

Introduction

This note briefly describes the manufacture, storage, composition and use of fish meal, and also touches on the problem of air pollution from fish meal plant.

The use of fish byproducts for feeding animals is not a new idea; a primitive form of fish meal is mentioned in the Travels of Marco Polo at the beginning of the fourteenth century: '... they accustom their cattle, cows, sheep, camels and horses to feed upon dried fish, which being regularly served to them, they eat without any sign of dislike.' The utilization of herring as an industrial raw material actually started as early as about 800 AD in Norway. A very primitive process of pressing the oil out of herring by means of wooden boards and stones was employed.

What is fish meal?

In the UK the term fish meal means a product obtained by drying and grinding or otherwise treating fish or fish waste to which no other matter has been added. The term white fish meal is reserved for a product containing not more than 6 per cent oil and not more than 4 per cent salt, obtained from white fish or white fish waste such as filleting offal.

These are semilegal definitions, and for convenience fish meal can be defined as a solid product obtained by removing most of the water and some or all of the oil from fish or fish waste. 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.

What raw material is used?

Virtually any fish or shellfish in the sea can be used to make fish meal, although there may be a few rare unexploited species which would produce a poisonous meal. The nutritional value of proteins from vertebrate fish differs little from one species to another; whole shellfish would however give a nutritionally poorer meal because of the low protein content of the shell. Most of the world's fish meal is made from whole fish; the pelagic species are used most for this purpose. Where a fishery catches solely for the fish meal industry, it is known as an industrial fishery.

Countries with major industrial fisheries are Peru, Norway and South Africa. Some countries like the UK make fish meal from unsold fish and from offal, that is the heads, skeletons and trimmings left over when the edible portions are cut off. Other countries like Denmark and Iceland use both industrial fish and processing waste. Fish meal made mainly from filleting offal usually has a slightly lower protein content and a higher mineral content than meal made from whole fish, but a high proportion of small whole fish in the raw material can have the same effect.

The following points are important when selecting species for an industrial fishery:

1. The species must be in large concentrations to give a high catching rate; this is essential because the value of industrial fish is less than that of fish for direct human consumption.
2. The fishery should preferably be based on more than one species in order to reduce the effect of fluctuations in supply of any one species.
3. The total abundance of long lived species varies less from year to year, and
4. Species with a high fat content are more profitable, because the fat in fish is held at the expense of water and not at the expense of protein.

Preservation of the raw material

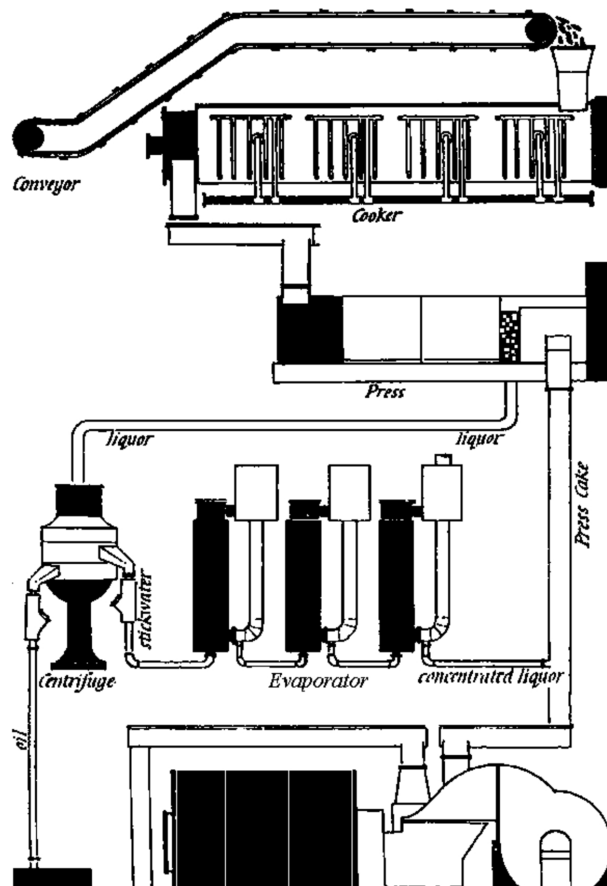
All fisheries experience periods of glut and scarcity, leaving the fish meal factory at times with no raw material to process and at other times with too much. Large amounts of unprocessed material cause storage and odour problems; moreover spoiled material becomes difficult to process and gives a lower yield.

