Review of Literature
2.0 REVIEW OF LITERATURE

2.1. Packaging

Food packaging is crucial to our modern food distribution and marketing systems. Without protective packaging, food spoilage and wastage would increase tremendously. The advent of modern packaging technologies and new methods of packaging materials made possible the era of convenient foods. In the past the packaging emphasized the expectations of the producers and distributors but has now shifted towards the consumer since they are becoming more demanding and aware of the choices available (Piergiovanni, 1991). A food package usually provides a number of functions in addition to protection. Convenience packaging for consumers requires a shape and size of containers that allow for easy opening, pouring, serving, carrying, reclosing and storage.

Fish is one of the most perishable of all foods. The best package cannot improve the quality of the contents and so the fish must be of high quality prior to packaging (Fujita, 1990). Different products have different packaging requirements and it is important to choose suitable packaging material accordingly. It is important to know the intended storage conditions of the product, i.e., temperature, relative humidity and expected shelf life. This is why multilayered plastics are very popular since properties of different films can be effectively used (Mueller, 1991). The basic function of food packaging is to protect the product from physical damage and contaminants, to delay microbial spoilage, to allow greater handling and to improve presentation. Emergence of thermo process-resistant films from the petroleum industry and advances in the thermo processing procedures have given rise to retortable packaging, which now plays a very important role in food packaging (Yamaguchi, 1990). Flexible retort pouch and semi rigid trays are used for thermal processed products (Fujita, 1990).
2.1.1. Retort Pouch

The concept of pouch as a container was developed by the US Army Natick Laboratories and a consortium of food packaging companies in the early 1960s (Herbert & Betteson, 1987). The technical and commercial feasibility of using retort pouches for thermo-processed products have been proven by (Hu et al., 1955). In 1967, Chinese dumplings and curry were packed in aluminum foil containing retortable pouches and marketed. In the year 1968-69 commercialization of curry in foil free and aluminum foil containing pouches were undertaken and this started the era of retort pouches in Japan (Tsutsumi, 1972). The boil in bag concept of warming the food before consumption gives an edge for pouches over cans (Arya, 1992). Retort pouched products are shelf stable ready to eat products which can be used as per the convenience of the consumer (Devadasan, 2001 and Rangarao, 2002). The most comprehensive work on flexible packaging for thermal processed foods was prepared by Lampi (1977). Heat sterilized low acid solid foods in pouches created a new segment within the canned foods category (Brody, 2003). Sara et al., (1989) studied the effect of increased over pressure levels, entrapped air and temperature on the heat penetration rates in flexible packages. Sacharow, (2003) did market studies in USA and Europe and reported a bright future for retortable pouches.

2.1.2. Components of retort pouch

The use of retort pouch for heat processing of food was reported earlier by Hu et al., (1955) and Nelson et al., (1956). Tripp, (1961) reported the feasibility of retort pouches for producing different food products. The US Military developed a packaging material made up of 75 μ vinyl / 9 μ foil / 25 μ polyester (McGregor, 1959) for use as retort pouch. Several authors have discussed in detail different properties of flexible packaging materials required for thermal processing of food products (Heidelbaugh & Karel, 1970; Nieboer, 1970; Rubinate, 1964; Szczebiowski, 1971; Schulz, 1973 and Tsutsumi, 1974). The three or four layer retort pouches consists of an outer polyester layer, a middle aluminum layer and an inner cast polypropylene layer (Griffin, 1987). Nylon is also added as an additional layer or is substituted for the aluminum layer to give
additional strength in a four layer pouch. Aluminium foil is the barrier layer which gives the product a longer shelf life (Rangarao, 2002). Polypropylene has a high melting point of about 138°C and is used as the inner layer to provide critical seal integrity, flexibility, strength and taste and odour compatibility with a wide range of products (Shorten, 1982). The different layers are held together with adhesives which are usually modified polyolefins such as ethylene vinyl acetate (EVA). Martin, (1966), Goldfarb, (1970) and Nieboer, (1970) have given an account of the different adhesives used for retort pouches. Taylor, (2004) has reported the possible use of liquid crystal polymers, which have superior oxygen and water vapour barrier properties compared to other polymer films. Some pouches contain polyvinylidene chloride, ethylene vinyl alcohol or nylon instead of the aluminium layer to permit viewing of the product. These are foil free laminated materials. These plastics are good barriers to oxygen molecules but are not complete barriers and therefore the shelf life is reduced (Jun et al., 2006). Nowadays retort pouch containing a coating of nano particles like silicon dioxide or aluminium oxide in addition to the other mentioned layers are commercially available in the market. These pouches have good barrier properties and are comparable to aluminium foil pouches. The different types of retort pouch and the layers which make up the retort pouch are given in Table 1.

2.1.3. Advances in retort pouch processing

Stephen and Wiley, (1982) compared general method and Ball's formula method for process calculation and found that Balls method was more suitable. Process determination for conduction-heated foods in retortable pouches was reported by Bhowmik and Tandon, (1987). Lebowitz and Bhowmik, (1989) reported the heat transfer coefficient for retortable pouches. Skipnes, (2002) studied heat transfer of vacuum packed farmed mussel subjected to different pressure, holding time and variations in vacuum in retort pouches. Evaluation of quality of chum salmon processed in retort pouches and metal cans to a equivalent lethality showed that the pouch products were firmer, drier, chewier than the canned ones (Durance & Collins, 1991). This is in agreement with the observations of Skipnes et al., (2002) on Alaska Pollack, shrimps and rainbow.
trout where the pouched samples had a firmer texture and lighter color. Heidelberg and Karel, (1970) reported the quality changes in pouched food.

Table 1. Properties of material used for retort pouch manufacture (Gopal, 2007)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyester</td>
<td>Good heat resistance and Reverse colour printing</td>
<td>Probability of having pin holes high</td>
</tr>
<tr>
<td>Biaxially oriented nylon</td>
<td>High strength</td>
<td>Shrinks during heat processing</td>
</tr>
<tr>
<td>Non oriented nylon</td>
<td>High strength and very good heat resistance</td>
<td>Difficulty in quality printing</td>
</tr>
<tr>
<td>Biaxially oriented</td>
<td>High strength and sealing</td>
<td>Develops shrinkage during heat processing; has the tendency to curl</td>
</tr>
<tr>
<td>Polypropylene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium foil</td>
<td>High barrier</td>
<td>Pin holes, has opaque colour, poor heat sealing quality</td>
</tr>
<tr>
<td>Polyester</td>
<td>High strength, heat resistant</td>
<td>Pin holes</td>
</tr>
<tr>
<td>Nylon</td>
<td>High strength and Impact resistance</td>
<td>Expensive</td>
</tr>
<tr>
<td>Inner layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High density polythene</td>
<td>Good impact resistance High sealing property; cheap</td>
<td>Poor heat resistance, translucent</td>
</tr>
<tr>
<td>Non-oriented polypropylene</td>
<td>Transparent, good heat resistance</td>
<td>Poor impact resistance</td>
</tr>
</tbody>
</table>

In the sensory acceptability, pouched products has a better overall acceptability than canned products since there is less impairment to the texture and colour due to the reduced exposure to heat (Durance & Collins, 1991). Dymit, (1973) reported that shrimp in pouches were superior in flavour and colour compared to canned products. Synder and Henderson, (1989) found that retort pouches reduced times for conduction heating products but in a liquid medium.
the agitated cooking of cans required less processing time than the pouches. Retort pouch products from Tuna and Salmon have a successful market in the USA. Brody (2000); Balange (2002) and Chai et al., (1984) observed that oysters could be processed with less severe treatment when packed in retort pouches and they had a extended shelf life. Heat penetration was faster in fish balls packed in curry in retort pouches with good sensory properties (Balange, 2002). Adams and Otwell, (1982) reported that products like fish, shrimp, crab and meat processed in pouches were superior to canned products. Kluter, et al., (1994) studied shelf life of cling peaches in retort pouches and Taiwo et al., (1997) studied cowpeas in tomato sauce and found that retort pouches are economically feasible as an alternative to the cans.

2.1.4. Benefits of retort pouches

Pouches provide better quality product due to rapid heat penetration, shelf stability without refrigeration, convenient end use preparation, and compact storage characteristics before and after packaging, easier opening and disposal (Ramaswamy & Tung, 1988). These pouches are able to withstand high sterilization temperatures including HTST operations (Awuah et al., 2007). In addition to this the pouches should be able to withstand cooling temperatures of around 40°C under counter pressure, to avoid opening of heat weakened seals (Brody, 2002). Retort pouches can withstand thermal processing and combines the advantages of the metal cans and boil in bags (Gopal et al., 1981). Natural convection plays an important role in the heat transfer in liquid products and conduction and convection in more solid products. Food packed in pouches have the advantage of improved quality, reduced weight, improved carrying ease and an energy saving advantage over the equivalent canned ration in military (Steffe et al., 1980). The advantages of retort pouches technology vs conventional metallic canning and advantages of retort pouches versus metallic cans are given in Tables 2 and 3 respectively.
Table 2: Retort pouch vs conventional metallic canning (Venugopal 2006).

