TECHNOLOGICAL APPROACHES TO UTILIZING BYCATCH IN LOW-COST PRODUCTS FOR HUMAN CONSUMPTION

by

YU SWEE YEAN
Faculty of Food Science and Biotechnology
Universiti Putra, 43400, UPM, Serdang
Selangor, Malaysia

ABSTRACT

The paper reviews and evaluates technological approaches to the increased utilization of bycatches, particularly in the Asian region. It notes that a significant reduction has been achieved in wastage in the region by using bycatch species in a variety of conventional and novel products. These include: fish minces, fish jelly products, fish protein concentrates, fish hydrolysates and a range of fermented products.

It concludes by emphasizing the need for a market-driven approach to product development and the requirement to stimulate the search for novel raw materials as components of the products necessary to fill the emerging gap between supply and demand for fish.

INTRODUCTION

Bycatch is defined as the catch of non-target fish, whether kept for market or discarded at sea (Alverson et al., 1994). Discarding is a natural consequence of the very nature of fishing. The direct reasons for discarding are:

- biological - there is a mixture of species available in the fishing grounds;
- technological - it is difficult to target specific fish for capture;
- economic - the accidental capture of fish of no value to the fishermen; and
- legal - in some fisheries, fishermen are limited as to the total quantities of fish of certain species that they can land (FAO 1997a).

The remainder is the ‘landed catch’ or ‘retained catch’ (i.e. that which is brought ashore). This can be further sub-divided into ‘target catch’ and ‘incidental catch’. A particular species can move from one category to another, depending on size, market demand, season or other criteria. In the context of international fisheries statistics, it should be noted that ‘target’ and ‘incidental’ catches are recorded, while discards and other fishery-induced mortalities, which may be substantial, are generally not recorded (FAO, 1997b).

Available data for 1994-1995, suggest that a significant reduction in discards has occurred between the mid-80’s and the mid-90’s as a result of:

- decline in the levels of fishing;
- time/area closures;
- new or more selective harvest and utilization technologies;
- greater utilization for human consumption and feed for aquaculture and livestock;
- enforcement of prohibition on discarding by some countries; and
- a more progressive attitude of fisheries managers, user groups and society to the need to resolve problems resulting from discarding.

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The magnitude of the decline has not been quantified, but indications are that the annual discard figure is now of the order of 20 million tons (FAO, 1997c).

Whilst elimination of discards altogether would be an unrealistic goal, the use of discards as a potential source of food will continue to play a role in the reduction of wastage. According to Alverson et al. (1994), bycatch from shrimp fisheries represent the single most important sector of the bycatch and discards from world fishing activities. It has been estimated that 11.2 million tons per year are generated world wide and of this 85 percent is discarded. Of particular concern is shrimp trawling in tropical waters, which produces high discard ratios (bycatch fish often outweigh shrimp by five and sometimes ten to one) and contributes a large volume of bycatch and discards. The location of many of these fisheries in waters adjacent to countries with low incomes and food deficits makes it imperative to utilize the discards for human food. Bycatches from shrimp and finfish trawlers are prevalent in South and Southeast Asia. In Southeast Asia, shrimp fisheries are the main contributors to bycatch and discards. The quantum of bycatch and discards for the Southeast Asian region was estimated at 3.4 million tons (Chee, 1997). Between 290 000 to 310 000 tons were discarded from 1992-1994 (Chee, 1997).

Before coastal mariculture was intensified, most bycatch was discarded at sea and only a small portion brought ashore. With the development of chilling systems for on-board storage and the greater demand for feed from aquaculture, much more of the bycatch is landed. Other portions of the bycatch are reduced to fishmeal. In addition, the processing of fish and fish-based products has created ready markets for bycatch, although the utilization of bycatch is still influenced by the location of the fishing grounds and ports, the socio-economic status of fishing communities and the available infrastructure. In poorly-developed areas, there may be no alternative but to discard the bycatch (Chee, 1997).

