

Production of Fish Oil

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CONVENTIONAL WET RENDERING METHOD

The relationship between the three basic products (meal, oil, and stick water) from a conventional fish meal plant are important in the preparation of plans and the selection of equipment used in a given operation.

Required plant capacity and raw material storage facilities are determined by the regularity of the supply and the quantity of raw materials. The fishing season and the nature of the raw material not only greatly influence the type of processing equipment, but the storage and packaging facilities for each of the three products.

A "lean" fish is usually considered as having less than 2–2.5% fat. The equipment necessary for processing lean fish is rather simple since the cooking and pressing operation are greatly minimized or even eliminated. However, oily fish containing over 2.5% oil require processing that will reduce the oil content in the meal to a level acceptable to the market. In the past, the so-called conventional or classical cooking and pressing technique has been the only economically practical method for producing large quantities of low-fat meal for the animal feed market.

Meal from a conventional plant contains 2–10% oil or even more. Hence, the yield of oil will be essentially that contained in the raw material less that left in the dry meal. Oil first emerges from the process as a mixture of water and oil from the pressing operation. Most of the solids in this "pressed liquor" are removed by straining. Oil and remaining solids are separated from the water by settling or centrifuging, or a combination of both. Separated oil is further purified by water washing and heating to remove water-soluble and volatile impurities.

Cooking

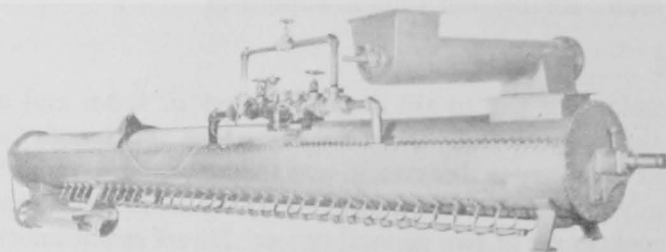
The cooking of fish to aid in the recovery of water and oil is the first step in the conventional fish reduction plant. Although the equipment employed may vary in design and use, the actual cooking is still an art and is generally regarded as the most critical step in fish reduction.

Fish cookers are of two general types: Direct steam injection and indirect cookers. On some designs of the later, provisions are also made for direct steam injection. The direct steam cooker is a simple, inexpensive, rugged piece of equipment that has been little changed since its introduction in the late 1800's. A modern direct steam cooker is shown in Fig. 26.

This model is 30 inches in diameter by 30 feet long. Fish are charged to a hopper located above the internal screw conveyor. The cooker loading rate is controlled by a variable speed motor driving the conveyor screw. Throughput (conveyor speed) is controlled by the operator and is varied as the quality, oil content, etc., of the raw material changes. The cooked fish are discharged through a short choke screw. Steam is introduced through a series of small inlet pipes into the lower part of the cooker. In some designs a single manifold is employed and in others more than one, thus enabling the operator to vary the temperature in different sections of the cooker.

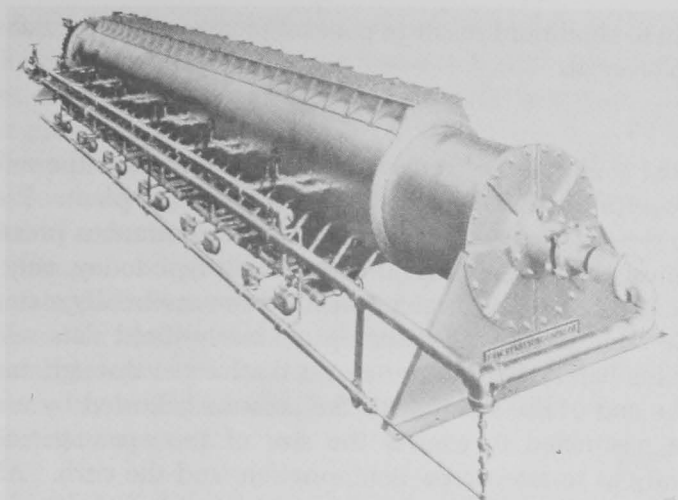
The steam requirements for direct cooking are rather high. Assuming a specific heat of 1 Btu per/lb./°F. for fish and in input temperature of 15.5°C. (60°F.) it would require 270,000 Btu or approximately 300 lb. of steam to bring a ton of fish to 90°C. (195°F.). During the early period of the reduction industry when settling tanks were used to recover oil and stick water and the water was dumped overboard, the addition of 300 lb. of water to a ton of fish was of little consequence. With the introduction of centrifugal separators for the recovery of oil and evaporators for the concentration of stick water, the water introduced by direct steam cooking becomes a significant factor in terms of capital investment and operating costs.

