3. REVIEW OF LITERATURE
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Food packaging is an integral part of food processing and the link between food processors and consumers. World over, consumers are showing greater awareness towards food packaging, as packaging provides assurance on quality and quantity and also hygienic environment for the food products. With the growing demand for convenience, the need for off the shelf, ready to cook and ready to eat packaged food is constantly on the rise. The industry has also to pay attention to the factors such as, the demand for portable ready to eat packaged foods, which can be carried home, or to the work place, use of safe packaging material, use of recyclable and environment friendly biodegradable materials. In the processed seafood industry ‘canned fishery products’ are considered to be convenience ready to eat foods. Canning is one of the important methods of fish preservation for future use. The seafood canning industry in India has virtually closed down mainly due to the non-availability of suitable raw material and high cost of tin plate containers, which together rendered our products incompetent in the international market (Nair and Girija, 1993; Lahiri, 1992; Sukumaran, 1992; Pillai and George,1984; Govindan,1984.) With the improved raw material availability, use of indigenously available packaging material and liberalized economic and trade policies of the government it is hoped that the seafood canning industry in the country can be revived.

3.1. Evolution of Containers for Canned Foods

Following the success of Nicholas Appert “glass bottles” were extensively used in the early days of canning. Although the tin containers have been used from ancient times, it was in 1810 a patent for its use as a container for packing foods was obtained by Peter Durand in England. The tin plate metal containers were called “canisters” from which the term ‘can’ is believed to be derived. Each container has certain exclusive uses; in the course of development we can see that one container is invading other fields. The selection of one container over
the other is usually decided on the basis of process and product, cost of production etc. The chronological events that contributed to the development of thermal processing as an important means of food preservation are given in table-1.

3.1.1 Glass containers

Glass is a mixture of silicates formed by heat and fusion with cooling to prevent crystallization. It is an amorphous, transparent or translucent super cooled liquid. Glass usually consists of three types of oxides (i) glass forming oxide of silica (ii) the fluxing oxide, sodium potassium or lithium oxides are used and (iii) stabilizing oxides generally calcia and magnesia.

Glass bottles present a number of problems. The major problem encountered is the breakage problem, which is categorized into three groups. (i) Impact breakage (ii) Internal pressure breakage and (iii) Thermal shock breakage. Another problem is their limitation at high temperature sterilization. Glass bottles are sterilized in boiling water and higher temperatures are risky during cooling. Heat processing of vacuum-sealed glass containers requires superimposed pressure during cooling to hold lids in place. These shortcomings limit the use of glass containers to certain semi preserved items like salted fish, pickled products, jams, jellies, fruit juices etc.

Glass containers have limited use as a container for heat processing of foods, despite the advantages of glass is being pure, easy to clean, corrosion free, leak proof and transparent (Gray, 1950). The major problems with glass containers are the breakage problem and pressure cooling. Breakage can be reduced by careful handling and by avoiding scratches. The blowing of lids during cooling under insufficient pressure may be counteracted by careful, preferably automatic regulation of the pressure during cooling (Anon, 1952) or by applying a special spray cooling (Powers et al, 1951). Bramsnaes and Rasmussen (1953) found glass jars require longer processing time than tin plate cans of similar size.
Table 1. The chronological events that contributed to the development of thermal processing

<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Development(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1795-98</td>
<td>Appert's experiment on heat preservation of foods</td>
</tr>
<tr>
<td>1804</td>
<td>Appert's first bottling factory</td>
</tr>
<tr>
<td>1810</td>
<td>Appert's disclosure of the process and received a prize of 12,000 francs from the French Government. Peter Durand receives UK patent for preservation of foods in glass, pottery, tin and other containers. Metal 'canisters' first time used.</td>
</tr>
<tr>
<td>1847</td>
<td>Machine for stamping out can bodies</td>
</tr>
<tr>
<td>1860</td>
<td>Louis Pasteur's discoveries: microbes shown to be responsible for decay and development of science of microbiology. But the knowledge not immediately applied to canning.</td>
</tr>
<tr>
<td>1874</td>
<td>Invention of Pressure retort by Andrew. K. Schriver</td>
</tr>
<tr>
<td>1890's</td>
<td>Double seaming machine invented, High speed can manufacture Research at MIT by Underwood and Prescott: Spoilage known to be due to failure to apply sufficient heat energy.</td>
</tr>
<tr>
<td>1904</td>
<td>'Hole and cap cans' replaced by open top sanitary (OTS) cans</td>
</tr>
<tr>
<td>1920's</td>
<td>Work of Bigelow and Ball; use of thermo couple for heat penetration in cans; development of mathematical methods of process time evaluations for safe processes.</td>
</tr>
<tr>
<td>1948</td>
<td>Stumbo and Hick developed integrated lethality method</td>
</tr>
<tr>
<td>1950's</td>
<td>Continuous agitating retorts introduced</td>
</tr>
<tr>
<td>Last50 years</td>
<td>Aseptic canning, HTST sterilization, aseptic processing and packaging, advanced mathematical method, retort pouch, computerized monitoring and control of thermal process, ohmic heating, flame sterilization, high pressure sterilization etc.</td>
</tr>
</tbody>
</table>
Glass jars are mainly used for home canning purposes and a new processing recommendation for home canned smoked fish in glass jars was made by Raab and Hilberbrand (1993). The adequacy of process time is important, as glass cannot be processed at high temperatures safely.

### 3.1.2. Tin containers

Most frequently used container for packing food for canning is tin plate can. Tin plate containers made their appearance in 1810. The tin can is made of about 98% steel and 2% tin coating on either side. The base steel used for making cans is referred as CMQ or Can Making Quality steel. Corrosion behavior, strength and durability of the tin plate depend upon the chemical composition of the steel base. The active elements are principally copper and phosphorous. The more of these elements present the greater the corrosiveness of steel.

Depending upon the degree of workability, strength and corrosion resistance required in the case of tin plates four types of steel are specified. They are type L, type MR, type MC and type M. First three are produced by cold reduction process. Type M is similar to type MC in composition but produced by hot reduction process.

Tinned food or foods packed in tin coated cans gradually lost their natural colour. A lacquer coating on the inner side of the can prevented this. This lacquer coating protects the steel and tin and prevents direct contact with the food material. The can body protects the contents against the entry of microorganisms, insects, air, light and moisture. They are light in weight and can be handled with ease. A very important advantage is that they can be sterilized at high temperature and pressure.

Tin plate is still one of the most widely used materials throughout the world by the canning industry for making cans. Its unique advantage lies in the
combination of the strength of the steel with the protective properties and the光泽 of the tin layer. Regarding its corrosion resistance and staining properties, the steel plate may be considered to be covered on both sides with 4 layers; alloy, tin, protective oxide and oil (Hoare, 1950). The trend towards reduced tin coating necessitated the development of enamels or lacquers as reinforcement. Many such protective lacquers have been developed (Midwood, 1954). These can be adapted to any type of canned food and to any canning procedure (Flugg, 1951). Nowadays cans are coated by inside spraying, which is more expensive but avoids damaging of the coatings during manufacture of the can.

Canned fish product normally belongs to the non-acid type of foods, so that corrosion is not the main problem. Canned seafoods are sulphur-staining foods, in that they are liable to produce sulfur ions during processing. So the sulphur resistant lacquer is especially needed as coating for fish species containing a large amount of TMAO (Anon, 1953). It has been observed that salmon packed in tin containers exhibited unpleasant odour (Koizumi and Nonaka, 1958). Inorganic compounds like Zn oxide may be added to organic coatings of the tin cans to absorb the sulphur by forming white Zn sulphide (Buck, 1952). Epoxifide lacquers are the next addition; they are both acid and sulphur resistant and thus have a wide range of application. The non-toxicity of can linings has been stressed by Ives and Dack (1957). The factors that mainly affect internal corrosion of food cans include the properties of tin plate, nature of food processes and the processing as well as storage conditions. The corrosion of tin in contact with acidic fruit juices is attributed to the reversal of polarity of tin and thus tin becomes anodic to iron in acidic medium, there by dissolving the latter (Albu-Yaron and Feignin, 1992; Gowramma et al, 1981).

Balachandran and Vijayan (1989) reported the blackening of the can and contents due to improper lacquering of tin can when canning was done for prawn, clam meat and crabmeat in brine solution. When crabmeat comes in
contact with the metal during canning it will result in blackening and blueing (Vijayan and Balachandran, 1981). Blackening of can interior and contents has been a major defect encountered at times prawns canned in tin cans (Govindan, 1972). Many countries have laws or directives related to food contact material. In the case of tin plate the primary concern has been lead pick up. Since 1993, the use of lead as an ingredient in the solder for food cans has been banned by FDA (Robson, 2001). But tin plate containers are considered as the ideal packaging material for preservation of food products due to their many advantages compared to other packaging material (Kapoor, 2001; Joshi, 2001).

Canning studies with tin cans were done with fresh water fish rohu (Balachandran and Vijayan, 1988). They studied the effect of citric acid and calcium chloride in the brining solution to improve the texture. A study was carried out by Chaudhari et al (1978) for the prediction of drained weight of canned prawn under laboratory condition in tin cans. An attempt to can Indian style fish curry in tin cans was made by Rai et al (1971). Later Vijayan and Balachandran (1986) developed sardine fish curry in tin cans. Canning procedures for three species of sardines landed on the east coast of India have been worked out by Srinivasan et al (1966). Chinnama George et al. (1985) found out that fresh frozen sardines were found to be suitable for canning in tin cans and can be stored up to 10-24 weeks depending upon the season and initial quality.

