Development of Fish Oil Industry in the United States[1]

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ABSTRACT

The American Fish Oil Industry began in 1811 in Rhode Island using extremely crude manufacturing procedures. By 1855 many of the current-day processing methods were being used, and by 1911 most of such procedures had been adopted. In the intervening years since 1911, most progress has been toward improving quality of the oil and in increasing mechanization. Menhaden oil makes up almost 90% of current American production. Much American fish oil is exported for hydrogenation for use abroad in margarine and shortening. Modern refining techniques have led to improved characteristics and uniformity of specifications permitting many industrial uses without most of the former problems associated with fish oil applications. Protective coatings and fatty acid and fatty acid derivatives are among the most important industrial uses. Some potential uses in the pharmaceutical field may widen demands for fish oil in the future. One such promising possibility, although requiring additional supportive research, is the use by the medical profession of fish oil or fish oil fatty acid fractions in capsule form for prolonging the life of heart patients.

INTRODUCTION

In this paper, the development of the fish oil industry in the United States will be traced from its beginnings in the early nineteenth century up to the present time. The menhaden industry. currently by far the leading segment of the American fish oil industry, will be treated fully during the discussion of the development of the fish oil industry. Current and potential uses for fish oils will be discussed. Special attention will be paid to potential uses for edible purposes, and problems restricting such uses will be considered.

MENHADEN OIL

Early Period — 1811 to 1912

Whale oil was the first oil of marine origin produced in the United States with initial production in a small way originating as early as 1640. Because whale oil is a marine mammal oil, not a fish oil, it will not be considered to any great extent in this report. Nevertheless, during the early history of our country, it was almost the only oil domestically produced, and with the inception of the menhaden processing industry early in the nineteenth century, fish oil was one of the products displacing whale oil as the latter's production declined.

The earliest record of production of menhaden oil is cited by Deblois (1) who states that in 1811 John Tallman and Christopher Barker set up an operation near Portsmouth, RI, to manufacture oil from menhaden. The fish were boiled in pots or kettles, then the fish were transferred to hogsheads and the oil pressed by putting stones on top of the fish. The oil was then skimmed off and shipped to New York. The operation was apparently successful since in 1814 the capacity of the plant was doubled. Barker next devised an alternate procedure whereby the processing of the fish was conducted in equipment built upon skids and hauled to farms where the cooked liquid and the pressed fish could be applied to crops as fertilizer. In 1842 Tallman improved upon the boiling step by using steam for cooking. In addition to his plant in Rhode Island, he then built additional plants in Massachusetts and New York.

In the meantime, menhaden were being landed on Long Island. In 1855 the first fully mechanical press was used at a Long Island plant. In 1860 at a new menhaden plant on Narragansett Bay, the most modern equipment then available, including a mechanical screw press and steam cookers, was installed. At this stage of development, although the operations were by today's standards conducted in a relatively crude way and with very little mechanization, most of the basic operations employed in current plants had been adopted.

During these early days of the menhaden industry, there is little indication as for what precisely the menhaden oil was used. It appears that at the earliest stages some, if not most of it, was added to whale oil, the supply of which was declining yet for which there was a steady demand. One of the earliest specific uses for menhaden oil was in tanning of leather.

During the early nineteenth century, menhaden was used for bait in catching other fish. This was a widespread practice and at first was the principal use for this species. As the fish scrap and oil production from menhaden expanded, however, it overtook the bait fishery so that shortly after the middle of the century, it had become the leading use. Since the fish scrap was used as fertilizer rather than as an animal feed during the early stages, it was not necessary to use fresh fish. In fact, since decomposed menhaden released their oil more readily than the fresh fish, they were first the preferred raw material. With such low grade basic raw material and with the crude methods used for oil separation, the oil was of very low grade by today's standards and had only limited use.