The inherent problems of bycatch are their extreme heterogeneity of composition, bony structure, dark flesh, small size, unattractive appearance and texture, strong flavour and the possible presence of toxic species. Many of the species are difficult to process by conventional techniques, and if processed, face poor marketability. Previous attempts at technology led utilization programmes have generally not led to long-term solutions especially with regards to economic viability. However, recent trends seem to indicate that, driven by increasing human population, gradual depletion of fish supplies from conventional sources, and the growth of aquaculture, increasing amounts of bycatch are now being used either directly as human food, in aquaculture or as animal feed (FAO, 1997b). The trend in recent years has, therefore, been towards greater utilization with previously-discarded fish species entering the food chain as ‘incidental’ catch.

This review focuses on the more-recent technologies that have been developed to utilize bycatch in low-cost products for human consumption in Asia, in particular, Southeast Asia.

MINCED MEAT RECOVERY

Due to the great variety and small sizes of fish caught as bycatch, rendering standardized processing and marketing difficult, recovery of meat by mechanical methods is perhaps one of the more viable means of utilizing many underutilized species for human consumption (Flick et al., 1990). For this purpose, a wide range of deboners are available. A common type is the belt and drum model (Wood and King, 1982; Agarwal et al., 1986), where the headed and gutted fish pass between a counter-rotating belt and a perforated drum. Another machine used is the stamp-type deboner, in which the fish is compressed against a perforated steel plate (Ghadi et al., 1976; Suwanrangsi, 1987). The feasibility of deboning several low-value species and using the mince for product development has been reviewed by Grantham (1981), Gopakumar (1987) and Burt et al. (1992).

The minced meat obtained after deboning is more unstable than intact fish muscle, (Grantham, 1981; Babbitt, 1986) and must therefore be processed immediately or frozen. Depending on the type of fish,
minces can be stored frozen for up to 8-9 months without appreciable quality deterioration (Revankar et al., 1981; Agarwal et al., 1986). Ghadi and Lewis (1977) found that tripolyphosphate and sodium chloride helped maintain mince quality during frozen storage. Ghosh, Ghadi And Lewis (1977) reported that mechanical deboning did not affect oil emulsification and protein extractability of minces from a variety of low-value fish, including anchovies, croaker, eel, shark and sole. Washing and addition of benzoate-phosphate extended the shelf life of mechanically-deboned bycatch mince in Thailand (Jantawat and Yamprayoon, 1990) for up to 13 days at 0°C.

Chakrabarti (1993) reported using dense media with specific gravities of 1.217-1.220 to efficiently separate meat and bone from small fish, small shrimps (Chakrabarti, 1989) and small crabs (Chakrabarti, 1988). The recovered meat from small fish contained considerably less bone than meat obtained using a conventional deboner. Propionic acid helped to control mould growth and prolonged shelf life for up to 3 to 4 months at ambient temperatures (34 ± 6°C). Processing costs depend mainly on the cost of energy for boiling and the successful recycling of media. However, this method remains largely untested. A code of practice for minced fish production has been provided by FAO (1983).

APPLICATION OF FISH MINCE

Conventional Products

Conventional products that can be manufactured from fish mince include sausages, pastes, patties, balls, wafers, loaves, burgers, fingers, fritters and pickled products. Processes for development of these products have been summarized by Setty (1987), Regier and Raizin (1988) and Gopakumar (1987). Highly-acceptable outlets of minces of threadfin bream, lizzard fish, jew fish and other low-cost fish were prepared by Joseph et al. (1984) at the Central Institute of Fisheries Technology, Cochin, India. The development of fish cake has been discussed by Rao (1981). Durairaj and Pichiah (1985) and Venkatanarasimha and Chidambaram (1987) have developed quick-salted fish cakes from sea bream and ribbon fish. Basu et al. (1987) developed intermediate-moisture fish cakes from fish mince by adding different humectants. Sankar et al. (1992) prepared semi-dried fish cakes from dhoma at 7 percent and 10 percent salt levels. Shelf lives at ambient temperatures were 18 and 21 days respectively. Ramachandran and Solanki (1990) and Ramanchandran and Sankar (1997) studied the sorption behaviour of semi-dried dhoma (Otolithus rubens) at different relative humidities, in order to predict the shelf life of the product at different water activities.

