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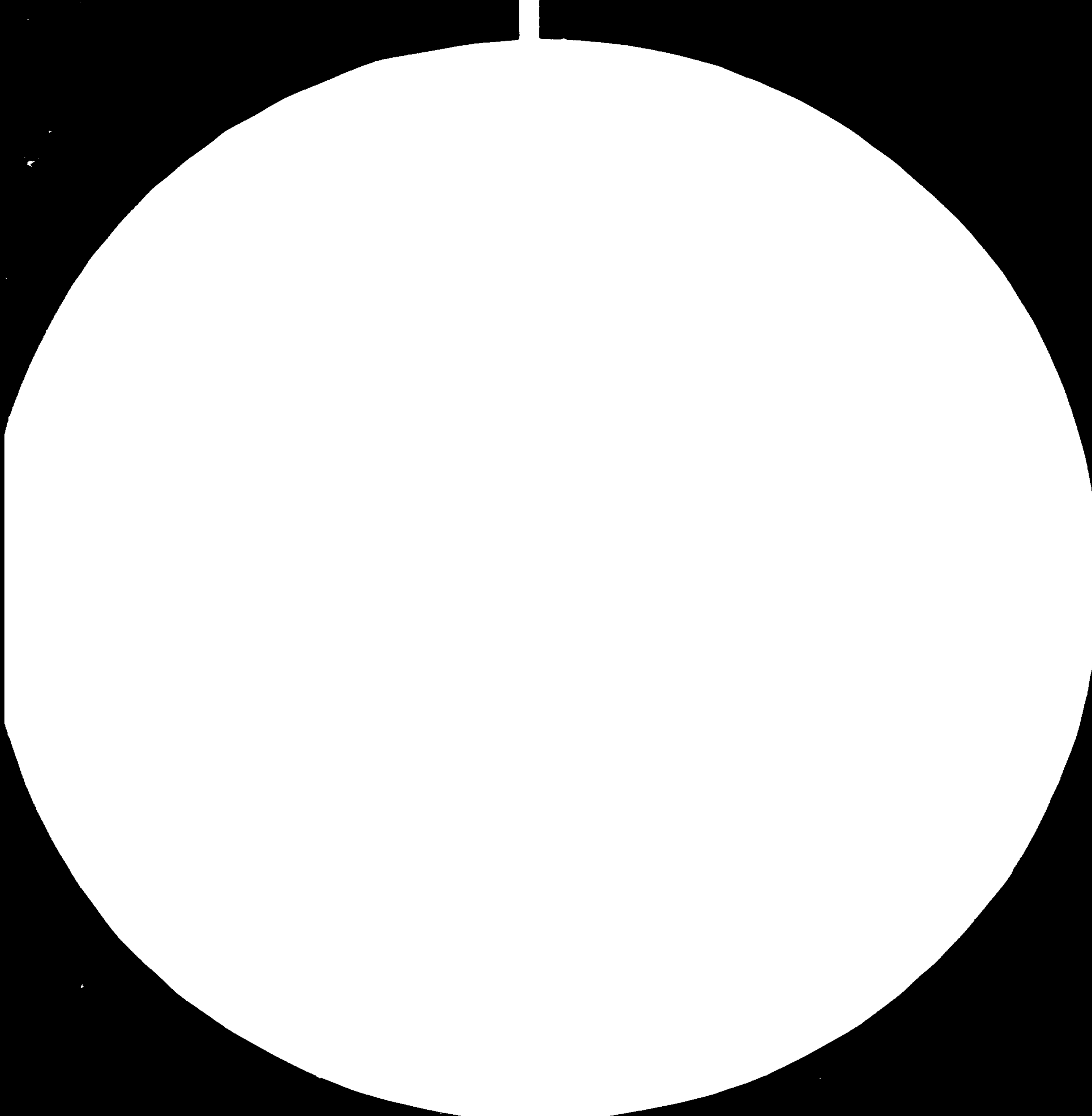

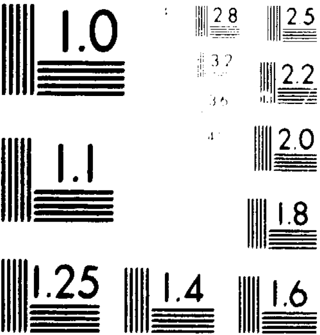
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AQUEOUS PROCESSING OF SMALL PELAGIC SPECIES (*Opisthonema libertate* and *Pneumatophorus peruanus*) INTO WET PROTEIN PRODUCTS FOR USE AS INGREDIENTS IN PROCESSED FOODS

UF/ECU/77/064
ECUADOR

Terminal report*

Prepared for the Government of Ecuador
by the United Nations Industrial Development Organization

