Fish By-Catch . . . Bonus From The Sea
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Fish By-Catch... Bonus from the Sea

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The Guyana Project: Industrial Use of By-Catch

E. Ettrup Petersen  A/S Atlas, Copenhagen, Denmark

Industrial production of processed by-catch is the aim of a project in Guyana; it incorporates the facilities to produce individually quick-frozen fillets from seatrout and similar species; frozen fillets in blocks from croaker and other fish; fish patties and sausages from backbones, belly flaps, and non-conditional fillets; dried, smoked, and canned fish from bangamary and similar fish; and fish meal and oil from the offal. All these products have a local market, and many will serve an international demand. The plant capacity and the processing steps have been detailed here.

Shrimp have for many years been an important Guyanese fishery, equaling, in recent years, about 4000 t/year. As in other tropical waters, large amounts of fish are caught with the shrimp, and the practice until recently has been to discard the fish by-catch at sea. The government of Guyana focused attention on the prevention of this enormous waste and decreed that the shrimp trawlers would bring part of the by-catch (1000 t/year) ashore, utilizing the freezing and storage capacity not occupied by shrimp. This directive resulted in fish landings that were used by Guyana Fisheries Ltd to pioneer a number of products, such as frozen fillets, fish paste, patties, and smoked fish — products that have found wide acceptance among local consumers.

The people of Guyana are accustomed to eating fish regularly, and about 50% of the protein consumption is marine or freshwater species. To enlarge the marine-protein supply, the government aims to intensify the landing of shrimp by-catch. In fact, it has initiated a program to acquire and rebuild a number of trawlers for finfish supply to the market. This program also includes a project to establish onshore facilities for processing raw fish (about 50 t/day) — 20 t for human consumption and 30 t for fish meal.

Plant Capacity

When planning the project, the authorities took the view that the products should be identifiable and directly acceptable to the population and that no investments would be made in equipment for manufacture of products that needed an extended introduction with an uncertain result. Furthermore, the government opted for a high degree of flexibility in the project, making it possible to reach all regions of Guyana, as well as other Caribbean countries, with fishery products.

A pilot plant is being tested, incorporating production capacities that have been chosen for their viability and feasibility so that increasing the scale of production constitutes no problems.

In brief, the project comprises:

- An ice plant to provide the necessary ice for raw-material storage in the trawlers and in the plant as well as preservation of processed material during distribution to the major population centres;
- A pretreatment line for inspection, de-icing, washing, and sorting of the fish;
- Scaling, gutting, filleting, and freezing facilities, for production of individually quick-frozen (IQF) and block fillets;
- A process to produce fish patties and sausages from minced fish, surplus fish, belly flaps, and nonconditional fillets;
- A special line to prepare materials to be smoked, dried, and canned;
- Two drying cabinets for batch processing of salted, dried fish;
- A kiln for processing of salted, smoked fish;
- A small pilot canning line to develop products to suit consumer preferences (expressed in surveys); and
- An integral operation to process offal and discarded fish into fish meal as a basis for the growing poultry industry in the country.

The project was outlined by Guyana
Fisheries Ltd, who had, on a small or medium scale, manufactured most of the items described and had tested them in the market. The first part of the project was funded by the Commission of the European Communities through the European Development Fund and elaborated by Fisheries Development Ltd, London, England, in association with C.A. Liburd and Associates, Georgetown, Guyana.

An international call for tenders was arranged and the contract awarded to A/S Atlas, Denmark. Atlas then arranged cofinancing with Danish sources, thereby almost tripling the funds available and making possible essential additions to the project, such as an ice plant, canning line, fish-meal plant, etc. The arrival of equipment in Georgetown commenced in September 1981; erection to be under the supervision of personnel from Atlas in cooperation with local staff, especially on matters such as processes and mechanical and electrical details.

The plant is geared to process 200–400-g fish, with yields ranging from 30% of weight for skinless fillets to 85% for gutted fish. Yields of mince and fish meal from the offal are 50% and 20% respectively. Gutting and filleting are done by hand (5 fish/minute and 2 fish/minute). Mechanical capacities are headling 40 fish/minute, filleting 150 fish/minute, patty forming 350 kg/hour, sausage cooking 125 kg/hour, drying 100 kg/hour, smoking 100 kg/hour, and canning 30 kg/hour. Figures for weight of fish, yields, capacities, etc. will vary widely, depending primarily on sizes and varieties of raw fish, which will deviate according to source, seasons, etc.

