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FISH MEAL AND FISH OIL: PRODUCTION, PROPERTIES AND STANDARDS

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Fish meal

Fish meal is a solid product that is obtained by cooking the fish/fish by-products, removal of water and some oil. Fish meal is generally sold as a powder, and is used mostly in compound foods for poultry, pigs and farmed fish; it is far too valuable to be used as a fertilizer. Fish meal is regarded as a highly concentrated nutritious supplement in feeds that contains high-quality proteins, vitamin B, minerals, etc.

Raw material

The raw material used for the production of fish meal varies from region to region depending on the availability. In general, three types of raw materials are used in fish meal manufacture which includes oily pelagic fish (oil sardine), low value whole fish containing more bones, inedible parts of fish and shellfish. Region-specific raw materials are anchovy in Peru, Menhaden in USA, Pilchards in South Africa, Herring and Capelin in Norway, and oil sardine in India. Oil sardine is most commonly used for fish meal and fish oil production in India due to its availability.

Production of fish meal

Methods of production of fish meal include;

• Dry rendering
• Wet rendering

The dry rendering or dry reduction method is suitable for lean fish containing less than 2-3% oil. It is not a continuous process. The wet reduction method is continuous and can be used for the production of fish meal from fatty fish. Wet rendering is a commonly used method of fish meal production throughout the world.

Process of Fish Meal Production: The following steps will be followed for fish meal production;

Cooking: The material is cooked at a temperature of 100°C for 20 minutes in indirect steam. This process stops microbiological and enzymatic activity in the product and helps to separate the oil.

Pressing: In this process, mechanical pressing is done to separate the material into two types of phases. The liquid phase and the solid phase.

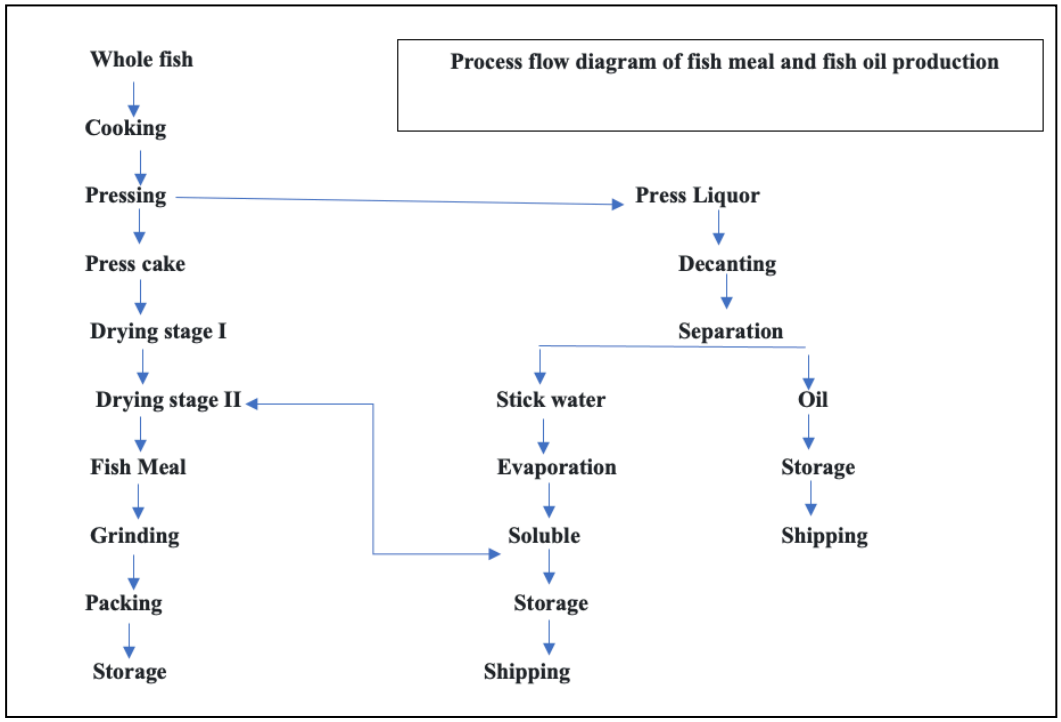
Decanting: In this stage, the liquid phase is decanted to recover more solid products and add them to the solid phase.