Based on the work of Maynard A. Steinberg,
UNIDO expert

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INTRODUCTION

Animal protein from beef, pork, poultry and other terrestrial animals is readily available to people who have the money with which to pay the market price. This applies to food fish as well but fish, differently from domestic mammals and birds comprise a very large number of species with different edibility characteristics and, therefore, different market prices. Usually, even the lowest of which either precludes or limits the ability of low income groups to buy. It is often, if not usually, the case that these groups suffer from protein malnutrition. Despite this, fish alone offers the possibility of increasing the supply of animal protein at a price low enough to become a part of the diet of many who cannot now afford it. This paradox is explained by the fact that world-wide there are large resources of small pelagic species (fish that live in the upper layers of the oceans) that are not used at all or are used only for the production of animal feed in the form of fish meal. These species are generally caught at relatively low cost because they are found in large, dense schools, usually fairly close to shore. They include the anchovetta, anchovy, menhaden, capelin, many other anchovy and herring-like species and several species of mackerel. They are characterized by high oil content, dark flesh, strong flavors and strong odors. All of these species tend to deteriorate rapidly after being caught because of the action of the very strong proteolytic enzymes in the gut, especially when they have been feeding. These qualities explain why most of these species are little used for food. There are exceptions, of course. The Atlantic herring is highly prized as a food and unique processing techniques have been developed through the years to utilize herring in a number of different forms as smoked, salted and pickled products. Some traditional methods of processing such as canning are used for thread herring, alewives, and mackerel but their use is limited, especially in developing countries where the cost of cans is high and, of equal importance, in many countries of Latin America there is little consumer interest in species that are not lean and light in color.

A specific example of the most common use to which small pelagic species are put is provided by the fishery statistics of Ecuador. In 1978 total fin-fish landings were 575,000 metric tons (MT).* Some 96 percent of these landings were small pelagic species and almost all of these were used for the production of fish meal. Not more than about four percent of the landings(about 25,000 MT) were used for food; presum ably they were predominantly lean, white fleshed species. The annual per caput availability of these fish, landed in the round (whole fish), is about 3.2 kilos or approximately one kilo of edible flesh. This is a shockingly low figure for availability considering that the landings of 550,000 MT of small pelagic species alone constitute a potential annual per caput food fish availability of about 70 kilos in the round or some 23 kilos of edible flesh.

Since the consumer has shown disinterest in these species in the traditional forms in which fish are marketed a new approach to their utilization is called for to increase protein foods supplies.

Success in these efforts will also broaden the base of the fish harvesting and processing industry and, depending on the characteristics of the processed fish flesh, it could lead to integration of the fish industry with the entire food-processing industry.

These goals can be realized if acceptability of the lowest priced and most abundant fish, the small pelagic species, can be developed by improving their edibility characteristics.

The problem is a difficult one. It has been attacked previously by efforts to produce fish protein concentrate (FPC) by extracting water and oil with organic solvents leaving a dry protein of high

* This does not include 24,000 MT of tuna. This species has not been included here because it is a fully developed, perhaps overdeveloped, fishery, the consumer products of which are expensive and in high demand by upper and middle income groups.

nutritional value but with no other property that might make it interesting to the food processing industry or to the consumer. FPC is a gritty powder that is difficult to wet, does not retain water well after it has been wet, does not emulsify oil, and, in one of the major uses for which it was intended, i.e., bread, it tends to reduce the volume of the loaf. Finally, its cost was higher than anticipated because of the high capital investment and operating costs.

Another approach to this problem was taken by Mackie* who studied enzymatic procedures for solubilizing the protein of cod and haddock (white-fleshed species of very low oil content). His final product had a slight bitter flavor, may have lost essential amino acids and required costly drying methods. He commented that "Such studies also relate to problems of recovering protein and oil from pelagic species. We have not yet studied this latter problem to any extent but it would appear to be a subject of even greater importance in a worldwide sense and one which clearly merits further attention. We have selected what we consider to be the simpler problem of determining methods of recovering protein from fish processing waste".

PROJECT OBJECTIVES

This very brief account of two earlier efforts to produce edible protein products from the waste of processed lean fish and from oily species is intended to clarify the complexity of our objectives i.e. the preparation of protein products from oily species by methods that are simple, low in cost, retentive of desirable properties and consistent with consumer standards for flavor, odor and the forms in which these products can be used.

Another and equally important objective is to bring development to a stage where timely demonstrations of potential uses can be made to stimulate new business ventures in the fish processing industry and

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* I.M. Mackie, Potential Production of Powdered and Liquid Fish Products for Human Consumption and Animal Feed. FAO Technical Conference on Fishery Products, Tokyo 4-II/12/1973.

segments of the food processing industry generally.

The problem was approached with the knowledge that the shortness of time available did not permit consideration of the development of a process for a product to be used directly by the consumer. Efforts were directed to the development of a procedure for the preparation of a fish protein product that could be incorporated as an ingredient into traditional products such as processed meats, dry soup-mixes, sauces, baking flours, etc., at levels that would upgrade significantly the quantity and quality of protein.

SPECIES SELECTION:

Before beginning the development of a preparative procedure a brief but adequate survey was made to determine which abundant pelagic species were available on a year-round basis and which were available only seasonally; to get whatever information was available on composition (protein, oil, and moisture) as it varied with the season; size-range of species, suitability for mechanical deboning - this has specific reference to skin tougness, bone size and bone flexibility. These determine whether deboning machines can produce minced flesh only or whether the flesh will contain bits of skin and pieces of bone.

Finally, we learned ex-vessel cost of several species of fish landed in the round and in the headed and gutted form.