<table>
<thead>
<tr>
<th>Features</th>
<th>Retort Pouch</th>
<th>Metal Can</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility</td>
<td>Highly suitable for delicate products such as seafood, sauces</td>
<td>Good for products having tough texture such as beef, pork etc</td>
</tr>
<tr>
<td>Product development</td>
<td>Slower filling, thermal processing more complex</td>
<td>Convenient product line including filling and thermal processing</td>
</tr>
<tr>
<td>Sterilization time</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Product quality</td>
<td>Superior in quality, with more natural colour, flavor and texture</td>
<td>Intense cooking results in loss of natural sensory attributes</td>
</tr>
<tr>
<td>Shelf life</td>
<td>Comparable with canned products</td>
<td>Comparable with retort pouch products</td>
</tr>
<tr>
<td>Convenience in handling</td>
<td>Less weight, needs less storage space</td>
<td>More weight, requires more space for storage</td>
</tr>
<tr>
<td>Convenience in consumption</td>
<td>Can be easily opened by tearing across the top notch in the side seal or by cutting with a scissors</td>
<td>Requires a can opener</td>
</tr>
<tr>
<td>Capital investment</td>
<td>Higher capital investment</td>
<td>Medium level of capital investment</td>
</tr>
<tr>
<td>Marketing</td>
<td>Trade and consumers need to be familiarized with handling the pouch</td>
<td>Established technology and hence minimum consumer attention needed</td>
</tr>
</tbody>
</table>
Table 3. Advantages of retort pouches vs. metal cans (Jung et al., 2006)

<table>
<thead>
<tr>
<th>Features of retort pouch packaging</th>
<th>Benefits of retort pouch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced cooking time</td>
<td>Better taste, nutritional value and faster turn around time</td>
</tr>
<tr>
<td>Complete product evacuation</td>
<td>Improved product yield and consumer value</td>
</tr>
<tr>
<td>Reduced bulk and weight</td>
<td>Lower transportation and storage costs</td>
</tr>
<tr>
<td>Environmental friendly</td>
<td>Less waste and fossil fuel consumption</td>
</tr>
<tr>
<td>Package differentiation and larger shelf display</td>
<td>Increased sales</td>
</tr>
<tr>
<td>Package durability</td>
<td>Eliminate cuts and promotes employee safety</td>
</tr>
<tr>
<td>Rotogravure printing</td>
<td>More attractive graphics on packaging</td>
</tr>
<tr>
<td>Package durability</td>
<td>No dented cans</td>
</tr>
</tbody>
</table>

2.1.5. Retort pouch in India

In India the research on retortable pouches started in the 1970s. General information on retort pouch processing and use of retort pouch as an alternative to cans has been reported by Gopakumar and Gopal, (1987). Flexible pouches of three layer configuration, which can perform the packaging functions of boil in bags as well as cans, were identified. (Gopal et al., 1981; Gopal et al., (1998) and Vijayan et al., (1998). Girija et al., (1996) reported the processing of various fish curry products in retortable pouches. A number of ready to serve fish products like ready to serve fish curry (Gopal et al., 2001), Kerala style fish curry (Vijayan et al., 1988) Rohu curry (Sonaji et al., 2002), Seerfish curry (Gopal et al., 2002; Ravishankar et al., 2002), Seerfish moilee (Manju et al., 2004), Ready to eat mussels (Bindu et al., 2004), Prawn Kuruma (Mohan et al., 2005), Grey clams (Bindu et al., 2007), and Etroplus curry (Pandey et al., 2007) have
been processed in retort pouches. Ali et al., (2006) compared the properties of indigenous and imported packaging material and studied the heat processing of fishes in retortable pouches. Madhwaraj et al., (1992) reported that spoilage in the flexible pouch is due to contamination of seal area.

2.1.6. Major physical properties of retort pouch

2.1.6.1. Thickness

The thickness of the pouch has a direct influence on the heat penetration characteristics and product quality. Non uniform thickness can affect the machine performance, product protection and integrity of the packages (Hemavathi et al., 2002). The acceptable limit for variation in thickness of individual layers is ± 2 μm (inner ply) or 10 % of the value (Lampi, 1977; 1980). The thin profile helps in rapid transfer of heat to the inner regions unlike in cans and glass bottles. About 20-30% reduction in process time was observed by Simpson et al., (2004) for vacuum packed mackerel in retortable pouch and processed in steam /air mixture at 116.8°C.

2.1.6.2. Barrier Properties

Plastic films may have pin-holes which under normal conditions are unlikely to occur when they are laminated (Yamaguchi, 1990). It has been confirmed that even a single layer film does not allow the microorganisms to pass (Lampi,1977). Hence the problem lies in careless handling during the manufacture of the products and during handling and exposure in transportation and storage.

a) Oxygen transmission rate (OTR)

Oxygen transmission rate is of great importance in the packaging of processed foods to exclude headspace oxygen (Kumar, 1994). The OTR in imported and indigenous pouches tested as per ASTM D 1434 was practically nil for the three layer pouches (Vijayalakshmi et al., 2003).
b) Water vapour transmission rate (WVTR)

The retort pouches consist of multiple films laminated together. Since the pouches do not have any pin-holes under normal manufacturing conditions the WVTR rate is practically nil. Contamination by penetration of water contaminated with microorganisms is of major concern during the cooling process. In retort foods, the wide sealing width does not allow the entry of water into the pouch from the seal area. The cooling water should be clean for maintaining a quality product (Yamaguchi, 1990).

2.1.7. Physical strength for packages

2.1.7.1. Tensile strength and elongation at break

Strength is required to protect the product during processing, distribution and retail handling. Polyester and nylon are commonly used as oriented films since they are generally stronger than unoriented films (Ghazala, 1994).

2.1.7.2. Heat seal strength

The heat seal strength is an important property for packaging integrity and to provide shelf life. Polypropylene (PP) can tolerate temperatures up to 130°C and can only be reheated in the microwave (Forshaw, 1990). PP has good heat seal strength and as such it is used as the inner layer for heat sealing.

2.1.7.3. Bursting strength

Low values of bursting strength indicate easy delamination of the layers during thermal processing which results in physical destruction of the pouch and reduction in barrier properties (Vijayalakshmi et al., 2003).

2.1.7.4. Residual air

The presence of residual air is associated with seal integrity and influences heat transfer, sterilization effect and product quality (Yamaguchi,
Different techniques for the removal of residual air have been proposed but have limitations when applied on a commercial basis (Mayer and Robe, 1963; Heid, 1970 and Schulz and Mansur, 1969). The stretch method is applied for pouches of standard sizes in Japan (Tsutsumi, 1972) and no particular problem has been experienced with the residual air (Yamaguchi et al., 1972). 15 ml or more residual air in the case of standard size pouch markedly interferes with the heat transfer and affect the sterilization process (Yamaguchi et al., 1971)

2.1.7.5. Overall migration test

Plastic in the finished form contain non polymeric components (mainly additives) which may leach out into the packed food when it come into direct contact with the food (Vijayalakshmi et al., 2003). The selection of suitable packaging material for food contact application is decided on the basis of the physical, mechanical, barrier and performance properties of the films (Iyer, 1992). These may contaminate the food and be harmful to the human body. Since the migration is inevitable, different countries have prescribed limits for these extractible substances. As per Indian Standard the limit for finished materials is 10mg/dm² or 60 ppm. Vijayalashmi et al., (1992) reported higher migration from retort pouches into n- heptane, than into water. This may be due to the structural similarities of n- heptane with the contact cast PP layer

2.1.7.6. Shelf life of retort pouch foods

The shelf life of a retorted food product is about 2 year for an aluminium foil pouch (Szczebkowski, 1971 and Thorpe & Atherton, 1972) 2-3 months for a barrier type non foil pouch and 1-2 months for a non foil retortable pouch (Yamaguchi, 1990). Studies on hamburgers packed in retort pouches showed that sensory characteristic depends on the oxygen permeability of the packaging material (Ishitani et al., 1980). Komatsu et al., (1970) have studied the effect of headspace gas on thermal processing and shelf life of processed products. Dymit, (1973) reported that after 8 years shrimp in a foil laminate was superior in flavor and color to the canned item. Pouches using aluminium foil have a longer shelf life with respect to quality. Vijayan et al., (1998) reported that curry
processed in indigenous retort pouches could be kept in good condition for 24 months even though there was slight transmission of water and oxygen.

2.2. Smoking preservation of fish

2.2.1. Smoking of Fish

Smoking is one of the oldest methods of preservation of fish and it combines the effects of salting, drying, heating and smoke components (Bligh et al., 1988). The preservative action is mainly by lowering the water activity and by the deposition of the smoke components produced by the thermal degradation of sawdust or wood. A wide variety of organic constituents such as phenolic, carbonyl and organic acids are present in the smoke (Asita & Campbell, 1990). These compounds, along with the low water activity and applied heat inactivate autolytic enzymes and retard the growth of spoilage microorganisms (Gilbert and Knowles, 1975; Dillon et al., 1994 and Sikorski, 1994). Smoke may mask the spoilage changes and affect the relationship between sensory and microbiological changes. The smoke is usually concentrated on the surface of the skin and penetrate not more than 1 cm under the skin during storage (Hansen, 1995 and Sikorski, 1994). In the underdeveloped and developing countries smoking is used as a method of fish preservation whereas in the developed countries, it is practiced mainly to impart colour of a particular wood rather than for preservation (Wheaton & Lawson, 1985). In traditional practices, the processors use unsophisticated equipments and has little control over the smoking parameters whereas in the present advanced techniques knowledge of the chemical and biological properties of the raw material combined with the use of smokehouses with precise control of smoke density, temperature, humidity etc facilitate the production of smoked products with desirable, predictable nutritional and sensory quality with appropriate shelf life (Doe, 1998). The use of controlled heating parameters makes it possible to calculate the bacteriological lethality of the smoking process (Sznajdowska, 1983). Cold smoking is a process where the dry bulb temperature is kept below 30°C for the entire process (Horner, 1992 and Regenstein & Regenstein, 1991). Hot smoking is simply a heating process that fully cooks the fish to 160 °F or higher (Raab & Hilderbrand.Jr., 1993). There is a
distinctly different flavour, texture and appearance between fish prepared by hot and cold smoking (Whelan, 1982). Traditional smoke-preserved fish are being replaced by light smoke flavoured fish products (Horner, 1992). In light smoking, the fish is light salted, light smoked to get a product of attractive appearance, odour, colour and flavour.

2.2.2. Smoke generation technology

Smoking is generated by burning wood or sawdust or a combination of both. Wood burns quickly and gives a hotter fire with a lesser smoke which may char the fish. Sawdust on the other hand burns slowly and unless the draught is very strong it will not catch fire. Hardwoods are preferred to softwoods since soft woods contain resins which impart a bitter taste to the product. A combination of wood shavings and sawdust can also be used in the case of hot smoking. The choice of wood depends on the flavour required (FAO, 1970). Oak, Mahogany, Cedar, Hickory, Teak and Mesquite are the commonly used woods for smoke production. The wood and sawdust should be dry and free of moulds and preservatives since the smoke may carry the harmful substances like moulds and other chemicals to the fish which may make the fish dangerous to eat.

