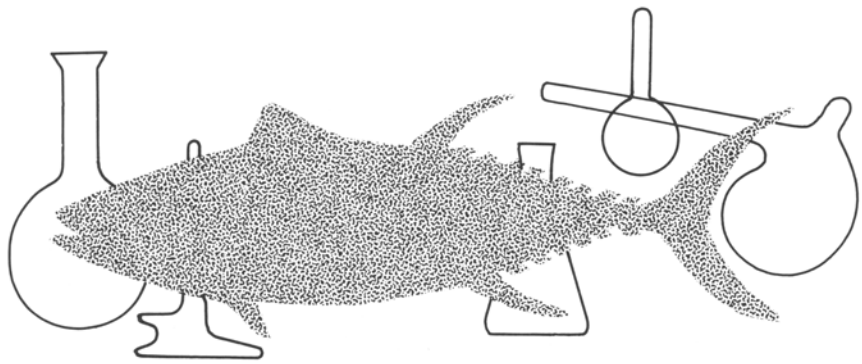
Feature

The emerging marine oil industry

The following article on the marine oil industry was written for JAOCS by AOCS member Anthony P. Bimbo, director of applied development for the Zapata Haynie Corp., Reedville, Virginia.



Introduction

On June 13, 1986, the National Fish Meal and Oil Association (NFMOA) filed a petition with the U.S. Food and Drug Administration (FDA) to affirm that menhaden oil and partially hydrogenated menhaden oil (PHMO) are generally recognized as safe (GRAS) as direct human food ingredients. The public comment period ended on September 29, 1986 (1). There were no negative comments.

Preparation for this petition actually began in June 1977 at a meeting of the U.S. menhaden industry and representatives of the U.S. National Marine Fisheries Service (NMFS). A task force was formed to develop the strategy necessary to obtain approval of menhaden oil as an edible product. During the early meetings of the task force, avenues of approach to a food additive or GRAS petition were explored. Preliminary meetings were held with FDA during the 1977–1979 planning stages to discuss information requirements, types of studies necessary and the FDA's position on marine oils in general.

Although marine oils had been consumed in the U.S. over a 20-year period and in Europe for the past 50 years, FDA maintained they were totally new ingredients and that a comprehensive and time-consuming series of toxicological tests would be required to be certain that adding such products to the food supply would not present an unacceptable risk to the public.

Based on these discussions and the FDA philosophy of the time, several studies were planned to prove the safety of menhaden oil. These tests basically fell into the subchronic and chronic toxicity area, with additional reproductive and teratology phases. They consisted of a rat multigeneration study, a rat life-span study with in utero exposure and a 12-month dog study. Funding for these studies was provided by Saltonstall-Kennedy Funds, which are obtained from a portion of import duties on fishery products (2). In addition, a fourth study with a different strain of rats, performed at a center in the United Kingdom and funded by the International Association of Fish Meal Manufacturers (IAFMM), was offered. This study used both partially hydrogenated soybean oil (PHSBO) and refined low erucic acid rapeseed oil (LEAR) as controls (3).

The petition requests affirmation of GRAS for menhaden oil and defines two product areas for consideration. The first is partially hydrogenated menhaden oil (PHMO) with an iodine value range of 10–150. This would cover the family of products currently in use worldwide as ingredients in margarines, shortenings, soft spreads, cooking fats, salad oils, emulsifiers and waxes. The second product category is for a refined product where the fatty acids remain intact. This product would find use in such food systems as canning oils, mayonnaise, salad dressings, sausages and soft spreads, to name a few. In essence, menhaden oil could be used wherever edible fats and oils are currently being used and where standards of identity do not impose ingredient limitations (3).