Landings of small pelagic species in Ecuador have increased enormously since 1965 at which time they were only about 7,000 MT. Ten years later landings were 132,000 MT and in 1978, the latest year for which statistics are available, they were 550,000 MT. According to some data from the Office of the Director General of Fisheries most of the landings were pinchagua (Opisthonema libertate) a sardine-like fish, but other statistics from the same source show macarela (Pneumatophorus peruanus) as the major species landed, at least in recent years.

Discussions with representatives of three of the major processors in the fishing port of Manta and with the Assistant Director of the School of Fisheries, Manta, informed us that pinchagua was available year-round and macarela only during its spawning migration of about four months, roughly from mid-October to January. Presumably, but not certainly, pinchagua is the major species landed; if not, it is landed in very large quantities.

Pinchagua is a small fish, averaging about 21 cm. in length* . Preparation of the fish for the deboning operation -- removal of head and viscera and thorough washing of the visceral cavity -- is, therefore, more costly than for larger fish. The skin is black and quite delicate in the smaller fish; this led to concern over difficulties in separating skin from flesh but working with :e species strongly suggested that the skin of larger pinchagua could be removed from the flesh on the deboner. Fortunately, the delicate lining of the visceral cavity of pinchagua is white, not black as in many other species, so the problem of discoloration of the flesh by this tissue does not occur. While not a lean fish by any means the flesh of pinchagua is relatively low in oil -- about 7 % at the time this work was done -- and the muscle is grey in color. Dark red, oily tissue occurs just under the skin and it would appear practical to leave it attached to the skin, which is "waste", by appropiate adjustments of the deboner. Because the relatively low concentration of red tissue the yield of myofibrillar protein (contractile protein low in oil, light in color, low in flavor and odor levels) should be relatively high; this would result in higher yields of end product than from macarela. At this writing no tests have been made on a deboner. There is none at the Institute.

Macarela averages about 25 cm. in length**. Those we have worked with have usually been closer to 30 cm. If the longer size are obtainable in large quantity manual evisceration and heading would be cheaper

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* Boletín Científico y Técnico, Vol. II, No.1 (1969) Instituto Nacional de Pesca del Ecuador (Guayaquil, Ecuador).

** Idem

than for pinchagua. Macarela has high oil content and high ratios of dark flesh to light. Since much of the protein of the dark flesh is discarded during extraction the yield of end product is relatively low. The skin is durable and would seem to lend itself to efficient deboning.

Ex-vessel prices for pinchagua are about the same as for macarela--about $ 90.00 per metric ton in October, 1980. A consideration of all factors makes pinchagua the clear choice for our work although the fishermen's preference for catching macarela during the availability of that species required that we work with whichever of the two species was being landed

EXPERIMENTAL:

As stated earlier, most efforts to use pelagic species as a raw material for the production of protein products for use in foods have been directed to extraction by organic solvents. The high cost of production and loss of functionality by the protein prepared by this method led us to approach the problem by means of aqueous extraction. The use of this extraction medium has the following advantages: low cost, simplicity, absence of hazards of fire and explosion, no residual toxicity, no need to remove residual extractant, retention of functionality in the finished product and, consequently, versatility of use of the product. Capital investment cannot be estimated at this point although it would be considerably lower than for an organic solvent-extraction plant and, would have very much lower insurance charges.

Aqueous extraction of fish muscle has not received much attention because it has theoretical deficiencies: poor solvent properties for the removal of oil and non-water-soluble flavor and odor components as well as reduced yield of end product because of good extractability of water-soluble proteins.

Work was begun on pinchagua by removing the spinal column and kidney manually from already headed and gutted fish. The skin and other bones were left on the flesh which was passed through a meat-grinder. The ground flesh was washed by agitation in five volumes of water, usually for ten minutes.

The free liquid was then decanted and the solids recovered by screening. Experiments included two water washes to determine the degree of improvement in odor of the product. Multiple washes did improve odor but readily detectable fishy odors always remained. Because the product contained skin it was dark grey in color and contained scales as well as bones. The apparent presence of these non-edible components was reduced considerably by passing the washed, minced flesh through a colloid-mill. Oil was rarely evident as an extracted component. Dissolved sarcoplasmic protein was the major product extracted and its presence and contribution to strong fishy odors became obvious when aqueous extracts were heated to 40° or 50° C. At these temperatures the soluble proteins precipitated quickly and gave off a strong odor of stale fish; lipids, too, seemed to be involved because some odor components were very similar to those of the brine in which barrelled herring have been held for some time.

Yields of macarela after one wash and screening were only about 15 percent of the weight of the round fish after converting the washed flesh to the original moisture content of the flesh.

Efforts to improve the odor of the product included aqueous ice-water extracts with: water, 0.1 M sodium bicarbonate, or 0.1 M sodium chloride. No obvious improvement in odor resulted from extraction with either of the salt solutions but analysis of the extracts showed that the bicarbonate solution extracted more oil than either of the other two treatments. Neither hot extraction alone at 50° C nor extraction at 50° C following an ice-water extraction nor alteration of pH from that of 6.4 -- normal for aqueous slurries of pinchagua -- to pH 5.1 or to 7.0 before extraction improved the odor of the final product.

