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Expert Group Meeting on Fish Protein
Concentrate Production

Agadir, Morocco, 14 - 18 December 1969

HISTORY AND PRESENT TRENDS IN FISH PROTEIN CONCENTRATE PRODUCTION 1/

by

Oswald A. Roels
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Palisades, New York, USA

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United Nations Industrial Development Organization

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Working Group Meeting on Fish Protein
Concentrate Production

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SUMMARY

HISTORY AND PRESENT TRENDS IN FISH PROTEIN CONCENTRATE PRODUCTION

by

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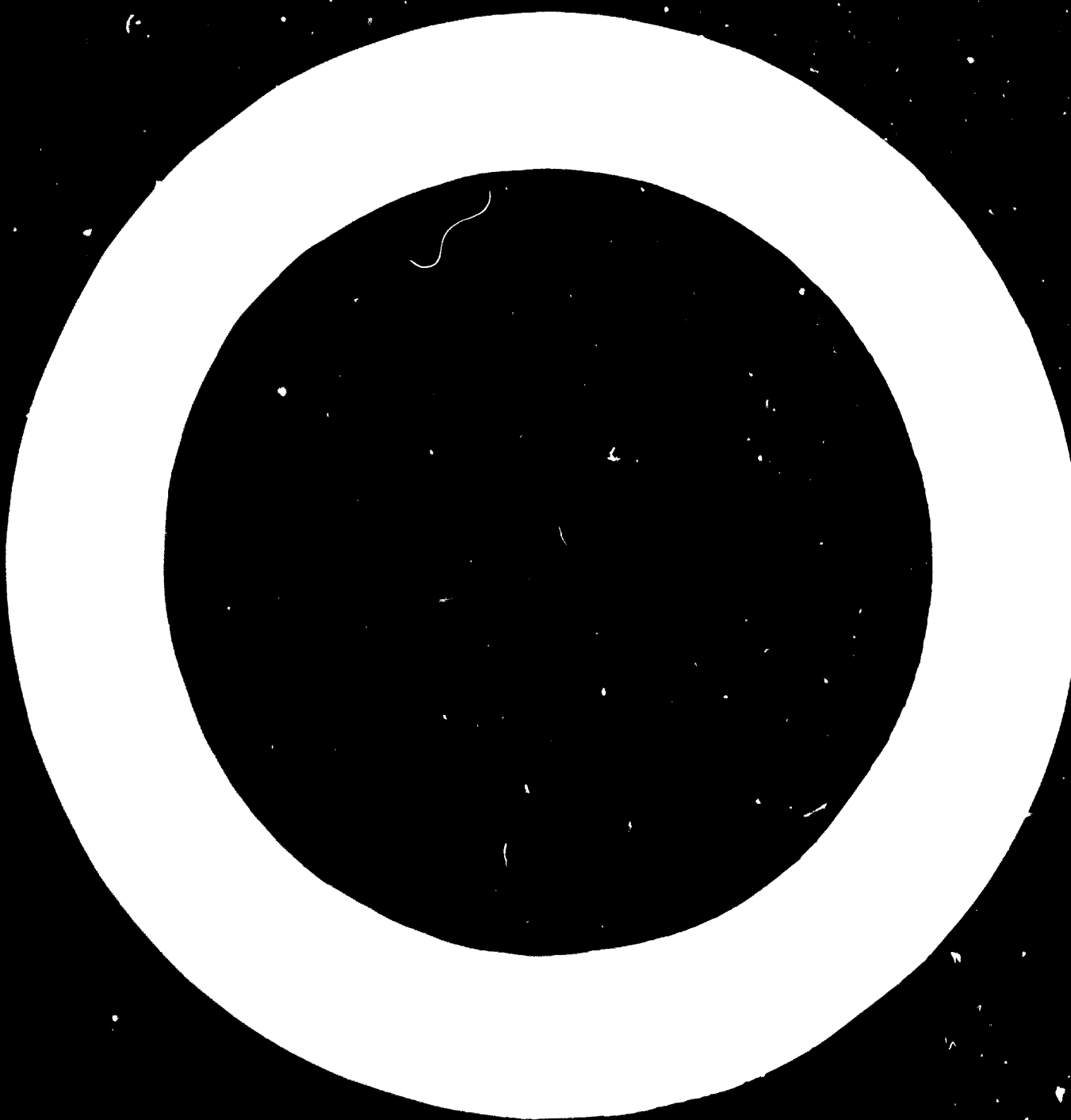
The paper discusses a series of topics as suggested by UNIDO.

