# SUITABILITY OF INDIGENOUS ALUMINIUM CANS AS AN ALTERNATIVE TO TIN CANS FOR FISH CANNING AND PROCESS TIME EVALUATION

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# CERTIFICATE

This is to certify that this thesis entitled "SUITABILITY OF INDIGENOUS ALUMINIUM CANS AS AN ALTERNATIVE TO TIN CANS FOR FISH CANNING AND PROCESS TIME EVALUATION" embodies the original work conducted by Mr.Ansar. Ali. A. under my guidance from 28.12.1999 to 30-04-2003. I further certify that no part of this thesis has previously been formed the basis of award of any degree, diploma, associateship, fellowship or any other similar titles of this or in any other university or institution. He has also passed the Ph.D qualifying examination of the COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY,Cochin held in October 2002.

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27-02-2004

# DECLARATION

I, AnsarAli,A. do hereby declare that the Thesis entitled "SUITABILITY OF INDIGENOUS ALUMINIUM CANS AS AN ALTERNATIVE TO TIN CANS FOR FISH CANNING AND PROCESS TIME EVALUATION" is a genuine record of bonafide research carried out by me under the supervision of Dr. T. K. Srinivasa Gopal, Principal Scientist, Fish Processing Division, Central Institute Of Fisheries Technology,Cochin-682029 and has not previously formed the basis of award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other university or Institution.

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# 1. INTRODUCTION

# 1. INTRODUCTION

The marine fish resources of India are vast. With Arabian sea on the west, Bay of Bengal on the east, both merging into the Indian ocean at the southern tip of Kanyakumari, Indian coastline stretches for 8,129 Kms. Over the years the seafood industry in India has recorded a phenomenonal growth and most of the expansion was accounted for by exports. India exported 424470 metric tonnes of seafoods worth 59570.5 million rupees in 2001-2002. Although there is a slight decline in the exports of seafood compared to 2000-2001, the trend of the decade shows it's increasing both in terms of quantity and value. Frozen shrimp is the largest single item exported from India.

Although a tremendous improvement in post harvest handling and operations has taken place in the seafood-processing sector in India, canning is perhaps the only area where there was a decline. There is a need for rejuvenating the Indian seafood canning industry when viewed from the standpoint of the growth of global fish canning industry. There is also an ever-increasing appreciation for canned fish products in the domestic front (Nair and Girija, 1996).

The existing canneries in India are operating only at about 5 % of their installed capacity. The indigenous demand for canned products is constantly on the rise. Defence requirements of canned fish alone accounts for about 450 Tonnes per annum. The demand from the Northeastern states for canned sardine and mackerel is assessed to be 500 tonnes per annum besides 300 tonnnes of canned tuna. While the existing machinery and equipments are idling canned products such as sardine, mackerel and tuna are enjoying wide spread acceptance in domestic as well as overseas market. In India, the future for canned seafood appears to be very bright in the super market culture where more people are interested in packaged and convenience foods.

History of development of canning as an important method of food preservation dates back to the late 1790's. Following the announcement by the French Government of a prize of 12,000 Francs and fame to any person inventing a useful method of food preservation, Nicholas Appert, a French confectioner developed a method of food preservation called 'appertization' and won the prize and fame (Benefactor of Humanity) in 1809. Appert started his studies on preservation of foods in 1795. During his studies he found out that foods remained safe for longer periods when heated in sealed containers. But he could not give a logical explanation to the process. However, it was believed that in some "magical and mysterious way" air combined with foodstuffs in a sealed container thus preventing its spoilage.

Since the introduction of appertization as a method of food preservation, the canning industry has witnessed a gradual and steady development. We can see that these developments have taken place by way of developing newer containers and their manufacturing technologies, development of new heat processing equipments and basic scientific work leading to the understanding of spoilage of food by microorganisms, their heat resistance characteristics and heat penetration into canned food. Tremendous achievements and scientific knowledge has generated through the last two centuries regarding the different aspects of canning. Several Scientists have contributed to the status quo of the thermal process technology. In 1920, Bigelow et. al. presented the first scientifically based graphical method for calculating minimum process conditions for sterilization. In 1923, Ball developed a mathematical model for determination of sterilization process. This was followed by a nomographic method for process determination by Ohlson in 1939. In 1957, Ball and Olson compiled the research findings of others including their own and published a book on heat sterilization. Since then, the technology continues to evolve and grow. Today, focus of the current developments has been geared towards increased efficiency in energy utilization and production, easy handling, more attractive packaging and better sensory quality (Durance et. al. 1997). At present, successful thermal sterilization process necessitates balancing the beneficial and destructive influence of heat on the desirable characteristics of food.

Thermal processing i.e. the application of heat energy for preservation of foods is the technique mainly responsible for the growth of food processing industry world over. It generally refers to a process during which a food product is subjected to high temperatures with the objective of inactivating undesirable microorganisms or enzymes.

Depending on the severity of the heat treatment, and the purpose of process, different thermal process regimes such as pasteurization and sterilization can be described (Lund, 1977). Pasteurization involves application of mild heat treatment with the purpose of inactivating enzymes and destroying spoilage vegetative microorganisms (Bacteria, yeasts and moulds) present in low acid foods (pH $< 4.6$). Alternatively, if the pH of the foods were high (pH$>4.6$), the main concern would be the destruction of the pathogenic microorganisms of public health risk. Such processes are referred to as commercial sterilization.

Tinplate cans are traditional containers for canned fish. The entire production of canned fish in India is at present in tin plate containers. However, almost the entire quantity of the cans used for processing fish is made of imported tin plate. High cost of the imported tin plate was one of the reasons for the collapse of the canned fish exports from India. India has one of the largest deposits of bauxite and can naturally become a world leader in aluminium production (Kothari, 1986, Srivatsa et. al. 1993). In India out of annual production of 3.5 lakh tonnes only about 10% is consumed by the packaging industry. The per capita consumption of aluminium in India is 0.41 Kg as against 27.5 Kg in USA and 16.2 Kg in Europe.

Aluminium container offers tremendous opportunities to take care of the packaging needs of the food-based industries like canned fish products. Besides the natural advantages like lightweight and corrosion resistance, the most important merit of aluminium is its recyclability. The present study was undertaken with the following objectives in mind.

- To find an alternative container to tin cans for fish canning.
- To reduce the cost of production of canned fish by using indigenously manufactured aluminium cans.
- To study the suitability of aluminium cans for heat processing of fish in various media.
- To standardize the heat penetration characteristics (Fo value and cook value) and process time of various canned fish products in aluminium cans
- To find out the shelf life of various canned fish products processed in aluminium cans.

# 2. STATUS OF CANNING INDUSTRY

# 2. STATUS OF CANNING INDUSTRY

Till the close of 1960 export of Indian marine products mainly consisted of dried items like dried fish, dried shrimp, shark fins, fish maws etc. The frozen items entered in the export basket in 1953 in negligible quantities. From 1961, the export of dried marine products was on decline and exports of processed items were making steady in progress. With the devaluation of Indian currency in 1966, the frozen and canned items registered a significant rise. These items continued to dominate the trade. Markets for Indian products spread fast to developed countries from the traditional buyers in developing countries.

Before 1960, the markets for Indian marine products were largely confined to neighboring countries like Srilanka, Myanmar, Singapore etc. This position continued as long as dried items dominated exports from India. When the frozen and canned items increasingly figured in our exports, the sophisticated affluent markets like USA, France, Australia, Canada, Japan etc become important buyers. Processing units with modern machinery for freezing and canning came up at all important centers to process and pack for exports.

Over the years, the frozen seafood markets for Indian marine products have witnessed changes. The USA was the principal buyer for our frozen shrimp for a long time but after 1977, Japan emerged as the principal buyer for frozen shrimp followed by the Western European countries. In the nineties South East Asian countries emerged as another important market due to the import liberalization in these countries.

## 2.1 Canning Industry in India- The past:

First canning factory in India was established in the year 1911 at a place called Chaliyam in the present Kozhikode district of Kerala. This had to be wound up after operation for about one and a half decades for several reasons like non availability of cheap containers, poor and uninterrupted supply of raw material, high processing costs and inability to compete with better quality imported products. The industry was later revived in India in the late fifties, mainly intended for canning of prawns for the export market. Export of this commodity started in the year 1959 which after touching the highest record of 2,200 tonnes worth Rs.52.4 million in 1973, recorded a step fall due to the very same reason that caused the closing down of the fist fish canning factory in the country. Thus the fish canning Industry in India is almost a dead industry.