Minced, skinned fillets from round macarela were given some of these treatments (cold and hot extractions) and showed major losses.

Extraction at 50° C caused losses estimated to be about 90 percent of the starting weight of the mince.

Despite only modest improvements in quality of the extracted flesh--due in part to the poor condition of the fish — cold-washed minced flesh of manually deboned headed and gutted pinchagua was used as a partial replacement for beef in sausages (frankfurters) and in drum-dried corn-flour-fish mixtures.

For sausages, the samples of minced pinchagua were treated with single ice-cold washes of five volumes each of: 1) water, 2) 0.1 M sodium Bicarbonate, 3) 0.1 sodium chloride. The yield of once washed flesh was 30 percent based on the estimated weight of round fish (we worked with Pinchagua already headed and gutted). Each washed sample of mince was used at beef replacement levels of 16,16 and 14 percent, respectively. The moisture levels of the washed fish were adjusted to the moisture content of the unwashed flesh, hence the differences in meat replacement levels. Sensory comparisons were made between the meat-fish sausages and all-meat sausages made according to the same formulation. Thirty five untrained panelists were presented with these samples simultaneously; two samples were identical, the third, of course, was different. Each presentation included either one or two samples of all-meat sausage. Panelists were asked to identify the odd (different) sample and to state the sample(s) they preferred. Seventeen of the panelists identified the odd sample correctly. Ten of these preferred the samples containing fish (water-washed-2, bicarbonate washed-3, salt washed-5), one had no preference and six preferred the all meat sausage. These tests were made after the sausages had been in refrigerated storage for 9 days - sufficient time for the development of flavors and odors peculiar to fish. Although the pinchagua used was not of good quality and included skin the results show that 51 percent of the panelists could not distinguish all meat sausages from meat-fish sausages and that 59 percent of those who made correct identifications preferred the meat-fish sausage.

A second test of sausages was made with preparations of manually deboned pinchagua (skin on) and skinless, manually deboned macarela, each washed once with ice-water and replacing beef at 14 percent and 20 percent levels, respectively. The emulsion of the fish-meat and the all-meat sausages were passed through a colloid mill before going to the stuffer, differently from the first test. Triangle tests similar to those described for the first tests were held to determine whether panelists could distinguish between meat-fish sausages and all-meat sausages. Unfortunately, panelists were scarce at the time and only six examined the pinchagua-meat sausages against the all-meat sausages. Five panelists identified correctly the all-meat sausage as being different. Of these, all five preferred the pinchagua-meat sausage. Tests on the macarela-meat sausage were made with only four panelists. All four distinguished between the all meat and the macarela-meat sausages; two preferred the macarela-meat sausage and two the all-meat sausage. While these last tests were inadequate because of the small number of panelists, both tests taken together permit several reasonably reliable conclusions: 1) the functionality of minced, once washed pinchagua is sufficiently unimpaired to permit the production of sausage with at least 16 percent of the meat replaced by the pinchagua. We are confident that higher levels of pinchagua could be used successfully but to this time we have not gone to higher levels; 2) the physic al characteristics (yield, color, weight-loss after cooking, moisture-content.) of the sausages containing fish are not different from those of all meat sausages; 3) there is a slight difference in texture between fish-meat and all-meat sausage in that with the same formulation fish-meat sausages are slightly softer. The detection of this difference requires side-by-side comparisons because the texture of fish-meat sausages is well within the range of textures of commercial meat sausages; 4) the flavor of fish-meat sausages is slightly different from that of all-meat sausages. The flavor of fish is not evident but the fish flesh alters the flavor to a degree that permits some panelists to detect the difference in side-by-side comparisons; 5) most of the panelists who could distinguish between the two types of sausages preferred those that contained pinchagua. The small number of panelists who tested macerela meat sausages precludes the development of any conclusions; 6) although our techniques at the time did not permit the manual separation of either skin or small bones from the flesh of pinchagua, processes that we consider essential to the production of products of good quality, no panelist commented on the presence of either of these foreign componets, even in the first tests on pinchagua, the fish meat emulsion of which was not passed through the colloid-mill; 7) spoilage characteristics of fish-meat sausages are no different from those of all meat sausages; 8) although the data are inadequate to permit conclusions, they suggest that there is little flavor difference in fish-meat sausages made from pinchagua extracted by: water, 0.1 sodium bicarbonate, or 0.1 sodium chloride.

The use of water-washed minced pelagic fish flesh in a strongly flavored product like sausage is, in my opinion, commercially feasible using the procedure already described, let alone a much more effective method to be described later. However, a more exacting application is one in which washed minced fish flesh is mixed with bland grain products like wheat or corn-flour for use as the nutritional base for products like soups and as proteinaceous ingredients in baked goods. Efforts were made to produce such bland mixtures on a 1:1 W/W (flour:wet washed, minced macarela and pinchagua) basis. The wet mixture was drum-dried. The dry product contained 10 percent fish with a protein content of approximately 86 percent. Corn flour was combined as above with manually deboned skin-on minced pinchagua treated with: one water wash; one wash with 0.1 M sodium bicarbonate; and one wash with 0.2 M sodium bicarbonate. The dry products were satisfactorily light in color but all had slight "fishy" after flavors. After storage at ambient temperature in polyethylene containers of about one mil for one to two weeks the flavor of fish in rehydrated mixtures was more pronounced. Efforts to mask the flavor with the flavoring ingredients from dehydrated commercial soups were not successful. The flavor of fish was attributed to the oxidation products of residual fish oil and the sarcoplasmic protein remaining in the coarse particles of ground fish.