Development of salted and dried minces from threadfin bream and Indian oil sardine has been reported by Sudhakaran and Sudhakara (1985). Preparation of fish fingers from croaker (Sciaenid spp.) and pink perch (Nemipterus spp.) consisted of extruding the mince in the presence of additives, dipping the 6-cm long pieces in batter, rolling in a breading mix, followed by frozen storage of the packaged products (Reddy et al., 1990). Minced fish can be stabilized for room temperature storage after mixing with tapioca starch, soya protein and salt, followed by dehydration at 71-82°C (Venugopal and Shahidi, 1995). A process has been described for preparing restructured sardine meat involving washing the mince, mixing it with alginate, and then dialyzing in a calcium chloride solution (Nakayama et al., 1988). Processing of smoked, dried and powdered sardine into instant soups has been described by Oh et al. (1988).

Etoh (1986) has used trash fish from shrimp bycatch in Bangladesh and developed nutritious fish burgers and fish fingers, which were favourably accepted. In Bangladesh also, shrimp bycatch was used to produce fish cakes, fish balls and highly-appreciated breaded fish burgers. Minced fish was handformed and spices such as dill and pepper added to the breading. The fishburgers were sold frozen to retailers who kept them in insulated boxes to be sold the same day for immediate preparation and consumption. The product retailed at 5 Taka for a 2-piece packet in Dhaka and Chittagong (Roessink, 1989). Mince from bycatch and/or trash fish normally sold off at very low prices can be formed into portions of various shapes and sizes, and battered and breaded to produce innovative value-added seafood products. Present market
trends reflect a rapidly-growing market for ready-to-eat convenience products and sophisticated equipment is not necessary for the production of battered and breaded fish products (Roessink, 1989). Ihm et al. (1992) developed precooked frozen burgers using sardine meat. Separated sardine meat was chopped and mixed with 14 percent emulsion curd, 8 percent bread crumbs, 3 percent soya protein, 1.5 percent salt, 2 percent sugar, 0.4 percent bicarbonate, 0.2 percent polylysophosphate and spices. The seasoned sardine meat was fried in oil at 165°C for 3 min. Yu and Siah (1996; 1997) used trevally and unicorn leatherjacket for battered and breaded burgers from surimi developed from the two species. Feedback from food caterers was favourable.

Convenience food were processed using bycatch in the Philippines (Marfori et al., 1991). Fishballs, noodles and sausages with acceptable sensory qualities and good shelf lives were developed from twelve low-value species, which could be used to supplement the raw material shortage for these products. Ravishankar et al. (1993a; 1993b) developed sausages from the mince of Indian oil sardine (Sardinella longiceps). Washing the mince six times with water improved meat characteristics and sausage quality (Ravishankar et al., 1993a). Addition of 0.5 percent sodium bicarbonate to the washwater further improved elasticity, gel strength and waterholding capacity of the sausages, (Ravishankar et al., 1993b) by more effective removal of fat, pigments and water-soluble proteins. Fish noodles were also developed from lizard fish in Thailand (Phithakpol et al., 1986). The protein content of the noodles was increased by about 28 percent by incorporation of 25 percent and 30 percent fish into the formulation.

Fish satay is another bycatch product developed from lizard fish (Saurida spp.) in Thailand (Pruthiarenun, 1986; Suwanrangsi, 1986; Suwanrangsi, 1988). The fish was deboned, mixed with salt, sugar, flour and sesame seeds, spread into sheets, dried for 4-5 hrs, and then fried. This cheap high-protein snack can be kept at ambient temperatures for at least 5 months, and is marketed locally and exported. Chasanah et al. (1986) in Indonesia found that, if properly handled, shrimp bycatch can be processed into fish satay. Yellow goatfish (Upeneus sulphureus), a trawl bycatch normally used for fertilizer or animal feed in Malaysia, can be successfully converted to satay fish (Atan and Mohamad, 1986; Bakar, 1987), now extensively sold in the market. A satay-like product has been prepared from Bombay duck (Harpodon nehereus), by alternatively pressing the fillets and drying, resulting in a product with 88.5 percent protein and a 6-month shelf life at ambient temperatures. (Doke et al., 1996).

