CC7:UNIT 5; FISHERY BYPRODUCTS

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Fish is principally used as food for human consumption. However, there are a variety of products from fish utilised as non - food products (inedibles) collectively called as byproducts. Head, skin, scales, bones, fins and viscera are inedibles. Together are also referred to as offal and constitute roughly 50% of the total weight of fish. In large scale processing of fish by freezing, canning, curing and surimi production, large proportion of wastes are generated. Being organic, they deteriorate rapidly and there is a need to use them effectively as a raw material for the production of various value added products. The maximum utilisation of inedibles efficiently in commercial fish processing operations ensures profitability and control losses. Certain value added products are produced using whole fish of low commercial value, which are underutilised. Some of them are oily pelagic species which yield valuable products such as fish meal, oil, solubles, protein concentrates and hydrolysates.

The following aspects are dealt with in this topic to understand the various steps necessary to process fish byproducts in order to obtain value added products of industrial importance.

1. Type of fishery byproducts
2. Processing of byproducts
3. PreparationofSurimi

1. TYPE OF FISHERY BYPRODUCTS

The term fish (whether of fresh water, estuarine or marine) include fin fish, crustaceans (cray fish, crab, prawn / shrimp, lobster) and molluscs (bivalve creatures such as mussel, oyster, scallop and univalves such as abalone, snail and conch and cephalopods such as squid, cuttle fish and octopus). Fish generally means fin fish unless otherwise stated. Quality of fishery products is influenced by both intrinsic and extrinsic factors. Species, size, sex, spawning, presence of parasite, toxins, contamination with pollutants and cultivation conditions are the intrinsic factors. Location of catch, season, methods of catch (gill nets, handling, longline or trap), on - board handling, hygienic conditions on the fishing vessel, processing and storage are the extrinsic factors responsible for changes in fish quality. Many of these factors influence body components of whole fish.

Head, skin, scales, bones, fins and viscera are the main byproducts of fish and are shown in Fig. 1. Fish head sometimes is used in India because of its meat content. The viscera constitute swim bladders, intestines, roes (fish eggs), liver and blood. The yields of body components of different varieties of fish are listed in Table 1. The different components as % total body weight of fish are in the range of viz., fillet (flesh) 36.9 – 69.6 %, bones 3.9 – 16.7 %, head with gills 10.3 -26.9% , skin with scales 4.2 – 12.3, %, fins 2.3 – 3.6 % and viscera 5.6 – 13.9 %. Processing crustaceans generate head and carapace (shell / skin) as byproducts, which together constitute 47 – 66 % of total body weight of crustacean.

Generally the following fishery products are considered as byproducts.

- Fishes of low market value also referred to as trash fish
- Fin fish: Head, bone, skin, fins, scales and viscera
- Crustacean: Exoskeleton, head and shells of shrimp, crab and lobsters
- Molluscs: Hard calcareous shell of clams, mussels and oysters
- Cephalopod: Skin, head and internal organs of squid, cuttlefish and octopus
- Marine plants: Sea weeds

Based on the application / usage, the fishery byproducts are grouped as:

- *Agricultural:* Fish manure (compost), fish meal, fish soluble, fish silage, bone meal
- *Industrial:* Fish body oil, glue, gelatin, isinglass, pearl essence, chitin, agar, alginic acid, carrageenan
- *Pharmaceutical:* Liver oil, lecithin, squalene, insulin, bile salts and protamines
- *Miscellaneous:* Shark fin rays, shark leather, shark teeth, fish roes

2. Processing of Byproducts

Different techniques are available for processing of fishery byproducts to obtain several value added end products such as fish meal, fish oil, fish silage, protein hydrolysates, fish protein concentrate and other miscellaneous products such as insulin, pearl essence, leather, fish glue, gelatin and chitin. The processing techniques for the production of a few important value added products are mentioned below.

A. Fish meal and fish oil

Largest share of fish processing byproducts goes for fish meal / oil production. Heat application to byproducts for the production of fish meal / oil is a critical process. Heat coagulates protein, ruptures cell walls releasing oil and water bound in cells. The production process is mechanised and consists of cooking, pressing, drying, pulverising, cooling and packaging of dried meal. The pressing operation yields press liquor consisting of oil and stick water which is separated by using centrifuge. The stick water obtained from press liquor after oil recovery is further evaporated to get fish soluble, which is mixed with press cake to enhance the protein content of fish meal.