3.1.3. Tin-free steel cans
This was developed in Japan under different names such as Can super, Hinac coat. These are prepared by electroplating cold roller steel sheet with chromium in chromic acid. TFS is an important alternative to tin can. TFS has a steel base with a chromium/chromium oxide coating on the surface replacing the tin in conventional cans. The appearance of the can is bright or semi bright as compared to tin plate. Because of the low abrasion resistance of Tin free steel it
needs to be protected by a lacquer film. However the surface of the TFS provides an excellent substrate for lacquer adhesion, which ensures superior performance in terms of product compatibility for many food products.

Normally cans fabricated from low carbon steel plate coated with a thin layer of tin on either side called ‘tin cans’ are used for canning of food products. Owing to shortage of metallic tin and its high cost attempts have been made in some countries to replace tin with cheaper chromium metal (Naresh et al, 1980; Mathews et al, 1998). India spends considerable foreign exchange to import tin while chromium is available within the country. Studies have been carried out by CFTRI, Mysore to find the suitability of both imported and indigenously fabricated chromium coated steel for canning low acid and dry food products (Naresh et al, 1980). The two main types of chromium-coated steel developed in Japan are Can super and Hinac coat (Mahadeviah, 1970).

Simic and Djordjevic (1976) conducted comparative storage trials with cured minced pork, cured pork pieces, cured beef pieces and pork with Sauerkraut. The suitability of chromium plated container for packing fish products was investigated and compared with electrolytic plate. Over a period of one-year chromium coated cans were found suitable for packing slightly or moderately corrosive fish products of low acidity (Hottenroth, 1972). The suitability of tin free steel has been evaluated for packing fruits and vegetable products, milk powders etc by researchers like McFarlane (1970) and Srinivasa Gopal et al (1977).

From information available on literature, introduction of tin free steel as an alternative to tin plate requires a major capital investment rather than comparatively minor conversion and hence economy would be a long range goal. Improvement in handling conditions, electroplating technique coupled with development of suitable lacquers will accelerate the process of replacement of
tinplate by TFS for at least a few suitable products especially dry fruits like
biscuits and confectionary (Naresh et al, 1980). The recent development in India
is the introduction of polyester coated tin free steel cans suitable for canning fish
and fish products. Mallick, A. K. (2003) studied the suitability if polyester coated
tin free steel cans for the thermal processing of rohu curry.

3.1.4. Retort pouches
Retortable pouches, as the name implies, pouches capable of retorting are latest
development in the canning industry. The retort pouch is a rectangular type
package usually made of a three-layer lamination. Some manufactures give
additional layer for better barrier properties. It is usually made up of outer
polyester, middle aluminium foil and inner polypropylene layer. The outer
laminate, which is polyester, provides atmospheric barrier properties as well as
mechanical strength. The aluminum ply provides protection from gas, light, and
moisture and ensures a better shelf life. The inner polypropylene layer provides
the best heat-sealing medium.

The salient features making the retort pouch attractive than the other
containers are the following:

(i). The retort pouch can be produced in any shape and size.

(ii). It has a high surface to volume ratio and a thin cross-section.

(iii). Rapid heat penetration is possible compared to conventional metal cans.
Heating is uniform.

(iv). There is 30 to 40 percent reduction in processing time.
(v). Less impairment of texture and flavouring particularly of fish and meat products due to reduced exposure to heat.

(vi). The retort pouch offers savings in terms of weight and space. Compared to an empty can, of the same volume, and empty retort pouch occupies 85% smaller space and weighs 84% less.

(vii). Retort pouches can be packed closely and tightly in master cartons. Hence, transportation is easy, safe and less costly.

(viii). Consumers can easily open pouches.

(ix). Compared to metal cans retortable pouches are easily destroyed by incineration.

(x). The packets can be very easily reheated, prior to eating, by immersing in hot water.

In spite of the above merits, the retort pouches have certain inherent disadvantages.

(i). Less physical strength: Pouch and pouch seals are more vulnerable to damage than a can. They are easily damaged by sharp edges and this requires an over wrap for individual pouches.

(ii). Slow process line speed: The out puts from retort pouch lines are low (30-120 pack/min) compared with canning line (200-400 cans/min).

(iii). Higher-packaging costs: Along with an outer carton the packaging cost goes higher than metal can.
(iv). Higher production costs: Higher-packaging costs along with low production makes the cost of production high.

3.1.5. Studies on aluminium containers:

It was noticed that the organoleptic qualities of foods packed in tin containers gradually decreased when they are kept for longer periods. This led to the introduction of another important container, the aluminium alloy can. Aluminium containers were used for packing meat and fish products as early as 1918. These are now being used extensively in European countries because of the availability of the raw material and less cost for its production due to plenty of electricity in those countries. Various types of aluminium and its alloys are used for packaging. The aluminium in grade of 1000 is called pure (99-99.7%) and these are used for foil and slug for impact extruded cans. The alloys in grade 3000 are used mainly as sheet for deep drawn cans and craned cans. Manganese is added to increase the strength. The best promising alternative to tin plate has been considered as aluminium modified by alloying with manganese and magnesium.

Aluminium possesses good corrosion resistance. They offer good resistance to external atmospheric corrosion. Aluminum containers are easy to fabricate. It's possible to set up a can manufacturing unit for a good canning factory. Machinery for such units is simple and highly profitable. Cans can be produced in a wide variety of sizes and shapes with attractive appearance.

They are light in weight. Aluminium has got a good scrap value. Aluminium cans do not show the phenomenon of blackening in presence of sulphur containing foods (Moinaux, 1998). Both steel and aluminum cans used an easy-open end (initially the pull-tab, now the stay-on tab), but the aluminum tab was much easier to make. Perhaps the most critical element in
The aluminum can's market success was its recycling value. Aluminum can recycling excelled economically in the competition with steel because of the efficiencies aluminum cans realized in making new cans from recycled materials versus 100 percent virgin aluminum. Steel did not realize similar economies in the recycling process. Aluminum can recycling became common and responded to the growing concerns of environmentally conscious community. The opportunity to market the all aluminum can as recyclable and environmentally friendly led to its growing acceptance as a product. Of the total 3.5 lakh tons of aluminium production in India, only about 10% is consumed for packaging (Mahadevaiah, 1995). India has a negligible per capita consumption figure of 0.7 Kg, compared to 11 Kg in U.K., 12 Kg in France, 18 Kg in Japan and 27 Kg in USA (Sucheta, 1998). Cans made of aluminium alloyed with magnesium and manganese are widely used for canning.

Rigid containers have played very significant role over several years in food processing and build of consumer acceptance in several years. In India, presently tin containers have become a major constraint for the development and expansion of food processing industry due to spiraling cost as well as non-availability of containers from indigenous raw material (TIFAC, 1991; Srivatsa, 1993). Alternate material for manufacturing rigid containers, in lieu of tin containers; have long been explored in various parts of the world (Leymarie, 1972). The most attractive and viable alternative material in India is aluminium and its alloys. Aluminium is abundantly available in the country as, India possesses 8% of the world’s bauxite reserves (Kothari 1986, Srivatsa, 1993). In addition aluminium is very light, as it weigh 1/3rd of steel. The corrosion resistant of aluminium is excellent, as compared to that of conventional low carbon steel, and it also possess good mechanical properties (Nair and Girid, 1996; Srivatsa, 1993; Lahiri, 1992; Ellis, 1981; Althen, 1965; Lopez and Jimenez, 1969) and recyclability.
3.1.5.1. Impact extruded containers

Used for the manufacture of collapsible tubes /containers. The starting material used here are slugs. These slugs are placed in a fixed die and the moving punch imparts the impact. Aluminium flows in the gap between the punch and the die and the component is formed which has an outer shape corresponding to the die and an inner shape corresponding to the punch. Containers made by this process have been replacing three-piece tin plate cans to a great extent due to their being seamless in nature.

3.1.5.2. Drawn cans

Aluminium sheet is specially alloyed with manganese and magnesium giving it high strength and malleability. A protective coating is applied to the interior surface to prolong the life of the content. A coil of aluminium is coated with a thin film of oil in the lubricator before the cupping press stamps out cup shaped pieces of metal from it. The 'cups' are rammed with precision through a set of tungsten carbide singe of decreasing diameter in a wall-ironing machine. This process irons the wall of the cups, reducing the metal thickness, until they reach required height. The bases of the cans are then domed inwardly to give them the strength required to withstand high internal pressure. The alloy used for these bodies are AA3004 and AA3014.

A variant to this process is the drawn and redrawn process where the blank disc flows into a container of lesser circumference but of the same thickness when it passed through a set of drawing operations. The alloys tried out in India are AA8011.
3.1.5.3. Three-piece cans
These cans/containers can be either mechanically seam welded or adhesive bonded. Mechanically seamed aluminum containers have been used for various applications.

Aluminium in the form of foil is already being extensively used as an excellent packaging material for processed and fast foods (Reddy and Khan, 1993; Sankaran, 1992; Rao et al, 1986). In the form of collapsible tubes and rigid containers, it finds use in various sectors like pharmaceuticals, beverages, and diary and cosmetic industries. However its use in the form of rigid containers for canning processed foods other than beverages is highly limited (Srivatsa et al 1993).

3.1.5.4. Application fields of aluminium containers:
Aluminium is found to be non reactive to a majority of food products. In case of certain products lacquering is recommended. The use of aluminium cans for different types of processed foods are described below.

(i). Meat: Meat products are non reactive to aluminium. Aluminium containers are commonly used for canned meat products.