Introduction

Fish is an important part of high-quality protein in the world. This is especially true for utilizing fatty fish — the world's largest fisheries [illegible]

Fish Protein Concentrate

[illegible]



Political changes resulting in economic upheavals in Africa brought these developments to a standstill.

Solvent-Extracted Fish and Fish Meal: Fish Protein Concentrate

A great number of processes to prepare defatted fish protein concentrate by solvent extraction were developed in several countries: the Union of South Africa, Chile, the U.S.A., Canada, Morocco, Peru, Sweden, Germany and Britain. In these processes, whole fish is extracted with one or more solvents to remove most of the lipids. The resulting defatted fish is dried and ground. The biological value of these products is generally excellent, but they have no 'functional' properties. They are bland and can be best incorporated in bread, cookies, macaroni and the like. Solvent extraction processes may be quite expensive. Punitive legislation in the U.S.A., including restriction of the preparation to lean or non-oily fishes, and a limitation on the size of the packages to one pound, make the product rather expensive.

Fish Protein Hydrolysates

Several processes have been developed, and others are under development, to prepare fish protein hydrolysates by chemical, enzymic or microbial hydrolysis of fish to prepare water-soluble fish protein hydrolysates.

Newer Developments

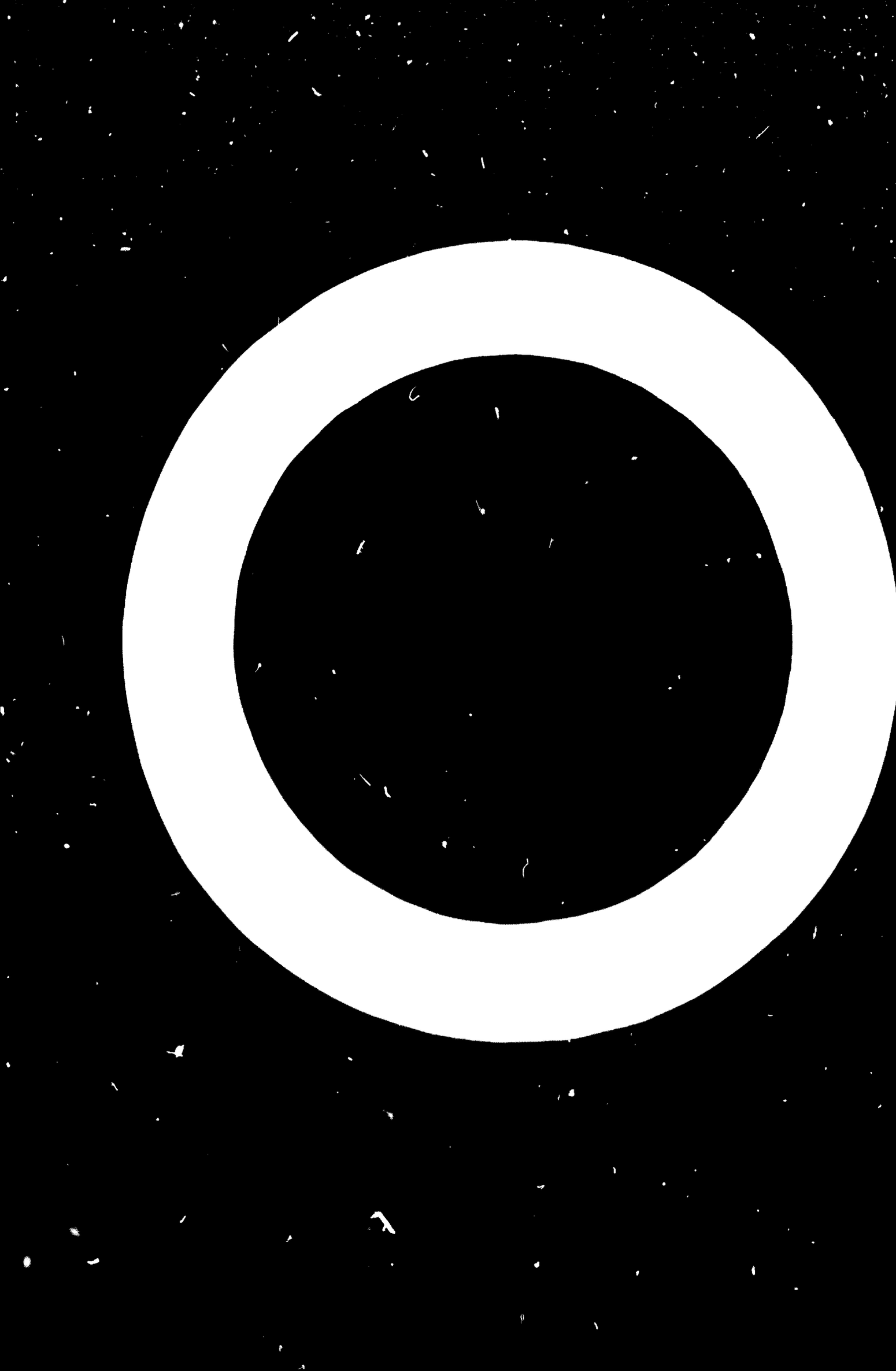
Other fermentation processes using lipolytic micro-organisms to convert the fish oils into microbial protein, carbohydrates and lipids, leaving the original fish protein unchanged, are under development.