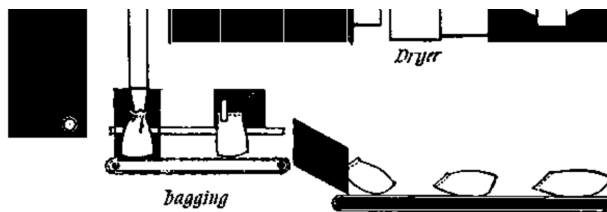
No cheap, completely safe method of preservation has yet been found. Refrigeration is not usually economic, and the known chemical methods of preservation have some disadvantages. Sodium nitrate with formaldehyde is very effective, but unless its addition is very carefully controlled poisonous nitrosamines can be formed when the nitrite reacts with small amounts of trimethylamine in the fish; for this reason nitrite is not used in the UK. Formaldehyde alone is quite effective in keeping the fish firm enough for processing; it is most useful for species like sand eels that rapidly become semiliquid soon after catching. Although the addition of about 0.2 per cent by weight of formaldehyde is often enough to provide the required toughening effect, the preservative effect is small at this dilution, and more formaldehyde may make the fish too tough to process.

Manufacturing fish meal

There are several ways of making fish meal from raw fish; the simplest is to let the fish dry in the sun. This method is still used, in some parts of the world where processing plants are not available, but the product is poor in comparison with ones made by modern methods. Almost all fish meal is made by cooking, pressing, drying and grinding the fish in machinery designed for the purpose. Although the process is simple in principle, considerable skill and experience are necessary to obtain a high yield of high quality product, and to make the plant efficient. A typical process is shown diagrammatically in figure 1:

Fig. 1. A typical process diagram.





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.

PRESSING

This stage of the process removes some of the oil and water. The fish are conveyed through a perforated tube whilst being subjected to increasing pressure, normally by means of a tapered shaft on the screw conveyor. A mixture of water and oil is squeezed out through the perforations and the solid, known as press cake, emerges from the end of the press. During the pressing process the water content may be reduced from about 70 per cent to about 50 per cent, and the oil content reduced to about 4 per cent.

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 water portion of the liquor, known as stickwater, contains dissolved material and fine solids in suspension which may amount to about 9 per cent by weight. The solids are mostly protein and stickwater can contain as much as 20 per cent 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 30-50 per cent solids, and sometimes marketed separately and known as condensed fish solubles. More usually however the concentrated product is added back to the press cake and dried along 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, moulds 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 much more likely 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 100°C.

The most usual type of indirect dryer consists either of a steam jacketed cylinder or a cylinder containing steam heated discs which also tumble the meal.

Much of the unpleasant odour from fish meal plants originates from the dryers; indirect dryers, which are normally used in the UK, cause less nuisance because they use less air.

In the UK, where white fish offal are the main raw materials, the pressing stage is not essential, since the material contains only very small amounts of oil. White fish meal can be produced by a simpler process of cooking and drying only. However the use of a pressing stage is increasingly favoured and there are two main reasons for this:

- The plant has greater flexibility in that it may be used for white and oily fish, or a mixture of both.

- The removal of water by pressing, and evaporation of the stickwater obtained, is less expensive because the triple effect evaporators used are more efficient in terms of use of steam than are dryers.

GRINDING AND BAGGING

The final operations are grinding to break down any lumps and particles of bone, 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 food compounder, and from there to the farm. The problems of storage and transport are discussed below.

HYGIENE IN THE FACTORY

Contamination of the material during processing may seriously affect quality; microorganisms like *Salmonella* that may ultimately cause disease in man have to be kept out. Much can be done by good housekeeping in the plant, for example by keeping floors, walls and conveyors clean and by separating 'wet' and 'dry' areas of the plant, but the processing machinery itself is often less readily accessible for cleaning. Contaminated water, from a dock for example, should not be used for cooling or other purposes if it can come in contact with the fish or the fish meal.