### 2. 2. Major Products Exported

Among the canned marine products exported from India, shrimp was the most imported item. The other canned items are canned crabmeat, canned clam, canned tuna and canned fish. When offered in international trade, Indian shrimp are commercially classified according to different grade. The most common are:

| | |
|---|---|
| Super jumbo | <10 pcs/125 gm |
| Jumbo | 10-13 pcs/125 gm |
| Large | 13-20 pcs/125 gm |
| Medium | 21-34 pcs/125 gm |
| Small | 35-53 pcs/125 gm |
| Tiny | >53 pcs/125 gm |

**The major Indian canned fish products are**

- Shrimp in brine
- Sardine in oil
- Sardine in tomato sauce
- Tuna fillets in oil
- Tuna chunks in oil
- Marlin fillets in oil
- Marlin chunks in oil
- Smoked oyster in brine
- Smoked oyster in oil
- Sailfish fillets in oil
- Sail fish chunks in oil
- Pink perch in oil
- Pink perch in tomato sauce
- Red mullet in oil
- Red mullet in tomato sauce
- Mackerel fillets in oil
- Mackerel in brine
- Mackerel chunks in oil
- Swordfish fillets in oil
- Swordfish chunks in oil
- Smoked clam in oil
- Smoked clam in brine
- Smoked mussel in brine
- Tuna with green peas in oil
- Tuna with green peas in tomato sauce
- Tuna with mixed vegetables
- Tuna with beans in tomato sauce

## 2.3 International Trade on Canned Seafood

Global trade of canned seafood during 2001- 2002 worked out to be 9379 million US dollars. Export of canned seafood reached its zenith in 1997- 98, which was found to be 9476 million US dollars. The USA, UK, France, Japan, Germany and Canada were the leading importers. Thailand is the major exporter of canned fishery products and become the market leader by exporting 2069 million US dollars of canned seafood. China is the next dominating country with an export of 1336 million US dollars. Thailand and China accounts for about 33% of the total international trade of canned seafood exports. Other major players of canned seafood are Denmark, Canada, Spain, Republic of Korea, Germany, USA, France, Netherlands, Japan, Ecuador, Chile, Morocco and Norway. In 2000-2001 canned shrimp was the major traded canned fishery product. The value of the canned shrimp exported globally was about 1943 million US dollars in 2001 – 2002. Other major fishery products that was canned and exported in 2001- 2002 were canned tuna, canned river eels, canned mollusks, canned crab meat, canned crustaceans, canned European sardine and canned lobster tail or meat.

## 2.4. Status of Canning Industry in India

India exported very insignificant quantity of canned shrimp amounting to 3.5 tonnes valued at 4.4 lakh rupees in 1996. This quantity was less than 1 % of the total seafood exports of 3,53,675 tonnes during that year. There after no significant export of canned seafood has taken place. Most of the canned seafood production is going for the defence supplies and small quantity to the domestic market. In the fifties and sixties India exported sizable quantities of canned shrimp. Cost of tin plates can is highest in the world in India. Recently some companies have ventured into the indigenous manufacture of containers.

Among the canned marine products exported from India, shrimp was the most imported item. The other canned items were canned crabmeat, canned clam, canned tuna and canned fish. India has been exporting canned products to USA, UK, UAE, Russia, erstwhile Yugoslavia, Australia, France and Netherlands. Market surveys made by MPEDA have identified Hong Kong, Singapore, Philippines, Middle East and African countries as potential markets for canned fish. Canned sea foods like sardine, tuna, mackerel and anchoviella are acceptable in many markets abroad.

There are 25 canning units registered with MPEDA and are having a production capacity of 84 tonnes/day. Out of these only two units are well equipped and in good working condition. Except the canning plants run by the Lakshadweep department of Fisheries at Minicoy Island, Integrated Fisheries Project at Cochin and 3 units run by the private companies, all other units have been declared sick due to high cost of production.

The fish canning industry heavily banks on the indigenous Sulphur Resistance Lacquered three-piece tin cans; one of the factors affecting the growth of canning sector is the inadequacy of indigenous tin cans with respect to their quality and price. The quality of lacquer, the finish and diversity are elements essential to ensure shelf life and appeal the consumers. Gauge of the sheet used is often thicker than what is required, causing inconvenience in opening and adding to the total freight. Poor quality of lacquer often results in its peeling off leading to sulphide blackening and adds metallic taste to the product eventually reducing its appearance and flavour.

In India, the price of the can alone works out to nearly 30% of the cost. Added the cost of labels, cartons and other items this shoots up to 50% of the total product cost, making it ill affordable to the average Indian consumer and not competitive in most of the overseas market. It may be seen that countries where the can cost is reasonable are ruling the canned fish sector even on as imported raw material base. Its therefore, felt that Indian canning Industry should be essentially supported by adequate supply of suitable alternative cans at competitive rates.

### 2.5. Major Markets for Canned Fish

India has been exporting canned products to USA, UK, UAE, Russia, erstwhile Yugoslavia, Australia, France and the Netherlands. Market surveys made by MPEDA have identified Hong Kong, Singapore, Philippines, Middle East and African countries as potential markets for canned fish. Canned seafoods like sardine, tuna, mackerel and anchoviella are acceptable in many markets abroad.

### 2.6. Prospects of Reviving the Indian Seafood Canning Industry

By exporting canned seafood items we can earn foreign exchange not only for the product packed, but also for the packaging materials and additional labour involved in the pre processing, processing and packaging operations. Apart from the high cost of tin plate containers which were imported, the non-availability of small sized shrimp for canning purposes due to severe competition for such shrimps from the freezing sector was the main reason that caused sickness in the canning sector. Many countries import frozen shrimp from India and use the same as raw material for canning/ re processing etc and export to third countries as their products even now. This situation in raw material availability had changed to some extent. The over seas market for small sized frozen shrimp had fallen considerably owing to over supplies by our competitors who dumped cultured shrimp at cheaper prizes. The problem of non-availability of adequate quantities of small sized shrimp no longer exists and the industry has therefore to take advantage of this situation. Canned tuna is the other most sought out product in the global market. Although we had a very good tuna resource in our deeper waters we have not yet actively ventured for the oceanic tunas. By exploring the deep-sea tunas we can produce quality-canned tuna, which will fetch a high price, compared to raw tuna.

The availability of raw material at competitive or reasonable prices alone cannot be considered for reviving the canning industry. The cost of cans or packaging materials should be brought down to meaningful levels. The most common material used by the fish canning units in the country is tin plated steel commonly referred as tin plates, due to its strength, toughness and malleability. Although tin cans have a long usage in our fish canning industry-packing materials such as aluminium alloys and laminated aluminium foils need introduction in view of the fact that they are indigenously available and the bulk of the canned seafood consumed in the world is being packed in aluminium.

By revitalizing the canning industry, the country can establish a vast finfish based processing industry, where the raw material is available at a comparatively cheaper price. The fish like tuna, sardine, mackerel and others now being exported from the country to neighboring countries in the form of raw material could be canned with value addition with our sound infra structure and availability of relatively cheap labour. In this way prospects for developing as export oriented canning industry are very bright. Its relevant to draw examples from Maldives, Mauritius and Seychelles where massive canneries bank only on their rich raw material base and successfully run a global trade in canned seafood by heavily relying on imported material and expertise inputs.Although the Government of India has completely exempted the processed foods from excise duty but this has not helped much in boosting our processed food exports since the cost of packing processed food is about 30 – 40 % of the cost of the total pack.

One of the reasons attributed to the death of the canning sector is the technical complexity and the large scales of production required for profitability overcoming the high cost of production. Recent research findings offer enormous potential by the use of indigenous aluminum cans and retortable pouches; the initial results of such technological advances are encouraging. Another major factor that hampered the growth of our canned seafood sector was the quality problems like underweight, low quality container and corrosion, excess salinity in the brine etc. We were not able to compete with superior quality canned fishery products produced by Thailand. We should give more emphasis to the quality standards and ensuring the quality of the packed finished product. In the highly competitive global market, Indian seafood canning industry should be able to provide quality product at a reasonable price.

# 3. REVIEW OF LITERATURE

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

## 3.1. Evolution of Containers for Canned Foods

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

### 3.1.1 Glass containers

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

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

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

Table-1.The chronological events that contributed to the development of thermal processing

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

Glass jars are mainly used for home canning purposes and a new processing recommendation for home canned smoked fish in glass jars was made by Raab and Hilberbrad (1993). The adequacy of process time is important, as glass cannot be processed at high temperatures safely.

**3.1.2. Tin containers**

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

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

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

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

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

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

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

### 3.1.3. Tin-free steel cans

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

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

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

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

### 3.1.4. Retort pouches

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

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

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

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

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

(iv). There is 30 to 40 percent reduction in processing time.