The earliest use of menhaden for oil (and scrap) occurred, as we have seen, in New England. As the demand for these products increased, the industry expanded to the South. Shortly after the end of the Civil War, plants were being established in Virginia and North Carolina. With expansion of the industry, more mechanical handling and processing equipment was introduced. By 1912 methods used for extraction of oil from menhaden had progressed to a great extent over the crude procedures used 100 years earlier and were not a great deal different from those employed today. In 1912 the Atlantic Coast menhaden industry, according to Greer (2), operated from 48 plants: 1 in Maine, 2 in Connecticut, 5 in New York, 5 in New Jersey, 2 in Delaware, 1 in Maryland, 19 in Virginia, 12 in North Carolina, and 1 in Florida. At that time, there were no plants in the Gulf states. During that year, over 6½ million gallons of menhaden oil were produced as well as 88,500 tons of scrap used as fertilzier. At a typical plant, the fish flowed from the raw box to the continuous steam cookers and then to the presses which were of the continuous screw type. Oil was separated by passing it through a series of separating tanks, then the nearly moisture-free oil was heated by steam. Because at this stage of development of the industry centrifuges had not yet been introduced for oil separation, fish solubles were not recovered. Mechanization was not yet as nearly complete as in present-day practice.

By 1912 the major use for menhaden oil was in the manufacture of paints and varnishes. Some was by then being used in the production of linoleum and for water-

[1]Presented at the AOCS Meeting, New York, May 1977.

proofing compounds. It was also extensively employed for leather manufacture.

Period of 1913 to the Present Time

In 1913 a number of situations were about to develop which would greatly widen the uses and markets for fish oils, including menhaden oil. The process of hydrogenation of oils, which was based upon principles first elucidated at the turn of the century, had by then gone through sufficient technological development as to be ready for commercial application. Just in the offing was World War I, which would create shortages of many raw materials and chemicals from which would develop a new technology in the United States in manufacture of many diverse chemical products. This, in turn, would add many potential uses for fish oils as a raw material. Shortages of feedstuffs for animals resulting from World War I would stimulate the conversion from use of menhaden and other fish scrap from fertilizer to animal and poultry feed. This development would lead to better quality control and processing methods in the menhaden industry which would result not only in upgrading the quality of fish meal but also of the oil.

The change in utilization of fish scrap from fertilizer to an animal feed occurred in the United States several decades after such change had occurred in Europe. Atwater, an outstanding American pioneer in agricultural science, attempted unsuccessfully to get fish meal used as a feed in this country in the early 1880s after observations he made during several visits to Germany on the successful use there of fish meal in animal and poultry feed. It was not until shortages brought about during World War I that fish meal started to be used in this country as an animal and poultry feed. As a result of cooperative efforts by the U.S. Department of Agriculture and the U.S. Bureau of Fisheries, use of American fish meal for feed was started in about 1917 and rose to one-fourth of the production in 1921 (3). Progress thereafter was impeded by false conclusions about the alleged toxicity of fish meal. For example, hemorrhages in chickens such as those reported by Dam (4) were interpreted by some as being caused by fish meal in the diet. It was not until several years later when the role of vitamin K was elucidated, that nutritional authorities in the animal and poultry field were unanimous in their recommendation that fish meal could be safely used. By 1935 nearly all of the American-produced fish meal was going into poultry or animal feed. With the need to modify rendering methods in fish meal and oil manufacturing plants in order to produce a fish meal of maximum quality, fresher raw material was employed. Not only the quality of the meal but also that of the oil was improved. Color of oil made from fresh materials was, of course, far lighter, and free fatty acid content much lower. The yield of oil is better both because of less free fatty acid formation and less tendency to produce persistent emulsions which, especially before introduction of centrifugal equipment, resulted in sizable oil losses when only settling tanks were used.

In recent years with introduction of centrifugal equipment and use of fresher raw material, the quality of the menhaden oil has improved tremendously. Furthermore, newer and more efficient refining methods often carried out at the manufacturing level result in production of an even better quality oil with less variability in composition and specifications.

OTHER AMERICAN FISH OIL INDUSTRIES

Currently menhaden fish oil comprises nearly 90% of American fish oil production. In this section will be briefly described other minor operations including two operations, the California sardine industry and the vitamin A fish liver oil industry. They are no longer in operation but once approached in magnitude and value that of the menhaden oil industry.