Centrifugation: In this procedure, the liquid phase is centrifuged. As a result, oil and water will be obtained.

Evaporation: the evaporation is done in the "tailwater" which is excess liquid, it is intended to reduce the volume of the product to concentrate it better and obtain solids.

Drying: The solids remaining from centrifugation are mixed with the solid cake obtained from pressing until a paste is obtained. Drying extracts more water from this mixture until the moisture content is reduced to 5-10%. This prevents bacteria growth and reduces chemical reactions.

Packaging: Fish meal is stored at ambient temperature either in HDPE bags. The fish meal does not require any refrigerating during storage. Additives such as antioxidants are added to fishmeal.



Physical and nutritional properties of fish meal

Physical Properties

- Color – light to dark brown, should be free from any evidence of scorching or burning
- Odor – shall be characteristic of fresh fish meal and free of rancidity
- Texture – fine granules and powder - generally free-flowing, but less so with higher fat meals

- Appearance – meals should be free of any visible signs of mold, clumps, or contamination Composition of fish meal varies considerably depending on the raw material and processing parameters.

Nutritional properties

- In general, chemical components in fish meals are protein, fat, ash and moisture which are 50-70%, 5-10%, 12-33%, and 6-10% respectively.
- Proteins in fish meal are rich in all essential amino acids which are not synthesized in the body and need to be supplied from the diet. All essential amino acids present in fish meal make it highly nutritive. Fish meal contains lysine in rich quantities which is deficient in cereals and legumes.
- Fish meal supplies vitamins such as riboflavin, niacin, pantothenic acid, choline, and Vitamin B12 in addition to fat-soluble vitamins such as Vitamin A and D. Oil present in fish meal contributes to energy for fish and other animals.
- Average values of vitamins in fish meal are riboflavin – 7.3 mg/100 g of fish meal, niacin 126 mg/100 g of fish meal, pantothenic acid - 30.60 mg/100 g of fish meal, Vitamin B12 – 0.25 mg/100g of fish meal, pyridoxine – 5.7 mg/100 g and choline – 4000 mg/100 g of fish meal. Fish meal also contains a significant quantity of Vitamin D due to residual oil in fish meal (5000 IU/ kg of fish meal).
- Inorganic constituents of fishmeal accounts for 11%. Indian fish meal exhibits higher proportions of phosphorus to calcium 1:1 against 1:2 proportions in other fish meals.
- Fish meal made from whole fish containing bones is rich in calcium, phosphorus and magnesium which are essential for growth. Mineral content in fish meal ranges from 25 to 30%. Mineral composition of fish meal involves zinc – 70 mg/kg, iodine – 70 mg/kg, iron – 250 mg/kg, copper – 7 mg/kg, manganese - 4 mg/kg, cobalt – 0.1 mg/kg
- Fish meal contains lower amounts of crude fibre in their diet which is good for proper digestion and absorption of nutrients in poultry and fish feeds.

General requirements for quality fish meal

Protein: Its value should be between 55 and 65% to ensure a product of good quality and high nutritional value.

Fat: This parameter should not exceed 13% in fishmeal. Higher values favor flour deterioration.

Humidity: This measure should be between 5-10%. Excess moisture affects shelf life and sanitary quality because water favors the replication of bacteria and fungi. On the other hand, values below this favor the heating and combustion of the fishmeal.

Ash: Its value should be less than 20%. Fishmeal is recognized for having a high value of calcium and phosphorus.

pH: should not be less than 5, it indicates the degree of chemical and physical reactions that occur in the flour.

Sodium Chloride: should be a maximum of 3%. Salt is used to preserve the raw material when there is no good storage chain.

Total Volatile Basic Nitrogen (TVBN): should be less than 125mg/100g. Flour should be stored at low temperatures to avoid degradation of nitrogen compounds that increase this parameter.

Fiber: this value must be less than 1% since it indicates the digestibility of the product. This is of utmost importance in poultry farming due to the size of 1-day-old chicks consuming feed.

Rancidity: should be less than 13meq/kg, evidence of packaging failure when oxygen enters the bags. This failure increases peroxides that degrade fishmeal.

Histamine: less than 20mg/10g alterations and hygienic-sanitary quality in conservation, bacteria grow and form toxic amine.

