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FISHERY BY-PRODUCTS

by

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SUMMARY

Of the annual world catch of fish about one-third is not used for direct human consumption and may be considered as raw material for fishery by-products. The most important by-products are fish meal and fish oil. Of world fish meal production, about 90% is produced from oily species of fish such as anchovy, capelin, and menhaden, and less than 10% from white fish offal such as cod and haddock.

Almost all fish meal is made by cooking the fish, pressing the cooked mass to remove most of the oil and a large proportion of the water, and drying the resultant presscake to which a concentrated fraction of the aqueous liquor removed during pressing is normally added. In some factories the pressing stage may be omitted since with white fish raw material there is no oil to be removed. Although the process is simple in principle, considerable skill and experience is necessary to obtain a high yield of a high quality product and to make the plant efficient.

Fish meal is usually a brown powder which normally contains a high level of protein and appreciable quantities of fat and minerals (Table 2). Details of the amino acid composition of various fish meals are given in Table 3. Fish meals contain a higher level of lysine and sulphur amino acids compared with soyabean meals. The biological availability of the amino acids for the pig and the chicken, when expressed as a

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percentage of the amino acid supplied to the animal by the dietary proteins are similar for fish meals and soyabean meals. The fatty acid composition of the fat extracted from various fish meals is given in Table 4. The composition of the fat in fish meal differs from most vegetable oils because it contains high levels of long chain (C20 and greater) polyunsaturated fatty acids. All the energy in fish meal comes from its content of protein and fat. Table 6 summarizes the results reported in the literature for the metabolizable energy values for chicks of various fish meals. Energy calculations based on practical experiments have led to the preparation of a table of metabolizable energy values for fish meals with different contents of protein and fat (Table 7). The information on the energy value of fish meal for pigs is very limited.

Table 8 gives the content of essential minerals in various fish meals. Table 9 summarizes some miscellaneous analyses for various heavy metals and other elements in fish meals. Table 10 gives the content of the important B vitamins found in fish meal.

Feeding trials have shown that fish meal in the diet of an animal can lead to increased growth and egg production, improved reproduction and better feed conversion, compared with nutritionally balanced all-vegetable diets. This is thought to be due to the presence of so-called unknown growth factors (UGF). Tables 11 to 14 summarize experimental data on effects upon feed conversion, growth and egg production. Therefore, many feed formulators ensure a minimum incorporation of fish meal in pig and poultry diets. On the other hand, many feed formulators set a maximum limit on fish meal in diets in order to prevent the introduction of fishy taint into the animal product. Tables 15 and 16 give recommended minimum and maximum levels of fish meal in poultry diets and pig diets respectively.

The use of fish meal in highly productive ruminants (e.g. dairy cows producing more than 5,000 l of milk per annum) has been shown to be advantageous. Of the protein concentrates, fish meal is among the least degradable in the rumen, and yet has high digestibility in the small intestine, and has an amino acid pattern that is complementary to microbial protein and similar to tissue needs. Published degradability values are given in Table 17.

A brief review of the use of fish meal in pre-ruminant animals as milk replacers, and in fish and mink diets, is given.

There are fishery by-products other than fish meal, but their commercial production is limited. Condensed fish solubles are occasionally sold separately as a supplement to animal feedingstuffs, mainly as a source of UGF but also as a source of protein, amino acids, energy, minerals and vitamins (Table 18). In addition, fish silage is made in one or two countries, principally in Denmark where it finds application in pig production as a supplement to the feed. Some typical proximate compositions of fish silages are shown in Table 19.

INTRODUCTION

The annual world catch of fish is about 70 million t, of which about one third is not used for direct human consumption and may be considered as raw material for fishery by-products. Table 1 summarizes the total world catch, the proportion used for other than human consumption, and the resultant world production of fish meals and fish oils.[1] Fish oils are principally used for direct human consumption in margarines and edible oils and they are, therefore, not considered further in this chapter.

Fish meal is the predominant product; probably about 95% of all raw material not used for direct human consumption is processed into fish meal because it is a stable, high protein concentrate which may be transported around the world without deterioration, whereas fish itself is highly perishable. This chapter will, therefore, deal mainly with fish meal, but some mention of other fishery by-products will be made.

RAW MATERIAL

Almost any fish or shellfish can be used to make fish meal and other by-products. The nutritional value of proteins for vertebrate fish differs very little from one species to another, though a product made from whole shellfish would be nutritionally poorer because of the low protein content of the shell. Of world fish meal production, about 90% is produced from oily species such as anchovy, capelin, and menhaden, and less than 10% from white fish such as cod and haddock. Only about 1% of meal is produced from other sources such as whales and shellfish. Most species of fish exploited for fish meal are quite constant in protein content, usually within 2 or 3% of 16% protein in the whole fish. The meals derived from them will, therefore, all be fairly similar in protein content; the range is normally between 60 and 70% protein. Fish vary considerably in oil content both between species and with season, but oil is normally held at the expense of water not at the expense of protein. Thus, the differences between species will result not in very different types of fish meal, but in the differing yields of fish oil and, to some extent, differing oil contents in the fish meal. White fish meal has the lowest oil content and being made principally from the offal, i.e., white fish frames remaining after filleting, it is slightly higher in minerals.

Where the raw material is caught and landed close to the fish meal processing factory, preservation may not be required. Fish is, however, a highly perishable commodity and spoilage will incur loss of solids and oil, as well as producing a softer material more difficult to process and producing malodors in processing. Chemical preservation is sometimes used, small amounts of formaldehyde and/or sodium nitrite being mixed with the fish. Preservation using ice or refrigerated sea water is also used. A small porportion of fish meal is manufactured at sea in factory ships.

PROCESSING FOR FISH MEAL

Almost all fish meal is made by cooking, pressing, drying, and grinding fish in machinery designed for that purpose.[2] In some factories the pressing stage may be omitted since with white fish raw material there is no oil to be removed. Although the process is simple in principle, considerable skill and experience is necessary to obtain a high yield of a high quality product and to make the plant efficient.

Table 1
TOTAL WORLD CATCH OF FISH, PROPORTION NOT USED FOR HUMAN CONSUMPTION, PRODUCTION OF FISH MEAL AND SOLUBLES, AND FISH OIL

	1970	1972	1974	1976	1977	1978
Total world catch (million t)	70.0	66.2	68.9	72.1	71.2	72.4
For other than human consumption[a]						
Million t	26.5	20.4	20.6	22.1	19.7	21.0
As % of world catch	37.9	30.8	29.9	30.7	27.7	29.0
World production of fish meals and solubles						
Million t	5.5	4.3	4.6	4.9	4.4	4.7
World production of fish oils						
Million t	1.0	0.9	1.2	1.1	1.1	1.2

[a] This includes only whole fish destined for the manufacture of fish meal and oil. Waste material derived from other processing activities such as canning and filleting are not included.

