2. REVIEW OF LITERATURE

2.1. TYPES OF THERMAL PROCESSING

Thermal processing is a food processing technique involving application of heat to food material. The heat treatment can be done as a single preservation technique or it can be used as one step in conjunction with other preservation techniques. The extent of heat treatment varies depending upon the specific objective concerning the preserving action of the heat treatment and the nature of the product. Thermal processing operations can further be divided into blanching, cooking, pasteurization and sterilization on the basis of severity of heat treatment, type of heat application, purpose of heat application etc.

2.1.1. Blanching

It is a mild heat treatment that is frequently applied to tissue systems prior to freezing, drying or canning. The objective of blanching process depends on the subsequent treatment of food stuffs. Blanching prior to freezing or drying is primarily done to inactivate enzymes. Pilnik and Voragen (1991) reported that the heat treatment of blanching fruits and vegetables in a water bath before their packing has as its main aim the activation and/ or inactivation of the enzymes present. (Eg. Oxidative enzymes in fruits and vegetables which would otherwise result in undesirable changes in colour, texture, flavour, nutritive value of the products during processing and storage). Blanching may also remove tissues gases, shrink the product, clean and stabilize colour (Barrett and Theerakulkait, 1995). In case of canning, it serves in wilting the tissues to facilitate the
packing, cleanses the tissue, remove the non-condensable tissue gases prior to container closing, activating or inactivating enzymes, improving colour and texture of foods. (Eg blanching helps in the generation of the characteristic curled shape and pinkish coloration of shrimp). Lund (1977) reported that a criterion frequently used to evaluate the adequacy of blanching operation regardless of the subsequent treatment is enzyme inactivation. Blanching is done in two ways, cold blanching and hot blanching. Cold blanching is done by immersing the food material in brine of sufficient strength for a predetermined period of time. The main objective of cold blanching is to enhance the color and texture of the product by the removal of excess moisture content and by the penetration of salt. Hot blanching is accomplished by heating the product in hot water or steam at temperature of less than 100 °C (Lund, 1977). This helps in reducing the microbial load of the product in case of frozen products. An important problem regarding the hot water blanching is the leaching of water soluble components of the food like vitamins. Arroqui et al. (2001) reported that blanching may have some negative effect on product quality, such as excessive loss of texture, unwanted changes in colour, and nutritional losses. If applied under the appropriate temperature and time conditions, it may also minimize disruptive textural effects.

2.1.2. Pasteurization

It is also a mild heat treatment aimed at inactivating not all, but the selected vegetative microbes (mostly pathogens) present in the food and enzymes. Pasteurization involves preservation of foods by heating to temperature generally below 100° C (Ohlsson, 1977). The food is thus not sterile as the process does not eliminate all the vegetative forms and none of the spore formers. Thus the choice of target organism is of
utmost importance. In the pasteurization of meat products the choice of critical microorganism (also called reference micro-organism or indicator microorganism) has been the object of several discussions (Reichert et al., 1988). In principle, such microorganism should be the most heat resistant among undesirable vegetative pathogenic bacteria or other microbes potentially causing spoilage, discoloration, rancidity, flavour, etc. in meat and meat products. It is widely accepted that in the case of mild heat treatment below 90°C only, vegetative bacteria can be chosen for this purpose, because spores are hardly destroyed during pasteurization. The severity of the heat treatment and length of storage depends on the nature of the product, pH conditions, the resistance of the test organism or enzyme, the sensitivity of the product and the type of application of heat. Ramaswamy and Marcotte (2006) listed the typical processing conditions required for a range of products based on the purpose of heat treatment. Ohlsson (1977) classified the enzymes causing undesirable changes in foods into four groups and concluded that the destruction of enzyme activity is either by irreversible denaturation or by hydrolytic breakdown of the protein molecules.

The pasteurization process should be done in conjunction with other preservation methods like fermentation (pickles), refrigeration (milk), maintenance of anaerobiosis or must be used on products like high acid fruit juices where the environment is not suited for the growth of spoilage and health hazard microbes, as it does not involve the destruction of all the microorganisms (Lund, 1977). Many of the recent advances in pasteurized foods have been in combination with chilled distribution and storage as a means to extend the product shelf-life, or by utilizing additional hurdles such as acidity, low water activity, preservatives, modified packaging atmospheres or high sugar content.
This combination of technologies has given food companies the opportunity to produce foods of a high quality that would otherwise require the lengthy heat treatments associated with full sterilization regimes (Tucker et al., 2002). Since pasteurization involves mild heat treatment, it slightly affects the sensory and nutritive value of the food. The quality of the pasteurized product continues to deteriorate during storage as it is a temporary method of shelf life extension. The shelf life depends on the post pasteurization packaging and storage environment. Ohlsson (1977) reported that during pasteurization, loss of nutrients occur as a result of leakage of juices during coagulation of proteins, fat melting and breakage of cells in vegetables. Chai et al. (1984) reported an oyster pasteurization process using flexible pouch packaging for a product with properties similar to fresh oyster. The effect of pasteurization of oyster at different temperatures was studied by Chai et al. (1991). They found a decrease in moisture content, increase in hunter L (Lightness) value and shear force value with increase in temperature of pasteurization. The effects of high pressures and thermal pasteurization on the survival of microorganisms, enzyme inactivation and quality changes of guava puree during storage at 4°C were investigated and compared with untreated samples by Yen and Lin (1996). After treatment at a pressure of 600 MPa and 25°C for 15 min, the microorganisms in guava puree were inactivated to less than 10 cfu /mL and the product exhibited no change in colour, pectin, cloud and ascorbic acid content as compared with fresh samples whereas the microbial count was reduced to 200 cfu /mL and the product showed marked changes in viscosity, turbidity and colour when heated at 88–90° C for 24 s. They also reported that inactivation of enzymes in guava puree by thermal pasteurization was greater than by high pressures.
2.1.3. Cooking

