Fish Protein Concentrate: the Growth of an Industry

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INTRODUCTION

Fish protein concentrates (FPC's) have been used in various parts of the world for several centuries. It has only been within the past 30 years, however, that the production of FPC's has been investigated on a scientific basis. Furthermore, it has only been within the past 10 years that serious consideration has been given to the production of the products on an industrial scale.

Today several pilot plants and full-scale industrial plants have been built. Some are now in operation and others will be within a matter of months. Most of these plants produce FPC by solvent (usually isopropyl alcohol) extraction procedures. The purpose of this paper is to describe these plants and to discuss the type of FPC produced. Only those processes which are now in commercial operation, or in the author's judgment soon will be, are reported.

Before discussing FPC's, they must be defined adequately. Most people tend to think of FPC as the nearly white, bland, highly nutritive product produced by isopropyl alcohol (IPA) extraction of whole fish. This product is an FPC; however, it is only one type of FPC. Fish protein concentrates are defined as those products resulting when water, oil and sometimes bone or other non-proteinaceous materials are wholly or partially removed from whole fish or parts of fish. The products (FPC's) thus produced may be in the form of pastes or dry solids, they may be high in nutritive value, or only intermediate in nutritive value. To avoid confusion, the type of FPC produced by isopropyl alcohol extraction (IPA) will be referred to as IPA-FPC.

AVAILABILITY OF FISH

Before an industry can be started, a continuing supply of raw material must be available. Adequate fish resources do exist on a world-wide basis; however, several limitations must be mentioned that have a direct effect on the industrial production of FPC's.

United States Resources — In the United States, the only species of fish that are permitted to be processed into FPC under present Food and Drug Administration regulations are whole hake and hakelike fish, herring of the genus *Clupea*, and menhaden.

Canada — In Canada, three families of fish have been approved for making FPC by IPA extraction. These families are Clupeidae (herring and herringlike species, such as alewives, menhaden, pilchards and sardines), Osmeridae (capelin and smelt species) and Gadidae (cod, haddock, hake and pollock).

Other Countries — In other countries, no regulations are known to be in effect. Therefore it is presumed that any wholesome food grade fish could be used in any "safe" process.

METHODS OF PROCESSING

There are two general methods of making fish protein concentrates: chemical and biological. Chemical methods use solvents alone or in combination to remove water and lipids from the protein. Biological methods use enzymes, natural or added, or microorganisms to degrade the protein into water-soluble components. The oil and solid residues are removed mechanically (by filtration and/or centrifugation) and the water-soluble fraction is concentrated by partial or complete drying.

Chemical (solvent extraction)

Most research efforts have been expended on solvent extraction methods. A wide variety of solvents has been investigated for use in making FPC. These range from non-polar solvents, such as hexane, to very polar solvents, such as methyl alcohol, and from chlorinated hydro-carbons to ketones and esters. It is interesting to note, however, that every commercial or near commercial procedure makes use of isopropyl alcohol somewhere in the process.

A description of each commercial or near commercial operation will serve to illustrate the extensive use of isopropyl alcohol for making FPC.

Alpine Marine Protein Industries, Inc.— Alpine Marine Protein Industries, Inc., New Bedford, Massachusetts, uses a two-solvent system. The process is based on the VioBin method of extraction of whole fish with ethylene dichloride resulting in a dehydrated and partially defatted material. This material is further extracted with IPA in a continuous countercurrent procedure. The final solids are dried, steam stripped, and milled. This company currently is test marketing a product called "Instant Protein," sold in quarter-pound packages. Each package contains eight one-half ounce packages of FPC along with some recipes. This material, reportedly, sells for $0.79 per box. The IPA-FPC produced was made exclusively from hake *(Urophycis chuss)*.

Nabisco-Astra Nutritional Development Corporation— This Corporation, with headquarters in New York City, is a joint venture between the National Biscuit Company, U.S.A., and the Astra Company of Sweden (Lawler, 1970). Astra Nutrition has developed a process for making IPA-FPC and Nabisco is experienced in the production and marketing of protein-enriched food products. The two companies united to form the Nabisco-Astra Nutrition Development Corporation.

