Fish Oil Industry in South America

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

Circular 282

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Chapter 26 reprinted from the book, "Fish Oils," M. E. Stansby, editor, Avi Publishing Company, Westport, Connecticut, 1967.

Circular 282

Washington, D.C.
December 1967

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INTRODUCTION

The potential of the fisheries in South America appears to be tremendous. For instance, in the Pacific Ocean, along the Peruvian coast, there is a great quantity of marine fish, mainly those of pelagic species such as anchovy, tuna, bonito, and mackerel. Bottom species such as merluza (*Merluccius gally*) have recently been found in a disperse pattern from San Gallan, south of Pisco, to Punta de Pariñas, north of Paita, and in a concentration suitable for commercial development between Chimbote and Paita. Predators such as tollos and rays are also found.

Since 1961, Perú has been the world's largest producer of fish oils. Because this industry is of much greater importance than any fisheries in the other South American countries, this chapter will be devoted primarily to the anchovy oil industry in Perú.

Fish oil manufactured from shark and bonito livers was the first fish oil produced in Perú, and since this industry has been operating for many years experience has made these operations the more advanced industrially than the more recently developed anchovy industry. The huge development in recent years of the anchovy fishery, exploited (1961–1964) by over 2,000 vessels, means that it uses over 95% of all fish handled in Perú.

With the great expansion of the production of fish meal, the fish oil production has also increased, becoming at present an important part of the Peruvian economy. The by-product, anchovy oil, obtained generally by centrifugation of the press liquor in the processing of fish meal, amounted to 155,000 metric tons in 1963. However, this great increase in production resulted in a low price in the international market.

Refined anchovy oil is an excellent product for many applications or it can be transformed into high quality hydrogenated oil using conventional processing techniques. The refining of the raw crude oils is best carried out promptly since after several months of storage or transportations, the exported crude oils cannot be refined to give a high quality product.

PRODUCTION AND DISTRIBUTION

General South American Statistics

A comparison of the production of fish oil in South American countries (Table 46) shows that in Argentina, Brazil, and Venezuela production and

TABLE 46

PRODUCTION AND EXPORTS OF FISH OIL IN METRIC TONS IN SOME SOUTH AMERICAN COUNTRIES (FAO 1963)

Year	Argentina	Production in Metric Tons Brazil	Chile	Perú	Venezuela	Exports in Metric Tons Chile	Perú
1958	1,300	300	700	10,000	—	—	1,600
1959	800	400	1,100	23,700	—	100	17,000
1960	900	300	2,500	48,200	—	3,100	35,000
1961	900	200	3,900	118,900	100	4,600	102,300
1962	700	100	12,100	150,800	—	10,900	128,000
1963	700	—	12,500	154,900	100	11,800	125,500

exports have remained constant in recent years. However, in both Chile and Peru there has been a very large increase. This increase is mainly due to the boom of the anchovy reduction industry.

Peruvian Production and Distribution

Since 1959, fish oil, obtained as a by-product of the anchovy reduction plants installed primarily for meal manufacture, has been of considerable economic significance. The production of fish oil has increased as the fish meal production increased. Plant owners have made substantial investments in centrifugal equipment of large capacity to replace the settling tanks and increase the yield of oil. During 1963, Perú occupied first place as a producer of fish oil with a production of 154,900 metric tons.

Although the export of anchovy oil from Perú in recent years has been increasing along with its production, it is noteworthy that domestic consumption of this type of oil has increased from 426 metric tons in 1954 to 37,071 metric tons in 1963. This increased consumption has been made possible through the development of the oil refining industry by the increased use of modern equipment of neutralization, bleaching, hydrogenation, and deodorization of fish oil. The refined oils are of such high quality that they find a ready market as products for human consumption.

Peruvian anchovy oil is exported in a raw or semi-refined state, being shipped mainly to Holland, Norway, Denmark, England, Germany, Columbia, and France.