Cooking is a heat treatment method, the primary objective of which is to improve the palatability of the food. It comprises several operations like boiling, baking, broiling, roasting, frying and stewing that differ in the method of heat application. Cooking can be considered as a preservation technique as cooked foods generally can be stored under proper refrigerated conditions longer than their uncooked counterparts if recontamination can be minimized. Gokoglu et al. (2004) studied the effects of different cooking methods (frying, boiling, baking, grilling, microwave cooking) on proximate composition and mineral contents of rainbow trout (*Oncorhynchus mykiss*). In all the cooking methods adopted, the moisture content was found to be decreasing and protein, ash and fat content were found to increase than raw material. Changes in dry matter, protein and ash contents were found to be significant for all cooking methods. The increase of fat content was found to be significant in fried fish mainly due to the absorption of fat by the fish. The Mg, P, Zn and Mn contents of fish cooked by almost all methods significantly decreased. The Na and K contents in microwave cooked samples increased, the Cu content increased in fried samples. Losses of mineral content in boiled fish were higher than those of fish cooked by other methods. The formation of heterocyclic aromatic amines (HAAs) has been shown to occur during cooking of protein-rich foods such as meat and fish at temperatures mostly over 150 °C (Knize et al., 1997; Solyakov et al., 1999). Many workers have reported that during the cooking of meat, HAAs are produced as a result of chemical reactions of creatine, sugars and amino acids, all common components of muscular tissue of animals (Jagerstad et al., 1983; Murkovic et al., 1997; Salmon et al., 1997). Oz et al. (2007) investigated The effects of cooking methods by deep-fat frying,
pan-frying, grilling and barbecuing on the formation of heterocyclic aromatic amines (HAA) of fillets of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta fario*). Ersoy et al. (2006) studied the effects of four cooking methods (baking, grilling, micro-waving and frying) on the heavy metal concentrations of sea bass fillets (*Dicentrarchus labrax*). The lead (Pb) concentrations of micro-waved and baked fish were significantly decreased. The Arsenic (As) concentrations of fried and micro waved samples were significantly increased. They recommended that micro-waving and frying are not suitable for sea bass. Retention of vitamins (retinol, thiamin, riboflavin, niacin and ascorbic acid) in earth-oven cooked samples was compared with the retention in micro-waved and oven-roasted chicken and lamb chops, microwave-cooked fish, boiled cassava and taro, and steamed cooked palusami, by Kumar and Aalbersberg (2006). The retention of retinol was found to be higher in microwave cooked samples than earth-oven cooked samples; Steam cooking was most detrimental to ascorbic acid. Samples cooked by microwave oven retained a higher percentage of thiamin than the oven-roasted or earth-oven cooked ones. Earth-oven cooked samples did not retain any detectable thiamin. Microwave cooking resulted in better retention with respect to niacin than the other methods of cooking adopted. A similar trend was observed in case of riboflavine. Puwastien et al. (1999) conducted studies on the changes on proximate composition, non protein nitrogen content of several species of Thai freshwater and marine fishes during different methods of cooking. They reported significant reduction in the moisture content and increase of crude protein, crude fat and ash in case of fishes cooked by many methods in comparison with the fresh ones. Changes in proximate, amino acid and fatty acid composition of farmed, commercially important rainbow trout (*Oncorhynchus*
Rainbow trouts cooked in microwave ovens had statistically significant higher total protein, total fat, and ash than electrical oven-cooked samples. The amounts of essential and nonessential amino acids were not different between cooking methods, but the difference between raw and cooked samples was significant. Lysine, leusine, methionine, threonine, valine, arginine and histidine were found most in microwave-cooked rainbow trouts whereas isoleucine, tyrosine and phenylalanine were found most in electrical oven-cooked samples. As total saturated fatty acid and total monounsaturated fatty acids amount were not statistically different between the cooking methods, the difference between raw and cooked fillets was found statistically significant.

2.1.4. Sterilization

It is a more severe heat processing technique intended to destroy microorganisms present in the foodstuff that can cause spoilage of the food or cause disease (Noronha et al., 1996). In commercial practice, the sterilization of food is accomplished after packing the food inside a hermetically sealed container. In-pack thermal processing of foods should deliver safe and high-quality products uniformly. Smout et al. (2000) reported that two main factors contributing to the nature of non-uniformity of safety and quality during thermal processing are (i) variability in heat delivery by the thermal process equipment to the food surface (heat distribution) and (ii) variability in heat delivery from the surface to the coldest spot of the food product (heat penetration). Sterilization of food stuffs in commercial point of view aims at attaining commercial sterility rather than absolute sterility. This is because targeting a food that is completely void of microbes would render the product wholesomeness or inferior in quality. During sterilization of low acid
foods, attention is given to Clostridium botulinum which can thrive comfortably under anaerobic condition resulting in the production of botulinum toxin. Brown (1991) reported that low acid foods must experience the minimum botulinum cook (\(F_0 = 3\) min) which is 12 D cycle reduction based on kinetic data for C. botulinum. However other heat resistant spores such as Clostridium thermsaccolyticum, Bacillus steathermophilus and Bacillus thermoacidurans can survive this sterilization condition and can cause spoilage and economic losses if processed cans are stored under abused storage conditions of temperature. But processed cans are usually stored at temperature below 30 \(^\circ\)C which is well below the optimum surviving temperature range of these organisms. Hayakawa (1977) reported that the effectiveness of the sterilization given is measured in terms of process lethality/ sterilization value which is given by,

\[
F_0 = \int_0^t 10^{(T-T_{ref})/z} dt
\]

where \(t\), \(z\), \(T\) and \(T_{ref}\) represent the time (min), temperature sensitivity of the target microorganism, temperature at any given time, and reference processing temperature, respectively. The ultimate goal in achieving commercial sterility is to ensure that the ratio of targeted lethality (\(F_0\)) to required lethality (\(F_{req}\)) is at least , equal to unity (Awuah et al., 2007). Thermal process lethality is influenced by biological, physical and operational parameters. Several researchers have studied the influence of variability of various parameters on process lethality. The important parameters influencing the lethality are heat penetration parameters (\(j_h, j_c, fh\) and \(f_c\)) and bacteriological parameters (D and z values) Hicks (1961), pressure regulation in the retort (Thompson et al., 1979), heating time and the heat transfer coefficient (Varga et al., 2000). Although a food that has been
sterilized for a minimum sterilisation value of 3 min can be considered as commercially sterile, it is common to process the food to still higher sterilization value mainly to attain better textural and other sensory properties. The recommended $F_0$ value for meat products is a minimum of 6 min (Shapton and Shapton, 1997). Frott and Lewis (1994) recommended an $F_0$ in the range of 5–20 min for fish and fishery products. A common relationship for estimating the quality loss is the Cook/ $C$ value, originally proposed by Mainsfield (1962) for aseptic processing of low acid foods. In terms of quality evaluation, the cook value is of little interest since focuses on a single point (Awuah et al., 2007). They reported that the mass average cook value is preferred and more appropriate for characterizing the impact of different time-temperature combinations on heat sensitive nutrients. A maximum range in the region of 100-200 min is considered as the range beyond which quality is said to be impaired. Conventional canning operations have the tendency to induce permanent changes to the nutritional and sensory attributes of the foods. Hence, recent developments in food processing operations have aimed at technologies that have the potential to substantially reduce damage to nutrients and sensory components by way of reducing the heating times and optimized heating temperature. Some of the best examples of the systems that have evolved in the effort to improve the sensory and nutritive parameters of food are agitated retorting, thin profile packages, variable retort temperature processing.
2.2. EFFECT OF THERMAL PROCESSING ON THE QUALITY OF CANNED FOODS

The heat treatment delivered during thermal processing results in the destruction of nutritive and sensory quality of the food (Lund, 1975). The extensive heat treatment involved in the cooking and the sterilization steps substantially alters the nature of the raw material so that, a product with different characteristics is formed. The destruction of various sensory and nutritive parameters upon application of heat depends upon the thermal resistance of each component. The thermal resistance of various components in foods or associated with thermal processing is listed in detail by Lund (1975). Since the purpose of thermal processing is to lengthen the shelf life of the product and to ensure a nutritious food source, it should be designed to retain as much as possible of all the nutritional constituents present in the initial matter to serve human nutrition. The quality changes associated with canning can also be attributed to the changes occurring during the cooking stage also. The various factors affected by the thermal treatment can be broadly classified into chemical and physical parameters.

