Onboard Handling and Processing of Tuna

K. Ashok Kumar
Fishing Technology Division, ICAR-Central Institute of Fisheries Technology, Kochi
E-mail: ashok1960@gmail.com

Introduction

The world demand for tuna is large and growing. Tuna processing industry has grown very rapidly in the last decade. In addition to the conventional processed products such as smoked, canned and frozen products, there is an increasing demand for the prime quality fresh tuna meat for sashimi and sushi production, which commands higher prices especially in the Japanese market. A review of the world tuna market revealed the existence of three categories.

1. The high-priced sashimi grade tuna catering to the soaring Japanese demand
2. The canned tuna, especially the low-priced skipjack segment, is relatively oversupplied and facing depressed demand and declining prices.
3. The third sector involving trade in fresh and frozen tuna.

Tuna is an important trade item, with about 40% of the catch entering global trade. For development of tuna fisheries, India must evolve medium to long-term strategies to participate in all the three areas of the world tuna market. The production of sashimi grade tuna in India requires special mention as it is only in its developmental stage and requires a real boost to catch up in the Japanese market. For Sashimi grade products, killing, damaging the brain, bleeding, gutting, precooling, freezing to -60°C etc are to be followed. Proper handling starting from catching and implementation of good handling procedures based on HACCP concepts, at every stage are highly required. The work done in India in tuna processing is related to various processing methods and product development. The work on production of sashimi grade tuna is comparatively limited. Not much work has been done on the utilization of oceanic tuna.

Tuna is unique among bony fish. It has high metabolic rate and higher body temperature than ambient temperature. It is reported that when tuna struggles, it uses all its energy to fight for escape. Hence it is very important to bring the tuna to the pre-exercise level before it is removed from the hook. The glycogen is depleted considerably during struggle. The Adenosine triphosphate, the chemical store of energy in the muscle starts decomposing. The struggled fish enters into rigor mortis very quickly after death. This has a deleterious effect on the quality of the meat. It is better to have a longer pre-rigor and rigor period for maintaining the quality. The struggling of tuna causes to accumulate lactic in the muscle in the live condition itself within a short period of struggle. This causes visual changes in the colour of the muscle and develops an effect known as 'burnt fish'.

Allowing minimum struggle during catch and onboard allows the quality of the muscle to retain for a longer period and also the shelf life. Bleeding of the fish reduces the post-mortem production of lactic acid. Other factors which contribute to the quality of meat are feeding habits, nature of food available, presence of parasites, sexual maturation, disease, fat content, killing methods, handling procedures, chilling and storage methods and holding temperature. The intervention to improve the quality can be done in the latter three parameters.

If tuna is not properly chilled immediately after capture, the high body temperature of tuna meat coupled with the presence of oxygen and iron in blood causes lipid oxidation and decomposition. This will lead to off taste of the meat due to rancidity. Proper bleeding can reduce a good source of oxygen and the pro-oxidant, iron.

Rapid chilling and maintaining at 0°C throughout handling is recommended to get high quality meat. If the quality of tuna is to be maintained for a long period, it has to be frozen to -60°C in a period of 8 h or less and should be stored at –50°C.

The storage life of chilled tuna is 10-12 days. Frozen tuna has the same initial quality as chilled tuna, but the thawed tuna has a short life of 3 days due to noticeable changes in colour and texture.

Handling of Catch Onboard

The various handling steps onboard fishing vessels are

1. Catch the fish with minimum stress,
2. The storage area of the vessel should be clean and safe
3. Quick stunning and killing of the fish
4. Destroying the spinal cord.
5. Proper removal of blood, guts and intestines without breaking
6. Washing in clean and safe water/ seawater
7. Lowering the temperature of the fish to 0°C by using chilled seawater and ice mixture
8. Storage the fish properly after chilling in flake ice or finely powdered ice in insulated containers or fish hold.

