

2 OVERVIEW OF FISH PROCESSING

The fish processing industry is very widespread and quite varied in terms of types of operation, scales of production and outputs. The species of fish processed include cod, tuna, herring, mackerel, pollock, hake, haddock, salmon, anchovy and pilchards. Marine fish account for more than 90% of fish production, with the remainder being fresh water fish and fish produced by aquaculture.

In general, fish processing operations are located close to commercial fishing areas. However in some cases catches may be transported long distances or exported for processing. The Northwest Pacific region is by far the most important fishing area in terms volumes caught and processed. China, Peru, Chile, Japan, the United States, the Russian Federation and Indonesia (in that order) are the top producing countries, together accounting for more than half of world fish production.

Approximately 75% of world fish production is used for human consumption and the remaining 25% is used to produce fish meal and oil. Fish meal is a commodity used as feed for livestock such as poultry, pigs and farmed fish and fish oil is used as an ingredient in paints and margarine.

Currently, only about 30% of fish produced for human consumption are marketed fresh. The supply of frozen fish fillets and fish, in the form of ready-to-eat meals and other convenience food products is growing in both developed and developing countries.

The end products from fish processing may be fresh, frozen or marinated fillets, canned fish, fish meal, fish oil or fish protein products, such as surimi. Surimi is an important fish product, with the majority of catches for some species used solely for its production.

Fish processing most commonly takes place at on-shore processing facilities. However some processing can take place at sea, on board fishing vessels—for example the gutting of oily fish. In some regions of the world, where large sea fleets operate, processing can also take place on board fishing vessels. For some sea fleets, 100% utilisation of the catch may be required by legislation. This means that the entire processing operation, including fish meal and oil production for offal and fish waste, takes place on board the fishing vessels.

Some sectors of the industry are very seasonal. Salmon processing, for example, may operate fewer than 100 days per year during the salmon harvesting season. During this time, plants operate at full capacity with little opportunity for down time and little incentive for waste reduction.

Focus of this guide

It is not possible to cover all aspects of fish processing in this guide. Instead its focus is on the filleting of white and oily fish, the canning industry and the production of fish meal and oil (Figure 2–1).

The production of fish meal has been included in this guide because, in terms of volume, it is a major product and has significant environmental impacts. The processing of seafoods such as squid, cuttlefish, octopus and mussels has not been included because production of these species is relatively small compared to the fish filleting industry.

The guide is mainly concerned with the processing of fish at on-shore processing facilities and does not cover at-sea operations specifically. However some of the basic principles will apply to them.

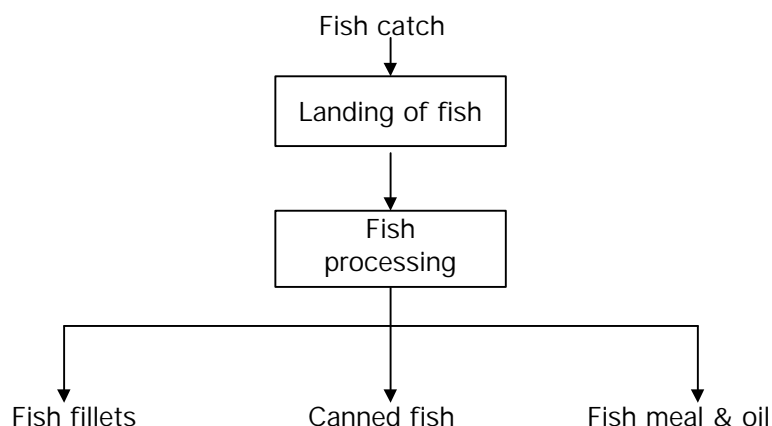


Figure 2–1 General flow diagram for fish processing

2.1 Process overview

2.1.1 Filleting of white fish

Filleting involves a number of unit operations: pretreatment, fish filleting, trimming of fillets, packing and storage. These processes generally take place within separate departments of the fish processing plant.

White fish species have a low oil content and, unlike their oily fish counterparts, are generally gutted, cleaned and sometimes de-headed on board the fishing vessel. The fish are kept on ice in boxes before being delivered to the fish processing plant. On arrival at the plant, fish may be re-iced and placed in chilled storage until required for further processing.

Pretreatment

Pretreatment of the fish involves the removal of ice, washing, grading according to size and de-heading, if this has not been done previously. Large fish may also be scaled before further processing.

Filleting

The next step in the process is filleting, which is generally done by mechanical filleting machines. The filleting department is generally separated from the pretreatment area by a wall, to prevent workers and goods passing from the non-sterile pretreatment area to the sterile filleting area. The filleting machines comprise pairs of mechanically operated knives which cut the fillets from the backbone and remove the collarbone. Some fish fillets may also be skinned at this stage.