2.2.1. CHEMICAL PARAMETERS

2.2.1.1. Vitamin Content

Although processes in general could be expected to affect all classes of nutrients, by far the most widely studied group is the vitamins. Prediction of vitamin losses in thermal processing of conduction heated foods has been reviewed by many workers (Lund, 1977; Paulas, 1989; Ryley et al., 1990). Generally vitamin C and vitamin B₁ are used as indices of retention of water-soluble vitamins and fat-soluble vitamins.
respectively (Lund, 1979). Bentereud (1977) reported that thiamine is the most thermo-
liable vitamin. In seafoods, nutrients affected by the time-temperature processes are
especially vitamins B1 and C, but losses to other B vitamins occur, more than with
freezing or home canning of seafood. About 70% of thiamin is lost during canning, but
seafood is considered only a moderately good source of this vitamin. Aubourg (2001)
reported that heat liable vitamins like thiamine, riboflavin, niacin, pyridoxine and
panthothenic acid are the vitamins most damaged by the sterilization process. Varying
results have been reported for vitamin losses (5-80% for Thiamine; 71-73% for Niacin;
49-50% Riboflavin) by many workers. (Bentereud, 1977; Seet and Brown, 1983; Banga
et al., 1993).

2.2.1.2 Protein and Amino acids

The nutritional value of a food protein depends on the distribution of the amino
acids that can be absorbed in a bioavailable form. This bioavailability may be modified
during processing and storage. Most phenomena involved in the improvement in or loss
of both nutritional and physiological properties of food proteins result from the protein
denaturation and chemical modification of amino acids (Finot, 1997). During canning
process, the loss of proteins can be due to three possible reasons namely pre-cooking,
thermal destruction and diffusion into the liquid in the can. No significant changes in
total free amino acid content could be seen between raw and cooked tuna (Perez-Martin
et al., 1988). However Seet and Brown (1983) reported some loss in case of total protein
lysine during cooking.

Several studies have been published on the changes in individual amino acids
caused by heating. Investigations on the amino acid content of several canned fish
products, and comparison with the results of raw materials have showed that there is no much significant loss, except for cystiene. Some losses on essential amino acids have been reported, except for histidine and sulfur containing amino acids (Tanaka and Kimura, 1988). Lysine, due to its highly reactive ε-amino group, is the most readily chemically modified essential amino acid. However in fish, due to smaller levels of available lysine, the loss of lysine is less (Hurrel and Carpenter, 1977).

2.2.1.3. Lipids and Fatty Acids

Marine lipid composition is highly unsaturated and oxidation during storage and processing is likely to occur, leading to quality loss (Pearson et al., 1977). Industrial and culinary processes can cause significant qualitative and quantitative alteration in fish fat contents. Changes in the palatability of the canned fish can result from the effects of canning and maturation processes. Gallalardo et al. (1989) have studied the effect of pre-cooking on the lipid classes at different loci of albacore. The study showed that there was an increase in PUFA and a decrease in saturated and mono unsaturated fatty acid contents. Triglyceride content did not vary much. A general decrease in total lipid content was noticed. Gallardo et al (1989); Garcia-Arias et al (1994) reported a relative increase in fat content of fish muscle after processing. They have attributed this to the loss of moisture content.

2.2.1.4. Minerals

Ackurt (1991) reported that mineral levels in some fish samples were affected by cooking methods. Slabyi and carpenter (1977) found that steaming of blue mussels reduced the iodine, potassium and sodium contents while freezing and canning produced
losses in magnesium and sodium. Schroeder et al (1967) found that the zinc content of lobster meat was increased by canning. Seet and Brown (1983) reported loss in minerals like sodium, potassium, magnesium, phosphorus, copper, iron and calcium from the muscle to the dipping medium during the canning of tuna. Reduced losses of minerals was associated with high fat content in the muscle, indicating a kind of interaction between the two constituents (Gall et al., 1983). During the canning of fishes, the bones become soft due to the heat treatment rendered. March (1982) reported that the soft textured bone can be consumed along with the meat thereby acting as an important source of calcium.

2.2.1.5. Indole

Indole is a metabolite released from degradation of amino acids Tryptophan by the bacterial enzyme tryptophanase. Duggan and Strasburger (1946) reported that indole level was not altered appreciably during cooking or extended storage at commercial holding temperatures in shrimps. Detection of indole is also desirable when sensory assessment is difficult and individual shrimp are very small (Ponder, 1978). Fresh uncontaminated shrimp contains indole at levels of 1\(\mu\)g/100g or less (Duggan and Strasburger, 1946; Chambers and Staruszkiewicz, 1981). The amount of indole produced in shrimp was proportional to the extent of decomposition that has taken place (Ponder, 1978), composition of the bacterial population, temperature, handling and storage (Chambers and Staruszkiewicz, 1981).
2.2.1.6. Volatile compounds

The changes in low molecular weight nitrogenous compounds can be used as an objective test for freshness evaluation (Slabyj and True, 1978; Yeannes et al., 1983). Assessment of TMAO decomposition and amine formation in albacore after cooking produced a significant increase in TMA and TVB contents (Gallardo et al., 1990). A gradual increase in volatile basses measured as TVB or as individual amines (DMA and TMA) has been observed by comparing the raw material and the final canned product (Yannes et al., 1983; Besteiro et al., 1993). Gallardo et al (1990) reported an increasing tendency in the order raw<cooked<canned for TVB and individual amines, while TMAO showed the inverse trend. They have reported that if a good quality raw material was employed and an appropriate sterilization treatment was carried out, canned samples would be within a satisfactory and acceptable limit of 40-45 mg TVB/100 g muscle.

2.2.1.7. Lipid Oxidation

The highly unsaturated lipids easily become oxidized, resulting in alteration in smell, taste, texture, colour and nutritional value. Oxidation starts immediately after the capture (Harris and Tall, 1989). Heidelbaugh and Karel (1970) have reported a lower degree of oxidation measured by peroxide values for pouched products compared to cans. The primary oxidized products easily break down into secondary products, such as aldehydes and ketones. Sinhuber and Yu (1958) reported a reduced TBA values in heat-processed products in pouches and cans, in which pouched products showed a smaller reduction after processing and during storage. Heidelbaugh and Karel (1970) reported a low TBA values for pouched products as compared to the cans. Chia et al. (1983) reported a faster rate of increase in TBA values in canned samples as compared to the
pouches. In spite of some drawbacks, the TBA value for estimating the oxidative change remains the most widespread procedure for meat and meat products (Shahidi, 1994). Many workers have reported that the strong heat treatment and the presence of some catalysts in the fish muscle can favor non enzymatic lipid oxidation and hydrolysis so that the detrimental flavor and essential nutrient losses can be produced (Hsieh and Kinsella, 1989). Aubourg et al (1990) reported a significant formation of free fatty acids during the sterilization of different muscle zones of albacore tuna. A comparison of different time/temperature sterilizing conditions (F₀ value = 7 mins) showed that treatments with shorter times but higher temperatures lead to a higher hydrolysis development (Aubourg et al., 1997). Hale and Brown (1983); Aubourg et al (1990) reported that no significant change in PUFA concentrations could be noted on heat processing of various sea foods like sardine, mackerel, tuna and crab in sealed containers.

