Processing and Product Development from Tuna

T.K. Srinivasa Gopal, C.N. Ravishankar, J. Bindu and K. Ashok Kumar

Central Institute of Fisheries Technology
P.O. Matsyapuri, Cochin - 682 029, India

E-mail: srigopal2002@yahoo.co.in

Tuna, commonly known as chicken of the sea, are relished by people in different forms. Tuna presently contributes 9% of the total fish production. They belong to the family Scombroidae and the species includes yellowfin (*Thunnus albacares*), bigeye (*T. obesus*), bluefin (*T. thunnus*), skipjack (*Katsuwonus pelamis*) and albacore (*T. alalunga).* Yellowfin and albacore are tropical warm water highly migratory species that are found throughout the world oceans. Skipjack together with yellowfin tuna contribute the largest to total tuna production.

World trends in fishing, processing and trading of tuna are influenced by a number of environmental and socio-economic factors. Fishing activities are influenced by factors such as resource availability, water temperature, current, season and operational costs, whereas, processing depends on availability and quality of raw material, product formulation and processing costs. The market for various tuna product forms like chilled, frozen, canned and smoked items is expanding worldwide. The recent expansion of the tuna fishery in the Indian Ocean has influenced to modify the fishing fleets and the processing facilities in India.

Global tuna production in 2005 reached 4.3 million t. The major tuna catching nations are Japan, Thailand, Taiwan, Indonesia, Republic of Korea and Philippines. The contribution of various species to the catch is skipjack (49.46%), yellowfin (32.8%), bigeye (10.47%), albacore (5.8%) and bluefin (1.56%). They are referred to as principal market species because of worldwide demand for *sashimi* and canned products.

The main internationally traded tuna forms are raw material for canning (fresh, frozen and pre-cooked loins), tuna for direct consumption (fresh, chilled and frozen) and canned tuna (solid pack, chunks, flakes and grated). *Sashimi* grade tuna is a delicacy in Japan and is from fresh tuna.

Bluefin, bigeye and yellowfin are the most preferred species for *sashimi*, whereas skipjack and albacore are preferred for canning. Canned products are packed in oil, brine, spring water or sauce. The principle producers of canned tuna are Thailand, USA and Spain. USA is by far the main canned tuna importing country followed by European countries. In 2005, 82% of tuna was consumed as canned product and 18% as fresh product (including *sashimi*). Japan consumes 78% of fresh tuna.

Tuna fishery and exports from India

The estimated resource potential of coastal tuna in the Indian EEZ is around 65,000 tonnes consisting mainly of skipjack, bullet tuna, long tail, little tuna, etc. The average annual landings of coastal tuna in India is around 49,000 t and the proportion of important species is little tuna (49%), frigate and bullet tuna (23%), longtail tuna (13%), skipjack (6%) and others (9%). More than 80% of the landings are on the West coast and in Lakshadweep. Recently, a fishery has emerged for the yellowfin tuna off Visakhapatanam. Fisheries Survey of India has conducted extensive exploratory surveys and has collected information on the biology and distribution of tunas, and published atlas for oceanic tunas. The fishery resource potential of oceanic tuna in the Indian EEZ is 2,13,000 t with estimated composition of yellowfin at 54%, skipjack at 40% and bigeye at 6%. Simultaneously, industrial fishing for yellowfin tuna has also emerged in the last two years in Bay of Bengal where 65% of the catch is exported as *sashimi*.

Tuna is the third major fish commodity traded internationally after shrimp and ground fish. Tunas and tuna-like species (true tunas, billfishes, and other tuna-like species) are an important food source, used mostly for canning and *sashimi* due to their high economic value and extensive international trade. Export of tuna from India was 23,788 tonnes valued Rs. 1303.830 million ($29.54 million) during 2006-07 compared to the exports during 2005-06 at 16,627 t valued Rs. 6931.07 lakhs. (MPEDA, 2007). Chilled tuna is the highest unit value-earning item, but large quantities of tuna are exported in frozen form. Export price of Sashimi tuna is more than twice as high as that for canned tuna. Export of chilled tuna was recorded as 758 t during 2006-07, as against negligible exports during the previous year. The major form of chilled tuna exported is tuna (whole), yellowfin loins and gutted tuna. The country topping in the import of tuna from India in terms of value was European Union, followed by South East Asia, Japan and Middle East.

Handling of tuna

Fishing methods play an important role in determining the quality of fresh tuna. Ideally the tuna should be caught with least stress to avoid accumulation of lactic acid in the flesh which tends to trigger the onset of rigor mortis and subsequent quality deterioration. Under a severe stress condition where tuna fight intensely for more than 2 minutes just before landing, a considerable amount of lactic acid may built up in the muscle and leads to a rise in acidic condition of the fish meat. Such conditions coupled with a high handling temperature, could result in a serious defect known as *yake niku* or burnt flesh. Fish in that condition are not suitable for *sashimi* because of their poor appearance, acidic flavour as well as metallic after taste. Such defects though not evident externally, can result in financial losses if packed and air-lifted to Japan and other foreign countries.

Killing methods

Tuna has to be killed immediately and properly after landing onboard to prevent further stress. Not withstanding the slight variations in the method of tuna killing, its main purpose is to ensure rapid destruction of the central nervous system which could prolong the shelf life of the fish. Japanese fishermen usually kill tuna by striking the head with a hammer or by driving a knife or spike into the brain, a method commonly known as shime. Some fishermen also use a coring tool called taniguchi or a wire rod to kill the fish.