Trimming

In the trimming department, pin bones are removed and operators inspect the fillets, removing defects and any parts that are of inferior quality. Offcuts are collected and minced. Depending on the final product, the fillets may be cut into portions according to weight or divided into parts such as loin, tail and belly flap. As a final step before packaging, the fillets are inspected to ensure they meet product standard.

Packaging/storage

Fresh products are packaged in boxes with ice, the ice being separated from the products by a layer of plastic. Frozen products can be packed in a number of ways. Fillets or pieces can be individually frozen and wrapped in plastic, but the most common method is for them to be packed as 6–11 kg blocks in waxed cartons. The blocks are typically frozen and then kept in cold storage.

The steps involved in filleting white fish are summarised in Figure 2–2.

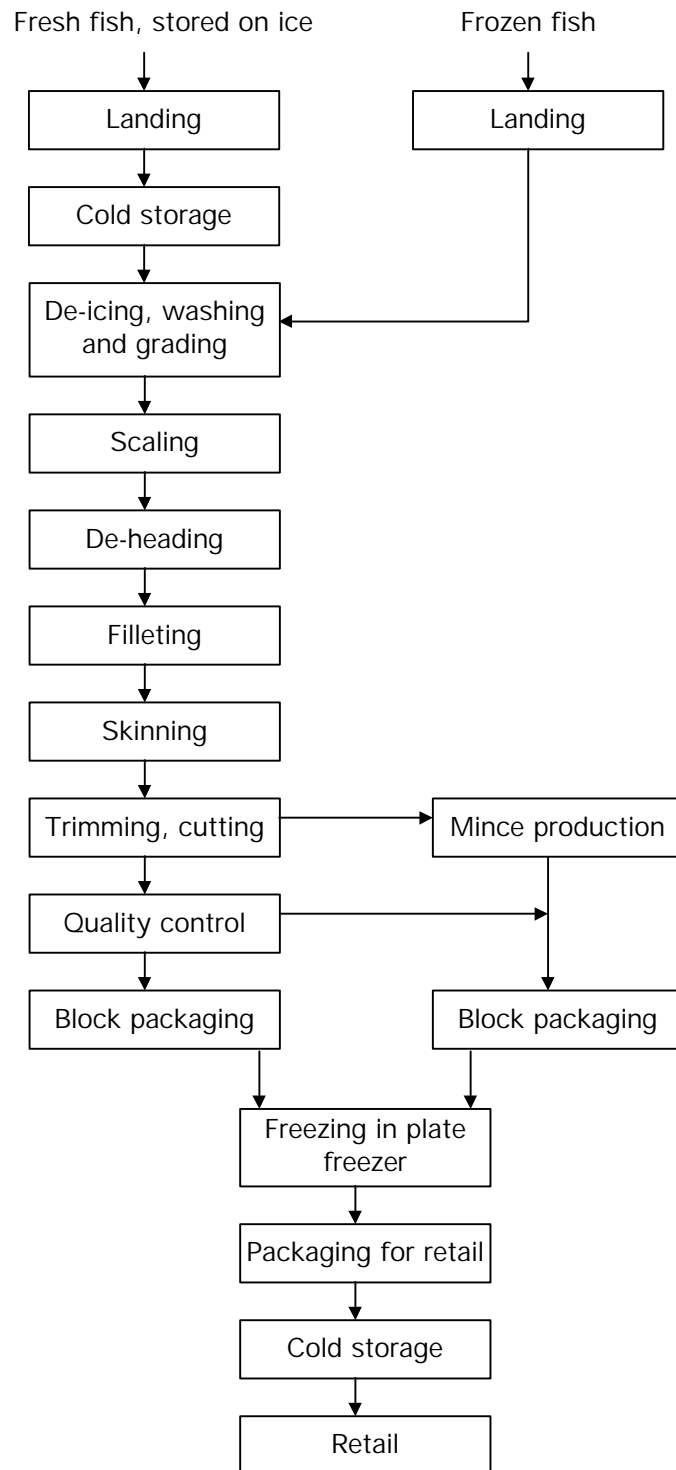


Figure 2–2 Process flow diagram for the filleting of white fish

2.1.2 Filleting of oily fish

Oily fish species are characterised as those having oils distributed throughout the fillet and in the belly cavity around the gut. Fillets from these species may contain up to 30% oil. Oil content varies not only between species but also within species.

Oily fish species are very rarely gutted or cleaned on board the fishing vessels, due to the high oil content and the consequent risks associated with oily surfaces. Keeping the skin of the fish intact also reduces oxidation of the oil and thus maintains flesh quality. Oily species can be filleted like white fish species, but they are also used for canning.