2.2.2. PHYSICAL PARAMETERS

2.2.2.1. Texture

Texture is one of the important quality parameters affecting the consumer acceptability of a food item. Various types of heating affect the fish muscle texture. Dunajski (1979) reported that cooking of fish muscle at about 60 °C leads to the loss of original structure of collagen fibers and they become solubilised and thus any textural changes above this temperature are solely due to the heat denaturation of myofibrillar proteins. The collagen content of muscle was important role in the textural changes of muscle during heating. Sato et al. (1986) pointed out that the texture of cooked muscle is affected by the gelatin derived from the collagen. Ma et al. (1983) determined the textural
changes in canned shrimp by sensory and instrumental methods. They found a direct relationship between sensory perception of toughness and instrumental shear force measurements in canned shrimp processed at 124° C. Shrimp muscle toughened during initial stages of heating and softened during later stages. Ali et al (2005) studied the effect of thermal processing in retort pouch and aluminum cans to different F0 values on the texture of oil sardine. They reported that product packed in retort pouch had better hardness, cohesiveness, springiness and chewiness than those in cans. They also reported that the various texture profile parameters decreased with increase of F0 value. Tanaka et al. (1985) compared the firmness of mackerel canned at three different retort temperatures of 110, 115 and 120° C and reported that thermal processing at higher temperature produce firmer products.

2.2.2.2. Colour

Colour is one of the main organoleptic characteristics used to establish the quality and acceptability of food products. Tarr (1952) reported a brown discoloration in white-fleshed fish upon heating. Changes in the salmon color pigments upon heating have been studied by Naughton et al (1956). Tarr (1958) stated that free ribose accounts for much of the Maillard type of reaction when fish is heated in presence of carbohydrates. Rainbow trout, Pollack, and shrimp processed to an equal lethality in cans developed a darker color when processed in cans than the ones in retortable pouches (Chia et al., 1983). This was attributed to the longer processing temperature needed in cans. Ali khayat (1978) examined the changes in the tristimulus color values of three tuna species, albacore, yellow fin and skipjack tuna. A significant loss in the tristimulus colour values of the samples during canning process noted and the greatest loss were found in albacore
followed by skipjack and yellow fin tuna. The same author has reported that greater the amount of reducing sugar in the raw material, darker the color of the canned product. The effect of heating process, animal harvest location and position of meat within the container during thermal processing was evaluated by Requena et al (1999). It was found that the meat became darker with increasing heating process, crab harvest location had significant effect on the lightness (L* Value) and the meat located on the bottom of the can was darker than that in the top.

2.3. METHODS OF REDUCING THE PROCESS TIME

Conventional canning operations have the tendency to induce permanent changes to the nutritional and sensory attributes of the foods. Hence, recent developments in food processing operations have aimed at technologies that have the potential to substantially reduce damage to nutrients and sensory components by way of reducing the heating times and optimized heating temperature. Some of the best examples of the systems that have evolved in the effort to improve the sensory and nutritive parameters of food are agitated retorting, thin profile packages, variable retort temperature processing and High temperature short time processing (HTST).

2.3.1. Agitated retorting

Agitation during thermal processing is an effective means for providing induced-convection, which results in a higher heating rate and more uniform heating. During agitation, heat penetration is accelerated by the generation of convection current in the liquid phase and by the displacement of materials with densities different to that of filling liquid such as the head space bubble and solid food particulates. This mixing of contents
reduce the temperature gradient within the container and lead to better product through shorter process at higher temperature. There are currently two methods of inducing agitation in containers. The first involves horizontally oriented cans (i.e. axial rotation), the second involves cans loaded in a vertical position (i.e. end-over-end or EOE rotation). EOE rotation is a more effective means of improving heating rates because the headspace "bubble" improves mixing and turbulence (Knap and Durance, 1998). The effect of end over end agitation on thermal softening of vegetable texture has been studied by Teherian and Ramaswamy (1996). The heat penetration during agitated retorting is influenced by many factors like rotational speed, system geometry, and headspace volume, product viscosity, off center axis of rotation, particle density and presence of particulates (Naveh and Kopel-man, 1980; Anantheswaran and Rao, 1985a; Anantheswaran and Rao, 1985b; Sablani and Ramaswamy, 1995, 1996; Ramaswamy and Sablani, 1997). Casales et al. (1988) reported that the movement of food within the can prevents burning of food contact with the wall of the container and higher sterilization temperature can be applied. Berry and Kohnhorst (1985) reported that burn-on at the surface of low viscosity foods can be substantially eliminated by inducing agitation Therefore, for low viscosity foods, rotation allows the application of higher processing temperatures and, leading to improved quality of the food (assuming agitation does not cause product damage). Rapid heating also has the advantage of increasing the throughput of process equipment and, hence, higher process efficiency and reduced production costs (Tattiyakul et al., 2002).

2.3.2. Thin profile packaging

The retortable pouch was developed during the 1960s in the USA, by a consortium of food packaging/processing companies working in conjunction with the US
Army Natick Laboratories (Herbert and Bettison, 1987). Gopakumar (1993) reported that the flexible laminated food package, the retortable pouch, which can withstand thermal processing and combines the advantage of the metal can and the boil-in-bag, can be used as an alternative to a metal can. Retort pouches have superior surface to volume ratio compared to metallic cans which along with its thin profile helps in faster heat penetration and thereby helps in attaining the required lethality value at the shortest time. Reduction of heating time while using pouches has been reported by a number of workers (Lampi, 1977; Chia et al., 1983; Durance and Collins, 1991). Chia et al. (1983) reported a reduction of 34%, 32% and 37% for trout, pollock and shrimps in pouches compared to cans. Durance and Collins (1991) reported a reduction of 48% process time for chum salmon in pouches than in cans. Various studies have shown the quality implications of the savings in terms of processing time. Dymit (1973) reported that shrimp in retort pouch were superior in flavour and colour to canned products. Mohan et al. (2007) compared the heat penetration characteristics and quality parameters of prawn kuruma packed in retort pouch and aluminum cans. They reported that shrimp kuruma processed in retort pouch took less time to attain the fixed sterilization value and had better sensory and nutritive parameters than those processed in aluminum cans. Other notable advantages of retort pouches are shelf stability, weight, storage space, ease of opening and preparation. Traditionally, retortable pouches are sterilized in batch-type retorts with custom designed racking systems. A method that allows continuous sterilization of flexible (soft) packaging materials (including retortable pouches) in a hydrostat has recently been patented by Brokaw et al. (2003).
2.3.3 Variable Retort Temperature (VRT) processing