Bleeding

Although bleeding is considered to be a good practice in tuna handling, it is not really compulsory and the application is very much dependent on the final use of the product. Fresh tuna meant for *sashimi* and sushi need not be bled as long as they can be marketed within 24-48 hours. On the other hand, bleeding is considered essential for frozen tuna.

Dressing, filleting and slicing

After bleeding, the gills have to be removed, followed by evisceration. Gills are severed at their points of attachment, and the membrane behind the gills as well as the viscera should be pulled out. Evisceration without opening the belly minimizes bacterial contamination and maintains the external appearances of the fish. The head is removed by cutting from the pectoral fin towards the dorsal line. In many cases the pelvic fins

are also removed. The head portion is finally removed by chopping the backbone by using a heavy knife or hacksaw. Fillets can be prepared from fully dressed tuna. Filleting is done by inserting a sharp knife through the back until it reaches the backbone and cutting along the dorsal line. The quarter-fillets are then carefully sliced into thinner fillets, or directly cut into blocks of 300-400 mm. Under proper chilling condition, these blocks can be stored up to one week.

Chilling onboard

Various methods of chilling adopted on-board fishing vessels include simple icing, chilling using chilled sea water as well as refrigerated sea water. Icing is the simplest, most efficient and cheapest method of chilling. After killing and dressing, tuna should be immediately kept in 2:1 ice/ sea water slurry. The melt water may be drained off after a few hours to leave tuna covered in ice or may be transferred to the ice store. Tuna should not be stacked too deep in the fish hold and their should be a layer of ice of at least 15 cm thickness between each individual fish. The fish should be held throughout at 0-1°C until further processing or export (Anon, 2001).

Freezing methods

There are two types of frozen tuna. The first category are tuna frozen at –20 to –30°C destined for canning, and the second category tuna frozen at ultra low temperatures (ULT) of –50 to –70°C destined for raw consumption. Frozen tuna using ULT method can be stored up to two years without significant quality changes. However, thawed ULT frozen tuna usually has a shorter shelf life compared to chilled tuna. To obtain *sashimi* quality frozen tuna, all the aforementioned handling methods have to be followed. Tuna has to be immediately chilled and maintained at chill temperature prior to freezing. Immersion or air- blast freezing would serve the purpose, and the tuna should be suspended vertically by the tail, or aligned head first into the air blast .

Effect of harvesting techniques on quality of meat

Almost all deep sea fishing vessels and majority of mechanized fishing vessels operating in the Indian waters are trawlers and they are not equipped for resource specific operations such as long lining for tuna fishing. The modification of vessels for operating monofilament long line system includes modifying the deck layout, rearranging the position of certain equipment, strengthening of certain parts of the vessel or modifying and compartmentalization of the fish hold for storing chilled fish.

Tuna flesh is extremely sensitive, so the fish must be handled carefully in order to prevent "burning" or bruising and damage to the flesh. If the tuna is killed under stress, the flesh undergoes rapid chemical changes resulting in the so-called "burning", which causes the flesh to become mushy and, for some purposes, inedible. The best fishing method to catch tuna is line fishing (hand line, pole-and-line and long line), as it generates minimal damage. Traps are considered to be equally good for catching tuna since tuna has ample space to move with less stress. Long lining is the second alternative, which allows tuna to calm down and restore their energy before being landed. Handlining, Trolling and pole and line are quite satisfactory provided that the fish are landed and killed immediately. Purse seining, on the other hand, tends to catch tuna in large numbers, but with physical damage and maximum stress.

Quality aspects of tuna

Speed and accuracy are needed in processing tuna for export. Fish has to be bled, gilled, gutted and chilled rapidly. Tuna for the *sashimi* market is graded not only on visual characteristics (such as bright / clear appearance of the skin, clear moist eyes, elastic skin and undamaged smooth abdominal walls) but also on the fat content of the flesh. In most buyer countries, tuna imports are generally covered by food safety regulations applicable to fresh / frozen fish. Limits for heavy metals vary. In Italy the upper limit for mercury is 0.7 mg/kg. In Japan it is 0.4 mg/kg. The permissible limit for cadmium is 0.5 mg/kg in most buyer countries while lead levels vary from 0.5 - 2.0 mg/kg. Internationally traded tuna is also tested for histamine, which causes vomiting, diarrhea, and skin irritation if ingested at high levels.

The Hazard Analysis Critical Control Point (HACCP) principle is generally applied to the tuna industry. HACCP requires that food safety controls be integrated within all processing stages, rather than applied just to the final product. It is mandatory to implement HACCP in tuna handling and processing to ensure food safety.

Colour

An important eating quality, freshness of the tuna, is indicated by the bright red colour of the raw meat. The desirable red colour is due to oxygenated muscle pigments. However, storage over a period of time and continued exposure to oxygen, the red colour of the meat gradually changes into various shades of brown due to oxidation and conversion of the oxymyoglobin to a brown pigment (metmyoglobin).