The steps involved in the filleting of oily fish are summarised in Figure 2–3.

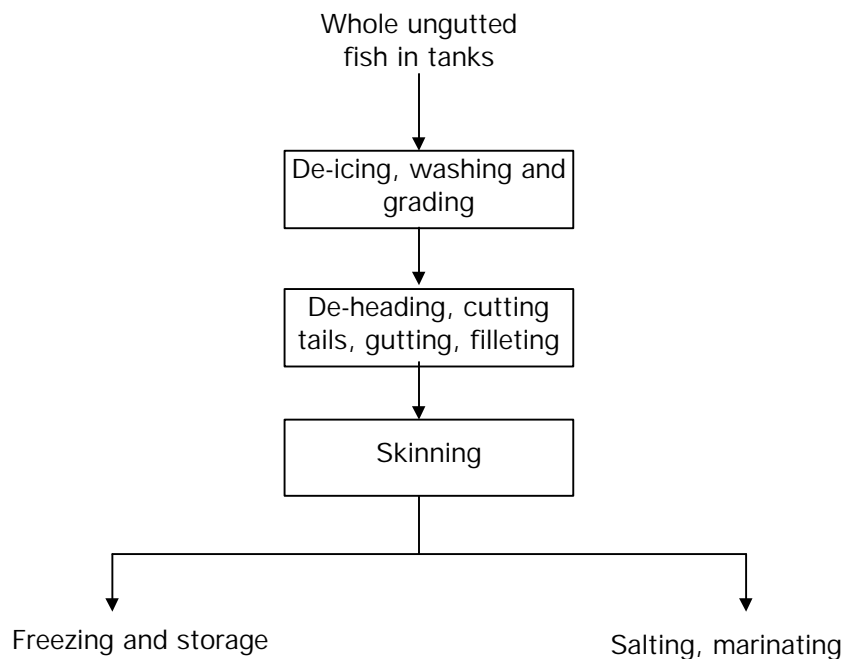


Figure 2–3 Process flow diagram for the filleting of oily fish (herring)

2.1.3 Canning

Off-loading and cutting

The fish are off-loaded at the plant, weighed and loaded into water flumes. The flumes transport the fish to holding vessels, where they remain until required for processing. Fish are flumed, as required, onto cutting tables, where the heads, tails and other inedible parts are removed.

Skinning

Some fish species, such as mackerel, need to have the skin removed by immersion in a warm caustic bath. The effluent generated from this process has a high organic load and has to be neutralised before being discharged.

Can filling and cooking

The canning process depends on the size of the fish. Small fish species such as sardines and pilchards are generally canned whole, with only the heads and tails removed. These whole-fish products are cooked in the can after it has been filled with brine or oil.

Medium-sized fish species are cut into pieces and pre-cooked in the can before the can is filled with brine or oil. For large fish species such as mackerel and tuna, the fish are filleted, cut into pieces of suitable size and also precooked in the can. Bones and inedible parts are removed when large fish species such as tuna are canned. After precooking, the liquid is drained from the cans and oil, brine or sauces are added. The cans are then sealed, sterilised and then stored.

Fish meal production

Most large canneries also operate a fish meal plant, in which fish not suitable for canning is combined with offal and processed into fish meal.

The steps involved in the canning of fish are summarised in Figure 2–4.

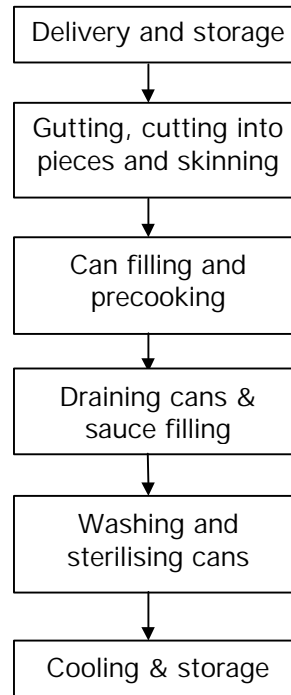


Figure 2–4 Process flow diagram of the canning process

2.1.4 Fish meal and fish oil production

Fish meal and fish oil are produced from fish that are caught specifically for this market, by-catch from fishing activities and solid waste from filleting and canning.

Fish meal and fish oil products have a high nutritional value. Fish meal is used as feed for livestock and farmed fish, and the oil is used as an ingredient in paints and margarine.

Fish meal is derived from the dry components of the fish, and the oil from the oily component. Water, which makes up the rest of the fish matter, is evaporated during the process.