Sophanodora (pers. comm. 1997) developed fish satay from S. leptolepis, a low-value fish in Southern Thailand. The butterfly fillet was baked or fried. The baked product used raw fish at 40 percent moisture content, which was pressed between drum rollers and dipped in seasoning before baking at 150°C for 80 min. To produce the fried product, the dehydrated and pressed fillets were deep fried in oil at 220°C for 45 seconds, then dipped in seasoning and baked at 150°C for 25 min. The mixture design method of Earle and Anderson (1985) was used to develop the formulations for the seasonings. 85 percent and 89 percent of consumers accepted the baked and fried satay respectively. Products were packed in high-density polyethylene and polypropylene. There were no significant differences in chemical, microbiological or sensory characteristics at up to 5 weeks for baked satay and 8 weeks for fried satay.

Small fishes such as ponyfish (Leiognathus spp.), jack (Caranx spp.) and sardines (Sardinella spp.) have been used for fish paste (Saisithi, 1987; Choorit et al., 1991). Fish biscuits were successfully developed from Decapterus russelli (Yu and Kaur, 1992). Two types of fish mince (water-heated and oven-dried) and three levels of fish (8 percent, 16 percent and 24 percent) were used in the formulations. The most-acceptable formulation was obtained using 16 percent of water-heated fish mince. The product had a long shelf life at ambient temperatures (25°C ± 4°C) and large-scale sensory evaluation trials showed good response.
Fish Jelly Products

Traditional fish jelly products, such as fishballs and fishcakes, have been part of the diet of the countries in Asia for decades. They are usually produced in cottage industries using fresh fish. However, with the advent of refrigeration and the increasing demand for these products, many large factories are now producing surimi, the raw material for fish jelly products. Surimi is the minced, washed fish meat to which cryoprotectants are added before freezing. The price varies with fish supply. To date, much of the demand for fish jelly products is still met by small and medium-scale industries, who depend on the day’s catch or use frozen-thawed whole fish.

Work directed towards the use of bycatch species for fish jelly products in Southeast Asia, has been undertaken largely by the Marine Fisheries Research Department (MFRD) in Singapore (Poon et al., 1981; Tan et al. 1981, 1982 and 1987), and the Department of Fisheries, Thailand (Saisithi, 1981; Suwanrangsi and Kiatkungwalkrai, 1983 and Pruthiareun, 1985).

In initiating the project on the utilization of bycatch as raw material for the production of fish jelly products in Southeast Asia, the MFRD introduced several basic technological concepts:

- the use of a mechanical deboner- this is essential for bulk processing the small sizes of fish, often bony and difficult to head and gut;
- leaching of mince meat twice with 4-5 times its volume of iced water (w/w), initially with 0.2 percent salt, followed by 0.3 percent salt. This confers several advantages;
  i. eliminates components that interfere with gel formation and makes it possible to utilize not only a wider range of fish species but also raw materials that are not fresh. Cheap and abundant fish resources can now be processed into good-quality fish jelly products (Poon et al., 1981);
  ii. whiten the product by removal of blood pigments and kidney tissues;
  iii. removes the fishy odour by leaching out the fat components and odoriferous materials, taste can then be adjusted to suit local preferences;

- double-step heating, at 40°C for 20-40 min, followed by cooking at 90-95°C for 20 min, determining the optimum conditions (temperature and time) for ‘setting’ if potential gel strength of the raw material is to be realized. This is especially important because the proteins of tropical fish behave rather differently from those of temperate origin. Traditionally, the fishballs are soaked in tap water (28-30°C) for 2-3 hr before boiling or frying. This time can be reduced to 20-40 min if a temperature of 40°C is used.

Pruthiareun et al. (1985) and Pruthiareun (1986) sought to produce fishballs from the large quantities of bycatch in Thailand (Pruthiareun, 1985), generally, used for fishmeal, to supplement supplies required for fishball manufacture. Threadfin bream (Nemipteridae), sole (Synodontidae), flat-head, (Platycephalidae), ponyfish (Leiognathidae), and goatfish (Mulidae) were used. Substitution using minced bycatch for fishballs, at a maximum rate of 50 percent and 75 percent for pelagic and demersal species was possible.