This stage incorporates an Atlas scale ice-making machine with a capacity of 20 t/24 hours. The machine consists of two vertical, rotating drums, internally cooled by direct expansion of freon 22. Water is sprayed on the surface and freezes to ice during the rotation. In the final part of the freezing, the ice is subcooled to a temperature of -6°C, which makes it shrink and drop off at the touch of a series of knives. The compressor plant and drums form a unit with all switches and controls assembled in one control panel. An ice silo is planned as well; it will include three more machines of the same type on top, bringing total ice capacity to 80 t/24 hours.

When the raw fish are unloaded at the factory, they are immediately inspected, and any material unfit for human consumption is sent to the fish-meal plant. Some of the material may be reiced and placed in chilled storage (0°C), whereas part of the catch is selected to be processed immediately. The latter is washed and deiced in a machine consisting of a vat filled with clean, running water, through which an inclined, continuous conveyor moves fish out of the vat and allows them to drain. In a subsequent operation, the fish are sorted according to species and size, the sorting line consisting of six working places and of conveyors for raw fish and for discarded fish. Fresh fish, destined for direct sale, are repacked in ice and placed in the chill storage, awaiting distribution. Further processing depends on the quality of the fish and their suitability for specific products.

**IQF fillets**

Seatrout (Cynoscion virescens) and similar species entering the line pass through a Canadian-made machine that removes the scales. This operation is performed by rotating cutters of flat and conical design, the fish being held by spring-loaded, curved, pressure plates. An internal spray of water flushes the scales out of the machine. Afterward, the fish are gutted by hand and washed in a stainless steel, perforated drum, furnished with internal water-spray nozzles and placed on an incline.

The washed fish are dumped into fish boxes and weighed on a platform scale for control of the filleting yield. The main filleting line consists of 12 working stations with cutting boards of hard nylon. There are three conveyors placed on top of each other, one for fillets, one for boxes with gutted fish, and one
Fig. 1. Products and processes for the Guyana plant.
for offal. The fillets are inspected on a special table and weighed; then they are ready for freezing. Trimmings and backbones are collected for production of fish mince in a flesh-and-bone separator.

The freezing is performed on an Atlas Rota-freeze IQF in-line system. The fillets are placed on a conveyor with wire mesh in stainless steel. The freezer itself is a large stainless-steel drum, internally cooled by a transfer liquid, which in return is cooled by a two-stage piston compressor system.

The freezing drum rotates slowly, and the fillets from the freezing conveyor are placed automatically on the drum, maximum contact being secured by a soft-pressure roller. At the end of the rotation, the frozen fillets are detached from the drum by means of a special device, and they drop onto a take-away conveyor. This conveyor transfers the fillets to the glazing unit from which they continue on a band conveyor to a portion-packing station with five tables, each furnished with scales. The prepacked products are weighed and placed in master cartons, which are labeled and strapped, ready for cold storage and dispatch.

Frozen fillets in blocks
Croaker (Micropogon spp.) and other fish of similar size and structure are to be filleted and frozen in blocks. Equipment already present in the plant includes a filleting machine from Japan and surplus freezers used for production of frozen shrimp. However, for flexibility, two lines — each with eight working stations — have been included. These lines — the same design as for IQF fillets — have three conveyors and will take care of fish not suitable for mechanical filleting and will operate even during breakdowns in the filleting lines. Also, the two lines may be used separately, for instance for packing of fillets in cartons before plate freezing.

The final arrangement of the machinery will be decided on the basis of experience, but care has been taken to provide for the elements necessary to obtain a smooth and flexible operation.

Fish patties and fish sausages
Quite a lot of importance has been attached to the production of patties, pâtés, and sausages, as these items have been produced on a small scale for some time with a good response from consumers. The raw material is backbones, belly flaps, and nonconditional fillets, which will be deboned in a Bibun flesh-and-bone separator into fish mince and offal for fish meal. The installation also permits the elaboration of methods for the manufacture of mince from small fish, with and without heading and gutting. Using the whole fish is a distinct possibility, as the colour of the mince as well as presence of black spots is much less critical in pâtés and sausages than it is for surimi, fish blocks, or fish sticks. The patties, pâtés, and sausages will be spiced and artificially coloured to suit consumer preferences in the various regions of the country. Smoke flavour can be added by the smoking plant.

The minced fish are transferred to a chopper-mixer machine, principally consisting of a cylindrical, vertical container, which has two sets of combined mixers and knives built into the bottom. By varying the speed of the rotating knives or removing them and keeping only the mixing device, one can adjust the consistency within wide limits: the mixture for sausages and pâtés will be rather smooth, whereas patties are expected to contain bits of fillet to be chewed.

During the mixing, scale ice is normally added to keep the temperature down, together with spices, colouring, preservatives, and antioxidant (when fatty fish are used). In patty production, the mix proceeds to a patty-forming machine consisting of a hopper with feed screw, a pressure chamber that ensures constant filling of the pistons, and a forming set, in which the round patties are shaped to a finely adjusted weight. When the moulds of the forming set are filled, the forming plate moves forward to the release position, the patties being expelled onto an outfeed conveyor. They are then frozen on the Rota-freeze and packed as for IQF fillets.