Marine oils in perspective

The world's catch of fish, crustaceans and mollusks is on the order of 85 million metric tons (MT) per year, of which about 30%, or 28 million MT, are processed into fish meal and oil. Commercial landings by U.S. fishermen at ports in the 50 states were 2.8 million MT in 1985. This was composed of 1.5 million MT of edible fish and shellfish and 1.3 million MT of fish for reduction

TABLE 1

1985/1986 Forecast of World Production of Selected Fats and Oils (000 Metric Tons)

Soybean	13640
Cottonseed	3430
Groundnut	3150
Sunflower	6380
Rapeseed	6250
Corn	1082
Coconut	3330
Palm kernel	1130
Palm	8290
Lard	5515
Fish	1330
Tallow and grease	6400
Olive	1480
Linseed	660
Butter fat	5390
Totals	67457

Source: U.S. Department of Agriculture Service *Oilseeds and Products* (FOP 6/86) and *Oil World Statistics Update*, ISTM Mielke GmbH, Hamburg, West Germany, Aug. 1, 1986, 1 World-133.

to meal and oil; in the latter category, 94% were menhaden (4,5).

The total world production of fats and oils is in the range of 60-70 million MT per year. Table 1 gives the 1985-1986 forecast for world production of major fats and oils (6,7). It is easy to see that soybean oil and animal fats make up almost 50% of the total while marine oils, consisting of whale, sperm whale, fish liver and fish body oils account for a little over 2% of the world supply of fats and oils. Fish body oils make up 97% of the total marine oil supply. The U.S. production of marine oils totaled 129,000 MT in 1985 and was composed of 126,000 MT of menhaden oil (98%) and 3,000 MT of tuna, mackerel, anchovy and others (5).

While marine oils only make up about 2% of the world supply of fats and oils, they represent a major source of fat in many countries and a valuable export commodity to others. Table 2 gives the major marine oil producing, exporting and importing countries for 1985.

Fats and oils of aquatic animal origin are composed of several product categories. Table 3 gives the breakdown of these products for three separate periods: 1938-1955, 1965-1975 and 1976-1984. What becomes apparent from this table is the major decline in the availability of marine mammal oils and their replacement by fish body oils. Fish liver oil production also decreased (8).

Menhaden oil represents 98% of the U.S. marine oil production. Table 4 gives 12-year production figures for marine oils in the U.S. (5).

Price-wise, marine oils compete with other fats and oils as a commodity on the world market. Table 5 gives a price comparison for marine oil and several animal and vegetable fats and oils over the period 1973 to 1986 (4,8).

Fish production

Fish used for reduction may be divided into three categories: (a) fish caught solely for marine oil and meal production; (b) by-catch or incidental fish from another (such as shrimp) fishery; and (c) fish offal or waste from the edible fisheries. The categories have several things in common: the fish are considered industrial because of their small size or high oil and bone content, which makes them of little edible use, or the raw material is a by-product and of no edible value (9). In the case of fish caught solely for meal and oil production, it must be pointed out that when handled correctly, these fish can be used in food products. A good example is the conversion of nontraditional species of fish into surimi and other food products in the U.S. and elsewhere (10-12).

Fats and oils production

The processing techniques involved in commercial production of edible fats and oils vary according to the type of raw material. The simplest is butter production, involving only churning of the matured cream from cow's milk. Tallow and lard can involve lengthy high temperature rendering of waste carcass parts. Extraction of oil from oilseeds entails precooking the crushed seed at temperatures reaching 120 C, with subsequent pressing to remove about half the oil. Treatment of the pressed cake with a solvent, usually hexane, removes the remaining oil. This requires oil recovery from the hexane solution, usually in several stages. The crude oil then is refined by degumming, alkali treatment, bleaching and deodorizing to produce refined vegetable oil.

Fish reduction to produce oil and fish meal generally uses the same principles, techniques and equipment as for production of other edible fats and oils. Solvent extraction is rare. In general, fish are processed by the wet-reduction method, in which the principal operations are cooking, pressing, separation of the oil and water emulsion with recovery of oil and drying of the residual protein material. Continuous processing from the time the fish are landed maximizes efficiency and product quality (3).