Handling and storage of tuna for sashimi:

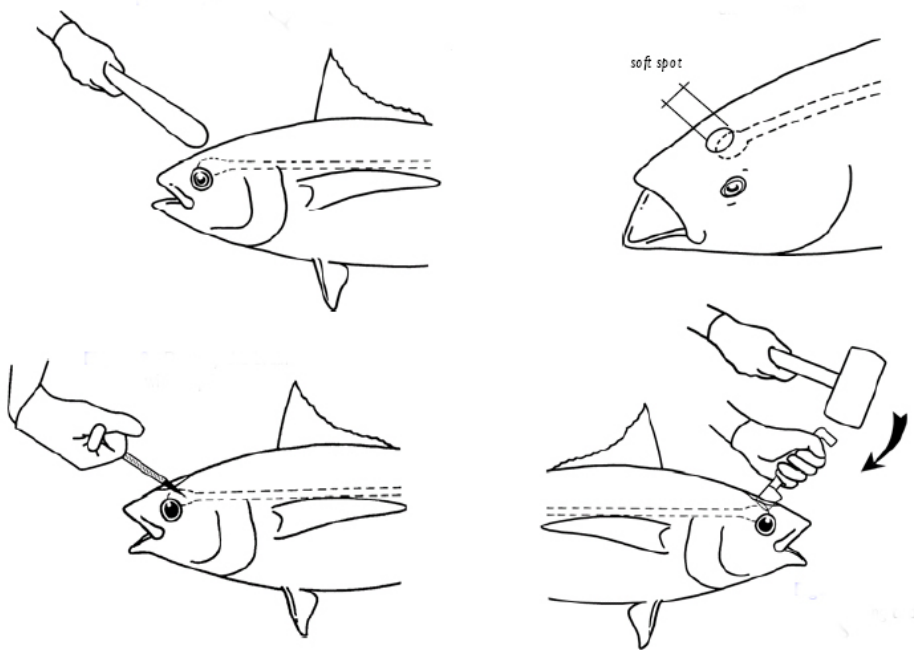
Tuna is killed either by a sharp blow to the head or inserting a spike into the brain at the soft spot. The soft spot is found between the two eyes. The purpose of giving a sharp blow is to prevent struggling, which will result in the development of anaerobic glycolysis and formation of lactic acid. The glycolysis will result in early ATP degradation and the resultant rigor mortis within a short period after death. This will affect the quality of the material.

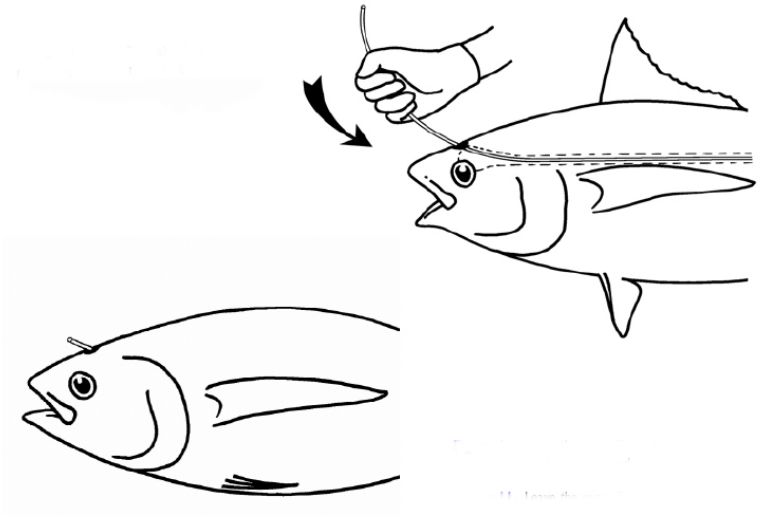
The brain should be destroyed by piercing a sharp object into the brain. The nerves should also be destroyed. The spinal cord can be destroyed by inserting a rod through the brain and into the spinal canal. This is carried out by cutting a wedge over the soft spot to expose the brain and then passing the rod through the brain into the spinal canal. The brain and spinal cord are destroyed to prevent enzyme actions and reduce the body temperature, which is controlled by the blood flow.

Tuna must be bled as soon as possible after the catch. Removal of the hot blood will allow the tuna to cool faster and reduce acidity. Blood is a source of iron, which is a pro oxidant. This will activate the peroxidation of fat and its decomposition, which will result in the development of off odours. There are three steps in bleeding.

1. Make a cut of 2 inches long behind the pectoral fin with a clean knife of 2 inches long and ½ inches wide so as to cut the blood vessel. The fish must be cut on both sides.
2. The next step is to cut the blood vessels in the gills. By opening the gill cover, make cut through the membrane behind the gill to cut the blood vessel without damaging the heart. This is repeated with the other gill also.
3. The final step is to cut vertically on both sides of the tail between the third and fourth dorsal fin without removing the tail.