A method in which fish is fermented with a micro-organism which prevents peroxide formation in the fish oil has been developed and is beginning to find small-scale application.

New Marine Protein Resources

Artificial upwelling of deep water can produce high yields of marine proteins, thereby avoiding erratic fish catches which may

adversely influence the economics of the operation of fish plants and Fish Protein Concentrate production. In this process, nutrient-rich deep water is pumped from the nutrient maximum in the sea—usually at 500–900 meters depth — to the surface, thereby fertilizing the euphotic zone where photosynthetic algae can grow. This creates a plankton bloom, capable of sustaining populations of filter-feeding organisms, such as shellfish and certain types of fish. The process is most easily applicable in areas where deep water is close to shore.



CONTENTS

Introduction

1. Food production per capita is declining in the developing countries.

Despite an estimated increase of world food production by about three percent in 1967, food production per capita in the developing countries as a whole averaged about three percent less in 1965-1967 than in the preceding three-year period (1).

2. The shortage of high-quality protein is acute.

The Advisory Committee on the Application of Science and Technology to Development reported to the Economic and Social Council of the United Nations in 1968 that "the quality (notably protein) of the food consumption pattern is even more critical than the quantity of food (calories), which is already causing considerable concern in many areas throughout the developing world. For over one-third of the present population in the developing countries, the protein-calorie balance of the diet is inadequate. The Advisory Committee has not tried to calculate the size of the protein gap.

Various methods have been devised in attempting to do so. Although there may be wide differences in the resulting figures, they all indicate that such a gap exists, and experts are unanimous in emphasizing that a gap is undeniable and increasing.

"The gap between the nutritional requirements and the actual consumption of protein by the greater part of the populations in the developing countries is widening rapidly. Protein deficiency already has serious consequences for the health and working efficiency of the populations of developing countries. If the situation worsens, the physical, economic, social and political development of the populations involved may be completely arrested. Protein-calorie malnutrition not only increases susceptibility to acute and chronic infections, but also causes a compensatory reduction in the capacity for physical activity and promotes apathy. These direct effects on adult populations impede the economic productivity and development of countries which are desperately in need of improving the status and potential of their peoples, quite apart from the human suffering involved.

