XXX.—CHEMICAL COMPOSITION OF FISH PRODUCTS, WITH SOME REMARKS ON THEIR NUTRITIVE VALUE.*

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The number of investigations on the chemical composition of the various substances used as food by man is not great. Owing to the experiments on the feeding of domestic animals, we have, for instance, hundreds of analyses of the various kinds of hay, while the available analyses of the different kinds of bread will hardly count by dozens. Of the alimentary substances used to prepare food for man, only those have been frequently investigated which at the same time find application in technical industries, such as the potato, the grains of cereals, etc.; and it is to be noticed that such investigations were called forth not by the requirements of hygiene but of technology. The reason is evident enough. Every manufacturer is deeply interested in the amount of profit he can obtain, whereas but few persons will take as great an interest in the life of people unknown to them.

Nevertheless, there can be no doubt as to the great importance of chemical investigations concerning the composition of the materials from which the food of man is derived. Aside from the physiological interest attaching to the problem, it must be taken into consideration that the results of such investigations, if held together with the necessary statistical data, will throw much light on the economical conditions of the national life, and may sometimes illustrate such points as would otherwise escape attention.

I have thought it might not be superfluous to say these few words as introduction to the following, because my investigations concerning the composition of the flesh and some other products of fish will afford me an opportunity to call attention to the importance of fish as food in our national life in general, and, in connection with the available statistical data, will allow me to show how much other food would have to be provided and what means would have to be used if, for some reason or other, the yield of the fisheries was considerably reduced.

[* Translated from the Russian Journal of Rural Economy and Forestry, Vol. CXLIV, Part II.]

The present article is therefore subdivided into two parts. In the first part I shall try to present the results of all investigations made up to the present time on the chemical composition of the flesh of fish. In the second part I intend as far as possible to show, with the aid of certain statistical data, what importance fish has as a food-substance in our domestic economy.

I.—RESULTS OF INVESTIGATIONS.

Investigations on the chemical composition of the flesh of fish can properly be said to have begun only with the year 1854. Before this date only two such analyses were made, and they were very incomplete, so that it is impossible to obtain from their results a correct idea of the composition of the flesh of fish.*

Last year Dr. Popòf analyzed the flesh of some Russian fishes.† Being evidently unacquainted with the work of Mr. Almen, to be referred to hereafter, he proceeded in his analyses in the same manner as did Payen and König. His results are as follows:

Name of fish.	Percentage of—			
	Water.	Fat.	Protein.	Ash.
Salt smelt (*Salmo eperlanus*)	42.58	8.28	29.98	18.93
Fresh smelt	79.01	4.31	13.80	2.97
Fresh "Vobla" (a fish found in the Volga, of the size of a crucian)	75.76	5.88	17.29	1.60
Smoked bream (*Cyprinus vimba*)	37.25	15.22	36.92	10.82
Salt-dried piko-perch	20.55	1.92	60.33	17.62
Salt-dried spirling	72.45	6.78	16.14	3.51
Roe of fresh "Vobla"	72.18	6.85	19.78	0.91
Roe of smoked bream	33.17	16.30	42.80	7.58

In the spring of the present year I made analyses of thirty species of fishes and fish products from Russian waters.‡ I determined in my analyses all the substances enumerated in the table, closely following the directions given by Hoppe-Seyler in his hand-book of physiological chemical analysis. Besides the substances indicated in the table, I also determined the amount of common salt in salt fish, and in certain (salted and preserved) fishes the amounts of phosphoric acid and iron.

*The author here recapitulates the analysis of fish reported previous to the year 1883, when the following analyses by himself were performed. It is deemed unnecessary to repeat his recapitulations here, the more so as the same data with others are to be included in a detailed discussion of the subject by Prof. W. O. Atwater in connection with a report of his to be published by the Commission. A series of analyses by Popòf are, however, included, as they have not become current in the literature of the subject.—EDITOR.

†Determination of the proportion of nutritive matter contained in the most common species of fish. Dissertation for the degree of doctor of medicine. St. Peters burg, 1882; in Russian. [The analyses are stated by Professor Kostytscheff to have been made in the usual way, from which it is to be inferred that the protein was estimated by multiplying the nitrogen by 6.25.—EDITOR.]