Data from *Yearbook of Fishery Statistic*, Vol. 47, Food and Agricultural Organization, Rome, 1979.

Cooking

When fish are cooked and the protein is coagulated, much of the water and oil runs off or can be removed by pressing, whereas raw fish lose very little liquor, even under very high mechanical pressure. A commercial cooker consists essentially of a long steam-jacketed cylinder through which the fish are moved by a screw conveyor. Some cookers also have the facility for injecting steam into the cooking material. The cooking operation is critical; if the fish are incompletely cooked the liquor cannot be pressed out satisfactorily, and if overcooked the material becomes too soft for pressing. No drying occurs during the cooking stage. Cooking has an important sterilizing action and assists in ensuring freedom from pathogenic organisms.

Pressing

This stage of the process removes some of the water and oil. The cooked fish is conveyed through a perforated tube while being subjected to increasing pressure, normally by means of a tapered shaft on the screw conveyor. A mixture of oil and water and some solids is squeezed out through the perforations and the remaining solid, known as press cake, emerges from the end of the press.

Press Liquor

After screening to remove coarse pieces of solid material, the liquor from the presses is continuously centrifuged to remove the oil. The oil is sometimes further refined in a final centrifuge, a process known as polishing, before being pumped to storage tanks. The refined oil is valuable and is used in the manufacture of edible oils and fats, for example, margarine. The aqueous portion of the liquor, known as stickwater, contains dissolved material and fine solids in suspension which may amount to about 9% by weight. The solids are mostly protein; stickwater can contain as much as 20% of the total solids in the fish so that it is normally well worth recovering. The material is recovered by evaporating the stickwater to a thick syrup containing 30 to 50% solids. Usually the concentrated product, sometimes known as condensed fish solubles, is added back to the press cake and dried with it to make what is known as whole meal.

Drying

Although basically a simple operation, considerable skill is required to get the drying conditions just right. If the meal is underdried, molds or bacteria may be able to grow; if it is overdried, scorching may occur and the nutritional value of the meal will be reduced.

There are two main types of dryer, direct and indirect. In the direct dryer, very hot air at a temperature of up to 500° C is passed over the material as it is tumbled rapidly in a cylindrical drum. This is the quicker method, but heat damage is possible if the process is not carefully controlled. The meal does not reach the temperature of the hot air because rapid evaporation of water from the surface of each particle of fish causes cooling; normally the product temperature remains at about 80 to 95° C. The indirect type of dryer consists either of a steam-jacketed cylinder or a cylinder containing steam-heated discs which also tumble the meal.

Grinding and Bagging

The final operations are grinding and screening to the correct particle size and packing the meal into bags or storing it in silos for bulk delivery. From the fish meal factory, the meal is transported to the animal feed compounder or agricultural merchant and from there to the farm.

COMPOSITION OF FISH MEAL

General Description and Analysis

Fish meal is a brown powder which normally contains a high level of protein and appreciable quantities of fat and minerals. The average figures and standard deviation for protein, oil, moisture, and salt in fish meals from various origins are given in Table 2. The sum total of protein, oil, moisture, and ash is about 100%.

Color of the meal is often thought to be related to fish meal quality. This is only partly true as several factors can affect the color, such as fish species, particle size, fat and moisture content, and the food on which the live fish had been feeding prior to capture. However, a very dark brown color may be the result of overheating during production or storage, especially if accompanied by an acrid "scorched" smell. Severe heating or even scorching to a blackish/brown color does not affect the protein content, but will damage the protein quality.

The particle size of fish meals varies depending upon the grinding practices within individual factories. In general, however, less than 10% of the fish meal will pass through a 1-mm sieve and greater than 90% will pass through a 10-mm sieve.

Protein and Amino Acids

The protein in fish meal has a high biological value in diets for animals. It is rich in the essential amino acids, particularly lysine and the sulfur amino acids, and the presence of fish meal in a complete diet will supplement any deficiencies of the amino acids in vegetable proteins. Details of the amino acid composition of various fish meals are given in Table 3.[3]

The figures demonstrate that although the content of protein varies in fish meals from different origins, the make-up of the amino acids within that protein is broadly similar.

Digestibility and Availability of Amino Acids

Although particular proteins might be analyzed to contain certain levels of amino acid, animal experiments have indicated that these amino acids might not be completely available to the animal ingesting the protein.

The digestibilities of the nitrogen and of the critical essential amino acids of fish meal are approximately 89% for the pig, 85% for the chicken and 94% for the rat.[56] In feed formulations the amino acid contribution of foods must be compared with target requirements that have been derived from the total amino acid content of optimal diets normally based mainly on soya bean meal and maize. Consequently, the availability of amino acids, of protein concentrates, and of cereals relative to those of soya bean meal and maize, respec-

Table 2
AVERAGE FIGURES AND STANDARD DEVIATIONS FOR PROTEIN, OIL, MOISTURE, AND SALT IN FISH MEALS FROM VARIOUS ORIGINS

Type of meal	Origin	Protein N × 6.25 (%)			Oil (%) Diethyl ether soluble			Moisture (%)			Salt[a] (%)		
Herring-type													
	U.K.	72.0	2.0[b]	(78)[c]	9.7 ±	1.6[b]	(77)[c]	7.7 ±	1.3[b]	(77)[c]	1.4 ±	0.4[b]	(20)[c]
	Norway	71.9	2.8	(90)	7.5 ±	1.8	(90)	8.4 ±	1.8	(90)	1.3 ±	0.5	(80)
	Denmark	[d]	—	—	—	—	—	—	—	—	1.6 ±	0.4	(138)
Capelin,	Iceland	66.4 ±	1.6	(27)	11.3 ±	1.2	(27)	8.5 ±	0.7	(27)	2.1 ±	0.3	(27)
Anchovy/Pilchard	South Africa	66.1 ±	1.9	—	9.7 ±	1.4	—	10.1 ±	1.6	—	2.9 ±	0.6	—
	Southwest Africa	65.0 ±	1.8	—	9.3 ±	1.5	—	9.4 ±	1.1	—	3.1 ±	0.9	—
Anchovy,	Peru	66.4 ±	0.8	[e]	9.7 ±	0.5	[e]	8.6 ±	0.5	[e]	—	—	—
White-fish	South Africa	64.0 ±	3.3	—	6.3 ±	2.8	—	7.6 ±	2.5	—	2.4 ±	0.9	—
	Iceland	65.8 ±	1.7	(42)	3.4 ±	0.8	(42)	7.0 ±	0.6	(42)	1.9 ±	0.3	42
	U.K.	64.5	—	—	4.5	—	—	10.0	—	—	—	—	—
Fish	Germany	60.4 ±	2.0	—	8.5 ±	4.5	—	10.5 ±	2.1	—	—	—	—
	Belgium	65.0	—	—	6.8	—	—	—	—	—	3.5	—	—

[a] Determined as total chlorides.
[b] Standard deviation.
[c] Number of samples.
[d] Figures not available.
[e] Represents analysis of 6 months production of 1975 — estimate more than 100 samples.