"The growing nutritional deficiencies have even greater impact on young children in developing countries. In some countries, as many as one-third die before reaching school age, and for most of the survivors physical growth and development are impaired. Moreover, there is increasing evidence of associated retardation in mental development,

learning and behaviour, due in particular to malnutrition in early childhood. Thus, the nutritional deficiencies existing at the present time in many developing countries already are jeopardizing the future for many millions of the world's people."

"The resources required to close the protein gap and then maintain adequate per capita production and consumption of protein are very large. While the land available and existing technology permit the world to feed adequately even larger populations than at present, improvement of conventional agriculture in the developing countries is not taking place rapidly enough, nor can it be expected to on the basis of presently projected efforts. It must be supplemented by protein-containing foods of unconventional origin, such as oil-seed meal, fish-protein concentrate, single-cell proteins and the effective use of synthetic essential amino acids and non-specific nitrogen sources. In order to achieve the improved utilization of these sources, there must be greater emphasis on nutrition education and on the processing, marketing and promotion of food products." (2)

3. Present fisheries resources, particularly fatty fish, are utilized inefficiently in long food chains.

The animal protein shortage could be filled readily by a more efficient use of present fisheries resources. The annual fish catch represents currently about fifty million tons of fish, containing about ten million tons of animal

- [redacted] and fish protein concentrates could [redacted] the [redacted] protein shortage.

[redacted] the conversion of fish flesh for human consumption [redacted] fish protein concentrates should therefore aim to:

  - [redacted] existing fisheries resources--[redacted] by converting fatty fish into an [redacted] for man;
  - [redacted] the waste of fish protein by cutting out [redacted] the extraction of oil;
  - [redacted] an [redacted] and enabled [redacted] a technically and economical point of view.

- [redacted] for human consumption

[redacted] the specialized agencies of [redacted] as the important contribution [redacted] can make to human nutrition on an [redacted] with technical aid. This [redacted] to the Third Inter-[redacted] Conference in September, 1958.

[redacted] the extraction [redacted] high [redacted], for the purpose [redacted] and related [redacted] the [redacted] steps in a

number of countries a flavorless fish flour would be preferred, whereas in a number of other countries, such as in South East Asia and Africa, fish flour with certain flavors might be preferred."

"In the meantime, a great number of nutritionists, government officials, etc., all over the world became interested in the great possibilities of edible fish flour and UNICEF and FAO are arranging for a series of acceptability tests in different countries in cooperation with local fisheries and nutrition people. In Malaya, Indonesia and the Philippines, a number of government workers have embarked on these experiments themselves. It is interesting to note that adults in Indonesia preferred a local fish flour of selar (Caranx spp.) with a rather pronounced flavor to a flavorless fish flour. According to information received, small children and infants do not show this preference, however." (4)

The development of fish flours with full fish flavor for human consumption is based on hard economic facts: the wholesale price of fish meal for animal food is currently (1969) about 4.6 U. S. cents per pound. Since this fish meal contains 65% protein, the cost of the protein in the meal is approximately 7 U. S. cents per pound. If such protein could be utilized directly for human consumption with relatively little increase in cost, few other available proteins could compete with it. Moreover, the biological value of fish meal is well established. Therefore, several attempts were made in the 1950's to produce inexpensive fish flours for human consumption.

All these products had strong fish flavour; it was for this reason that they were accepted and bought by the consumers. In these African countries, the staple food is usually a bland starch, and the fish flour was used to prepare a sauce which added flavor to this food.

It should be realized that in many underdeveloped areas, the population groups which most require high quality protein supplementation of their diet live essentially in a subsistence economy; they grow and produce their own food and have a very low monetary income available for buying food. In the African countries where I have had experience, one of the regular purchases made was salt. When the fish flour could be presented as another type of condiment to add flavour to the diet, it sold well, even in areas such as Rwanda and Burundi where the population was traditionally vegetarian.