(ii). Fruits: Some of the acids in fruits have been found to be corrosive to aluminium alloys. Due to the presence of dextrose, proteins and pectin in fruit, the corrosive action is inhibited in many cases. Protected aluminium alloys have been used for canning fruits.

(iii). Fruit juices: Fruit juices commonly canned in aluminium cans lacquered with acid resistant (AR) lacquers. Citrus fruit juices can be stored in alloys AA3003, AA5052 and AA5086.
(iv). Jam/Jelly: Aluminium is resistant to some jams and with others there is a mild action. Lacquered aluminium containers are used for the packaging of jams. Aluminium is non reactive to jellies.

(V). Butter/cheeses: Aluminium is non reactive to butter, on the other hand aluminium is resistant to some varieties of cheese, while corrosive with others. when necessary protected aluminium alloys can be used for canning cheese.

(VI). Margarine: AA 3003 has been found to be resistant to margarine at ambient and refrigerated temperatures. Aluminium alloys have been used for processing margarine.

(VII). Coffee/Tea: Aluminium is resistant to coffee whether dry or as a hot or cold beverage. It also used for packaging and storing tea.

(VIII). Pickles: Due to the combination of salt and vinegar aluminium gets corroded by pickles usually with deep pitting.

(IX). Fish and fishery products: Aluminium alloys are used widely for fish packaging. Alloys AA 1100 and AA 3003 have been focused to be resistant to most fish products.

Lund et al (1937) conducted mice feeding experiments with canned sardines packed in aluminium containers. Products contained 85-103 ppm aluminium. Rats fed for five generation under the same condition developed and reproduced normally. Chevillotte (1947) stated that although a small quantity of aluminium may dissolve in the food when some vegetables were canned in aluminium cans, its not harmful to the consumer. Hugony (1953) found out that foods and beverages in contact
with aluminium foil or cans generally absorbed much less aluminium than their natural aluminium content. He also stated that vegetables should not be canned in bare aluminium containers if their pH is not above 5.2.

Jacobsen (1944) found that spinach canned in aluminium containers depends upon the quality of the aluminium sheet, the amount of water-soluble oxalates in the spinach and storage temperature of the cans. Bauer (1944) stated that bare aluminium cans are not attacked by foods having a pH of 5.7-7.6. Jacobsen (1946) reported that fruit jams are less corrosive to aluminium cans than fruits packed in sugar syrup. Corrosive action of canned fruits was greatly affected by storage temperature with both coated and uncoated anodized aluminum cans. Bramsnaes (1948) stated that internally varnished cans must be used with vegetables, especially those containing oxalic acid like spinach.

Kemp et al (1958) found that enamel lined aluminium cans performed quite well for foods. Althen (1965) discussed the characteristics of aluminium plate used in the manufacture of cans, as well as the different mechanical process used in aluminium can manufacture. Hotchner and Schwild (1969) studied the use of aluminium container as a packaging material for distilled spirits and wines. The success of the package depends upon the proper choice of aluminium alloy and a high degree of organic coating coverage. Lopez and Jimenez (1969) evaluated the suitability of aluminium cans for canning a number of fruit and vegetable products. Generally tin plate cans performed better with acid foods than coated aluminium cans. With low acid foods coated aluminium cans compared well with tinplate containers. The majority of the products tried rapidly corroded uncoated aluminium cans. Corrosion was not a problem with coated aluminium cans, but some of the coatings affected the taste and colour of the products. Hughson (1992) illustrated the merits of aluminium in comparison to tin plate as a packaging material for the
canning industry. On an international scale, aluminium cans dominate the North American and Australian market.

In India, a few canning factories are using imported aluminium cans for packing fish products. In view of shortage of tin metal and high cost of tin plate containers, a few can manufacturers have made an attempt to produce aluminium cans for packing food products. Naresh et al (1988) studied the corrosion behaviour of aluminium cans by canning vegetables like potatoes, carrots and beans in brine. Research and development of two-piece aluminium cans using indigenous materials was undertaken by Jayaraman et al (1988). Srivatsa et al (1993) conducted a detailed study of canning different types of Indian food products in aluminium containers.

Gargominy, I and Astier-Dumas (1995) Studied the Aluminium levels in raw, cooked (microwaved for 2 min or cooked in an aluminium pan for 10 min) and canned (in steel or Al cans) tomatoes. Changes in Al content of canned tomatoes over 2 yr were carried out. Aluminium was determined using Atomic Absorption Spectrophotometer. Raw tomatoes contained 0.11-mg/100 g fresh wt. Al levels increased when tomatoes were cooked in an Al pan (1.56 mg/100 g fresh wt.) and on canning (1.37 and 1.41 mg/100 g fresh wt. for steel and Al cans, respectively). Micro waving did not affect the Al content of tomatoes. After storage for 2 yr, Al levels in products in Al cans had increased to a greater extent than in those in steel cans (2.22 vs. 1.68 mg/100 g fresh wt.). For comparison, Al levels were determined in non-acidic products (mackerel, mushrooms and liver pate) stored in Al or steel cans; there were no significant differences in Al content between the 2 types of can. Ranau and Oehlenschlaeger (1997) carried out herring canning studies to find the migration of aluminium from the can to the fish during thermal processing and storage.
3.2. Methods of Fish Preservation

Fish is one of the most perishable of foods and begin to spoil immediately after catching. Bacterial and autolytic spoilage are biological systems, which operate only under certain optimum conditions. Therefore altering these conditions can prevent or reduce spoilage. Preservation techniques retard biochemical and chemical reactions and also destroy or inhibit the growth of microorganisms. Preservation however, will not produce an indefinite storage life for foods since no technique can fully inhibit all likely changes. The most common methods of preservation are chilling, freezing, curing, changing the atmosphere, curing and canning.

3.2.1. Chilling

Short term preservation by chilling, is carried out using ordinary water and ice, although dry ice and chilled seawater are also used. The bacteria responsible for spoilage are psychrophilic, so even fish is chilled at 0°C under the best conditions of handling, bacterial quality can result in severe loss of quality approaching inedibility after 14-16 days (Paine & Paine, 1992). Objective of chilling is to cool the fish as quickly as possible, to low temperature, without freezing. Chilling cannot prevent the spoilage altogether, but in general, the cooler the fish, the greater the reduction in bacterial and enzymic activity (Clucas & Ward, 1996). Ice storage is relatively short-term method of preservation, with storage life varying between a few days to 4 weeks. Moreover proteins and some minerals and vitamins, are lost if the fish are washed or if they are stored in refrigerated or chilled seawater systems.

3.2.2. Freezing

This is used for long-term storage. The fishes are cooled below temperatures of -35°C and stored at -18°C. The much long shelf life is due to the almost complete halting of autolytic and bacterial action at
these lower temperatures and also free water is effectively locked as ice (Clucas and Ward, 1996). Freezing may be useful for long-term storage and export through the cold chain. But freezing plants are expensive and costly to run. Another disadvantage during freezing, especially when its slow or if the storage temperature is allowed to fluctuate considerably, the texture of fish can deteriorate because of cell damage and this increase the amount of drip when thawing (Martin et al, 1982). During badly controlled freezing processes, denaturation of proteins with loss of amino acids, break down of fats with loss of fatty acids and vitamins, and production of unpleasant odors and chemical reaction between the major nutrients can also occur. Frozen stored products require cold chain through out the distribution.

3.2.3. Vacuum packaging
Vacuum packaging represents a static form of hypobaric storage. Which is widely applied in the food industry due to its effectiveness in reducing oxidative reaction in the product at relatively low cost. By vacuum packaging, the growth of bacteria in fish can be slowed down and the rate of development of rancidity can also be decreased, because of these changes measurable extension in keeping time was observed. Its emphasized that the success of vacuum packaging is completely dependent upon the initial quality of fish and adequate temperature control through out storage (Banner, 1978). While oxygen depletion is effective in retarding the growth of typical spoilage bacteria, there is a possibility that if the product temperature is abused, it may become toxic (Mead, 1983).

3.2.4. Fish curing
The moisture content of the fresh fish varies between 75-80 %. Bacteria cannot survive if the moisture of the fish is reduced below 25%. Below
15% moulds ceases to grow (Clucas & Ward, 1996). Drying can be carried out alone or in combination with salting and smoking.

3.2.4.1. Drying
Drying can be achieved either naturally or by mechanical means. Natural drying is by using the sun energy to drive the moisture out. The main advantage of sun drying is that the energy is free. But traditional sun drying methods are heavily depending upon the mercy of weather. Mechanical drying allows the temperature; humidity and air flow to be controlled.

3.2.4.2. Smoking
Fishes are generally smoked over open fires or in simple kilns to accelerate the drying process. If the relative humidity is high and salt is scarce, hot smoking, during which the fish are cooked is the common method. In cold smoked products the flesh is not cooked. Cold smoking is usually done for imparting the smoked flavor. Drying and smoking both results in a loss of weight mainly due to loss of water rather than nutrients.

3.2.4.3. Salting
Salting is often used in conjunction with drying and smoking. As most bacteria cannot grow in salt concentrations above 6%, salting will reduce bacterial action. If the product is salted, there will be a loss of water and water-soluble nutrients during the salting process, and a further reduction during drying process (Sidwell, 1981).

3.2.5. Irradiation
Another method of fish preservation, which has not been widely used but has been gaining in popularity, is the use of ionizing radiation. Radiation in
suitable does can kill the microorganisms, insects and parasites, which may be present in food and inhibit enzyme activity. Irradiation is not used commercially to any great extent because of the costs involved and consumer resistance.