The carbon monoxide gas has been used to treat tuna meat in order to retain its fresh red colour for a longer period of time or to convert the brown colour to the desirable red colour. The carbon monoxide reacts with the muscle pigments to form a very stable complex, carboxymyoglobin. Fresh, chilled or thawed out frozen tuna cuts can be treated with carbon monoxide to obtain the desired colour effect on appearance. The cherry red colour induced in carbon monoxide treated tuna is however abnormal or artificial looking. The residual carbon monoxide concentration in the fish is set at 1100-2200 µg/kg. The use of carbon monoxide as a colour additive in food is banned in the European Union and in many other nations mainly because it could potentially mask spoilage (Henk, 2006). The health and safety risks from the use of CO are fairly limited, because of the high reactivity of CO in combination with fish muscle compounds, mainly myoglobin.

Health benefits of tuna consumption

There are numerous health benefits of eating tuna. Tuna, like other oily fish (salmon, mackerel and swordfish) is rich in Omega-3, a polyunsaturated fat. The consumption of fish that are rich in Omega-3 is associated with a decreased risk of heart diseases, cholesterol reduction, regulation of high blood pressure, prevention of arteriosclerosis and other health benefits. Tuna also contains minerals, such as phosphorous, which is important for the nervous system and the bones and iodine, which is conducive to balanced growth. It also contains proteins and vitamin B_{12} for cell growth, and niacin, which ensures correct metabolism of fatty acids and cholesterol. Studies demonstrated the link between Alzheimer's disease and low levels of docosahexaenoic acid (DHA) which is easy to get by regularly eating fish such as tuna.

Health risks

Histamine: The most likely hazard of consuming improperly-handled scombroids (tunas and mackerels) is histamine poisoning. Histamine is produced in certain types of fish when microbial decarboxylase enzyme breaks down the amino acid histidine. Failure to promptly chill or freeze freshly-caught fish accelerates the growth of microorganisms normally present in the fish, accelerating the breakdown of histidine into histamine. Histamine is a toxin that produces symptoms similar to an allergic reaction. Scombroid fishes with high content of histamine cause scombroid poisoning. The symptoms of scombroid poisoning may include rashes, a metallic taste in the mouth, nausea, vomiting, diarrhea,

hypertension, palpitations, tingling, muscle weakness and respiratory paralysis, and sometimes death. Cooking tuna might kill the bacteria, and even destroy the enzymes, but pre formed histamine is not affected by heating. Raw tuna used for *sashimi* is less likely to be contaminated because it is usually stored in chilled condition or freezing temperatures and sliced right before serving, making it less susceptible to warming temperatures. On the other hand, when tuna is ground to prepare tuna burgers, the friction could raise the temperature of the fish, thus promoting bacterial growth and histamine production. The easiest way to prevent this type of food poisoning is to store the fish at temperatures below 0°C. Each time the fish is handled, its temperature is likely to increase; so it is essential to keep it at or below 0°C while handling it.

Mercury: Another cause of concern possibly linked to the consumption of tuna and tuna-like species is mercury content. Mercury occurs naturally in the environment, or it can be released into the air as industrial pollution and absorbed by surface waters. Bacteria living in water convert inorganic mercury into methyl mercury, and fish absorb it through the water and by feeding on other aquatic organisms. Long-lived predators such as sharks, tilefish (Macalanthidae), swordfish and king mackerel (*Scomberomorus cavalla*) tend to accumulate the highest levels of methyl mercury. The primary danger of methyl mercury in fish is the harmful effect it has on the development of the nervous system in unborn children and in children of less than six years of age.

Dioxins: Dioxins/ furans, and dioxin-like Poly Chlorinated Biphenyls (PCBs) are naturally occurring contaminants in the ocean. Tuna, being a migratory fish, is believed to be harboring residues of dioxins in its meat. The highest level of dioxins recorded in tuna is about 27-33 % of values prescribed by European Action level. The levels of dioxin in tuna fished from Indian waters are not regularly monitored. The permissible level of dioxin in fish oil is 2 pg/g for human consumption.

Processing of value added tuna products

The tuna processing industry has grown very rapidly in the last decade. In addition to conventional processed products such as smoked, canned or frozen products, there is an increasing demand for prime quality fresh tuna meat for *sashimi* and sushi products which commands much higher prices.

Sashimi products

Sashimi is the raw meat used for direct consumption. The meat should be bacteriologically safe, very fresh, tender and juicy and having fresh flavour. The most common tuna used for *sashimi* is blue fin tuna, big eye tuna and yellow fin tuna. Only prime quality selected tuna are suitable for *sashimi* production. The method of fishing of tuna and its handling play an important role in deciding the quality of the tuna meant for *sashimi* production. Tuna has to be killed immediately and preserved properly to maintain its freshness. Immediate killing and destruction of the central nervous system, which controls body temperature, is essential to maintain the high quality of the meat. Currently, *sashimi* grade tuna fetches an average price of US$ 10-12 in the Japanese market. However, the main hurdle for the packing of chilled *sashimi* quality tuna is the lack of technical knowhow and handling infrastructure. Chilled *sashimi* quality tuna should be preserved at a temperature of 2 – 3^0C till it reaches to the ultimate consumer.

Fig.1. gives the pictorial presentation of a *sashimi* grade tuna meat. Only prime quality selected tuna species are suitable for *sashimi* production. Unfortunately, tuna quality varies from region to region and are greatly influenced by biological and non biological factors, such as feeding, age, sexual maturation, disease and parasites, fishing and killing methods, as well as handling/dressing, chilling and storage methods employed. Various measures have been suggested to reduce variations in the quality of tuna meat including the choice of fishing method, limitation of fishing season, standardised methods of handling, killing and chilling as well as thorough sorting and grading techniques. It is important to avoid bruising the tuna in the initial handling process, because of the effect of the blood on the colour of the flesh and bruising can also cause flesh to lose its firm texture and consistency.