American Fish Liver Oil Vitamin Industry

Cod liver oil was known and used for medicinal purposes long before the value based upon vitamin content was recognized. In this country, one of the first ventures to exploit Alaska shortly after its purchase from Russia was an effort to produce cod liver oil. In 1866 (5) several thousand gallons were prepared in Alaska and shipped to San Francisco. The low value of the product plus lack of any great demand kept this market from expanding although sporadic production continued up to about 1920. In the meantime, a small production of cod liver oil was built up by the Massachusetts cod fleet. Here again no massive market developed. According to Tressler (6) in 1922 the production of cod liver oil in New England was only about 6,000 gallons. This compares very unfavorably with the 1,320,000 gallon production of cod liver oil in Norway in 1920.

Only during World War II when the foreign sources of vitamin A oils rapidly dwindled was there a buildup of vitamin A oil production from fish livers in the United States. Discoveries of the much higher vitamin A content of swordfish liver oil (7) (hundreds of thousands of units per gram of oil) as compared to cod liver oil (6,000 units per gram of oil) had led to some increase in American production of fish liver oils just prior to World War II. With almost complete loss of importations following outbreak of hostilities in the early 1940s, new American sources were found in the livers of halibut and of certain sharks, such as dogfish and especially soupfin shark.

Methods used over the past hundred years and more for extraction of the vitamin A oil from cod livers by simple boiling and pressing continued to be used for high oil content fish livers. The lower oil content livers such as those from shark, and especially from halibut, required other procedures. Development of an alkali digestion method was widely adopted. Also, some solvent extraction of the livers was employed. Methods of concentrating low vitamin A fish liver oils by means of molecular distillation were also devised.

From the early 1930s before expansion of production by utilization of the higher vitamin A potency livers, the value of vitamin A fish liver oils increased several hundred fold. In the peak production year of 1943, the value of such oils was about 15 million dollars as contrasted to just under $50,000 ten years before.

The increased American production of vitamin A fish liver oils was very short-lived. During the late 1940s, methods of manufacture of synthetic vitamin A were developed which made competition in this country from the fish liver oil industry infeasible. The production of fish liver oils in the United States plummeted rapidly, and today this industry no longer exists. Production continued, however, in several other countries including Norway, the United Kingdom, and Japan.

The California Pilchard Oil Industry

During World War I, the production of the California sardine or pilchard was rapidly expanded, and during 1918, 150,000,000 lb of fish were landed. The expansion in this fishery continued with a peak landing in 1935 of 1.5 billion lb being achieved. The fishery then declined slowly, by 1951 the landings having dropped to 380,000,000 lb. The landings then declined at a tremendous pace, those in 1952 being only 1/30 of those of the previous year. Today the landings of this species are of the order of 100,000 lb per year. During its peak production period, the California pilchard fishery was the largest (except for menhaden) ever reached for any species in the United States, yet today it is a very minor fishery.

All of the trimmings from the canned California sardines and a portion of the whole fish were used for manufacture of fish meal and oil. During the period 1934-1936, the average production of pilchard oil was 23 million gallons per year. The pilchard oil was manufactured by the wet process in much the same manner in which menhaden oil was produced. The uses for sardine oil, however, differed from that of menhaden. A considerable portion was hydrogenated in California and used either as a main component of margarine or was converted to hydrogenated mono- and diglycerides for use as an additive to shortening. Other uses were quite similar to those to which menhaden oil was employed during that period.

Miscellaneous Currently Produced Fish Oils Other Than Menhaden

In California tuna oil is produced by the wet process in a manner similar to that formerly used for California sardine oil. The raw material comes from trimmings from the canned fish operation. Sometimes, trimmings from both canned tuna and mackerel operations are combined and used together to make a mixed tuna and mackerel oil. The quantity of mackerel trimmings available is far less than that from tuna.