In Malaysia, fishballs and fishcakes have been produced from yellow goatfish (U. sulphureus) long-finned silver biddy (Pentaplan longimimus) and large-scaled brimmed gunter (Eutherapa therapa) (Alan and Mohanad, 1986). Yu (1993) successfully substituted Decapterus russelli up to a level of 60 percent in fish cake formulations. Yu and Senapi (1996) have used Leiognathus equulus, an abundant low-value specie in Malaysia, for fishball processing. Although its use is limited by its weak gel strength, L. equulus can be incorporated at up to 15 percent in the formulation without affecting product quality. Acceptable fishballs were also developed from low-value fish in Bangladesh (Etoh, 1986), the Philippines (Marfori et al., 1991) and from shark meat in Indonesia (Nasran et al., 1986). Irianto et al. (1995) used a 4 step washing treatment and various spices to reduce and mask undesirable odour and flavour due to urea and
ammonia in fishcakes produced from Cawtail ray (*Trygon sepheh*). Results showed that a good product can be produced by the addition of 5 percent tapioca flour and 0.4 percent sodium tripolyphosphate. Gopakumar et al. (1992) and Muraleedharan and Gopakumar (1997) studied the feasibility of using trawl bycatch in India. Species used include *Saurida tumil*, *Johnius dussumieri*, *Sphyraena spp.*, *Trichiurus lepturus*, *Scomberoides lycan*, *Megalaspis cordyla* and *U. vitatus*. Generally, all species were suitable for surimi. Fatty fish yielded darker-coloured surimi with softer gel characteristics. Jasmine et al. (1995) at the Fisheries College and Research Institute, Tuticorin, India, used *N. bloekeri*, a trawl bycatch for fish mince. Cryoprotectants sorbitol (4 percent w/w) and ascorbic acid (0.1 percent w/w) effectively prevented protein denaturation during storage at -20°C for 6 months and resulted in products with better gel strength and sensory qualities.

Of the many bycatch species available in Thailand, threadfin bream is in most demand for fish jelly products, i.e. *N. japonicus* and *N. hexodon* (Suwanrngsi, 1988). In response to shortages and price surges of Alaskan pollock (*Theragra chalcogramma*), the traditional raw material for surimi and fish jelly products manufacture, the Japanese surimi industry has successfully diversified into the use of tropical fish for raw material (Kano, 1992). One of the advantages in using tropical fish species is the stability of their proteins, especially the myofibrillar proteins responsible for gel formation. Alaskan pollock very rapidly loses its gel-forming ability and cannot be used for surimi after 3 months at -25°C (Okada, 1996). If the temperature rises above 15°C during surimi processing, Alaskan pollock gels became fragile and poor, but that of threadfin bream remains strong. Itoyori or threadfin bream surimi is a commercial success, and has been growing in terms of quantity and value. Thai Itoyori is regarded in Japan as amongst the highest in quality.

There are now 14 surimi factories in Thailand with a total production of 60,000 tons per year with 90 percent exported to Japan and South Korea. These factories produce surimi from threadfin bream, big-eye snapper and croaker. Some factories also produce lizard fish surimi but these are generally of lower quality, as the gel-forming ability of lizard fish decreases sharply during storage (Yasui et al., 1987; Whitehead, 1995) and it must be processed quickly. Ng et al. (1996) found that the formaldehyde level of lizard fish must be less than 15 parts per million to produce best-quality surimi. A two-time leaching in 0.2 percent sodium pyrophosphate enhanced gel-forming ability of lizard fish.

Many processors have also started to use chilled-leached meat from threadfin bream and big-eye snapper for fishball manufacture. 2-3 tons of chilled-leached meat is produced by a Singaporean manufacturer for daily distribution to fishball processors (Tan, 1997). Fishballs produced from chilled-leached meat have better gel strength than those produced from frozen surimi. Chilled-leached meat however, does not have a long shelf and must be processed quickly.

Bycatch is now a supplementary, and in some cases, has become the main source of raw material for the fishball processing industry. Species widely used for frozen surimi include threadfin bream (*Nemipterus spp.*), big-eye snapper (*Priacanthus spp.*), barracuda (*Sphyraena spp.*) and croaker (*Sebastes spp.*), all of which are found in bycatches from the shrimp trawlers in Southeast Asia (Putro, 1989).