CHARACTERISTICS OF ANCHOVY AND ITS OIL

Anchovy

The anchovy belongs to the following classifications: class, *Engraulis ringens*; order, *Teleostomi*; family, *Clupeidae*; species, *Engraulidae.*

In its fresh state it has the following average chemical composition:

Solids:	19.2%
Proteins–16.0%	
Minerals– 3.2%	
Oil:	8.0%
Water:	72.8%
	100.0%

Of these components, the oil content is the most variable, changing with regard to the time of year, the habitat, the state and the conditions of the fish, etc. These variations affect the texture of the fish and the quality and commercial value of the resulting oil.

The accumulation of oil in the anchovy depends primarily on the hydrological factors that are responsible for plankton distribution. Factors such as spawning, population, migration, etc. also have a marked influence. During the life of the anchovy there is a marked increase in the oil content until at spawning the fish cease to eat, resulting in a decrease in the oil content. The average oil content in the anchovy at Callao, Chimbote, and Ilo for the year 1964 is shown in Fig. 48. The minimum oil contents for fish landed at Ilo and Chimbote were 3.5% and 4% respectively. In Callao the value was 4%. These analyses were performed by the Technological Department of the Instituto del Mar del Perú on a total of 325 samples (65,000 specimens).

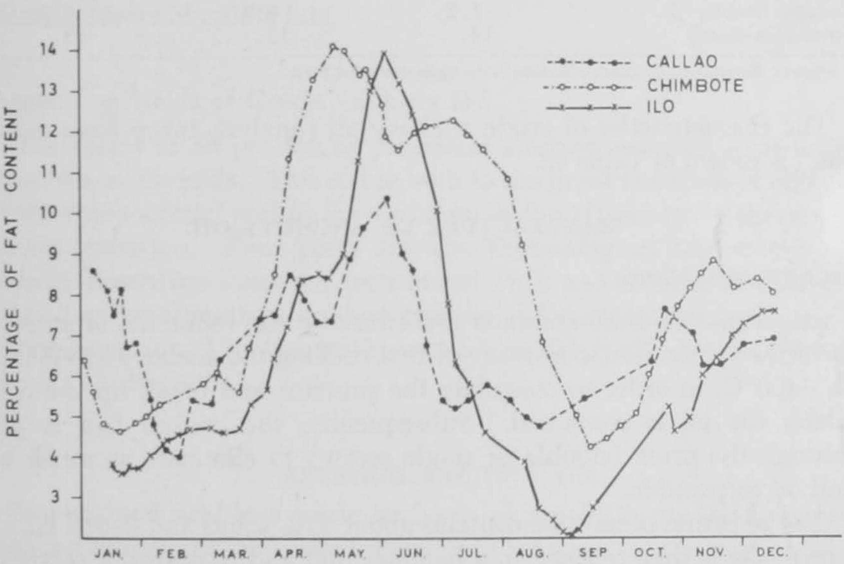

Fig. 48. Average Percentage of Fat Content in Anchovy

TABLE 47

TYPICAL FATTY ACID COMPOSITION OF ANCHOVY OIL

Chain Length	Double Bonds No.	Composition %	Chain Length	Double Bonds No.	Composition %
C12	0	0.16	C20	0	0.27
C14	0	12.40	C20	1	2.10
C15	0	0.46	C20	2	2.48
C16	0	20.50	C20	X1	0.50
C16	1	11.10	C20	X2	16.70
C17	0	1.88	C22	1	1.73
C18	0	4.08	C22	X1	2.19
C18	1	14.35	C22	X2	1.39
C18	2	3.56	C22	X3	4.37

X1, X2, and X3 are probably 4, 5, and 6 double bonds respectively.

Anchovy Oil

Table 47 shows the chemical composition of fatty acids in raw anchovy oil (analysis taken from only one sample) obtained by centrifugation at the fish reduction plants.