A smaller evaporator can be used with an indirect cooker allowing greater fuel economy. Furthermore, an even greater savings can be realized if exhaust steam from the evaporator is used as the heat source for the cooker. Although the direct steam cooker is still widely used in the United States, particularly in the menhaden industry, the indirect steam cooker has gained widespread acceptance in most of the other fish-oil producing countries of the world. A representative type of indirect cooker is shown in Fig. 27. This cooker has indirect heating by both a steam jacket



Courtesy of Edward Renneburg & Sons Co., Baltimore

FIG. 26. DIRECT STEAM COOKER



Courtesy of Edward Renneburg & Sons Co., Baltimore

FIG. 27. INDIRECT STEAM COOKER

and a steam-heated internal hollow screw. Provisions are also made for direct steam injection into the cooker when faster cooking is required. The external steam jacket is divided into a number of sections, thus enabling a high degree of control of the internal temperature. Indirect cookers, although widely used, are not practical on all fish due to the build-up of scums on the heat transfer surface. Use of indirect heat cookers in these situations is further complicated, but can be made more effective, by the use of scrape surface exchangers.

In many installations, particularly in the package plant, a single cooker is used to feed a single press. This is common in the fixed capacity production line where the capacity is increased by increasing the number of lines. Another arrangement involves the use of one or more cookers in parallel feeding one or more presses in parallel. Single direct steam injection cookers capable of cooking up to 60 tons of fish per hour are not unusual. The indirect cookers, on the other hand, seldom have a capacity in excess of 20 tons/hr.

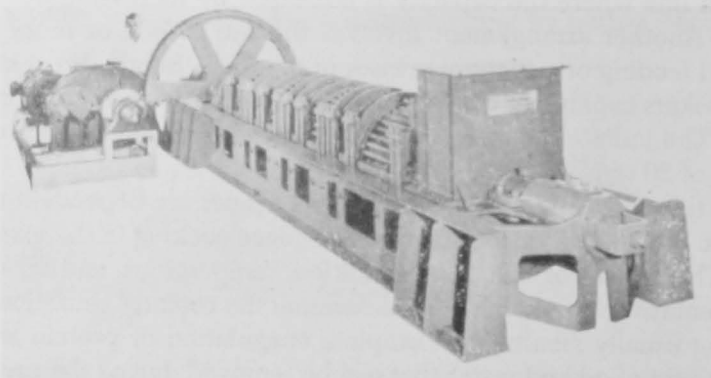
The temperatures used and the cooking times are dependent upon many factors. It is these various factors that place cooking in the category of an art. The species of fish, size, condition, temperature, and oil content are representative of factors which determine the cooking conditions. Undercooking usually results in incomplete coagulation of protein and reduces the amount of oil and water that can be removed during the pressing operation. Overcooking results in a breakdown in the coagulated muscle tissue to the extent that it is very hard to develop a solid core in the press.

Both of these conditions result in poor oil recovery and excessive oil in the fish scrap or meal.

De-Watering

From the standpoint of removing water, the press is the most efficient piece of equipment in a conventional fish reduction plant. Presses are of two basic types, batch and continuous. Since continuous presses are used to the almost complete exclusion of the batch type today, only the former will be considered. The original presses were essentially a single tapered screw operating in a barrel made up of closely fitted slats which ran the length of the barrel. The material was discharged through annular openings in the end of the screw with the pressure adjusted by a cone which could be positioned to control the size of the opening. Single-screw presses vary as to size, screw conformation, and the curb. Although the curbs in most early presses consisted of horizontal steel slats, held in position by heavy metal bands, present day presses usually employ perforated brass cylinders reinforced by a metal framework. The openings in the slotted presses and perforations in the brass cylinder are larger on the outside than on the inside in order to minimize plugging. Single-screw presses are still the most widely used in the industry but the trend is toward multistage screws. A 12-foot, 4-stage screw press is shown in Fig. 28. Externally these presses closely resemble the early models; however, capacity is greatly increased and the efficiency of de-oiling and de-watering can be maintained over a wide range of materials. The ability to handle soft fish and "feeding" fish constitute advantages over the older processes.