**Fish Protein Concentrates**

Fish protein concentrate (FPC) was one of the earlier products developed from low-cost fish protein for human consumption. There are two types of FPC. Type A is colourless and odourless, with less than 1 percent fat and is produced by solvent extraction. It has poor functionality, may contain residual solvents and suffers from high preparation costs (Finch, 1977). FPC type B is prepared by drying and grinding fish mince, and therefore has a fishy odour due to the presence of higher amounts of lipids. The product has seen some success as a dietary supplement in several countries (Tagle et al., 1977).

Moorjani (1977) developed odourless fish protein concentrate, partially-deodorized and defatted fish and soluble fish proteins from low-value fish. Although insoluble in water, the FPC contained 80 percent protein and could be incorporated as a food supplement. Treatment with ammonia solubilized
the proteins which could then be used for beverage-like preparations. Chen (1981) prepared FPC from three underutilized species in China: filefish (*Navodon modestus*), anglerfish (*Lophiomus litulon*) and undersized hairtail (*Trichiurus haumela*) by solvent extraction. The FPC was effective in treating infant malnutrition. Chaaya et al. (1982) reported development of protein concentrate tablets from low-cost fish meat. The authors reported health benefits as a result of administering the tablets. Espejo-Hermes et al. (1981) and Orejana (1983) have developed FPC (Type B) from low-cost fish, using appropriate technology, suitable for small-scale industry. The FPC was successfully incorporated into two local products and could be made into tablets and capsules (Orejana et al., 1985), using a locally-fabricated manual tablet machine and capsule filler.

Yamprayoon and Kiatkungwalkrai (1983) improved the sandy texture and water absorbance of FPC type B prepared from trash fish. Three kinds of FPC were produced from dried-ground-whole fish, dried-ground-smoked-whole fish and dried-ground-smoked-headed fish. All the FPC’s fulfilled the minimum protein requirement of 60 percent and were found to be acceptable when incorporated into Thai recipes. Pruthiarenun (1986) used sorted bycatch to produce affordable FPC Type B, with high protein content. The approximate yield was 1 kg FPC from 46 kg of bycatch. Pruthiarenun and Srisansane (1987) and Pruthiarenun (1990) showed that sardine protein powder and sardine FPC (type B) were stable for up to a year’s storage at ambient temperatures in low-density polyethylene. Fish powder incorporated into nine supplementary food formulations for pre-school and school children were highly acceptable (Charoenphol et al., 1988). Pruthiarenun (1990) improved the quality of the FPC Type B produced by Yamprayoon and Kiatkungwalkrai (1983) by separation of bone before cooking and recombination of the meat and bone after dehydration. The product had better texture, odour, taste, appearance and improved rehydration characteristics.

Fish powder from whole bycatch marine fish was used to produce fish crispies (Charoenphol et al., 1992; Charoenphol and Suanpan, 1992). A high-protein (20 percent), high-calcium (821mg. 100 g⁻¹) snack was developed. They suggested that the product could be an alternative source of protein and calcium for consumers allergic to dairy products. Doke et al. (1992) spray-dried *Scoliodon laticaudus* with 0.1 percent butyl hydroxyanisole and obtained a colourless, odourless and stable fish powder, compared to the conventional brown fish powder produced by air drying.

**Fish Protein Hydrolysates**

Development of FPC represented one of the first concerted efforts to increase the use and the value of underutilized fish by converting it into a more readily acceptable form. However, the FPC produced by these technologies were deficient in some functional properties and their cost of production was high. Recognizing this problem, subsequent investigations have aimed at improving functional properties of FPC by modifying the parameters of extraction and by employing enzymes, acid or alkali, to hydrolyse the proteins.