The mixture of fine mince, destined for sausages proceeds to a vacuum-filling machine for casings, and the sausages are portioned and clipped according to the desired weight. The clipped sausages are then pasteurized in a cooking vat for about 1 hour, the centres reaching a temperature of about 90°C, whereafter they are cooled in cold water. Perfect shrinking of the casing is ensured by a final dip in hot water for about 10–30 seconds, and the sausages are ready for packing and storage.
**Dried, smoked, and canned fish**

The raw material for dried, smoked, and canned fish will be bangamary (Macradaon spp.) and fish of similar shape and size. Filleting machines, of the type successfully developed for handling herring and blue whiting in the north Atlantic region, will be tested in this operation because they can deliver single or block fillets, skin on or off. If the filleting tests are not successful, dressing of the fish can be undertaken on the filleting line.

The fish destined for drying will be split or filleted, skin on, then salted lightly (brined) or heavily. As brining is also the initial process in smoking and often also in canning, the plant has been furnished with an automatic brining unit. This unit consists of a main tank, furnished with paddles that convey the fish through the brine at an adjustable speed. A saturated sodium chloride solution is kept in a tank and is added in measured amounts to the main system so that the concentration of salt in the brine is constant. A pump circulates the brine from the main tank through a buffer tank with filter in which solid particles are settled and can be drained.

It is normal to use a brine of about 210 g NaCl/L and an immersion time of 1–5 minutes, depending on size, thickness, and oil content of the material. This treatment gives a salt content of about 3% in the fish, which, after being dried to 15–17% moisture content, will have about 8–11% salt content.

To produce heavily salted fish, one places alternate layers of material and salt in containers, possibly keeping the brine in the container until the fish have obtained the desired amount of salt. Whereas lightly salted fish must be dried to a moisture content of less than 15% to prevent growth of bacteria and moulds, a moisture content of 35–40% is suitable for heavily salted products. Also, the drying time for heavily salted fish is shorter than that for lightly salted fish, and, thus, the output of the dryers will be considerably higher for heavily salted fish.

After being salted, the fish are washed so that crystals don't form on the surface; they are then placed on wire-mesh trays in the trolleys of the drying cabinets. Two dryers (Afos, England) have been supplied to the project, each one accommodating four trolleys with about 20 trays each. Each batch per dryer will be about 1270 kg (based on medium-sized cod fillets).

The dryers consist of cabinets with four doors for passage of the trolleys, which are stationary during the drying. On the top and sides of the cabinet, there are air ducts furnished with aerofoils and diffuser walls for even distribution of the air current throughout the cabinet. The air flow is provided by a fan placed in the upper duct. In the same duct is also placed a thermostatically controlled air heater. The bulk of the air is recycled, but the humidity is controlled by an exchange between fresh and moisture-laden air.

The air velocity is about 1–2 m/second, and, according to experiences from other tropical countries, the air is about 40°C or even higher at the end of the drying. In temperate countries, it is normal to work with lower temperatures. The relative humidity should be 45–55%, as a lower value may cause a crust to form on the surface of the drying material and a higher value will reduce the drying rate. The finished products are discharged from the trays, inspected, and packed in portions, whereafter they are master packed, strapped, and labeled, ready for distribution.

**Smoked fish**

There are two types of smoking in general use, namely cold and hot smoking. In cold smoking, the temperature of the fish is kept low, so that coagulation of the proteins is avoided; in hot smoking, the fish flesh attains temperatures of 60–80°C, and the proteins are practically fully coagulated.

Cold smoking results in relatively little drying of the fish as well as in only a minor reduction of the bacterial count. Therefore, the products must be distributed with great care. Hot smoking can be carried out so that a higher drying rate is obtained, and the high temperature lowers the bacteria count.

In both cases, brining is done before smoking, the fish being dipped into a 75% saturated brine for 5–15 minutes — the amount of time depending on the thickness of the fish. When hot smoked and properly dried, the fish have a long shelf life. Therefore, hot smoking should be the preferred method in tropical countries.

In both stages — a preliminary drying period (30°C) during which the skin is toughened against breakage, a smoking and partial cooking period (50°C), and a final cooking period (80°C). The total time and the proportion spent on each stage depend on the fish species, size, and fat content; the kind of products re-
Early experience in Guyana showed the wisdom of smoking by-catch fish.

required; the final moisture content; and degree of smoking.