In addition to multi-stage presses there are also a series of new twin



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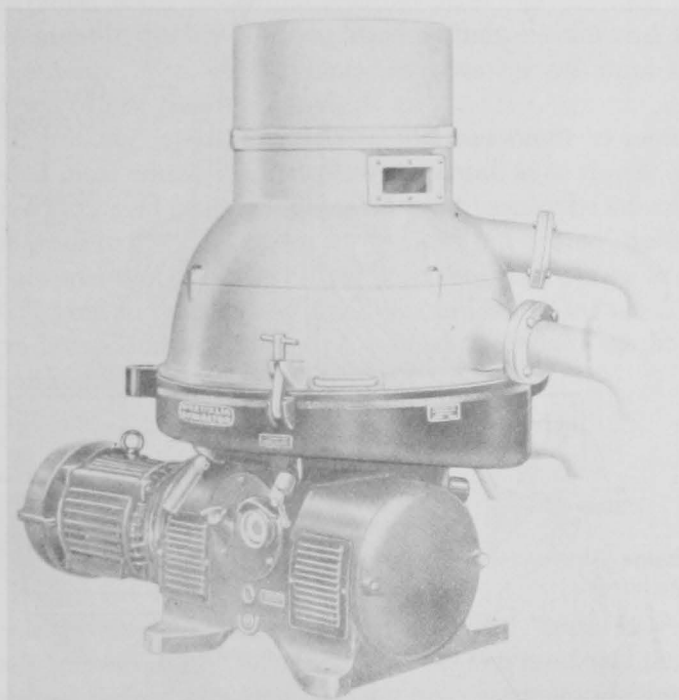
FIG. 28. FOUR-STAGE SCREW PRESS

screw presses. One line of these presses is designed in side-by-side placement of the screws while another line features an over- and under-arrangement. The same advantages are claimed for these presses as for the multi-stage type press.

It has been proposed that cooked fish be de-watered with the aid of a horizontal bowl centrifuge. Cooked fish are passed through a disintegrator in order to reduce them to a pumpable slurry. The slurry is pumped to the centrifuge, and clarified pressed liquor and solids are recovered. Although not generally used, the method is workable and generally recovers slightly more oil than a conventional press. This process also leaves approximately ten per cent more water with the solids. It is possible that a better recovery would be effected if the centrifugally recovered solids were subjected to pressing.

Separating

Pressed liquor, other than that obtained centrifugally, normally contains a considerable quantity of solids. These are in the form of coagulated proteins, scale, and bone fragments that have been extruded through the