Venugopal and Lewis (1981) isolated odourless proteins with high-organoleptic ratings from croaker (*J dussumieri*), anchovy (*Trissoeches spp.*) and bombay duck (*H. nehereus*). Whole fish was cooked in 0.3 percent orthophosphoric acid, the separated meat was pressed to remove moisture and odiferous compounds and then hydrolysed using enzyme, acid or alkali. The protein extract was further deodorized by steaming for one hour and then drying. Ghadi et al. (1987) used deboned meat from dhoma for hydrolysis with papain at 55°C for 2 hr to obtain a product containing 90 percent protein. Ghosh et al. (1992) hydrolysed trash fish proteins using *Bacillus megaterium* cells immobilized in a wood matrix for repeated usage. Mahesh et al. (1993) produced functional fish protein hydrolysate from *N. japonicus* using papain for partial hydrolysis, followed by drying. The hydrolysate exhibited better functional and sensory properties compared to conventionally-prepared FPC. Anchovy (*Engraulis japonicus*) was partially and exhaustively hydrolysed using a proteolytic enzyme from *Bacillus subtilis* (Wang et al. 1996). The nonbitter partial hydrolysate (31.86 percent degree of hydrolysis) can be used as a seafood flavouring. A similar product produced by exhaustive hydrolysis (68.66 percent degree of hydrolysis) was high in protein...
content and can be used as a protein supplement. The authors estimated that the process can be utilized for the large reserves of *E. japonicus*, an underutilized fatty fish found in the East Sea of China, the Yellow Sea and parts of the Western Pacific, where the anchovy catch can reach up to 500 000 tons a year. Proteins from *Liza subviridis* were hydrolysed using Alcalase 2.5 L (Yu and Ahmad, 1997). The hydrolysate has good water-absorption properties and emulsifying capacity increased with degree of hydrolysis. The occurrence of bitterness (due to a high hydrophobic amino acid content) in fish protein hydrolysates limits its use in human food. Chakrabarti (1995) used ethyl alcohol to remove bitter components from low-value fish hydrolysates. The alcohol was subsequently removed by vacuum drying at 50°C. Wang et al. (1996) used active carbon to absorb bitter peptides and masking with β-cyclodextrin. The end product was free from bitterness.

**Fermented Products**

Fermentation of fish has been used extensively in Southeast Asia as well as Korea, Japan and China, for the preparation of flavoured products, since it offers a simple and low-cost method of preservation. Fermentation products from fish can be classified into two types: fish and salt formulations (high-salt enzyme hydrolysed) e.g. fish sauce, ‘nam-pla’ in Thailand, and fish, salt and carbohydrate mixtures (low-salt lactic acid bacteria LAB fermented) e.g. ‘burong isda’ from the Philippines (Owens and Mendoza, 1985).

Velayudham et al. (1987) produced fish sauce from silver belly, salted at a ratio of 1:4 at 50°C. Subasinghe et al. (1990) used *Amblygaster sirm* for fish sauce as a means of preserving seasonal gluts of small pelagic species which constitute up to 50 percent of total fish landings in Sri Lanka. Caranx, sardine and horse mackerel were found to be suitable for the preparation of ‘nam-pla’, a Thai fish sauce (Rattagoon, P. 1997, pers. comm.). Protein solubilization and therefore fermentation rate was faster using minced instead of whole fish. Addition of *Pediococcus halophilus* and 2 percent glucose to 22 percent-salted *Stolephorus commersonii* sauce hastened fermentation time by 20 percent. The sauce produced had acceptable colour and flavour.

Fish sauce production can be take up to 12 months from salting to maturation. Much research has been carried out to hasten the fermentation process by (a) increasing the temperature (Mabesa et al., 1990; Mabesa and Babaan, 1993) and (b) using enzymes (Mabesa et al., 1983; Bigueras et al., 1986; Thongthai and Srisutipruti, 1990; Kumalaningsih, 1990; Mheen, 1993; Putro, 1993). Using *D. macrospoma*, Mabesa et al., (1990) used artificial agitation and/or aeration in addition to heating at 45-50°C for 4 hr a day for 10 days, after an ageing period of about a month. Fish sauce with quality comparable to traditionally manufactured sauce could be obtained in about 2 months or less under certain conditions. In a similar fashion, a 10 percent increase in protein and total yield was achieved. Thongthai and Srisutipraturat (1994) found that fish sauce produced outdoors had a better aroma than that produced in indoors vats. This was associated with a higher temperature, higher salinity and a more rapid penetration of salt into the fish tissues and a lower brine pH. Fermentation time was also shorter. A rapid process utilizing proteases sourced from plants, animals and microbes has been applied industrially in Thailand (Thongthai and Srisutipruti, 1990).

LAB fermentation of fish-carbohydrate mixtures in the presence of small amounts of salt (6-10 percent) provides possibilities for developing a number of products from underutilized fish. Lactic-acid fermented products can be produced in a shorter time (and hence more cheaply) than fish/salt products which depend primarily on autolytic processes. Their lower-salt contents also permit them to be consumed as a main course, rather than as a condiment as in high-salt fish sauces and pastes.