The anchovy fishery, which in Peru and Chile is the basis for the world's largest fish oil (and meal) production, extends northward along the coasts of Mexico and California and with lesser concentrations of the species as far north as the Pacific Northwest. These anchovy have been harvested over past decades chiefly to a very small extent for use primarily as live bait for use by other fisheries. After the demise of the California pilchard fishery, some small attempts were made to utilize whole anchovy as the raw material for a fish reduction industry. For a few years during the 1950s, a fair amount of this species was used in California for meal and oil production. California state authorities were reluctant, in view of the disappearance of the California pilchard, to authorize use of large quantities of anchovy until more biological data were available to establish safe catch limits which would not endanger survival of the species. In 1965, annual quotas were established starting initially at 75,000 tons and increasing later to as high as 140,000 tons. In the 1975-1976 season, the quota was 115,000 tons. The highest annual landing achieved during this period was 100,000 tons in the 1973-1974 season. There is indication that annual quotas in future years may be increased, possibly to as high as 200,000 tons.

The anchovies are processed in a manner identical to that used in California for reduction of other fish species. The anchovy oil, with a relatively high iodine number, is in demand for such uses as a drying oil. The quantity of anchovy oil produced in California in recent years is comparable to that of tuna oil. For example, in 1975, 931,000 gallons of anchovy and 920,000 gallons of tuna oil were manufactured in California.

A somewhat smaller but rapidly expanding landing of anchovy has in recent years been taking place in Baja Califonria, in Mexico. It is centered at Ensenada, and the fish are used for reduction to meal and oil.

Herring oil is produced in Maine from trimmings from the Maine sardine industry (Maine sardines are small herring). In former years, a fairly large production of herring oil (and meal) was produced on the Pacific Coast in southeastern Alaska and British Columbia. Herring are currently used in these areas primarily for roe with only the carcasses being rendered. Oil yield is low because, at the season when roe is taken, the oil content of the herring flesh is at a minimum; furthermore, brine used in separation of the roe hinders full recovery of oil during subsequent rendering. Again, in these operations the wet reduction process has been used.

There is a small production of meal and oil made from miscellaneous "trash" fish in different parts of the United States. Such production comes from fish taken by otter trawlers and contains species not wanted by the fresh fish market. Also, the fish are harvested primarily for use in conversion to meal and oil. The largest production of this type takes place in New England. The dry process is generally used for such fish which are mostly of a low oil content. This results in very little oil being obtained in relation to the fish meal yield.

CURRENT AND POTENTIAL FUTURE USES OF FISH OILS

Current Production

In 1976 the production of all American fish oils was 204 million lb valued at about 40 million dollars. Of this total production, 186 million lb or nearly 90% was menhaden oil. Of the oil from other species, most of it was anchovy and tuna oils in about equal quantities.

The volume of American fish oil production fluctuates somewhat from year to year caused chiefly by natural variation in the abudnance and oil content of menhaden. For example, in 1975 due largely to higher oil content of menhaden, its oil production was 14% higher or 212 million lb.

Industrial Uses

American fish oils in the nineteenth century were used first as an adulterant to and then as a substitute for whale oil. Later they found use in their own right for tanning leather and for making soap. Still later they began to be used in paint because of their high iodine number but initially on account of their crude quality and dark color were used only in dark-colored paints and for outdoor use where the fishy odor occurring during drying was not a great problem.

Today with modern methods of manufacture and refining, the use of fish oils for protective coatings is first among all industrial uses. Fish oils are used in the manufacture of most paints and varnishes including alkyd resins. Most of the problems formerly associated with use of fish oils in paints such as poor drying qualities, after-tack, yellowing and off odors during drying have either been eliminated or can be minimized by judicious selection of fish oils processed to have the desired characteristics and blending them with non-fish oil components in the proper way. Use of polymerized (heat bodied) fish oil is particularly effective in adapting fish oils to uses where vegetable oils such as linseed oil have, in the past, been superior to fish oils. In some applications such as in formulation of aluminum paint, heat-bodied fish oil is superior to that where vegetable oils are employed. DeSesa (8) has reviewed the uses of fish oil in protective coatings.