2.2.3. Smoke and its components

The preservation of smoked fish is mainly due to the different stages in the smoking process and the different components present in the smoke. The initial process of brining the fish before smoking helps in removal of water and thereby reducing the water activity. This inhibits the growth of many pathogens and spoilage microorganisms. The smoke helps in surface drying of the fish and as a result there is a physical barrier for the microorganisms to proliferate into the fish. Smoking at high temperatures cooks the fish and removes the moisture inside the fish and lowers the water content thereby retarding the spoilage. Smoke deposits antioxidant compounds like phenols which delays the auto oxidation of the unsaturated fish lipids and avoids rancidity. Antimicrobial compounds like phenols, aldehydes, nitrites etc. also enhance the preservative action of smoke (Balachandran, 2001). Wood smoke is complex systems consisting of disperse
and particulate phases. The disperse phase contains vapors which imparts the characteristic colour, flavour and preservative properties to the smoked fish. The particulate phase acts as a reservoir for compounds having a high vaporization temperature. Between the particulate and vapour phase of the smoke there is a dynamic equilibrium that changes with fluctuations in temperature, density of smoke, velocity of smoke and absorption of smoke components by the fish surface (Tilgner et al., 1965). Smoke contains more than 400 chemicals of which about 200 have been identified. The commonly found chemicals are carbonyls, organic acids, phenols, organic bases, alcohols, hydrocarbons and gases such as CO₂, CO, O₂, N₂ and NO (Daun, 1979). Smoke contains antioxidative and antimicrobial properties. The antioxidative properties are due to the presence of high boiling phenols like 2, 6, dimethoxyphenol, 2, 6 dimethoxy-4-ethylphenol, 2, 6, dimethoxy-4-ethylphenol, guaicol, etc (Wheaton & Lawson, 1985). Low boiling point phenols show weak antioxidative properties (Tilgner et al., 1965, Radecki et al., 1975). According to Daun, (1979) the method of smoke generation influences the antioxidative properties of smoke, with a smoldering type fire producing better properties.

2.2.4. Antimicrobial or bactericidal properties of smoke

Antimicrobial properties of smoke are mainly influenced by chemical components of the smoke and the treatment of the fish prior to smoking. Carboxylic acids, phenols, aldehydes and ketones have a distinct role in reducing the bacteria. Vegetative forms of bacteria are more sensitive to wood smoke whereas spores are more resistant. The temperature of smoke generation influences the antimicrobial properties of smoke. Fredheim et al., (1980) found that smoke condensates produced at 350°C inhibited the growth of S. aureaus, E.coli and S.cerevisae at lower concentration than the condensates that were produced at higher temperatures. The effect of pasteurization in hot smoking depends on the composition of fish, the salt content, humidity, temperature, type of wood and duration of the process and on the interaction of the smoke components (Doe et al., 1998). The important factor determining the multiplication of bacteria in smoked fish is the temperature of storage. The microbial hazard of the formation of toxin by Clostridium botulinum type E can be
avoided by sufficient heating of the product followed by chilling and maintaining the storage temperature of the product below 3°C (Sikorski & Kolodziejska, 2002). As per FDA requirements, the thickest part of the fish should have maintained a temperature of 82°C for 30 minutes and the NaCl content in the water phase of the meat is 3.5%. To get a superior quality smoked fish product the salt and heat used should be mild and hence the antibacterial effect of smoke is not very effective here. Moreover vacuum packed samples being anaerobic have a greater chance of harboring the organisms and hence the only protection from botulinum is by maintaining good manufacturing practice and keeping the product below 3°C and avoiding temperature abuse (Sikorski & Kolodziejska, 2002). Smoking effects a change in the bacterial flora from gram negative to gram positive microflora probably due to the sensitivity of the gram negative bacteria to the antimicrobial compound of the smoke. Hansen, (1995) and Leroi et al., (2000) did not find any difference in the sensitivity of gram negative and gram positive organisms to smoke. Gancel et al., (1997) isolated lactobacilli from vacuum packed salted and smoked herring and found all strains to be resistant to liquid smoke. Cold smoked products are not cooked and have to be refrigerated and hence post the risk of the presence of L. monocytogenes which can grow at low temperatures. Listerosis caused by smoked fish can be avoided by control of temperature in the range of 60-65°C as the ultimate core temperature necessary to ensure thermal inactivation of L. monocytogenes. (Kolodziejska et al., 2002).

2.2.5. Antioxidative properties of smoke

Different types of wood components at certain levels have proven to contain antioxidative properties. Tilgner et al., (1965) have demonstrated the antioxidant activity of phenolic compounds present in curing smoke. Smoke flavoring was found to have an inhibitory effect on the auto oxidation of lard (Chomiak & Goryn, 1977). Curing smokes obtained by three smoke generation methods was found to vary in its antioxidative properties (Tilgner & Daun, 1970).Smoke can be used to retard lipid associated rancidity in a wide variety of smoked foods (White, 1941). Toth and Potthast, (1984) fractionated wood smoke into acid, basic and neutral portions. They demonstrated that neutral portions contain a major portion of the phenolic compounds which had the best
antioxidative properties, whereas the acidic portion had minor antioxidative properties while the basic portion actually promoted lipid oxidation. Phenols are the primary antioxidant-related compounds associated with wood smoke (Daun, 1969). Most commonly used synthetic antioxidants like (butylated hydroxyanisole (BHA) and butylated hydroxytolulene (BHT) are phenolic in nature (Maga, 1988). Smoke flavorings ranging from 0.2 to 2% levels have been found effective in antioxidant properties (Watts & Faulkner, 1954). Use of 10% of liquid smoke for antioxidant properties was actually found to be prooxidative in lard (Chomiak & Goryn, 1977). Radecki et al., (1975) found that smouldering smoke generation results in strong antioxidative properties. The particle phase of smoke has more antioxidant properties than the vapour phase (Daun & Tilgner, 1977).

2.2.6. Effect of smoke on lysine content

Amino acids are easily lost during different stages of processing. In smoking the amino acid of major concern is the essential amino acid lysine. Lysine is available in small quantities and is a very reactive compound and can enter into many chemical reactions. Chen and Issenberg, (1972) have reported a loss in the total lysine content during smoking. Di Cesare et al., (1980) have reported a loss in lysine content in fillets of Sardine pilchardus. Similar results were obtained by Petrichenko and Dolzhenko, (1981) in muscle proteins of Cyprinids and by Cattaneo et al., (1983) in smoked Salmo gardneri. Dvorak and Vognarova, (1965) concluded that short smoking time did not influence lysine loss. Losses up to 44% was reported in uncured beef smoked at 65°C for 10 hour whereas samples processed without smoking lost up to 15% lysine indicating that smoking lowers the available lysine content when compared to other processing methods (Chen & Issenberg, 1972).

2.2.7. Smoke and food colour

Carbonyls and certain phenols present in the wood smoke are responsible for the colour of the smoked foods. Colour, is important since it is the first sensory factor followed by aroma, flavour and texture that denotes the food acceptability (Maga, 1988). Carbonyl compounds present in the smoke are major contributors
to the colour formation in smoked meat. A series of non enzymatic reactions similar to maillard reactions occurs due to the interaction between the carbonyls in the smoke vapor and the amino group from the protein on the food surface (Chen & Issenberg, 1972; Gilbert & Knowles, 1975 and Ruiter, 1970). The most reactive carbonyls are glycolic aldehyde, methyl glycol, formaldehyde and acetol and the first two produces the most colour (Ruiter, 1970). Phenols with high molecular weight present in the vapour phase of the smoke also contribute to the colour formation in smoked foods. (Caurie et al., 1974). These phenols should have sufficient number of hydroxyl group to cross link protein at numerous sites through hydrogen bonding. Coniferaldehyde and sinapaldehyde are such polyphenols which can react to form colour, however their levels in food are usually low when compared to carbonyls (Chen & Issenberg, 1972).

2.2.8. Potential health concerns associated with smoke

Poly aromatic hydrocarbons (PAH) act as potent chemical carcinogen and hence their presence in smoked fish is of major concern. PAH compounds are formed during the thermal degradation of wood, especially when the wood is burnt with limited access to oxygen (Bartyle, 1991). Smoke generation conditions can significantly affect the level of PAH in the smoke and smoked fish (Potthast, 1978; Steinig, 1976 and Steinig et al., 1977). There is an increase in the PAH content with increase in temperature of smoke generation especially in the ranges of 400-1000°C (Toth et al., 1972). The international agency for research on cancer (IARC) classified benzo (a) anthracene, benzo (a) pyrene and dibenzo (a,h) anthracene as probably carcinogenic to humans and benzo(b) fluoranthene and benzo(k) fluoranthene and indeno (123-cd) Pyrene as possibly carcinogenic to humans (US-EPA, 1984; IARC, 1987). Benzo (a) pyrene (BaP) is the leading carcinogenic compound which is accepted as the indicator of total PAH presence in smoked foods (Andelman et al., 1970). PAH compounds when ingested into the human body interact with enzymes to form derivatives which are believed to be carcinogenic in nature. These are capable of forming covalent adducts with proteins and nucleic acids and initiate cell mutation which results in malignancy (Rogan et al., 1993; Stahl & Eisenbrandt, 1998 and IARC, 1987). Kangsadalampai et al., (1997) concluded that the most potential mutagenicity
was observed in PAH fractions isolated from smoked fish treated with nitrates in an acid solution. The European commission, (2005) in its regulation 208/2005 limits the level of BaP content to 5 µg/kg in smoked meat, smoked meat products, muscle meat of smoked fish and smoked fishery products. And for liquid smoked flavored products the maximum permissible limit is 0.03 µg/kg as per directive 88/388/EEC. Preparation of heavy- smoked products in uncontrolled conditions typical of home smoked without the application of good manufacturing practices is far more dangerous than those produced in controlled conditions (Simko, 2002). Exposure to UV light degrades PAH compounds and forms oxidation compounds like aromatic alcohols, ketones, quinines and esters (Bernstein et al., 1999). Toxicity of these compounds maybe even enhanced when compared to the original compounds (Bernstein et al., 1999). The rate of deposition of PAH on fish depends on smoke characteristic like temperature, humidity, flow rate and density of smoke. The PAH content are higher for fish with a higher lipid content (Storelli et al., 2003).