Most fish meal and fish oil production processes are automated and continuous, and comprise several process lines, each with a certain processing capacity. Production rates vary considerably, according to the season and types of fish being processed.

The steps involved in fish meal in fish oil production are summarised in Figure 2–5.

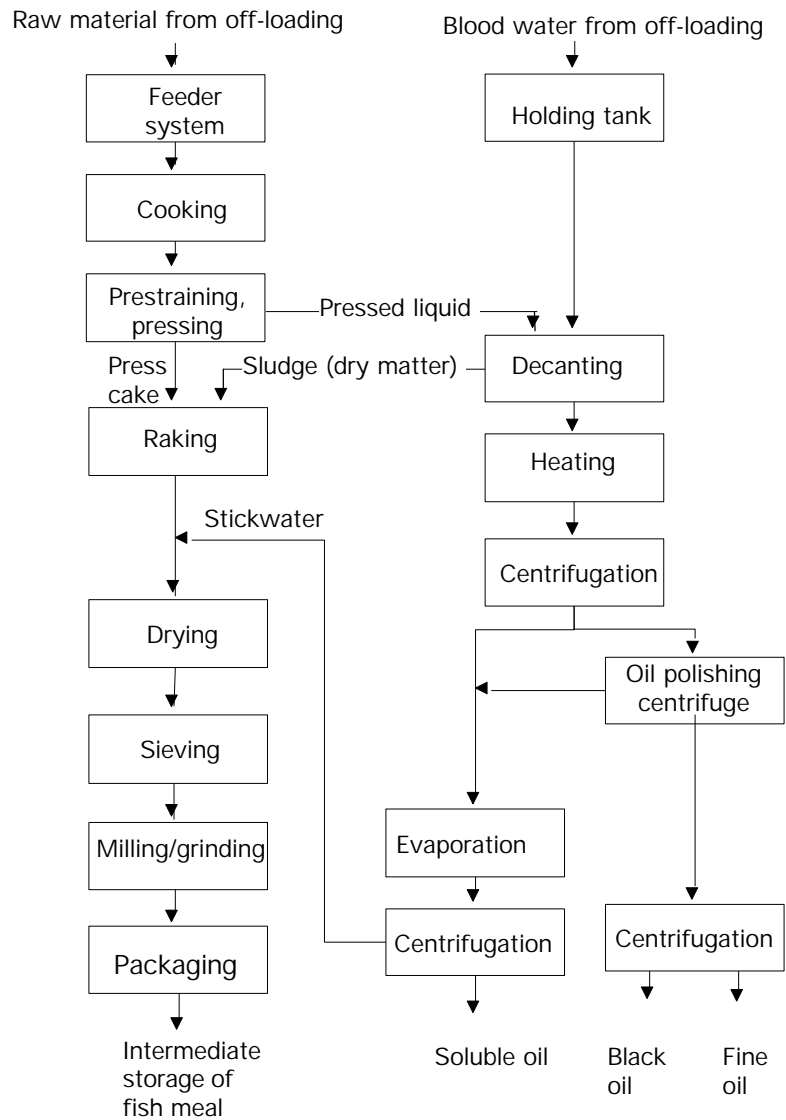


Figure 2–5 Process flow diagram of fish meal and fish oil production

Off-loading

On board the fishing vessels, the catch is normally stored in tanks of water. Upon arriving at the processing plant the fish are pumped to holding bins, where they are stored until required for processing. Extra sea water may need to be added to pump the fish.

Fish meal process

From the storage bins, the fish are transported by screw conveyors to a cooking process which acts to coagulates the protein. The cooked mixture is then screened, using a strainer conveyor or a vibrating screen, and then pressed to remove most of the water from the mixture.

The pressed cake is shredded and dried, using an indirect steam drier or a direct flame dryer. The meal passes through a vibrating screen and on to a hammer mill, which grinds it to the appropriate size. The ground meal is automatically weighed and bagged.

Fish oil process

The pressed liquid generated from the previous processes passes through a decanter to remove most of the sludge, which is fed back to

the meal dryer. Oil is separated from the liquid by centrifuges, polished and refined to remove any remaining water and impurities. The separated aqueous phase, referred to as stickwater, is concentrated in an evaporator and then added to the pressed fish meal prior to being sent to the dryer.

2.2 Environmental impacts

As for many other food processing operations, the main environmental impacts associated with fish processing activities are the high consumption of water, consumption of energy and the discharge of effluent with a high organic content. Noise, odour and solid wastes may also be concerns for some plants.

A characteristic of fish that has a bearing on the waste loads generated, is its highly perishable nature compared with other food products. If not properly refrigerated it spoils rapidly, the flesh becomes soft and loose, and pieces are easily lost. As the quality of the fish deteriorates over time, product yield decreases and product losses contribute to the waste loads. These losses often find their way into the effluent stream.