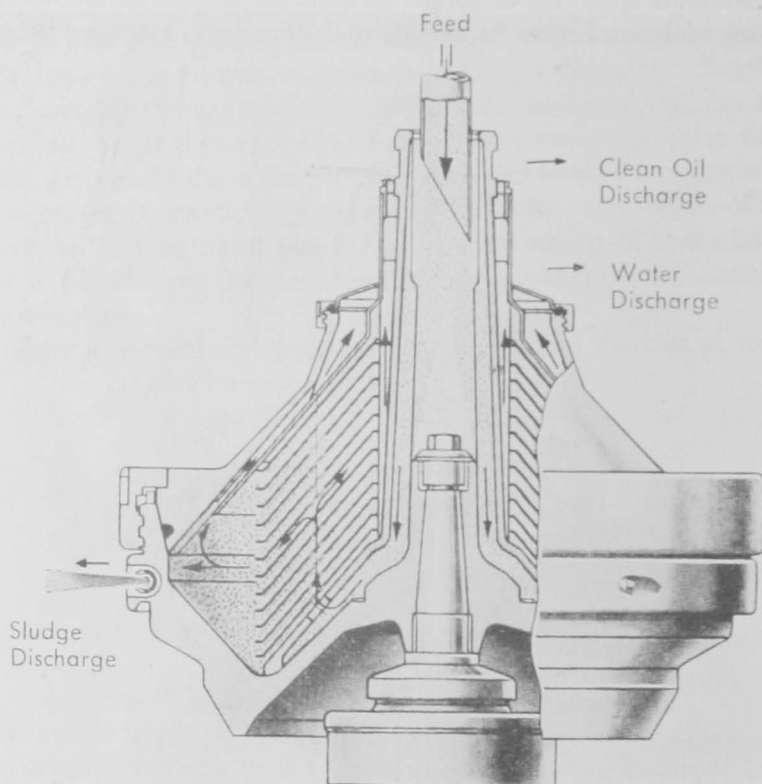


Courtesy of Centrico, Inc., Englewood, New Jersey

FIG. 29. THREE-PHASE NOZZLE CENTRIFUGE

small openings in the brass cylinders or between the barrel slats during the pressing operation. These solids are normally removed by screening and/or centrifuging. A preliminary coarse screening or scalping is followed by passing the product over fine-mesh vibrating screens or feeding to a solid bowl centrifuge. The solids recovered are higher in oil than regular press cake and are usually fed back through the presses, pressed separately, or added to press cake and dried. After removal of the suspended solids, the press liquor is ready for separation.

In most reduction plants, centrifugal recovery of oil is used to the almost complete exclusion of the older settling tank method. The centrifuges in use today for the recovery of oil from pressed liquor are referred to as "sludgers." These are three-phase machines with either continuous sludging or periodic self desludging. The continuous desludging or nozzle machine has been in use the longest and is found throughout the industry. A modern three-phase nozzle machine and the design and operating principles of the bowl are shown in Figs. 29 and 30 respectively. The operating



Courtesy of Centrico, Inc., Englewood, New Jersey

FIG. 30. OPERATION DIAGRAM OF THREE-PHASE NOZZLE CENTRIFUGE

principles of the bowl are basically the same as those of any liquid-separator-disc bowl. The liquid to be separated rises through channels in the disc set. The position of the rising channels is determined by the proportion of the liquid phases to each other. The light liquid phase (i.e., oil) passes to the inside of the head of the bowl and is discharged through a special section of the hood. The solids, together with a quantity of the heavy liquid phase, are continuously discharged through the nozzles. The number of nozzles depends upon the characteristics of the feed material, the percentage of solids, and the particle size. The remaining heavy liquid phase (i.e., water) leaves the bowl over an exchangeable ring dam. The diameter of the ring dam is determined by the specific gravity of the two liquid phases.

Purification

The older settling tank method of separating oil press liquor allowed long contact time between oil, water, and meal. This allowed oxidation and degradation of the oil that was then characteristic of the finished product. Modern centrifuging produces a much better quality oil since the oil separation takes place immediately after the pressing operation. The improvement in quality is exemplified by lighter color and lower free fatty acid content. Also, centrifuging increases the oil yield by several gallons per ton of raw fish processed.

Oil that is initially separated contains slight amounts of moisture, and finely divided meal which tend to allow degradation of the oil and an increase in free fatty acid content. Since oil must usually be stored for a period of time prior to use, it is necessary to carry out a final "polishing" operation. This operation consists of stripping the oil by steam or hot water and recentrifuging to remove any final contaminants that would have allowed degradation during storage. A typical analysis of sardine oil that has been finished by a commercial system is as follows:

Moisture and volatiles	0.11%
Insoluble impurities	0.01%
Free fatty acid (as oleic)	0.45%

Oil of the above analysis would not significantly deteriorate over extended storage.

The increased emphasis on world utilization of "trash fish" indicates that a greatly increased volume of high-protein fish meal will be produced by conventional reduction plants and by new extraction techniques. A corresponding increase in high quality fish oil will be assured by modern techniques of oil purification and finishing.

OTHER FISH-OIL RENDERING METHODS

Dry Rendering Process

The dry rendering process which is commonly employed for preparing meal from meat scraps finds limited use in the manufacture of fish oil and meal. It is employed primarily for raw material which is both relatively low in oil content and available in relatively small quantities.

The process, nearly always of a batch-type of operation, involves a combined cooking and drying step. The material to be rendered, often whole fish, is processed in a rotary-type cooker-drier, which is often of the steam-jacketed type, with drying sometimes occurring under vacuum. A paddle-type stirrer may be used to slowly agitate the material during drying. Equipment with a capacity of up to five tons of raw material is common. This might be about 5 ft. in diameter by 18 ft. in length. The cooking-drying operation is completed in 5 to 6 hr.