TABLE 2

Major Marine Oil Producing, Exporting and Importing Countries (000 Metric Tons), 1985 Estimated

	Production	Exports	Imports
Belgium	0	0	38
Denmark	85	69	1
Fed. Rep. Germany	12	13	252
Other EEC	28	15	0
Iceland	95	95	0
Netherlands	0	17	210
USSR	97	1	0
Canada	7	5	0
Mexico	6	0	1
Ecuador	35	11	0
Japan	400	245	5
United Kingdom	10	4	245
Norway	150	140	34
Rep. South Africa	24	1	22
US	140	130	6
Colombia	0	0	20
Chile	180	95	0
Peru	160	55	2
Panama	34	12	9
Totals	1463	908	845

Source: International Association of Fish Meal Manufacturers' *Digest of Selected Statistics*, 1986.

TABLE 5

Prices of Selected Fats and Oils ($/MT CIF Rotterdam)

Year	Fish	Palm	Soy	Coconut	Rapeseed	Lard
1973	340	413	520	650	NA	NA
1974	540	670	860	1002	NA	NA
1975	400	483	628	503	NA	NA
1976	370	415	460	450	415	482
1977	488	545	593	627	584	618
1978	453	550	580	733	593	626
1979	445	650	660	1020	636	716
1980	445	595	605	749	571	648
1981	415	560	525	581	483	610
1982	340	450	460	482	417	574
1983	385	545	573	743	500	503
1984	370	773	775	1120	687	575
1985	303	520	573	655	540	553
1986	275	318	417	358	340	465

Source: International Association of Fish Meal Manufacturers' *Digest of Selected Statistics*, 1973-1986.

TABLE 6

Selected Fatty Acid Composition of Some Edible Fats and Oils (in g/100 g)

	M[a]	S	P	B	L	C	SS	R	O	T	C
4:0	—	—	—	3	—	—	—	—	—	—	—
6:0	—	—	—	2	—	—	—	—	—	—	—
8:0	—	—	—	1	—	—	—	—	—	—	—
10:0	—	—	—	3	—	—	—	—	—	—	—
12:0	—	—	—	3	1	—	—	—	—	1	1
14:0	9	—	—	10	1	—	—	—	—	4	1
16:0	19	11	10	26	24	11	6	5	12	25	24
18:0	4	4	2	12	13	2	4	2	2	19	6
20:0	—	—	1	2	1	—	—	1	—	—	—
16:1	13	—	—	2	3	—	—	1	1	5	6
18:1	16	23	46	25	41	25	22	53	72	36	40
20:1	2	—	1	—	—	—	—	1	1	—	—
22:1	1	—	—	—	—	—	—	—	—	—	—
18:2	2	51	31	2	10	57	66	22	8	4	17
18:3	1	7	—	1	1	1	—	11	1	1	1
18:4	2	—	—	—	—	—	—	—	—	—	—
20:4	1	—	—	—	—	—	—	—	—	—	—
20:5	13	—	—	—	—	—	—	—	—	—	—
22:5	2	—	—	—	—	—	—	—	—	—	—
22:6	8	—	—	—	—	—	—	—	—	—	—

Source: Petition to the Food and Drug Administration Requesting Affirmation of Menhaden Oil and Partially Hydrogenated Menhaden Oil as Generally Recognized as Safe for Use in Foods, 1986.

[a]M, menhaden; S, soy; P, peanut; B, butter; L, lard; C, corn; SS, sunflowerseed; R, rapeseed; O, olive; T, tallow; C, chicken.

Processing steps include winterization to remove low-melting-point triglycerides for clarity at refrigerator temperatures; degumming to remove phosphatides and proteinaceous materials; neutralization to remove free fatty acids and some pigments; bleaching to remove pigments, oxidation products, trace metals and soaps; and deodorization or steam stripping to remove volatile components including some pigments, chlorinated pesticides and PCBs. In cases where the end use of the oil will be margarine or shortening, a partial hydrogenation step is performed prior to deodorization (14).