Fish processing plants often have little direct control over the handling of the fish catch before it arrives at the plant, except where the fishing vessels are owned by the processing company. In this case, the processor can set quality standards and expect certain handling practices.

Water consumption

Fish filleting and canning processes consume very large quantities of fresh water. Water is used for transporting fish and offal around the plant in flume systems, for cleaning plant and equipment, for washing raw materials and product, and for de-icing and thawing.

For fish meal and fish oil production, sea water is typically used for cooling and condensing air from the evaporators and scrubbers, and comparatively minor quantities of fresh water are used for the centrifuges, for producing steam and for cleaning.

Energy consumption

Energy is used for operating machinery, producing ice, heating, cooling, and drying. As well as depleting fossil fuel resources, the consumption of energy also produces air pollution and greenhouse gas emissions, which have been linked to global warming.

Production of fish meal and fish oil requires significant amounts of energy for cooking, drying and evaporation. This energy is usually generated by the combustion of fuels on site.

Effluent discharge

Effluent streams generated from fish processing contain high loads of organic matter due to the presence of oils, proteins and suspended solids. They can also contain high levels of phosphates and nitrates.

Sources of effluent from fish processing include the handling and storage of raw fish prior to processing, fluming of fish and product around the plant, defrosting, gutting, scaling, portioning and filleting of fish and the washing of fish products. For operations where skinning is carried out, the effluent can have a high pH due to the presence of caustic.

In canning operations, effluent is also discharged from the draining of cans after precooking, from the spillage of sauces, brines and oil in the can filling process, and from the condensate generated during precooking.

In fish meal and fish oil production, sources of effluent are bloodwater from unloading the vessels, bloodwater from intermediate storage of fish, stickwater from the centrifuges, condensate from the evaporators and cleaning in general.

Effluent quality is highly dependent upon the type of fish being processed. Pollution loads generated from the processing of oily fish species are much higher than from white fish species, due to the high oil content and the fact that these species are usually not gutted or cleaned on the fishing vessel. The entrails from the gutting of oily fish contain high levels of easily soluble substances, which generally find their way to the effluent stream.

Effluent quality also depends on the type of processing undertaken. For example, additional pollution loads arise from the pickling of fish. Brine is used in this process, the wastewaters from which contain salts and acids, making them difficult to treat.

If the effluent streams described above are discharged without treatment into water bodies, the pollutants they contain can cause eutrophication and oxygen depletion. In addition, fish processing industries have been known to pollute nearby beaches and shores by releasing wastewater containing oils. Since oil floats on water, it can end up on the surrounding coastline.

Refrigerants

For operations that use refrigeration systems based on chlorofluorocarbons (CFCs), the fugitive loss of CFCs to the atmosphere is an important environmental consideration, since CFCs are recognised to be a cause of ozone depletion. For such operations, the replacement of CFC-based systems with non- or reduced-CFC systems is thus an important issue.

Emissions to air

Odour generation can be an important environmental issue. The main causes are the storage and handling of putrescible waste materials, and odorous emissions during the cooking and drying processes used in the production of fish meal.

2.3 Environmental indicators

Environmental indicators are important for assessing Cleaner Production opportunities and for comparing the environmental performance of one fish processing operation with that of another. They provide an indication of resource consumption and waste generation per unit of production.

The consumption of resources and the generation of wastes can vary considerably from one plant to the next. Variations are most obvious when different fish species are being processed. Variations also result from the type of equipment used, the extent of processing and the attention paid to optimising resource consumption.

Different species produce different yields by virtue of the amount of edible flesh on the fish. For example, *orange roughie* from Southern Hemisphere fisheries produces relatively low yields (30%), whereas tuna produces higher yields (50%). In addition, the oil content of oily fish species may vary from 2% to more than 25%, depending on the season, and this has a considerable impact on the pollution load generated from the process. There is also a big difference in yield between a small fish canned whole and a large fish that is de-headed, gutted, filleted and skinned.

For the fish processing industry, indicators can be represented either as per tonne of raw material (RM) or per tonne of finished product (FP). The latter takes into consideration the yield of the fish species being processed, but it is often more convenient to calculate the figures per tonne of raw material. Equipment manufacturers often give consumption indicators per tonne of raw material or per hour.

This section contains input and output for each of the processes covered in this guide. The figures are representative of average technology. Also provided are indications of the resource input and waste generation figures that could be achieved by adopting best available technology (BAT).

The figures are derived from Danish plants, and from a few African and American plants. They should be used with care, due to the processing variations discussed above. Rates of resource consumption and waste generation can be much higher than stated in this section.