Microbiological analysis: Fishmeal should be free from of *Salmonella* bacteria and ensure the safety of the product.

ISI- Requirements for fish meal as poultry feed ingredient

- Fish meal shall be in the form of powder ground to such fineness that 99 percent of material shall pass through 2.80mm IS Sieve.
- The material shall have the characteristic odor and shall be free from any off-odor indicative of spoilage.
- The material shall be free from adulterants, arthropod infestation, visible fungal growth and any harmful material.
- Fish meals shall be packed in high-density polyethylene bags or jute bags with polyethylene lining inside. The mouth of each bag shall be either machine-stitched or rolled over and hand-stitched.
- Each bag shall be suitably marked or labeled with the following information: a) Name and grade of material, b) Name of the manufacturer, c) Batch or code number indicating the date of manufacture. d) Net mass in kg, and e) Guaranteed composition

ISI- Requirements for fish meal as livestock feed ingredient		
Parameters	**Grade I**	**Grade II**
Moisture (%max)	10	10
Crude protein (% min)	60	50
Ammoniacal nitrogen (% max.)	0.5	0.5
Crude fat (% max.)	10	10
Acid insoluble ash (% max.)	3	3
Chloride (as NaCl) (% max.)	4	5

Fish oil

Fish oil, which was previously a by-product of fishmeal used for animal feed, is now recognized as the primary source of these fatty acids. Fish oil can be extracted from whole fish and liver. Fish oil extracted from both resources has industrial and medicinal uses. Methods to extract fish oil include cooking, use of solvents and, recently, extraction by supercritical fluids, by enzymatic procedures and by chemical (i.e. applying acids) or biological silages. The extraction of fish oil by wet pressing is the most commonly used method for production on an industrial scale. The press liquor is the oil-water emulsion containing dissolved proteins and other substances as well as particulate matter. The press liquor is passed through a series of settling tanks or a series of centrifuges. The amount of particulate matter depends on the degree of cooking, the condition of the fish when processed and also the manner of pressing.

Fish oil Extraction by settling tank system

The settling tanks are heated to assist the breakup of the emulsion and prevent solidification of the stearin portion of the liquids. In a series of five or more heated tanks, the press liquor is admitted to the first at a point below the surface. Oil rises to the top and is passed to the bottom of the second tank containing water and the process is repeated in succeeding tanks. Finally, oil is heated to evaporate the remaining water.

Centrifuge system of extracting fish oil

In this system, a centrifuge is heated and the water phase is spun off and almost clean oil is obtained. Further to get a clean bright oil, oil is heated to about 94 degrees, mixed with clean water of the same temperature and passed to the polishing centrifuge. Oil produced through a centrifuge system is finer, cleaner and brighter and has a lower moisture content than oil from a settling tank system.

Major species used for fish oil extraction	
Species	**Country**
Anchovy	Peru
Jack mackerel, anchovy, sardines	Chile
Various species, anchovy	China
Various species, trimmings	Thailand
Menhaden, Alaska pollock, trimmings	USA
Blue whiting, herring, sprat, trimmings	Iceland
Blue whiting, capelin, herring, sand eel, trimmings	Norway
Sand eel, sprat, blue whiting, herring	Denmark
Sardine, pilchard, various species	Japan
Sardine, various species	India