During these cutting operations clean salt water must be running over the cut so as to prevent the blood from clotting.





Gutting and Gilling

It is important that all the internal organs are removed as quickly as possible after bleeding. To remove the internal organs, make a straight cut 4 inches long in the belly cutting towards the anus. The anus should not be cut

through; but cut as close to the anus as possible may be made. The attachment of intestine to the body wall is removed by pulling it through the cut. Next step is to remove the gills from the head without damaging the heart. Cut the main muscle attaching the gill cover to the head and also the membrane behind the gills. Remove the gills and guts and any remaining attachments. On completion of this process, the belly area and gill portion must be properly cleaned using clean and safe seawater. The cut remnants and blood should be completely removed. The gill area is usually scrubbed with a soft nylon brush to remove complete blood in that area. After the process is completed, the outer surface must be washed properly to remove any slime or foreign material present. The seawater used for cleaning must be cooled. This will also help the initial cooling of tuna.

Gut contains a large amount of enzymes and hydrolytic bacteria. These enzymes will act on the belly walls, which will make the belly wall soft and penetration of bacteria easy. Since the gut contains digested food materials, it is a good source for the bacteria to grow. These bacteria will penetrate into the muscle through the soft belly wall caused by the enzyme action and make the flesh to deteriorate early.

Chilling

After the gutting, gilling, bleeding and cleaning operations are over, it must be kept in salt water ice slurry for a period of upto 12 hours or until the core temperature of tuna reaches 0°C. The mixture of ice and water should have at least two parts of ice to one part of water. This procedure

should be adopted on vessels wherever possible. Better quality product is obtained if the temperature is lowered as quickly as possible. In small vessels where these operations are not possible, the tuna must be stored in ice immediately after catch. Sufficient ice should be added or repacked periodically to ensure proper cooling. Early chilling is advantageous to bring down the temperature to zero degree centigrade and the following problems will be reduced considerably.

1. reduce the burnt tuna syndrome (BTS).
2. reduce the enzyme activity
3. reduce bacterial growth

Icing Tuna Onboard

When the core temperature attains 0°C, the tuna must be removed from the ice slurry and kept in fish hold having one layer of ice in the bottom. The belly part of the tuna must be packed properly with ice. The outer area of the tuna must be covered with a green tuna paper soaked in salt water so as to protect the skin from damage during contact with ice. Fresh water causes bleaching of skin, whereas saltwater helps to maintain the natural colour of the skin. Green tuna paper is a special parchment paper available in Japan.

If block ice is used for icing, it must be properly crushed. There should not be any large pieces of ice or pieces with sharp edge. The tuna should be properly covered with ice throughout the storage. The tuna are placed head to tail to ensure sufficient ice between each fish. Tuna must be laid flat to ensure that tuna does not bend. Bending will cause tearing of meat. There can be two layers of tuna in a fish hold. If more layers are needed, shelving must be used. Between each layers of tuna, there should be at least 30 cm of ice. The ice should be spread evenly over the fish. The melt water must be able to run clear of the fish and melt water must be removed. Large and small tuna must not be iced together. Refrigerated seawater system also can be used. In this system tuna must be kept in plastic bags.

When tuna is stored in the fresh state, the temperature of the meat should not fall below –2.5°Csince rapid browning of the meat in the outer layer can occur at this temperature.

Onboard Freezing of Tuna

All the handling and processing operations must be carried out before freezing the fish. The core temperature of tuna must be reduced to –60°C within 8 hours. The shorter the time, the better is the quality. Air blast freezing is recommended. Tuna should be suspended vertically by the tail or aligned the head first in the air blast freezing. Tuna must be placed flat and protected from bending. The recommended storage temperature for sashimi type tuna is –50°C or below.