Data provided by members of the International Association of Fish Meal Manufacturers, 1976.

Table 3
MEAN VALUE AND STANDARD DEVIATION (WITHIN LABORATORY) OF TOTAL AMINO ACID COMPOSITION (g/16 g N) OF FISH MEALS DETERMINED MAINLY BY ION-EXCHANGE CHROMATOGRAPHY

	Herring-type meals	Anchovy meals	Pilchard and Maasbanker meals	Tuna (mixed species) offal meals	Menhaden meals	White fish meals
Lysine	7.73 ± 0.52[a]	7.75 ± 0.43[a]	7.94 ± 0.33[b]	7.30 ± 0.49[c]	7.56 ± 0.39[d]	6.90[e]
Methionine	2.86 ± 0.21	2.95 ± 0.17	2.71 ± 0.23	2.75 ± 0.11	2.82 ± 0.16	2.60
Cystine	0.97 ± 0.12	0.94 ± 0.13	0.95 ± 0.04	0.79 ± 0.12	0.90 ± 0.11	0.93
Tryptophan	1.15 ± 0.10	1.20 ± 0.14	1.02 ± 0.11	1.05 ± 0.10	1.07 ± 0.15	0.94
Histidine	2.41 ± 0.31	2.43 ± 0.25	3.02 ± 0.34	3.41 ± 0.28	2.32 ± 0.21	2.01
Arginine	5.84 ± 0.62	5.82 ± 0.29	5.95 ± 0.29	6.43 ± 0.28	6.04 ± 0.37	6.37
Threonine	4.26 ± 0.33	4.31 ± 0.21	4.38 ± 0.28	4.34 ± 0.24	3.97 ± 0.20	3.85
Valine	5.41 ± 0.30	5.29 ± 0.35	5.41 ± 0.46	5.31 ± 0.44	5.10 ± 0.21	4.47
Isoleucine	4.49 ± 0.27	4.68 ± 0.20	4.48 ± 0.36	4.46 ± 0.23	4.40 ± 0.22	3.70
Leucine	7.50 ± 0.36	7.62 ± 0.35	7.30 ± 0.33	7.20 ± 0.34	7.14 ± 0.34	6.48
Phenylalanine	3.91 ± 0.17	4.21 ± 0.21	3.91 ± 0.36	4.10 ± 0.19	3.95 ± 0.19	3.29
Tyrosine	3.13 ± 0.22	3.40 ± 0.53	3.23 ± 0.40	3.28 ± 0.17	3.22 ± 0.23	2.60
Aspartic acid	9.10 ± 0.48	9.49 ± 0.64	9.37 ± 0.51	9.30 ± 0.53	9.07 ± 0.42	8.54
Serine	3.82 ± 0.22	3.84 ± 0.24	4.27 ± 0.17	4.18 ± 0.85	3.61 ± 0.21	4.75
Glutamic acid	12.77 ± 0.68	12.96 ± 0.81	12.92 ± 0.66	11.93 ± 0.38	12.70 ± 0.56	12.79
Proline	4.15 ± 0.23	4.17 ± 0.28	4.52 ± 0.52	5.43 ± 0.39	4.58 ± 0.27	5.34
Glycine	5.97 ± 0.37	5.62 ± 0.33	6.92 ± 0.90	8.15 ± 0.78	6.78 ± 0.41	9.92
Alanine	6.25 ± 0.21	6.31 ± 0.38	6.17 ± 0.40	6.76 ± 0.26	5.94 ± 0.29	6.31
Crude protein (%)	73.6	65.4	65.4	53.24	62.01	65.01
Moisture (%)	6.93	8.01	9.0	6.20	8.25	8.49
Ash (%)						20.92

[a] 37 samples.
[b] 17 samples.
[c] Ca. 11 samples.
[d] Ca. 26 samples.
[e] Comparable SD figures not available.

From Miller, E. L., *Available Amino Acid Content of Fish Meals*, Fish. Rep. No. 92, Food and Agricultural Organization, Rome, 1970. With permission.

tively, are more appropriate for feed formulation purposes. From a review of amino acid digestibilities and biological potencies in growth assays, it has been concluded that there is no difference in availability of amino acids between fish meals and soya bean meals. Therefore, setting the availability of soya bean meal at an arbitrary 100%, the relative amino acid availability of fish meals should also be designated 100%.[33,56,57]

Fats and Fatty Acid

The fatty acid composition of the fat extracted from various fish meals is given in Table 4. The composition of the fat in fish meal differs from most vegetable oils inasmuch as it contains high levels of long-chain (C20 and greater), polyunsaturated fatty acids. Most vegetable oils contain only small quantities of fatty acids with carbon chain lengths in excess of 18; maize is given as an example in Table 4. Most of the polyunsaturated fatty acids in the fat from fish meal are of the W3 acid family, whereas those from vegetable oils are mainly of the W6 acid family. The linoleic acid family (18:2W6) are generally regarded as the essential fatty acids, but some evidence suggests that fatty acids of the linolenic acid family (W3) have essential fatty acid functions as far as chick growth, reproduction, and

Table 4
TYPICAL PERCENT FATTY ACID COMPOSITION OF FAT FROM MEAL MADE FROM DIFFERENT SPECIES OF FISH AND FROM DIFFERENT PROCESSES AND PERCENT FATTY ACID COMPOSITION OF FAT FROM MAIZE MEAL

Fatty acid (%)	White fish meal[a] (Stored Meal)	Capelin[b] (Fresh Meal)	Anchovy[b] (Stabilized)[d]	Herring[b] (Fresh)	Herring[b] (Oxidized)	Herring[b] (Stabilized)[d]	Sardinella/[a] horse mackerel (Stabilized)[d]	Maize[c]
14:0	3	5	7	7	9	7	4	—
15:0	11	17	23	15	21	15	14	12
18:0	2	2	4	2	3	2	4	1
16:1	7	7	7	5	6	5	5	—
18:1	17	18	13	13	15	13	10	26
20:1	10	9	1	11	15	12	2	1
22:1	9	7	1	18	23	17	2	—
24:1	1	1	—	1	1	1	1	—
18:2 w6	1	2	1	2	1	2	3	59
18:3 w3	—	—	—	1	—	—	—	1
18:4 w3	2	2	2	2	—	2	2	—
20:5 w3	12	10	16	6	—	6	18	—
22:5 w3	2	1	2	1	—	1	4	—
22:6 w3	19	17	14	13	1	12	26	—

[a] See Reference 4.
[b] See Reference 5.
[c] See Reference 6.
[d] Antioxidant treated.