1. Ghana

In Ghana, the Fisheries Service of the government built a pilot plant in Accra in 1951 to produce fish flour for human consumption (5, 6). The fish used was [illegible] caught in the coastal waters from June to September. The product was prepared by autoclaving the fresh fish, pressing it to remove part of the oil, and drying the resulting cake; it was sold at twenty-one cents per kilo in 1953 and the small pilot plant could never produce enough to satisfy the demand. A larger fish flour factory was therefore included in the construction plans for Tema Harbour.

This approach can obviously also be used to produce fresh-water fish.

[redacted]

1. **South Africa**

One of the early efforts in this area was undertaken by the "Fishing Industries Research Institute" of South Africa in collaboration with a private firm, "Marine Oil Refineries of Africa." This group prepared a deodorized fish protein concentrate by extraction of whole fish (Trachurus trachurus) with ethanol (19, 11). This deodorized, defatted fish flour was [illegible] in all the bread baked in [illegible]. It was then found that the population groups who needed the protein supplement most did not buy bread in the first place. This highly motivated government-[illegible] was therefore abandoned.

2. [illegible]

[illegible] of this [illegible] in South Africa [illegible] reported [illegible]

[illegible] edible [illegible]

2. the "fish consciousness" of the population and authorities of Chile is very high after the work of an FAO Technical Assistance Expert in Fisheries Propaganda, and of others;

3. the FAO Regional Office in Santiago has the services of a Nutrition and of a Fisheries Officer;

4. at present, the Chilean diet is short in animal protein;

5. official authorities and a number of interested nutritionists and other workers are eager to give their full cooperation.

"In preparatory experiments the fish flour was mixed into a number of foods such as vegetable soup, potato soup, tagliarini (alimentary paste), cochayuyo (edible algae), fried potatoes and lettuce, beet leaves pie, beans, beef stew, boiled potatoes, cocktail crackers, coffee cake and white bread.

"In the preliminary tests, these combinations were judged by a limited number of persons, who found the preparations generally acceptable, except for the tagliarini, the cochayuyo and the beef stew, about which the main complaint was that the texture was not normal (this may be overcome by using a more finely milled fish flour). The beet leaves pie, the crackers (2% fish flour), the coffee cake (10% fish flour) and the bread (10% fish flour) were unanimously accepted.

"Based on these preliminary results a large scale trial was started involving 140 school children, 5 to 14 years old, who every day during six weeks, as part of their school lunch each received an 80-gram bread roll made at a commercial bakery, which used flour containing 10% fish flour. Compared with normal bread, the only difference was a slightly darker color; smell, taste, form and consistency of crust and crumb being normal.

"The bread was very well accepted by the children. There was not a single case of rejection or complaint. No digestive trouble traceable to the bread occurred.

"Each bread roll contained 6.1 g fish flour, which provided a child with a daily supplement of: 4.4 g protein, 115 mg calcium, 320 mg phosphorus, and 3 mg iron, where the roll itself supplies 6.5 g protein.

"The same type of fish-flour-fortified flour was used during a short period in bread given to young men in a military camp. Here also this type of bread was very well accepted.

"After these results had been obtained the Chilean Government sent a request to UNICEF and FAO to help them in setting up a plant for the manufacture of edible fish flour to be used mainly in supplementary feeding schemes."