TABLE 48

TYPICAL COMPOSITION OF CRUDE ANCHOVY OIL

Substance	Maximum	Minimum	Average
Free fatty acid, %	2.8	1.7	2.2
Moisture, %	0.55	0.30	0.415
Impurities, %	0.060	0.045	0.0495
Iodine number	185.	183.	184.
Unsaponifiable, %	1.2	0.9	1.0
Color (Gardner)	14.	13.	13.

Source: Servicio de Pesqueria, Ministerio de Agricultura del Perú

The characteristics of crude anchovy oil (analysis taken from ten samples) is shown in Table 48.

MANUFACTURE OF ANCHOVY OIL

Processing Methods

At present the most common procedure for the reduction of anchovy is the orthodox method, consisting of first cooking the anchovy 12–15 min. at 98°–100°C. in order to coagulate the proteins and break up the cells in which the oil is contained. Subsequently, the cooked fish is passed through the press (double or single screw) to eliminate as much water and oil as possible.

The resulting press-cake contains about 45% solids and 3–5% oil. This press-cake is then crushed in a hammer mill and passed to a rotary drier using a direct flame where the cake is in contact with the petroleum combustion gases. The moisture content of the meal is now approximately 8–10%, with approximately an equal amount of fat.

The press-liquor produced from fresh anchovies consists of a stable emulsion maintained by the soluble proteins. In contrast, the stabilizing emulsion factors for the product produced from spoiled fish consists of free fatty acids and ammonia soaps. When the solid content is low, the press-liquor is treated in sedimentation centrifuges; when the content is high, solids should first be eliminated from the press-liquor by desludgers. Several of the more popular makes, such as DeLaval, Sharples, Titan, and Kraus Mafei, are used in Perú. The press-liquor from which the final oil is recovered should be as free from solids as possible. To accomplish this, the press-liquor is first heated with direct steam up to a temperature of 92°–95°C. and is then passed through nozzle centrifuges. Machines such as DeLaval, Titan, Westfalia, and Sharples, with capacities varying from 1500 liters to 25,000 lph, are used at this stage.

From one of the centrifuge exit ports, the stickwater is obtained (generally containing about 0.6% of oil). This stickwater passes to the concentrating equipment (multiple effect evaporators), producing the fish solubles which will be mixed with the press-cake. From the other exit port the product obtained is the oil plus water with an approximate density of 0.930.

This is the process usually employed in most fish meal plants, although some also have purification centrifuges in order to obtain a better quality product. The crude oil is now ready for sale to the refiner and also to the manufacturers of edible fats.

Processing Yields of Crude Anchovy Oil

The yields of oil per ton of processed anchovy is much more variable than fish meal yields. This is due both to the great variation of oil content of the raw material and to the variation in the efficiency of the manufacturing operation. Four years ago the Technological Laboratory of the Marine Resources Research Institute of Perú and its coastal laboratories carried on investigations on the variation of fat content of anchovy. This is being continued by the Institute del Mar del Perú. Yield findings are given in Table 49.

REFINING ANCHOVY OIL

Impure and acid-free crude anchovy oil is sold in the local market for refining or exportation. The following refining methods are those used in Perú for the domestic oil consumption.

TABLE 49

AVERAGE YIELD IN KILOGRAMS OF ANCHOVY OIL PER METRIC TON FOR 1962[1]

Month	Average Yield Kilograms Per Metric Ton	Month	Average Yield Kilograms Per Metric Ton
January	17.7	July	21.0
February	18.5	August	11.8
March	17.8	September	11.8
April	23.0	October	16.9
May	24.9	November	17.9
June	31.2	December	22.8

[1] Data from 14 fish meal plants
Source: Seccion Técnica Instituto de Investigación de los Recursos Marinos-La Punta-Callao, Perú

Typical Refining Method

The primary purpose of refining is the neutralization of the free fatty acids and the elimination of impurities, moisture, and certain coloring agents. The refined product keeps better than the "crude" or raw oil and it may be given additional treatment when used industrially or nutritionally. The oil at the refinery undergoes four consecutive refining stages: neutralization, washing, drying, and bleaching.