3.2.6. High pressure processing
This is a method of hyperbaric storage. High pressure can stop microbial growth and reduce enzymic activity. Refrigerated storage of lean fish at high pressure extends the shelf life considerably (Brown et al., 1980). It is widely accepted that conformational changes of protein takes place at higher pressure, which may be responsible for the shelf life extension. High pressure processing destroys the bacteria without changing the nutritive value of the product. However, because of the technical difficulties in building a commercially feasible high-pressure storage unit, this method of preservation has not become popular.

3.2.7 Canning:
In canning, fishes are processed at high temperatures after enclosing in airtight containers. Thus the product is protected from further bacterial contamination by being hermetically sealed within the cans. Canning is a method of food preservation in which selected food materials are prepared for the table, packed in containers capable of being sealed airtight, heated sufficiently to destroy the spoilage organisms within the container and cooled rapidly (Balachandran, 2001). The inside of the can must be resistant to its contents and the out side to ambient temperatures. The advantages of canned foods over other type of preserved foods are

- They need not or less need to prepare before consumption.
• Canned foods have got a very long shelf life compared to any other methods of processing.
• They can be stored at ambient temperatures.
• Spoilage rate is very less since enclosed in airtight containers.

3.3. Different sizes of cans used commercially:
Various sizes of cans designated by different trade names are usually employed commercially for different varieties of foods. Details of the common sizes of cans used in the industry are presented in Table -2.
Table 2. Varieties of cans employed in the industry

<table>
<thead>
<tr>
<th>Common name</th>
<th>Dimension (the first fig. Indicates inches and the next two figures $\frac{1}{16}$th of an inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 ounce</td>
<td>301 X 206</td>
</tr>
<tr>
<td>8 ounce tall</td>
<td>211 X 304</td>
</tr>
<tr>
<td>½ Tuna</td>
<td>307 X 113</td>
</tr>
<tr>
<td>No.1. Picnic</td>
<td>211 X 400</td>
</tr>
<tr>
<td>No.1. Tall</td>
<td>301 X 411</td>
</tr>
<tr>
<td>No.1. Flat</td>
<td>404 X 206</td>
</tr>
<tr>
<td>No.1. Tuna</td>
<td>401 X 206</td>
</tr>
<tr>
<td>No.2</td>
<td>307 X 409</td>
</tr>
<tr>
<td>No.2. Cylinder</td>
<td>307 X 512</td>
</tr>
<tr>
<td>No.2. Vacuum</td>
<td>307 X 306</td>
</tr>
<tr>
<td>No.2 ½</td>
<td>401 X 411</td>
</tr>
<tr>
<td>No.3</td>
<td>404 X 414</td>
</tr>
<tr>
<td>No.3. Cylinder</td>
<td>404 X 700</td>
</tr>
<tr>
<td>No.10</td>
<td>603 X 700</td>
</tr>
<tr>
<td>No. Squat</td>
<td>603 X 408</td>
</tr>
<tr>
<td>¼ Dingley</td>
<td>404 X 302 X 014</td>
</tr>
<tr>
<td>½ Oval</td>
<td>309 X 515 X 103</td>
</tr>
<tr>
<td>½ Oblong</td>
<td>508 X 204 X 103</td>
</tr>
</tbody>
</table>
3.4. Canning Studies in Fishes
Thermal processing of foods has been one of the most widely used methods for food preservation during the 20th century and has contributed significantly to the nutritional well being of much of the world’s population (Teixeira and Tucker, 1997). Two different methods of conventional thermal processing are known, the aseptic processing in which the food product is sterilized prior to packaging, and canning in which the product is packed and sterilized (Barbosa-canovas et al, 1997). Canning is defined as the preservation of foods in sealed containers and usually implies heat treatment as the principal factor in the prevention of spoilage (Frazier and Westhoff, 1998). Mostly canning is done in tin cans, which are made up of tin coated steel, other metals or glass containers are also used. The tin plate metal containers where called canisters from which term can is assumed to be derived (Derosier and Derosier, 1977).

The conventional canning operation consists of (i) Preparing the food (cleaning, cutting, grading, blanching etc), (ii) filling in the container, (iii) sealing the container and (iv) subjecting the container to a heat cool process sufficient for commercial sterility (Lund et al, 1975). The heat treatments sometimes called terminal sterilization, is designed to eliminate extremely large numbers of spores of the pathogen Clostridium botulinum and reduces the chance of survival of the much more heat resistant spores of spoilage organisms (Jaiswal et al, 2002).

Low acid canned foods are generally processed so that every particle of food is exposed to 250°F for 2.5 - 3 minutes. This reduces contamination loads of Clostridium botulinum spores from 10 to 1 and therefore provides a considerable safety factor for expected levels of contamination (Bryan, 1974). Only those having enough expertise and thorough understanding of product safety should establish sterilization process. Change in recipe,
manufacturing method, filling method or location may significantly and adversely alter the effectiveness of the sterilization process. In these circumstances, heat penetration or other tests must be made to reestablish a satisfactory sterilization process (Shapton and Shapton, 1997).

Process time and temperature for retorting must be accurately measured, controlled and recorded (Jaiswal et al, 2002). After retorting, cans should be cooled in a water container containing disinfectant, as the contaminated water can enter defective through minute leaks and can cause spoilage and even health risk. In conveyor product washer and can coolers, continuous chlorination beyond the break point to a residual of 5-7 ppm is recommended (Frazier and Westhoff, 1998). Concentration of disinfectant at cooler end, its monitoring and recording which is very important in prevention of contamination during cooling of the processed can, must also be considered (Bryan, 1994).

Canned fish and other marine species are products of economic importance in many countries. Among the most common species, sardines, herring, albacore and other tuna fishes, mackerel, anchovy, mussel etc can be mentioned (Cheftel and Cheftel, 1976). Many studies relating to the pre cooking effect on the quality of canned products (Slabyj and True, 1978; Joshy and Saralaya, 1982) as well as those focusing on the fatty acid and lipid class composition of canned species have been carried out (Melwa et al, 1982; Hale and Brown, 1983). Changes in quality of canned fish have been investigated as a function of packaging method (Oliviera et al, 1986) and storage temperature (Pirazzoli et al, 1980).
Canned tuna is one of the most important fish products in many countries (Alimarket, 1992), supporting a significant market demand and playing an important role as component of diet. These products are considered of high nutritional quality because of their high proportion of $\omega$-3 polyunsaturated fatty acids (Gallardo et al, 1989; Medina et al, 1995) which have shown potential benefit to human health, particularly in the prevention of cardio vascular diseases (Carrol and Braden, 1986; Lees and Karel, 1990).

### 3.4.1. Prawns

From the point of view of magnitude and earnings, prawn-canning industry had a pride of place in our country. The method employed consists in peeling and deveining of prawns, blanching the peeled and deveined meat in 10% boiling brine for 4 - 8 minutes, cooling the blanched meat under the fan, grading into different sizes, filling weighed quantities of graded meat into cans, followed by hot 2% brine containing 0.1% citric acid, exhausting, double seaming, retorting the sealed cans at 0.7Kg/cm² steam pressure for 18 minutes cooling and labeling (Govindan, 1972). The fluctuations occurring in drained weight in canned prawns have been attributed to the tendency of the cooked prawn to attain an equilibrium moisture level when in contact with brine (Chodhari and Balachandran, 1965). Sanitation quality of water and ice used in processing operations, utensils coming into contact with raw and blanched meat, environments and personal are important factors controlling sterility in canned prawns. Proper maintenance of these factors yielded standard product with sufficient degree of sterility (Choudhari et al, 1970). The drained weight of a can is dependent upon moisture content of blanched meat which is again dependent upon time of blanching, concentration of salt in blanching liquor, size of prawns and method of cooling after blanching (Varma et al, 1969; Choudhari and Balachandran, 1965).
Chaudhari et al (1978) carried out a study to predict the drained weight of canned prawn under laboratory conditions. Bacterial spoilage of canned prawns has been reported by Nambiar (1980).

3.4.2. Mackerel
The bulk of the canned mackerel produced in our country goes for army rations, a very small portion sold in the internal markets and still smaller fraction for export. The process employed for mackerel consists in dressing and washing the fish free of any slime and blood, brining in 15% Sodium chloride for 25 minutes at room temperature, precooking at 0.35 kg/cm$^2$ steam pressure for 45-50 minutes, filling weighed quantities in cans, adding hot refined ground nut oil (85-90°C), exhausting, double seaming at 0.91 kg/cm$^2$ steam pressure for 60 minutes. (Anon, 1964).

Processing details for canning of mackerel in different media like brine, oil, tomato sauce or curry type of pack have been described by Rai et al (1970). Canning operations suitable for packing Indian mackerel (*Rastreliger Kanagurta*) in the form of skinless boneless fillets in oil were studied and standardized by Saralaya et al (1975). Vijayan et al (1985) developed a process for canning mackerel as skinless boneless fillets in oil. The dressed mackerel is cold blanched in a solution containing 15% NaCl and 0.1% citric acid for 15 minutes. The brined fish was cooked in steam at a pressure of 0.35 Kg/cm$^2$ for 30 minutes, cooled to room temperature, manually skinned and stored overnight in a cold room. The fish is subsequently split into two halves parallel to the bone frame and the two pieces put together and packed in a plain quarter dingly can filled with hot refined ground nut oil, exhausted in saturated steam, seamed and heat processed at 0.7 Kg/cm$^2$. 