Later on, UNICEF assisted the government of Chile in the production of Fish Protein Concentrate by providing the supervisory engineering services and the necessary processing equipment which was installed at the ISFSA (Industria Pescera

de Altamar) plant at Quintero in Chile. A report on the operation of the plant, the biological value of the product, and all cost details was prepared by Layton F. Allen, the senior engineer for the United Nations Children's Fund, and published in Fishing News International in January, 1963 (12). The plant used fresh hake (merluzza), which is a lean, edible fish. The process uses a combination of hexane and ethanol extractions for fat removal and deodorization. The plant used a horizontal, steam-jacketed, air-swept, raw fish dehydrator with scraper, agitator and condenser; a horizontal steam-jacketed rotary extractor with integral cloth filters and the necessary connections for a vacuum solvent flow and steam stripping; a solvent recovery and storage system; an alcohol purification system; a hammer mill for the dehydrated meal; a hammer mill, flour sieve and packing arrangement for the deodorized product; and the necessary hoppers, conveyors, bucket elevators and cyclones to transport the materials between operations. In this plant the raw fish is first heat-dried in air and the so-obtained meal is extracted with ethanol or with hexane/ethanol. Drying of the raw fish is accomplished in a steam-jacketed horizontal vessel, agitated by a steam-heated cage of cubes. Meal-drying temperature can be controlled over a range of 70-100°C by adjustment of rate of air circulation. Under these conditions, drying requires about six hours per batch of two tons of whole, fresh merluzza, including time for charging and discharging. Defatting and deodorizing of the ground meal are accomplished

by solvent extraction of batches of the dried meal in a jacketed rotary extraction vessel by countercurrent washings with batches of solvent. Most of the solvent is removed from the fresh meal by agitation and heating under vacuum. The partially fried meal is then stripped of residual solvent with reduced-pressure steam under vacuum. Maximum temperatures during this operation is 80°C. The yield of dried, defatted product is about 16% of the initial fresh fish. The product contained, on an average, 1.5-10% moisture, approximately 80% protein (N x 6.25), 1.6-3% fat, with the rest ash. The fluoride content varied from about 150 to 220 parts per million, and the lysine content approached 5%. Total processing costs, including the price of raw fish, the fish oil recovered, electricity, steam, water, labor, solvents and packaging supplies, were estimated to be 268 U. S. dollars per metric ton of defatted and deodorized fish flour, with the hexane/ethanol process, based on prices in Quintero, Chile, in December, 1961.

In a recent publication describing the Quintero Fish Protein Concentrate (13), it was stated that the product was sold at 35 to 55 U. S. cents per kilogram, but that the exact cost of this product was hard to calculate since the plant was built with the technical and financial aid of UNICEF, is owned by the Chilean government, and is operated by private industry. The Chilean government is expected to favor Fish Protein Concentrate produced locally in Chile for

[redacted]

[redacted]

- [redacted]

[redacted] the same time, the Stolle Research and Development Corporation (SRDC) began work on a process to extract oil from fish by means of ethylene dichloride. This solvent separates the oil and removes the water from fish by azeotropic distillation. SRDC had been using this process for oil and water extraction from liver, marrows and whole organs from cattle and also which they undertook on a contract basis for the pharmaceutical industry. This first extraction yields a product with approximately 71.7% protein content, 1.1% ash, 1.1% fat, 0.5% crude fiber, and 8.5% moisture when lean fish is used. This product is now offered as a milk replacer in animal feeds, and sells for about fifteen cents per pound (Smith 1969) when bought in fifteen ton lots.

The advantage of this type of partially defatted fish protein feed is that it can be used to feed chickens, pigs, etc., right until slaughter without impairing the flavor of the meat. Regular fish meal cannot be fed to animals for several weeks prior to slaughter because it gives a fishy flavor to the meat.

VioBin utilizes a second extraction of the ethylene-dichloride extracted product with isopropanol to remove the last traces of fat and the flavor.

of view of protein supplementation of the diet (14). The Bureau of Commercial Fisheries uses a multi-stage isopropanol extraction process to remove both water and oil from the fish, and obtains a bland and finely ground product. A very detailed description of the multi-stage isopropanol extraction process developed by the Bureau of Commercial Fisheries is given in the brochure "Marine Protein Concentrate," published by the United States Department of the Interior, Fish & Wildlife Service, Bureau of Commercial Fisheries, Fishery Leaflet 534, Washington, D.C., April, 1966 (14).