2.3.1 Filleting white fish

Figure 2–6 below shows the process for filleting white fish including approximate figures for quantities of inputs and outputs.

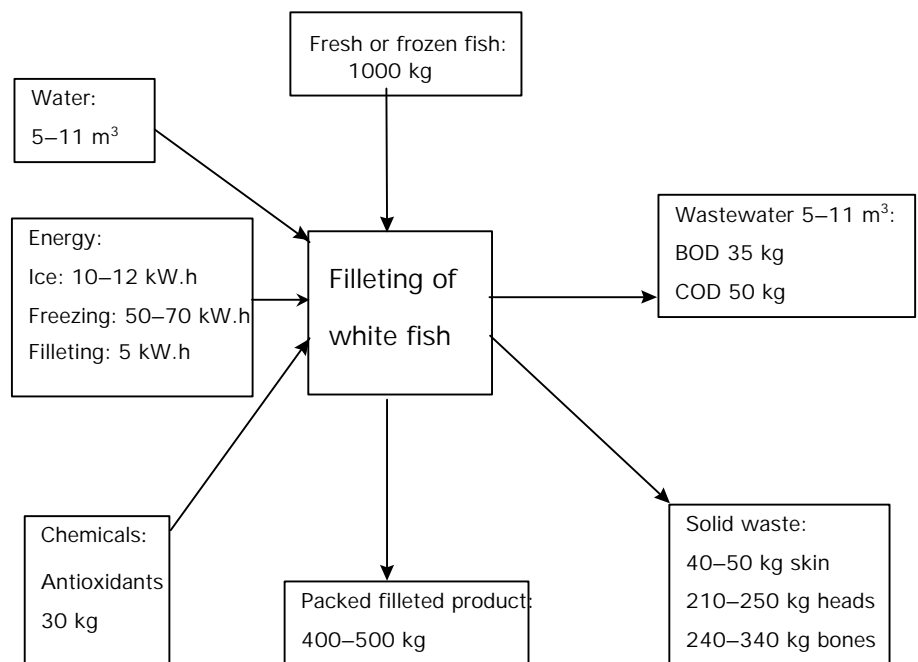


Figure 2–6 Inputs and outputs for filleting of white fish using average technology

By adopting best available technology, the following rates of resource consumption and waste outputs could be achieved:

- Water consumption and wastewater generation could be reduced to 1.2–4.4 m³ per tonne of raw material.
- Organic loads in the effluent could be reduced to about 12 kg BOD or 17 kg COD per tonne of raw material.
- Energy consumption could also be reduced, especially if the equipment and rooms for freezing were to be improved.
- Product yields would also increase, resulting in a decreased rate of solid waste generation.

2.3.2 Filleting oily fish

Figure 2–7 below shows the process for filleting oily fish including approximate figures for quantities of inputs and outputs.

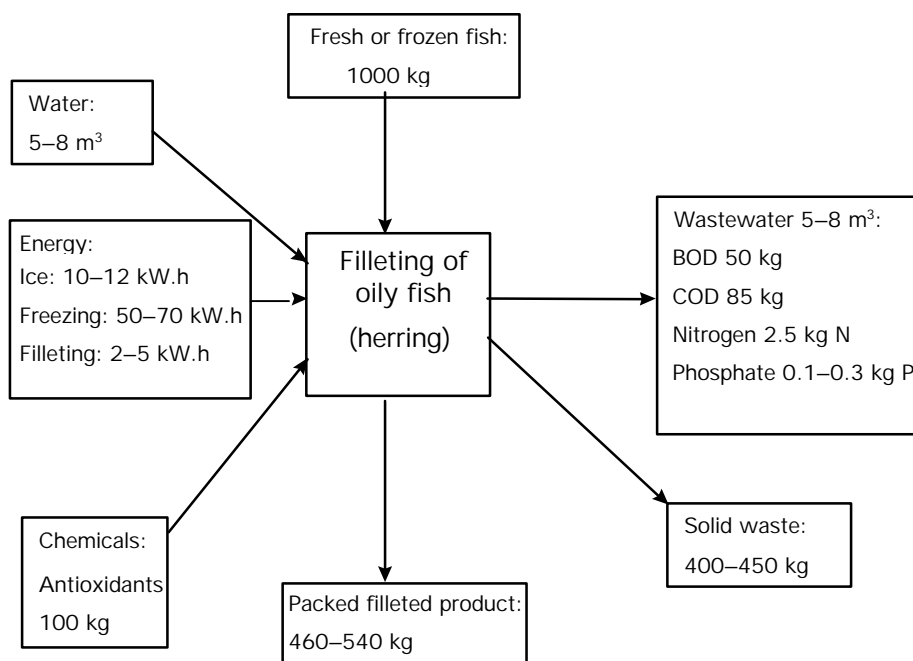


Figure 2–7 Inputs and outputs for filleting of oily fish (herring) using average technology