Process Control

- **Requirements**

1. Proper washing during and after processing and ensure removal of blood, gut remnants and foreign material
2. Use of clean and safe sea water
3. Handle and process tuna quickly and carefully after being taken onboard
4. Cool tuna in ice slurry with 2:1 ice water ratio
5. Keep only properly cooled tuna in fish hold
6. Keep tuna properly to avoid bending
7. Check the temperature of fish hold and tuna at regular intervals and ensure that the core temperature is 0°C
8. In the case of freezing tuna the core temperature should be lowered to –60°C within 8 hours

Defects

1. Inadequate washing
2. Improper cooling

Fresh Storage Requirements

1. Fish hold must be free from any contamination
2. Fish hold must be properly insulated
3. The ice should be clean and safe
4. In RSW system, only clean and safe seawater with adequate temperature should be used
5. The core temperature of the tuna must be maintained at 0°C

Handling of Tuna On-shore

The material should be delivered at the receiving end in insulated containers in ice or in ice water slurry. Care should be taken to control the temperature rise and prevent the material from any damage during handling onshore.

At the receiving end, the tuna should be sorted and graded. All material, which are decomposed, unwholesome or contaminated shall be removed. Also remove all un-gutted tuna. Do not keep tuna on the floor of the receiving area to avoid contamination. Grading should be conducted based on colour, condition and size.

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 are tuna frozen at ultra-low temperature (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. While chilled tuna has a shelf life up to twelve days at 0°C, thawed tuna has a commercial shelf life of only three days before the taste and colour changes become noticeable. Thawed tuna also tends to exudate drip accompanied by rapid textural changes.

To obtain sashimi quality frozen tuna, all the aforementioned handling methods have also 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 tuna should be suspended vertically by the tail, or aligned headfirst into the air blast. The frozen product should then be stored at –50°C and maintained at this temperature until final sale to avoid desiccation and freezer burn. The best quality tuna has round sides and a straight natural appearance. Tuna stored in a bent position will suffer gaping or tissue damage upon thawing. Frozen tuna could meet the quality standards for sashimi when they are immediately frozen until the body temperature of –55°C is reached, and held there for at least 5 hours followed by frozen storage at –45 to –50°C.

Frozen storage requirements

1. Freeze tuna to –60°C within 8 hours
2. Frozen storage temperature should be at least –50°C or below
3. Record the temperature of frozen storage
4. During handling, transportation, and storage, the rise in product temperature should be minimized

Packing and Air Freighting

International Air Traffic Authority (IATA) regulations call for stringent air freighting practice for fresh chilled tuna, particularly to avoid leakage and fishy odour. Various containers have been developed to serve the purpose, including sturdy plywood boxes or single sheet waxed fiberboard boxes. Both types are usually insulated with polystyrene sheeting (25-30 mm) and lined with polyethylene to ensure water – tightness. Prior to shipping, the tuna have to be chilled to a core temperature of less than 5°C and the temperature has to be maintained throughout the transportation process.

Tuna Grading

All imported chilled tuna to Japan are sold by auction. 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 prices, 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 cuts grade will determine the end-uses and their possible substitution. Toro meat of blue fin and big eye, for example, have no direct substitute, but lower grade akami might be substituted by other fish

including skipjack, yellow tail or marlin. Grading systems based on colour and conditions scores are given below.

Condition Scores For Yellowfin and Bigeye Tuna

1.*Very good (Score 50)*

- ✪ No apparent defects/damage (no rips, tears, cuts, abrasions)
- ✪ Scales intact
- ✪ Fish looks as though it has been lifted from the water; Natural body colour, bright
- ✪ Flesh at notch very firm (springs back quickly on pressing lightly with finger tips. No 'soft spots' present on carcass surface

2.*Good (Score 40)*

- ✪ Slight defects/damage (a few minor rips, tears, cuts, abrasions)
- ✪ Some scales lost
- ✪ Body colour are a little dull
- ✪ Flesh at notch firm, springs back slowly on pressing lightly with fingertips. One or two very small 'soft spots' present on carcass surface

3. Medium (Score 30)

- ✪ Noticeable defects/damage (a maximum of two rips, tears, cuts, abrasions which could affect meat yield)
- ✪ Small patches of scales lost
- ✪ Body colour dull/dark
- ✪ Evidence of minor water ingress (bleaching), and/or red staining
- ✪ Flash at notch less firm, does not spring back fully on pressing lightly with fingertips. Several 'small spots' present on carcass surface

4. Poor (Score 20)

- ✪ More than two rips, tears, cuts or abrasions which could affect meat yield
- ✪ Large patches of scales lost
- ✪ Body colour dark
- ✪ Bleaching, red staining very apparent
- ✪ Flesh at notch soft, does not spring back at all on pressing lightly with fingertips. Large soft areas on carcass surface