Purification/Hardening of fish oil

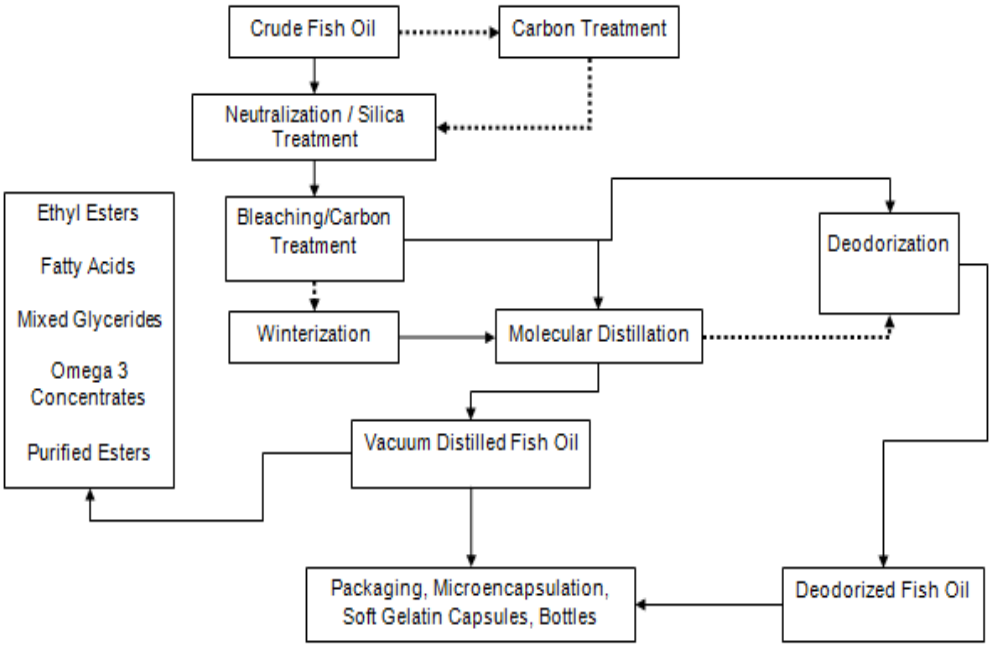
Once fish oils are extracted they require a purification process to achieve the quality characteristics that make them acceptable for human and animal consumption. Crude oil has a number of impurities such as free fatty acids, phospholipids, diglycerides, monoglycerides, pigments, pigment decomposition products, oxidation products, sulfur compounds, proteinaceous compounds, aldehydes, ketones, pesticide residues (preferably organochlorine pesticides and polychlorinated biphenyls. Fish oil may be contaminated with toxic heavy metals (such as Cd, Hg, Pb, Cu, Zn, etc. Cu and Zn are known for their distinct prooxidant effect. The Major steps involved in the purification of fish oil are given below;

Bleaching: Bleaching materials commonly used are natural or activated clays and activated carbon. It removes any colored matter, natural pigments and some of the suspended mucilage. It is also effective in the reduction of oxidation products, phosphorus, to a lesser extent sulfur compounds and heavy metals and non-metals. As an alternative to activated clay and carbon, the treatment of fish oil dissolved in hexane with silica gel gives a nearly colorless oil.

Winterization: It is a cold clearing process, an additional operation for refining fish oil. When the oil is cooled sufficiently, the saturated triglycerides (which have high melting points) commence to solidify and separate out. Cooling must be gradual by circulating cold brine

Refining: Treatment of oil with an aqueous alkaline solution which reacts with the free fatty acids to form soaps and remove any mucilage.

Deodourization: It is done by steam distillation under high vacuum (2 – 5 mm absolute pressure). Dry steam (free from oxygen and temp range of 170 – 230^{0}C) is used, which is passed through the oil under a vacuum for a prolonged period (maybe up to 5 h in a batch process). This step removes free fatty acids, decomposition products of hydroperoxides such as aldehydes and ketones, odoriferous and other volatile impurities. This step is a very critical one. If time and temperature are not strictly controlled as per schedule, the most valued components of the fish oil undergo distinct deterioration. When retention of EPA and DHA are the concern then a temperature not exceeding 170^{0}C is recommended.



Process flow for Production of edible and pharmaceutical-grade fish oils and derivatives

The following additives may be used in fish oil as per the codex guidelines

Additive	**Additive name**	**Maximum level**
Antioxidant		
E300	Ascorbic acid, L	GMP
E 304, 305	Ascorbyl esters	2500 mg/kg, as ascorbyl stearate
E307a, b, c	Tocopherols	6000 mg/kg, singly or in combination
Emulsifier		
E322	Lecithin	GMP
E471	Mono- and diglycerides of fatty acids	GMP

Physical and Chemical properties of fish oil

Physical property	**Value**	**Chemical properties**	**Value**
Specific heat (cal/g)	0.50–0.55	Moisture and impurities (%)	Usual basis 0.5 up to 1 % maximum
Heat of fusion (cal/g)	ca. 54	Free fatty acids (% oleic)	Range 1–7 % but usually 2–5 %
Calorific c value (cal/g)	ca. 9,500	Peroxide value (meq/kg)	3–20
Slip melting point (°C)	10–15	Anisidine number	4–60
Flashpoint (°C)		Totox value	10–60
as glycerides	ca. 360	**Iodine value**	
as fatty acids	ca. 220	Capelin	95–160