Tuna is considered to be a warm- blooded animal which makes them less susceptible to small temperature changes. In addition, because of their large/ thick size and high body temperature (up to 38^0 C on landing in tropical countries) they present problems in chilling particularly in deep muscle layers. Tuna meat usually has a high content of amino acids, histidine, which is very susceptible to de-carboxylation into toxic histamine and related compounds especially under abused handlings. A high proportion of dark red meat which poses problems with meat colour, coupled with an excessive amount of lactic acid due to struggling during capture and prolonged exposure to high ambient temperature, could

render the tuna meat pale and watery, resulting in a poor cooked appearance and reduced value.

For these reasons, fresh tuna especially intended for *sashimi* or sushi demands special handling and processing methods, including gentle catching and landing, proper and swift killing, careful dressing, followed by rapid cooling or freezing and keeping them chilled at 0^0 C throughout the handling process. Quick freezing at -60^0 C followed by frozen storage at -30^0C is highly desirable for the frozen tuna.

Tuna loins: The tuna loins (Fig.2) are prepared from fresh material. The head and intestine are removed, the fish is then filleted and skinless fillets are centre cut into two pieces. The dark meat is trimmed off and the loins are frozen individually. The loins are then vacuum sealed in polythene bags, weighed, labelled and packed in master cartons for export. For *sashimi* grade tuna fresh loins are either wrapped in plastic bags or individually vacuum packed in poly bags. They are then packed in polystyrene master cartons and chilled with gel ice. The individual boxes are then labelled.

***Sushi*:** In Japanese cuisine, sushi (Fig.3) is vinegared rice, usually topped with other ingredients, including fish, various meats, and vegetables. Outside of Japan, sushi is sometimes misunderstood to mean the raw fish itself, or even any fresh raw-seafood dishes. In Japan, sliced raw fish alone is called *sashimi* and is distinct from *sushi*, as *sashimi* is the raw fish component, not the rice component. The word *sushi* itself comes from an outdated grammatical form of a word that is no longer used in other contexts; literally, *sushi* means "it's sour." There are various types of *sushi*: *sushi* served rolled inside *nori* (dried and pressed layer sheets of seaweed or alga) called *makizushi* or rolls; *sushi* made with toppings laid with hand-formed clumps of rice called *nigirizushi*; toppings stuffed into a small pouch of fried tofu called *inarizushi*; and toppings served scattered over a bowl of *sushi* rice called *chirashi-zushi.*

***Saku* blocks:** Saku blocks (Fig. 4) are prepared from fresh loins of *sashimi* grade AA yellowfin Tuna by hand cut. It is brine frozen in 45minutes which eliminates deterioration of the meat. As a result the texture is noticeably firmer. The loins are cut in thickness and trimmed to give a rectangular appearence. The blocks are then used for various preparations or for raw consumption.

Poke cubes: Poke cubes (Fig. 5) are 3/4 inch uniform cubes of raw tuna meat. The poke cubes are usually made from smaller steaks and

Fig. 1 *Sashimi* grade tuna meat

Fig. 2 Tuna loins

Fig. 3 *Sushi*

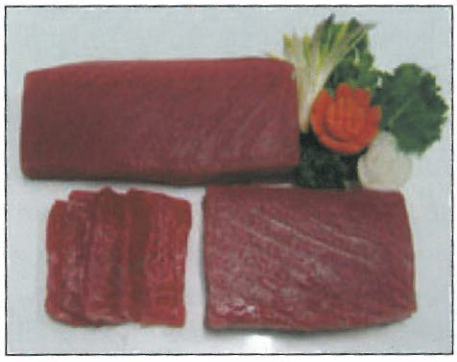

Fig. 4 *Saku* blocks

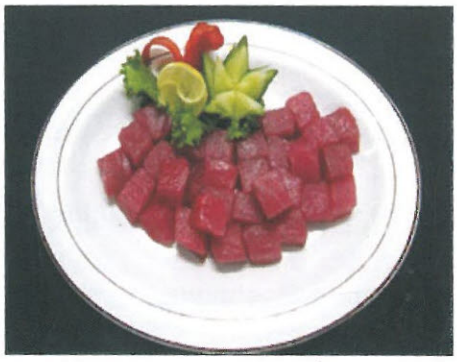

Fig. 5 Tuna poke cubes

pieces of tuna which cannot be presented as tuna steaks and saku blocks. These cubes are cut from AA grade *sashimi* quality and quick frozen to ensure superior texture and flavour.

Tuna steaks: Steaks (Fig. 6) are triangular pieces of tuna of 3/4 inch thickness and cut from treated or untreated fresh tuna loins. The steaks are then frozen and marketed.

Packaging and transportation

Regulations for transportation of fresh chilled tuna are very stringent, particularly to avoid leakage and fishy odours. Various containers have been developed to serve the purpose, including sturdy plywood boxes or single sheet waxed fibreboard boxes. Both types are usually insulated with polystyrene sheeting (25- 30 mm) and lined with polyethylene to ensure water tightness.