The process for making EFP-90 (eviscerated fish protein) as it is called, is a modified IPA process.

Fish are cut into segments, washed to remove viscera and blood, and slurried in water and cooked. The cooked material passes through a deboner, a desludging centrifuge, a hot water treatment, and a second centrifuge. From there it enters a continuous extractor where fat is removed by isopropyl alcohol. On discharge, the IPA is centrifuged to clarify it for return to the solvent recovery plant. The extracted fish is passed through a steam-heated agitating desolventizer where any remaining solvent is removed. The operation is completed by drying in a steam-heated unit, milling, and bagging the finished protein. The EFP-90 contains between 92-94% protein with an IPA residue of less than 100 ppm. At present herring is used to make EFP-90. Reportedly, the EFP-90 is offered for sale at about $0.49 per pound.

Cardinal Proteins, Ltd. — Cardinal Proteins, Ltd., Nova Scotia, Canada, is constructing a multimillion dollar IPA-FPC plant with a capacity of 200 tons of fish daily. This plant, being built in Canso, Nova Scotia, will use the IPA process, probably as developed in Halifax, Canada, which means that the initial slurry is acidified with phosphoric acid. Cardinal's representatives have stated that the plant construction is nearly completed, but operation was delayed because of a fishermen's strike in Canada. It is expected, however, to begin operation in early 1971.

The plant is located next to an established fish processing plant. Cardinal expects to meet one-third of its daily requirement for raw material by fluming cod and haddock trimmings directly from the processing plant. These trimmings currently are being used in fish meal production. However, this material, having been handled under sanitary conditions, is considered superior to fish normally used for making fish meal. This ability to obtain sanitary fish trimmings will help hold down the cost of raw material. No firm cost figures for IPA-FPC are available at this time.

Societe Nationale Farine Alimentaire Poisson (SONAFAP), Agadir, Morocco — The Agadir plant uses batch extraction procedures. This plant operated for a few weeks in 1965 and for several months in 1966. About 170 tons of product were produced using hexane and ethyl alcohol, but because of poor odor and color the product was unacceptable. The plant remained idle until about a year ago when operations were once again resumed and an acceptable FPC was made by IPA extraction of sardines *(Sardinia pilchardus).*

This plant will be used to produce IPA-FPC for acceptability studies in Morocco. No cost figures are available.

FPC Experiment and Demonstration Plant — The Experiment and Demonstration Plant now under construction at Aberdeen, Washington, was authorized by the 89th Congress in Public Law 89-701. It is designed to demonstrate the feasibility of commercially producing FPC, by a countercurrent isopropyl alcohol extraction technique developed by the National Marine Fisheries Service. The plant will be completed in December 1970 at a cost of approximately $2 million. The plant is being constructed under Government contract by Ocean Harvesters, Inc., a company formed through equal capitalization of Star-Kist, Inc., a subsidiary of Heinz, Inc., and SWECO, a company specializing in construction of shaker screens. SWECO, as a subcontractor to Ocean Harvesters, is constructing the plant. Star-Kist, acting in a similar capacity, will operate the plant after it is constructed. The plant is designed to process 50 tons of raw fish into approximately 7-1/2 tons of FPC in a 24-hour period.

Fish to be utilized will include hake *(Merluccius productus),* anchovy *(Engraulis mordax),* and possibly Pacific herring *(Clupea harengus pallasi).* Using data obtained from plant operation, the cost of producing FPC via this method will be calculated for varying sizes of commercial plants.

Heat Transfer Method

This method is one that might be called "half completed." The half that has been completed on a commercial scale removes water from the fish and removes part of the oil. Experimental work is now underway to develop an economical method to further extract the partially defatted product with either IPA, hexane, or both. This process is potentially valuable for two reasons: (1) the intermediate product can be sold as is for animal feed, and (2) the intermediate product can be stored for long periods of time (at least a year) without noticeable deterioration. Thus, the market for the product is diversified (animals and humans) and the intermediate product will be available for further processing on a steady basis throughout the year. This steady state year round operation is very favorable from an economic standpoint.