Second only to the use of fish oils in protective coatings in the industrial field is their use for making fatty acids. Since the largest demand for fatty acids from fish oils is at least in a partially hydrogenated form, the first step is usually the hydrogenation of the highly unsaturated fish oil glycerides using activated metal catalysts such as nickel. The hydrogenated triglycerides are then saponified to produce the acids which can then be used directly or converted to metallic soaps. The fish oil fatty acids or soaps have a large variety of uses, the biggest being for preparation of lubricants.

Smaller quantities of fish oils are used for a very wide range of applications including in printing inks, in insecticides, for caulks and sealants, as surfactants and plasticizers, and as leather treatment agents. Fish oil fatty acids serve as a starting point in making a wide range of other chemical derivatives such as esters, alcohols, and nitrogen derivatives like amides. All these have additional applications. Uses for fish oils and their chemical derivatives have been reviewed by Fineberg and Johanson (9) and Dyer (10).

Uses for Food and Feed

Fish oils are not readily marketed as a food product in their unchanged state because of their extremely high susceptibility to oxidation which renders them vulnerable to off-flavor development. The use of fish oils after hydrogenation as a component of margarines and shortening is their major use worldwide. The greatest portions of the fish oils produced in this country are shipped abroad where they are hydrogenated and used in this way. This practice, rather than to use the oil for the domestic processing and marketing in the United States, is based upon historical precedents plus a number of problems which are difficult now to overcome, and this subject was reviewed in depth by Stansby (11). The situation has changed only a little since that time; the obstacles toward use domestically of fish oils in this country for margarine and shortening will be treated here only briefly.

The chemical basis for modern hydrogenation of oils was developed around the turn of the century. Soon after 1910 the necessary industrial application research toward production of hardened oils for food use was available, and an industry rapidly developed during World War I which included the use of hydrogenated fish oils on a large scale in margarine. The use of margarine in Europe was much greater at that time than in the United States where restrictive legislation at the state level hampered the expansion in marketing of this commodity. Thus there were markets in Europe for menhaden oil produced in the United States which did not exist at home, and the practice of exporting this product for hydrogenation and incorporating it into food products abroad was developed.

In the meantime, the rapid growth and expansion of the California sardine industry resulted in larger amounts of oil becoming available during the 1920s and 1930s. By 1925, with new plants in California for hydrogenation of oils for food use, sardine oil found use in margarine domestically. Also, another outlet for even larger quantities of sardine oil resulted from hydrogenated mono- and diglycerides from sardine oil in superglycerinated shortening, a product much in demand in the baking industry. At the peak of production of sardine oils during the 1930s as much as 100 million lb of sardine oil per year went to superglycerinated shortening. By 1952, however, the shortage of California sardines caused the oil production to fall off to nearly zero, and these uses ceased.

Shortly after the cessation of availability of sardine oil, the Food and Drug Administration set standards of identity and of sanitation for margarine and its production. Since, by then, no fish oil was being used in margarine production in this country, fish oil was not included in the list of acceptable ingredients for its manufacture. In later years when American fish oil manufacturers had looked into the possibilities for use of hydrogenated menhaden oil in domestically produced margarine, it was found that not only would it be necessary to get the law changed so as to have fish oil included as an acceptable ingredient, but also, a sanitation problem existed. The constructionsl conditions of the buildings in which many menhaden plants are located are such that it would be very costly to remedy them so as to meet minimum sanitation requirements for handling of raw materials for margarine.

Recently so much publicity has appeared concerning the belief that C_{22} monoene fatty acids may have harmful physiological effects upon the human heart that the levels of hydrogenated fish oils permitted in margarine in certain countries (e.g., Canada) have been legally restricted (12). Some recent research of Ackman and Loew (13) which included a study of cynomolgus monkeys on a diet which included 25% partially hydrogenated herring oil containing about 20% erucic acid failed to show deviation from satisfactory cardiac muscle functionality. The content of such C_{22} monoenes in menhaden or tuna oil either before or after hydrogenation is about one-tenth of the amounts that are sometimes present in herring or herring-like species.