‡Owing to an offer made by Mr. N. M. Solsky, director of the Museum of Rural Economy, and late general commissioner to the International Exhibition of Fisheries at London.

The results of my analyses will be found in the following tables:*

TABLE I.—*Percentage of substances found in certain fishes.*

Name of fish.	Water.	Extraneous substances.	Gelatin	Albuminous matter.	Fat.	Ash.	Common salt.
FRESH FISH.							
Coregonus Baerii (Russ. Sig.)	79.13	2.93	3.70	11.69	1.53	1 22	.....
Pike-perch	79.87	3.28	3.55	12.10	0.20	1.00	.....
Common codfish	81.02	3.45	4.24	10.11	0.07	1.11	.....
Carp (Russ., "Sazàn")	70.89	3.92	2.84	10.79	1.42	1.14	.....
Pike	80.70	3.14	3.32	11.23	0.33	1.18	.....
Crucian (carp)	80.82	4.56	3.63	9.44	0.48	1.07	.....
Haddock (Russ., "Navàga")	81.35	4.99	2.46	9.01	0.59	1.58	.....
Smelt	78.38	4.14	2.84	10.00	3.08	1.57	.....
Salmon	62.02	2.70	5.08	12.98	14.82	1.30	.....
Salmon trout	75.35	3.11	1.71	16.01	2.49	1.33	.....
Sturgeon (Russ., "Osiòr")	76.02	3.05	1.58	13.04	5.15	1.16	.....
Sterlet	76.81	1.69	1.74	13.21	5.59	0.26	.....
Sprat	76.11	2.54	1.20	13.46	4.89	1.71	.....
Liver of eel-pout	45.58	2.55	1.01	5.20	44.89	0.61	.....
PRESERVED FISH AND FISH PRODUCTS.							
Dried smelt; the whole fish, with the bones	47.12	3.56	2.27	20.55	8.03	18.47	13.14
Pickled anchovy; whole fish, with bones	60.72	3.73	3.06	3.79	17.14	11.56	9.90
Salmon (Russ., "Siomga")	53.48	3.96	5.08	15.64	12.19	11.65	11.21
Salt turbot	54.65	5.57	1.09	16.83	6.82	15.04	13.77
Salt sturgeon (Russ., "Beluga")	61.85	1.83	2.05	14.82	8.93	10.52	10.03
Pickled lamprey; whole fish, without head and tail	44.62	2.70	4 05	27.57	16.57	4.49	3.33
Smoked shield-fish	54.89	5.42	6.14	18.48	5.08	9.20	7.99
Smoked herring (Russ., "Shemaia")	43.53	6.37	3.47	18.99	16.21	11.43	9.86
Smoked Astrakhan herring	59.56	3.78	4.87	13.41	6.86	9.52	8.08
Roe of *Coregonus Baerii*	66.05	2.16	1.10	14.37	8.97	7.26	6.16
Fresh roe of sturgeon	56.07	1.62	0.78	25.47	12.85	2.31	0.35
Dried "Vobla" (kind of crucian?)	27.96	9.44	8.23	30.18	9.88	14.31	8.92
Dried cod	25.23	5.21	13.23	50.44	0.69	5.20	1.20
"Balyk" * of whitefish	57.55	3.99	4.59	14.91	13.07	5.78	4.13
"Balyk" of sturgeon †	36.67	8.34	2.63	31.08	14.35	6.93	3.53
"Vinziga" (*i. e.*, the spinal cartilage of sturgeon)	50.99	5.21	40.04	0.18	0.06	3.52	.....

* "Balyk" is the Russian term for the flesh of fish dried in the sun.

† The "balyk" investigated by me was too dry; fresh "balyk" ought to contain at least 48 to 50 per cent. of water, with corresponding amounts of other constituent parts.