After intensive toxicological and biological evaluation, the FDA passed a regulation on February 2, 1967, admitting the wholesomeness of the product, but restricted its preparation to fish protein concentrate made from whole hake and hake-like species of fish prepared by solvent extraction of fat and moisture with isopropanol or with ethylene dichloride, followed by isopropanol (15).

The Food and Drug Administration's specifications for fish protein concentrate are the following:

1. It must be made from hake or hake-like fish.
2. It should have a minimum protein content of 75%.
3. It should have a maximum water content of 10%, a maximum fat content of 0.5%, a maximum fluoride content of 150 parts per million, a maximum isopropanol content of 250 parts per million, a maximum ethylene dichloride content of 5 parts per million.

4. It should be free of [illegible]

The Food & Drug Administration has stated that fish protein concentrate is supposed to be an additive intended for use in the household only as a nonstaple supplement. The additive must be packed in containers that each contain not more than one pound in weight. This regulation effectively prevents the use of FPC in formulated foods at the manufacturing level. The U. S. Food and Drug Administration approval of whole FPC, achieved through the determined efforts of the U. S. Bureau of Commercial Fisheries, was nevertheless extremely important despite its restrictive aspects. Now several firms in the United States and outside are now seriously considering the production of protein foods utilizing whole fish (16).

The Bureau of Commercial Fisheries has very recently awarded a two-million-dollar contract to Seattle Engineering, Inc., to build a pilot demonstration plant at Seattle, Washington, U.S.A. The plant will be operated by Pan Fish Foods, Inc., and will use the isopropanol process developed in the Bureau of Commercial Fisheries.

e. Cardinal Proteins

The "Cardinal Proteins Co." is building a plant in Canada which will use the U. S. Bureau of Commercial Fisheries process for the production of thirty tons of Fish Protein Concentrate per day from red hake. This company plans to debone the fish with a specially developed [illegible] machine prior to isopropanol extraction. This should bring

product contains 85-91% protein, 1-1.5% minerals, 1-8% water and less than 1% lipid. The product has high biological value. Extensive biological evaluation of the product was made, by both animal and human testing.

7. Germany

A process was developed in Germany during World War II in which ground whole fish was stirred in 0.5% acetic acid. This slurry was then pressed and the press cake extracted with ethanol. Following ethanol extraction, the press cake was hydrolyzed with alkali and filtered. This yielded a protein solution which was neutralized with acetic acid and spray-dried. The product is a pale white, water soluble powder which was used as an egg white substitute during World War II in Germany. The product was manufactured on a large scale in that period.

German patent 577,130 was issued to Vogel and Company in Germany to extract fish with ethanol after acid or alkali treatment. The fish is subsequently re-extracted with acetone and dried in vacuo.

8. Britain

Cavanagh and Inman obtained British patent 81,909,130 for the production of fish protein concentrate by extracting fish with solvent mixtures of acetone, ethyl acetate, and ethanol.

c. [redacted]

[redacted] research has been undertaken recently in our own laboratory [redacted] several others to try to improve these methods [14]:

i [redacted]

- [redacted]

[redacted] a process which yields a product containing [redacted] extremely low [redacted] than 0.1%. The product is water soluble up to 20% w/v. The process uses a chemical hydrolysis yielding a product which is [redacted] of great biological value. The process follows a number of very simple steps: chemical hydrolysis is followed by filter cake separation of the precipitate which from the oil stage this [redacted] phase. The precipitate is then washed and the resulting liquid is spray dried.

- [redacted]

[redacted] of enzymic hydrolysis are also under study [redacted] a number of commercial processes in the [redacted] have been investigated and comparisons made of the [redacted] for the production of [redacted] products [redacted] and have been [redacted] which is [redacted] and [redacted] the [redacted] and the [redacted] of the [redacted] and the [redacted]

mass is desludged in a centrifuge and the aqueous and oily phases are separated. The aqueous phase is then dried by various means, yielding a protein hydrolysate consisting essentially of fish amino acids and small peptides.