Of all the common agents of refining, caustic soda is the most frequently used. It reacts not only with the fatty acids but attacks other substances that must be eliminated to obtain a good quality oil. However, the caustic soda refining also results in losses either by forming emulsions of the neutral oil in the sludge or by causing partial saponification of the triglycerides.

Oil Neutralization.—The most frequently used method of neutralization in Perú is the alkali treatment, using ordinarily sodium hydroxide which has the advantage of being more effective than other weaker alkalis, and it also has a bleaching action. Its main disadvantage is that it saponifies a small amount of the neutral oil.

The batch-type neutralization method for alkaline bleaching is performed in vertical steel tanks called neutralizers which are open or closed, and which are of cylindrical form with a conical-shaped bottom. The length of these neutralizers is generally 2–2.5 times the diameter. The angle of the cone is 90° in order to have a satisfactory inclination for discharge. Spiral tubes for heating are used as well as agitators of different types to produce a homogeneous mixture.

In this method, the oil is heated to a temperature of 95°C. and mixed with a solution of caustic soda sufficient for its neutralization and an excess of about 0.25%. The solution is distributed throughout the oil at a rate of 40 liters per square meter during the mixing process. After settling for about an hour, the sludge is drained. To eliminate gumming substances, hot water is added. This wash water, along with the collected substances, is drained after having settled for half an hour. The next step is the treatment with several batches of caustic soda (eight per cent of the weight of the oil) after heating to a temperature of 95°C., continuing as many times as it is necessary until the drain water in the washing process becomes yellow. After the water and caustic soda mixture has drained, the oil generally contains less than 0.05% of soap and can be bleached. This method is used only for small-scale production.

For operations above 40 metric tons per hour the continuous alkali neutralization method is used to give better results and yields. In this method, the caustic solution is injected along with the flow of oil, increasing the quantity of alkali by using special pumps that regulate its flow according to the free fatty acid content and the amount of oil. The alkali-oil mixture is then pumped to a high speed mixer for 2–3 seconds of mixing and is then flushed to a plate heat-exchanger until it reaches a definite temperature, normally about 140°C. The oil is then pumped to a refining separator (hermetic desludger). If necessary, the semi-refined oil may be heated and passed to another high speed mixer, where more alkali is added to improve the color and quality. The mixture, with the added hot water, then passes to the wash mixer where it is treated to remove the soap dissolved in it.

Finally, the oil from the wash separator passes to the vacuum drier. Due to the low pressure and the hot oil, any moisture vaporizes rapidly, and the oil passes to the bleacher.

Oil Bleaching.—The pigments in the processed oil are generally formed by the degradation of the natural pigments, or they may be formed as a consequence of the deterioration of the fish. They may also result from defective methods of processing, or from the oxidation of the fatty acids in the oil.

The oil can be bleached in several ways, but the method most commonly used is the decoloration by surface-active substances, such as carbon or earth bleaches that retain by adsorption the coloring materials without harming the oil. The substances most commonly used in Perú are Tonsil, Superfitrol, Specialfitrol, Activite, Alsil, and Claret.

The bleaching is generally done in tanks at temperatures varying from 104°–110°C. (in the vacuum bleachers lower temperatures are used) by vigorously mixing the refined oil with the bleaching agent. In the common intermittent bleaching process the oil is heated along with the adsorbing agent in a closed vacuum boiler of approximately 12 metric tons capacity in order to avoid oxidation of the oil at a high temperature. The bleaching earth is separated in a horizontally-closed filter press and the adsorbent cake is insufflated with air or with a steam-air mixture to reduce its oil content to a minimum of 30–40%. The continuous decolorizing process is not in common use, and at present the industry employs chiefly the intermittent or batch methods.