2.2.9. Textural changes in smoked fish

Heating results in protein denaturation or loss of solubility and brings about textural changes in the protein which is a major component of muscle foods (Maga, 1988). Smoking significantly lowers the myofibrillar and sarcoplasmic protein nitrogen fractions and increases the stromal fractions (Randall & Bratzler, 1970). These changes result in cross linking of surface proteins resulting in a firm and stable crust which is texturally harder than the inner portion of the fish muscle. This skin like formation hinders the penetration of smoke components towards the interior portions of the flesh and thus results in uneven distribution of colour and flavour (Maga, 1988). The outer surface of the smoked meat was found to be rather dry and had a low water holding capacity probably due to the fact that the smoke components had reacted with the proteins by not permitting protein to hold large quantities of water. Therefore the texture on the outer surface of the material was rather dry and tough in comparison to the interior portion (Radetic et al., 1982).
2.2.10. Brining and its effect on smoking

Brining helps in reducing the water activity and thereby increasing the antimicrobial effect of the smoke at higher temperatures. The reduction in water activity is related to the amount of salt that is used for the product. Salt used should be within the permissible limits so that it will not affect the palatability. In light smoked vacuum packed trout contaminated with *C. botulinum* the least concentration of NaCl required for inhibiting toxin was 2% (Cann & Taylor, 1979). A minimum of 3% salt is required to inhibit *C. botulinum* for 30 days at 10°C. Peterson *et al.*, (1993) found that neither 3% nor 5% water phase NaCl prevented the growth of *L. monocytogenes* at 5 or 10°C. Inhibition of growth of the organisms were found at 6% water phase salt only and was found to be inversely proportional to the size of the population. Growth of *Staphylococcus aureus* on hot smoked Snoek was inhibited at 4°C when the water activity was 0.96 but multiplied at 24°C when the water activity was 0.94 (Theron & Prior, 1980).

2.2.11. Biogenic amines in smoked fish

Biogenic amines are low molecular weight organic bases that occur due to the microbial action during storage of foods products. These amines are formed and degraded as a result of normal metabolic activity and can be produced by the decarboxylation of amino acids (Halasz *et al.*, 1994). They are generated as a result of endogenous amino acid decarboxylase activity or by the growth of decarboxylase positive microorganisms under favourable conditions for enzymatic activity. (Evan & Malmberg, 1989). In human and animal physiological functions serotonin, histamine and tyramine plays an important role and in plants spermidine, spermine and putrescine are important. Biogenic amines are of great concern in relation to food spoilage and food safety. Since microbial spoilage of food is accompanied by the increased production of decarboxylases, the presence of biogenic amines serves as indicators of bacterial contamination and food spoilage. Biogenic amine estimation is important from the point of view of their toxicity as well as indicators of the degree of freshness or spoilage of food (Halasz *et al.*, 1994). Histamine along with other amines like putresine, cadaverine may have a synergistic effect and hence efforts to optimize
production and storage conditions to secure low amine levels in food may be
done (Smith, 1980). Other biogenic amines are less toxic than histamine,
however nitrosoable secondary amines like agmatine, spermine and spermidine
can form nitrosamines by reaction with nitrites and produce carcinogenic
substances.

Histamine poisoning is also referred to as scombroid fish poisoning and is
associated with the consumption of scombroid fishes like tuna, mackerel, saury
bonito and seer fishes (Taylor, 1986). Non scombroid fishes like sardines,
anchovies, herring, marlin etc have also been implicated in cases of histamine
poisoning (Taylor, 1985). Tuna and other related species like mackerel, seer fish
are found to contain high level of histidine which may be converted to histamine
by microorganisms. The formation of histamine was dependent on the
temperature of storage and microbial activity. Klausen and Lund,(1986)
suggested that amine content depends on temperature and observed that at
10°C the amine contents were 2-3 times higher than at 2°C in both mackerel and
herring. A positive correlation was found between increasing microbial counts
and amine levels.

Taylor (1983), observed high levels of histamine in smoked mackerel
products which have been exposed to high ambient temperatures which
accelerates the reaction. Use of properly chilled fresh fish with less contamination
during the various stages of handling will result in minimum increase in the
histamine levels in Spanish mackerel (Trinidad et al., 1986). Hot smoking
preserves the product by reducing the bacterial flora and denaturing the enzymes
but is incapable of destroying the bacteria toxin already formed. (Poulter, 1998).
Thermal death trials by, Bremer et al., (1998) on H. alvei isolated from hot
smoked kahawai indicated that hot smoking has the potential to eliminate H. alvei
from seafood products. A retail survey on the levels of histamine in hot smoked
products in New Zealand conducted by Fletcher et al., (1998) showed that
samples with high bacterial counts has low histamine content and vice versa.
Here there was no consistency between the levels of microbial load and
histamine content indicating that the histamine has been formed prior to smoking
and histamine developing bacteria have been destroyed during smoking.
2.3. Thermal Processing

2.3.1. General Thermal processing

Thermal processing is a method of preserving food by heating in hermetically sealed containers to eliminate the microbial pathogen at a given temperature and specific time. The first book on canning was published by Appert, where he packed food into wide mouth glass bottles, corked and heated and preserved them. However it was in 1864, Louis Pasteur explained that the heating process killed (or inactivated) the microorganisms which extended the shelf-life of food. Several authors studied the link between thermophilic bacteria and spoilage of canned vegetable (Lopez, 1987). Shortly, Peter Durand took a patent for the use of metal canisters. This initiated the beginning of the canning industry (Holdsworth, 1997). In the early nineteenth century studies on the importance of Clostridium botulinum and its role in canned foods was established. Bigelow et al., (1920) classified the food based on pH and developed the first scientifically based method for the calculation of minimum sterilization processes for canned foods. This.is method is known as the graphical or general method of process calculation. Ball (1923), developed the mathematical or theoretical method for process calculations. Schultz and Olson (1940) developed a nomographic method for process determinations. Ball and Olson (1957) published the first comprehensive book on heat processing followed by Stumbo's book on thermo bacteriology. The mathematical methods which eliminated certain relatively small errors inherent to some of the previous mathematical procedures were developed by Hayakawa and Ball, (1968). In the last 30 years, in addition to Ball, Stumbo, and Hayakawa, Teixeira et al., (1969); Griffin (1969a, b); Manson et al., (1970); Manson (1992); Pflug, (1964); Tung and Garland, (1978) and others have further refined mathematical heat process determination concepts and applications. Comprehensive information on all aspects of food canning is available from the research work of Ball and Olson (1957); Lock (1969); Kramer and Twigg, (1970); Pillsbury, (1973); Stumbo, (1973); Desrosier and Desrosier, (1978); Jackson and Shinn, (1979); Hersom and Hulland, (1980); Gilbert et al., (1982); Stumbo et al., (1983); Herbert and Bettison, (1987); Lopez, (1987); Teixiera, (1992) and Larousse and Brown, (1997).
2.3.2. Principles of thermal processing

Thermal process regimes like pasteurization and sterilization vary in the severity of the heat treatment and the purpose of the process (Lund, 1975). Pasteurization involves application of mild heat to high acid food (pH <4.5) to inactivate the enzymes and destroying the spoilage vegetative microorganisms present. In Sterilization all pathogenic and most spoilage causing microorganisms in a hermetically sealed container are destroyed and an environment is created inside the package that does not support the growth of spoilage-type microorganisms and their spores. Thermal destruction of bacteria takes place following a first order-semi logarithmic reduction rate. Theoretically a sterile product cannot be produced however long the product is subjected to heating (Fellows, 1990). To determine the extent of heat treatment following factors given in below must be known (Awuah et al., 2007).

a) The type and the heat resistance of the target microorganism, spore, or enzyme present in the food.
b) The pH, water activity and salt content of the food.
c) The thermo-physical properties of the food and container shape and size
d) The heating conditions.
e) The storage conditions following the process.

Classification of foods based on pH (Ramaswamy & Abdelrahim, 1991) is given in Table 4. Acid foods have a natural pH of 4.5 or below. Low acid foods have a pH greater than 4.6 and a water activity above 0.85. It is scientifically proven that Clostridium botulinum does not grow and produce toxin below a pH 4.6. (Gavin & Weddig, 1995). Hence the pH of 4.5 is kept as the demarcation line between high and low acid foods. In low acid canned foods there is every chance that C. botulinum may survive if under processed or not adequately stored. These are anaerobic rod shaped bacteria capable of producing toxin if the spores are allowed to germinate.
Table 4. Classification of Foods Based on pH (Ramaswamy & Abdelrahim, 1991)

<table>
<thead>
<tr>
<th>pH Class</th>
<th>Typical Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>High acid pH&lt;3.7</td>
<td>Fruit juices, cranberry sauce, fruit jellies, grape fruit pulp, orange juice, plum, sour pickles, sauerkraut, vinegar.</td>
</tr>
<tr>
<td>Acid pH 3.7-4.5 pH</td>
<td>Fruit jams, fruit cocktail, Grapes, tomato, peaches, pineapple slices, potato salad, prune juice, vegetable juice.</td>
</tr>
<tr>
<td>Low acid pH&gt;4.6</td>
<td>All meats, fish, vegetables, mixed entrees (beans and pork, chicken with noodles, etc.) and most soups</td>
</tr>
</tbody>
</table>

2.3.3. Microbial Destruction Kinetics

Microorganisms differ in their characteristics and thermal resistance. This resistance depends on endogenous factors like genetic, age, moisture content, and competing microbial flora and on exogenous factors like presence of lipids, protein stabilizers, organic salts etc. Spore forming bacteria are of main concern in low acid foods especially when the vegetative growth has been restricted. Bacteria like Clostridium and Bacillus produce endospores that contain essential cellular components and show no metabolic activity for prolonged survival under adverse conditions. In canned foods the primary area of concern is the prevention of the germination and growth of the surviving spores. The minimal thermal process concept introduced by USFDA in 1977 is defined as the application of heat to food, either before or after sealing in a hermetically sealed container, for a period of time and at temperature scientifically determined to be adequate to ensure the microorganisms of food spoilage and pathogens are eliminated or inactivated. Stumbo (1973) summarized various factors that influence the thermal resistances of bacteria and also conditions present during sporulation (temperature, ionic environment, organic compounds, lipids, age, or phase or growth) and conditions present during heat treatment (pH and buffer components, ionic environment, water activity, and composition of the medium). C. botulinum is the microorganism of public health concern in low-acid canned foods, due to its high thermal resistance and its capability of producing spores. C. botulinum can produce super dormant spores with high thermal resistance (Sebald, 1982). Low pH or acidification reduces the thermal resistance
depending upon the nature of acidifying agent used (Lynch & Potter, 1988). Long chain fatty acid and presence of calcium and iron in the medium also increased the thermal resistance of spores.