Table 5
THE LINOLEIC ACID CONTENT OF FEEDSTUFFS

Feedstuffs	Linoleic acid (%)	Linoleic acid equivalent (%)
Maize	1.9	
Barley	0.85	
Soyabean meal	0.4	
Corn gluten meal	1.2	
Stabilized poultry offal fat	22	
Stabilized animal tallow	2.5	
Fish oil	2.6	
Fish oil[a]		50.0
Stabilized[b] anchovy meal (12% fat)		6.0
Stabilized[b] menhaden meal (10% fat)		5.0
Stabilized[b] herring type meal (8% fat)		4.0

[a] See Reference 7
[b] Antioxidant treated.

Data from Scott, M. L., Nesheim, M. C., and Young, R. J., *Nutrition of the Chicken*, M. L. Scott & Assoc., Ithaca, N.Y., 1971.

egg production are concerned.[7-10] The linoleic acid contents of typical feedstuffs are given in Table 5. The linoleic acid content of fish fat is low. Because the polyunsaturated fatty acids, which predominate in stabilized fish fat (i.e., antioxidant treated), may meet all of the growing bird's requirements for essential fatty acids,[7,8] using only linoleic acid as a measure of the content of essential fatty acids may undervalue the contribution of fish fat. In general, a stabilized fish fat appears to be at least as effective as corn oil and safflower oil on a weight for weight basis in meeting the bird's requirement for essential fatty acids. The fat fraction of treated fish meals may thus be taken as having an "equivalent essential fatty acid content" of 50% of the fat. Such figures are summarized in Table 5.

As can be seen from Table 4, oxidation of the fat in fish meal reduces the content of polyunsaturated fatty acids considerably. This in turn reduces the linoleic acid equivalent to negligible values. Figures in Table 5 are, therefore, only applicable to antioxidant-stabilized fish meals.

Energy

All the energy in fish meal comes from its protein and fat content. The quantity of fat present in fish meal depends on several factors including the species of fish (see Table 2), season of catching, the feeding of fish, processing, and whether antioxidant was used or not. Oxidation in fish meal significantly reduces the availability of the fat to the animal. Table 6 summarizes the results reported in the literature for the metabolizable energy values for chicks of various fish meals. As most fish meal is antioxidant treated, the results obtained with antioxidant-treated meals, where given, should be taken as representing fish meals currently available. Based on metabolizable energy values determined for a unit of protein in fish meal and a unit of oil in fish meal, it is possible to prepare a table of metabolizable energy values for treatment with different contents of protein and fat (Table 7).

With regard to pigs, a number of different energy systems have been suggested. However, most feed formulators use the total digestible nutrients (TDN) system (equivalent to the GN in Germany) for commercial pig diets. The amount of information available on fish meal is limited; McDonald et al.[16] quoted a TDN value of 65 for white fish meal and Morgan et al.[17] quoted a TDN value of 78.5 for herring meal.

Table 6
MEAN METABOLIZABLE ENERGY VALUES OF VARIOUS FISH MEALS

Type of meal	M.E. chick $_n$O kcal/kg DM	M.E. chick $_n$O kcal/kg as received	Number of samples	C.V.[b] (± %)	Dry matter (%)	Ether extractable fat (%)	Protein n × 6.25 (%)	Ref.
Anchovy								
Peru	3214	2886	1	—	89.8	7.9	61.5	11
Peru[a]	3757	3378	1	—	89.9	13.1	62.4	11
Anchovy	2772	2483	1	—	89.6	5.8	64.9	11
Herring								
Icelandic	3412	3061	1	—	89.7	9.6	65.6	11
East Coast Canada[a]	3466	3233	7	4.7	93.3	8.9	73.6	12
West coast Canada	3193	—	5	3.8	—	—	—	13
West coast Canada[a]	3623	—	6	5.5	—	—	—	13
Herring type-Norwegian	3608	3251	40	—	90.1	7.7	71.4	14
Menhaden[a]	3370	3100	10	5.6	92.0	9.8	62.6	15

[a] Antioxidant treated.
[b] Coefficient of variation.

Table 7
METABOLIZABLE ENERGY VALUES (MJ/kg) FOR POULTRY OF FISH MEALS WITH DIFFERENT CONTENTS OF PROTEIN AND FAT

Crude protein (%)	Crude fat (%)	4	5	6	7	8	9	10	11	12
Fish meal[a]	63	11.55	11.83	12.01	12.29	12.56	12.84	13.07	13.35	13.62
	64	11.59	11.87	12.15	12.43	12.70	12.98	13.26	13.53	13.81
	65	11.77	12.06	12.33	12.68	12.89	13.16	13.44	13.67	13.95
	66	11.95	12.23	12.51	12.79	13.03	13.30	13.58	13.85	14.13
	67	12.09	12.37	12.65	12.93	13.21	13.49	13.76	14.04	14.31
	68	12.28	12.56	12.84	13.12	13.39	13.62	13.90	14.18	14.45
Herring-type fish meal	68				12.85	13.12	13.39	13.66	13.93	14.20
	69				13.03	13.30	13.58	13.81	14.08	14.37
	70				13.16	13.44	13.72	13.99	14.27	14.54
	71				13.35	13.62	13.90	14.18	14.41	14.68
	72				13.53	13.76	14.04	14.31	14.59	14.87
	73				13.68	13.95	14.22	14.50	14.77	15.00
	74				13.85	14.12	14.41	14.64	14.91	—

Note: Metabolizable energy values, adjusted to zero nitrogen retention (ME_nO), in Table 7 was calculated from the determined ME_nO with adjustments for the stated crude fat and crude protein contents using the formula:

$$\underset{\text{adjusted}}{ME_n0} = \underset{\text{tabulated (assayed)}}{ME_n0} + \frac{(F_a\ F_t)}{100} \times ME_n0 \text{ for fish fat} + \frac{(P_3\ P_1)}{100} \times ME_n0 \text{ for fish protein MJ/kg}$$

where F_t and P_t are the fat and protein contents of the tabulated samples respectively, and F_a and P_a are the actual fat (ether extractable) and crude protein of the consignment.