There are no standards of identity for shortening in the United States. Therefore, it would appear more likely that it might be possible to market menhaden or tuna monoglycerides for use in preparation of superglycerinated shortenings in the American trade with a minimum of legal problems.

In the past, fish oils have been used in the United States as an animal and poultry feed supplement. In recent years, the use of fish oils as a feed supplement in the United States has ceased because the content of chlorinated hydrocarbons such as DDT and PCBs exceeds limits established by Federal authorities. Considerable research is currently under way to determine whether any economically feasible methods can be developed to remove chlorinated hydrocarbons from fish oils to a point where their marketing as feed supplement could be reestablished.

Uses for Medical and Pharmaceutical Purposes

Effects attributed to shark liver components: Because sharks have not been fished extensively in this country since the demand for their livers as a source of vitamin A ceased about 1950, there are substantial stocks of shark that doubtlessly could supply a considerable quantity of such fish if any need for them existed. At present only a very small fishery for dogfish operating sporadically exists, and it involves shipment to Europe of this species for human food.

In addition to the use of shark liver oil for its vitamin content, which is no longer economically profitable in the United States, the liver oil of various sharks contain certain other components which have been purported to have desirable pharmaceutical properties. A major component of the liver oils, and to a lesser extent of the body oils, of some shark including dogfish, are the glyceryl ethers such as batyl and selachyl alcohols. Over the past 40 years, various uses for the glyceryl ethers have been proposed. These uses have been reviewed by Stansby (14). Perhaps the best documented use is their employment to minimize side effects in irradiation treatment. Extensive research in Sweden [Brohult (15)] indicated such beneficial results, and it has been common practice in Sweden to administer orally to hospital patients undergoing irradiation treatment small doses of batyl alcohol. While some workers in the U.S.S.R. had obtained similar results, others, e.g., Snyder (16) have been unable to confirm these effects.

Another alleged curative effect of glyceryl ethers based upon the work of Bodman and Maisin (17) is the acceleration in healing of burns and wounds by topical application. These results have received no confirmation by several other workers. Thus Stansby, Zollman, and Winklemann (18) found no increased curing rate of burns or wounds on hairless mice treated with fish oils as compared to mineral oil whether the fish oil contained no additive glyceryl ethers, or large supplements of vitamin A.

In research at New England Institute of Medical Research, Heller, Pasternak, Ransom, and Heller (19) report isolation from shark liver oils of fractions which stimulate reticuloendothelial systems, but again these results have not always been reproducible by other workers, e.g., by Ringle,

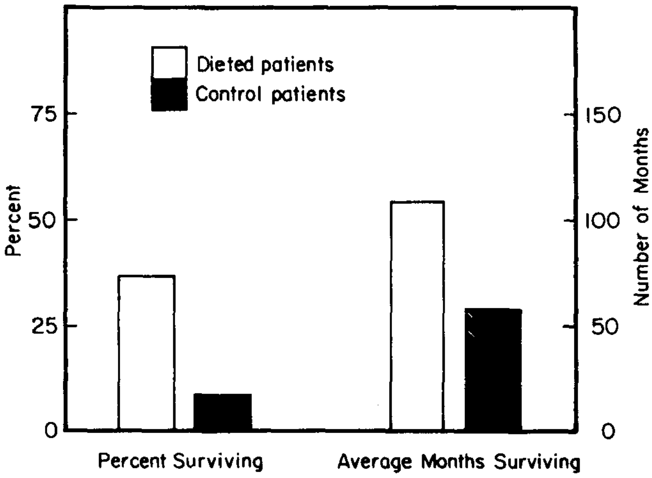

FIG. 1. Effect of diet high in seafood on longevity of heart patients.

Herndon, and Bullis (20). Glyceryl ethers from shark have been reported by Chalmers, Wood, and Shaw (21) to have beneficial effects for rheumatoid arthritis.