Continuous Short-Mix Refining Method

The continuous DeLaval short-mix method is used in Perú by five plants with capacities ranging from 45 to 140 metric tons per day. The usual hermetically sealed plant has four steps in the processing: neutralization, re-refining, washing, and vacuum drying. In the neutralization step the refining separator and the high-speed mixer are arranged to permit the regulation of the degree of separation at any time during the process to avoid the formation of emulsions. Since the system works under pressure, it can readily cope with gums and viscous sludges.

During neutralization, the oil is heated to approximately 70°C. and then passed through the high-speed mixer. The exact amount of alkali needed for a specified quantity of oil is automatically metered into the mixer, where neutralization takes place in a few seconds. The neutral oil, containing fine soap particles, passes directly from the mixer into the refining separator where the soap is removed. The soap stock which contains a very small amount of neutral oil is discharged to atmospheric pressure while the neutralized oil passes through closed pipes for re-refining. In the re-refining step, an excess of alkali is used to obtain an improvement in color and quality without unnecessary losses by saponification which occurred in the older continuous method.

In the washing step, the neutral oil is passed to a washing mixer where it is treated with hot water. The dissolved soap is later separated in the hermetic centrifuge separator. In this type of plant, one washing of the anchovy oil is as satisfactory as the two or three washings needed in older methods.

In the vacuum drying step, the oil from the washing separator is sucked into a drying tower. The refined oil enters the tower through nozzles that give such a very fine spray that the oil is atomized immediately. The vacuum used in the tower is at a pressure of 50–60 mm of mercury, which reduces the moisture content from approximately 0.5% to 0.005%.

Refining Losses

Neutralization of the free fatty acids during refining inevitably produces losses of neutral fats, either occluded or emulsified in the soap stock as soap which is formed during saponification as a result of the presence of the excess alkali needed for neutralization.

In the washing process there is a slight loss of neutral oil, not exceeding

).1% During bleaching there is also a loss of oil retained by the bleach-ng agents. Although part of this oil can be recovered it is of inferior quality.

The following example typifies losses occuring in a commercial refining operation. In 1,000 metric tons of crude oil, with 2.95% of free fatty acids and 1.15% moisture and impurities, there were 87 metric tons of refining osses and ten metric tons of bleaching losses so that the actual amount of bleached oil produced was 903 metric tons.

PRODUCTION OF EDIBLE FATS FROM PERUVIAN ANCHOVY OIL

In the production of edible fats there are three important stages: Oil ıydrogenation, post-refining, and deodorization.

)il Hydrogenation

Industrially all of the hydrogenated oil is produced in Perú by the batch process. The continuous method is not used because of the me-hanical problems involved in such precise control and the need for greater flexibility.

For a much more complete discussion of the hydrogenation of fish oil, he reader is referred to Chapter 18. The following example illustrates briefly the methods used in Perú. Analyses and figures given are from actual plant operations. Refined anchovy oil was used, having the follow-ng characteristics:

Free fatty acids	0.1%
Iodine value (Wijs)	202
Refractive index	1.4722
Color (Gardner)	8–9

The hydrogenation is carried out in two stages. To start hydrogenation or stage 1, the reactor, containing 10.3 metric tons of refined oil, is heated and vacuum-dried for two hours at 100°C. Then 20 kgs. of a nickel cata-yst (22–23% Ni) are dissolved in 40 l of hot oil and put into the reactor. Hydrogenation is carried out at a temperature of 150°C. and 1.5 atmo-pheres of pressure for 4 h and 10 min.

The hydrogenated oil after stage one had the following characteristics:

Iodine values (Wijs)	100
Refractive index (45°C.)	1.4616
Melting point	30.2°C.

To start the second stage, 20 kg. of catalyst are added and the tempera-ure of the reactor is raised to 190°C. with the same pressure. The operating conditions remained constant until a melting point of about 38°C. is reached. This stage takes 1 h and 40 min, making a total elapsed time for the entire hydrogenation process of 5 h and 50 min.