For "Fish Meal" ME_nO tabulated (assayed) is taken from Cappett, S. L. and Soares, J. H., *Poult. Sci.* 51, 2078, 1972, and is 12.97 MJ/kg for 10 fish meals with average protein content of 62.6% and average fat content of 9.8%. For "Herring Type Fish Meal" ME_nO tabulated (assayed) is taken from Opstvedt, J., *Feedstuffs,* 15.3.76, 23, 1976, and is 13.60 MJ/kg for 40 fish meals with average fat content of 7.7% and average protein content of 71.4%.

Values used for ME_nO fish fat = 27.00 MJ/kg; and ME_nO fish protein = 16.52 MJ/kg are taken from Opstvedt, J., *Acta. Agric. Scand.*, 23, 11, 1973.

Worked example
White-fish meal; Fat content (ether extraction) 5%
Protein content 65%

$$\underset{\text{adjusted}}{ME_n0} = 12.97 + \frac{(5 - 9.8)}{100} \times 27.00 + \frac{(65-62.6)}{100} \times 16.52 \text{ MJ/kg}$$

$$= 12.97 \quad \frac{4.8}{100} \times 27.00 + \frac{2.4}{100} \times 16.52 \text{ MJ/kg}$$

$$= 12.06 \text{ MJ/kg}$$

[a] Includes white fish meal.

Table 8
CONTENT OF ESSENTIAL MINERALS (MEAN VALUES ± SD) IN FISH MEAL

Species of meal	Anchovy[a]	Herring-type[b]	White fish[c]	Menhaden[d]
Element				
Ash (%)	15.4 ± 2.23[e]	10.14 ± 1.13[f]	20.0[g]	18.0 ± 1.74[h]
Calcium (%)	3.95 ± 0.65	1.95 ± 0.53	8.0	5.26 ± 0.65
Phosphorus (%)	2.60 ± 0.40	1.50 ± 0.35	4.8	2.98 ± 0.30
Sodium (%)	0.87 ± 0.34	0.42 ± 0.19	0.77	0.34 ± 0.05
Magnesium (%)	0.25 ± 0.05	0.11 ± 0.01	0.15	0.14 ± 0.01
Potassium (%)	0.65 ± 0.12	1.20 ± 0.16	0.9	0.72 ± 0.14
Iron (ppm)	246 ± 59	150 ± 38	300	438 ± 134
Copper (ppm)	10.6 ± 4.38	5.4 ± 1.29	7	11.4 ± 3.51
Zinc (ppm)	111 ± 19.7	120 ± 8.3	100	151 ± 10.3
Manganese (ppm)	9.7 ± 5.0	2.4 ± 0.85	10	35.6 ± 15.9
Iodine (ppm)	N.A.[i]	197[j] ± 0.44	N.A.	N.A.
Selenium (ppm)	1.39 ± 0.20[k]	2.78 ± 0.67[k]	1.50[l]	2.22 ± 0.72[k]

[a] See Reference 18.
[b] See Reference 19.
[c] See Reference 20.
[d] See Reference 21.
[e] 12-25 samples.
[f] 13-23 samples.
[g] Comparable SD figures not available.
[h] 12-33 samples.
[i] NA = not available.
[j] See Reference 22.
[k] See Reference 23.
[l] See Reference 24.

Mineral Content

Table 8 gives the content of essential minerals in various fish meals. Generally speaking the higher the level of ash in the meal, the higher the content of certain minerals, particularly calcium and phosphorus. Other minerals present no obvious relationship with the ash content of the meal because they are not localized in the bone material. For example, selenium is partly localized in the protein phase, where at least some of it is probably present in the form of seleno-amino acids, and a certain amount of it is present in the lipid phase as a lipoprotein complex.[25,26]

With regard to availability it is well known that a proportion of total phosphorus in vegetable matter is unavailable because of the poor utilization of phosphorus contained in phytic acid, with which the phosphorus is associated. With fish meal, on the other hand, the phosphorus is completely available.

Table 9 summarizes some miscellaneous analyses for various heavy metals and other elements in fish meals. The presence of these elements in fish meals has not been known to cause any toxicity problems to animals.

Vitamins

Table 10 summarizes the content of the important B vitamins found in fish meal.

THE USES IN ANIMAL NUTRITION

General Attributes

Fish meal is a good source of protein, essential amino acids (particularly lysine and sulfur amino acids), energy, minerals (particularly phosphorus), vitamins, and essential fatty acids.

Table 9
HEAVY METALS AND OTHER ELEMENTS IN FISH MEAL

Element	Average content (ppm)	Range (ppm)	Numbers of samples
Aluminium	112.8	22.5 — 616	61
Antimony	0.041	0.012 — 0.20	11
Arsenic	4.75	<0.15 — 19.1	24
Barium	7.29	1.0 — 51.5	61
Boron	10.6	3.7 — 19.8	68
Chromium	6.46	2.0 — 13.8	61
Fluoride	227	57 — 400	20
Lead	3.72	0.1 — >12	68
Mercury	0.15	0.01 — 0.41	188
Molybdenum	0.56	0.03 — 3.0	23
Strontium	63.88	22.8 — 171	61
Vanadium	1.50	0.6 — 2.7	5

Data provided by members of the International Association of Fish Meal Manufacturers (1976). With permission.

Table 10
CONTENT OF B VITAMINS (MEAN ± SD) IN FISH MEAL

Vitamin (ppm)	Peruvian[a] anchovy	Norwegian[b] herring	White fish[c]	Menhaden[d]
Pantothenic acid	9.3[e]	30.6 ± 8 .4[f]	15[e]	8.8[e]
Riboflavin	2.5	7.3 ± 1.0	6.5	4.8
Niacine	95	126 ± 36	50	55
Folic acid	0.16	0.5[d]	0.5[d]	N.A.[g]
Choline[h]	4396 ± 995	4396 ± 995	4396 ± 995	4396 ± 995
B12	0.18	0.25 ± 0.04	0.07	0.06
Biotin[i]	0.26	0.42	0.08	0.26

[a] See Reference 28.
[b] See Reference 22.
[c] See Reference 20.
[d] See Reference 29.
[e] Comparable SD figures not available.
[f] 14—20 Samples.
[g] Not available.
[h] See Reference 27.
[i] See Reference 30.

A considerable number of research papers state that fish meal contains unknown growth factors (UGF) in addition to the nutrients listed above and these have been summarized by Pike.[31,32] It has also been shown that fish meal can lead to increased egg production, improved reproduction, and feed conversion as well as to increased growth compared with nutritionally balanced all-vegetable diets. Tables 11 to 14 summarize experimental data on effects upon feed conversion, growth, and egg production. In spite of numerous attempts to identify UGF, it is still not possible to specify it as an exact nutrient.