Experiments with macarela were done to determine whether the use of a commercial mixture of antioxidants containing tertiary butyl hydroquinone as well as unknown antioxidants would be helpful in retarding rancid flavors and probable reactions between oxidized oil and protein, both mycfibrillar and sarcoplasmic.

In brief, antioxidant levels as high as 600 ppm had no beneficial effects on minced, manually skinned and deboned macarela treated with 1) a cold water wash; 2) a cold water wash followed by screening of the solids and heating for 10 minutes at 50° C to precipitate the sarcoplasmic protein in solution. The protein, which floated, was removed by suction and the hot residual protein rinsed with hot water; and 3) a hot water wash for 10 minutes at 50° C. This was not preceded by a cold water wash. The sarcoplasmic protein was removed as above.

During extraction with hot and with cold water, and centrifugation of extracts made at several pH's there were indications that the relatively large particle size of the ground flesh precluded efficient extraction of soluble componets and oil. The method of treating the flesh was then changed to one of grinding the flesh in a meat grinder and then macerating it in a Waring blendor at maximum speed for two minutes. The weight: volume ratio of flesh to iced water was 1/5.7. A plastic baffle that fitted the top of the jars closely prevented foaming (denaturation of the protein) during blending. Separation of the finely divided particles by screening was not possible; it was done in a Westfalia dairy-type separator. The centrifuge was always prechilled with ice water. It separated the extracts into four fractions: 1) The spent extractant containing oil, dissolved sarcoplasmic proteins and other water-soluble components; 2) a very finely divided paste-like fraction called the light fraction. In the case of pinchagua this fraction contained most of the grey flesh pigment; 3) a fibrous fraction called the heavy fraction. This was the largest fraction; 4) a solid oil fraction usually on the heavy fraction but sometimes on the light fraction as well. The heavy fractions of extracts of blended macarela and pinchagua of indifferent quality could be made essentially odor-free after two extractions and centrifugations. The light fractions usually had a "fishy" odor after the first extraction. This odor was essentially eliminated by a second extraction of that fraction alone. The question of the origin of the light fraction was considered but not resolved because of the lack of time and fresh fish. It may well be derived from the heavy fraction alone but there are arguments against this, e.g. the concentration of oil and of skin pigments of pinchagua in that fraction. The solidified oil probably results from the equivalent of a "winterization" treatment, i.e., the low temperature extraction and centrifugation freezing out the more saturated triglycerides, leaving the unsaturated oils in the light fraction and in the spent extractant. Its presence on the heavy fraction remains unexplained. The solid oils could always be removed easily with a jet of cold water. An experiment with ground, blended pinchagua, skin-free, treated this way for one blending and centrifugation changed the composition of the major fraction as shown in Table 1.

Table 1. Comparative Composition of Minced, Skinless, Manually Deboned Pinchagua with its Heavy Fraction Obtained by Blending and Centrifugation

Sample	Moisture	Oil % Dry Basis	Protein % Dry Basis
Minced Pinchagua	76.9	5.9	87.1
Heavy Fraction	78.7	0.3	91.3

The apparent increase in protein content of the heavy fraction reflects the removal of 95 percent of the oil. Four other experiments with pinchagua showed reduction in oil content of the heavy fraction ranging from 94 percent to 98 percent.

The average yield of the heavy fraction from three different preparations of pinchagua was 72 percent of the weight of the ground fish introduced to the blendor. Additional blending and centrifugation causes only small reductions in the heavy fraction and nearly corresponding increases in the light fraction, indicating that very nearly all oil and water-soluble proteins are removed from the heavy fraction in the first blending (wash) and centrifugation. This was confirmed by heating the spent extractant from the first and second blendings (washes). Precipitates of protein were copious in the first extractant but nearly absent in the second, even after acidification and centrifugation. However, both spent extractants gave off strong fishy odors when heated indicating that a second extraction is desirable.

Changes in composition of minced macarela flesh after one blending and centrifugation are shown in Table 2.

Table 2 Comparative Composition of Minced, Skinless, Manually Deboned Macarela with its Heavy and Light Fractions Obtained by one Blending Followed by Centrifugation

Sample	Moisture %	Oil % dry basis	Protein % dry basis
Minced Macarela	76.5	2.8	89.9
Heavy Fraction	84.1	0.4	92.1
Light Fraction	81.5	2.6	90.1

The heavy fraction was 65 percent of the weight of the minced macarela flesh, unadjusted for moisture.

The low oil content of the macarela mince is explained on the basis of careful removal of the light flesh from the fillets. The red flesh, which contains most of the oil, was left on the skin to the degree possible.

The oil content of the whole flesh of macarela is about 12-14 percent.