TABLE II.—*Proportions of phosphoric acid and iron contained in certain fish products.*

	Percentage of—	
	Phos. acid.	Iron.
Flesh of *Coregonus Baerii* (Russ. "Sig.")	0.4711	0.0031
Flesh of pike-perch	0.2602	0.0025
Flesh of fresh cod	0.3731	0.0018
Flesh of pike	0.3980	0.0034
Flesh of haddock (Russ. "Navaga")	0.4833	0.0041
Flesh of salmon	0.3822	0.0035
Flesh of salmon-trout	0.3998	0.0040
Flesh of sturgeon	0.2993	0.0027
Flesh of sterlet	0.3104	0.0025
Dried smelt (*Salmo eperlanus*)	1.3701	0.1341
Flesh of salt turbot	0.4007	0.0041
Flesh of Astrakhan herring	0.2733	0.0020
Roe of sturgeon	1.0340	0.0047

* Where nothing is specified, the substance analyzed is the flesh alone.

[At the International Fisheries Exhibition in London in 1883 there were displayed in the Russian exhibit two printed charts of analyses of the fishes of Russia by Pro-

By comparing these results in their different bearings we are led to the following conclusions, which are not without interest:

(1) The greater the proportion of water contained in the flesh of a fish the smaller is the proportion of fat, as is also the case with the mammalia.

This will readily appear from the tables given above. It will be seen, for instance, that all our most common fishes—the perch, pike, pike-perch, etc., and also the cod—contain in their flesh about 80 per cent. of water, while the proportion of fat amounts to a little over 1 per cent. or less than 1 per cent.* On the other hand, such fishes as the salmon, sturgeon, eel, etc., which contain much fat, have a far smaller proportion of water. The greatest proportion of fat was found in the liver of the eel-pout, which also contains the smallest proportion of water. One and the same fish, if it has more fat, will have less water, as will be seen from the following examples:

	Water.	Fat.
Salmon (according to Almen)	70.33	10.12
Salmon (according to my analysis)	62.02	14.82
Eel (according to Payen)	62.08	23.86
Eel (according to Almen)	52.78	32.88

(2) In general it may be said that the more expensive a fresh fish is the more it contains of nutritious matter. In this respect it will be instructive to compare, on the one hand, the figures showing the propor-

fessor Kostytscheff. Aside from one evident misprint, the figures are the same as here given, except that in the shield-fish (*Pelecus vulgaris*) the percentage of fat is 5.87 instead of 5.08, and in the balyk of whitefish (*Coregonus leucichthys*) the fat is 13.17 instead of 13.07 per cent. The names are somewhat different, and the Latin names are added. As they are (it is to be presumed) the author's translation into English, the names are inserted here, by the aid of Professor Atwater, to supplement the names as here translated from Professor Kostytschef's article.

Fresh fishes.—Flesh of Sig, *Coregonus Lacrii;* Pike-perch, *Lucioperca sandra;* Cod-fish, *Gadus morrhua;* Carp, *Cyprinus carpio;* Pike, *Esox lucius;* Crucian carp, *Carassius vulgaris; Gadus navaga;* Smelt, *Osmerus eperlanus;* Salmon, *Salmo salar;* Salmon-trout, *Salmo trutta;* Sturgeon, *Acipenser güldenstaedtii;* Sterlet, *Acipenser ruthenus; Clupea harengus* var. *membras;* liver of Burbot, eel-pout, *Lota vulgaris.*

Preserved fishes.—Salted and dried entire *Osmerus spirinchus;* marinated entire *Maletta vulgaris;* salted salmon, flesh of *Salmo salar* ("Semga"); salted flesh of the halibut, *Hippoglossus maximus;* salted flesh of the great sturgeon, *Acipenser huso;* marinated entire river lamprey, *Petromyzon fluviatilis;* salted and smoked flesh of *Pelecus vulgaris;* salted and smoked flesh of *Alburnus chalcoides;* salted flesh of caspian shad, *Alosa caspica;* salted caviare of *Coregonus* species; fresh caviare of sturgeon; salted and dried flesh of *Leuciscus rutilus* var. *caspica;* dried flesh of codfish, *Gadus morrhua;* salted and dried backs of *Coregonus leucichthys* ("Balyk"); salted and dried backs of sturgeon ("Balyk"); dried cartilaginous dorsal chords ("Vezeega").