Tryptophan tends to be low in fish protein hydrolysates.

The Rohm & Haas Company in Philadelphia, Pa., U.S.A., has developed an experimental proteolytic enzyme which hydrolyzes solvent extracted, completely deodorized and defatted Fish Protein Concentrate. Their enzyme is called "experimental enzyme 'A.'" Its pH optimum is 10.0. Rohm & Haas claim that up to 95% of the original protein nitrogen can be solubilized by incubation of solvent-extracted FPC with this enzyme. They recommend a temperature of 60°C for the enzymic digestion. The resulting enzymic digest is filtered and the filtrate, containing small peptides and free amino acids, is spray dried. The product is colorless and almost tasteless, and contains 77% protein. The biological value and the cost of the process are not known to the author.

3. Fermentation Processes

a. Proteolytic microorganisms

The microbiologists of the University of Uruguay have developed a method to process a fish protein hydrolysate using a proteolytic yeast, Yarrowia lipolytica. Molasses is added to the whole ground fish. The mixture is then inoculated with the yeast culture and fermented for 18-20

hours at 30°-32° with slow stirring. A primary filtration removes scales and bones and a centrifugation step removes the oil. The product is concentrated by low temperature evaporation until it reaches 50% solids, followed by spray drying. This yields a product containing 70-72% protein, 5-6% moisture, 12-14% ash and approximately 5% fat. A pilot plant utilizing this process is now in operation in Uruguay.

The Reliance Chemicals Corp. has obtained U. S. Patent #3,170,794 for the production of protein meal from fish by utilizing fungal enzymes to digest and liquefy the fish and to neutralize the fish taste and odor. The fish meat is cooked for 5-15 minutes at 60°-70°C. The fungal proteolytic enzyme is added with wheat bran, brewer's yeast and sugar. The fermentation is carried on for 8 hours at 52°-54°. The product is then heated to 70° and dried.

The Central Food Technological Research Institute in Mysore, India, has prepared protein hydrolysates from fish using papain as the proteolytic enzyme.

Israeli Patent #11,912 was issued to the Prolax Company to prepare a fish protein hydrolysate by fermenting fish with Lactobacillus plantarum in a culture medium containing rye bran, ground barley, wheat bran, grass meal and mannose flour. Lactobacillus plantarum has high proteolytic activity at pH 6.

b. Lipolytic microorganisms

Another process now under development in my own laboratory attempts to produce acceptable human foods from abundant and inexpensive fatty fish, by fermentation with lipolytic microorganisms capable of reducing the fat content of the fish by about 50% and producing a pleasant flavor reminiscent of certain foodstuffs commonly acceptable in Western society (29). The object of our fermentation program was:

1. To utilize an abundant and inexpensive fish product not much consumed by man
2. To produce a food with pleasant aroma and flavor;
3. To maintain or increase the protein content of the product without impairing its biological value;
4. To reduce the fat content of the raw material, thereby increasing the shelf life of the product.

The best results were obtained with an unidentified fungus, Geotrichum candidum, in herring fish. This fungus shows very considerable lipolytic activity when inoculated onto fish has a high fat content is fermented with this microorganism. The fermentation product has a mushy cotton like aroma and any remaining traces of the smell of the starting material although there was flavor removal after the ferment a change. There was a significant gain in amino nitrogen and a small tentative reduction of the amount of amino nitrogen during fermentation

[redacted]

the energy necessary to raise the water about 10 feet--
i.e., to overcome the friction in the pipes, since there
is a considerable pressure differential between the deep
water and the surface waters.

It is hoped that this "brine pump" project will, in the long run, contribute very significantly to increase the protein resources from the sea, and that the development of suitable forms of fish preservation will eradicate protein malnutrition.

[illegible]

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[illegible] [illegible] and [illegible] [illegible]

[illegible] [illegible]

[illegible] United Nations Economic & Social Council [illegible] of the [illegible] Food [illegible] of the [illegible] the [illegible] Report of the Secretary General [illegible]


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