Stumbo (1973), have shown various procedures for experimental evaluation of thermal destruction kinetics of microorganisms. The thermal destruction rate of the test microorganism must be determined under the conditions that normally prevail in the container so that an appropriate heating time can be determined at a given temperature.

2.3.4. Survivor Curves and D-value

Thermal destruction of microorganisms follows a first-order reaction indicating a logarithmic order of death (Esty & Meyer, 1922). The logarithm of the surviving number of microorganisms following a heat treatment at a particular temperature plotted against heating time will give a straight line. These lines are commonly called survivor curves. The microbial destruction rate is defined as a decimal reduction time (D-value), which is the heating time in minutes for a given temperature to bring about one decimal reduction in the surviving microbial population. Graphically, this represents the time range between which the survival curve passes through one logarithmic cycle (Ramaswamy & Marcotte, 2006).

2.3.5. Thermal Death Time (TDT) and D-Value

Thermal death time (TDT), is the heating time required to cause death or destruction by subjecting microbial population to a series of heat treatments at a given temperature and testing for survivors. The death in this instance generally indicates the failure of a given microbial population after the heat treatment, to show a positive growth in the subculture media. Comparing TDT approach with the decimal reduction approach, it can easily be recognized that TDT value depends on the initial microbial load (while D value is not). TDT is always measured with reference to a standard initial load or load reduction and represent a multiple of the D-value. For example, if TDT represented the time to reduce the population from $10^{12}$ to 1 then TDT is a measure of 12 D values. Deviations of
the logarithmic order of microbial death has been provided (Stumbo, 1973) showing typical survivor curves for each situation: (1) heat activation for spore germination, (2) mixed flora, (3) clumped cells, (4) flocculation during heating, (5) nature of the subculture medium, and (6) anaerobiosis.

2.3.6. Temperature Dependence and Z-Value.

The decimal reduction or D value is a function of the thermal treatment at a given temperature. D value has a linear relationship with temperature and changes inversely. The temperature sensitivity of D-values at various temperatures is normally expressed as a thermal resistance curve with log D-values plotted against temperature. The temperature sensitivity indicator is defined as a z value, which represents a temperature range that results in a 10-fold change in D-values, or graphically it represents the temperature range through which the D-value curve passes through one logarithmic cycle (Ramaswamy & Marcotte, 2006) or how many degrees the temperature has to be raised to shorten the heating time by 90% or in other words to make the destructive effort tenfold (Eistner, 1988).

2.3.7. Heat penetration and thermal process evaluation

The process evaluation and heat penetration of thermal processed products in containers have been researched extensively (Stumbo 1973; Lopez, 1981 and NFPA, 1982). Mathematic modeling has been reviewed by (Hayakawa, 1977 and Holdsworth, 1985). The general method by Bigelow et al., (1920) is also known as graphical trial and error method. Improvements in this method have been done by Schultz and Olson (1940). The numerical method normally uses the trapezoidal rule or Simpson’s rule to calculate the area of irregular geometric figures (Holdsworth, 1997). Formulae methods for calculating the heat penetration makes use of theoretical and empirical formula. Hayakawa (1977 b) first made use of analytical or numerical solutions of theoretical heat equations while the formula method is based on heat penetration data. However Pham (1987), pointed out that the formula methods are somewhat misnomer since they are invariably presented as tables rather than equations. Hayakawa (1978),
further divided formula methods into two groups. First group comprised of methods that calculate the lethality at the cold spot for example such as that of Ball (1923); Jakobsen (1954); and Ball and Olson, (1957). Second group consists of methods that calculate mass average lethality for whole containers. Such methods have been developed by Gillespy (1951); Ball and Olson (1957); Stumbo (1973); Hayakawa (1969) and Jen et al. (1971). This grouping is similar to what is in some places referred as biological method (Biological Indicator Units) or thermocouple method commonly used to estimate process lethality.

Time-Temperature data for heating and cooling are collected by using thermocouples which are inserted into the geometric centre or cold spot determined for the container. Thermocouple output is measured using a data recorder. The heat penetration parameters are determined by plotting temperature deficit (Tr-T) on semi log paper (temperature difference on log scale and time on linear scale). The intercept is obtained by extending the straight line portion of the curve to the Y axis representing pseudo initial temperature (T_{pin}). The lag factor for heating (Jh), slope of the heating curve (fh), time in minutes for sterilisation at retort temperature (U) and lag factor for cooling (Jc), fh/U, final temperature deficit g, process time B and total process time (T_B) are calculated by the mathematical method of (Stumbo 1973). Total process time was determined by adding process time (B) to the effectiveness of the come up time which has been established to be 58 %.

2.3.8. 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 (Potter & Hotchkiss, 1995). For convenience, this is defined as an equivalent heating of 1 min at a reference temperature, which is usually taken to be 121°C for the sterilization processes. Thus the F value would represent a certain multiple or fraction of the D-value depending on the type of the microorganism. Time-temperature combinations are used by processors to integrate the lethal effects of microorganisms. The combined lethality so obtained for a process is called process lethality and is also represented by the symbol Fo. From microbio-
logical safety point of view, the assurance of a minimal lethality at the thermal center is of utmost importance, while from a quality standpoint it is desirable to minimize the overall destruction throughout the container.

The minimum process should be severe enough to reduce the population of *C. botulinum* through 12 decimal reductions. Based on published information, a decimal reduction time of 0.21 min at 121°C (Stumbo, 1973) is normally assumed for *C. botulinum*. A 12-decimal reduction would thus be equivalent to a Fo-value of 12 x 0.21 = 2.52 min. The minimal process lethality (Fo) required is, therefore, 2.52 min.

### 2.3.9. Cook value

Cook value (Cg), a measure of heat treatment with respect to nutrient degradation and textural changes that occur during processing, is determined by measuring the extent of cooking and nutritional loss during processing in a manner similar to the D value, except that the reference temperature is 100°C instead of 121°C, and the z value is 33°C, which is required for the denaturation of thiamine (Ranganna, 2000). Theoretical evaluation of quality changes during thermal processing has been expressed as cook value (Ohlsson, 1980 b)

### 2.3.10. Factors affecting heat penetration

Penetration of heat into the food is influenced by several factors and a clear understanding is necessary to obtain good results in commercial operations. The characteristics of the retort, the container used, heating medium, filling medium, the temperature gradient between the container and retort, ratio of liquids to solids in the pouch contents, arrangement of containers inside the retort, steam distribution etc. are some of the important factors to be taken care of (Balachandran, 2002). Duckwall (1905), studied the rate of heat penetration in various foods. Zavalla (1916), studied the effect of filling media and the effect of air in steam retorts and the advantage of jumble stacking of cans in the retort for obtaining better heat penetration. Ingredient related factors also affect heat penetration in cans, where fatty tissues are poor conductors of heat. Solids with
gelling properties also absorb water and change solid liquid ratio thereby affecting heat transfer. Liquid and semi-liquid foods are mainly heated by convection while solid foods are heated by conduction. In semi-liquid products heating is by both convection and conduction implying a longer process time due to the slow rate of heat transfer (Clifcorn et al., 1950). Rotation of the cage of the retort during heating significantly increases the rate of heat penetration. (Bindu & Gopal, 2008; Ali et al., 2006). Shape and size of the container affects the heat penetration because smaller containers heat more rapidly due to the larger surface area in relation to the volume of the container.

2.3.11. Heat Sterilization process in retort pouches

Retort pouch process filling is similar to can filling and requires the same care and attention. The major steps in retort pouch packaging are filling, air removal, sealing, traying, autoclaving and cooling (Madhwaraj et al., 1992). Once the product is filled and sealed it is then subjected to temperatures of 121.1°C with counter pressure so that the cold point or slowest heating point within the food reaches the predetermined time temperature integral (Brody, 2003). Once this temperature is reached, the product is cooled, labeled and stored (Madhwaraj et al., 1992; Balachandran, 2002 and Venugopal & Shahidi, 1998).

There are mainly two types of retort pouches viz, preformed and pouches which are made from laminates on the process line. Preformed retort pouches are more commonly used and they are filled manually or by using automatic filling machines. Sauces and curry products are packed instantaneously in pouches that are produced from laminated rolls which are simultaneously formed, filled and sealed (Yamaguchi, 1990). In case of products with solid contents, either pouch are filled with solids together with some liquid and sealed using a vacuum sealing machine.

Extreme care should be taken during filling of pouches so that there is no contamination of the seal area, since this would result in improper sealing. Duxbury et al., (1970) reported that there should not be filling within 1.5 inches of the open top of the package so as to minimize the product contamination to the seal area. Hughes, (1971) suggests leaving as much as one third of the pouch
volume free for the same reason. Lampi and Rubinate, (1973) reported that a significant percentage of process related failures was due to the contamination of seal areas during the filling operation. Schulz and Mansur, (1969) indicated that steam flushing not only cleaned seal surfaces but also removed residual air from the pouch.