(v). Less impairment of texture and flavouring particularly of fish and meat products due to reduced exposure to heat.

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

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

(viii). Consumers can easily open pouches.

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

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

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

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

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

(iii). Higher-packaging costs: Along with an outer carton the packaging cost goes higher than metal can.

(iv). Higher production costs: Higher-packaging costs along with low production makes the cost of production high.

### 3.1.5. Studies on aluminium containers:

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

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

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

Rigid containers have played very significant role over several years in food processing and build of consumer acceptance in several years. In India, presently tin containers have become a major constraint for the development and expansion of food processing industry due to spiraling cost as well as non-availability of containers from indigenous raw material (TIFAC, 1991; Srivatsa et. al. 1993). Alternate material for manufacturing rigid containers, in lieu of tin containers; have long been explored in various parts of the world (Leymarie1972). The most attractive and viable alternative material in India is aluminium and its alloys. Aluminium is abundantly available in the country as,India possesses 8% of the world's bauxite reserves (Kothari 1986, Srivatsa1993). In addition aluminium is very light, as it weigh 1/3$^{rd}$ of steel. The corrosion resistant of aluminium is excellent, as compared to that of conventional low carbon steel, and it also possess good mechanical properties (Nair and Girija, 1996; Srivatsa et. al. 1993; Lahiri, 1992; Ellis, 1981;Althen ,1965;Lopez and Jimenez, 1969) and recyclability.

### 3.1.5.1. Impact extruded containers

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

### 3.1.5.2. Drawn cans

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

A variant to this process is the drawn and redrawn process where the blank disc flows into a container of lesser circumference but of the same thickness when itpassed through a set of drawing operations. The alloys tried out in India are AA8011.

### 3.1.5.3. Three-piece cans

These cans/containers can be either mechanically seam welded or adhesive bonded. Mechanically seamed aluminum containers have been used for various applications.

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

### 3.1.5.4. Application fields of aluminium containers:

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

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

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

(iii). Fruit juices: Fruit juices commonly canned in aluminium cans lacquered with acid resistant (AR) lacquers. Citrus fruit juices can be stored in alloys AA3003, AA5052 and AA5086.

(iv). Jam/Jelly: Aluminium is resistant to some jams and with others there is a mild action. Lacquered aluminium containers are used for the packaging of jams. Aluminium is non reactive to jellies.

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

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

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

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

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

Lunde et al (1937) conducted mice feeding experiments with canned sardines packed in aluminium containers. Products contained 85-103 ppm aluminium. Rats fed for five generation under the same condition developed and reproduced normally. Chevillotte (1947) stated that although a small quantity of aluminium may dissolve in the food when some vegetables were canned in aluminium cans, its not harmful to the consumer. Hugony (1953) found out that foods and beverages in contact with aluminium foil or cans generally absorbed much less aluminium than their natural aluminium content. He also stated that vegetables should not be canned in bare aluminium containers if their pH is not above 5.2. Jacobsen (1944) found that spinach canned in aluminium containers depends upon the quality of the aluminium sheet, the amount of water-soluble oxalates in the spinach and storage temperature of the cans. Bauer (1944) stated that bare aluminium cans are not attacked by foods having a pH of 5.7-7.6. Jacobsen and Mathiesen (1946) reported that fruit jams are less corrosive to aluminium cans than fruits packed in sugar syrup. Corrosive action of canned fruits was greatly affected by storage temperature with both coated and uncoated anodized aluminum cans. Bramsnaes (1948) stated that internally varnished cans must be used with vegetables, especially those containing oxalic acid like spinach.

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

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

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

### 3.2. Methods of Fish Preservation

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

#### 3.2.1. Chilling

Short term preservation by chilling, is carried out using ordinary water and ice, although dry ice and chilled seawater are also used. The bacteria responsible for spoilage are psychrophilic, so even fish is chilled at 0°C under the best conditions of handling, bacterial quality can result in severe loss of quality approaching inedibility after14-16 days (Paine & Paine, 1992). Objective of chilling is to cool the fish as quickly as possible, to low temperature , with out freezing. Chilling cannot prevent the spoilage altogether, but in general, the cooler the fish, the greater the reduction in bacterial and enzymic activity (Clucas and Ward, 1996). Ice storage is relatively short-term method of preservation, with storage life varying between a few days to 4 weeks. Moreover proteins and some minerals and vitamins, are lost if the fish are washed or if they are stored in refrigerated or chilled seawater systems.

#### 3.2.2. Freezing

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

### 3.2.3. Vaccum packaging

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

### 3.2.4. Fish curing

The moisture content of the fresh fish varies between 75-80 %. Bacteria cannot survive if the moisture of the fish is reduced below25%. Below

15% moulds ceases to grow (Clucas & Ward, 1996). Drying can be carried out alone or in combination with salting and smoking.

#### 3.2.4.1. Drying

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

#### 3.2.4.2. Smoking

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

#### 3.2.4.3. Salting

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

### 3.2.5. Irradiation

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

### 3.2.6. High pressure processing

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

### 3.2.7 Canning:

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

- They need not or less need to prepare before consumption.

- Canned foods have got a very long shelf life compared to any other methods of processing.
- They can be store at ambient temperatures.
- Spoilage rate is very less since enclosed in airtight containers.

### 3.3. Different sizes of cans used commercially:

Various sizes of cans designated by different trade name are usually employed commercially for different varieties of foods. Details of the common sizes of cans used in the industry are presented in Table –2.

Table-2. Varieties of cans employed in the industry

| **Common name** | **Dimension** (the first fig. Indicates inches and the next two figures $16^{th}$ of an inch) |
|---|---|
| 8 ounce | 301 X 206 |
| 8 ounce tall | 211 X 304 |
| ½ Tuna | 307 X 113 |
| No.1.Picnic | 211 X 400 |
| No.1.Tall | 301 X 411 |
| No.1. Flat | 404 X 206 |
| No.1.Tuna | 401 X 206 |
| No.2 | 307 X 409 |
| No.2.Cylinder | 307 X 512 |
| No.2.Vaccum | 307 X 306 |
| No.2 ½ | 401 X 411 |
| No.3 | 404 X 414 |
| No.3.Cylinder | 404 X 700 |
| No.10 | 603 X 700 |
| No. Squat | 603 X 408 |
| | (Length X Breadth X Height) |
| ¼ Dingley | 404 X 302 X 014 |
| ½ Oval | 309 X 515 X 103 |
| ½ Oblong | 508 X 204 X 103 |

### 3.4. Canning Studies in Fishes

Thermal processing of foods has been one of the most widely used methods for food preservation during the 20th century and has contributed significantly to the nutritional well being of much of the world's population (Teixeira and Tucker, 1997). Two different methods of conventional thermal processing are known, the aseptic processing in which the food product is sterilized prior to packaging, and canning in which the product is packed and sterilized (Barbosa-canovas et al, 1997). Canning is defined as the preservation of foods in sealed containers and usually implies heat treatment as the principal factor in the prevention of spoilage (Frazier and Westhoff, 1978). Mostly canning is done in tin cans, which are made up of tin coated steel, other metals or glass containers are also used. The tin plate metal containers where called canisters from which term can is assumed to be derived (Derosier and Derosier, 1977).

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

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

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

Canned fish and other marine species are products of economic importance in many countries. Among the most common species, sardines, herring, albacore and other tuna fishes, mackerel, anchovy, mussel etc can be mentioned (Cheftel and Cheftel, 1976). Many studies relating to the pre cooking effect on the quality of canned products (Slabyj and True, 1978; Joshy and Saralaya, 1982) as well as those focusing on the fatty acid and lipid class composition of canned species have been carried out (Melwa et al, 1982; Hale and Brown, 1983). Changes in quality of canned fish have been investigated as a function of packaging method (Oliviera et al, 1986) and storage temperature (Pirazzoli et al, 1980).

Canned tuna is one of the most important fish products in many countries (Alimarket, 1992), supporting a significant market demand and playing an important role as component of diet. These products are considered of high nutritional quality because of their high proportion of ω 3-polyunsaturated fatty acids (Gallardo et al, 1989; Medina et al, 1995) which have shown potential benefit to human health, particularly in the prevention of cardio vascular diseases (Carrol and Braden, 1986; Leese and Karel, 1990).

### 3.4.1. Prawns

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

Chaudhari et al (1978) carried out a study to predict the drained weight of canned prawn under laboratory conditions. Bacterial spoilage of canned prawns has been reported by Nambiar (1980).