Normally the cooking retort consists of a long steam jacketed cylinder through which the raw materials are moved by a screw conveyor. Cooked material is pressed with a continuous double screw system to obtain pressed cake. The pressed cake is dried in direct hot air dryer with the inlet temperature up to 600 ºC and outlet temperature of 80 – 100 ºC. Fish oil is separated by decanting or centrifugation after heat treatment.

Oil sardines are the main raw materials for the production of fish oil. The oil is obtained during fish meal production by pressing the cooked fish. The press liquor is an emulsion of oil, water and solids which are subjected to centrifugation to get oil and stick water. Fish oils are a mixture of triglycerides, containing about 70% unsaturated and 30% saturated fatty acids. It is a rich source of omega 3 fatty acids such as Ecosapentaenoicacid (EPA) and Docosahexaenoicacid (DHA). Both have beneficial effect in controlling cardiovascular diseases (CVD). The essential processing steps are presented in Fig. 2.

One ton of raw fish byproduct normally yields about 210 kg fish meal and 110 kg fish oil. Fish meal contains 50 – 75 % protein, 3 – 12 % oil, 1 – 4 % salt, 10 - 20 % ash and 7 – 11 % water. Shark and cod livers are known for high oil content in the liver, hence utilised for liver oil production. Fresh livers are cut into small pieces and cooked at abort 90 ^{0}C for about an hour. The oil floats at the top and is separated by using centrifuge. The oil is stored in a cool and dry place. The liver oils are rich source of vitamin A and D.

Use: Fish meal is used as source of high quality animal protein in feeds especially poultry and swine and also as an ingredient in pet foods. Fish oil is used in the preparation of margarine and shortenings, cooking oil, cosmetics, paints and varnishes, industrial coatings, lubricants, rubber manufacture, printing inks, shoe polish, insecticides, leather tanning and in animal feeds. Hydrogenated fish oils are used for the manufacture of stearic acid, glycerin, soaps and detergents, candles and greases. Derivatives of fish oils are used in the manufacture of urethane and epoxy coatings.

B. Fish silage

Ensiling or silaging is a process of preserving the nutrients in food by using acids. Organic (formic, propionic) and / or inorganic (sulphuric, hydrochloric) acids are used. This lowers the pH to 3.5 – 4.0 to prevent microbial spoilage. Tissue structures are degraded by the enzymes naturally present in fish and liquefied product is called acid silage. Ensiling can also be initiated by bacterial fermentation (fermented silage). Fish and fish offals are rich in proteins and lipids but poor in carbohydrate. To effect fermentation the offal is mixed with molasses, which contains fermentable sugar and is a byproduct of sugar industry. Addition of lactic culture hastens the process of fermentation. The lactic acid bacteria produce acid and antibiotics which together destroy competing spoilage and pathogenic bacteria. Sugar contributes to the preservation effect during the initial stages of fermentation by repressing bacterial production of enzymes liberating ammonia and amino acids. Autolysis occurs in 3 – 4 days at 25 – 30 ºC. Heating silage to 95 ºC facilitates the separation of oil, if required. The aqueous phase, oil and sludge are separated. The liquid phase contains proteins, peptides and amino acids and is concentrated and stored in tanks or bags. The oil goes for refining. Flow diagram for the production of fish silage is presented in Fig. 3. Only easily biodegradable byproducts such as trash fish, fish viscera and blood can be used for silage production.

The composition of silage is almost the same as that of the raw material except for the slight dilution due to the addition of acids or molasses. Deoiling, if done, produces silage of low oil content. Protein is broken down by the enzymes to peptides and amino acids. Oil deteriorates due to increase in free fatty acids while oxidative change causes the oil to darken in color. Preferably oil separation is done within 24 h of liquefaction.

The advantages of fish silage in comparison to fish meal are:

- Silage production causes less pollution problems.
- Silage is sterile and pathogen free.
- Scale of production can be varied to low to high without affecting the economy of production.
- Silage production requires very low energy input.
- Silage mixed with other feed ingredients can be sun dried without fly infestation.

The main disadvantage is that the silage is more bulky and expensive to transport.

Use: The silage is cheaper to fish meal and is used as an ingredient in animal feed in place of fish meal. Better growth and performance in fish and poultry has been observed when silage is used in feed instead of fish meal.