The smoking kiln for the Guyana project has only two trolleys and a batch capacity of 400 kg (based on white-fleshed fish fillets). However, as the ambient temperature and humidity in Guyana are often too high for safe operation of the initial process to toughen the skin, a dehumidifying system has been foreseen in the inlet for primary air. The dehumidifier is designed as a refrigerating system, with an air cooler having a capacity of about 30,000 kcal/hour at -1.1/54.5°C.

The smoking kiln (Afos, England) is
furnished with a smoke producer in which smoke is generated under controlled conditions. Sawdust from resin-free wood is poured into a hopper, and a feed screw with adjustable speed conveys it to a perforated grate, where it is electrically ignited and burned with a measured amount of air supplied by an adjustable fan. A rake pushes the burning sawdust forward on the grate until it falls as ash into the ashpit. After being smoked, the fish must be allowed to cool at least to room temperature, whereafter they are packed and kept in chilled storage until dispatch.

Canned fish
The possibilities for variation of canned products are legion. This fact is reflected in the canning plant to the extent that the design and capacity have been chosen as a pilot plant plus, which has a capacity high enough to test consumer preference without too much involvement in sophisticated equipment. Extensions can be made safely.

The raw material is placed on a buffer table and taken by a conveyor to the upper section of a packing table. This table is a circular rotating machine with three levels, of which the upper one is sectioned for raw material and empty cans, the middle one for filled cans, and the bottom one for offal. Five working stations are connected with the packing table.

The filled cans proceed on a conveyor to a saucing station in which they are filled with a measured amount of tomato sauce, brine, or oil; lids are added by hand, and closing takes place in a semiautomatic double seamer with a capacity of about 1500, 0.45-kg cans/hour. The cans are washed in a continuous washing machine and are dumped into crates for sterilization.

An autoclave, a water-filled, overpressure type, sterilizes the cans in a water bath at 115–120°C. Afterward, the hot water is pressed into an upper tank by cooled water entering from below. The hot water is reused for the start of the next batch.

The cooled cans are extracted from the autoclave, emptied from the crates, labeled, and packed; after a quarantine and inspection for swells, they are ready for distribution.

Fish meal and oil
Sorting of the raw fish as well as other operations produces considerable amounts of offal, which, together with the part of by-catch not suitable for human consumption, is used in fish-meal production.

The raw material is collected in carts and dumped into the feed hopper of the fish-meal plant. Backbones, sharks, rays, and other large items are cut into finger-sized pieces in a rotary knife-hasher. An adjustable screw conveyor feeds the material into an indirect cooker, which is a steam-heated, horizontal cylinder with a transport screw. The exit temperature is automatically controlled. The cooked material falls into a press with two counter-rotating screws having conical shafts. The pressed cake is dropped into a Rotadisc dryer—a horizontal cylinder with an internal heating element consisting of a steam-heated shaft furnished with a number of hollow, steam-heated discs that provide a large surface for heat transfer. The dried meal is extracted from the dryer by a screw conveyor that transports it to a hammer mill after which it is bagged, ready for dispatch.

The liquid expressed from the cakes is pumped to a vibrator sieve in which sludge particles are removed and returned to the pressed cake. The oil is separated from the water in a centrifuge. The water is pumped to a tank, and, having a dry-matter content of only 8–10%, it is concentrated to about 45% in a two-stage, concentrating unit. The results are subsequently mixed with the pressed cake before it enters the dryer. This material increases the yield of fish meal by about 20%.

The plant is equipped with a wash tower for condensing the vapour in the dryer exhaust. Noncondensable gases can be used as primary air in the burner of the boiler plant so that obnoxious odours are removed.

The fish-meal plant will be erected close to a sawmill; therefore, the boiler plant has been designed to burn logs, shavings, and other offal from the sawmill. An auxiliary oil burner secures the operation of the boiler during periods of standstill at the sawmill. The main elements of the plant are supplied as preerected units with pipes, control panels, electric wiring, etc. ready for hookup. The cooker, press, dryer, strainer form one unit; the tanks, pumps, oil separator a second; the two-stage evaporator a third; and the boiler plant a fourth.

Conclusion
Having read this far, one may ask how the setup will accommodate new developments
such as fish-protein concentrate (FPC), hydrolysates, silages, etc. The answer is simple: it won't. This project is based on the philosophy that the primary factors in elaborating a project are the raw materials and the markets. These will decide the products to be manufactured, and the products will determine the equipment, budgets, and economy, whereafter financing, cash flows, etc. will have to be taken into consideration.

This project is a pilot project plus — i.e., with regard to capacity, it is on the upper side of what is normally considered a pilot project. With the great flexibility built into the plant — its ability to transform a multitude of fish species into products already acceptable to consumers, in quantities that permit genuine cost and marketing experience — there is a fair hope that the venture will contribute to solving the by-catch problem.