### 3.4.2. Mackerel

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

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

### 3.4.3 Sardines

As in the case of canned mackerel our canned sardines were mainly consumed by the defence personnel, comparatively smaller quantities being sold in the internal markets and exported to other countries. The method employed commonly is to dress and clean the fish, brine in 15% Sodium chloride solution for 15 minutes, precooking at 0.35 Kg/cm$^2$ steam pressure for 35-40 minutes, filling in cans followed by hot refined ground nut oil (90-95°C), exhausting, double seaming and sterilization at 0.84 Kg/cm$^2$ steam pressure for 70-75 minutes (Anon, 1964). Sardines can be preserved in ice for a period of two days prior to canning without materially affecting the overall quality of canned product (Madhavan et al, 1970). Srinivasan et al (1966) developed canning procedures for three species of sardines. The method involves dressing and cleaning of the fish, brining in saturated Nacl solution for 15- 20 minutes, packing in cans, cooking in flowing steam for 25-30minutes, draining of the cook drip, filling with hot refined groundnut oil at 100°C, exhausting, seaming and sterilizing at 0.7-0.84 Kg/ cm$^2$ steam pressure for 80-90 minutes.

Unnikrishnan Nair et al (1977) developed a process for canning smoked sardines. The process consists of cold blanching the dressed fish in 15% brine for 20 minutes and smoking the fish at a temperature of 45 ± 5°C. The smoked fish was then packed in 301X206 cans and cooked in steam at 0.7 Kg/cm$^2$ pressure. Refined groundnut oil, tomato sauce and dilute brine were added as filling media. The cans after filling with media were exhausted in steam, hermetically seamed in a double seamer and heat processed at 1Kg/cm$^2$ steam for 45 minutes. George et. al.(1985) studied the suitability of frozen oil sardine for canning. The fresh frozen sardines were found to be suitable for canning up to 10-24 weeks depending upon the season and initial quality.

Vijayan and Balachandran (1986) made an attempt to develop canned fish curry using sardine. Dressed and cleaned fish was cut into two third the size of the can and was blanched in 15% Nacl solution for 15 minutes at room temperature. The blanched fish was packed in S.R. lacquered cans and cooked for 30 minutes in steam at 0.35 $Kg/cm^2$ pressure. After draining the drip the curry media was added to the cans maintaining the proportion of fish to curry of 60:40.The cans were exhausted in steam for 10 minutes, seamed and heat processed in steam at 1.05 Kg/ $cm^2$ pressure for 60 minutes and cooled.

### 3.4.4 Tuna

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

A procedure for canning of three species of tuna viz skipjack (*Katswonus pelamis),* Yellow fin *(Neothunnus macropterus*), and big eye tuna *(Parathunnus obesus*) has been described by Madhavan and Balachandran (1971). In this process, the fish is precooked for such a period that the surface of the backbone attains a temperature of 93-94°C and solid salt containing 0.5% Sodium bicarbonate was added instead of the usual brining step.

Effect of pre-cooking of albacore tuna (*Thunnus alalunga*) has been studied by Gallardo et al (1989). In fish canning, precooking is a very important step to reduce water content. Aubourg et al (1990) adopted a canning method while studying the changes in flesh lipids and fill oils of albacore (*Thunnus alalunga*) during canning and storage. The eviscerated fish is precooked fora period so that the backbone attains a temperature of 65°C (90 minutes) , the fish were then cooled at room temperature (14°C) for about 5 hrs. Then 90 gms of fish were placed in OL-20 cans (105.1X64.7X 28.8mm) and soybean oil and salt (2gm) were added. The cans were vaccum sealed and sterilized in a retort at 115° C for 60 minutes. Gallardo et al (1990) followed the method of Aubourg et al (1990) with some variations. The fill weight was 82 gm instead of 90 gm in small flat rectangular cans (105x 65X29mm, 120ml) containing vegetable oil (35ml) and salt 2gm. The cans were vaccum sealed and sterilized in retort at 110°C, 115°C, and 118°Cfor 90, 55 and 40 minutes respectively. Medina et al (1998) canned frozen Atlantic tuna (*Thunnus alalunga*) by following the precooking and cooling method suggested by Gallardo et al (1990). Filling was done by using cooked white muscle in Ro-100 cans (6.52 cm dia X3cm height). 20 ml of 99.9% purity aqueous sodium chloride or 20 ml of oil with 2gm sodium chloridel was then added. The cans were then vaccum sealed and sterilized in retort at 115° C for 60 minutes.

### 3.4.5 Other fishes

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

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

Process development for canning of freshwater fish rohu (Labeo rohita) has been reported by Balachandran and Vijayan (1988). Different methods were adoptd to process rohu fish viz. (i) Cleaned fillets cut to size were packed in quarter dingly cans, sprinkled salt over it at 3% level and processed as natural pack, (ii) cold blanched the fillets in 15% brine for 10 minutes and then processed as natural pack. (iii) Cold blanched the fillets in 15% brine containing1% each of alum and citric acid for 10 minutes and processed as natural pack. (iv) Cold blanched the fillets in 15% brine for 10minutes cooked in steam at 0.35 Kg/$cm^2$ pressure for 30 minutes and canned in oil. (v) Same as the previous one and using tomato sauce. The cans were heat processed in steam for 25 minutes at 121.1°C.

The suitability of canning white sardine (Kowala kowal) was studied by Jeyasakaran and Saralaya (1981). The canning procedure of white sardine in natural pack, oil and brine were standardized. Blanching the product in saturated brine at room temperature for 6 minutes, precooking the product for 45 miniutes in steam at 100°C and sterilization at 115.6°C for

75 minutes. Heat processing of Kerala style fish curry in retortable pouches has been reported by Gopal et al (2001) and canning of fish curry in indigenous aluminium cans by Srivasta et al (1993).

**3.5. Heat Penetration and Thermal Process Evaluation:**

The practice of sterilization of foods in hermetically sealed metal containers has been researched extensively since 1920s. The theory and practise of establishing and evaluating thermal process for metal containers can be found in several sources (stumbo 1973; Lopez 1981;NFPA1982). The mathematical modeling of thermal processing has also been studied extensively and has been thoroughly reviewed (Hayakawa1977a; 1977b; 1978; Holdsworth 1985). The most widely used agent to accomplish food preservation is heat. The primary objective of thermal processing is to free the foods of micro organisms which might cause deterioration of the foods or endanger the health of persons who consumes the food (Stumbo1949). With respect to evaluating thermal process for foods important concerns are the effect of heat on bacteria and the rates of heating of the different foods during process and the mechanism of heat transfer within the food itself during the process.

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

### 3.5.1. Evaluation of the thermal process:

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

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

### 3.5.1.1. Mathematical methods:

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

Studies reported by Bigelow (1921) indicated that thermal death time curves, for certain important food spoilage bacteria, approximated straight lines when plotted on semi logarithmic paper- time being plotted in the direction of ordinates and temperature in the direction of abscissac. Ball's methods were based on the assumption that thermal death time curves are straight lines when plotted. Stumbo (1949) stated that the heating curves can be constructed by plotting, on semi logarithmic paper, temperature on the log scale and times on the linear scale are generally straight lines. However, instead of food temperature being plotted on the log scale and time on the linear scale, values representing differences between the retort temperature and food temperature are plotted.

Ball (1928) experimentally established that 42% of the " coming up time should be considered as process time at retort temperature. The slope of the heat penetration curve is represented by the symbol $f_h$ which is defined as the number of minutes required by the straight line portion of the heat penetration curve to travel one log cycle; $f_h$ is most easily ascertained by plotting the heat penetration data on semi log paper (Stumbo, 1949), though it may be calculated. Ball, (1928) introduced the symbol F to designate the time in minutes required to destroy an organism al 121.1°C (250°F). Stumbo (1948) discussed the concept regarding the effect of heat on bacteria with regard to the order of death when subjected to heat.

In the physico mathematical method, a time temperature profile imposed on the food is integrated to evaluate the impact of a thermal treatment on the parameter of interest. The exercise is carried out either to determine the F value for a given process time, or to calculate the process time for a given F value. F value is defined as the number of minutes at a specific temperature required to destroy a specific number of organisms having a specific Z value . The term Fo is designated when the process temperature is 121.1$^0$C and Z value of 10. The required information is the time temperature history of the product at the slowest heating point and fh and j values.