Despite the low oil content of the minced flesh the process removed 85 percent of the oil in the heavy fraction. The light fraction which is about 30 percent of the weight of the heavy fraction contains about the same concentration of oil as the minced flesh. After blending and centrifugation the oil content of the minced flesh is distributed between: the solidified oil found on the heavy fraction, the oil in the light fraction, and oil in the spent extractant.

The results with pinchagua are closely comparable in that the light fraction has about the same concentration of oil as the minced flesh after one blending and centrifugation. After a second blending and centrifugation of the light fraction the oil content is reduced by 99 percent. Table 3.

Table 3 Comparative Composition of Minced, Skinless Pinchagua and its Light Fraction after Blending and Centrifuging

Sample	Moisture %	Oil % Dry Basis	Protein % Dry Basis
Minced Pinchagua	76.9	6.0	86.6
Light Fraction, One blending and centrifugation	87.9	5.8	86.8
Light Fraction, Two blendings and centrifugation	85.2	0.06	92.3

The spent extract of the first blending and centrifugation was heated to precipitate the protein. This dried sarcoplasmic protein had an oil content of 15.8 percent.

Because of the encouraging results, both analytical and sensory, of this method of "deodorizing" fish flesh we prepared a product in which only lean, white-fleshed washed fish has been used previously*. The heavy fraction of macarela was combined with appropriate quantities of vegetable oil, flavoring, and other ingredients to make products whose flavor depends entirely on the ingredients used without the intrusion of the flavor of fish unless that is specifically desired. The spreads, flavored in one case with an onion-soup mix and in another with liquid smoke, met with good acceptance in informal tasting sessions involving non-laboratory people.

Mixtures of wheat-flour and the heavy fraction of pinchagua washed once were prepared so that the drum-dried product contained 10 percent fish by weight (equivalent to 50 percent fish on a wet weight basis). This product will readily reveal the presence of off-flavors like fish because the wheat does nothing to conceal or mask undesired flavors. The dry wheat-fish mixture, when suspended in hot water containing about two percent salt had no detectable flavor of fish for most people. The predominant flavor was that of wheat flour. When flavoring ingredients were added the mixture had all the characteristics of a good soup-stock.

We are enthusiastic over the results obtained by blending or milling ground fish flesh with water and then centrifuging the mixture to obtain separate fractions of protein and oil. Because the centrifuge equipment available was not designed for the use to which we put it our fractions were not always as cleany demarked as we wished. Discussions with manufacturers of industrial, low gravitational force, continuous centrifuges are needed together with tests on a pilot-plan scale to determine suitability of existing equipment. A flow-sheet for proposed production including equipment is shown in Figure 1.

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* Patashnik, M., G. Kudo, and D. Miyauchi. Smooth, White Spread from Separated Fish Flesh Forms a Base for Flavored Dips, Snack Items. Food Prod. Dev., July-August, 1973.

Additional work is needed, even with the somewhat inadequate centrifuge at the Institute in order to collect more data on the method itself. Deboning tests are essential to provide information on skin contamination, if any, of the flesh; flesh yield - the basis for accurate calculation of flesh costs, -frozen storage tests on the blended and centrifuged product, storage tests on drum-dried products, the selection and testing of packaging materials, -the testing of antioxidants to stabilize the product - consumer-type acceptance tests, demonstrations of the method and products to industry, protein efficiency ratio studies in various products to establish the improvement of nutritional value resulting from the use of these low cost species and, of course, scaled up tests at pilot-plant level (production of 50 - 100 kilos of wet product per day).

If the work is to be done by the Institute Staff, and I recommend it, some new equipment should be provided as well as replacement of some existing equipment. My suggestions include 1) a small deboning machine, 2) a minced flesh strainer of the Japanese type, 3) a silent cutter, 4) a stainless steel blendor jar of 4-8 liter capacity, 5) a continuous centrifuge appropriate to the needs of the project, 6) a stainless steel sink of large capacity, 7) a garbage grinder.

COSTS

Following is an estimate of production costs based on: capital investment (cost of buildings, processing and office equipment, etc.) labor, product yield, and value of waste products converted to fish meal. These estimates do not include profit, taxes, insurance, cost of money or land. Depreciation is ten years.

All estimates are crude, even including yield figures. These are based on findings with fish of acceptable but not good quality. They have been cut by hand in the laboratory by inexperienced people. Yields should be significantly higher from fresh fish cleaned by machine and deboned on properly adjusted machines.

All costs are in U.S. dollars.

Estimate of Production Costs

Capital Investment

Processing plant - building	$ 700,000
Processing equipment:	
tables sinks conveyors screens flumes pumps carts, etc.	$ 100,000
headers & gutters, 9 ea at $ 30,000	$ 270,000
deboners, 2 ea at $ 23,000	$ 46,000
centrifuges, continuous, wet stream 2 ea at $ 30,000	$ 60,000
centrifuge, solids discharge 1 ea at $ 25,000	$ 25,000
centrifuge, solids discharge (waste) 1 ea at $ 25,000	$ 25,000
strainers, 2 ea at $ 15,000	$ 30,000
colloid mill or equivalent 1 ea at $ 20,000	$ 20,000
Refrigeration: 0° C storage - 20° C storage ice machines	$ 400,000
Office equipment	$ 15,000
Vehicles 1 truck 1 car	$ 40,000
Fish meal plant capacity - 50 tons/day raw product - complete package	$ 1,000,000