Marine oil fatty acid composition

Like other food fats and oils, marine oils are mainly a mixture of triglycerides of various long chain fatty acids with small amounts of mono- and diglycerides. The fatty acids that characterize marine oils are similar to those in the various edible vegetable oils and animal fats but differ principally in a relatively higher proportion of polyunsaturated fatty acids, with five or six double bonds and the position of the first double bond from the terminal methyl group. The principal marine fatty acids are in the n-3 position, while the major vegetable oil fatty acids are in the n-6 position (15). Table 6 compares the major fatty acids of some common edible fats and oils.

Marine oils differ among themselves in the percentage of different fatty acids and their distribution on the triglyceride molecule. Table 7 shows the fatty acid composition of the major commercial marine oils (16).

There is a major difference in the vitamin content of fish body and fish liver oils. While liver oils may contain concentrated amounts of vitamins A and D, the body oils contain relatively low or nondetectable levels.

Partial hydrogenation of edible fats and oils reduces the polyunsaturates by adding hydrogen to the double bonds. Table 8 shows the composition of a partially hydrogenated menhaden oil taken during processing to a raw margarine stock (17).

Marine oils with iodine values (IV) over 140 can yield a product with IV of 110-120 when hydrogenated under highly selective conditions. This product will have all fatty acid radicals with fewer than three double bonds. When this oil is winterized, a liquid fraction is obtained, which can be blended with another soft oil, such as soybean, and used as a salad oil. This type of product is used principally in South America. It can also be used in single-use shallow frying. The hydrogenated marine oils of higher melting points, preferably 34-36 C, can be used for deep-fat frying, either alone or as the major component of a blend, with palm oil, for example (19-21).

PHMO with 30-32 C MP can be used in a similar manner to lightly or brush-hydrogenated soybean oil. It is primarily used as a replacement for soybean oil when the latter is considered too expensive (22).

PHMO with 32-34 C and 34-36 C MP are the most commonly used marine oils in Europe. They are valued as the middle-melting components of margarine and shortening blends because of their steep solid fat content. The plastic range of blends incorporating these oils can be increased by using higher-melting-point fats, again combined with soft oils for plasticity. Blends containing 50-70% hardened marine oils of this melting point range are widely used for both table and industrial margarines and shortenings (19-22).

Because of their relatively high solid fat content at 30 C and above, the PHMO of 40-42 C MP and those with higher melting points are frequently referred to as hardstocks. They give the product its skeleton of solid triglycerides at 25 to 35 C that are responsible for the long plastic range needed for good bakery performance. The 40-42 C MP oil is frequently combined with those in the 32-36 C MP range (19-22).

PHMO with 46-48 C MP is used in small quantities (about 5%) in wrapped or stick table margarines or lower-melting-point industrial products to improve temperature resistance, or at much higher levels (about 50-60%) for puff pastry products having melting points in the 40-44 C MP range.

Bread fats and bread emulsions use 32-36 C MP PHMO. These are used on their own or are blended with PHMO of 46-48 C MP, palm, lard or beef tallow, depending upon the texture and melting point desired (19-22).

For high-speed dough mixing, a fat with a higher melting point is required to withstand the temperature rise during mixing. For this purpose, PHMO of 46-48 C MP is used in higher proportions, in the range of 20 to 50%, in combination with one or more of PHMO with 32-36 C MP, lard, beef tallow and, in some instances, liquid vegetable oils. Bread emulsions consisting basically of fat, water and emulsifier, as well as other bread additives, are made using similar blends but usually with a higher solid fat content to compensate for the added water. PHMO of 36-38 C and 40-42 C MP are also suitable for use in bread fats and are adjusted where necessary to obtain the desired melting point or solid fat content (19-22).

The solid fat content figures for hydrogenated marine oils are very close to those of hydrogenated soybean and rapeseed oils for melting points from 30 C upward. Oils with the same melting points are interchangeable. Wrapped or stick table margarines have blends in which the solid fat content curve is adapted to the ambient temperature (22).