C. Fish hydrolysate

Hydrolysates of fish products are produced by mixing them with water and proteolytic enzymes. The enzymes used are:

- Peptic (Fish intestinal mucosa), pH 2.0, commercial pepsin, incubation 12 h, 35 ºC

- Tryptic (*Pyloric caeca*), pH 0.5 – 1.5, 121 ºC, 15 min to 5 h
- Plant enzyme (Bromelin)

Fish filleting byproduct is chopped / minced, mixed with water and enzyme for digestion. After completing digestion, the mix is sieved to separate liquid which is pasteurized at 80 ºC and dehydrated to obtain dry hydrolysate. Fig. 4 presents the processing steps for the production of fish hydrolysate.

Soluble fish hydrolysate is a fine cream colored powder which is not very hygroscopic. Antioxidants can be used if oil content is more in the hydrolysate. Dried fish hydrolysate contains 3 – 8 % water, 70 – 90 % protein with 75 – 80 % digestibility, 1 – 23 % oil and 2 – 9 % ash. Total bacterial count will be less 10,000 per g of hydrolysate.

Use: Fish hydrolysates are primarily used in animal (calves) feeds as milk replacer.

D. Fish protein concentrate (FPC)

The FPC is upgraded version of fish meal for use as an ingredient in human food. The FPC includes fish hydrolysate, fish paste, fish sauce and dried protein powder. There are two types of FPC, FPC – A and FPC – B. FPC – A is odorless and tasteless powder with minimum of 67.5 % protein and maximum of 0.25 % fat. FPC – B has fishy odor with 60 – 70 % protein and about 10 % fat.

Minced fish is subjected to extraction with isopropyl alcohol 3 times. The solids and liquids are separated. The protein rich solid is dehydrated to obtain A – grade FPC. Liquid portion containing lipids and odorous compounds is distilled to obtain solvent for reuse. The production steps for FPC –A are presented in Fig. 5.

Solvent recovery is essential due to high cost of solvent. Solvent extraction is not necessary for the production of FPC – B grade as the raw material with high fat content is used. Production of FPC –B is similar to that of fish meal. But the material of construction, design and layout of plant are reorganized to meet food standards of hygiene. Utensils should be made of stainless steel and non - corrosive materials. These factors increase the processing cost slightly.

Use: FPC - A is used as an ingredient (at 5 – 10 %) in human foods without compromising their acceptability. FPC – B is also used as human food where slight fishy odor is acceptable. However, low solubility of FPC checks its use in drinks. The FPC has not been widely accepted as a protein supplement in human food because of high capital requirement, strict regulatory measures and lack of ready market.

Some of the other commercially important byproducts are:

Chitin: Chitin is a major component of exoskeleton of invertebrates. The main raw materials for chitin production are the wastes from crustacean processing, principally the head and shells. The shrimp wastes contain about 6 – 8 % chitin. This is extracted by removing the protein (deproteinisation) and minerals (demineralisation), which together constitutes 20 - 25% of the wet weight. The moisture content ranges between 60 - 70%. The chitin obtained is converted in to chitosan by deacetylation process. Chitin and chitosan find application in paper and textile industries as a sizing agent. They also used as flocculent and coagulant for the removal of suspended matter from water, as anti - caking agent and as adhesive. The chitin derivatives are valuable as artificial kidney membranes as a biodegradable pharmaceutical carrier, in anti - acid and anti – perspirent preparations, in infant foods and for characterisation of lysozymes.

Shark leather: The skin is separated from dorsal side in order to avoid the holes from I and II dorsal fins in the centre of the skin. The skin is washed and soaked in water for 2 h. It is subjected to liming and the softened skin is delimed and tanned, dyed and trimmed. Shark leather is classified as fancy leather and used for making high value wallets, belts and other leather goods.

Shark fin rays: The fins of shark are cut off, washed and soaked in 10 % acetic acid for 3 - 5 days. The skin is scrapped using a wire brush, the fin rays are separated manually, washed and dried. The dried product is used for the preparation of soups for human consumption. Shark cartilages are a good source of chondroitin sulphate classified as nutraceutical and is used in curing arthritis.

