14·86	11·24	73·1	78·2

These figures show that the mean values of the percentage yields of ether extracts from the gonads of S. eba varied between the two sexes—being in milt 4·16 and in roes 6·9. This result fairly agrees with the corresponding mean values in Table VII obtained from the analyses of the gonads of S. aurita.

The amount of fatty acids in the extracts also varied between males and females—its mean value in milt being 43·05 per cent and in ovaries 58·90 per cent. On the other hand, the yield of unsaponifiable matter varies in the reverse sense, *i.e.* 14·86 per cent in males and 11·24 per cent in females.

The mean value of the iodine numbers of fatty acids showed a difference between testes and ovaries, being in the former 115·5 and in the latter 126·5. The analyses showed also a corresponding difference in the average iodine values of the unsaponifiable substances, being in testes 73·09 and in ovaries 78·15. This difference in the iodine values between testes and ovaries indicates that the fat of the testes is more saturated than that of the ovaries, but this point—due to the few analyses dealt with here—needs a further study before it can be finally settled.

CONCLUSION

The variation in the chemical composition of a species of fish does not only occur between individuals, but it also occurs with the different seasons of the year. This result was established by several workers on the chemical composition of food fishes—among whom Atwater (1888), who analysed 52 species of American food fishes; Clark and Almy (1918) in their work on 20 species of Atlantic food fishes: Dill (1921) in his study of a number of Pacific food fishes; Balland and Hollande in their study of European food fishes, and Saby (1933) in the work on the dietetic value of 22 species of Egyptian food fishes may be mentioned.

The amount of fat present in species having a low fat content does not undergo wide variation between individuals. On the other hand the fat contents of fat-rich species such as: salmon, herring, shad, sardine, etc., show striking variations between individual fish, between species in different localities and at different seasons of the year.

The works of Miescher-Ruesch on the Rhine salmon; Paton on the Scotch salmon; Green (1919 and 1921) on the Pacific Coast salmon: Milroy (1906, 1907, 1908) on the muscles and gonads of Loch Fyne herrings: Johnstone (1915, 1918, 1919, 1920) on the estimations of the muscle fat of Manx-herrings; Bruce (1924), Channon and Saby (1932) on the fat metabolism of the Manx herrings

strikingly show that the fat stored in the body during the periods of growth and feeding is the immediate source of energy expended by the fish at the time of its spawning migration, when no food is taken.

The analyses of the three species of Sardinella were undertaken over a period long enough to show the range of variations in the fat content of whole fish, flesh, and gonads. The results of the analyses showed a close similarity to those obtained by the different authors in their investigations on herring, salmon, shad, etc., and can be concluded in the following :—

(1) The comparison of the mean values obtained for the fat content and its properties of whole fish, flesh, and gonads of S. aurita and S. eba shows that these values are essentially identical in both species all the year round. When S. granigera appeared, it showed similarity to the other two species.

(2) Radical changes occurred in the tissues as regards the fat content and its properties. These changes could be pictured for the two periods when the mean values of the results are tabulated such as in Table IX.

TABLE IX. MEAN VALUES OF FAT CONTENT AND ITS CONSTANTS FOR WHOLE FISH AND FLESH OF S. AURITA AND S. EBA DURING THE TWO PERIODS OF FEEDING AND SPAWNING.

	Period	% Yield of extract	% Fatty acids	Iodine value of fatty acids	% Unsap. matter	Iodine value of unsap. matter	Acid value
Whole fish	Feeding S. aurita ...	31·12	89·18	105·3	0·80	64·7	6·08
	Spawning ...	6·42	84·82	132·5	3·62	74·2	23·62
Flesh	Feeding S. eba ...	23·61	88·30	103·7	0·84	60·6	8·69
	Spawning ...	6·56	82·80	127·2	3·06	78·6	19·67

These figures show :—

(*a*) Close similarity between the mean values obtained for the analyses of the whole fish and flesh during the two periods of feeding and spawning save the percentage yield of the fat content of whole fish during feeding period was greater than that of the flesh due to the presence and accumulation of the "Mesenteric fat" round the alimentary tract.

(*b*) The increase in the fat content of whole fish and flesh from the spawning period to the feeding period in both species S. aurita and S. eba caused—an increase in the percentage yield of fatty acids with a definite fall in their iodine values ; a decrease in the unsaponifiable substances with an apparent decrease in their iodine values ; and a striking fall in the acid values of the extracts.

(3) Neither specific nor sexual differences were observed between males and females of the two species S. aurita and S. eba as regards difference in the fat content and the properties of the fat.

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