The temperature during processing is normally high enough to kill any *Salmonella* present, but when a plant is restarted after a stoppage there is likely to be moist meal standing in the plant that will not reach a high enough temperature; for this reason it is now USA practice to recirculate the meal produced in the first 45 minutes after starting again.

OTHER METHODS OF MANUFACTURE

Of the other processes used, the most well known is the heat transfer method, htm, developed in the USA, where oil added to a slurry of the raw material acts as a heat transfer medium. In some other methods the presses are replaced by centrifuges, and in others the oil is removed by solvent extraction. A very high proportion of the world's fish meal is however manufactured by the process described above.

Storage and transport of fish meal

Fish meal is not readily spoiled by bacterial action because of its low water content, and it has a very small bulk compared to the fish from which it is made; indeed, these are two of the main reasons for making fish meal. There is no need to refrigerate the meal in storage.

Fish meal is usually stored and transported either in sacks made of paper, hessian or plastics, or in bulk. Fish meal in bulk is sometimes pelletized to make mechanical handling easier, since it does not flow readily as a powder.

Fish oil present in the stored meal can react with oxygen in the atmosphere; the heat generated may damage the meal nutritionally and, on occasion, cause the meal to catch fire. Fortunately this is now a rather rare occurrence, due to the widespread use of antioxidants. Not all fish oils are equally reactive; some oily meals seem to require antioxidant treatment; whilst others do not. The most commonly used antioxidant is ethoxyquin; the amount used varies but is normally in the range 200-1000 mg/kg. Sacks of newly made oily meal are frequently stored in ventilated stacks, particularly in hot climates. White fish meal, with a low oil content, does not require antioxidant treatment.

Fish meal is best kept in a cool dry place protected from rodents and birds. Spoilage is normally very slight even after excessively long periods of storage; fish meal will keep for several years without detectable change in its nutritional value.

Fish meal made from fatty fish, however, will show a gradual decrease in fat content, as measured by extraction with ether, unless antioxidants are present; this is because the fats slowly oxidize during storage and become relatively insoluble in common organic solvents. Oxidized fat is less valuable nutritionally because the animal cannot utilize it for its energy needs. The risk of taint to the animal flesh is much reduced, however, once the fats are oxidized.

Protection against contamination during the manufacture of meal has been mentioned; protection during storage is equally important. The floors, walls and handling equipment in the store must be kept clean, and screens over doors and windows help to keep out birds and rodents that may be carriers of *Salmonella* organisms. Foot dips are sometimes provided to prevent workers carrying harmful bacteria into the store. The risk of contamination is generally much higher when handling meal in bulk, particularly during loading and unloading of transport.

Composition and nutritional value

Before examining the composition of the finished meal it is interesting to consider the composition of the intermediate products. Figure 2 shows the composition of the material at each stage of its flow through the process and is based on the assumption that the raw fish contain 70 per cent water, 18 per cent solids and 12 per cent fat. It can be seen that more drying occurs in the evaporators than in the dryer. The composition of the intermediate products in this example is as follows:

	water	solids	fat
material	%	%	%
raw fish	70	18	12
press cake	53	44	3
press liquor	78	6	16
dilute stickwater	95	5	<1

conc. stickwater	65	33	2
fish meal	9	85	6

Fig. 2. Composition of material during the process.

Figure 2 shows a yield of 21 per cent whole meal from oily fish of the assumed composition; in practice there may be some processing losses which will slightly reduce the actual yield. For example, raw material awaiting cooking will lose some drip as it spoils; since the lost liquor contains protein in solution, yield will decrease when raw material is delayed for long periods. The extent of this loss varies from species to species.

The composition of the final product depends both on the kind of raw material and on the type of process. A whole meal made from fatty fish like herring might contain about 71 per cent protein, 9 per cent fat, 8 per cent water and 12 per cent minerals, whereas a meal made mainly from white fish and white fish offal and dried to the same extent will contain about 66 per cent protein, 5 per cent fat, 8 per cent water and 21 per cent minerals.