Numerous physico-mathematical methods are employed for thermal process evaluation, the universally agreed are i] the general method, which include graphical and numeric methods ii] Analytical methods and iii] Formula method. The General method was developed by Bigelow et al (1920). The Numerical method is normally used the trapezoidal rule or Simpsor's rule to calculate the area of irregular geometric figures

(Holdsworth, 1997). Today several formulae are presented by characterizing temperature response of foods to be sterilized. Depending on the approach to the solution of the problem, they can be classified in to theoretical and empirical formula. The first make use of analytical or numerical solution of theoretical heat equations, while the latter is based on heat penetration data. Hayakawa (1978) further divided formula in to two groups: First group comprised of methods that calculate the lethality of cold spore (Ball, 1923). Second group consists of methods that calculate mass average lethality for whole containers ( Stumbo ,1973; Hayakawa 1977). This grouping is similar to the thermocouple method commonly used to estimate lethality. In each case a hole is to be punched and thermocouple be installed at the slowest heating spot. From the time temperature profile of the cold spot of the container, the heating index fh, the lag factor jh and lethality of the process (Fo) can be calculated.

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

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

### 3.5.2. Order of death of bacteria and commercial processes:

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

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

Clostridium botulinum is the only bacterium known which produces highly heat resistant spores and is greatly significant from the standpoint of food consumption and public health (Stumbo, 1949). Many of the foods of low acid type will support its growth. If it were not destroyed by the thermal process it may grow in the foods and produce toxin which if ingested would generally prove fatal to the consumer. Therefore, knowledge concerning the maximum resistance of spores of Clostridium botulinum in food is extremely important to the establishment of adequate thermal processes for those foods, which will support its growth.

Esty and Meyer (1922) reported the results of studies in which the thermal resistance of many strains of Cl. botulinum had been determined. An ideal thermal death time curve for spores of Cl. botulinum in neutral phosphate solution was suggested. This curves was designated by the values of F=2.78 minutes and Z=18°F. Townsend et al (1938) reported corrected values for these factors namely, F=2.45 and Z= 17.6. The maximum resistance values reported by Esty and Meyer (1922) were obtained by suspensions containing billions of spores. The F value of 2.45 is higher than the F values generally reported by other workers for this organism (Townsend et al 1938, Tanner1944). These higher values are still employed as the basis for establishing commercial processes throughout the canning industry.

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

**3.5.3. Mechanism of heat transfer and process evaluation:**

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

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

### 3.5.3.1 Conduction heat transfer

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

$$Q = \frac{K\,(T_i - T_{ii})}{X}.\,At$$

Q = quantity of heat (J)

$T$ = Temperature in (K or °C),

i and ii refers to the two sides of the body.

$t$ = Time (s)

$X$ = Distance (m)

$A$ = Cross sectional area ( $m^2$ for heat flow)

$K$ = Thermal conductivity ($wm^{-1} K^{-1}$ )

### 3.5.3.2 Convection heat transfer

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

$$\mathbf{Q = hs\ A\ (Tb - Ts)}$$

$Q$ = Quantity of heat flow ( $Js^{-1}$)

$hs$ = Surface heat transfer coefficient

$A$ = Surface area ($m^2$)

$Tb$= Bulk fluid temperature (K)

$Ts$ = Surface temperature

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

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

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

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

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

The integrated sterilizing value of a process or Fo is the basis of comparison of thermal processes and the starting point in the design of a thermal processes. The sterilizing value of a heat process is obtained by integrating the lethal effect as the product is heated and then cooled. Three procedures have been developed for evaluating heat processes and Known as the general or graphical method (Bigelow et al 1920), the formula method (Ball1923, 1928) and the nomogram method (Ohlson and Stevens 1939). A simplified procedure for determining the sterilizing value has been discussed by Patashnik (1953) by Knowing the Z value and core temperature and determining lethal rate at equal time intervals.This method is ideal for routine analysis if the sterilizing value of heat processes.

### 3.6. Studies on The Reduction in Process Times

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

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

### 3.7. Studies on Microbial Spoilage and Sterility Tests:

Spoilage of heated foods may have a chemical cause or a biological cause or both. Biological spoilage of canned foods by microorganisms may result from either or both of two causes. First if the sealed container is not subjected to sufficient heat the contents are not effectively sterilized and so spoil on storage. This type of spoilage is known as under processing. The second type of spoilage is known as post process reinfection or leaker spoilage and it result when the contents of the can, having been effectively sterilized are subsequently reinfected by microorganisms from the surrounding environment gaining access to the contents through leaks in the sealed container (Nambiar 1980; Put et al 1972; Anon 1968; Jarvis1940).

Mild heat treatments may be only enough to permit the successful storage of the foods for limited periods with the help of refrigeration. Surviving microorganisms are likely to be of several kinds and may include vegetative cells (Bultiaux and Beerens 1955; Cameroon and Esty1940).

Acid foods such as fruits are processed at temperature approaching 100°C, treatments which result in killing all vegetative cell of bacteria, yeasts, moulds and their spores and some bacterial spores. Only survivors ordinarily are spores of bacteria which cant grow in a very acid food. Any survivors of heat treatment by steam under pressure are very heat resistant bacterial spores, usually one or two kinds (Frazier and Westhoff, 1998).

### 3.7.1. Post process contamination

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

### 3.7.2. Under processing

Many cases of food poisoning are associated in the literature with post process reinfection of canned food, and these cases include typhoid and staphylococcal food poisoning and intoxication due to Clostridium botulinum (Sandiford, 1954; Dickinson, 1959; Johnston et al, 1963; Foster et al, 1965). Reports have also appeared on the economic losses of the canned food products as a consequence of reinfection by non-pathogenic bacteria (Shapton and Hindes,1962; Everton et al, 1968; Bean and Everton, 1969).

Clostridium botulinum is an obligate anaerobe, which is widely distributed in nature and is assumed to be present in all products intended for canning. C.botulinum is a member of the genus Clostridium characterized as gram+ve, rod shaped endospore forming obligate anaerobe (Varnum and Evand, 1991). For low acid canned foods the anaerobic conditions that prevail are ideal for growth and toxin production of Clostridium botulinum. This organism is also the most heat resistant, anaerobic spore forming pathogen that can grow in low acid canned foods, and consequently its destruction is the criterion for successful heat processing of this type of product. The toxin is extremely potent but can be destroyed by exposing it to moist heat for 10 minutes at 212°F (Lund et al 1975). The severity and fatality rate of botulinum have been a significant worry to food processors and consumers since the late 1800 (Francis et al 1999). Clostridium botulinum type1 (proteolytic strains) and clostridium botulinum type 2 (non proteolytic strains) are responsible for human food borne botulism (Peck, 1997).

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

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

### 3.7.3. Commercial sterility

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

### 3.8. Storage Studies and Changes in Chemical Parameters:

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

The rate of quality deterioration of a food product, once it leaves the processing stage, is a function of its microenvironment namely gas composition, relative humidity and temperature (Taoukis and Labuza 1989). Where the gas composition and RH are usually relatively well controlled by appropriate packaging, the temperature of storage becomes the important controlling factor. Loss of shelf life in a food product is usually evaluated by the measurement of one or more characteristic quality parameters. These parameters can be physical, chemical, microbiological or sensory indices (Labuza 1982).

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

Hydro peroxides formed as primary products of lipid oxidation, are rapidly decomposed to produce a variety of secondary volatile compounds of low molecular weight. Aldehydes are the main volatile secondary products responsible for off flavours and odours during storage and treatment of foods (Frankel 1982,; Przbylski and Eskin1994). Medina et al (1999) suggested static headspace gas chromatographic analyses to determine oxidation of fish muscle, lipids during thermal processing. In many countries, the quality evaluation of canned seafood involves checks on net weight, vacuum, cleanliness, oil and brine content, overall condition, flavour, odour, texture, colour and the presence of specific toxic products.

Shelf life evaluation has been carried out for a variety of food products processed in aluminium can by different researchers. Jacobsen (1944) found that shelf life if spinach canned in aluminium containers depend upon the quality of the aluminium sheet, the amount of water soluble oxalates in the spinach and the storage temperature of the cans. Kemp (1958) found out that fruits and vegetables can be stored in aluminium cans up to 24 months at 70°F and for 12 months at100°F. When the pH is 5 or above simple enameling will result in a shelf life of 2-3 years at room temperature storage. For the more acid products such as fruits, the room temperature shelf life ranges from 12-18months (Taranger, 1956; Gotsch et a l 1958,1959). Lopez and Jimenez (1969) conducted shelf life evaluation for 22 different canned fruit and vegetable products packed both in enameled and uncoated aluminium cans.

Kluter et al (1996) evaluated the shelf life of Barlett pears in retort pouches. Minimum shelf life requirement prescribed by them are that the product should be acceptable after 36 months at 21°C and 6 months at 38°C. The pouches were kept at room temperature (23±3°C) until equilibration and sensory and biochemical analysis were done on a scale of quality (extremely poor=1; fair-5; excellent=9).