Hydrogenated marine oil in the 32-36 C MP range is the predominant component of blends that are not all vegetable products. It comprises 25-85% of the blend and is used with lauric oils, palm, lard, beef tallow and liquid vegetable oils.

Industrial cake and creaming margarines are required to give good air incorporation into the cake batter or cream so that the product has good volume and a light texture. A longer plastic range is required for those products compared to wrapped retail margarines to allow for the higher temperatures typical in bakeries. However, when used to produce synthetic creams, the final cream must melt clearly in the mouth. Depending

TABLE 9

Fats and Oils Used in the Production of Margarine and Solid Cooking Fat in the U.K. in the 52-Week Period Ended December 28, 1985

	Margarine		Solid cooking fat	
	1000 MT	%	1000 MT	%
Coconut	0	0	1.5	13.9
Groundnut	0	0	0	0.00
Maize	1.4	0.44	0	0.00
Palm	7.1	2.23	20.4	18.92
Palm kernel	2.4	0.75	4.6	4.27
Rapeseed	30.9	9.70	19.9	18.46
Soy	38.4	12.06	7.1	6.59
Sunflowerseed	29.6	9.30	0	0.00
Other vegetables	27	8.48	1.5	1.39
Marine oils	137.6	43.22	46.5	43.14
Lard	0	0.00	1.9	1.76
Butter	.2	0.06	.1	0.09
Other animal oils	43.8	13.76	4.3	3.99
Total	318.4		107.8	

Source: United Kingdom Ministry of Agriculture, *Fisheries and Food Statistics*, April 2, 1986.

4,000–18,000 MT for 1928–1940 reflected by USDA Tables of U.S. Fats and Oils Statistics 1914–1965 (25). This use involved the preparation of hydrogenated mono- and diglycerides from sardine oil. Mixtures of these glycerides were added to shortening at a level of 2.5–3% in the preparation of superglycerinated shortening. This shortening was in great demand in the baking industry, especially for cakes, since it permitted a higher sugar-flour ratio without harming the final texture of the product. It was produced during the 1930s and 1940s and reached a peak of 45,000 MT per year (24).

Total U.S. consumption of marine oil for all edible purposes during this peak period was approximately 75,000 short tons per year. In 1951, because of declining availability of marine oil due to disappearance of the California sardine, the large processing plants on the West Coast of the U.S. ceased operations. In 1936, California sardine oil represented 60% of the U.S. marine oil production, while menhaden represented less than 15%. In 1960, menhaden oil suddenly represented 88% of U.S. production, while California sardine oil was less than 0.6%. Today, menhaden oil represents 98% of U.S. marine oil production (26).

Menhaden oil and PHMO are suitable for any current use of other edible fats and oils, including shortening and margarine. The maximum level of use could be limited by the supply of fish and by economic and manufacturing considerations, since it is common practice in the food industry to vary formulations as the properties and costs of alternative ingredients change.

Although most marine oils used in food are partially hydrogenated, there is growing interest in food systems where the n-3 fatty acids remain unchanged. A relatively small volume of high value use has been evolving, that is, the bottled oil and capsule market, which utilizes various unspecified, imported marine oils as food supplements. Many of these products claim deep cold-water fish as the source of the oil but are not labeled with species of origin. Table 7 demonstrates that fish need not be deep cold-water species to be a source of n-3 fatty acids; there are pelagic species common to the temperate zone that are quite rich in these fatty acids.

Zapata Haynie Corporation has been involved in this area of research since the early 1960s and has been supplying samples of a specially processed marine oil (SPMO) from menhaden for n-3-related research since the mid-1970s. Several hundred researchers have used or routinely use SPMO-grade oils from our refinery, in a wide range of health-related research. In the last 10 years, I have spoken to hundreds of people about marine oils—how they are manufactured, what they are and what they are not. I have been amazed by the lack of knowledge about the fishing industry and the proliferation of misinformation to fill the void.