Seaweed extracts: Agar agar, algin and carrageenan are the important hydrocolloids extracted from seaweeds. The red seaweed species belonging to family *Rhodophycea*, *gelidlium sp* and *gracilaria sp* are soaked in water and boiled. The boiled extracts are poured into shallow wooden trays and allowed to solidify and dried. The yield of dry agar ranges between 15 - 20%. Agar is sold as shreds, powder, sheet and flakes. It forms firm gels at 35 – 40 ^{0}C and melts at 75 – 80 ^{0}C, with good clarity, resistance and stability. It is used as a solidifying agent in microbiological culture media.

Insulin, nucleic acid, protamines, glutathione, cortisone, bile salts and enzymes are the other pharmaceutical compounds obtained from fish byproducts. Fish glue, fish gelatin, isinglass are other minor products extracted from fish byproducts. Few fishery byproducts such as fish glue have lost their importance due to the advent of cheaper synthetic substitute.

Processing of fishery byproducts is mandatory in view of strict enforcement of regulatory agencies for pollution control. Processing of such byproducts instead of disposal also has additional advantage of reducing cost of disposal, generating additional income and provide employment opportunities.

Surimi

Surimi is a Japanese term for separated fish mince, water washed, partially dehydrated, mixed with additives, block frozen and frozen stored. Lean fishes are mostly used for surimi production. In Japan, Alasca Pollock is the fish mainly used as raw material for surimi. The surimi processing consists of several unit operations and principally depends on the type or fat content of fish. The lean or non-fatty species have light or white colour meat and are most suitable. Surimi based products are: Fish cakes, Fish balls, Crab analogs

Pre- preparation for Surimi

a)Fresh whole fish., b)Washing c)Heading and gutting, d)Washing e)Meat separation (the separated flesh is called fish mince/the raw material for surimi.

Surimi Peparation

Water washing – 3-4 cycles(1 part of mince and 2 part of water -chilled 5^{o}c)
Dewatering (straining).,Addition of cryoprotectants.,Forming blocks and
Freezing in plate freezers at -40^{o}C.,Packaging in plastic bags.,Cartooning in card board boxes.,Frozen storage at -20^{0}C.

Conclusion: Considerable amount of fish are wasted during capture and processing, commercialisation and industrialisation processes. Classical approach in the utilisation of fish byproducts is for the production of fish meal, fish oil, silage, fertiliser and pet foods. Vegetable proteins are deficient in some essential amino acids. Proteins animal source are rich in essential amino acids. Addition of protein rich processed fish byproducts improves the nutritional quality of feeds. Efficient processing of fish byproducts in the manufacture of hydrolysates, meals, silages etc not only contributes to environmental preservation, but also improves the plant economy. New approaches have been introduced to the production of number of high value components from fish byproducts such as enzymes, chitin and chitosan etc for use in food and pharmaceutical industries. With the pollution norms becoming more stringent, it is mandatory to utilise the byproducts for the recovery of marketable products.

Table 1. Body components (as % whole body weight) of different varieties of fish

Type of fish	**Fillets / meat**	**Bones**	**Head with gills**	**Skin with scales**	**Fins**	**Viscera**
Hake	47.5	-	15.2	4.3	2.3	-
Cyprinus carpio	42.2 – 55.9	6.1 -15.2	11.4 – 19.3	9.4 – 10.3	3.4 – 3.6	4.7 – 13.9
Catla catla	36.9 – 53.4	4.5 – 16.7	11.4 – 26.9	9.4 – 9.6	2.8 – 3.4	7.3- 13.9
Cirhinus mrigala	46.7 – 54.9	8.1 – 10.5	10.3 – 13.5	10.3 – 12.3	3.1 – 3.6	10.8 – 11.0

Labeo rohita	47.5 -69.6	3.9 -13.8	12.7 – 16.9	7.0 – 9.9	2.4 – 3.6	9.0 – 11.0
Cod	-	9.7	20.2	4.2	-	5.6
Haddock	-	10.6	18.9	4.5	-	6.2

Note: Body components of fish vary widely depending on different fish species, size of fish and season of fishing.