By adopting best available technology, the following rates of resource consumption and waste outputs could be achieved:

- Water consumption and wastewater generation could be reduced to 2.5–3.0 m³ per tonne of raw material.
- Organic loads in the effluent could be reduced to about 12–15 kg BOD or 20–21 kg COD per tonne of raw material.
- Nitrogen loads in the effluent could be reduced to 0.4–0.6 kg N per tonne of raw material.
- Phosphate in the effluent could be reduced to 0.02–0.03 kg P per tonne of raw material.

- Product yields would also increase, resulting in a decreased rate of solid waste generation.

2.3.3 Canning

Figure 2–8 below shows the process for canning including approximate figures for quantities of inputs and outputs.

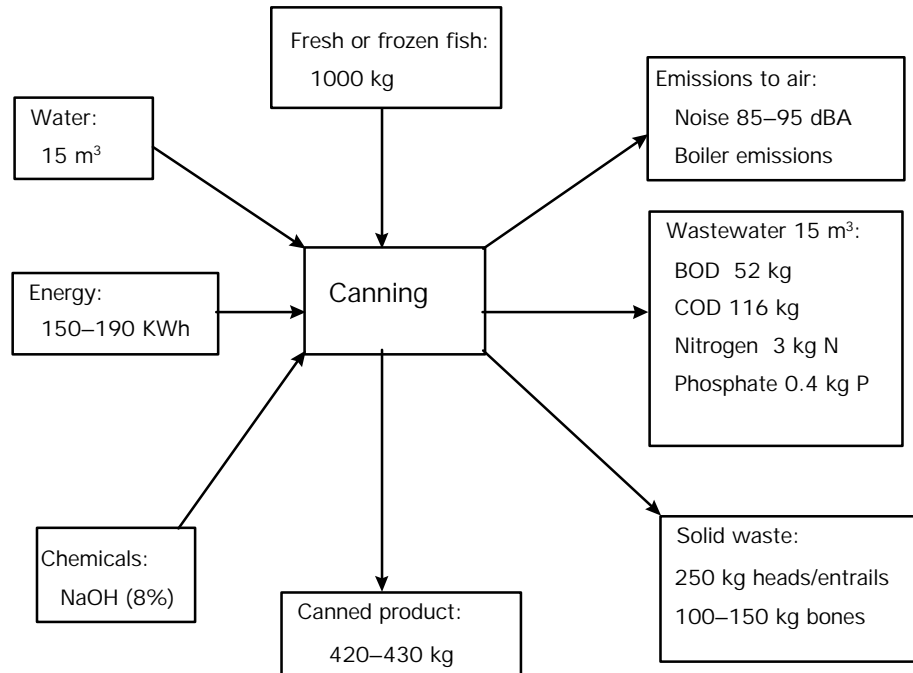


Figure 2–8 Inputs and outputs for canning industry using average technology

By adopting best available technology, the following rates of resource consumption and waste outputs could be achieved:

- Water consumption and wastewater generation could be reduced to 7 m³ per tonne of raw material.
- Organic loads in the effluent could be reduced to 12 kg BOD or 27 kg COD per tonne of raw material.
- Nitrogen loads in the effluent could be reduced to 0.7 kg N per tonne of raw material.
- Phosphate in the effluent could be reduced to 0.1 kg P per tonne of raw material.
- Energy consumption could also be reduced, especially if the equipment and rooms for freezing were to be improved.
- Product yields would also increase, resulting in a decreased rate of solid waste generation.

Table 2–1 demonstrates the variation in wastewater characteristics that can occur between one fish species and another. In this case the comparison is between the canning of sardines and of tuna.

Table 2–1 Wastewater characteristics for canning of sardines and tuna¹

Species	Parameter	Range (per tonne FP)	Typical value (per tonne FP)
Sardines	Wastewater (m ³)	NA	9
	BOD (kg)	NA	9
	Suspended solids (kg)	NA	5
	Oil and grease (kg)	NA	2
Tuna	Wastewater (m ³)	6–45	22
	BOD (kg)	7–20	15
	Suspended solids (kg)	4–17	11
	Oil and grease (kg)	2–13	6

NA: not available

¹ UNIDO, 1986

2.3.4 Fish meal and fish oil production

Figure 2–9 below shows the process for fish meal and fish oil production including approximate figures for quantities of inputs and outputs.