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3.4.3 Sardines

As in the case of canned mackerel our canned sardines were mainly consumed by the defence personnel, comparatively smaller quantities being sold in the internal markets and exported to other countries. The method employed commonly is to dress and clean the fish, brine in 15% Sodium chloride solution for 15 minutes, precooking at 0.35 Kg/cm² steam pressure for 35-40 minutes, filling in cans followed by hot refined ground nut oil (90-95°C), exhausting, double seaming and sterilization at 0.84 Kg/cm² steam pressure for 70-75 minutes (Anon, 1964). Sardines can be preserved in ice for a period of two days prior to canning without materially affecting the overall quality of canned product (Madhavan et al, 1970). Srinivasan et al (1966) developed canning procedures for three species of sardines. The method involves dressing and cleaning of the fish, brining in saturated NaCl solution for 15-20 minutes, packing in cans, cooking in flowing steam for 25-30 minutes, draining of the cook drip, filling with hot refined groundnut oil at 100°C, exhausting, seaming and sterilizing at 0.7-0.84 Kg/cm² steam pressure for 80-90 minutes.

Unnikrishnan Nair et al (1977) developed a process for canning smoked sardines. The process consists of cold blanching the dressed fish in 15% brine for 20 minutes and smoking the fish at a temperature of 45 ± 5°C. The smoked fish was then packed in 301X206 cans and cooked in steam at 0.7 Kg/cm² pressure. Refined groundnut oil, tomato sauce and dilute brine were added as filling media. The cans after filling with media were exhausted in steam, hermetically seamed in a double seamer and heat processed at 1Kg/cm² steam for 45 minutes. George et al (1985) studied the suitability of frozen oil sardine for canning. The fresh frozen sardines were found to be suitable for canning up to 10-24 weeks depending upon the season and initial quality.
Vijayan and Balachandran (1986) made an attempt to develop canned fish curry using sardine. Dressed and cleaned fish was cut into two third the size of the can and was blanched in 15% NaCl solution for 15 minutes at room temperature. The blanched fish was packed in S.R. lacquered cans and cooked for 30 minutes in steam at 0.35 Kg/cm$^2$ pressure. After draining the drip the curry media was added to the cans maintaining the proportion of fish to curry of 60:40. The cans were exhausted in steam for 10 minutes, seamed and heat processed in steam at 1.05 Kg/ cm$^2$ pressure for 60 minutes and cooled.

3.4.4 Tuna

Indian canned tuna finds limited export market besides catering to the needs of the defence personnel and internal market (Govindan, 1972). The method of canning consists of dressing and cleaning the fish, cutting into chunks of convenient size, brining in 15% NaCl solution containing 0.075% Sodium bicarbonate for 22 minutes, pre-cooking at 0.84 Kg/cm$^2$ steam pressure for 90-120 minutes, cutting into small pieces avoiding black meat, filling in cans followed by hot refined ground nut oil at 95°C, exhausting, seaming and sterilizing at 0.84 Kg/ cm$^2$ steam pressure for 60 minutes (Anon, 1964).

A procedure for canning of three species of tuna viz skipjack (Katswonus pelamis), Yellow fin (Neothunnus macropterus), and big eye tuna (Parathunnus obesus) has been described by Madhavan and Balachandran (1971). In this process, the fish is precooked for such a period that the surface of the backbone attains a temperature of 93-94°C and solid salt containing 0.5% Sodium bicarbonate was added instead of the usual brining step.
Effect of pre-cooking of albacore tuna (*Thunnus alalunga*) has been studied by Gallardo et al (1989). In fish canning, pre-cooking is a very important step to reduce water content. Aubourg et al (1990) adopted a canning method while studying the changes in flesh lipids and fill oils of albacore (*Thunnus alalunga*) during canning and storage. The eviscerated fish is pre-cooked for a period so that the backbone attains a temperature of 65°C (90 minutes), the fish were then cooled at room temperature (14°C) for about 5 hrs. Then 90 gms of fish were placed in OL-20 cans (105.1X64.7X 28.8mm) and soybean oil and salt (2gm) were added. The cans were vaccum sealed and sterilized in a retort at 115°C for 60 minutes. Gallardo et al (1990) followed the method of Aubourg et al (1990) with some variations. The fill weight was 82 gm instead of 90 gm in small flat rectangular cans (105x 65x29mm, 120ml) containing vegetable oil (35ml) and salt 2gm. The cans were vaccum sealed and sterilized in retort at 110°C, 115°C, and 118°C for 90, 55 and 40 minutes respectively. Medina et al (1998) canned frozen Atlantic tuna (*Thunnus alalunga*) by following the pre-cooking and cooling method suggested by Gallardo et al (1990). Filling was done by using cooked white muscle in Ro-100 cans (6.52 cm dia X3cm height). 20 ml of 99.9% purity aqueous sodium chloride or 20 ml of oil with 2gm sodium chloride was then added. The cans were then vaccum sealed and sterilized in retort at 115°C for 60 minutes.

**3.4.5 Other fishes**

Though tuna, sardine, mackerel and prawns are the major canned fish items other fishes like Pomfret, Seer, Crab and clams have also been utilized for canning. A comparative study of the canning properties of Silver pomfret (*Pampus argenteus*), Black pomfret (*Parastromatus niger*), and hilsa (*Hilsa toil*) has been reported by Venkataraman et al (1970). The fishes were filleted, brined in 20% NaCl for 30 minutes, filled in cans,
precooked at 0.49 Kg/cm$^2$ steam pressure for 15 minutes, drained, filled with refined ground nut oil at 80°C, exhausted, seamed and processed at 1.05 Kg/cm$^2$ steam pressure for 45 minutes.

Canning of seer fish has not been widely practiced in our country, although the technical know how for it has been worked out. Anon (1965) reported the canning of seer fish in oil. The method consists in dressing, cleaning and cutting the fish into chunks of convenient size, brining in 15% NaCl solution containing 0.05% sodium bicarbonate for 24 minutes, pre-cooking at 0.7 kg/cm$^2$ steam pressure for 60 minutes, cutting into small pieces, filling in cans followed by hot refined oil at 95°C, exhausting, seaming and sterilizing at 0.91 Kg/cm$^2$ steam pressure for 75 minutes.

Process development for canning of freshwater fish rohu (Labeo rohita) has been reported by Balachandran and Vijayan (1988). Different methods were adopted to process rohu fish viz. (i) Cleaned fillets cut to size were packed in quarter dingly cans, sprinkled salt over it at 3% level and processed as natural pack, (ii) cold blanched the fillets in 15% brine for 10 minutes and then processed as natural pack. (iii) Cold blanched the fillets in 15% brine containing 1% each of alum and citric acid for 10 minutes and processed as natural pack. (iv) Cold blanched the fillets in 15% brine for 10 minutes cooked in steam at 0.35 Kg/cm$^2$ pressure for 30 minutes and canned in oil. (v) Same as the previous one and using tomato sauce. The cans were heat processed in steam for 25 minutes at 121.1°C.

The suitability of canning white sardine (Kowala kowal) was studied by Jeyasakaran and Saralaya (1981). The canning procedure of white sardine in natural pack, oil and brine were standardized. Blanching the product in saturated brine at room temperature for 6 minutes, pre-cooking the product for 45 minutes in steam at 100°C and sterilization at 115.6°C for
75 minutes. Heat processing of Kerala style fish curry in retortable pouches has been reported by Gopal et al (2001) and canning of fish curry in indigenous aluminium cans by Srivastava et al (1993).

3.5. Heat Penetration and Thermal Process Evaluation:
The practice of sterilization of foods in hermetically sealed metal containers has been researched extensively since 1920s. The theory and practise of establishing and evaluating thermal process for metal containers can be found in several sources (Stumbo 1973; Lopez 1981; NFPA1982). The mathematical modeling of thermal processing has also been studied extensively and has been thoroughly reviewed (Hayakawa 1977a; 1977b; 1978; Holdsworth 1985). The most widely used agent to accomplish food preservation is heat. The primary objective of thermal processing is to free the foods of micro organisms which might cause deterioration of the foods or endanger the health of persons who consumes the food (Stumbo 1949). With respect to evaluating thermal process for foods important concerns are the effect of heat on bacteria and the rates of heating of the different foods during process and the mechanism of heat transfer within the food itself during the process.

Integration of lethal effects, determined from a consideration of bacteriological and physical data, involves the application of basic mathematical principles (Stumbo, 1949). The first scientific approach to this problem of applying bacteriological and physical data to evaluation of the thermal processes for foods was the General method described by Bigelow et al (1920). Simpler and more versatile methods involving mathematical integrations of heat effects were developed by Ball (1923; 1928). Prior to the development of the methods, time temperature requirement of thermal process for foods were determined almost entirely by trial and error.
3.5.1. Evaluation of the thermal process:

The method described by Bigelow et al (1920) is essentially a graphical procedure for integrating the lethal effects of various time temperature relationships existent in a container of food during the process. According to concepts on which the method was based, it may be said that each point on the curves describing, heating and cooling of a container of food during process represents a time, a temperature and a lethal rate. By plotting the times represented against the corresponding lethal rates represented, a lethality curve representing the process is obtained. Since the product of lethal rate and time is equal to lethality, the area beneath the lethality curves may be expressed directly in units of lethality. This is a trial and error procedure. And for this reason, the method is sometimes referred to as 'graphical trial and error method' (Stumbo, 1949).

Notable improvement in the general method was made by Schultz and Olson (1940). A special coordinate paper for plotting lethality curves was described. Formulae were introduced for converting heat penetration data obtained for one condition of initial temperature and retort temperature to corresponding data for different retort and initial temperatures. These improvements greatly increased the applicability of general method, however the method is laborious and is ordinarily used only for calculation of processes which are not readily calculated by the simpler mathematical procedures developed by Ball (1923; 1928). The two well-established techniques for evaluating thermal process are the in situ approach and physico-mathematical method. In the in situ method, changes in the actual quality or safety attributes are determined before and after processing to have a reliable estimate on the status of attribute of interest. On practical grounds, however, measurement of microbial counts, texture and vitamin content & organoleptic quality by in situ
method is usually slow, costly and sometimes infeasible due to detection limits or sampling difficulties.