Residual air inside the pouch will affect the heat transfer, product quality and seal integrity of the pouch. The residual air in the pack should be less than 2% of the volume of the pouch contents (Venugopal, 2006) and higher levels of air in the pouch may result in deflating of the pouches during thermal processing. The most commonly used methods for removal of residual air is vacuumisation and steam flushing. Vacuum chamber (Goglio, 1968), counter pressure (Tsutsumi, 1972), steam flush (Schulz & Mansur, 1969), and water head pressure (Heid, 1970) are some of the air removal techniques. Air from the solid pack pouch can be removed with the help of vacuum machine and in semi-solid type by the help of steam injection method. Super heated steam is generally used because it causes less moisture condensation in the seal area. Stretch method is applied effectively for the curry types of products (Tsutsumi, 1972). For large pouches, vacuum-sealing machine is very effective to remove the residual air (Yamaguchi et al., 1972). Residual air affected the physicochemical, sensory properties and shelf life of wet pack pears (Olives, 2002).

Sealing is an important stage in the operations for retort pouch packaging. Methods of sealing flexible polymeric film pouches have been reviewed thoroughly (Young, 1975 and Brown & Keegan, 1973) and the equipment aspects by McGillan & Neacy, (1964) and McCloskey, (1971). A seal width of 5-10 mm is desirable for good seal strength. Hot-bar sealer and the impulse sealer are commonly used for retort pouches (Tsutsumi, 1974, 1975). Hot bar sealing method is more preferable than impulses sealing since in latter the seals are narrower. Hence, the pouches should be double sealed to reduce the risk of seal defect (Nieboer, 1973). It has been reported that the overseal of retort pouch should be extended over the mouth of the pouches to prevent mold growth in any package above the closer seal (Venugopal, 2006).
Sterilization is usually done in a batch or continuous retort systems. The filled pouches are laid on trays or racks to maximize uniform heat transfer. An additional mesh restraint over the trays is used to restrict pouch inflation and distortion in the retort (Jeffs, 1984). The temperature and duration of the process depends on a variety of factors like type and size of the product and container, type of retort, types of heating medium, etc (Ramaswamy & Singh, 1997). Usually the product is retorted at 121.1°C for a predetermined time. Retort pouches have the tendency to burst open due to the development of internal pressure developed by expansion of headspace gases during retorting. Over pressure is supplied to the retort to counter the steam pressure developed during heating and cooling (Bhowmik & Tandon, 1987 and Tung et al., 1990).

Different types of retort systems and their operations are thoroughly described by different authors (Lampi, 1977; Yamaguchi, 1990, Venugopal, 2006). Steam air mixture and water immersion over pressure retort are commonly used for thermal processing of food in retort pouches. Pflug, (1964) and Pflug and Borreto, (1967), using both laboratory and commercial batch retorts made a comparative study of steam, steam-air mixtures, and water as processing media. In continuous retorts hydro lock sterilizer was used for processing pouches (Lawler, 1967 and Goldfarb, 1970).

After retorting the pouches are removed carefully from the retort and washed in chlorinated water to avoid post process contamination and dried using air knives to remove the water and packed in suitable cartons to facilitate display on shelves of supermarkets and further transportation.

2.3.12. Effect of rotation on heat penetration characteristics

Several factors like retort temperature, product viscosity, head space and rotation speed, rotary diameter etc will affect the heat penetration rate into the food particles sterilized in a retortable pouch or can (Ghani, et al., 1999 and Krishnamurthy, et al., 2001). Pflug and Barrero, (1967) observed that heat transfer coefficient was one of the critical processing factors. The rate of heat transfer depends on the circulating rate of heating medium across the pouch surface (Peterson & Adams, 1983). Rotation or agitation will help in faster heat
penetration and a quicker attainment of the recommended Fo value. Rotation is more applicable when a filling medium like oil or brine is used. This is mainly because the contents gets agitated during rotation thereby eliminating cold points and bring in more contact to the product. Moreover the heating will be faster and a shorter process time is achieved thereby giving a product with better sensory and nutritional qualities and reduced nutrient losses (Smout, et al., 2000). Thermal softening of the texture of vegetables due to agitation has been reported by Taheran and Ramaswamy, (1996). Excessive heating produces losses in the nutritional quality and organoleptic properties of foods (Hayakawa & Timbers, 1977). Ramaswamy and Sablani, (1997a and b) also recorded the effect of particle shape and particle motion on heat transfer in cans during end over end rotation and the influence of rotational speeds. Increase in rotational speed (rpm) in an end over end rotation or axial rotation has resulted in an increase in heat penetration rate in liquid and semi liquid foods, (Ansar et al., 2006; Berry et al., 1979; Berry & Bradshaw, 1980, 1982; Naveh & Kopelman, 1980; Berry & Dickerson, 1981 and Berry & Kohnhorst, 1985). Vanloey et al., (1994) have found that increasing the rate of rotation is limited, since at higher rotational speed of 20 rpm there is breakage of the product. At high rotational speeds the centrifugal force becomes more than gravitational force resulting in no or poor mixing of the product in the pouch and hence the heat penetration can be slower.

2.3.13. Nutritional quality of thermal processed products

Processed foods should be either refrigerated or heated at high temperatures to eliminate pathogens and microorganisms. Although some of these changes are desirable, prolonged heating at high temperatures would result in unwanted chemical reactions, resulting in loss of nutrients and sensory qualities. Canning is an important method of preservation of fish (Aitken & Connell, 1979). The flesh of certain fishes cannot be canned because they disintegrates after heating and hence commonly canned species are tunas and bonitos, sardines, herring, shrimps and prawns and salmon. The process should be designed in such a way that nutritional constituents present in the initial matter are retained to the maximum to serve human nutrition (Aubourg, 2001). Severe
heat treatment permanently destroys the spoilage bacteria, deactivates enzymes, proteins and vitamins.

Heat processing or sterilization is the most drastic step carried out during the manufacture of canned products and by definition guarantees the sterility of the product (Aubourg, 2001). To keep the quality of the canned fish, three conditions have to be maintained. Firstly the container should be hermetically sealed and the seal integrity should be guaranteed so that the can is sterile all the time (Lopez 1987). Secondly, adequate thermal process lethality to kill the target organism should be given. The temperature at the cold spot which is the most inaccessible part of the food should be recorded by heat penetration studies (Banga et al., 1991). Time and temperature studies depend on the characteristics of the product and container, geometry of the package and the type of heating medium (Lund, 1975, Oliviera et al., 1986 and Vietes et al., 1997). Finally a scrupulous and hygienic post process treatment should be carried out and the products should be stored adequately. The water used for cooling should always be chlorinated so that it is not a source of contamination. Kramer, (1982) and Ruiz-Roso et al., (1998) suggested 3-4 months canned storage to obtain advantageous textural changes and optimal palatability in most canned fish products. Thermal processed products should be stored at ambient temperature much below 30°C in order to prevent the outgrowth of thermophilic spores which may have survived the processing. The effect of storage temperature and duration of storage also is very important for fish products preserved in sauces which are acidic in nature and have corrosive action on the containers used (Lopez, 1987).

2.3.14. Canning of tuna

Canned tuna are considered highly nutritious because of the high omega-3 polyunsaturated fatty acids (PUFA) content. (Medina et al., 1995a and Gallardo et al., 1989). PUFA is considered to be beneficial to human health for the control of cardiovascular diseases (Carroll & Braden, 1986). The raw material composition, process condition and filling medium have a great effect on the lipid composition (Perez-Camino et al., 1991 and Hale & Brown, 1983). Filling media
may result in differences in the heat penetration and may even extract some components from the fish muscle (Aubourg et al., 1990). The two most commonly used filling medium in the canning industry are brine and oil. Different types of vegetable oils are used. Virgin olive oil is considered to contain natural polyphenols having a role in oxidation (Papadopoulos & Boskou, 1991). Tuna protein has high nutritional value and Duel et al., (1946) reported that tuna protein yielded higher biological values than casein. Pigott and Tucker, (1990) after studying the essential amino acids found that the composition of tuna protein was of very high quality. Heat processing and storage of the canned product can facilitate amino acids, vitamins and minerals to leach out into the medium, leading to significant loss of nutrients if not consumed along with the fish solids. (Aubourg et al., 2001). During canning proteins get denatured due to the excessive heating and releases water to the medium. Proteins, minerals and vitamins get released and give a curdled appearance to the contents on opening the pack. Curd formation is noticed in some of the canned fish products like mackerel and salmon. Curd is gelatinous off-white substance that forms on the surface of canned fish. This is due to the heat coagulation of soluble proteins that have exuded from the cut surface of the fish during thermal processing (Tanikawa et al., 1952). Fish with higher oil content tend to give a less curdled appearance due to the effect of lipids on water migration (Aubourg et al., 2001).

2.3.15. Biochemical Parameters

2.3.15.1. Proximate composition

The moisture content of tuna decreases during steam cooking (Castrillon et al., 1996) and the same trend has been observed for sardines (Puga & Diaz, 1989). Canning has found to decrease water content in albacore tuna and increase the protein and fat content (Garcia - Arias et al., 1994). In the case of lipids there was an increase in the fish muscle after canning in oil medium. The lipid content of various fishes were studied by several authors (Gallardo et al., 1989: Hearn et al., 1987). Changes in the fat content and protein content during the canning of fish has been studied by Palle's et al., 1985), Aubourg et al., (1990) and Garcia - Arias et al., (1994) and follow a similar trend. Mai et al., (1978) reported that during cooking, food may lose or gain weight by dilution of
components or by absorption from the filling medium. Longer sterilization time increases ash content due to the absorption of salt added in the filling medium. Increase in fat and ash content decreased the protein in the canned product, with a higher decrease for longer sterilization (Castrillon et al., 1996).