Storage studies in aluminium cans for a variety of Indian food products were conducted by Srivatsav et al (1993). The cutout examinations revealed good seaming integrity and satisfactory hooking of the lids to the body of the can. Storage studies were carried out, by storing the product at room temperature (19-30°C) and compared to those stored at 5°C.Results of chemical analysis of the stored product didn't show any significant change. Gopal et al (2001) reported a shelf life of one year at room temperature for the traditional kerala style fish curry processed in indigenous pouches. The curry remained sterile through out the storage period at ambient temperature. Sensory evaluation were carried out on a10 point hedonic scale with excellent=10 and unacceptable below4.

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

### 3.9. Optimization of Thermal Processes:

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

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

### 3.10. Studies on The Texture Properties:

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

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

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

# 4. MATERIALS AND METHODS

# 4. MATERIALS AND METHODS

## 4. 1. Machineries and Accessories:

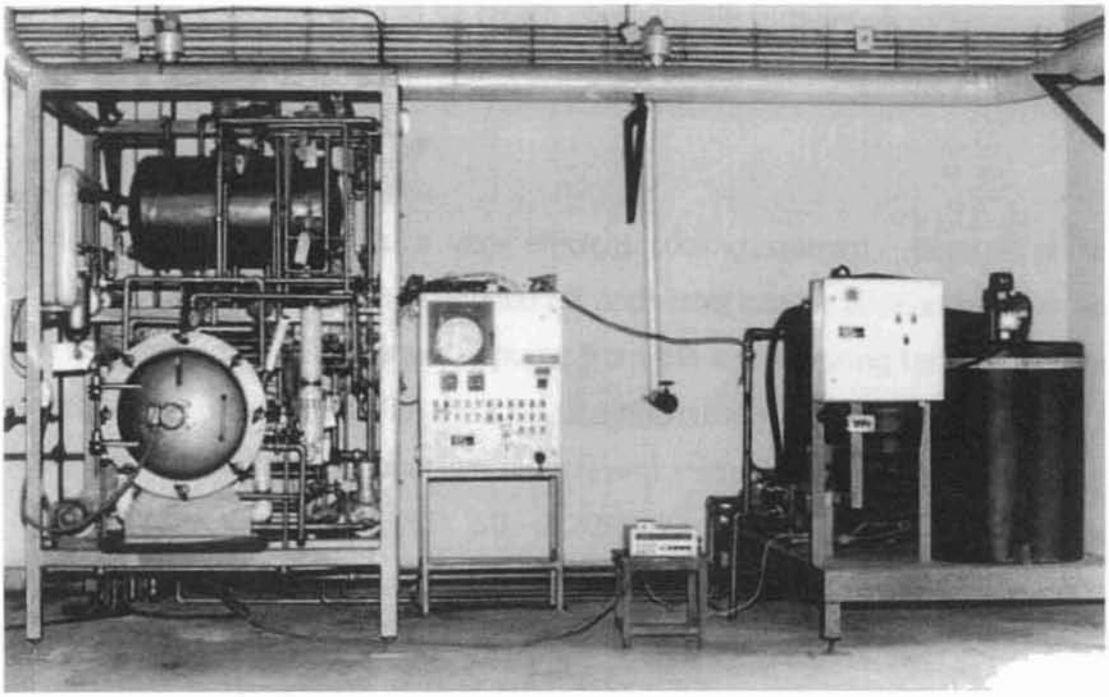
### 4. 1. 1. Pilot scale retorting unit:

The pilot scale mill wall model 24 rotary retorting system (John Fraser and sons Ltd, UK. Model.no.5682) was used for the experiments. This pilot scale retorting system performs laboratory scale thermal process in a manner which ensures close simulation with commercial scale equipment and which produces a high degree of process reproducibility and accuracy. Plate-1 shows The pilot retort used for the study.

The model 24 system for pure steam, steam /air and over pressure water immersion process comprises three major components; the retort, the receiver and the control system. The retort provides a chamber in which the product is subjected to the required thermal process. The receiver provides a pressurized volume to balance the overpressure in the retort during super heated water cooks and during overpressure cooling. The control system provides the means to sequence process events, regulate energy flows and document retort temperature and pressure.

Retort is constructed of mild steel and it can withstand a working pressure of 50 psig. It has got a dimension of 594mm inside diameter X 650 mm inside length on parallel portion. It has got a swing bolt type door with hinge on the left side. It has a standard square cage, which was perforated with side slots. The speed of rotation of cage ranged from 0 to 51 rpm and was electronically controlled. Instrument pockets are provided on the right side of the shell. These include pressure gauge, retort thermometer, pockets for thermocouple glands and petcock at the rear end. Sparge pipes are provided on the retort. They are four

**Plate-1**



Overpressure autoclave (John Fraser Ltd, Model 24 Rotary Pilot Scale Retorting System) n number and provide on the bottom and top, left and right. Number of holes are 43 per sparge in 3 rows. The holes are of 4mm diameter. A water gauge is provided on the right hand side of the retort, the gauge bottom indicates retort half full and the gauge top indicates retort is full. A pressure relief valve is provided on the retort which gas got a size of 1"and it will release if the pressure is above 55 psig. The pressure gauge, which is provided on the retort, has got a range of 0 to 60 psig. A 4-blade stainless steel fan is fitted to the retort for use during processing. The fan is designed to run at 1500 rpm and to displace in the order of 500 CFM free air and so create considerable turbulence within the retort during processing to ensure well mixing of steam and that no stagnant air pockets are allowed to exist.

The retort is connected to a very efficient cooling system. As soon as the process is over steam can be switched off and water can be allowed to enter into the retort with the help of a water pump from the water-storing tank. The same water can be recirculated with the help of a recirculating pump. This will provide a very efficient cooling mechanism by spraying water from the top of the retort. A high specification Myson MSK 50 –2/2090 pump suitable for use with super heated water up to 130°C is fitted to recycle water through the retort.

The receiver is also constructed of mild steel and has got a working pressure of 50 psig. The dimension of the receiver is 594mm inside diameter X 850 mm on parallel side. It has got a water gauge with the gauge top indicates the receiver is full and the gauge bottom indicates receiver below over flow level. It has got a pressure relief valve and the setting is on 55 psig. It also has got a pressure gauge with a range of 0-60psig. The pressure in the receiver is hydraulically and pneumatically transmitted to the retort at the points in the sequence when the retort is required to be at over pressures. Two modulating valves control the receiver pressure, one regulates air into the vessel and the other acts on the vent and regulates air out. The controller is designed with a dual output to perate the system. The pressure control valve is connected to the vent valves n the receiver and so the transfer line between the two vessels must be open then the pressure is controlled from the sensor mounted on the retort.

Networks of pipes are provided for the entrance of the steam, air and water into the retort and also discharge of the steam, air and water from the retort. All pumps are on the left side and the hand valves are on the right hand side. Incoming services are on the rear left, between upright members and outgoing discharges is on the rear center and right between upright members. Safety valve discharges are on the rear, between upright members and then to local drain.

The control systems specification sequence of all aspects of the retort operation is performed manually but with assistance from discrete electronic controllers on retort temperature and receiver pressure. The controllers and a number of other components are integrated into a PLC managed safety system.

The control system has got a digital temperature indicator and pressure indicator. A digital three-pin circular chart recorder is fitted to record retort temperature and pressure and receiver pressure. A eurotherm digital indicator is fitted to display cage rotation speed. The instrument is connected to the 0-10 V output of the motor control unit and is scaled for 0-51 rpm. A digital electronic timer is provided to assist the timing of the cook period. The timer is integrated into the PLC monitor system and is used to prompt the operator to begin cooling. A Mitsubishi FI series 60 I/O Programmable Logic Controller is provided to monitor system safety. The PLC observes retort door interlocks and temperature and pressure alarms and acts upon the automatic valves pump and cage drive.

A set of 23 valves is fitted to isolate and regulate the services to and interconnections between the two vessels. Four styles of valves are fitted; they fall into two categories, automatic and manual. The automatic valves include modulating valves on retort system receive air and receiver vent, air line link to the receiver and retort steam line and the transfer line between the retort and the receiver. The manual valves are all globe valves for local service isolation. Water flow direction, vent, drains, bypasses and safety transfer valve.

### 4. 1. 2. Ellab CTF 9008 Precision Thermometer and Fo- value computer:

Temperature range of the instrument is –100.0 to +350.0°C . Resolution of the instrument is 0.1°C. There are 8 channels with selective functions for product ($T_c$) and chamber ($T_a$) temperatures. These 8 channels are updated within 4 seconds with each channel getting updated within 30 seconds. The Fo constants are programmed T=121.1°C, Z=10°C and Cook value constants T=100°C, Z=33°C. The print out interval from the instrument can be selected and it varies from 30 seconds to 60 minutes. The print out shows Tc and Ta min/max, peak temperatures, channel numbers and the actual process time they were measure and the corresponding Fo and Cook value value of each channel.