Any retort process in which the environment temperature within the retort is modulated during the process, according to a predetermined temperature sequence, to alter the heating profile within the product may be described as a VRT process (Durance, 1997). In the case of VRT, the variable factors are the temperatures of the retort at different points in time during the heating and cooling phases of the process. Because a large number of different VRT’s are possible for a given product, selection of an optimum process is most easily found with a computerized experimental search technique. In case of (constant retort temperature) CRT, the heating rate of the can centre is greater early in the process while the overall heating rate may be greater in the VRT process, owing to a higher final retort temperature. The VRT approach was not seriously considered in the earlier days of canning research, mainly because of the fact that the processes were cumbersome and unreliable when retort operation was strictly manual and VRT processes are difficult to study without the aid of computer simulations of heat transfer. The first comprehensive study regarding the VRT was conducted by Teixeira et al. (1975). They fixed thiamine as the specific quality attribute chosen for improvement. Only a slight improvement with respect to his specific attribute could be attained which lead them to suggest that VRT was not likely to be very useful. This in turn has led to the development of research in the field of VRT. Banga et al. (1991) studied the VRT process from two angles; the optimum nutrient retention and the surface quality and process time. They attained small advantage only with respect to nutrient retention while they could attain 20 % improvement in terms of surface quality and 16.5% reduction in processing time as compared to the CRT process. Studies on the effect of variable retort
temperature on surface quality by Noronha et al. (1993) indicated that variable temperature profiles improved surface quality by up to 20% compared to a constant temperature retort profile. They have also found greater reduction in retort times with VRT process of low profile rectangular containers as compared to cylindrical cans examined in other studies. A change from constant to time-variable retort temperature could increase canning capacity by 20–50% depending on product specifications (Almonacid-Merino et al., 1993). Most of the studies regarding VRT have been based solely on computer simulations and only few have described the application of these principles to actual retort operations. Durance et al. (1996) applied VRT processing to a particular product, canned salmon, and confirmed with actual retort trials. VRT processes were shown to be capable of producing products of superior surface quality with equivalent $F_0$ values. Alternatively equivalent quality could be produced with a process time (i.e. steam-on time minus come-up time) of 54 min as compared with 64 min for the CRT process. Durance et al. (1996) concluded that the benefits of VRT may include improved nutrient and flavor retention, reduced heat damage to product surface, lower energy costs or shorter process times.

2.3.4. High Temperature Short Time processing (HTST)

HTST as the name indicates involves sterilizing food at high temperature so that it takes less time to attain the fixed sterilization value in comparison to conventional canning. The underlining principle of HTST is that the if a product is sterilized at two different temperatures but to the same bacteriological inactivation level, mostly negative changes in the quality will be smaller for the product sterilized at higher temperature (Ohlsson, 1980). The basis of utility of HTST relies on the fact sterilization rates are
generally slower than cooking rates at low temperature and are higher than cooking rates at high temperatures and as one goes higher and higher in temperature, one obtains less and less cook effect at constant sterilizing values (Mansfield, 1962). This implies that it is possible to go so high in process temperature that the resulting sterile product food may be inadequately cooked. Nutrient and quality factors are up to six magnitude resistant to thermal destruction than spores and vegetative cells and as a result, thermal death of bacteria generally undergo greater acceleration with increased temperature than concurrent reactions that lead to quality loss (Lund, 1977). HTST is applied mostly to liquid foods due to the fact the high temperature of processing imparts much greater heat than the centre leading to surface overcook and the related quality problems and thus particulate foods are still processed by the in container sterilization method But HTST can be applied to solid foods though the process of flame sterilization

2.3.5. Aseptic processing

This method of HTST is employed for the processing of milk, fruit juices mainly due to their low viscous nature. The heat treatment is done to a thin layer of the pumpable liquid food in a heat exchanger or by direct stem injection followed by holding to achieve required lethality and rapid cooling to minimise the impact of heat on nutrients. The product is subsequently filed into sterile containers in a sterile atmosphere. In contrast to in container sterilization where most of he lethal affect occurs at the end of the heating stage and beginning of the cooling phase, commercial sterility in HTST processing occurs in the holding tube at a constant temperature within seconds (Awuah et al., 2007). Smith and Ball (1955) described a new process for continuous milk sterilization and high temperature filling of low acid foods. Livingston et al. (1957) processed green beans,
beets, carrots, spinach, peas and soups by an HTST method and obtained during extended storage periods, retention of color and thiamine hat was higher than in foods canned by conventional methods. Eliot-Godereaux et al. (2003) developed a new Time-Temperature Integrator (TTI) in order to quantify the effects of High Temperature Short Time (HTST) processing on food quality. They selected a product of non-enzymatic browning as a potential marker and its formation was studied in a glucose/serine system, by means of absorbance measurements at 285 nm. Over the last decade, considerable research efforts and capital investments have focused on extending the aseptic concept to products containing large particles. These efforts somewhat paid off when the FDA approved a low acid soup containing large potato particles (Palaniappan, 1997). However the commercialization of aseptic processing to large particles is offset by the stringent regulatory demands for clear demonstration of achievable lethality. The process and machinery related issues that limit the extension of aseptic processing to particulate foods have been listed by Awuah et al. (2007).

2.3.6. Flame sterilization/ Steriflame process

It is a HTST method that is used for processing of filled close cans in which heating is achieved by the direct contact of cans with burner flame along with rapid rotation to induce convection (Leonard et al., 1975). It is a recommended method for particulate foods packed in brine, syrup or juice and for liquid foods. Flame sterilization was invented in France in 1957 (Cheflel and Beauvais, 1957; 1958 a, b, c) and first described in scientific literature in 1961 (Beauvais et al., 1961). Unlike conventional canning operations, flame sterilisation is done at atmospheric pressure and during processing a large pressure differential build up between the inside and outside of the can.
and the can must act as its own pressure vessel. Due to the high internal pressure developed, Beauvais et al. (1961) recommended the use of heavier temper plates for cans. The method can be extended for cans having higher diameter by using stronger ends with single high expansion ridge (Casimir, 1972). The cans are agitated in order to attain better heat penetration (Richardson, 1987). Since flame sterilization causes the rapid destruction of microorganisms before extensive heat damage to the product can occur, the quality of the steriflamme products is superior to those from conventional retorts (Kieseker, 1972). Richardson (1987) reported that flame sterilization can be applied commercially to vegetables, milk shakes, cream, rice pudding, meat products and fish. Gillespy and Thorpe (1965) reported that flame sterilized strawberries and raspberries were firmer in texture but weaker in flavour than conventionally processed samples. Casimir et al. (1976) found that vacuum closed/ flame sterilized diced potato and whole kernel corn after 18 months of storage had better colour, texture flavour and acceptability than conventionally processed packs.

2.4. READY TO EAT FOODS

Ready to Eat (RTE) foods are pre processed foods which are normally packed and served or consumed when required. Technological innovations, particularly in the field of food processing equipment, processing and packaging materials have brought about revolutions in the field of RTE. Indian RTE food scenario is exhibiting tremendous growth rate in the recent years and today it has become a multi billion industry with large number of firms involved. The changes in the socio economic pattern of the society like the changing life style, increasing number of working women, increase in the family
income of people which makes the RTE foods affordable, awareness about healthy foods, changes in the meal pattern and existing food habits, desire to taste new food products have all contributed to the growth of RTE industry and we are in the midst of RTE revolution. Ready to eat thermally processed foods have the additional advantage that they can be stored for a period of more than one year without employing cold chain. RTE has now become an option to Home Meal Replacement (HMR) segment along with conventional options like restaurant, hotels, mess/ canteen, catering service etc. The development in the RTE industry had its reflections in the sea food sector also. The RTE industry has helped in the revival of the once collapsed sea food canning industry in India. Vijayan and Balachandran (1986) reported the development of canned sardine curry in metallic containers using two different types of curry medium. They found that, though the product was organoleptically acceptable upto 18 months of storage at room temperature, the curry acquired the lacquer taste and the cans exhibited rusting at the seam area. Srinivasa Gopal et al. (2001) standardised traditional Kerala style fish curry in indigenous retort pouch and reported a shelf life of not less than 12 months at room temperature. They have also reported that an $F_0$ value of 8.43 was satisfactory for fish curry products. Ravishankar et al. (2002) conducted studies on the heat penetration and storage characteristics of seer fish curry in retortable pouches. They reported that a sterilization value of 11.5 min is ideal for seer fish curry and the product is acceptable upto 24 months based on sensory attributes. Manju et al. (2004) reported studies on the heat penetration characteristics and shelf life studies of seer fish moilee, a traditional fish based product of kerala in retort pouch. They reported that the product stored at ambient temperature ($27\pm1^0$ C) was acceptable up to 18 months and those stored at $37^0$ C was
acceptable up to 10 months based on the sensory attributes. Ready to eat rohu curry in north Indian style processed to $F_0$ value of 46.42 min and cook value 102 min was found to be acceptable even after 6 months of storage at room temperature and at elevated temperature of $37^\circ$C with respect to sensory and chemical attributes (Mallick et al., 2006). Mohan et al. (2007) compared the heat penetration characteristics and quality parameters of prawn kuruma packed in retort pouch and aluminum cans. They reported that shrimp kuruma processed in retort pouch took less time to attain the fixed sterilization value and had better sensory and nutritive parameters than those processed in aluminum cans. The standardization of thermal processing parameters for ready to eat squid masala in tin free steel cans was described by Sreenath et al. (2007). They found that a sterilization value of 8 min with cook value of 91 min was ideal for squid masala based on sensory analysis and instrumental texture profile and shear force analysis.