Fish meal is valuable not only for the quantity but also the quality of its protein. By this is meant that the amino acids which make up the protein are present in just the right balance for animal or human nutrition. The amino acid composition of typical samples of herring meal and white fish meal might be:

	<i>herring meal</i>	<i>white fish meal</i>
<i>amino acid</i>	<i>g/100 g protein</i>	<i>g/100 g protein</i>
lysine	7.7	6.9
methionine	2.9	2.6
tryptophan	1.2	0.9
histidine	2.4	2.0
arginine	5.8	6.4
threonine	4.3	3.9
valine	5.4	4.5
isoleucine	4.5	3.7
leucine	7.5	6.5
phenylalanine	3.9	3.3
cystine	1.0	0.9
tyrosine	3.1	2.6
aspartic acid	9.1	8.5
serine	3.8	4.8
glutamic acid	12.8	12.8
proline	4.2	5.3
glycine	6.0	9.9
alanine	6.3	6.3

Not only is the balance of amino acids in fish meal suitable for animal feeding, but the availability of the essential amino acids is also greater in fish meal than for example in meat meal; available means capable of being liberated by the animal's digestive juices and utilized by it, and essential acids are those the animal must have in its diet. The first ten amino acids in the table are those believed to be essential for growing animals. Fish meal is also a valuable source of minerals calcium, phosphorous, magnesium, potassium, of vitamins B₁, B₂, B₆ and B₁₂, and of trace elements, notably zinc, iodine, iron, copper, manganese, cobalt, selenium and fluorine.

In many feeding trials, animals fed on diets containing a similar amino acid composition to fish meal have grown less well than those fed on fish meal itself; this has led to the hypothesis that fish meal contains an unidentified growth factor sometimes abbreviated to UGF. However this ingredient has never been isolated, and in other experimental feeding, results with carefully supplemented vegetable protein diets have been as good as with fish meal. The answer to this problem may be simply that fish meal contains such a wide range of nutritionally valuable materials that whatever is lacking in the diet fish meal can provide it. Thus the attribute of UGF may be due to nutritional balance rather than to the presence of some unknown, and as yet unisolated growth-promoting substance.

How is fish meal used?

Fish meal in the UK was used mainly as a fertilizer until about 1910, but since then its high nutritional value has been far better utilized in animal feeding. The demand in the UK for fish as fish meal is far greater than the demand for fish for direct human consumption; therefore imports of fish meal to the UK are high. The pig and poultry industries producing large amounts of bacon and eggs, pork and chicken, at relatively low prices could not survive without large scale use of high protein animal foods like fish meal. Usually about 10 per cent of the diet of pigs and poultry consists of fish meal; 10 per cent is the upper limit for meal containing 10 per cent fat, because more than about 1 per cent of fish oil in the diet of the animal may taint the taste of its flesh. Much of the UK production is of white fish meal with a fat content low enough to eliminate any risk of taint. Fish meals with an extremely low fat content are sometimes made for certain specialized purposes.

Other uses of fish meal include the feeding of mink, farmed fish, dogs, cats and cattle. Very small amounts of specially processed meals have been used in prepared foods for humans, and fish meal is also used in the preparation of certain antibiotics for the pharmaceutical industry.

How are fish oils used?

Fish oils are produced whenever fatty fish are processed into meal. In Europe they are widely used in the manufacture of edible oils and fats, for example margarine. Other uses include the paint and varnish industry. In addition, there are several other specialized uses for small quantities of fish OILS. Fish oils usually have to be low in free fatty acids, less than 2 per cent, to obtain the best price; production of high quality fish oils depends on the use of fresh raw material, proper purification and good storage.

Measuring the quality of fish meal

Since fish meal contributes so many of the necessary ingredients of a diet, quality can be measured only on the basis of specific components; no single laboratory test has been or is likely to be devised that can give a total estimate of quality. Furthermore, all tests other than feeding trials are rather artificial; the growth record of the animal is the best standard. Feeding trials however are expensive and time consuming; thus the possibility of using chemical or physical tests is attractive.