Therefore, many feed formulators ensure a minimum incorporation of fish meal in pig and poultry diets. On the other hand, many feed formulators set a maximum limit on fish meal in diets in order to prevent the introduction of fishy taint into the animal produce (meat or eggs). The reduction of flavor score in aminal produce caused by fish meal is correlated with the content of polyunsaturated fatty acids which is generally higher with antioxidant treatment (see Table 4).

Table 11
SUMMARY OF RESULTS OF BROILER EXPERIMENTS COMPARING DIETS WITH AND WITHOUT FISH MEAL

Fish meal type	Level in diet (%)	Feeding period days	Number of birds/ test diet	Improvement in liveweight compared with all-veg diet (%)	Improvement in feed conversion compared with all-veg diet (%)
Herring	4	0—56	64	4.7	5.5
	5	0—49	120	4.0	3.0
White Fish	2	0—42	72	0	0
Anchovy	3	0—56	80	0.7	1.1
Menhaden	1.25	0—35	40	3.3	1.7
	2.5	0—35	40	4.4	2.8
	5	0—35	40	5.9	4.0
Unknown	2	0—56	128	0.6	0.2
	4	0—56	128	0	1.1
	6	0—56	128	4.8	1.3
	6	0—56	128	−2.8	−1.7
	6	0—56	120	3.6	3.4
Mean	3.9			2.4	1.9

From Miller, E. L., *Available Amino Acid Content of Fish Meals*, Fish. Rep. No. 92, Food and Agricultural Organization, Rome, 1970. With permission.

In general, fish meals are free of toxins and have an acceptable bacterial content and composition. Some parcels of fish meal, however, can be contaminated with Salmonellae organisms caused by bad processing practices or contamination during transport of the meal. Salmonellae can pass into the human food chain via animal produce causing food poisoning. Some parcels of fish meal can contain nitrite residues mainly from the use of chemical preservative applied during the storage of raw fish. These nitrite residues, if present at high enough levels, can form nitrosamines which are particularly toxic to mink. Pigs and poultry are less susceptable.

In contractual terms, the quality of a fish meal is normally defined by its quantity of protein, moisture, fat, salt, and sand. The quality of the protein is not currently the subject of contractural arrangements, but a number of chemical tests are occasionally employed by recipients of fish meal to test the quality of the protein. Generally these are FDNB-available lysine, pepsin digestibility, and dye-binding capacity. The use of these methods only provides limited information and can give misleading results to those not fully informed about their theory and practice.[34,35]

There have been suggestions that oxidation or degradation products of the fat in fish meal can be toxic. Therefore, free fatty acids or peroxide values have been determined in the fat to assess its suitability for animal feeding. Both tests have been shown to be meaningless in most practical circumstances.[36,37] Indeed, there is no evidence that oxidation or degradation products of the fat in fish meal have been responsible for detrimental effects in pigs, poultry, cattle, or sheep provided that diets have been adequately fortified with vitamins, particularly vitamin E. Fish, mink, and possibly weaning pigs, on the other hand, appear to be susceptible to fat oxidation products. Thus care should be taken to use fish meals prepared from fresh fish which have been stabilized with antioxidant or low fat fish meals in diets for these animals.

Attempts have been made to check that fish meal has been properly stabilized by analyzing the meal for antioxidant residues (ethoxyquin in nearly all cases). Unfortunately, the ethoxyquin, soon after its addition, is impossible to extract from some meals. This is possibly due to tight binding of the ethoxyquin in the meal or the formation of secondary antioxidants

Table 12
EFFECT ON GROWTH AND FEED CONVERSION OF INCORPORATING FISH MEAL IN TURKEY DIETS

Type of fish meal	Inclusion rate (%)	Period of growth	Improvement in liveweight (%)	Improvement in feed conversion (%)	No. poults per treatment
Herring meal	5	0—3w	11.6	5.4	32
Fish solubles	3	0—3w	0.7	2.8	32
Herring meal	5	0—3w	5.4	0.6	32
Menhaden meal	4	0—8w	1.5	1.5	18
	8	0—8w	1.0	0.2	18
	3	8—18w	1.7	3.4	18
	6	0—8w	1.3	0.9	18
	9	0—8w	1.3	0	18
Menhaden meal	5	0—8w	6.3[2]	3.5[2]	18
Anchovy meal	5	0—8w	11.9[2]	1.4[2]	18
Herring meal	5	0—8w	8.0[2]	3.3[2]	18
Peruvian anchovy	12	0—6w	3.4[a]	3.7[a]	300
	6	0—6w	0	4.3[a]	300
	2	0—6w	—	—	300
	6	6—14w	5.0	24.0	300
	2	6—14w	2.5	6.9	300
	3	14—18w	2.6	−1.4	300
	1.5	14—18w	−0.8	0	300
Herring meal	5	0—8w	16.4[b]	2.7[b]	18
Crab meal	3	0—4w	5.2[c]	1.3[c]	160
	6	0—4w	6.8[c]	1.3[c]	160
	5	0—4w	1.4[c]	0	—
Herring meal	5	0—4w	2.0	4.2[c]	—
Mean	5.0		2.8	3.6	

[a] Results expressed relative to those for the 2% diet — a fish meal free diet was not used from 0—6 weeks.
[b] Results excluded because diets not isocaloric and basal diet contained nonmarine animal protein, i.e., was not a straight comparison of animal v vegetable protein diets.
[c] Results excluded because diets were not isocaloric.

From Pike, I.H., IAFMM Tech. Bull. No. 3, *International Association of Fish Meal Manufacturers*, Potters Bar, U.K., 1975. With Permission.

which do not have ethoxyquin's chemical properties.[38] A rule-of-thumb technique for checking that meals have been stabilized consists of comparing the fat extracted from a sample of meal by a mixture of chloroform/methanol with the fat extracted by diethyl ether. Large differences in the results (e.g., 13 and 6%, respectively) indicate that stabilization has not occurred, whereas small differences (e.g., 13 and 10%, respectively) indicate that stabilization has occurred.

Poultry

Table 15 gives recommended minimum and maximum levels of fish meal in poultry diets. The minimum levels are based on practical experience and experimental results indicating that this level of fish meal produces increases in meat or egg production and better feed utilization compared with diets not containing fish meal. Adequate diets can be made without fish meal, but these minima are justified when the income from the increased egg or meat production exceeds the cost of incorporating these minimum levels in the diet.