The dried meal which at this stage contains the oil then goes to a batch-type hydraulic press which removes most of the oil. This process, however, generally leaves about ten per cent of oil in the meal.

The recovered oil is generally much darker in color than oil rendered by the usual wet rendering method. If refined promptly after manufacture, the usual alkali refining and clay-bleaching methods yield an oil of acceptable color.

The dry rendering method, being a batch process requires considerable labor and is more expensive to operate than the conventional method. It does have the advantage of being highly flexible and can be used for a wide variety of raw material available in irregular supply. It is common practice to employ a dry rendering operation alternately for meat scrap and fish reduction.

Enzymatic and Solvent Processes

Since fish oil is essentially a by-product of fish meal production, it is natural that oil processes are closely related to the basic meal production. Recently, emphasis has been placed upon the production of high-protein concentrates for human consumption. The protein supplement produced by these processes must contain a very low amount of oil in order to make the product palatable to humans. Although these processes are in the early stage of development, there is a possibility that increasing proportions of the fish oil on the market will in the future be a by-product of fish protein concentrate production. These processes may include both enzymatic digestion and solvent liquid extraction process.

Enzymatic digestion is one of the techniques that is being investigated for possible production of fish meal and fish protein concentrate. Theo-

retically, this technique should give greater yield and be more efficient. Although there are many different techniques being tried, the basic approach is to mince or homogenize the fish and treat it with about 0.25 to 0.50% enzymes based upon the weight of the whole fish. Following digestion, the reactive material is pressed and filtered. Oil that is liberated from this type of process will float to the surface and can be skimmed or centrifuged in a manner similar to that of reclaiming oil from stick water or press cakes in the conventional process. (See Chapter 14 for additional details on enzyme digestion methods.)

The other processing technique involves that of solvent extraction. This can be further broken into two basic procedures, one employing a standard cycling of a solvent through homogenized fish and the other employing a solvent in an azeotropic distillation-solvent extraction technique.

Typical of the azeotropic extraction technique is the two-step VioBin process (Levin and Finn 1955) which utilizes ethylene dichloride in the azeotropic distillation-liquid extraction. The first extraction takes place between 71°C. (160°F.)—the azeotropic temperature and 83°C. (182°F.)—the normal boiling point of ethylene dichloride. The water is removed by distillation, thus preventing any water-soluble nutrients from being extracted from the fish. The extracted meal is desolventized by purging with direct steam and by agitating under vacuum. This meal (commonly called undeodorized fish flour) can be competitively sold on the animal feed market. A second extraction with isopropanol removes any traces of ethylene dichloride (approximately 150 ppm ethylene dichloride residual in the animal feed supplement is beneficial as a pesticide and insecticide) and gives a high-quality deodorized fish flour for human consumption which is generally referred to as "fish protein concentrate" (FPC). The small amount of oil recovered from the second extraction is highly polymerized and cannot be added to the oil recovered by distillation from the ethylene dichloride.

Typical of the conventional liquid extraction processes is the isopropanol extraction process that was developed by the Canadian Government and has been further investigated by the U.S. Bureau of Commercial Fisheries (Anon. 1966A and B). In this process, hot isopropanol is circulated into the homogenized fish where it extracts water, oil, and a certain amount of water-soluble nutrients. The isopropanol in contact with wet fish is quite tightly bound to the protein and considerable effort must be made to extract all of the solvent from the finished product.

Since the VioBin process is the only technique that is currently being used commercially in the United States today, it is quite difficult to get an accurate cost comparison between the two types of solvent extraction. However, initial engineering estimates indicates that the isopropanol pro-

cess may be considerably more expensive than the VioBin method. The latter method also can produce by a single extraction method a relatively inexpensive undeodorized meal for animal feed which is of somewhat higher quality than is conventionally produced fish meal.

Oil removed during the enzyme digestion process would be finished and polished in a very similar manner to that of the conventional meal plant process. Both of the solvent extraction techniques produce a somewhat inferior oil initially which must be further processed in order to remove the various solvents, solubles, pigments, etc., that have been removed with the oil. Refining methods in current use for treatment of fish oils may not be adequate to upgrade the darker oil produced in the FPC process, and very likely new refining methods may have to be developed.

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