### 4. 1. 3. Can punch:

Ellab TC 89 can punch for rigid containers were used for making holes to fit thermocouple glands into the can.

### 4. 1. 4. Packing glands and accessories:

Ellab GKM-13009-CXXX packing glands for all kinds of containers for used for the experiments. The GKM is as standard delivered with a GKM-U rubber oring. For special applications it can be used with wedge washers and silicon washers. Packing glands are usually made up of brass, stainless steel or polyoxymethylene.

### 4. 1. 5. Standard Thermocouple Probes

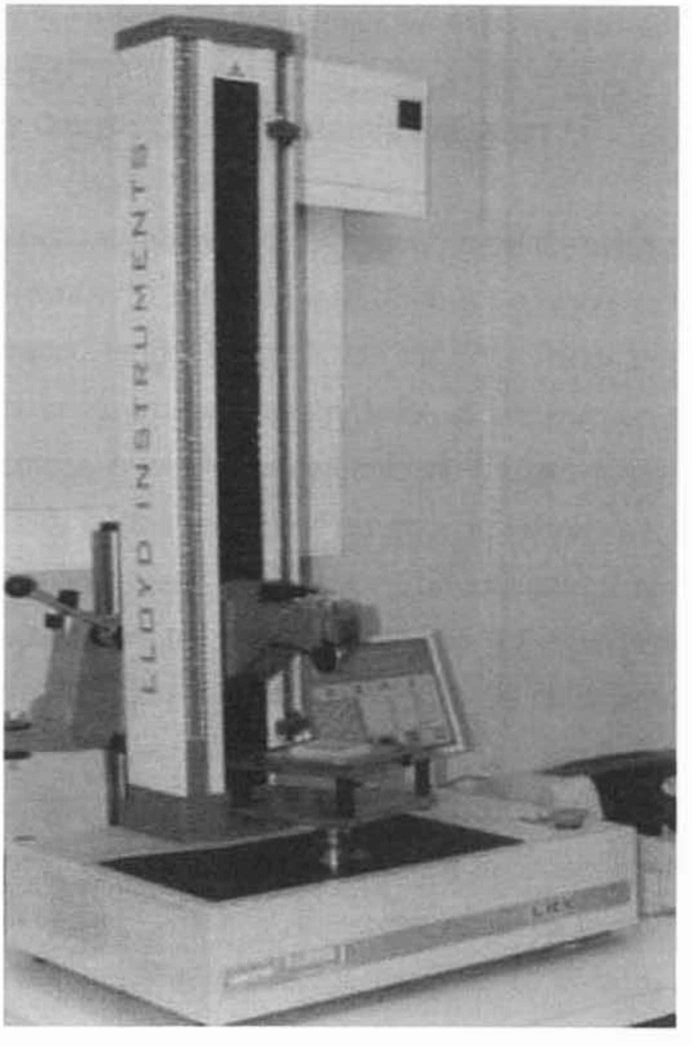
The probes used for the experiments are that of Ellab SSA- 12050-G700-TS stainless steel electrode with a length of 50mm, diameter 1.2mm and SSA-12100-6700-TS-stainless steel electrode with a length of 80mmXdiameter 1.2mm. These probes are copper/cupronickel thermocouples; they are sealed probes with the conductor being insulated from the process medium. The pouches are E.M.F. characteristics corresponding to the probe output voltage of Cu/Cu Ni thermocouples.

### 4.1. 6. Food Texture *Analyzer*:

It is a general-purpose material-testing machine manufactured by Lloyd instruments, UK (Model LRX plus). The software used in the instrument is Nexygen. When used with Nexygen software, data output is to a computer display and printer. The main part of the instrument is a load cell. Standard cells are there with values of 5000 N, 500N and 50 N and each one can be used depending on the type

The LRX plus machines are fitted with two magnetically activating limit stops. Reaching magnetically activated limit stop will result in the machine stopping. The speed of the cross edge movement varies from .01-1016mm/min. The unit has a liquid crystal display (LCD) to show set up information, load and extension values and a key pad to input information for operating the machine when under the control of the console. The operating status of the machine is shown on and described on the display. The display, which has 4 lines of forty characters, is

**Plate-2.**

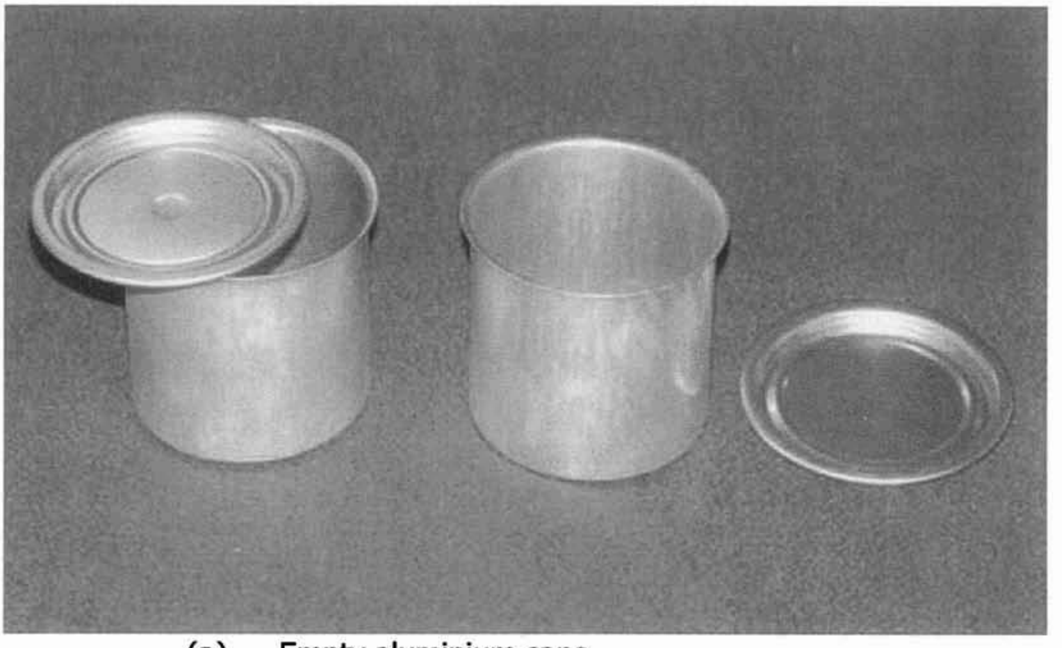



Food Texture Analyzer Used for the study used to show or request information. The information displayed depends up on the status of the machine but generally; the top line displays title or help information for each display. The lower lines are split into four blocks, one block above each soft key to indicate the function of the key.

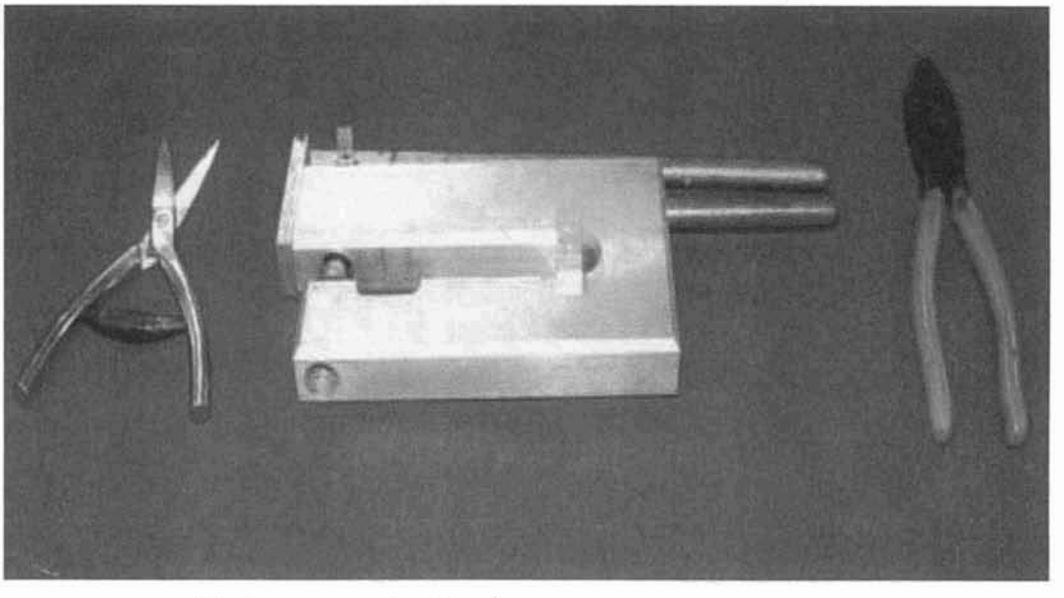
### 4.1.7. Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES):

ICP-AES is an important analytical technique in multi- elemental analysis demonstrated by Greenfield 1964 and Fessel1965. It's a highly sensitive method permitting concentration range, varying from major to minor trace levels with equal facile. Plasma emission spectrometry involves introduction of the sample into an excitation source in which the determinant is converted to trace atoms. These are then raised, by the energy of the source, into an excited state and emit radiation at a characteristic wavelength. The intensity of emission at that wavelength is proportional to the concentration of the determinant and quantification involves isolation and measurement of the radiation of interest in a spectrometer. In the model used fpr the study (Lab Tam 8410 plasma scan) the monochromator is an optical filter driven by a computer controlled stepper motor to locate the different optical emission lines. Photo multiplier tubes convert the light into electrical energy, which is then converted to digital data by the computer. Slimpac is the software package designed to control, organize and manage the data.