2.5. STORAGE STUDY OF THERMALLY PROCESSED FISHERY PRODUCTS

One of the important advantages of thermally processed foods over foods processed by other methods is its longer shelf life at room temperature. Thus the thermally processed foods helps in avoiding the cold chain thereby avoiding the machinery and the operational costs involved in maintaining the cold chain. Taguchi et al. (1982) reported that canned products undergo changes in both sensory and nutritional value during long term storage due to chemical reaction within the food and also between the food and container metal. The rate of such changes are dependent on the storage temperature. Various studies have been conducted to assess the useful shelf life of hermetically processed foods. Most of these works were conducted based on the study of
the sensory and biochemical changes associated with long term storage. Bhandary (1971) while studying the keeping quality of common carps noticed considerable browning in mirror carp packs and this was attributed to high sugar content of the fish. Telles–Siqueira et al. (1975) have examined the organoleptic, chemical and bacteriological aspects of canned freshwater trout and sea trout during storage. Mai et al. (1978) concluded that lipid changes in cooked fish are least in fillets with high levels of lipids. Mai et al. (1978) reported that canning process followed by storage produced an increase in the proportion of FFA in the muscle lipids. Ribarova et al. (1991) reported that contents of lysine and leucine decreased gradually during storage whereas contents of glutamic acid and aspartic acid increased during storage of canned carp. Aurbourg et al. (1997) studied the effect on muscle lipid deterioration of initial cooking and of there time temperature processing combination after 4 months storage of albacore tuna canned in oil. Storage for 5 years resulted in slight decrease in SFA and MUFA and slight increase in n3 PUFA and no significant change in n6 PUFA in sardine canned in oil (Roso et al., 1998). No significant change in the muscle mass and moisture content could be noted during 5 weeks storage of tuna canned in water (Bell et al., 2002). Ravishankar et al. (2002) studied the heat penetration and storage stability of ready to eat seer fish curry processed in retort pouches. They found that the product remained in acceptable condition based on the analysis of sensory attributes of flavor, texture and overall acceptability. Manju et al. (2004) reported that seer fish moilee stored at room temperature and at 37°C in retort pouches had shelf life of 18 and 10 months respectively. Bindu et al. (2004) reported that vacuum packed and retorted ready to eat mussel meat remained in good condition based on taste panel results even after one year.
of storage at room temperature. One of the important factor that limits the long term storage life of thermally processed products in tin and aluminium cans coated with lacquer is the development of metallic taste resulting from the dissolution of metal in the food and the leaching of the endocrine disruptors like BPA from the can coating to the food. Development of internal corrosion and bitter taste in sardine curry canned in tin cans after 15 months of storage was reported by Vijayan and Balachandran (1986). Gracia Arias (2004) reported that sterilisation and storage of tuna led to increase in lipid and decrease in moisture and protein. They also reported that protein digestibility and biological value did not show any deterioration.

2.6. CONTAMINATION OF FOOD MATERIALS FROM PACKAGING

Packaging makes food more convenient and gives the food greater safety assurance from microorganisms, biological and chemical changes such that packaging has become an indispensable element in the food manufacturing process. Despite of all these advantages, packaging has been the subject of many debates concerning environmental and health issues. This is due to its potential to contaminate the food that is coming into contact with it by the dissolution in the food that is coming into contact with the migrated substance. The term ‘migration’ is used to describe the process of mass transfer from packaging material to the food. It has been reported that diffusion is one of the main mechanism for the transfer and migration of substances from packaging material to food (Aravnitoyannis and Bosnea, 2004). Katan (1971) classified migration into 3 classes. Due to its various advantages, plastic and plastic based materials have emerged as the most widely used packaging material and nowadays more than 30 different plastic
materials are being used as packaging material (Lau and Wong, 2000). All plastics, apart from the basic polymer contain several non-polymeric components either inherent or added deliberately (Gopal and Ravishankar, 2003). They have classified these substances into polymerization residues, processing aids and end use additives. Since the polymers are of high molecular weight and are inert, they have limited solubility in aqueous and fatty systems. But non-polymeric substances may leach out form the plastic to food thereby contaminating the food with the consequent risk of toxic hazard to the consumer (Murthy and Raju, 1989; Crosby, 1981; Crompton, 1979). Lau and Wong (2000) separated the migration of additives or contaminants from polymeric packaging to food into three different but inter related stages: diffusion within the polymer, salvation at the polymer-food interface and dispersion into bulk food. One of the major decisive factors in the migration from the packaging material is the type of food that is coming into contact with it, it’s composition, the prevailing temperature, pH, the physical state of the food, moisture content etc.. Hence, Robertson (1983) classified food items into 8 categories in order to determine the over all migration residue. Since the use of food stuffs for determination of migration is impractical mainly due to its perishable nature and varying composition, food stimulating liquids that can be used instead of actual food stuffs have been recommended by Crosby (1981); CEC (1985). The testing condition and the choice of simulating solvent are decided on the basis of various factors like the conditions under which the food is packed and stored (IS: 9845-1981). Two methods that have been recommended for carrying out the migration tests are the quantity in material (QM) which is the overall by quantity of substance which may be present in the packaging material and the quantity that could migrate to the food stuff i.e.; Specific
Migration limit (SML). A QM is more convenient than SML when the compound is shown to degrade in the food stimulant or if the QM is of such number that even if 100% of the compound migrates to the food, it would still be too low to become hazardous to public health (Aravnitoyannis and Bosnea, 2004). Traditionally, migration data were obtained from the migration tests performed using food stimulating liquids like water, edible oils, ethanol water solutions etc. However, these tests are time consuming and expensive. Hence predictive migration models have been proposed to estimate the extent of migration. These models help in the identification of factors affecting migration which in turn allow the manufactures to improve the quality by determining the variables that have the greatest impact on the migration and also in controlling and limiting chemical contamination of food from packaging. Aravnitoyannis and Bosnea (2004) reported that Fick’s first and second law can be applied since migration is actually a diffusion process. Crank (1975) provided a simple model to predict the extent of migration from polymer into extraction solvent. Barner et al. (1994) developed a model to predict the migration which is actually a modification of the Crank’s model.