Source: Sachindra and Mahendrakar 2015

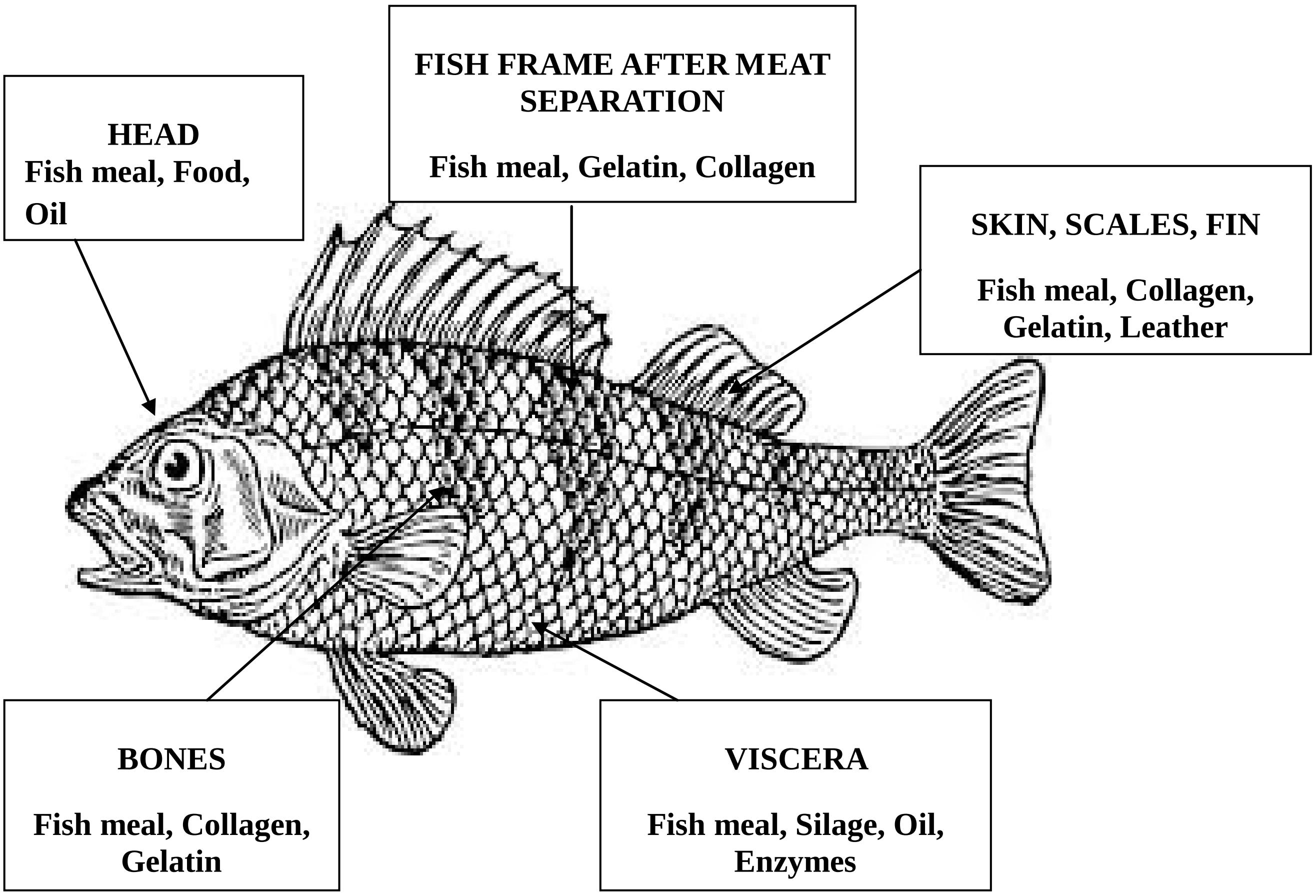

Fig. 1. Byproducts generated during fish processing and their potential uses

Source: Sachindra and Mahendrakar 2015

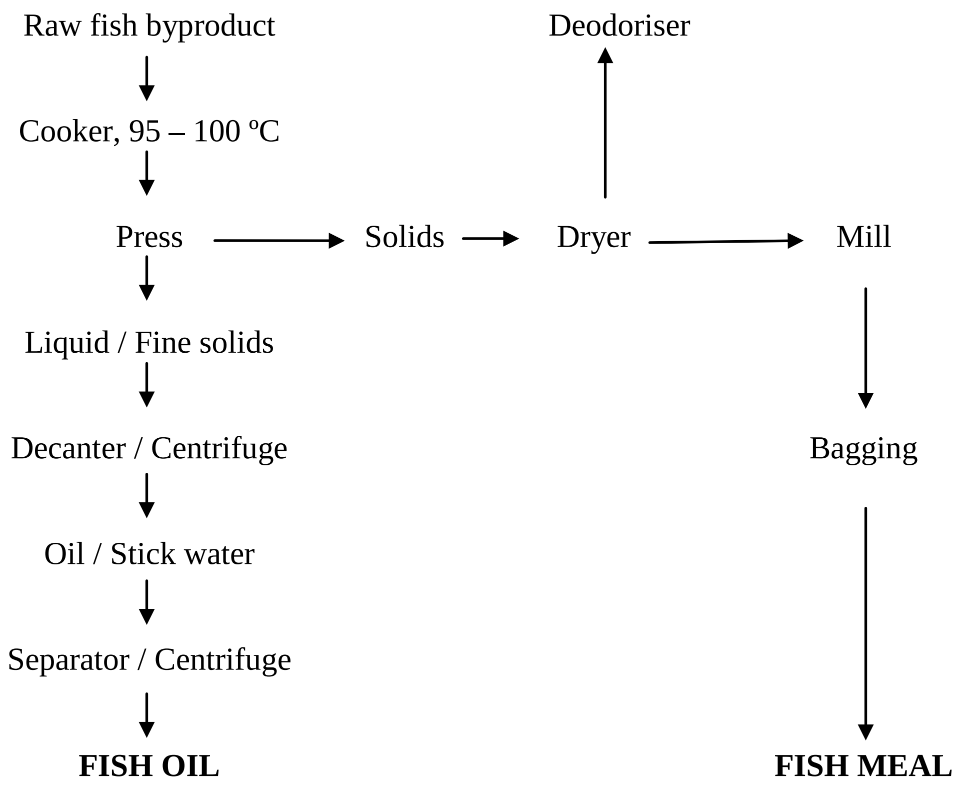