In addition to the marine oil capsule market, a recent trend has been toward higher concentrations of the n-3 fatty acids. The theory is that more is better, and so we have seen 30% concentrates, then 50% concentrates and now 80% concentrates, all claimed to be natural marine oils. I was involved in the processing of a highly refined marine oil in the early 1960s. A small pharmaceutical company encapsulated it and marketed it as a cholesterol depressant. Numerous research projects have studied concentration of polyunsaturates by the Solexol process, and ester and fatty acid production followed by liquid-liquid counter-current extraction, urea inclusion compounds and molecular distillation to produce various fractions—all to take advantage of reported health-related benefits of polyunsaturated fatty acids (PUFA). This research has come full circle and is being heavily pursued by a number of companies and research institutes in the U.S. and abroad.

Another possible food use of nonhydrogenated marine oils involves their incorporation into popular food systems, such as purees and spreads, butter analogues and margarines, salad dressings, dairy foods, oils and oil

TABLE 11

Summary of Suggested Uses for Partially Hydrogenated Menhaden Oil (PHMO) Products

Type of fat	Uses
PHMO IV 110-120	Salad oil, single use shallow frying
PHMO 30/32	Economic replacement for brush hydrogenated soybean oil
PHMO 32/34	Margarine, shortening (both table and industrial), bread fats and emulsions
PHMO 34/36	Deep fat frying blends, margarine, shortening (both table and industrial), biscuit cream filling fat, puff pastry compound fats
PHMO 36/38	Bread fats and emulsions
PHMO 40/42	Baking fats, bread fats and emulsions, industrial cake and creaming margarine, retail shortening, puff pastry compound fats
PHMO 46/48	Baking fats, stick table margarines, bread fats and emulsions, high speed dough mixing, industrial cake and creaming margarines, retail shortening, puff pastry compound fats
PHMO 35/39	Danish pastry
PHMO 36/40	Shortenings for biscuit dough
PHMO 40/44	Industrial puff or flaky pastry margarines
PHMO 46/52	Baked products eaten when hot

Source: Young, F.V.K., AOCS short course on hydrogenation, Honolulu, May 1986.

blends, sausages and smoked and spiced foods. Such applications offer the most viable approach to utilizing the unique nutritional properties of marine oil. There is still much work to be done, but some early research results show that refined marine oils can be successfully incorporated into food systems without serious technical or flavor problems. Shelf-life studies and flavor profiles are still being investigated.

There is also ongoing reseach in several countries to upgrade some of the industrial species of fish to food status. Products made from them may be high in oil, offering additional possibilities for the introduction of n-3 fatty acids into foods. In the U.S., a surimi demonstration plant is operating at the Zapata Haynie Corporation facility in Reedville, Virginia. The plant is a joint project between the National Marine Fisheries Service and Zapata Haynie, with funding coming from both groups. This plant will use menhaden to produce surimi and intermediate minces. These products may contain some of the marine oil not removed in washing (27).

Summary

After nine years of planning and research, a GRAS petition requesting approval of two product categories—a partially hydrogenated menhaden oil and a refined menhaden oil—was filed with the U.S. Food and Drug Administration on June 13, 1986. No negative comments were submitted about the proposal. In general, world marine oil production is about one million MT per year. The U.S. produces about 125,000 MT annually, of which 98% is menhaden. The price of marine oils is generally competitive with other edible fats and oils and, like those products, marine oils are expressed and further refined to remove minor amounts of nontriglyceride substances that may contribute to off-flavors and poor shelf-life.