At this point the hydrogenated oil has the following characteristics:

Free fatty acids	0.26%
Iodine value (Wijs)	72
Refractive value (45°C.)	1.4590
Melting point	37°C.

The oil is then cooled and filtered to separate the catalyst.

Post-refining of the Hydrogenated Oil

The hydrogenated oil, obtained in the example just cited, is treated with 1,000 l of 0.1 N caustic soda solution, washed three times with hot water, and vacuum-dried at a temperature of 95°C. 284 kg. of activated earth C-K 525 Fulmont (2.8%) are used in the bleaching. The final characteristics of the post-refined oil are as follows:

Free fatty acids	0.08%
Iodine value (Wijs)	72
Refractive index	1.4586
Melting point	37°C.
Color (Lovibond units, $5^1/_4''$ cells)	20 yellow and 2.2 red

Deodorization

The post-refined hydrogenated oil is deodorized under reduced pressure. Superheated steam is directly injected to eliminate impurities that might give odor to the fat. At present, the continuous methods for deodorization in large-scale production is preferred in South America.

USES AND APPLICATIONS OF ANCHOVY OIL IN PERÚ

Fish oil in Perú is classified as raw or crude, semi-refined, refined, and oil sludge. There are also subclassifications for each category.

The main uses and applications of anchovy oil are: (1) in the manufacture of margarine; (2) in the manufacture of soaps; (3) in the manufacture of vitamin concentrates; (4) in the steel industry; (5) in the tannery industry; and (6) for exportation, either crude or semi-refined.

POSSIBILITIES FOR FUTURE EXPANSION

The efficient treatment of fresh fish oils makes it possible to utilize them for nutritional purposes to lessen fat deficiency in humans. In Perú, the price of fish oil is low in comparison to that of vegetable oils which are in low domestic supply.

In order to supplement the vegetable oil shortage with fish oils, it is necessary to process them into edible products. Ordinary refining to give an edible fish oil is not at present feasible because the high iodine number of anchovy oil makes this product highly unstable and readily oxidized. Until future research may find ways to stabilize this highly labile oil, it is necessary to convert it to the stable hydrogenated fat for food use. In spite of the relatively high cost of hydrogenation, the price difference between fish oil and other edible oils in Perú is such that the hydrogenation treatment still offers a favorable economic balance.

After the hydrogenation and deodorization of fish oil a product is obtained that must undergo a final treatment (immediate solidification and rapid agitation) in order to get a fat of adequate homogeneity and plasticity. This can be mixed with other vegetable fats for food use.

The hydrogenated fish oil, with an adequate melting point, is also an excellent basic material for the manufacture of soap.

In the light of the notable increase in local consumption in Perú and other South American countries, the fish oil industry has an encouraging future and the derived products, being of high quality, will contribute to industrial progress and development.

LITERATURE CITED

ANON. 1963. Yearbook of Fishery Statistics. Fishery Commodities F.A.O. *17*.

ARNESEN, E., and SANCHEZ, J., 1963. J. Technical Analysis of the Fish Industry in Perú. Marine Resources Research Institute Bull. *13*. La Punta-Callao, Perú.

BAZALAR, A., 1965. Technological study of the hydrogenization process of fish oil. Faculty of Chemistry, University of San Marcos Thesis.

BULNES, E., 1965. Installation of a plant for semi-refining of *Engraulis Ringens* (anchovy) oil for exportation. Faculty of Chemistry, University of San Marcos Thesis.

IPARRAGUIRRE, J., 1963. Social Economic Diagnosis of the Fishery. Ministry of Agriculture (Oficina Sectorial de Planificación Pesquera).

IPARRAGUIRRE, J., 1965. Economical Politics of Peruvian Fishery. Ministry of Agriculture. Servicio de Pesquería. Informe *18*.

NIETO, M., 1962. Technology of anchovy oil. Revista Ingeniería Química e Industrias *4*.

GPO 929-313