Fig. 2. Processing of fish byproducts for the production of fish meal and fish oil

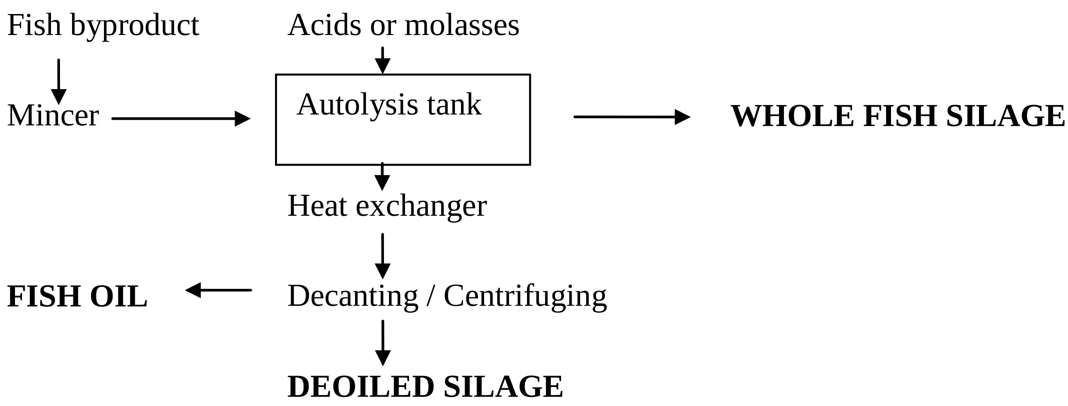

Fig. 3. Processing of fish byproducts for the production of fish silage and fish oil