The pepsin digestibility test can distinguish between a very poor meal that has suffered heat damage and a good, properly processed meal, but these could probably be distinguished by colour alone; the test is thus of limited practical use.

A total amino acid analysis gives useful information about the meal but is very expensive and tells nothing about the availability of individual acids to the animal being fed. Alternatively, the availability of a single important amino acid like lysine is often measured; this is probably the most useful approach, but nothing is then known about the other components. In short, there is no single comprehensive test for quality. The requirements of the user may vary; for example fish meal may be included in one diet primarily for its methionine content but, in another, methionine in fish meal may be unimportant because it is supplied by other foods.

A very important measure of fish meal quality is its freedom from microorganisms that cause disease in man by contaminating the animals he eats; *Salmonella* is generally of most concern in this respect. The need for good housekeeping practice in the fish meal factory and store has already been emphasized for this reason.

Can fish protein concentrate be made from fish meal?

Fish meal is a fish protein concentrate, but the term fish protein concentrate, FPC, usually means a material suitable for human consumption. Fish meal prepared under hygienic conditions can be FPC in this sense, and small amounts made from white fish meal have been sold for incorporation in other foods. The specification for some types of FPC demands a very low fat content and in some plants it is possible to treat the press cake or the meal with a solvent to extract the fat. However it may be preferable to extract the fat from the raw material rather than from the finished meal when making FPC of very low fat content. The manufacture and uses of FPC are described in Advisory Note 39.

The reduction of smell from fish meal plants

Fish meal manufacture is often associated with a characteristic unpleasant smell in the neighbourhood of the factory. The smell comes mainly from the dryers, where hot air passes over the fish and carries away vapours. The smell often arouses opposition among people living or working near the factory, and planning permission for new plant is frequently difficult to obtain.

The chemicals in the effluent vapours from a fish meal plant are very much diluted, and are normally not harmful, but they are particularly smelly even when present in very low concentrations; thus the smell from a fish meal plant is often noticeable to a public that remains unaware of air pollution from industrial processes that produce little or no smell.

There is no simple way of reducing the smell, but much can be done to alleviate the problem. Fresh raw material causes less trouble than stale; therefore rapid handling and processing has a beneficial effect. It is also important to keep the plant clean; all floors and working surfaces should be regularly washed. Complaints about smell when a factory is not operating are almost always due to fish remaining unprocessed in the storage pits; a cover over the pits helps considerably. Scraps of fish or partially processed material left around the plant or in parts of the machinery will decay and also add to the smell.

A suitable scheme for dealing with the effluent air from the dryers might be to condense the vapours, possibly in an indirect condenser to reduce water pollution and then incinerate them at a fairly high temperature, thus oxidizing the organic components to simple odourless substances such as carbon dioxide and water.

Incineration can be done either in the plant's steam raising boiler or in a separate incinerator, but there is not yet enough experience to indicate whether these are equally effective. Use of the steam boiler is attractive in that there are no additional fuel costs, but boilers are not designed to mix and incinerate polluted air and the effect on boiler life is not known.

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Separate incineration means putting the vapours through an afterburner specifically designed for the purpose; incineration can continue even when the plant boiler is not running. The polluted air must be raised to a high temperature, at least 600°C, to oxidize the organic substances; thus cost may be high. By using a catalyst the vapours can be incinerated at a much lower temperature, about 350°C, thus reducing fuel cost, but little is yet known about catalyst life. The final choice between a boiler, an afterburner, and an afterburner with a catalyst will depend on the effectiveness and the economics of each method as well as on local circumstances, for example abundance of cheap water, distance of the boiler from the dryers, and fuel cost. Recirculation of the air used in drying can make considerable saving in fuel consumption of the afterburner by reducing the amount of air to be incinerated, and makes the use of the plant's steam boiler as an incinerator more practicable.

The problem of reducing odour is a complex one and further work on the effectiveness of the various methods outlined above and others will be needed, before a complete solution is found.

There is growing awareness of the danger and unpleasantness of air and water pollution, and it is likely that these issues will continue to be of great concern to the fish meal industry.