Table 13
EFFECT OF INCORPORATING FISH MEAL IN DIETS FOR LAYING HENS — EGG PRODUCTION AND FEED CONVERSION SUMMARY OF RESULTS

Type of fish meal	Level in diet (%)	No. birds per protein treatment	Expt. period (weeks)	No. eggs produced per bird	Improvement in no. eggs (%)	Improvement in feed conversion (%)
British Columbia						
Herring meal	5	Not stated	52	257	3.8	7.9[a]
Pacific Ocean hake	5	Not stated	52	261	5.7	9.1[a]
Norwegian herring	5	Not stated	52	257	3.9	3.4[a]
Peruvian anchovy	5	Not stated	52	255	3.2	5.2[a]
Fish meal	6	120	46	211	0	0
White fish meal	5	1297	56	250	3.3	3.2[a]
	5	1368	56	245	7.4	7.4[a]
	2 1/2	1368	56	239	4.8	4.3[a]
Herring meal[b]	2	80	51	245	4.2	7.6
Fish meal[b]	2	2108	50	216	−0.9	0
Angola fish meal	2	400	52	251	5.5	7.7[a]
	4	400	52	249	6.6	5.7[a]
	6	400	52	246	7.5	9.2[a]
Mean	4.2				+4.2	+5.4

[a] Based on feed/doz egg.
[b] Diet with fish meal also included 3% meat meal and 1% whey.

From Pike, I.H., IAFMM Tech. Bull. No. 3, *International Association of Fish Meal Manufacturers*, Potters Bar, U.K., 1975. With Permission.

Table 14
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS SUMMARY OF RESULTS[a]

Country	Level of fish meal in diet (%)[b]	Improvement in liveweight fish meal vs. no fish meal (%)	Improvement in feed conversion fish meal vs. no fish meal (%)
U.K.	5	+0.3	+0.3
France	3.5	−0.8	+0.9
W. Germany	4/2	−0.2	−1.0
W. Germany	4	+6.5	+6.0
Czechoslovakia	7 1/2 /6/3	+5.9	+7.3
Finland	N.A.	+3.4	+2.9
Australia	9.5	+3.5	+2.7
W. Germany	8/5	−0.2	+4.9
W. Germany	9	+8.9	+3.8
W. Germany	12/8	+5.9	+6.7
W. Germany	5/3	+1.8	+3.2
W. Germany	7.5/5	+5.2	+2.2
Norway	2	+1.7	+1.8
Norway	8	+1.1	+3.0
Denmark	2	+1.7	+2.2
	5	+0.2	+1.6
	8	+5.5	+4.4

[a] Total number of experiments is 37, including the 21 carried out in the U.K.
[b] Two or more values indicate decreasing inclusion levels as the pigs got older. See Reference 32.

Table 15
MINIMUM AND MAXIMUM RECOMMENDED LEVELS OF FISH MEAL IN POULTRY DIETS

Diet	Minimum fish meal	Maximum fish meal: Low fat fish meal (<6%)	Medium fat fish meal (7—10%)	High fat fish meal (>10%)
Broiler starter	4	No practical limit[a]	10	8
Broiler grower	4	No practical limit[a]	8	6
Broiler finisher	2	No practical limit[a]	8	6
Turkey starter	6	No practical limit[a]	12	9
Turkey grower	4	No practical limit[a]	10	7
Turkey finisher	1	8	5	3
Hen layer	2	No practical limit	No practical limit[a]	No practical limit
Hen breeder	4	No practical limit	No practical limit[a]	No practical limit

[a] Assuming that fish meal is not fed at levels higher than about 15%.

Table 16
MINIMUM AND MAXIMUM RECOMMENDED LEVELS OF FISH MEAL IN PIG DIETS

Diet	Minimum fish meal	Maximum fish meal: Low fat fish meal (<6%)	Med. fat fish meal (7—10%)	High fat fish meal (>10%)
Weaner (3 weeks—20kg)	5	No practical limit	No practical limit[a]	No practical limit
Grower (20kg—50kg)	2	No practical limit[a]	8	5
Finisher (>50kg)	1	10	4	3
Breeding and lactating	4	No practical limit	No practical limit[a]	No practical limit

[a] Assuming that fish meal is not fed at levels higher than about 12%.

The maximum levels are based on the need to prevent the production of fishy tainted meat. These levels are again based on practical experience and experimental results.[55] The maximum levels are not absolute, but given as a guideline. There appear to be differences in flavor acceptability of meat between different population groups of which account should be taken.

Pigs

Table 16 gives recommended minimum and maximum levels of fish meal in pig diets. The choice of these levels is subject to similar comments made in the poultry section.

With the weanling pig, it is necessary to feed a low fat fish meal or one which is selectively prepared from fresh fish and antioxidant treated in order to avoid any possible digestibility problems due to rancidity in the fat.[39]

Cattle and Sheep

In general, fish meal in recent years has been regarded as too expensive for feeding to ruminants. However, the use of fish meal in highly productive ruminants (e.g., the dairy cow producing more than 5000 ℓ of milk per annum) has been shown to be advantageous,[40]

Table 17
DEGRADABILITY IN THE RUMEN OF CRUDE PROTEIN FROM PROTEIN CONCENTRATES

Fish meal	0.29
Fish meal, Peruvian	0—0.31
Fish meal, white	0.61—0.63
Soya bean meal	0.39
Soya bean meal	0.59[a]
Groundnut meal	0.63
Groundnut meal	0.78
Lupin	0.65
Sunflower seed meal	0.72—0.81

[a] Values calculated from authors data.

From Miller, E.L., IAFMM Tech. Bull. No. 5, *International Association of Fish Meal Manufacturers*, Potters Bar, U.K., 1978. With Permission.

which is probably attributable to a requirement for dietary protein in excess of the microbial protein, and possibly to a better balance of amino acids reaching and being absorbed from the small intestine.

It is inappropriate to assess the economic value of alternative protein sources based on a calculation of the cost per unit of digestible crude protein. Accurate assessment requires costing the complete diet where all factors, such as microbial growth, dietary protein absorbed from the intestine, amino acid balance, energy minerals, and vitamin supply are taken into consideration. Even assessment of the protein value alone requires the first three of these factors to be considered. The outline of schemes to evaluate protein feedingstuffs in these terms has recently been proposed.[41,45,58] In general, the needs of rumen microorganisms for degradable protein can be largely met by the basal feed such as grass silage, roots, and hay supplemented, if necessary, with nonprotein nitrogen sources such as urea. For rapidly growing young animals and high-yielding dairy cows, microbial protein produced in the rumen is inadequate to meet amino acid needs of these animals. In this case, protein supplements are required which will escape substantial degradation in the rumen yet to be absorbed from the small intestine. Of the protein concentrates, fish meals are among the least degradable, have high digestibility in the small intestine, and have an amino acid pattern that is complementary to microbial protein and similar to tissue needs. Published degradability values for protein concentrates have been reviewed[59] and the values are given in Table 17.