Grading of *sashimi* tuna

Initially, buyers inspect tuna prior to sale to evaluate the quality and to determine the bidding price. Tuna are usually graded according to freshness, meat colour, oil content (fatness), physical condition and size, although there is a slight variation in their order of importance from market to market. Because of environmental variations and fishing methods used, only a small proportion of tuna catch will fetch high price, the bulk comprising medium and lower grade species. It should be borne in mind that tuna carcasses are further graded into high, medium and low priced cuts. The cut grade will determine the end users and their possible substitution.

Depending on the type of freezing method and the initial quality of tuna, whole frozen tuna is used for various types of products. Frozen products of international trade include tuna loin's individually frozen, precooked loins and tuna steaks or chunks. Many of the *sashimi* grade products, and battered and breaded products are marketed in the frozen forms.

Carbon monoxide and tasteless smoke for treating fresh and frozen tuna

Sashimi freshness is generally indicated by the colour of the raw meat. The red colour is due to the high content of oxymyoglobin present in the muscle. Prolonged exposure to high ambient temperature could render fish to lose its colour due to the oxidation of myoglobin. In order

to prevent this, fish should be handled carefully and stored chilled throughout handling. The main objective in using carbon monoxide (CO) is to retain the natural colour of the fish. Even bad quality fillets look good if they are treated with CO. This application of CO as a single gas or as a component in tasteless smoke is increasing. Tasteless smoke is produced from natural wood by using filters and carbon to remove the tar and odour emitting to get a clear smoke. The gas is stored in cylinders and used as required for treating raw fish.

In the US, the use of CO as an unapproved additive and the application of CO to impart colouring fish is adulteration. However, the USFDA has given permission for the application of "tasteless smoke" in the preservation of tuna prior to freezing but has not granted GRAS status. Japanese food sanitation law stipulates an initial CO content less than 200 µg/kg which decreases significantly during refrigerated storage.

Non *sashimi* grade tuna

Non *sashimi* grade tuna is processed into frozen Saku and Loins which may be further processed and sold as different products based on the demand situation. Frozen loins which constitutes about 62 % of the whole tuna are individually packed and marketed (Pawiro and Krishnaswamy, 2005)

Canned tuna products

Canning is one of the several methods employed for preservation of a wide range of food including fish. Preservation by canning is achieved by controlling or preventing the micro-organisms responsible for spoilage. Canning involves heating of fish to destroy the spoilage organisms present in them and elimination of the possibility of post - process reinfection by enclosing it in a container and hermetically sealing it before sterilization. Canning is defined as the process of preserving food stuffs achieved by the application of a thermal sterilization procedure to products contained in hermetically sealed containers. Indian canned tuna finds limited export markets besides catering to the needs of the defence personnel and internal markets.

Canned tuna is the most important processed commercial product highly popular in countries such as Japan, USA, UK and Europe. It is also in great demand in the North-East hilly regions, urban centres in India and regularly supplied to the defence services. There are only two canning plants exclusively meant for canning of tuna in India, which are

at Minicoy and Cochin. Other small plants on the main land process tuna occasionally for the domestic market, depending on the availability of raw materials and market demand.

Bureau of Indian Standards has formulated quality standards for tuna canned in oil (IS: 4304, 1967). According to this, only yellow fin (*Thunnus albacares*), albacore (*T. alalunga*), bluefin tuna (*T. thynnus*), Bigeye tuna (*T. obesus*), northern bluefin tuna (*T. tonggol*) and oceanic skipjack (*Katsuwonus pelamis*) are the species that can be used for canning. Canning requirements for products confirming to the requirements laid down in the Indian standards specifications are available for three of these species, *viz.,* skipjack, yellowfin and bigeye tuna.

A major share of the tuna catch in India is comprised of the little tuna (*Euthynnus affinis)*, a dark meat variety that is not included in the list of species specified for canning by the BIS. The dull colour of the meat and high proportion of red meat and the generally unacceptable taste and flavour reduced its overall acceptability either for fresh consumption of converting into processed products. To improve the acceptability of little tuna in the canned form a process has been developed which involves canning in oil spiced and coloured with the extract of red chilly. The red colour of oil masks the dull colour of meat and improved the overall taste and flavour of the pack.

There has been a significant diversification of products in the canned tuna sector. Uncertainties in the major markets, strict quality considerations imposed by major markets, dolphin issue, excess production capacities, etc, have all resulted in decline of canning industries. Tuna can be canned in different containers like tin (Fig. 7), aluminium, tin free steel, etc. Tuna can also be processed in retortable pouches (Fig.8) made of 3 or 4 layer laminates consisting of polyester, aluminium foil, nylon, cast poly propylene. Canned tuna in different mediums like oil, brine, tomato sauce, curry, etc are very popular in the urban markets. Nowadays curry products are having great demand and curries suitable for people from different regions, countries can be prepared and marketed. Central Institute of Fisheries Technology, Cochin has standardised many canned products from fish and shell fish harvested from both marine and fresh waters in different styles suitable for both domestic and export markets. Many products like tuna in oil, tuna in brine, tuna in mayonnaise, tuna in tomato sauce, tuna in curry (Bengali, Oriya, Goan, Malabar, style) in Tin Free Steel and Gold Lacquered tin cans are available in the domestic market. These products have very good demand in international markets also specially

by ethnic Indian population living abroad. Canned tuna products in the international markets include (i) canned, "solid packs", (ii) canned, "chunks" (a mixture of pieces of tuna), (iii) canned, "flakes" (smaller pieces of tuna) and (iv) canned, "grated" (packed pieces of tuna flesh).