Since the overall migration tests cannot identify the exact chemical nature of the contaminant and its toxicity and official methods are time consuming, complicated and impractical for routine controls, more practical test methods have evolved. The analytical procedures typically involve sample preparation, extraction, clean up and final determination using chromatographic and spectrophotometric techniques. The common analytical procedures and the instruments used for the determination of chemical contaminants have been listed by many workers (Low and Wong, 2000).
Rigid metallic containers by themselves also are not free from the food contaminating potential though they don’t present an array of contaminants like plastic packaging materials. In metallic containers, the contamination is contributed mainly by lacquer coating, the soldering compounds in case of three piece cans, tin coating and the base metal.

2.6.1. BPA and BADGE

Metal cans are traditionally protected against corrosion by the application of inner coatings based on epoxy and organosol type of resins (Frott and Lewis, 1995). Epoxy polymers are resistant to solvents and can bind to a variety of substrates especially metals. This property makes epoxy resins a popular choice for use in enamel coatings on the food contact surface of metal food and beverage cans. If the coating is inadequately formulated, they can be a source of contamination due to the migration of chemicals to food. Bisphenol A (BPA) and its condensation product with epichlorohydrin, bisphenol A-diglycidyl ether (BADGE) may remain unreacted if the curing process of lacquer coated can is insufficient (Mungia Lopez and Sato-Valdez, 2001). These residual BPA and BADGE can be a potential contaminant to the food that is packed. When the cans are heated at high temperature as in case of commercial canning, BPA may leach out of can coating. This statement is supported by the reports of BPA contamination in canned vegetables (Brotons et al., 1995), canned beverages (Horie et al., 1999), canned fish and meat (Imanaka, 2001).

BPA contamination is a serious issue for canned fish and meat products as various studies have shown that the leaching out of this compound is higher in fish and meat products than in other canned products (Brotons, 1995; Biles et al., 1997; Horie et al.,
The oestrogenic activity of the BPA was accidentally discovered by Krishnan et al. (1993). Kupier et al. (1997) reported that BPA can interact with α and β oestrogen receptors. It is among the oestrogenic xenobiotics that may affect the reproductive system of animals and cause proliferation of breast cancer cells in vitro (Krishnan et al., 1993; Simal-Gandana et al., 1998). The toxicity of BADGE is related to cytotoxic effect in tissues with a high rate of cell division. The US National Institute of Occupational Safety and Health has listed BADGE as a tumorigen, mutagen and primary irritant. The migration limits for BPA and BADGE are 3 mg/kg (CEC, 1990) and 1 mg/kg (Simal-Gandara et al., 1998) of food or food stimulant, respectively. BPA, BADGE and the related compounds are mainly determined by liquid chromatography using UV detection (Crathorne et al., 1986). However, fluorescence (Losada et al., 1991) or mass spectrometry could provide more sensitive and specific methods for the detection of these compounds.

### 2.6.2. Tin

Just under one third of the world’s total tin production goes into the manufacture of tinplate, for which food packaging is by far the largest of many diverse applications. Tin coated containers are used for food packaging either with lacquer coating or as plain cans. As a result of the use of tinplate for food and beverage packaging, it is obvious that some tin will dissolve into the food content, particularly when plain uncoated internal surfaces are used. Tin dissolution from coated cans occur through the coating imperfections. Dissolution of metallic tin from the inside of a can body into the food content will result in it being present in the divalent form. The precise chemical nature of the divalent tin in a canned food product is important, as it is likely to have a major
influence on its ability to cause an acute toxicological response. However, the exact species present and their distribution will be different in each individual food type, since a number of factors have a role to play (Blunden and Wallace, 2003). The actual rate of dissolution of tin is dependent on a number of factors. Of these, the presence of oxidizing agents or depolarizers that corrode tin by direct chemical attack without evolution of hydrogen is probably the most significant. Other factors that have been attributed to favour the dissolution of tin are storage conditions, particularly investigated include temperature, can size (Marsal and Darre, 1976), types of base steel and the level of hydrogen in the base steel (Reznik, 1991). The effects of inorganic anions (NO$_3^-$, NO$_2^-$, Cl$^-$, CrO$_4^{2-}$, SO$_4^{2-}$, HPO$_4^{2-}$, H$_2$PO$_4^-$, IO$_3^-$, and B$_4$O$_7^{2-}$) on the corrosion of tin in nitric acid has been investigated by Al-Suhybani (1989). It has been found that some of these anions inhibit corrosion while others accelerate it.

The Provisional Tolerable Weekly Intake for tin is 14 mg/kg body weight (JECFA, 1988a, 1988b) and recommended maximum permissible levels of tin in food are typically 250 mg/kg (200 mg/kg UK; MAFF, 1992) for solid foods and 150 mg/kg for beverages (Codex, 1998). Acute effects have been reported following the ingestion of inorganic tin via dietary products stored in tin cans. These generally take the form of digestive disturbances with symptoms of acute gastro-enteritis, i.e. nausea (97%), abdominal cramps (87%), vomiting (70%), headache (57%), diarrhoea (33%) fever (13%) (Piscator, 1979; Schafer and Femfert, 1984; Dewitte et al., 2001). To date, many spectrophotometric methods for tin determination have been reported. Kontominas et al.
(2006) reported the determination of tin using atomic absorption spectrophotometer having graphite furnace accessories.

2.6.3. Iron

Iron is the base metal for tin cans. Apart from being an ideal packaging medium, iron forms a potential source of contamination in tin coated metallic containers. The leaching of iron into the food materials occur through the areas of discontinuity developed on the internal surface coating of the cans due to improper application of tin and lacquer layer. Bernando et al. (2005) reported that during the double seaming operation due to friction, breakage occurs on the coating at the body hook and end hook. Product-package interaction occurs through this discontinuity leading to iron dissolution. The action of certain detinning agents also favors the dissolution of iron in the food. Farrow (1970) recognized inorganic nitrates in food products as a potential detinning agent. A potential detinning agent in case of fish cans is TMAO. Taguchi (1975) investigated the role of TMAO in the detinning process in case of fish cans and reported that the rate of tin liberation was proportional to the amount of TMAO added. The detinning action of TMAO increased at higher storage temperatures. The dissolution of iron in food results in the development of metallic flavor in the product. Sometimes the exposed iron may react with the sulfur containing compounds liberated from the product during retorting thereby forming iron sulphide (FeS) often seen as black spots on the internal container surface and in extreme cases, on the product surface. The control of iron migration is of great significance in case of tin plate beverage cans as even smaller levels of iron migrated to drink can affect the flavor of the drink (Hollander, 1998).