The *Osmerus spirinchus* here is the smelt of the tables; the *Pelecus vulgaris* the shield-fish; the *Alburnus calcoides,* smoked herring; the *Alosa caspica* the Astrakhan herring; the salted caviare, the roe of *Coregonus Lacrii;* the *Leuciscus rutilus,* the vobla, and the *Coregonus leucichthys* the whitefish.—EDITOR.]

*[The original has "or *not* less than 1 per cent.;" probably a misprint.]

tions of fat and albumen in the flesh of the salmon, salmon-trout, sturgeon, and sterlet with the corresponding figures for the pike-perch, pike, perch, cod, etc., on the other. Among the cheap fishes only one presents an exception, namely, the sprat. Its flesh has precisely the same composition as that of the sturgeon and sterlet. It will be noticed that, of all fresh fish-products, fresh (granulated) caviare or roe of sturgeon contains the greatest proportion of nutritious matter.

(3) As regards digestibility, certain kindred species of fish appear to present a remarkable diversity; for instance, salmon and salmon-trout. The flesh of salmon is much fatter than that of "*siomga*,"* which, however, contains more albuminous matter; and compared with other fishes it has much soluble albumen, as far as could be judged from the size of the coagulated albumen without weighing it. Hence, a weak stomach will stand salmon-trout more readily than salmon.

(4) Some fish products used as food apparently contain scarcely any nutritive matter; for instance, "*viaziga*," which is almost exclusively composed of water and gelatin-forming substances. The liver of the eel-pout contains mainly fat (nearly 45 per cent.), with a small quantity of albuminous matter.

(5) The investigation concerning the proportions of phosphoric acid and sesquioxide of iron contained in the flesh of fish did not result in any definite indications of particular interest, excepting, perhaps, the fact that granulated caviare is distinguished by a large proportion of phosphoric acid. The high figures resulting in the case of dried smelt are due to the circumstance that the whole fish, with its bones, was subjected to analysis, and that the ashes were not free of extraneous matter adhering to the smelt from the drying process.

I restrict myself to the present few remarks and the incomplete grouping together of figures, leaving it to the reader to evolve from the tables those more minute indications and results that may be of interest to him.

II.—IMPORTANCE OF FISH AS A FOOD-SUPPLY.

It is well known that in general our waters are comparatively rich in fish, and that a very large quantity of fish is caught there every year. In a recently published pamphlet by O. A. Grimm,† the amount of fresh fish caught every year in Russia is estimated at 40,000,000 puds.‡ Whoever will take the trouble to examine closely the statistical data presented in this work will find that such data are very incomplete, and that this figure of 40,000,000 puds is far below the actual number.

But even this incomplete estimate will allow us to deduce some very instructive conclusions concerning the importance of fish as food in our

[*It would seem as if this ought to be "salmon-trout" and not "*siomga*."]

†Fishing and Hunting in Russian Waters. (International Fisheries Exhibition.) St. Petersburg, 1883. (English.)

‡1 pud = 40 Russian pounds = about 36 English pounds.

national life. To do this, let us determine the quantity of nutritive matter derived from the fish caught and prepared in various manners in Russia. In doing this we may restrict ourselves to the consideration of the albuminous matter as the most important constituent of animal food.

Let us first select for our calculation those more important species of fish about which Mr. Grimm's pamphlet gives definite data, and for which we have also analyses:

	Puds.
1. Pike-perch, amount sent out from Astrakhan, not less than	2,000,000
2. Salmon, caught in various places, not less than	60,000
3. Smelt and spirling	1,000,000
4. Salt-dried "vòbla"	3,000,000
5. Bream, shield-fish, etc	3,500,000
6. Astrakhan herring	7,000,000
7. Sturgeon, sturgeon caviare, and "balỳk"	1,500,000

It will be seen from Mr. Grimm's figures that this whole amount of fish, which is mostly in a preserved condition, corresponds to 25,000,000 puds of fresh fish. Consequently, the quantity of all other kinds of fish caught every year amounts to not less than 15,000,000 puds.