Raw fish are charged into a prebreaker, cutting the whole fish into roughly 1-inch chunks. From here the chunks are fed into disintegrators, previously produced hot fish oil is added and the whole mass is slurried into a pea soup consistency. The slurry is now pumped to large two-stage vacuum evaporators, and the slurry is almost instantaneously dehydrated under reduced pressure, leaving protein, solids, bones and oil in a fine suspension. The oil and solids are then partially separated by centrifugation, producing the intermediate product. Following this, the oil content may be lowered further, either by the use of expellers or by solvents.

Biological Methods

These methods, while not as well developed or publicized as solvent extraction methods, produce FPC's with a wide variety of flavors, odors and functional characteristics. Most of the work thus far has been limited to small scale efforts and will not be reported here.

TYPES OF FPC'S

Chemical (solvent extraction)

In general these types of FPC's are bland tasting and vary in color from white to dark tan. They contain between 75 and 95% high-quality protein. FPC's made from different species of fish have different textures, different colors and, in some cases, different odors. As experimentation proceeds and we become more knowledgeable in our manufacture of IPA-FPC's, these differences will be minimized. The nutritive values of the IPA-FPC's are equal to or better than casein when fed as a sole source of protein. IPA-FPC is intended for use, however, mainly as a protein supplement and not as a sole source of protein. This cannot be emphasized strongly enough. For this market, numerous nutritional studies have been conducted on the effect of supplementing various vegetable protein sources with IPA-FPC. Substantial increases in nutritive value have been obtained in all cases.

Much has been said about FPC being non-functional. If non-functional is defined as not changing the product characteristics of that foodstuff to which it is added, then, indeed, FPC can be termed non-functional. This characteristic of limited functional properties, far from being a drawback, is in many circumstances advantageous since FPC can be added to existing food products, markedly improving the nutritional quality without significantly altering other characteristics.

In addition to chemical analyses and animal-feeding studies, we have also tested various IPA-FPC's in food products. IPA-FPC can be used in relatively small amounts to increase the quality and quantity of protein in a variety of commercial foodstuffs. We have studied the use of IPA-FPC in such products as bread, pasta, crackers, cookies, soups, tortillas and beverages. In all cases the nutritive quality has been increased tremendously.

The product characteristics of breads containing IPA-FPC from various species of fish, including hake, Atlantic menhaden, Atlantic herring, Northern anchovy, ocean pout and alewife, were acceptable with no exception.

For pasta, the same thing might be said–that as far as flavor and odor evaluations were concerned no significant differences were found.

In crackers, a sensory evaluation was conducted using 50 panelists. No significant differences were found in the texture or flavor of crackers with no IPA-FPC and those fortified with IPA-FPC. Differences were, however, detected in the appearance of the crackers in that those containing IPA-FPC were slightly darker than the unfortified cracker.

For cookies, a bland sugar cookie was used to evaluate the sensory characteristics of IPA-FPC prepared from the various species of fish. No significant differences were found in flavor and texture. However, the appearance of the cookies made from anchovy and alewife was slightly less acceptable than that of the control.

From our investigations, it appears that perhaps FPC is not quite as non-functional as one might have first suspected. We have indications, although no proof at this time, that certain products have an increased shelf life upon the addition of IPA-FPC. Furthermore, it appears that some products are more resistant to breakage. We found, for example, that crackers containing IPA-FPC appear to be less apt to crumb in the box or to be damaged in shipping. These observations will be investigated further.

Biological

Most of the work done at the NCFPC on biological methods has been oriented toward development of a totally water soluble FPC through the use of enzymatic hydrolysis. The basic process includes enzymatic digestion of the whole fish slurry with control of pH and temperature, screening out the bones and scales, and separation of undigested solids by centrifugation, followed by spray drying of the clarified hydrolysate to yield a soluble product consisting of peptides, polypeptides and some free amino acids. More work needs to be done in this area before these FPC's are ready for commercial production.