3.5.1.1. Mathematical methods:
Mathematical methods, developed by Ball (1923; 1928) mathematically accomplish integration of the lethal effects produced by time-temperature relationships existent at that point of great temperature lag in a container of food during the process. The formulae developed for use are relatively simple and constitute a great improvement over the General method for calculation of processes for most foods. According to Olson and Stevens (1939) "these formulae can be applied to any case where in the major portion of the heating curve on semi-logarithmic paper approximates a straight line, and where in the thermal death time curve on semi logarithmic paper is, or can be assumed to be a straight line" Ball's work not only greatly extended the scope of process calculations but simplified them as well.

Studies reported by Bigelow (1921) indicated that thermal death time curves, for certain important food spoilage bacteria, approximated straight lines when plotted on semi logarithmic paper- time being plotted in the direction of ordinates and temperature in the direction of abscissae. Ball's methods were based on the assumption that thermal death time curves are straight lines when plotted. Stumbo (1949) stated that the heating curves can be constructed by plotting, on semi logarithmic paper, temperature on the log scale and times on the linear scale are generally straight lines. However, instead of food temperature being plotted on the log scale and time on the linear scale, values representing differences between the retort temperature and food temperature are plotted.
Ball (1928) experimentally established that 42% of the "coming up time should be considered as process time at retort temperature. The slope of the heat penetration curve is represented by the symbol $f_h$, which is defined as the number of minutes required by the straight line portion of the heat penetration curve to travel one log cycle; $f_h$ is most easily ascertained by plotting the heat penetration data on semi log paper (Stumbo, 1949), though it may be calculated. Ball, (1928) introduced the symbol $F$ to designate the time in minutes required to destroy an organism at 121.1°C (250°F). Stumbo (1948) discussed the concept regarding the effect of heat on bacteria with regard to the order of death when subjected to heat.

In the physico mathematical method, a time temperature profile imposed on the food is integrated to evaluate the impact of a thermal treatment on the parameter of interest. The exercise is carried out either to determine the F value for a given process time, or to calculate the process time for a given F value. F value is defined as the number of minutes at a specific temperature required to destroy a specific number of organisms having a specific Z value. The term Fo is designated when the process temperature is 121.1°C and Z value of 10. The required information is the time temperature history of the product at the slowest heating point and $f_h$ and $j$ values.

Numerous physico-mathematical methods are employed for thermal process evaluation, the universally agreed are i) the general method, which include graphical and numeric methods ii) Analytical methods and iii) Formula method. The General method was developed by Bigelow et al (1920). The Numerical method is normally used the trapezoidal rule or Simpson's rule to calculate the area of irregular geometric figures.
(Holdsworth, 1997). Today several formulae are presented by characterizing temperature response of foods to be sterilized. Depending on the approach to the solution of the problem, they can be classified into theoretical and empirical formula. The first make use of analytical or numerical solution of theoretical heat equations, while the latter is based on heat penetration data. Hayakawa (1978) further divided formula into two groups: First group comprised of methods that calculate the lethality of cold spore (Ball, 1923). Second group consists of methods that calculate mass average lethality for whole containers (Stumbo, 1973; Hayakawa 1977). This grouping is similar to the thermocouple method commonly used to estimate lethality. In each case a hole is to be punched and thermocouple be installed at the slowest heating spot. From the time temperature profile of the cold spot of the container, the heating index \( f_h \), the lag factor \( j_h \) and lethality of the process (\( F_0 \)) can be calculated.

Another parameter for evaluating a thermal process impact on food is cook value. Cook value is the measure of heat treatment with respective to nutrient degradation and textural changes that occur during processing. \( T_{ref} \) is the reference temperature of 100°C and \( Z_c \) is actually taken as 33°C which is the thermal destruction rate for quality factors analogous to Z factor for microbial inactivation.

These indices are considered as the pre requisite tools for proper calculation of process time. They can be evaluated from the time temperature profile. It has been shown that when the log of the temperature difference between the retort and the product center, known as temperature deficit (\( T_r - T \)) during heating is plotted against time on linear scale, a straight line is obtained after initial lag. The intercept is obtained by extending the straight-line portion of the curve to the Y axis representing \( T_{pib} \).
### 3.5.2. Order of death of bacteria and commercial processes:

From the standpoint of Food sterilization, bacteria may be considered dead if they have lost their process of reproduction. Quantitative studies by Chick (1910) indicated the death of bacteria to be logarithmic in nature. Results of many studies confirming that the order of death of bacteria is logarithmic in nature (Weiss, 1921; Esty and Meyer, 1922; Viljoen, 1926; WatKines and Winslow, 1932; Rahn: 1934, 1943, 1945a; Pflug and Esselen, 1987). Many explanations have been given for this. The most plausible of explanations is that of Rahn (1929, 1945b). He stated that the loss of reproductive power of a bacterial cell when subjected to heat is due to the denaturation of one gene essential for reproduction.

According to Ball (1943), suggested the symbol 'Z' to represent the slope value of the rate of destruction curve, Z is defined as the no of degree on the temperature scale when the TDT curve traverse one log cycle. Considering 'Z' is the unit of time, it follows that 90% of the organisms subjected to given lethal temperature are killed during each unit of time.

Clostridium botulinum is the only bacterium known which produces highly heat resistant spores and is greatly significant from the standpoint of food consumption and public health (Stumbo, 1949). Many of the foods of low acid type will support its growth. If it were not destroyed by the thermal process it may grow in the foods and produce toxin which if ingested would generally prove fatal to the consumer. Therefore, knowledge concerning the maximum resistance of spores of Clostridium botulinum in food is extremely important to the establishment of adequate thermal processes for those foods, which will support its growth.
Esty and Meyer (1922) reported the results of studies in which the thermal resistance of many strains of Cl. botulinum had been determined. An ideal thermal death time curve for spores of Cl. botulinum in neutral phosphate solution was suggested. This curve was designated by the values of $F=2.78$ minutes and $Z=18^\circ F$. Townsend et al (1938) reported corrected values for these factors namely, $F=2.45$ and $Z=17.6$. The maximum resistance values reported by Esty and Meyer were obtained by suspensions containing billions of spores. The $F$ value of 2.45 is higher than the $F$ values generally reported by other workers for this organism (Townsend et al 1938, Tanner1944). These higher values are still employed as the basis for establishing commercial processes throughout the canning industry.

The accomplished lethality ($Fo$) for any thermal process could be easily calculated by numerical integration of the cold spot temperature over time. Thus if the cold spot temperature could be accurately predicted, so could be the accumulated process lethality (Texiera, 1999). Raab (1993) used a $Fo$ value of 5.6 for canning smoked fish. Mackerel curry processed to a $Fo$ value of 8.43 in retortable pouches gave an acceptable product with desired texture and sensory characteristics (Gopal et al, 2001). Frott and Lewis (1994) recommended $Fo$ in the range of 5-20 for fish and fish products. Normally herring in tomato sauce are processed to $Fo$ of 6-8 (Brennan et al, 1990).

3.5.3. Mechanism of heat transfer and process evaluation:

Stumbo (1948) stated that the mechanism of heat transfer within the food container must be considered, if greatest accuracy in process evaluation is to be attained. The General method and Balls mathematical method of process evaluation are based on the concept that a thermal process adequate to accomplish sterilization of the food at the point of greatest
temperature lag in a container during process is adequate to sterilize all the foods in the container. (Bigelow et al, 1920; Ball, 1923, 1927, 1928, 1943, 1948; Olson and Steven, 1939; Schultz and Olsen 1938, 1940; Jackson, 1940; Jackson and Olson, 1940; Sognefest and Benjamin, 1944).

Jackson (1940) on the basis of data accumulated over a number of years covering heat penetration tests in a large number of food products, classified the products according to the mechanism of heat transfer within the food container. Six main classes of products are listed, ranging from those, which heat by rapid convention throughout the process to those, which heat by conduction throughout the process. But the main two classifications with respect to mechanism of heat transfer are foods, which primarily heat by convection, and foods, which primarily heat by conduction (Stumbo, 1949).

### 3.5.3.1 Conduction heat transfer

Conduction heat transfer occurs when different parts of a solid body experiences difference in temperature. As a result, the energy flows from the hotter region to the colder one. In canned solid foods heated by conduction, the slowest heating point is the geometrical center of the can. The mechanism of heat transfer through the container wall is conduction. With regards to the heat transfer from the container wall into the product, the mechanism largely depends upon the consistency of the food. The governing equation is given by

\[ Q = K \left( T_i - T_{ii} \right) \times \]

\[ Q = \text{quantity of heat (J)} \]
\( T = \) Temperature in (K or °C),
i and ii refers to the two sides of the body.
\( t = \) Time (s)
\( X = \) Distance (m)
\( A = \) Cross sectional area (m² for heat flow)
\( K = \) Thermal conductivity (Wm⁻¹ K⁻¹)

### 3.5.3.2 Convection heat transfer

In the case of convection heat transfer, inside containers, the mathematical model required for the prediction of temperatures in order to determine the process requirements are more complicated. Liquid and semi liquid foods are mainly heated by convection, where the cold point is below the center of the can. Three main approaches used in convective heat transfer are film theory, use of dimensionless numbers and use of mathematical treatments and heat transfer models. Of these three approaches, Film theory happens to be less complicated and widely applied. This approach employs the basic heat transfer for convection expressed as

\[
Q = h_s A (T_b - T_s)
\]

\( Q = \) Quantity of heat flow (Js⁻¹)
\( h_s = \) Surface heat transfer coefficient
\( A = \) Surface area (m²)
\( T_b = \) Bulk fluid temperature (K)
\( T_s = \) Surface temperature

Heating of foods in containers, is in general a slow and inefficient process compared with heating in heat exchangers. The rate of heating food products in containers is a function of the geometry of the container,
physical properties of the food product, heat transfer characteristic of the container (Pflug and Esselen, 1981). The nature or consistency of the food product, the presence of particles of food and the use of starch or sugar in the covering liquids are some of the factors that determine whether the product heats by conduction or convection. The rate of heating of a food product can be illustrated by $f_h$ value. The $f_h$ of conduction heating food products varies approximately as the square of the container diameter or height whichever is smaller. The $f_h$ of convection heating food products varies approximately as the surface to volume ratio.