Effects attributed to fish oil polyunsaturated fatty acids: Bernsohn and Stephanides (22) have made an etiological study of the relationship of diet on multiple sclerosis incidence in populations throughout the world. This study reveals that populations consuming oils in their diet high in ω-3 fatty acids have far less multiple sclerosis than do those consuming foods containing little such fatty acids. Furthermore, consumption of the longer chain length ω-3 fatty acids such as pocosahexaenoic acid which is higher in amount in fish than in any other food seemed more correlated with lack of incidence of multiple sclerosis than consumption of simpler ω-3 fatty acids such as linolenic acid. These observations need more definite confirmation by the carrying out of feeding studies with fish oils. If positive confirmation should be obtained, the use of fish oils in multiple sclerosis treatment should prove to be very important.

During the 1950s and 1960s, considerable research was conducted, much of it sponsored by the Bureau of Commercial Fisheries, which showed that intake of fish oils, whether taken by consumption of fish or directly as the extracted oils, drastically reduced serum cholesterol levels (14). Research had already related lowered serum cholesterol levels to reduced incidence of heart disease. During this early period, at least one menhaden oil concern experimented with production of capsules containing menhaden oil (or fractionated polyunsaturates from it) for use by heart patients under care of a physician. The marketing of this new product was never successfully expanded, probably largely because the research upon which the effectiveness of fish oils was based had been conducted very largely with experimental animals. Only a very limited number of experiments had at that time been made in which fish or fish oil was used by humans, and the results did not seem to fully confirm those obtained when rats or other animals were used. The length of these few medical tests, however, were of very short duration, of the magnitude of a few weeks only.

One very long term experiment using human patients was begun by a heart specialist in Seattle during the early 1950s. This work was carried out with heart patients who had suffered at least one heart attack. The results were reported by Nelson (23) in 1972 (shortly before he died). Because this research paper received little publicity, the principal results will be summarized here.

TABLE I

Fatty Acid Composition of Commercial Crude Menhaden Oils from Gruger (26)

Location of catch	Date of Production	Fatty acid[a] (%) 14:0	16:0	16:1	18:0	18:1	18:2	18:3	18:4	20:1	20:4	20:5	22:1	22:5	22:6	15:0 & 17:0	Others
South prodn.[b]	Feb. 1961	15.1	24.0	16.8	3.0	11.1	1.0	0.9	0.8	1.6	1.4	10.4	1.0	1.6	4.8	3.1	3.4
Empire, LA	May 1960	13.5	22.4	17.3	2.6	14.1	0.9	0.4	1.1	1.6	0.8	13.5	0.9	1.4	3.3	2.2	3.9
Fernandina Beach, FL	May 1960	13.7	21.6	17.9	2.9	11.6	1.0	0.8	1.0	2.4	0.7	11.9	0.8	1.4	5.0	3.5	3.7
Beaufort, NC	May 1960	16.3	23.5	17.3	3.1	10.7	1.3	0.7	0.9	2.2	0.6	10.2	0.7	1.4	5.0	3.2	3.9
Port Monmouth, NJ	May 1960	6.7	21.9	12.2	3.0	23.4	1.3	0.5	1.5	1.9	1.2	12.9	0.9	1.1	5.1	1.8	4.4
Port Monmouth, NJ	July 1960	10.6	23.6	14.8	3.0	12.6	1.2	1.0	0.9	2.7	0.8	13.1	1.0	1.4	6.5	3.4	3.3
North prodn.[b]	Feb. 1961	12.5	19.6	14.1	2.4	19.3	1.2	1.1	1.8	2.0	1.3	10.3	1.0	1.2	5.6	2.4	4.1

[a]Shorthand notation for fatty acids: (carbon number: number of double bonds), e.g., 14:0 meaning 14-carbon-atom chain length with zero number of double bonds.
[b]Exact origin unknown.

Dr. Nelson consulted frequently with the staff of the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) during the conduct of his work, so we are thoroughly familiar with his work. Patients were requested to alter their diet by reduction of the content of foods containing saturated fat and to obtain increased polyunsaturates primarily from consumption of fatty species of fish at meals five or more times per week.