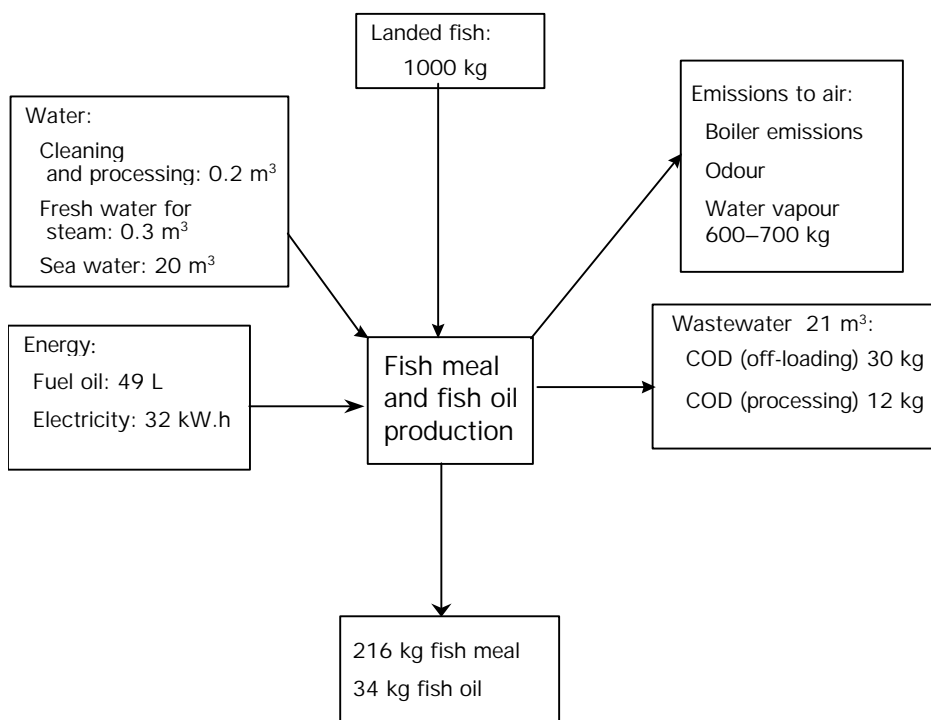


Figure 2–9 Inputs and outputs for fish meal and fish oil production using average technology

By adopting best available technology, the following rates of resource consumption and product and waste outputs could be achieved:

- Product yields for fish meal could increase to approximately 270 kg fish meal per tonne of raw material, but only a minor increase in fish oil yields could be expected.
- Organic loads in the effluent could be reduced to 22 kg COD per tonne of raw material for off-loading processes and to about 9 kg COD per tonne of raw material for processing.
- Fuel oil consumption could be reduced to approximately 35 L per tonne of raw material.

2.3.5 Processing of other seafood species

Table 2–2 below provides indicative figures of water consumption and wastewater generation rates for the processing of a number of other seafood products. If the raw material is frozen, the quantities of water vary enormously depending on thawing method and availability of water.

Table 2–2 Table of wastewater characteristics for various species¹

Type of processing	Unit	Water (m ³ /tonne)	BOD (kg/tonne)	SS (kg/tonne)	Oil and grease (kg/tonne)
Marine finfish					
- conventional plant	FP	5	3	1–2	0.4
- mechanised plant	FP	14	12	9	2.5
Tuna processing					
- range	FP	6–45	7–20	4–17	2–13
- typical value		22	15	11	6
- average of 8 plants	FP	12	137 ²	NA	NA
Canned sardine	FP	9	9	5–6	27
Blue crab					
- conventional plant	FP	1–2	5–6	1	0.2–0.3
- mechanised plant	FP	29–44	22–23	12	4–7
Dungeness crab	FP	14–38	7–15	2–4	NA
Shrimp plant					
- frozen	RM	73	130	210	17
- frozen (without cleaning) ³	RM	23–30	100–130	NA	NA
- canned	RM	60	120	54	42
- breaded	RM	116	84	93	NA
Shrimp	FP	120–175	250		
Clam plant					
- conventional plant	FP	5	5	10	0.2
- mechanised plant	FP	20	19	6	0.5
Salmon plant					
- conventional plant	FP	4–5	2–3	1–2	0.2–8
- mechanised plant	FP	19–20	45–51	20–25	5–7
Catfish ⁴	FP	16–32	6–9	-	4–6
Mussel ⁴	FP	20–120	60	NA	NA

¹ UNIDO, 1986 and Danish EPA, 1996A

² This value is for chemical oxygen demand (COD)

³ Author's own data

⁴ Water Quality Institute of Denmark