Abraham et al., (1995) used *Leiognathus spp.* for lactic fermentation by *Lactobacillus plantarum*. They found that addition of 4 percent (w/w) glucose or sucrose accelerated fermentation rate. Olympia and Salazar (1997, pers. comm.) used *S. longiceps*, *D. kurroides*, Auxis thazard and *T. haumela* for ‘burong isda’, a lactic-acid fermented fish-rice product in the Philippines, usually produced from freshwater species and only available in inland areas (Olympia et al., 1995). All species resulted in acceptable products.
Except for *T. haumela*, all the marine species used were histidine-containing ones. However, the production of histamine during fermentation was found to be below the safety limit of 20 mg per 100g. Further tests demonstrated the probability of an *in situ* inhibition of the histamine-producing bacteria by the LAB present. The study also showed that ‘burong isda’ can be packed in natural casings instead of the usual bulky bottles. They can then be stored chilled or frozen, thus improving marketability. LAB-fermented products could also be produced from bullet tuna (*A. rochii*), mackerel (*Rastrelliger spp*), moonfish (*Menke maculata*), common slipmouth (*L. equulus*), big-eye scad (*C. crumenophtalmus*), and goatfish (*Upeneus spp*) (*Olympia, M. 1997. pers. comm.*). Although these products were judged to be different to the traditional ‘bagoong’, a fish paste consumed in the Philippines, most panelists agreed that they would be acceptable as an accompaniment to rice. ‘Somfag’, a Thai-fermented fish, usually produced from freshwater species, was successfully prepared using *Sphyraena abutsata* (Chanthachum and Kimhamanon, 1997, pers. comm.). A 60 hr fermentation period resulted in the most acceptable product, with a pink colour, firm and elastic texture and acceptable odour and flavour. ‘Pla-ra’ a Thai salt-fish-carbohydrate mixture, could also be produced from anchovy (*S. commersonii*) at a salt concentration of 20 percent and a carbohydrate level of 10 percent, yielding a product with good organoleptic quality (*Rattagool, P., 1997, pers. comm.*)

**THE FUTURE**

It is obvious that many technological solutions are available for the production of bycatch products for human consumption. Although earlier attempts at technology-led initiatives have generally not provided long-term solutions, particularly with regards to economic viability, recent trends do indicate that increasing amounts of bycatch are now being used as human food, instead of as animal feed.

Apart from solutions offered through fisheries management, such as gear-based selectivity and regulatory-based controls (*Alverson et al., 1994*), technological approaches can be one of the solutions through which bycatch can be effectively utilized. However, finding a technological solution may not be sufficient in itself. Firstly, although the raw material may be low cost, any form of processing will inevitably add to the cost of production and may not add sufficient value to cover these costs. Any processing involved therefore must contribute minimum added costs. Secondly, since food habits are among the most difficult of all to change in any community, one of the requirements that precedes value-added product development is to know more about the factors that influence consumer acceptance and their relative importance in different societies and under different living conditions i.e. the social, cultural and economic variables that influence consumer attitudes, preferences and consumption. Such knowledge is necessary to design successful approaches to fish promotion, product development and marketing.

This market-driven approach will reflect the needs of the target groups and if programmes and projects are to be increasingly market-driven, there should be greater emphasis on a systems approach, identifying key constraints in the system and subsequently planning research and development activities around these constraints. Technological solutions therefore should be part and parcel of an overall strategy to improve bycatch utilization:

1. evaluate resources and markets;
2. identify and develop products acceptable to potential markets;
3. promote products;
4. monitor handling and processing with respect to product safety and quality; and
5. ensure that adequate standards and specifications are met.

This is all the more imperative as demand for protein escalates. Much of the future increase in demand will come from developing countries, particularly those of Asia (*James, 1988*). Fish resources in the Asian region are in short supply and as traditional food fish become increasingly under pressure, more non-traditional species in the bycatch will be taken into the food chain. Ultimately, this would result in
more food available for human consumption, reduction of fish prices to the consumer, reduction of pressure on existing fish stocks, reduction of wastes entering the environment and increased incomes to industry.

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