2.3.15. 2. Amino acid profile

Thermal processing affects proteins in two ways. On one hand it results in changes in the secondary, tertiary and quaternary structure of proteins which breaks the bonds and unfolds the proteins and improves their bioavailability since peptide bonds become readily acceptable for intake into the human body. On the other hand alterations in the primary structure may lower digestibility and produce proteins that are not biologically available (Swaisgood, 1985). Phenomena resulting in improvement in loss of both nutritional and physiological properties of food proteins result from the protein denaturization and chemical modification of amino acids (Finot, 1997). In the canning processes, the changes in protein occur mainly at three different stages, namely pre-cooking, thermal processing and diffusion into the filling media. Bender, (1972) and Broek (1965) have reported the effect of thermal processing on fish proteins. Seet and Brown (1983) reported no increase in amino acid content of cooked vs canned tuna. Comparison of thermal processed and raw materials have shown that there is a significant loss in cysteine content. Geiger and Borgstorm, (1983) found that the nutritive value or amino acid content of fish is not destroyed during careful processing. Fellows (1990) reported a reduction of about 10-20% of amino acid in canned foods. Lou (1997) reported a decrease in purine content of shrimp during thermal processing. Severe heating at high temperatures brings about changes in the loss of amino acids like Lysine, L- arginine and L- histidine (Awuah et al., 2007). The loss of lysine is important to the diet since it is an essential amino acid. Lysine due to its highly reactive amino group, is the most chemically modified amino acid. Tooley and Lowrie (1974) found about 25 % loss in lysine content during thermal processing. The loss of lysine in fish is less due to its smaller levels (Hurrel & Carpenter, 1977). Seet and Brown (1983) found only small changes in protein digestibility and available lysine in canned albacore processed in a batch retort and flame sterilization. Banga et al., (1992) developed
a kinetic model for thermal degradation of available lysine and protein digestibility for albacore in oil and found no significant changes in the parameters.

2.3.15.3. Fatty acid profile

Marine lipids are an important source of unsaturated fatty acid and as such are of great nutritional significance (Piclet, 1987 and Simopoulos, 1997). Marine lipids contain a high content of unsaturated omega fatty acids which have proven health benefits (Iltingworth & Ullmann, 1990). Since the lipids are highly unsaturated loss of quality is likely to occur during processing and storage (Pearson 1977). Shiau and Shue,(1989) reported that frying of Tilapia fillets prior to canning releases moisture from the meat into the oil which hydrolyses triglycerides to form FFA, diglycerides, monoglycerides and glycerol. Gallardo et al., (1989) observed that there is an increase in PUFA and a decrease in the saturated and mono lipid content of precooked albacore. When oil is added as the filling medium, the fatty acid in the fish react with those of the oil and vice versa and alterations occur in the fatty acid content of both the fish and the oil medium (Garcia et al., 1994; Ruiz-Roso et al., 1998). These interactions between the two fatty acids continue till equilibrium is reached throughout the canned storage (Garcia et al., 1994 and Aubourge et al., 1998). Aubourge et al., (1990) reported a decrease in the lipid content of canned and cooked samples. FFA and phospholipids increased significantly during canning. Hale and Brown,(1983) recommended the usage of filling media containing high PUFA content to retain the positive medical benefits of omega 3 –PUFA present in the fish products.

2.3.15.4. Biogenic amines

Biogenic amines particularly histamine is a significant amine even in canned products due to its ill health. Histamine once formed in a product cannot be destroyed by heating and hence fish that has not been refrigerated adequately before thermal processing cannot be made safe for consumption. Luten et al., (1992) have found that majority of the biogenic amines remain as such in the fish muscle after thermal processing and there is no significant change in their
content before and after thermal processing. This is in agreement with the observations of Windyga et al., (1992), Murray et al., (1982) and Hall et al., (1995). The level of histamine in fresh tuna has been used as an indicator of decomposition prior to canning (Mietz & Karmas, 1977). Shalaby, (1990) found that there is a partial decrease in the histamine levels during canning cycle. But this change is so negligible that the fish cannot be used as a material for canning (Arnold & Brown, 1978). This decrease in histamine may be due to the leaching of the amine into the filling medium and hence cannot be taken as a significant reduction in amine levels. Frank et al., (1981) have seen that histamine levels in immediately caught tuna are negligible. Fran and Sims, (1987) found a decrease in the histamine levels in canned tuna subjected to precooking and retorting, but found that higher levels of putrescence and cadaverine in the final fish samples which showed that the initial raw material was a decomposed one. Tuan and Tsai, (1981) found that histamine content is affected by freshness of fish, fish species, chilling methods, transportation and precooking. Mietz and Karmas (1977) established a chemical quality index for canned tuna for estimating the level of decomposition in fresh tuna prior to canning by using the relationship of dansyl derivatives of five amines (histamine, putrescine, cadaverine, spermine and spermidine) extracted from the canned fish. Veciana et al., (1997) used histidine, cadaverine, tyramine, putrescine as indicators in fresh and canned tuna. Precooking and heat processing of canned tuna lowered biogenic amine levels (Frans & Sims, 1987). The higher levels of putrescence or cadaverine in the canned tuna indicate that the fish has undergone decomposition in the raw form. Histamine limits also vary with countries. USDA (FDA, 1982) regulations for canned tuna (albacore, skipjack and yellow fin ) is 20 mg histamine per 100 g as an indication that the material has been mishandled or the raw material quality has decomposed and a level of 50 mg/100 gm as an indicator of a potential health hazard.

Bacteria capable of decarboxylating amino acids are found in certain species like enterobacteriaceae, clostridium and lactobacillus. The bacteria responsible for the high histamine levels in fish are Morganella morganii, K. pneumonia and H. alvei (Wei et al., 1990, Kimata, 1961; Arnold & Brown, 1978). Since the production of histamine is mainly by bacteria like Morganella morganii
and *Enterobacter aerogenes* etc., it is possible to inhibit their growth and amine formation by adding any antimicrobials and preservatives. Spices like clove and cinnamon were found effective against biogenic amine formation (Wendakoon & Sakaguchi, 1992). Histamine toxicity levels have been found to increase in the presence of amines like putrescine and cadaverine and hence FDA suggested the possibility of using these biogenic amines with regard to safety in fish evaluation (Taylor & Sumner, 1987) and FDA, 1995). The problems of histamine fish poisoning would be greater in a tropical country like ours where the average ambient temperatures are high and would result in the growth of these bacteria.

2.3.16. Browning in thermal processed products

Heat treatment triggers browning or maillard reactions which are a complex series of reactions between the amino acids and sugars. Compounds involved in the maillard reaction include amino compounds such as free amino acid and volatile amino compounds associated with microbial spoilage (Nakamura *et al.*, 1973) and carbonyl compounds such as reducing sugars, aldehydes and ketones from lipid oxidation (Pokorny *et al.*, 1973). During the initial stages of the reaction colorless compounds are formed and during the later stages brown coloured pigments called melanoides are formed (Whistler & Daniel, 1985). Even though the characteristic cooked flavour is desirable, in creating the typical cooked flavour there will be a loss in the quality. Maillard reactions can be inhibited by reducing the pH or temperature if the product is in the liquid form or by decreasing moisture to very low levels. The removal of one of the substrates responsible for browning, mainly sugar may also reduce the reaction (Yamaguchi & Kishimoto, 1976). They also studied the relation of retort pouch thickness and temperature to browning and concluded that minimum browning was achieved at 130°C for 20 mm, 135°C for 15 mm and 140°C for 8 mm. During thermal processing, carbonyl compound from oxidized lipid may be solubilised and react with the nitrogenous compound in the fish flesh to form browning compounds (Fujimoto & Kaneda, 1973).
2.3.17. Changes in vitamins and minerals

Vitamin degradation is dependent on agents like oxygen, light, water solubility, pH and can be catalyzed by the chemicals present. Vitamins are easily affected and degraded by high temperature. Fat soluble vitamins like A, D and E and β–carotene, and water soluble vitamin C (ascorbic acid), vitamin B₁ (thiamine B₂ (riboflavin) are heat sensitive vitamins (Ryley & Kajda, 1994). Heat labile vitamins like thiamine, riboflavin, niacin, pyridoxine and panthionic acid are the ones which undergo drastic changes during thermal processing (Banga et al., 1993b). The vitamin thiamine is considerably lost during thermal processing (Chia et al., 1983) and vitamins like A and D which is found in abundance are retained (Bender, 1987). Water soluble nutrients leach into the liquid medium, but in general, nutrient retention in canned seafood products is at an acceptable level (Pigott & Tucker, 1990). Braecken, (1962) found vitamin B₁ levels to be similar for both fresh and canned fish.

Some loss in minerals like sodium, potassium, magnesium, phosphorous, copper, iron and calcium has occurred in canned tuna by leaching into the dipping medium (Seet & Brown, 1983). Fishes with higher fat content produce lesser losses in minerals. Major advantages of thermal processed fish are that the bones become soft and can be consumed, thereby providing valuable calcium.

2.3.18. Changes in smoke components

2.3.18.1. Changes in Total Phenols

Phenolic compounds seem to be mainly responsible for the smoky odour and the major phenols present in smoke flavourings are phenol, p-cresol and o-cresol. The rate of diffusion of the compound into the fish depends on the character of the surface, type of meat and the type of compound deposited, (Stolyhwo & Siroski 2005). Majority of the phenols are deposited on the surface of the fish and depending on the fat content of the fish, penetrate inside. In lean fishes more than 50 % of the mass of phenols can penetrate deeper layers (Kurko & Mezenova, 1985). Phenol content in meat of whole gutted and fillets of
smoked mackerel depend on the smoking conditions and the area of tissue exposed to the smoke (Kolodziejska et al., 2002).