One of the factors which enabled Nelson to achieve success in getting significant numbers of his patients to adhere to their diet was the frequent meetings held by him and his dietician with the patients to explain the need for adherence to the diet. Another important factor was that in the diet the patients were permitted to go off their diet for four successive meals within a 24-hr period once each week. Thus, for example, they might choose to ignore their diet for a Saturday evening dinner and all the next day (Sunday) but stick to their diet the remainder of the week.

Out of a total of 206 patients over a period of 16 to 19 years, Dr. Nelson was successful in getting about 40% of them to adhere to the diet. Their serum cholesterol was usually lowered considerably. The amazing result, however, was the extreme difference in the survival and longevity of the patients on the diet as compared to the undieted ones.

Of the 80 dieted patients, 29 or 36% were alive after the 16-19 years had elapsed. Of the 126 undieted patients, only 10, or 8%, were alive at the end of the same period. The survival rate was 4½ times greater in the dieted group than in the control group (see Fig. 1). Furthermore, the average survival time for the patients in the dieted group was 109 months as compared to 58 months for the undieted ones.

These results are far more striking and conclusive than those in any other published paper. In this author's opinion, this is true because (a) Nelson had superior success (based on his attention to convincing patients of the need to adhere to their diet) in getting a significant proportion of his patients to follow rigidly the diet; (b) Nelson was one of the first to start a dietary regime for heart patients and thus his data covers a longer period than most others; (c) all of the members of the group were subject to heart attacks; and (d) Nelson recognized the very superior action of fish oils as compared to vegetable oils. Nelson recommended a reduction in vegetable oil intake in order to prevent an obscuring of the potent effect of the fish oil by dilution with excessive amounts of vegetable oil.

For physicians who are not so successful in getting their patients to adhere to a prescribed diet as was Dr. Nelson, the availability of fish oil in capsule form might well make it possible to achieve results at least as good as those of Dr. Nelson. The menhaden and tuna oils which are available in this country would be ideal for use in such a product. They contain a considerable quantity of highly polyunsaturated fatty acids with five and six double bonds per molecule, yet have minimal amounts of the undesirable long chain monoenes such as erucic acid, which have been shown to have potentially undesirable properties for heart patients. Research by Gauglitz and Gruger (24) have shown that commercial menhaden oil can be refined to a point where it is nearly tasteless and reasonably palatable. Several tons of such material, both in its original form and as polyunsaturate concentrates, have been dispersed by the Bureau of Commercial Fisheries (NMFS) in past years to hospitals and medical institutions where it was found to be reasonably palatable, and when sealed in air tight containers, reasonably stable over many months of storage.

Although in the work of Nelson, the patients were fed the fish oil in the form of fresh fish, the work of Peifer, Janssen, Muesing, and Lundberg (25) has shown that essentially identical results are obtained in animal feeding work whether the fish oil is fed as such or while in the flesh of the fish. Thus, use of American produced fish oil might possibly find a new market based upon its cholesterol depressant activity as a pharmaceutical product.

During most of the 165 years that American fish oils have been produced, the quality of the oil has been so very poor that its uses have often been limited to instances where low price has been the main consideration. It is only within very recent years that modern manufacturing methods and improved refining and processing techniques have made it possible to tailor inherent properties of fish oils to meet specific needs.

I have suggested that future applications for fish oils may be in the medical field. Whether this develops or not, the future outlook appears to be an optimistic one. Fish oils, in the future, should find expanded outlets where uses depend upon chemical characteristics which can be adapted to specific applications. This should lead to a much more stable and profitable industry.

Fatty acid composition of Menhaden oil: Table I gives the fatty acid composition of several menhaden oils. Although each batch of oil analyzed was from large industrial production representing many thousands of fish, there is a considerable fluctuation from batch to batch in the fatty acids. For example, the content of $C_{22:6}$ fatty acids ranged from a low value of 3.3% in a sample produced in May in Louisiana to a high value of 6.5% for a sample manufactured in July in New Jersey. These differences are dependent upon the feed composition ingested by the fish from which the oil was made. The feed type varies both with respect to geographical and seasonal factors.

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[Received June 10, 1977]