Smoked and dried tuna products

Smoked tuna is a delicacy in many parts of the world and is also a traditional product in Lakshadweep. For a product of good eating quality, tuna with a fat content of at least 10 % should be used. The smoked product can be whole gutted fish (small fish), with or without the head on, or fillets. For smoked whole fish, the tuna are gutted, or headed and gutted, as required. The gut cavity must be cleaned and the black belly wall lining must be removed. For hot smoked fillets, single fillets with skin on are cut from the whole fish. Brining requires some care. In order to minimize the risk of food poisoning organisms growing in the finished product it is recommended that the salt concentration in the water phase of the product should be at least 3 per cent.

Masmin

Masmin (Fig. 9) is a traditional smoke cured product of Lakshadweep Islands and Maldives. Lakshadweep has flourishing tuna fishing using motorized and traditional crafts. However, it is not used for processing in modern ways like freezing and canning in many islands due to lack of facilities like freshwater and electricity.

In the preparation of masmin, tuna is cut into loins and cooked in a mixture of fresh water and sea water in 1:1 ratio. The cooked meat is smoked using coconut husk and saw dust. After smoking, the product is sun dried. The process of smoking and drying is repeated several times until a brown to black hard dried product is obtained. Variations in the production pattern of this commodity in different islands of Lakshadweep and the lack of Good Manufacturing Practice (GMP) reflect in the inconsistent quality and storage stability. A fall in the overseas market demand for Masmin has recently been reported mostly because of the inconsistent quality and inconvenient size of the material. Poor storage stability is another factor which comes in the way of increasing its consumer appeal. To improve the quality and profitability, the Central Institute of Fisheries Technology has established good production technique based on HACCP and also has standardised many masmin based convenience products, viz., mas fingers, mas powder and mas granules. All these products packed in LDPE-PEST laminated pouches the products have a shelf life of 10-12 months at ambient temperature.

Katsuobushi

Katsuobushi (Fig. 10) is the Japanese name for a preparation of dried and smoked bonito (skipjack tuna). *Katsuobushi* is the main ingredient in dashi, a broth that forms the basis of many soups (such as *miso* soup) and sauces (e.g., *soba no tsukejiru*) in Japanese cuisine. It is today typically found in bags of small pink-brown shavings, looking somewhat like cedar shavings used for caged pet litter, or the shavings of a plain wooden pencil. Traditionally large chunks of *katsuobushi* were kept at hand and shaved when needed with an instrument similar to a plane turned upside down, but in the desire for convenience this form of the food has nearly disappeared. *Katsuobushi*, however, retains its status as one of the primary ingredients in Japanese cooking today. Popular uses of *katsuobushi* include stuffing for rice balls (*onigiri*), seasoning for cold tofu along with grated ginger and green onions, topping for rice (called *furikake*), and sprinkling with sesame seeds and chopped *nori* atop cold soba noodles (*zarusoba*), as well as its primary use in *dashi* and other prepared foods.

Dried tuna (*Mojama*)

Dried Tuna Fillets is a product with a salted and mildly-sweet flavour; the tuna is air-dried and has been named **Spain's Coastal treasure**. It is gaining international recognition in the restaurant and specialty food sectors around the world (Henk, 2006)

Battered and breaded products

Tuna croquette

Croquette (Fig.11) is prepared from tuna mince meat and minced vegetables which are made into a cake and usually coated with bread crumbs and fried in deep fat.

Tuna finger

Tuna fingers (Fig.12) is prepared by mixing tuna mince with other binding agents and freezing them to set. Then it is battered and breaded and frozen and marketed. To use we can either fry in oil or bake microwave in oven.

Tuna burger

Tuna burger (Fig.13) consists of a mixture of tuna meat paste with onion, flour, other ingredients and spices. It is useful that the percentage

Fig. 6 Tuna steaks

Fig. 7 Tuna in cans

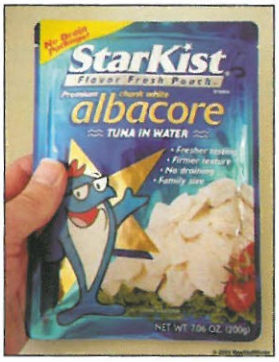

Fig. 8 Tuna in retortable pouches

Fig. 9 Masmin

Fig. 10 Katsuobushi

Fig.11 Tuna croquette

of coarse ground tuna meat is not less than 30% so that consumers will be able to distinguish the value added chunk meat. The starch content should not be more than 15% of the product otherwise the texture will give a starchy bit.

Breaded and battered tuna slices

Breaded and battered tuna slices (Fig.14) are prepared by slicing tuna loins into suitable shape, battering, breading and frying them in oil. They are then mixed with onion and other ingredients.

Other Value Added Tuna Products

Barbecued tuna

Barbecued tuna (Fig.15) is a ready to eat snack suitable for the young as well as the adult. The product has a slightly chewy texture with an acceptable fishy taste or smoky flavor which is optional. The taste and the flavor can be easily varied and adjusted such as sweet and sour, spicy, to name a few. The product has a light brown and pinkish colour. The moisture content of the product is about 30 %.

Seasoned tuna cubes

Seasoned tuna cubes resemble sweets in wrappers. The dried marinated tuna cubes give a good aftertaste and is a healthier snack substitute for the sweet loving children. It can be eaten as snack or together with rice porridge.