Total - plants and equipment	$ 2,731,000
Cost of fish - 50 tons/day at $ 90/ton	4,500
Value of waste, 41 tons/day (wet) = 8 tons meat at $ 400/ton	$ 3,200
Net cost of fish = (gross cost) - (value of meal) = $ 4,500 - $ 3,200	$ 1,300

Daily Production - 9 tons at 20 %
solids = 1,800 kilos dry solids/day
Solids contain about 92 % protein
= 1,656 kilos protein/day

Labor: $ 400/day

Manager	$ 2,000/mo.
Supervisor	$ 600/mo.
Secretary	$ 300/mo.
Driver	$ 475/mo.
Mechanic	$ 600/mo.

Unskilled
Labor - 15 each at $ 250/mo.

Power: $ 100/day

Water: $ 100/day

Capital investment	= $ 1,092/day
Labor	= 400 "
Power and water	= 200 "
Fish (net cost)	= 1,300 "
Total daily cost	= 3,032
Daily production	= 1,656 kilos protein
Cost/kilo of pure protein	= $ 1.68

ADDENDUM

Since the preparation of the report other work has been done. The wet (about 80 % moisture) heavy fraction, H_2, of macarela prepared 24 hours previously and held at 0° C until used replaced 10 % of the flour in a typical bread-roll formula. Each baked roll (50 grams) contained 1.0 gram of the fish preparation, equal to about 0.9 gram of fish muscle protein. The rolls were tasted by Institute Staff and other untrained panelists and were well received. There were no comments made on the presence of unusual flavors. Separate tests made by workers on the project confirmed that there was no flavor or odor of fish in the rolls.

Using the crude production cost estimate of $ 1.68/kilo of protein, the cost of added fish muscle protein to each 50 gram roll would be $ 0.0015. It would be interesting and important for animal feeding studies to be done to determine the degree to which the fish muscle protein raises the quality of the wheat-flour protein in addition to the direct contribution made by the fish protein itself.

As stated at several places in the report, getting fish when needed has been a continuing problem. Getting fish of good quality has been an even greater problem. During the first week of the two week extension of the contract a trip was made to Guayaquil to establish contact with management of IMPECA, a large fish processor and fish meal manufacturer with its plant in Monteverde, to describe to them our project and to enlist their help in obtaining fish of good quality. The general director was attentive and most cooperative. In addition to providing about 60 kilos of good quality frozen fish on the following day he informed us that a relatively large resource of Sardinops sagax was being fished by his company. There is no information available from the National Institute of Fisheries on the established size of the resource but industries experience has been that it is significant.

We worked with the fish, average size about 25 cm., to see some of its characteristics. The skin is relatively tough and should lend itself to easy removal on the deboner. The large scales should also be kept out of the flesh by the deboner. Like pinchagua there is a substantial deposit of red, oily muscle under the skin. The rest of the muscle is light grey in color and the centrifuged fractions are very light tan. Estimates on ratio of red flesh to grey are 1:2.

A trial was made with Sardinops to see if the ratio of wet fish to wheat flour in the drum-dried product could be raised succesfully from 1:1 to higher levels. That trial showed clearly that stabilization of the washed product is necessary if it is to remain odorless. A storage time of only 3 hours at 0° C was sufficient for the development of a fishy odor. When the trial was repeated with no interval between preparation of the fish product, mixing with flour, and drum drying a 4:1 wet fish preparation: wheat flour product was prepared. The only detectable odor was that of wheat flour. The product, when moistened, could be formed into stick-like shapes and pan-fried. The fried product had no flavor of fish.

Analytical data (moisture, protein, oil) on this species have yet to be obtained.

Product (sausages, spread, wet fish preparation) is now being prepared for demonstration-tasting to UNIDO, Quito and to the Director of the Escuela Politécnica Nacional.

One last point. As stated earlier, product yield is relatively low due in part to poor quality and in part to inexperienced hand cutters. Another, and most important factor causing low yield is the high content of oily red flesh. This is estimated to be 30 % of the total flesh in pinchagua and sardine and as much as 40 % in macarela. The development of a food use for modified red muscle would alter drastically the production cost of the washed lean muscle product as well as providing another high protein, low cost fishery product. A comparative analysis of the minced lean flesh and red flesh of macarela is shown below:

SAMPLE	Percent		
	Moisture	Oil (dry basis)	Protein (dry basis)
Minced lean macarela muscle	71.3	4.9	87.2
Minced red muscle plus skin of macarela	67.9	28.1	63.9

The primary factor limiting its use for food may well be its high oil content and associated flavors. If so, the procedure described here for producing odorless and flavorless flesh from lean muscle may be equally effective with red muscle. If not, an alternative would be a good tasting product with an acceptable flavor of fish.

During the typing of the addendum there was time for a closer estimation of yields of light and red flesh from macarela of good quality. The fish were hand-cut, as usual, and the reported yields are probably lower than would be the case if the fish had been mechanically deboned. Light and red muscle were 26 and 10 percent, respectively, of the weight of the round fish.# The addition of red flesh would increase the total yield by 40percent and would, of course, decrease production costs correspondingly provided that a closely similar process was effective in removing flavors and odors.