Assuming that in the fishes mentioned above two-thirds of the weight is flesh and one-third makes up the weight of bones, skin, etc., it will be found, with the aid of the analyses given before, that the amount of dry albumen obtained from these fishes is not less than 2,330,000 puds. Assuming further that in the remaining 15,000,000 puds of fish the skin, scales, bones, etc., amounts to one-third and the flesh to two-thirds of the total weight, and supposing all these fishes to be such as contain the least amount (10 per cent.) of albuminous matter, the amount of dry albumen obtained will be at least 1,000,000 puds.

We thus find that we annually derive from our fisheries 3,330,000 puds of albuminous matter. This estimate is certainly below the actual amount; first, because many fishes contain more than two-thirds of flesh; second, because the annual yield of the fisheries in Russia is no doubt greater than 40,000,000 puds. At first sight this figure of 3,330,000 puds of albuminous matter may not appear very great. To realize better its true signification let us try to calculate what resources would be required to obtain the same amount of animal albuminous substances from cattle.

Let us suppose that, to replace fish as food, we keep black cattle of such kind that, on an average, every head when fully grown weighs 20 puds. Such an animal will contain 45.9 per cent. of flesh without bones, or 9.18 puds; and this flesh will contain 1.61 puds of albuminous matter. Now, to obtain from such black cattle 3,330,000 puds of albuminous matter annually it will be necessary to kill not less than 2,000,000 head of cattle a year.

Let us further assume that our cattle will be ready for slaughter when four years old; it will be seen that the supply of cattle in Russia would have to be increased by 8,000,000 head of cattle for slaughter

and not less than 2,500,000 cows for breeding. Consequently, even under the most fortunate (but impossible) circumstances, such as the absence of special cattle diseases, sterility of cows, etc., the number of black cattle in Russia would have to be increased by at least 10,500,000 in order to supply those 3,330,000 puds of albumen, and it would require not less than 25,000,000 *desiatin** of meadows and pastures of good quality to keep and feed these cattle.

How enormous these figures are will be seen from the fact that the number of milch cows in European Russia (not including Poland and Finland) is estimated by various authors at from five to ten millions, and the area of pasturage at 55,000,000 *desiatin*.

We have, however, neglected in our calculation to take into account the milk provided by the cows. Supposing that, on an average, every cow gives 60 pails, or 180 pounds, of milk, this milk represents 1.44 pud of albuminous matter (the average proportion of albumen in milk being 3.2 per cent.). Every cow thus furnishes nearly as much albuminous matter per year as is contained in the flesh of the full-grown animal.

Taking into account the milk, our figures will therefore have to be reduced by one-half. But even then they are exceedingly high, amounting to 6,000,000 head of cattle that would require over 12,000,000 *desiatin* of meadows and pastures. Approximately, we may adopt as our final result that, in order to substitute the albuminous matter of the milk and flesh of our domestic animals for that obtained from our fisheries, we would have to raise by 10 per cent. the productivity of our cattle-breeding industry and the supply of food for the same.

These figures define (with the degree of approximation attainable with the available statistical data) the position and rank the fisheries take in the animal food-supply of the population of Russia. It would of course be possible to replace it by the products of cattle-breeding, but only with the same prices for food. But the prices for the products derived from cattle are far higher than those for the corresponding nutritive products of fish (taken on an average, of course): 1 pud of albuminous matter of fish is worth less than 20 roubles [1 rouble=58.2 cents], whereas the same amount derived from the flesh of cattle will be worth not less than 40 to 50 roubles; the latter food is therefore accessible to a smaller number of people.

It is true, however, that to replace fish by vegetable food would require very much smaller resources. To produce 3,330,000 puds of albuminous matter requires, for instance, only 600,000 *desiatin* of rye, assuming a yield of 55 puds per *desiatina* exclusive of seed, or not over 900,000 *desiatin* in the case of triennial farming and neglecting the meadows necessary for obtaining manure.

* 1 *desiatin* = about 2.7 acres.