The heat transfer through tin plate or metal containers is more rapid than through glass or plastic containers; however these heating rate differences are often minimized by the nature of the product itself (Pflug and Esselen, 1981).

Under a given set of product conditions, the time required for the food to accumulate the desired lethality can be decreased by (i) increasing the initial temperature of the products of the container, (ii) raising the heating medium temperature and (iii) agitating the container during processing (Denys et al, 1996). In the heat processing of food product in containers, the last few minutes of the heating cycle contribute the major part of the lethality or sterilizing effect of the process (Pflug and Esselen, 1981). The rate of heating of a food product must be known before a thermal process can either be designed or evaluated. A thorough discussion of the equipment used for measuring temperature using thermocouples and potentiometer is presented by Ecklund (1949).

The majority of the heating and cooling curves when plotted on semi log paper can be represented by a straight line and described by two
parameters, \( f_h \) and \( U \) (Pflug and Esselen, 1981; Stumbo, C.R, 1973; Teixeira et al, 1999). If the heating rate \( f_h \) is known for a food product is size of container, the heating rate of the same food product in other sizes of containers processed under similar conditions can be calculated. The \( J \) value is usually assumed invariable with can size changes (Teixeira et al, 1999).

The heating rate \( f_h \) of conduction heating products is a function of the size and shape of the container and a property of the food product called thermal diffusivity; \( f_h = \text{can factor/thermal diffusivity} \) (Pflug and Esselen, 1981). The convection heating process in containers of food is not as fully understood or conduction heating. In general, homogenous food products with viscosities not greatly different from water have heating rates proportional to the surface/volume of the container. Surface and volume can be incorporated onto a can factor (Schultz and Ohlson, 1938).

The integrated sterilizing value of a process or \( F_o \) is the basis of comparison of thermal processes and the starting point in the design of a thermal processes. The sterilizing value of a heat process is obtained by integrating the lethal effect as the product is heated and then cooled. Three procedures have been developed for evaluating heat processes and Known as the general or graphical method (Bigelow et al 1920), the formula method (Ball 1923, 1928) and the nomogram method (Ohlson and Stevens 1939). A simplified procedure for determining the sterilizing value has been discussed by Patashnik (1953) by Knowing the \( Z \) value and core temperature and determining lethal rate at equal time intervals. This method is ideal for routine analysis if the sterilizing value of heat processes.

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3.6. Studies on The Reduction in Process Times

The dimension and wall thickness of the cans will affect the heat penetration during thermal processing. For a can of same dimension heat penetration will be the same if the other processing conditions are not altered. For foods sterilized in still retorts the heat transfer is the rate-limiting step and is affected by the heating medium, resistance incurred at the container wall, size of the container and thermo physical properties of food. Influence of particle shape and particle motion on heat transfer in cans during end over end rotation and the influence of rotational speeds were carried out by Ramaswamy and Sabalini (1997a, 1997b). The effects of rotational speeds and headspace were more significant than those of retort temp. and radius of rotation (Sabalini and Ramaswamy, 1996). Heat transfer in liquid, semi viscous or particulate foods can be significantly increased by mechanical agitation during processing. This is the underlying principle of agitating sterilization or retorts. As cage rotates contents are agitated, this eliminates cold spots and reduces processing time as the cans are heated up faster and evenly. The effect of different agitation rates (0-30rpm) during end over end agitation of containers filled with water and model food system (Potato alginate mixture) were studied by Knap and Durance (1999).

Reduction in process time will have an advantageous effect on the sensory and nutritional qualities of the thermally processed fish products. Effect of end over end agitation processing on thermal softening of vegetable texture has been studied by Taherian and Ramaswamy (1996). Moscarello and Vestito (1994) studied the effect of raw material characteristics and process variables including the rotation of the cans during sterilization. Results showed that F value of the sterilization process was highly depend upon the tomato wt/ can; other factors studied had smaller effect on F values. Abbatemarco and Ramaswamy (1994) studied
the effect of end over end agitation on the texture and colour of vegetables during thermal processing. They observed that processing at higher temperatures and rotational speeds resulted in better retention of vegetable texture. Rotary thermal processing was more advantageous than stationary thermal processing, mainly for a high viscosity medium as it reduced sterilization time by approximately 50% (Alvez Ortiz et al, 1995). Rotation of the cage of the retort has a positive effect on the heat penetration in cans during thermal processing. End over end rotation resulted in a faster heat penetration and better quality retention (Van et al 1994). The aim of thermal processing with rotation or agitation is to produce a product that is safe to consume with maximum nutrient retention.

3.7. Studies on Microbial Spoilage and Sterility Tests:

Spoilage of heated foods may have a chemical cause or a biological cause or both. Biological spoilage of canned foods by microorganisms may result from either or both of two causes. First if the sealed container is not subjected to sufficient heat the contents are not effectively sterilized and so spoil on storage. This type of spoilage is known as under processing. The second type of spoilage is known as post process reinfection or leaker spoilage and it result when the contents of the can, having been effectively sterilized are subsequently reinfected by microorganisms from the surrounding environment gaining access to the contents through leaks in the sealed container (Namblar 1980; Put et al 1972; Anon 1968; Jarvis 1940).

Mild heat treatments may be only enough to permit the successful storage of the foods for limited periods with the help of refrigeration. Surviving microorganisms are likely to be of several kinds and may include vegetative cells (Bultiaux and Beerens 1955; Cameroon and Esty 1940).
Acid foods such as fruits are processed at temperature approaching 100°C, treatments which result in killing all vegetative cell of bacteria, yeasts, moulds and their spores and some bacterial spores. Only survivors ordinarily are spores of bacteria which cant grow in a very acid food. Any survivors of heat treatment by steam under pressure are very heat resistant bacterial spores, usually one or two kinds (Frazier and Westhoff, 1998).

3.7.1. Post process contamination
Leakage and subsequent spoilage of canned food may be a result of mechanical damage of empty can so that side and seams are defective, rough handling of filled cans may also result in damage. Microorganisms may enter from contaminated cooling water after the heat process (Put et al 1972; Frazier and Westhoff 1998). Leakage also may cause a loss in can vacuum, thus encouraging chemical and microbial deterioration of the canned foods. The presence of organisms’ known to be of low heat resistance and especially many species indicates spoilage (Corlett and Denny 1984; Herson and Hulland 1964).

3.7.2. Under processing
Many cases of food poisoning are associated in the literature with post process reinfection of canned food, and these cases include typhoid and staphylococcal food poisoning and intoxication due to Clostridium botulinum (Sandiford, 1954; Dickinson, 1959; Johnston et al, 1963; Foster et al, 1965). Reports have also appeared on the economic losses of the canned food products as a consequence of reinfection by non-pathogenic bacteria (Shapton and Hindes,1962; Everton et al, 1968; Bean and Everton, 1969).
Clostridium botulinum is an obligate anaerobe, which is widely distributed in nature and is assumed to be present in all products intended for canning. C. botulinum is a member of the genus Clostridium characterized as gram+ve, rod shaped endospore forming obligate anaerobe (Varnum and Evand, 1991). For low acid canned foods the anaerobic conditions that prevail are ideal for growth and toxin production of Clostridium botulinum. This organism is also the most heat resistant, anaerobic spore forming pathogen that can grow in low acid canned foods, and consequently its destruction is the criterion for successful heat processing of this type of product. The toxin is extremely potent but can be destroyed by exposing it to moist heat for 10 minutes at 212°F (Lund et al 1975). The severity and fatality rate of botulinum have been a significant worry to food processors and consumers since the late 1800 (Francis et al 1999). Clostridium botulinum type 1 (proteolytic strains) and clostridium botulinum type 2 (non proteolytic strains) are responsible for human food borne botulism (Peck, 1997).

Nambiar and Iyer (1970) have made a detailed study of the type of microorganisms present in bacteriologically defective canned prawns. A study was taken by Nambiar (1980) to find out the bacteriology of spoilage of canned prawns. The pattern of spoilage, namely production of off odour, bulging of the cans and disintegration of meat were observed. Ababouch et al (1987) studied the cause of spoilage of thermally processed fish in Morocco. Upon microbiological analysis of 256 cans, viable microorganisms were recovered from 168 cans of which 72% contained typical leaker spoilage organisms, while 28% contained typical under processing spoilage organisms.