5. Very Poor (Score 10)

- ✪ Severe body damage, distortion
- ✪ Severe scales loss
- ✪ Body colour dark
- ✪ Severe bleaching, staining
- ✪ Flesh at notch very soft, falling apart, Carcass surface breaking up
- ✪ Meat has evidence of parasites or disease

Colour Scores for Yellowfin

1. ***Very Good (Score 50)***
   - ✪ Meat is translucent, glossy
   - ✪ Colour are bright
   - ✪ Fat is clearly visible in the out layer

2. ***Good (Score 40)***
   - ✪ Meat is a little translucent, and less glossy
   - ✪ Colour are less bright
   - ✪ Fat just visible in outer layers

3. ***Medium (score 30)***
   - ✪ Meat is translucent, and has lost its gloss
   - ✪ Colours are a little brown
   - ✪ No fat visible in outer layers

4. ***Poor (Score 20)***
   - ✪ Meat is almost opaque. No gloss
   - ✪ Colours distinctly brownish and dull
   - ✪ No fat visible in outer layers

5. ***Very Poor (Score 10)***
   - ✪ Meat is opaque
   - ✪ Colour is brown, whitish, or gray
   - ✪ No fat visible in outer layers

Colour Scores For Bigeye Tuna

1. **Very Good (Score 50)**
   - ✪ Meat is translucent, glossy
   - ✪ Colour are bright
   - ✪ Large amounts of fat, penetrating into the inner muscle layers

2. ***Good (Score 40)***
   - ✪ Meat is a little translucent, and less glossy
   - ✪ Colour are less bright
   - ✪ Large amounts of fat, penetrating into the inner muscle layers

3. ***Medium (score 30)***
   - ✪ Meat is translucent, and has lost its gloss
   - ✪ Colours are a little dull
   - ✪ Fat is present, but with little or no penetration into the inner muscles
   - ✪ Meat colour may appear a little brown

4. ***Poor (Score 20)***

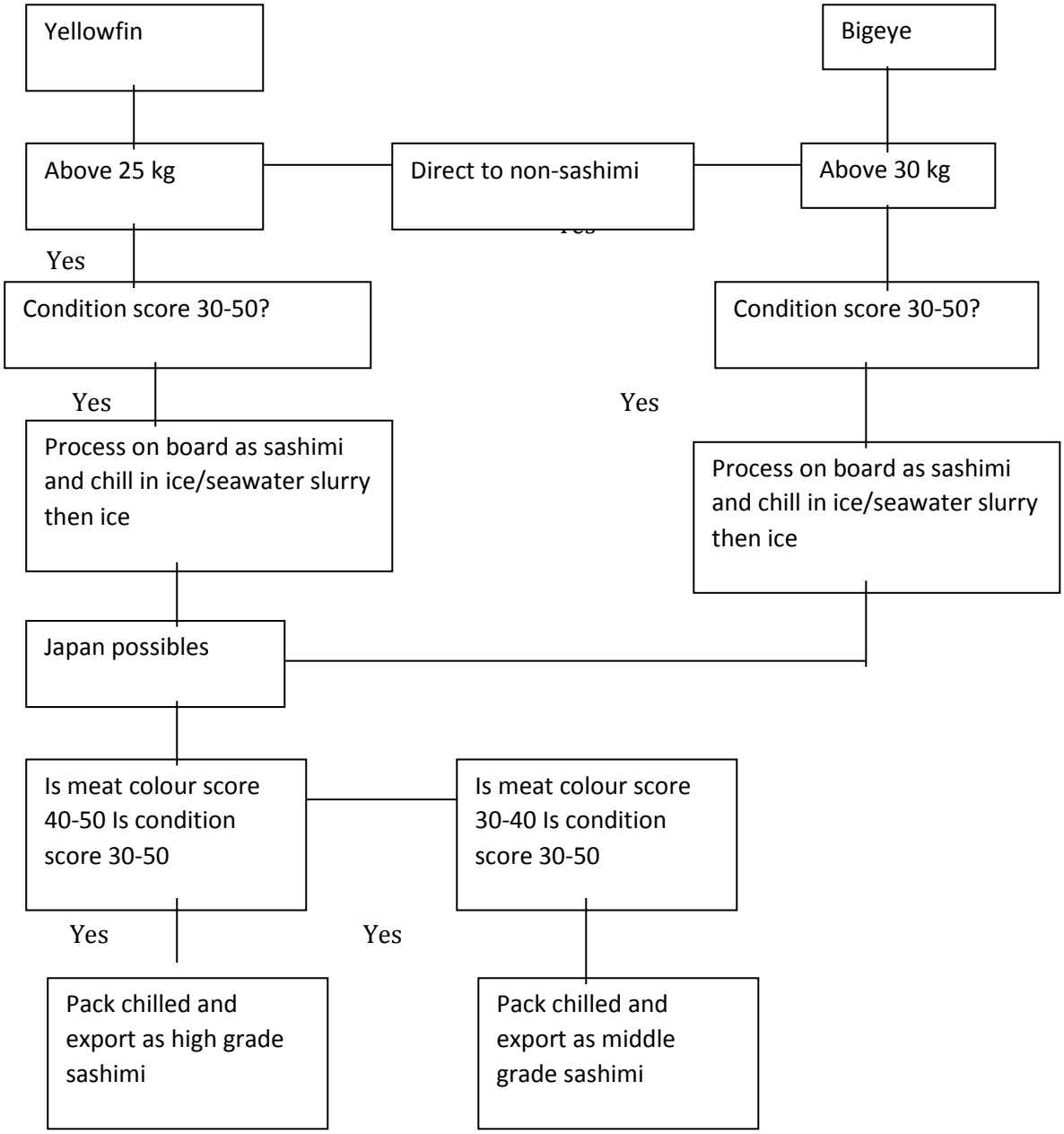
- ✪ Meat is almost opaque.
- ✪ The colour of the meat is distinct brownish, and dull
- ✪ There is little or no visible fat in the outer muscle layers. Meat has the same colour throughout