Preruminant Animals

In recent years research has been aimed at replacing milk protein in milk replacers with an alternative animal or vegetable protein. Using fish meal or fish protein concentrate (FPC) no allergic responses in young animals have been reported. A problem of sedimentation of the fish protein has been quoted, but this problem can be overcome. The high iron content of FPC may also be a disadvantage if light-colored veal product is required. However, several research reports have indicated that up to 50% of the protein in a milk replacer can be supplied by FPC without affecting growth rate.[41-44,46,47]

Fish Cultivation

Salmon, trout, catfish, and eels are among the most common species of fish raised by intensive aquaculture. All of these species have an essential requirement for fish protein in the diet in order to maintain adequate health and growth. The amount of fish meal used varies between 10 and 70%, depending upon the type of diet and economics. Low-fat fish or antioxidant-stabilized fish meal prepared from fresh fish is preferred.

The majority of fatty acids in fish oil are of the linolenic acid family, and it seems that certain fish species have a nutritional requirement for these fatty acids which can be regarded as essential fatty acids for the growth and natural development of the fish. This situation has to be contrasted with mammals where the essential fatty acids are considered as mainly members of the linoleic acid family, which is present in vegetable oils and cereals. Consequently, stabilized fish oil is commonly used in fish feeding because of its high energy contribution, content of essential fatty acids, liquid nature, and relatively low cost compared with some other fats.

Mink

Fish meal is commonly used in mink feeding. The amount of fish meal used varies, but up to 60% of the protein can originate from fish meal provided the meal is of high quality. Low-fat or antioxidant-stabilized fish meal prepared from fresh fish and carefully dried is preferred. Dimethyl-nitrosamine (DMNA), sometimes found in fish meal, is toxic to mink. It is recommended that the daily intake of DMNA should be lower than 0.05 mg/kg body weight. Thus a maximum level of 0.3 ppm DMNA should be specified for fish meal.

OTHER FISHERY BY-PRODUCTS

Condensed Fish Solubles

Condensed fish solubles is a product of fish meal processing (see section of "press liquor" under "Processing for Fish Meal") which is usually returned to the pressed fish and dried with it to make a "whole" meal. Occasionally the product is sold separately as a supplement to animal feedingstuffs. It is sold mainly as a source of UGF, (see section on "General Attributes" under "The Uses in Animal Nutrition") but is also a source of protein, amino acids, energy, minerals, and vitamins (Table 18).

Fish Silage

The process of making silage from fish is not the same as that used for ensiling crops. Fish silage is a liquid product made only from fish, or parts of fish, and an acid. Liquefaction, which normally proceeds fairly rapidly depending upon the temperature (e.g., within 2 days at 20°C), is brought about by the action of the enzymes and prevents bacterial spoilage; the pH necessary depends upon the acid used, but with formic acid a pH of 4 is suitable. This means addition of about 3.5% by weight of 85% formic acid to the minced fish.[49,50]

The production process is a relatively simple one. Whole fish or fish offal is minced and reduced in size to pieces preferably no larger than about 5 mm in diameter. Acid is then added to the mince and thoroughly mixed; if mixing is inadequate and some material remains untreated, it will putrefy. After this initial mixing the ensilage process will start naturally, but occasional stirring is normal over the next 2 to 3 days.

The product is a liquid with a composition similar to that of the fish from which it was made. Where oily fish are used, the oil content can be greatly reduced by centrifugation after liquefaction. Some typical proximate compositions are shown in Table 19.

Fish silage is made only in one or two countries, principally in Denmark where it finds application in pig production as a supplement to the feed which also is thought to improve appetite. In animal nutritional terms there has been little scientific study compared to that on fish meal. The evidence available, however, points to nutritional properties very similar to those of fish meal, so that on the same protein basis there is probably little to choose between the two products.[51] Fish silage, being a liquid product, has some advantages where liquid feeding systems are used, but no drying is involved in the process so the product is bulky and costly to transport over large distances.

Table 18
NUTRIENT COMPOSITION OF MENHADEN FISH SOLUBLES

ANALYSES	
Protein (N × 6.25)%	31.8 + 2.52
Ash (%)	7.8 ± 0.93
Ether fat (%)	8.9 ± 2.13
Moisture (%)	48.7 ± 2.18
Arginine (% of protein)	3.9 ± 0.65
Lysine (% of protein)	4.8 ± 0.56
Trytophan (% of protein)	0.3 ± 0.07
Methionine (% of protein)	1.6 ± 0.17
Cystine (% of protein)	1.1 ± 0.28
Threonine (% of protein)	2.1 ± 0.25
Potassium (%)	1.57 ± 0.18
Sodium (%)	1.4 ± 0.28
Phosphorus (%)	0.56 ± 0.14
Magnesium (%)	0.11 ± 0.03
Calcium (%)	0.06 ± 0.02
Selenium (ppm)	2.4 ± 0.44
Choline (ppm)	4429
ME broilers (kcal/kg)	2120

Data from Soares, J., Jr., Miller, D., Cuppett, S., and Baeursfeld, P., *Fish. Bull.*, 71(1), 255, 1973.

Table 19
THE COMPOSITION OF FISH SILAGES MADE FROM VARIOUS RAW MATERIALS

	Silages made from various raw materials				
Composition (%)	**White fish offal**	**Herring offal**	**Herring offal (deoiled)**	**Sprat**	**Sprat (deoiled)**
Moisture	78.9	75.4	80.8	69.4	78.0
Oil	0.5	8.7	2.0	13.0	2.0
Protein (N × 6.25)	15.0	13.5	14.5	15.5	17.4
Ash	4.2	2.6	2.8	2.2	2.5

Data from Tatterson, I. N. and Windsor, M. L., *J. Sci. Food Agric.*, 25, 369, 1974.

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FISH MEAL SCIENTIFIC ADVISORY SERVICE

The International Association of Fish Meal Manufacturers (IAFMM) announces the establishment of a permanent Scientific Advisory Service mainly for Feed Compounders and Concentrate Manufacturers and Agricultural Institutions. The staff of the IAFMM, in conjunction with its Scientific Committee, representing an international group of experts in nutrition, bacteriology, engineering and product development, will provide up-to-date information on any aspect of Fish Meal and its uses. All enquiries should be directed to:

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