Severe sterility heat treatments are most often applied to low acid foods (pH>4.6) packaged in hermetically sealed containers. Temperature of
treatment ranges from 115°C to 150°C. For the low acid canned foods commercial sterility is necessary i.e. foods must be free of pathogens, as well as microorganisms capable of growing in the food under normal non-refrigerated conditions of spoilage. The spores of C. botulinum must be destroyed, if they are not, they may germinate and form the deadly toxins of botulism (ICMSF, 1980). The minimum sterilization process for C. botulinum is usually expressed as 12 log cycles as decimal reduction assuming all organisms are spores and is called a 12 D reduction (Jaiswal et al, 2002). One Fo is equivalent to one minute at 121°C, assuming instantaneous heating and cooling. Meat products generally processed to a Fo of 6 (Shapton and Shapton 1997).

3.7.3. Commercial sterility
Commercial sterility for low acid foods may be defined as that condition in which all C. botulinum spores and all other pathogenic bacteria have been destroyed as well as more heat resistant organisms if present, could produce spoilage under normal conditions of storage and distribution (Denny1970, 1972). Sterility testing is used to assist in determining the efficacy of a heat process and is the assessment of the soundness of container (Evancho et al 1973). The occurrence of contamination during sterility testing of foods has been recognized and documented. In an early study, William and Clark (1942) stressed the importance of multiple controls in sterility testing of canned salmon.

3.8. Storage Studies and Changes in Chemical Parameters:
Processing improves the keeping quality of products allowing availability of nutrients during storage from foods, which have a limited season of maturity. The permanent seal of the can protects food from changes in moisture conditions during storage. This long shelf life protection cannot be achieved when processing and storing fresh foods, even for a short
time. The major component of canned foods, such as protein fat and carbohydrates would not be expected to change during storage. Ascorbic acid and thiamine are two, micronutrients most vulnerable to deterioration during processing and storage, and a number of factors affect this such as pH, the presence of dissolve oxygen and time at high temperatures during processing (Amr, 1998).

The rate of quality deterioration of a food product, once it leaves the processing stage, is a function of its microenvironment namely gas composition, relative humidity and temperature (Taoukis and Labuza 1989). Where the gas composition and RH are usually relatively well controlled by appropriate packaging, the temperature of storage becomes the important controlling factor. Loss of shelf life in a food product is usually evaluated by the measurement of one or more characteristic quality parameters. These parameters can be physical, chemical, microbiological or sensory indices (Labuza 1988).

Pearson et al (1977) and Chan (1987) described the important role of lipid deterioration during food processing on the quality of the final product. Lipid oxidation is often related to a significant number of volatile compounds that can be produced from polyunsaturated fatty acids (PUFA) during thermal treatment of foods (Hale and Brown, 1983; Maeda, 1985; Yasuhara and Shibamoto, 1995). Different methods were employed to evaluate the mechanism of fish lipid oxidation and to assess its overall flavour quality (Medina et al, 1998; Przbylski and Eskin1994). These methods were mainly based on the formation of specific compounds or their interaction with other products in foods.

Hydro peroxides formed as primary products of lipid oxidation, are rapidly decomposed to produce a variety of secondary volatile compounds of low
molecular weight. Aldehydes are the main volatile secondary products responsible for off flavours and odours during storage and treatment of foods (Frankel 1982; Przybilski and Eskin 1994). Medina et al (1999) suggested static headspace gas chromatographic analyses to determine oxidation of fish muscle, lipids during thermal processing. In many countries, the quality evaluation of canned seafood involves checks on net weight, vacuum, cleanliness, oil and brine content, overall condition, flavour, odour, texture, colour and the presence of specific toxic products.

Shelf life evaluation has been carried out for a variety of food products processed in aluminium can by different researchers. Jacobsen (1944) found that shelf life if spinach canned in aluminium containers depend upon the quality of the aluminium sheet, the amount of water soluble oxalates in the spinach and the storage temperature of the cans. Kemp (1958) found out that fruits and vegetables can be stored in aluminium cans up to 24 months at 70°F and for 12 months at 100°F. When the pH is 5 or above simple enameling will result in a shelf life of 2-3 years at room temperature storage. For the more acid products such as fruits, the room temperature shelf life ranges from 12-18 months (Taranger, 1956; Gotsch et al 1958, 1959). Lopez and Jimenez (1969) conducted shelf life evaluation for 22 different canned fruit and vegetable products packed both in enameled and uncoated aluminium cans.

Kluter et al (1996) evaluated the shelf life of Bartlett pears in retort pouches. Minimum shelf life requirement prescribed by them are that the product should be acceptable after 36 months at 21°C and 6 months at 38°C. The pouches were kept at room temperature (23±3°C) until equilibration and sensory and biochemical analysis were done on a scale of quality (extremely poor=1; fair=5; excellent=9).
Storage studies in aluminium cans for a variety of Indian food products were conducted by Srivatsav et al (1993). The cutout examinations revealed good seaming integrity and satisfactory hooking of the lids to the body of the can. Storage studies were carried out, by storing the product at room temperature (19-30°C) and compared to those stored at 5°C. Results of chemical analysis of the stored product didn’t show any significant change. Gopal et al (2001) reported a shelf life of one year at room temperature for the traditional kerala style fish curry processed in indigenous pouches. The curry remained sterile through out the storage period at ambient temperature. Sensory evaluation were carried out on a 10 point hedonic scale with excellent=10 and unacceptable below4.

Vijayan and Balachandran (1986) stored sardine curry in tin cans at room temperature (29±2°C) and periodically examined. The observations were that the pH of the curry medium, which was 5.55 initially in the two type of curry, processed remained more or less steady through out the storage. The texture of the fish meat changed from firm and soft to firm in both type of curry medium during storage. Sensory evaluation was done on a nine-point scale (Extremely like=9; Acceptable=4 and Extremely dislike=1).

3.9. Optimization of Thermal Processes:
In commercial heat sterilization of foods in cans or retortable pouches, the container has been heated in a pressurized steam or hot water retort at certain conditions of temperature and time. Although this process will make microorganisms and spores inactive, it may also cause destruction of essential nutrients that leads to deterioration of product quality. Consequently much attention has been given to maximizing quality retention for a specified reduction in undesirable microorganisms during sterilization (Terajima and Nonaka, 1996). First optimization study was
conducted by Teixeira et al (1969) for the heat sterilization of conduction-heated foods. They calculated the optimum processing temperature for cylindrical cans using thiamine retention as optimization criteria. The optimum retort temperature was highly depend upon the Z value of the nutrient but was generally in the practical range of 120-140°C. The term cook value was used to describe changes in sensory and nutritional properties (Mansfield1962; Ohlson 1980a, 1980b). Nadkarni and Hatton (1985) concluded that a bang bang control of the retort temperature where heating and cooling rate should be as fast as possible, was the optimal strategy.

Thermal inactivation of microorganisms is more temperature dependent than quality and nutrient degradation, optimization of a thermal process in terms of quality is necessary (Van Loey et al, 1998). Differences in temperature dependence suggest that high temperature short time process is favorable (Lund, 1977). Usually HTST process is adopted for liquid foods. Several thermal process optimizations studies have been reported (Teixera et al, 1969, 1975; Thijssen et al, 1978; Saguy and Karel, 1979; Ohlson, 1980a. 1980b, 1980b; Nadkarni and Hatton, 1985; Tucker and Holdsworth, 1990; Banga et al, 1991; Hendrickx et al, 1995; Silva et al, 1992). All of these studies focused on conductive heating foods only and were limited to theoretical considerations. Van Loey et al (1996) attempted thermal process optimization studies of convection heating foods. Computed optimal process es were validated with a trained taste panel.

3.10. Studies on The Texture Properties:
Texture is one of the most important quality parameter of fish for producers, processors and consumers. For majority of fish species, texture becomes very important for consumer acceptability. Texture is influenced
by intrinsic and extrinsic factors (Barraro et al, 1998; Sigurgisladottir et al, 1997; Mackie, 1993; Love, 1983). No agreement exists to which methods are the best for measuring the texture of fish, and there is no universal recommended method (Heia et al, 1997). One of the main problem encountered with fish and fish products is that the fish muscle is very heterogeneous making sampling, and hence measurements difficult to reproduce.

Texture has got many definitions; most of them are very broad because food can be regarded as very complex physico chemical systems. Bourne (1982) concluded from different definitions that texture of the food has several characteristics. (i) It's a group of physical properties that derive from the structure of the food. (ii) It belongs under the mechanical or rheological subheading of physical properties. (iii) It consists of a group of property not a single property. (iv) Texture is sensed by touch, usually in the mouth but other parts of the body may be involved (mostly the hands). (v) Objective measurements of texture are by means of functions of mass, distance and time only. Meilgard et al (1999) defined texture as the sensory manifestation or inner make up of products in terms of their reaction to stress and tactile properties. The reaction to stress is measured as mechanical properties such as hardness, adhesiveness, cohesiveness, gumminess, springiness etc.

Many of the methods used for measuring the instrumental texture of fish are modified versions previously used for meat. It’s however, important to keep in mind that many of these methods are not suitable for fish, because of the low content of collagen in fish (Dunajski, 1979). The most common types of measurements are based upon rheological principles (1) shear strength (2) puncture and (3) compression. According to Sigurgisla dotter et al. (1997) the recent trend is away from the point
measurements that reflect either only one parameter or as overall value for a group of parameters, and towards a multiple point or curve method that can give information on several parameter. Compression test can include 1 or 2 successive compressions. For measuring the hardness single compression is only required. Those with two successive compressions from the Texture Profile Analysis (TPA) result in curves from which several textural parameters can be obtained. Two compressions are said to be necessary, if parameter such cohesiveness, elasticity, adhesiveness, chewiness and gumminess are to be measured (Friedman, et al., 1963).