2.3.18.2. Changes in Total Carbonyls

Carbonyls are end products or compounds that are formed due to the oxidation of fat present in the product (Semwal & Arya, 2001). Carbonyls are known to influence the flavour of the fish and fishery products. The carbonyl content of several species of fish and shellfishes by different extraction methods were studied by Ammu et al., (1986). Josephson et al., (1984) studied the carbonyl content of several marine and freshwater fish species. Carbonyls were found to increase initially during chill storage but subsequently showed a decrease (Ammu & Devadasan, 1989). This is in agreement with observations of Tokunaga et al., (1982) who reported that fish held in ice showed a decrease in the aldehyde content unlike fish held in iced water where there was no significant change. Carbonyl value of canned tuna packed in variable ratios of filling media was found to be low (Gu et al., 2001). However, browning of packing medium positively correlated with the carbonyl value since the carbonyl compounds solubilised into the packing medium solution after thermal processing.

2.3.18.3. Changes in Poly aromatic hydrocarbons (PAH)

Most of the PAH in smoked fish comes from the wood smoke. In hot and cold smoked fish there is an increase in the PAH content when compared to the raw fish, depending on the smoking parameters (Tilgner & Daun, 1969 and Steinig & Meyer, 1976). Petrun and Rubenchik, (1966) found that electrostatically smoked fish had a lower Benzo (a) pyrene (BaP) content than those smoked in commercial smoke houses. Kannappan et al., (2000) did not find any BaP in commercially smoked sardine, silvercarp, squid or tuna. Zabik et al., (1996) found that lean and fat trout fillets hot smoked was found to contain BaP. The surface layers of the smoke dried bonito were found to contain 20-40 times more BaP than the meat of the deeper layers (Kikugawa et al., 1986). In smoked fish canned in oil, the contamination can be from the oil used as the filling medium. Certain oils have reported to contain up to 50 µg/kg of PAH. (Stolyhwo & Siroski, 2000).
2005). This high PAH content in the oil may be due to the extraction process employed for oil extraction from seed (Slayne, 2003). The PAH content in canned smoked sardine showed that the oil contained 5 times more PAH than the fish flesh (Lawrence & Weber, 1984). PAH compounds are photosensitive and get oxidized. Exposure to light brings about further degradation of the compounds. Simko (1991) observed that immediately after smoking the surface contained 10.6 μg BaP /kg which reduced to 1.3 μg /kg after seven days storage.

2.3.19. Commercial sterility tests

Spoilage of heated foods may be due to under processing where the target lethality is not achieved to kill the microorganisms in the product or through post process leakage or contamination during storage. In this case the contents having been effectively sterilized are reinfected by microorganisms through leaks in the sealed container (Put et al., 1972; Anon, 1968 and Jarvis, 1940). The surviving microorganisms are likely to be of several kinds and may include vegetative cells (Bultiaux & Beerens, 1955 and Cameroon & Esty 1940). Any survivors of heat treatment by steam under pressure are very heat resistant bacterial spores, usually one or two kinds (Frazier & Westhoff, 1998).

2.3.20. Shelf life studies

2.3.20.1. Thiobarbituric acid value (TBA)

The severe heat treatment and the presence of certain catalysts in the fish muscle favours lipid oxidation and hydrolysis resulting in off flavors and loss of nutrients (Hsieh & Kinsella, 1989 and Harris & Hall, 1994). Canned tuna muscle with brine as the filling medium had higher TBA values indicating a higher rate of oxidation activity for muscle kept in aqueous medium (Medina et al., 1998). The influence of the physical state of the muscle affect the rate of oxidation of oils (Frankel et al., 1996) Oxidation can increase depending on the partitioning of the PUFA in oil – water emulsion. (Coupland, 1996). Unsaturated fatty acids have high surfactant activities and tend to accumulate at the oil-water interface and hence are more susceptible to lipid oxidation (Coupland, 1996). Damage to the
unsaturated fatty acid can lead to primary and secondary lipid oxidation products, which can result in browning (Aubourg, 1999). A large decrease in the Thiobarbituric Acid reactive substance content in Tuna muscle was found after sterilization followed by storage (Medina et al., 1999). Aubourg and Medina, (1997) and Aubourg et al., (1995 a) observed that primary and secondary lipid oxidation detections were not a reliable method for testing the quality differences in canned products. The same decreasing trend has been reported by several other workers in other thermal processed fish products (Mallick et al., 2003, and Manju et al., 2004, Bindu et al., 2004 and Bindu et al., 2007). TBA reactive substances are highly reactive and react with other food components like the amino groups to produce interaction compound with fluorescent properties (Pokorny et al., 1981).

2.3.20.4. Free Fatty Acid (FFA)

Free Fatty acid showed an increasing trend during the sterilization in different muscle zones of albacore (Aubourg et al., 1990). Time Temperature data of canned tuna processed to $F_0$ value of 7 minutes indicated that treatments with higher temperatures lead to a higher hydrolysis development even if the processing time was of short duration (Aubourg et al., 1997). The filling medium employed, oil or brine was independent of the extent of free fatty acid formation (Medina et al., 1994). Tanaka et al., (1985) observed a remarkable decrease in the FFA value of the canned mackerel in natural pack processed to equal lethaliies at different temperatures. Pre-cooking and subsequent removal of exuded liquid greatly increases the level of FFA in the meat (Medina et al., 1995). Tanaka et al., (1985) also found that at lower temperatures of processing there was an increased level of FFA formation due to the longer process time.

2.3.20.3. Texture Profile Analysis

Texture, appearance and flavour are three important components of food acceptability. Texture can be defined as the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetic (Szezesnaik, 2002). Texture is
influenced by intrinsic and extrinsic factors (Barraro et al., 1998; Sigurgisladottir et al., 2000; Mackie, 1993 and Love, 1983). One of the main problems encountered with fish and fish products is that the fish muscle is very heterogeneous and hence measurements are difficult to reproduce. Factors known to affect textural variation in fish flesh are freshness, size, age, season, pH and other environmental factors (Love, 1979). There is no universal testing method for fish (Heia et al., 1997). Periyam (1967) has studied the effects of food texture on either chewing force or chewing pattern and found that the masticatory parameters are influenced by the material properties as well as the size of the food tested. Bourne (1982) concluded that texture is a group of physical properties that derive from the structure of the food. It is under the mechanical or rheological subheading of physical properties and consists of a group of properties. Texture is perceived by touch, mostly in the mouth and the objective measurements of texture are by means of functions of mass, distance and time only.

Instrumentally texture measurements have been divided into three classes like Fundamental tests, Empirical tests and imitative tests. Texture profile analysis (TPA) falls in the imitative test (Szezesnaik, 1963). Two successive compressions from the Texture Profile Analysis (TPA) results in curves from which several textural parameters can be obtained. Two compressions are said to be necessary, if parameters like cohesiveness, elasticity, adhesiveness, chewiness and gumminess are to be measured (Friedman, et al., 1963 and Szezesnaik, 1963). The height of the force peak on the first compression cycle is defined as hardness. Fracturability or brittleness was defined as the force of the significant break in the curve on the first bite. The ratio of the positive force areas under the first and second compressions was defined as cohesiveness. The work necessary to pull the compressing plunger away from the sample is defined as adhesiveness. The distance that the food recovered its height during the time that lapsed between the end of the first bite and the start of the second bite is described as springiness. Gumminess is defined as a product of hardness x cohesiveness. Chewiness is defined as the product of gumminess x springiness. Gumminess and chewiness are mutually exclusive and hence while reporting TPA values one should report
either value only or not both for the same food (Szezesnaik, 1995). Aitken and Connell, (1979) reported that unless supported by sensory texture evaluations, instrumental methods are of limited use and can be used only by processors and researchers for studying the textural change. Karl and Schreiber, (1985) reported an excellent correlation between maximum shear cell force and first bite hardness and structure retention during mastication for canned fish fillets.

2.3.20.4 Colour Profile

The colour of processed food is an important factor from the consumer acceptability perspective. Naturally occurring pigments and components may be degraded or destroyed during heat processing. Carotenoids present in the fish and meat products are isomerised from 5,6-epoxides to 5,8-epoxides which have less colour. Anthocyanin is changed by heat to brown pigments. High-temperature, short-time minimizes the thermal changes considerably and hence has advantages over conventional retorting where the changes are on a larger magnitude (Awuah et al., 2007). Heating denatures myoglobin and oxidizes carotenoid pigments (Haard, 1992). Free riboses are responsible for majority of the maillard type of reaction that occurs when fish is heated (Tarr, 1958). The fish muscles have a lower water activity and hence browning takes place at a faster rate (Labuza, 1972). Trout, Pollack and shrimp processed to an equal lethality in cans developed a darker colour than ones processed in retortable pouches; This was attributed to the longer process time in cans (Chia et al., 1983). By measuring the intensity of colour in the liquids of canned sardines processed for a longer time, Tanaka and Taguchi (1985) found that loss of sugars and lysine is more even if the material was heated at a lower temperature for a longer time. Color changes are more pronounced when the raw material is of poor quality. The green colour discoloration in canned tuna is attributed to the TMAO, myoglobin, cysteine concentration and the cooking operation itself (Khayat 1978). Determination of a combined TMAO and TMA content of the raw fish can be used to indicate the probability of greening occurring during the heat process. (Yamagata et al., 1971).
2.3.20.5. Sensory Tests

The most widespread means of evaluating the edibility of the fishes are the senses- smell and sight, supplemented by taste and touch (Farber, 1965). Sensory evaluation is the subjective taste panel that is used as the standard to determine the accuracy of any objective test (Gould & Peters, 1971). Sensory evaluation is still the most reliable method for evaluation of the freshness of raw and processed fishery products. Heating of meat is accompanied by changes in appearance, smell, taste, texture and nutritive value. Flavour development during heating involves the Maillard browning reactions, fatty acid oxidation and the formation of low molecular weight volatile compounds like ammonia and hydrogen sulfide. Jarvis (1952) reported that excessive heating of little tuna produced a toughening of texture. Tanaka et al., (1983) evaluated quality of canned sardine (Sardinella melnosticta) as a function of initial quality. Tanaka et al., (1985) observed that mackerels canned at a higher temperature had a tougher texture than the ones processed at a lower temperature.