Markets

United States —According to Hammonds and Call (1970) the market for FPC's depends upon price-functionality relationships.

An FPC with no functional properties will have to be lower in cost than a more functional FPC.

Hammonds and Call assumed a price range for FPC of between $0.288 to 0.538 per pound of protein. They state that this price range would place FPC costwise between soy flour ($0.126 to 0.164 per pound of protein) and nonfat dry milk ($0.556 - 0.694 per pound of protein). Furthermore, since this range is neither clearly lower than that of present protein ingredients, nor clearly higher, the functional characteristics of FPC then becomes crucial in determining the market potential. Starting at the low price range ($0.29 per pound of protein) they conclude that FPC could compete with soy flour providing taste advantages are realized (soy flour has a bitter-beany taste when present in concentrations of greater than 4 to 5% by weight of finished product).

FPC priced between $0.40 - 0.50 per pound of protein with a very bland taste but a low level of functionality could penetrate the following U.S. markets:

". . .baby food at 2.4 million pounds of protein yearly; breakfast cereal at 1.4 million pounds; candy at 16.6 million pounds; and diet drink at 2.2 million pounds. These markets total to a potential volume of 22.6 million pounds of protein or 28.3 million pounds of FPC." They add however: "If functional properties can be developed along with acceptable taste, FPC in the $0.40 - 0.50 per pound protein price range could also compete in a number of other markets currently using nonfat dry milk. Moderate fat absorption would open the canned and processed meat markets using 16.1 million pounds of protein yearly. The ability to prolong freshness and shelf life would open the baked goods market at 68.3 million pounds of protein yearly. Whippability and emulsion stabilization would open the desserts and toppings market at 28.6 million pounds of protein yearly."

One other market potential is the U.S. school lunch program--notably the "Type A" school lunch. It has been stated (Hines, 1970), that in a few years there will be 55,000,000 children getting school lunches at a cost of $7 billion at 1968 price levels. The animal protein in the lunches represents 60% of the cost. Fish protein concentrate is now being investigated as a source of protein for these lunches.

Other Countries—Outside the United States, the competitive market for FPC will be subject to essentially the same type economic analyses as reported by Hammonds and Call. Some countries, however, have plans to require FPC supplementation in bread and baked goods. This could lead to a sizeable market for FPC.

In addition, Nabisco-Astra reported the following: "Fish protein is marketable wherever protein is in short supply: in industrial countries, developing countries, and among people of different ages, social conditions and customs. Until today there was little awareness of the protein needs of the developing countries so it is important that these areas receive our initial attention. However, significant markets for fish protein also exist in prosperous countries with a high degree of industrialization.

"Nabisco will develop food products that lend themselves to enrichment with high-level protein, provide high-grade nutrients for such products, and market them with necessary adjustments to local eating habits."

It appears, then, that potential markets do exist for a bland type IPA-FPC. Obviously, however, if more functional FPC's can be developed, the market potential will be expanded.

PRESENT RESEARCH

Efforts are now being directed toward development of FPC's with improved functional properties. Extraction with a combination of hexane and isopropyl alcohol markedly improves protein solubility. Also, FPC with markedly improved functional properties--especially oil emulsifying capacity--can be produced by extracting fish with isopropyl alcohol at room temperatures instead of at 70C.

Research at our Seattle Laboratory has been directed toward the development of an aqueous extraction process including a short enzyme digestion followed by separation and isolation of the partially digested protein. Reportedly, the spray-dried material is stable as well as having desirable functional properties.

The biological processes also hold promise for producing highly functional

FPC's, and research in this area will be continued.

SUMMARY

In summary, an FPC industry has been established and is growing. Several plants are either now in operation or under construction. Isopropyl alcohol is used, in each instance, as the solvent to remove water and lipids. The IPA-FPC produced is essentially a "non-functional" product, but has a place on the world market. FPC's with improved functional properties are desirable and research is underway to develop functional FPC's. Barring unforeseen circumstances, the FPC industry should continue to grow.

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