Marine oils possess the same fatty acids as other edible fats and oils and also contain longer-chain n-3 polyunsaturated fatty acids. Contrary to some popular myths, these n-3 fatty acids are present in most marine species, not just in deep cold-water fish. Marine oils have a long history of food use in Europe and were consumed in both margarine and shortening in the U.S. over a 20-year period. PHMO's unique properties improve the physical structure of a number of bakery-type products. PHMO is used in food products throughout the world, including cooking oils, frying fats, margarine and shortening. In their refined form, marine oils possess unique amounts of the n-3 fatty acids, currently under investigation in a number of health-related areas. Imported marine oils extracted from unnamed species are marketed in the U.S. as food supplements. Research in progress indicates that refined marine oil can be successfully incorporated into a number of popular food systems. Clearly, marine oils deserve a place in the American market basket.

REFERENCES

1. *Federal Register 51*:27461 (1986).
2. Bimbo, A.P., and P.E. Bauersfeld, in *Proceedings, Part 2,* International Association of Fish Meal Manufacturers 22nd Annual Conference, 1982, pp. 129–148.
3. National Fish Meal and Oil Association, petition to the U.S. Food and Drug Administration Requesting Affirmation of Menhaden Oil and Partially Hydrogenated Menhaden Oil as Generally Recognized as Safe for Use in Foods, 1986.
4. International Association of Fish Meal Manufacturers, *Digest of Selected Statistics,* 1986, pp. 39–56.
5. U.S. National Marine Fisheries Service, *Current Fishery Statistics No. 8380,* 1985, pp. 75–76.
6. *Oil World Statistics Update,* ISTA Mielke GmbH, Hamburg, West Germany, Aug. 1, 1986, 1 World-133.
7. U.S. Department of Agriculture, Foreign Agricultural Service, *Oilseeds and Products,* FOP June 1986.
8. International Association of Fish Meal Manufacturers, *Digest of Selected Statistics,* 1975–1985.
9. Bimbo, A.P., in *National Fisheries Institute Home Study Course,* in press.
10. Miller, T.M., *Menhaden—A Versatile Fish,* Mid-Atlantic Fisheries Development Foundation Inc. (1983).
11. Dreosti, G.M., and T.J. Billy, in International Association of Fish Meal Manufacturers *Technical Report No. 1* (1983).
12. Cook, R.Y., G.J. Flick and R.C. Ernst Jr., paper presented at the 45th Annual Meeting and Food Expo, Institute of Food Technology, Atlanta, 1985.
13. International Association of Fish Meal Manufacturers *Technical Bulletin No. 17* (1985).
14. Bimbo, A.P., in *n-3 News: Unsaturated Fatty Acids and Health,* Vol. 1, No. 3 (1986).
15. Lands, W.E.M., and A.P. Bimbo, *Possible Beneficial Effects of Polyunsaturated Fatty Acids in Marine Foods,* International Association of Fish Meal Manufacturers (1983).
16. International Association of Fish Meal Manufacturers, *Technical Bulletin No. 18* (1986).
17. Sebedio, J.L., and R.G. Ackman, *J. Am. Oil Chem. Soc. 60*:1986 (1983).
18. United Kingdom Ministry of Agriculture, *Fisheries and Food Statistics* (1986).
19. Young, F.V.K., paper presented at the American Oil Chemists' Society Hydrogenation short course, Honolulu, May 1986.
20. International Association of Fish Meal Manufacturers *Technical Bulletin No. 20,* in press.
21. International Association of Fish Meal Manufacturers *Technical Bulletin No. 19,* in press.
22. International Association of Fish Meal Manufacturers *Fish Oil Technical Bulletin No. 13* (1982).
23. Bimbo, A.P., in *Marine Biogenic Lipids, Fats and Oils,* edited by R.G. Ackman, CRC Press, Boca Raton, FL, in press.
24. Stansby, Maurice E., *J. Am. Oil Chem. Soc. 55*:238 (1978).
25. U.S. Department of Agriculture, *Statistical Bulletin No. 376* (1966).
26. Bimbo, A.P., presentation at the National Fish Meal and Oil Association's Congressional Breakfast, Washington DC, Sept. 23, 1983.
27. Bimbo, A.P., in *Proceedings,* International Association of Fish Meal Manufacturers 26th Annual Conference, in press.