Pickled tuna

Tuna meat has been found to be well suited for processing into pickles. Light salted and partially dried small pieces of tuna meat (including dark meat) is fried in sesame oil and is mixed with pre fried ingredients like ginger, green chilly, garlic, chilly powder and other flavoring agents. It is then mixed well with required quantity of vinegar and the remainder of the salt and allowed to remain as such for a few days and then packed in glass jars.

Tuna jerky

Tuna jerky is marinated, dried tuna. For producing jerky the loins are cut into thin slices and marinated in various sauces and spices like, teriyaki, pepper, onion, garlic, etc to suit the intended market. Sometimes smoked flavour is also added to get an enhanced barbeque feeling. The

jerky is then dried in the sun or in artificial driers. The dried product is then cut into strips and packed in multilayer laminate films. This product is also another interesting fish snack which is basically a seasoned dried tuna product and is comparable to beef jerky which is available commercially. Tuna sticks or jerky can come in various taste and flavours by varying the seasonings and spices used during processing.

Tuna biriyani

Tuna biriyani (Fig.16) is a rice based preparation. It is prepared as per standard recipes available for chicken or mutton and tuna is substituted instead of them as the meat source. Ready to eat tuna biriyani can be processed in flexible retortable pouches, cans or semi rigid thermoformed trays.

Tuna ham or loaf

Tuna ham is produced by compressing seasoned tuna chunks and ground surimi paste into a metal container. The ground surimi paste will bind together with the tuna chunks to become what is known as tuna ham or tuna loaf

Tuna chunk sausage

Tuna chunk sausage (Fig.17) is produced by mixing seasoned tuna chunks with ground surimi paste containing food ingredients such as binding reinforcement and additives. The mixture is then filled into plastic casings, sealed and followed by heat sterilization. The product must contain more than 20 % tuna chunks, not more than 20 % carbohydrate and below 10% vegetable protein.

Tuna paste

This is another traditional product of Lakshadweep which is prepared from the water used for cooking tuna fillets during Masmin processing. The same water is repeatedly used for boiling fresh batches of fillets until the water becomes thick. It is further concentrated to yield the thick paste. Scraping of dried Masmin are some times added to this paste to increase its nutritional value. It is stored in earthen ware and is used as a flavoring agent. Shelf life of the product is 1-2 years. A similar product called *rihakuru* is processed in the Republics of Maldives also.

Tuna shavings

Another smoked/ cured product processed from tuna is 'Tuna shavings'. It is prepared by dipping tuna fillets in the saturated brine for

1 hour followed by smoking at 70-80^0 C for 8 hours. These fillets are dried in air at 70^0 C for 16 hours after which they are trimmed and converted into thin shavings using a carpenter's planer. This can be packed in polythene bags or glass bottles and stored at ambient temperature with shelf life of about 6 months.

Byproducts from tuna processing waste

Tuna is generally processed as raw meat and marketed as loins/ steaks or as a canned food. Due to global competition the profit margin on tuna loins/steaks is limited. In the canning process, only about one-third of the whole fish is available for value addition. Processing discards from the tuna canning industry are estimated at 450 000 metric tonnes annually. With profits getting leaner due to global competition, tuna industry would do well to look into the possibility of developing by-products from the waste from tuna processing. By-products from tuna would include skins, heads, bone, viscera and muscle after loins. The by-products from the waste could be processed for the food, feed and pharmaceutical industries. Value addition and waste utilization are two areas in the tuna industry which have shown some interesting developments over the last few years. There has been significant growth in non- canned, innovative value added tuna products in some major markets such as US, Japan, and EU.

Tuna silage

Silage processing which does not depend on quantity is a good option for value addition. Fish silage is a liquid product made from whole fish or parts of the fish to which no other material is added other than acid and in which liquefaction is brought about by enzymes already present in the fish. The main benefit of silage is the high level of protein and essential amino acids in the proteins especially lysine. Fish silage is usually added to pig, poultry and aqua feed to substitute for fish meal which is one of the most expensive ingredient added to feed (Sultanbawa and Aksnes, 2006).

Tuna protein hydrolysate

Fish viscera and frames are used as a potential source of protein hydrolysate. Hydrolysates are defined as proteins that are chemically or biologically broken down to peptides of varying sizes. The fish protein hydrolysate is of increasing interest due to their potential application as a source of bioactive peptides (Sultanbawa and Aksnes, 2006)

Tuna bone powder

Fish bone powder is a potential value added by-product from the tuna processing industry. Fish bone contains proper balance of calcium and phosphorous that can be used as a calcium food supplement mainly in animal feed. It can be an environmental hazard if disposed without any value addition. Such food supplements can be taken as an alternative to drugs to treat osteoporosis (Sultanbawa and Aksnes, 2006)

Tuna gelatin

Gelatin is a hydrolysed form of collagen and is a gelling protein which has widely been applied in the food and pharmaceutical industry. Industrial application of fish gelatin are in the areas of micro encapsulation, light sensitive coatings, low set time gels, and as an active ingredient in shampoo with protein. Gelling needs large molecules greater than 10000 D and the non gelling contains smaller molecules less than 10000 D, since gelatin extracted from tuna contains a higher percentage of molecules larger than 10000 D, it has good gelling property and has the potential to use as a gelling agent in the food industry (Sultanbawa and Aksnes, 2006)