2.6.4. Aluminium
Due to its abundance, aluminium (Al) is distributed in the whole food chain (Lopez et al., 2000). Environmental aluminium is considered as non toxic, (Bunnig, 1984) and it has been regarded as harmless for healthy human beings until recently. But the possible connection between elevated tissue Al content and problems such as osteomalacia and neurodegenerative disorders has awakened interest in Al intake via the diet (Martyn et al., 1989; Storey and Masters, 1995). General possibilities of oral aluminium exposure of humans occur via food stuffs, use of aluminium containing food additives, migration of aluminium from food packaging into food and also drinking water. Due to various advantages over tin, aluminium has been used as a major container for canned fish and several other commodities like beer/soft drinks, several types of food products and also collapsible tubes for different paste products (Balachandran et al., 1994). The major route of contamination of food packaged in aluminium containers is by leaching out of the aluminium from the can body. The leaching occurs mainly though the imperfections in the lacquer coating. Oduoza (1992) reported that the concentration of aluminium in canned seafood depends on quality of inside lacquer coating of the cans. The leaching of aluminium to the food that is packed depends upon a wide range of parameters like quality of the container, duration of cooking, pH level and presence of Cl⁻ ion (Jagannata and Murthy, 1990), oxygen concentration of the head space, storage time and the temperature and humidity of storage (Oduoza, 1992). Muller et al. (1998) surveyed the aluminium content of a variety of German foods including canned fish. The aluminium content of the canned fishes ranged from 1.2-5.5 µg/FM. They also reported that the aluminium content of canned fish is comparable with those found in meat. The aluminium content of foods and beverage consumed in the Spanish diet was estimated by Lopez et al. (2000). Orally consumed aluminium is increasingly considered as a
contaminant of the food chain playing a role in the aetiology of neurodegenerative disorders like morbus Alzheimer and amyotrophic lateral sclerosis. An abundance of research has continued to link Al with Alzheimer’s disease (Flaten, 1990). Animals loaded with Al develop both symptoms and brain lesions which are similar to those found in Alzheimer’s disease (Lopez et al., 2000). The relationship of aluminium with various disorders has lead to the growing public concern regarding its consumption. The acceptable daily intake (ADI) of Al established by WHO-FAO is 60 mg/60 kg of body weight (WHO-FAO, 1989). Graphite furnace atomic absorption spectrometry is the method of choice for the determination of Al in food stuffs (Smeyers-Verbeke and Verbeelen, 1985, 1988).

2.6.5. Lead

Lead contamination is mainly associated with food packed in three piece cans. In case of three piece cans, the solder used to seal the side seam is composed 98% of lead and 2% of tin. Some amount of lead contamination may also originate from the tin coating in which it may be present as an impurity. Although attempts have been made to prevent the lead contamination by coating the interior of the can thereby preventing the can contents from coming in contact with food, little success could be achieved in this direction with respect to acidic foods. Bielig et al. (1978) found more than twice as much lead in orange and tomato juices stored in lacquered cans than in the identical juices stored in unlacquered cans. They have also reported that the rate of lead uptake in lacquered cans is temperature dependent whereas it is independent of temperature in unlacquered cans. The advent of two piece cans which are free from side seam has helped in reducing the contamination from this source. Rouseff and Ting (1980) studied the
effect of acidity, storage time and temperature on the lead content of canned grape juice employing flameless atomic absorption spectroscopy. They reported that acidity of the juice and exposed solder area of the side seam are the two important factors affecting the lead concentration in canned grape fruit juice. During early life, human infants are particularly susceptible to lead exposure, with a greater portion of the retained lead being distributed to bone and brain in infants than in adults (Robertson, 1983). Sub acute ingestion of lead by children results in encephalopathy, convulsions and mental retardation. Estimated daily dietary intake of lead for adults range from 0.015-0.1 mg, depending on the composition of the diet and where the consumer lives (Codex, 1996). The regulatory limits for lead in canned foods in almost all countries are now 2.0 ppm but only 0.5 ppm in baby foods and 0.2 ppm in soft drinks. The newer welded and two piece cans have eliminated the solder and has done much to reduce the lead contamination. Capar (1978) noted that some foods which are stored in refrigerator after being opened for days accumulated increasing amounts of lead.

2.7. TIN FREE STEEL CONTAINERS

The world wide effort that started in the sixties for finding a suitable container for canned products that is free of tin resulted in the birth of Tin Free Steel in Japan. The steel for TFS is produced in much the same way as steel for tinplate and has the same specification for gauge and temper. The deposition of either chromium / chromium-oxide or chromium/ phosphate on the surface is done both in cathodic and anodic-cathodic manner. The various TFS material differs mainly with respect to surface treatments
applied to the steel and the resulting differences in corrosion resistance, appearance and enamel adhesion (Anon, 1974).

Commercial developments of chrome-plated and chromate-treated steels for food cans began in Japan and material of this type are now being manufactured in Japan, Europe and Britain. Typical examples of these materials are; ‘Can Super’ made by Fuji Iron and Steel Co. Ltd., and ‘Hi-Top’ made by Toya Kohan. The US Steel Corporation has developed ‘TFS-210’ which is made by a cathodic chromate phosphate process (Mahadeviah and Gowramma, 1996 a).

Naresh et al. (1989) have reviewed on the chromium coated steel plate as an alternative to tinplate for canning food products and in this report they have reviewed the manufacture of tin-free steel, fabrication of TFS Cans and different properties of TFS and have compared the economics of TFS with aluminium and tin cans. Barbeiri et al. (1970) studied the suitability of various type of chromium-coated steel against tinned steel for packaging food product.

Rice (1992) reported that microwaveable steel cans have a number of benefits including ensuring a 2 year non-refrigerated shelf-life for products contained with in them and being easy to secure and stated that it may be problem for consumer acceptance because of seemingly placing metal in the microwave. A new easy to open all steel can (TFS) offered by Continental Can Company was introduced in U.S.A. during 1970 for canning of number of vegetable, meat and fish products (Anon, 1971). Pielchowska and Chrzanowski (1972) studied the suitability of tin-free steel cans for canning various fish products and compared with anodized aluminium and electrolytic tin plate cans. Hottenroth and Verpack-Rdsch (1972) studied the suitability of chromium plated
‘Ancrolyt’ for packaging fish products and compared with electrolytic tin plate and reported that over a period of one year chromium plated cans were found suitable for packaging slightly or moderately corrosive fish products of low acidity.

Different types of tin free-steel plates developed in Japan are as follows (Mahadeviah and Gowramma, 1996b).

**Can super** - this is manufactured by electroplating coled-rolled steel sheet with chromic acid. Bending, drawn and impact tests show that the coated material on the plate doesn’t peel off or flake. This type of container is used for mineral oils, gasoline tanks, paints, organic solution, dehydrated foodstuffs etc.

**Hinac coat**: - this is manufactured by treating cold-rolled steel strip with an emulsion containing chromic acid and an organic high polymer as main constituents with high-temperature baking for a short time. These types of containers have high corrosion resistance, supreme paintability great chemical and thermal resistance and good workability. It is used for packing sugar, cake, soap, motor oil, solvents, paint, ink electrical cases, crown caps, etc.

**Hi-top**: - the process of manufacture of this type of sheet was developed by Toya Kohan’s technical research in co-operation with its affiliated firm, Toyoseikan Kaisha Ltd., in Japan. Hi-top is a tin free steel sheet manufactured by treating electrolytically, cold-rolled steel strip with chromic acid. Container prepared by these types of sheet can be used for packing beer and carbonated beverages.

**Stainless weirchrome**: - this is a steel plate deposited electrolytically with metallic chrome on both sides. The chrome film coating ranges from 0.1×10 \(^{-6}\) to 0.5×10 \(^{-6}\) in thickness (0.1-0.5 micron in).