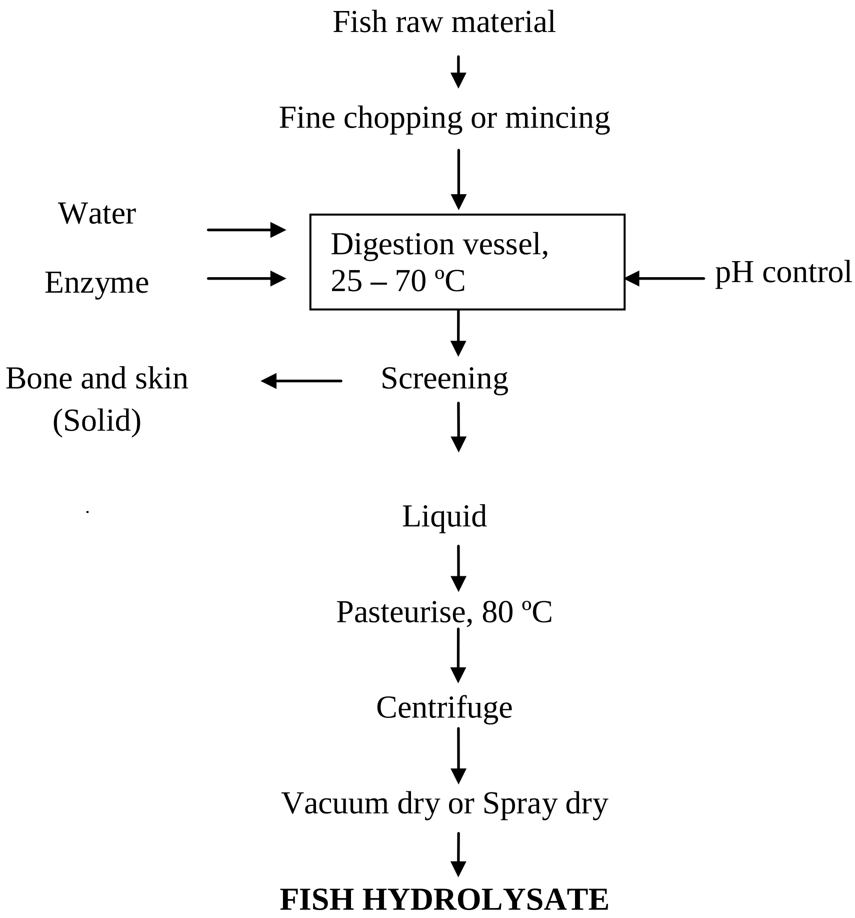

Fig. 4. Processing steps for the production of fish hydrolysate

Source: Fredrick W Wheaton and Thomas B Lawson 1985.

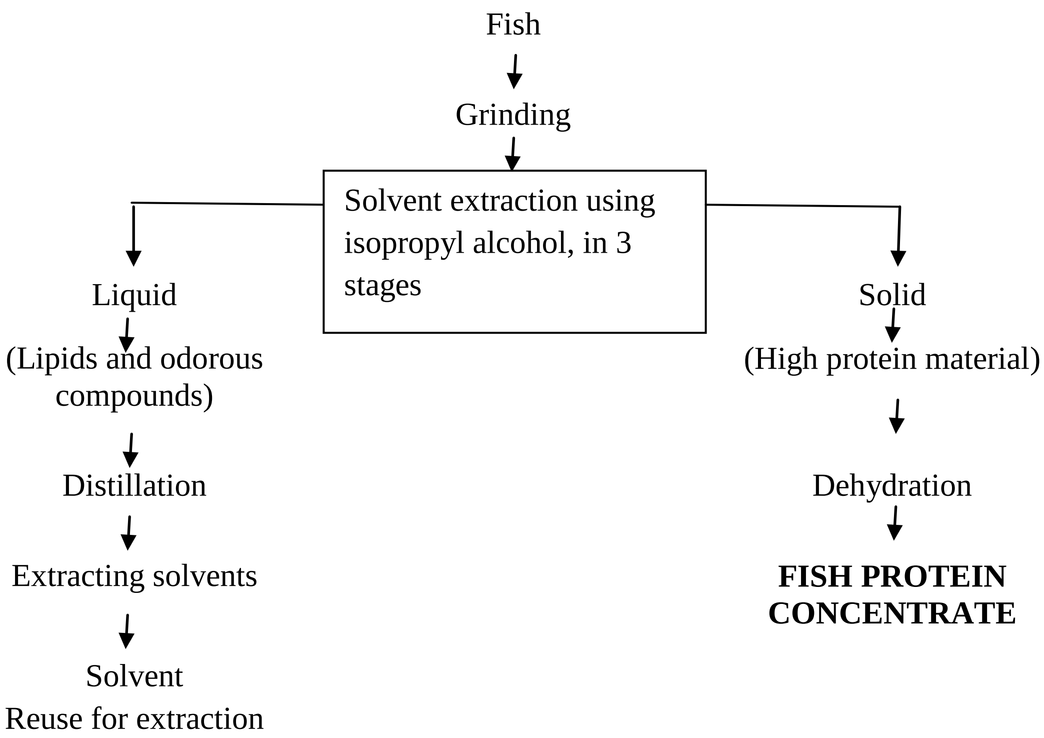

Fig. 5. Processing of fish for the production of fish protein concentrate