Tuna orbital oils

Tuna eyes (Fig.18) are one of the most popular "brain foods" in Japan. Fish heads are a culinary delicacy in most South- East Asian Countries. However, the health food image of tuna head, particularly tuna eyes, is unique in Japan. The popularity has also related to the reported high DHA/ EPA content of eye muscles. Tuna eye balls are now available pre cooked and vacuum packed (Sultanbawa and Aksnes, 2006). Marine fish oils have been well documented for beneficial health effects such as reducing the risk of cardio vascular diseases, hypertension, and auto immune and inflammatory diseases. High amount of long chain PUFA like EPA and DHA, make marine lipids unique when compared to other lipids. Tuna orbital (Fig.18) comprises of a total lipid content of 22.4% of which PUFA constitute 26.4 g/100g oil, DHA 19.7 g/100 g and EPA 3.9 g/100g. The sum of n-6 is 3.8 g/100g and MUFA constitute 23.3g/ 100g. This data indicates that tuna orbitals are a good source of PUFA and MUFA which are essential for good health. Encapsulated tuna orbital oil (Fig. 19) is used as a health supplement in many countries.

Tuna meal

The wastes from tuna processing plant, especially head, fins, bone and red meat can be effectively utilized by converting them into valuable fish meals to be used in cattle/poultry/ pet feed manufactures.

Fig.12 Tuna finger

Fig. 13 Breaded tuna burger

Fig.14 Breaded and battered tuna slice

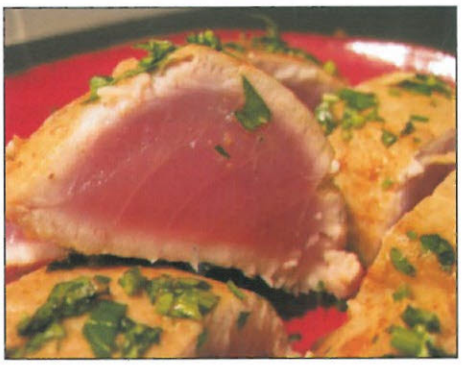

Fig.15 Barbequed tuna meat

Fig.16 Tuna Biriyani

Fig.17 Tuna sausages

Tuna viscera powder

Tuna viscera powder is made from tuna viscera and the resulting hydrolysate is formed by enzymatic action. It can provide fish flavour to animal feed products which attracts fish and shrimp or as a flavour enhancer in pet foods. It is soluble, dark brown coloured, hygroscopic (moisture absorbing) powder.

Functional protein concentrates from little tuna

Mechanically separated mince from tuna is first washed with water, then with 2% (W/V) aqueous solution of sodium bicarbonate and finally with water to remove pigments, lipids, colour and odour bearing compounds. Homogenization of the washed meat in water followed by acidification of the dispersion with acetic acids produced a weak gel which was diluted and spray dried. Protein powder contained 5% moisture, 1.2% lipids and 89.55% protein with good functional properties. Packed in 300 gauge polyester/ polythene laminated pouch, it does not undergo significant browning during three months storage at ambient temperature.

Fish calcium

Tuna bone can be used as a good calcium source and is effective in maintaining skeletal metabolism. Calcium powder processed from the back bone of tuna can be used to combat calcium deficiency in the diet of children, which causes weak bones and spine curvature problems. The method mainly involves removal of the gelatin from the crushed bone and pulverizing the remaining portion. First the bone frame is crushed and washed in clean water many times. A solution containing 10% calcium carbonate is then added to the residue and left for an hour and drained. Washing and treatment with calcium carbonate solution is repeated a number of times. Finally, the washed bone residue is dried and pulverized to the required mesh size.

Tuna skin leather

Tuna skin can be used for producing good quality leather. This can be used for the manufacture of leather products like bags (Fig.20), belts, wallets, slippers, etc.

Fig. 18 Tuna Eyes

Fig.19 Encapsulated tuna orbital oil

Fig. 20 Bag made of tuna skin leather

Conclusion

Tuna is the most widely consumed sea food, and is the corner stone of the global fish trade. The world tuna market can be divided into two distinct types: The higher prized *sashimi* market, which consumes fresh and uncooked tuna; and low, priced canned tuna markets. The *sashimi* market relies on bluefin, bigeye and yellowfin tunas, while the canned tuna market uses mostly skipjack and albacores. The high priced *sashimi* market is very strong catering to the soaring Japanese demand and very recently to Europe and USA. On the other hand, the canned tuna markets, especially the low priced skipjack segments, are relatively over supplied and facing depressed demands and declining prices. A third segment involving trade in fresh and frozen tuna, particularly loins, is

coming up well with doubling of world trade between 1986 and 2005. The other tuna products which are of importance are breaded and battered products, sausages, pickled tuna, smoked tuna and other value added byproducts. Hence the tuna fishery has a bright future in the coming years.

References

Anon (2001), INFOFISH International (5): 64

Henk, B. (2006). Non-canned tuna products: Prospects in European market. INFOFISH International (6): 44-48

MPEDA (2007) Development of Tuna Fisheries in Andaman and Nicobar Islands, Project Proposal submitted to the Ministry of Commerce, Govt. of India, Marine Product Export Development Authority, Cochin.

Pawiro, S. and Krishnamurthy. N. (2005). The good and bad years in tuna industry, INFOFISH International (4): 54

Sultanbawa, Y. and Aksnes, A. (2006) Tuna process waste - an unexploited resource, INFOFISH International (3): 37-40