6. Very Poor (Score 10)

- ✪ Meat is opaque
- ✪ The colour of the meat is brown, white or gray
- ✪ Little or no fat visible in outer layers

Tuna intended for sashimi should be free from all patpathogenic organisms and should not have any harmful chemical compounds. Tuna contains high amount of the amino acid histidine, which is converted to histamine during microbial spoilage. It is a harmful chemical and the presence indicates the bacterial growth. The chemical and microbiological changes are also reflected in the colour and condition of the fish. The acceptability of tuna based on condition score and colour score are given in the following flow chart. Skillful handling and care is needed to maintain the quality

Flowchart for Tuna Grading



Value Addition

A wide range of tuna products is available in the international market. They include sashimi tuna, raw frozen tuna in the round and as cleaned tuna loins, fresh tuna in local markets, tuna burgers, tuna jerky, tuna sausage, tuna roe, and tuna in pouch products. Speciality products include smoked tuna, katsuobushi, tuna steaks, seasoned tuna cubes, barbecued tuna slice, tuna ham, and tuna fillets. Animal feed and pet food are also produced from the processing waste from tuna canneries.

Canning

Indian canned tuna finds limited export market besides catering to the needs of defence personnel and internal market. Tuna is more susceptible to histamine development than sardines or mackerel. The method for canning tuna in different containers like tin can, tin free steel cans, aluminium cans and retort pouches have been standardized. High temperature short time process will yield a better quality product. Rotating retort cages during the thermal processing of tuna can reduce the process time and decrease energy consumption during processing.

Modified Atmosphere Packaging

Modified atmosphere packaging (MAP) gives only slight inhibition of histamine-forming bacteria in bigeye tuna. But storage in MAP with 40% CO_2 and 60% O_2 is reported better than Vacuum Packaging for cold storage of fresh tuna. No histamine formation is found in tuna stored under 40% CO_2/60% O_2 for 28 days at near 0°C.

Pulsed Light Treatment

Pulsed light treatment is an innovative technological concept that has great potential for extending the shelf life of foods, without a heat treatment step. It is a method of food preservation that involves the use of intense and short duration pulses of broad - spectrum white light where each pulse, or flash, of light lasts a fraction of a second and the intensity of each flash is approximately 20,000times the intensity of sunlight at sea level. It reduces the microbial load considerably of such products. This can be utilized for the extension of shelf life of chilled tuna and disinfestation of masmin.

Utilization of Tuna Waste

Several products can be prepared from the waste obtained during canning of tuna like wafers, paste, fingers and cutlets. The tuna processing waste can also be utilized for the preparation of silage.