Boiling point (°C)	>250	Herring	115–160
Specific gravity at		Menhaden	120–200
15 °C	ca. 0.92	Sardine	160–200
30 °C	ca. 0.91	Anchovy	180–200
45 °C	ca. 0.90	Jack mackerel	160–190
Viscosity (cp) at		Sand eel	150–190
20 °C	60–90	Color (Gardner scale)	Up to 14
50 °C	20–30	Iron (ppm)	0.5–7.0
90 °C	10	Copper (ppm)	Less than 0.3
Refractive index (n D 30)	1.46–1.48	Phosphorus (ppm)	5–100

Nutritional properties of fish oil:

The interest in PUFAs of fish oil in human diets has led to the intense use of fish oil in human and animal diets. It is a good source of energy and also possesses many health benefits. Vitamins A and D occur in the oil of most fish, but many species store large amounts of vitamins A and D in their livers (cod, halibut, and tuna). The body oils of fish generally contain vitamins in minute amounts and are not consumed for that purpose. Fish oils contain varying amounts of vitamin E, which also acts as an antioxidant. The tocopherol levels reported in crude fish oils are 30 μg/g in menhaden oil, over 60 μg/g in anchovy oil, and 25 μg/g in capelin oil.

Application of fish oil

- **Food:** Foods fortified with fish oil are emerging as a novel food category promoted as containing omega-3. These products include margarine, milk, bread, cheese, yogurt, infant formulas etc.
- **Feed:** Pig, poultry, cattle, sheep, fish and pet foods
- **Pharmaceutical:** Fish oil has important roles in the prevention of some types of cancer, including colon, breast, renal, prostate, pancreatic cell, and liver. Several in vitro and animal experiments have clearly shown that the LC omega-3 PUFAs, EPA and DHA, are responsible for the inhibition of promotion and progression of cancer. There has been tremendous growth in the use of fish oil in the pharmaceutical industry including improve the heart health, lower blood fat, ensuring bone, brain, eye and skin health etc.
- **Others**: Leather, paint, fuel, lubricants, printing ink, soaps

Recommended Intake of Omega-3

Several international scientific authorities have published recommendations for the daily intake of omega-3 PUFAs. The UK Government has recommended that people eat fish twice a week, including oily fish, to provide 3 g of LC omega-3 weekly. A similar recommendation has been made by the US Heart Association.

Organization	Recommended level
Health and Welfare Canada	1.0–1.8 g omega-3 PUFAs/day
International Society for the Study of Fatty Acids and Lipids (ISSFAL)	0.22 g DHA and EPA/day
British Nutrition Foundation (BNF)	1.4 g DHA and EPA/day (males) 1.1 g DHA and EPA/day (females)
Institute of Medicine (IOM)	0.5 g omega-3 PUFAs/day (for infants)
United States Food and Drug Administration (US FDA)	3 g DHA and EPA/day

FSSAI standards for Fish oil

Fish oil shall also conform to the requirement given in table below

Sr. No	Characteristics	Requirement
1.	Free fatty acids as % oleic acid, w/w, max	1.0
2.	Moisture, % by weight, max	0.5
3.	Iodine Value	145-180
4.	Saponification value	185-205
5.	Unsaponifiable matter, %, w/w, max	2.0
6.	Refractive Index (40°C)	1.4739-1.4771
7.	The product shall be a bright and clear liquid when heated to a temperature of 40°C.	
8.	The product shall be free from foul and offensive putrefactive odour and should have only characteristic fish- oil odour	

Codex Standards for fish oil (329-2017)

- Acid value <3mg/KOH/g
- Peroxide value < 5 milli equivalent of active oxygen/kg oil
- Anisidine value<20
- Total oxidation value $(ToTox)^2$<26

Fish oils with a high phospholipid concentration of 30% or more such as krill oil shall comply with the following

- Acid value <45mg/KOH/g
- Peroxide value < 5 milli equivalent of active oxygen/kg oil

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