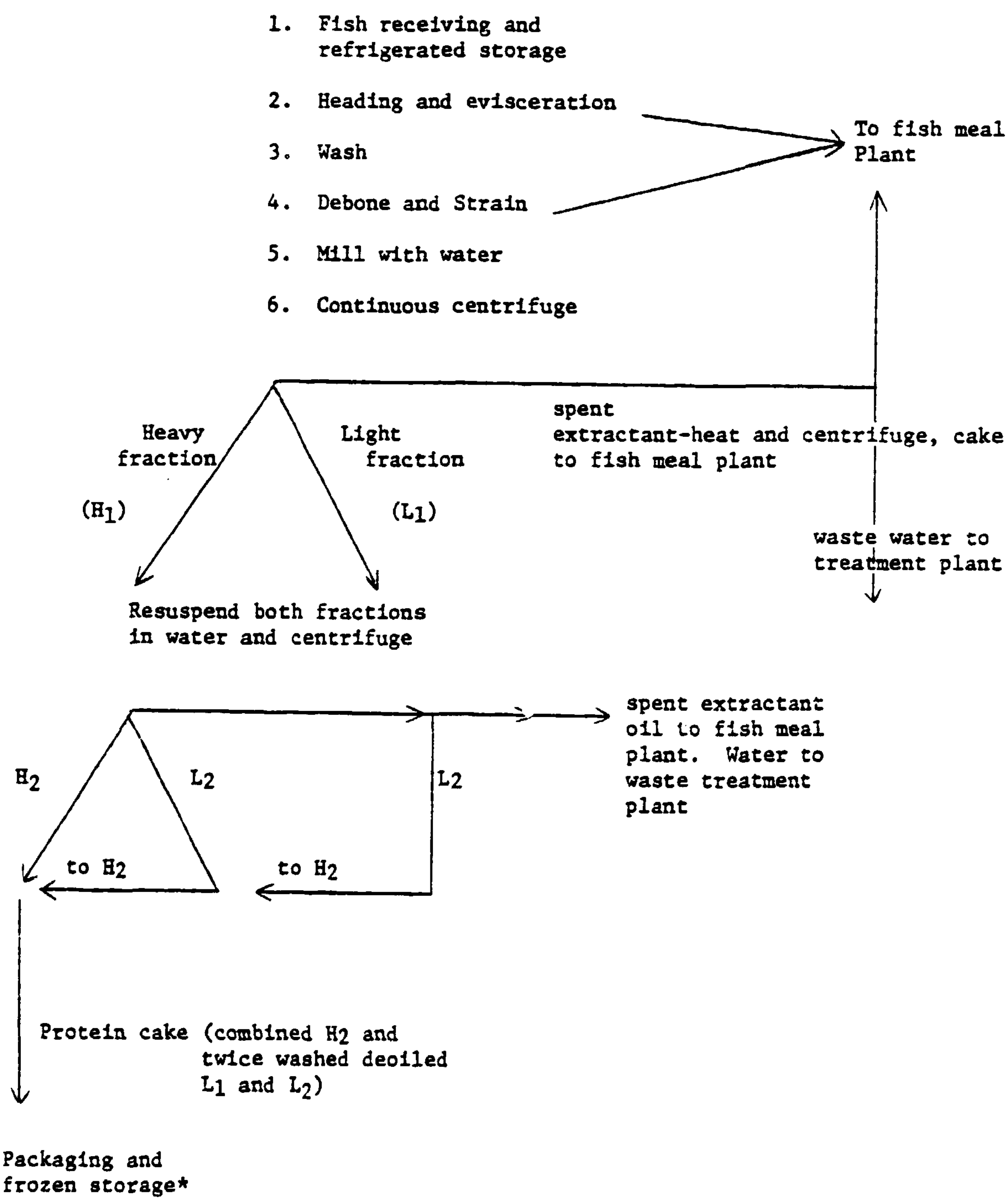
A single trial with the red flesh of macarela(two series of washes—one series consists of dispersing ground flesh in five volumes of ice-water and passage three times through the colloid mill—each followed by recovery of suspended solids in the Westfalia Separator LWA205, with the Clarifier bowl) produced a nearly odorless and flavorless product. This was mixed with cooked potato, vegetable oil and a dry onion soup-mix, formed into balls and cooked in water. The balls were put into a heated white sauce flavored with the same soup mix. A small informal panel reported no flavor of fish. This might have been due to the masking flavor of the onion, but perhaps not.

See p. 20, last paragraph. The estimate for macarela should be changed to 20 percent. Estimates for pinchagua and sardine are probably close to correct.

The trial suggests that the red flesh can be used as a flavorless protein ingredient in foods, perhaps even in combination with deodorized light flesh. It will require additional work to develop a satisfactory procedure, the basis of which would seem to be that developed for light flesh.

FIGURE 1

A proposed plant layout for the production of washed, deodorized fish flesh and the recovery of waste as fish meal



* Alternatively Protein cake can be drum dried with cereal-flour for use in soups, baked goods, sauces, etc.