**Plate3**

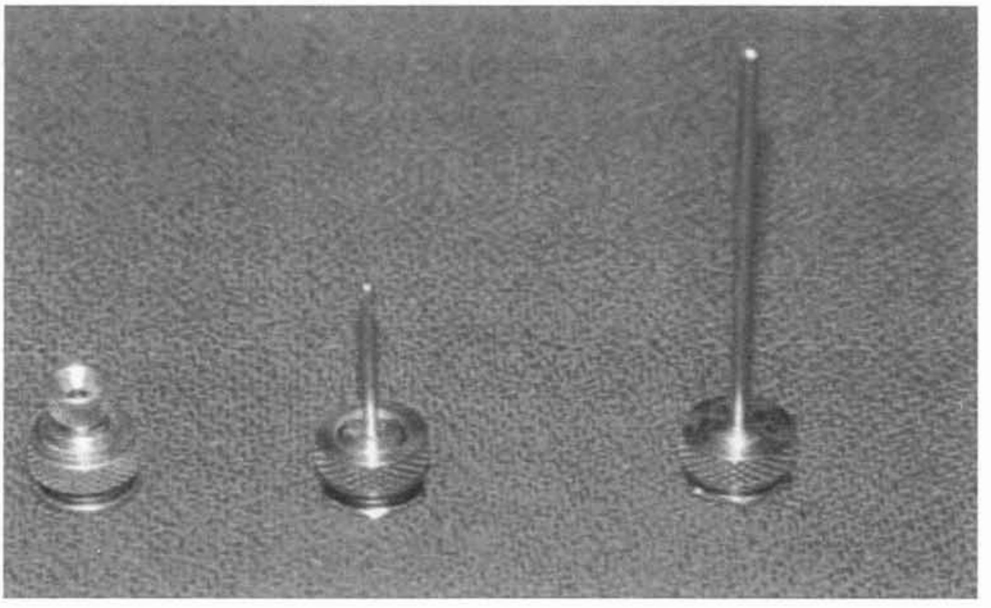


(a) Empty aluminium cans

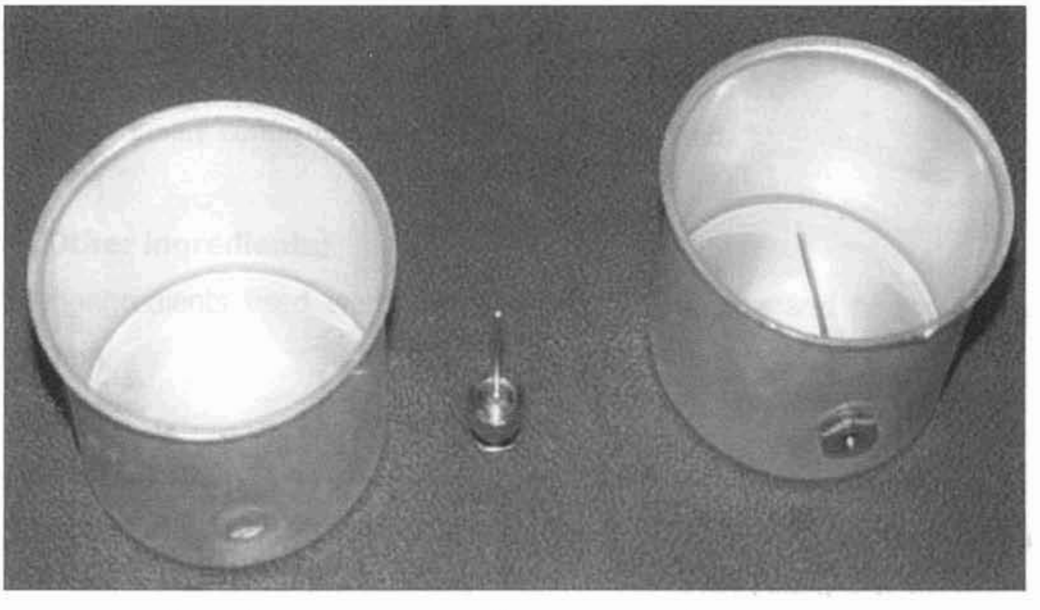


(b) Cutting tools for aluminium cans

**Plate-4**



(a) Different types of themocouples



(b) Aluminium cans fitted with thermocouple

## 4. 2. MATERIALS:

### 4. 2. 1. Aluminium cans:

M/s. Klass Engineering Pvt. Ltd., Bangalore, manufactured aluminium cans used for the study. It was a two-piece drawn can of 8 oz capacity (301X206). It was internally lined with sulphur resistant lacquer coating. The lacquer coating was done by spray coating by the manufacture.

### 4. 2. 2. Fishes:

Fishes used for the study were yellow fin tuna (*Thunnus albacores*) and Mackerel (*Rastelliger kanagurta*). Fishes were obtained from the Polakandam fish market, Thoppumpady; Cochin. Fishes were purchased according to the requirement and brought to the laboratory in iced condition.

### 4. 2. 3. Oil:

Double refined ground oil was used for filling the cans and also used for the curry preparation.

### 4. 2. 4. Salt:

Salt of edible quality confirming to IS: 594-1962 was used.

### 4. 2. 5. Other ingredients:

All other ingredients used were clean, sound, wholesome and fit for human consumption.

### 4. 2. 6. Fish Curry

Ingredients used for the fish curry preparation is presented in the table-3 and the curry was prepared by the following method. Chopped Onion was ground in a mixer and was heated in refined groundnut oil till the colour become light brown. Chopped ginger and green chilies were also fried. Chopped tomato was made into a paste and boiled. Malabar Tamarind was boiled in one litre water and the clear solution was added to the tomato paste and again boiled. Turmeric powder, chilly powder, powdered fenugreek and coriander powder were added to the onion-ginger-green chilly mixture and fried gently. To this mixture the tomato paste was added. Potable water was added to adjust the consistency of the curry.

Table-3.

**Ingredients used in fish curry**

| **Ingredients** | **Quantity** |
|---|---|
| Dressed fish | 1000 g |
| Onion | 50 g |
| Garlic | 15 g |
| Ginger | 25 g |
| Green chilly | 25 g |
| Coriander powder | 20 g |
| Chilly powder | 60 g |
| Turmeric powder | ½ tsp |
| Fenugreek | ¼ tsp |
| Malabar Tamarind | 100 g |
| Tomato | 150 g |
| Salt | 20 g |
| Water | 1000 ml |

## 4. 3. Methods:

### 4. 3. 1. Determination of moisture:

A known weight of sample (10 gm) was weighed in a preweighed clean petridish on an electronic balance. The samples were allowed to dried until uniform weight by placing in a hot air oven at 100°C for 6 hrs. Then cooled in a desiccator and weighed. The moisture content was calculated and expressed as percentage (AOAC, 2000).

### 4. 3. 2. Determination of ash content:

About 1-2 gm of the sample was transferred into a preweighed silica crucible. The samples were then charred by placing in a muffle furnace at 550°C for 4 hrs until a white ash was obtained. Crucibles were weighed after cooling in a desiccator and percentage of ash was calculated. (AOAC, 2000)

### 4. 3. 3. Estimation of crude fat:

About 2-3 gm of accurately weighed moisture free sample was taken in a thimble plugged with cotton and extracted with petroleum ether (40-60°C boiling point) in a soxhlet apparatus for about 10 hrs at a condensation rate of 5-6 drops per second. Excess solvent was evaporated and the fat was dried at 100°C to constant weight. The crude fat was calculated and expressed as percentage. (AOAC, 2000)

### 4. 3. 4. Determination of crude protein

About 0.5- 1 gm of the minced sample was transferred into a Kjeldahl flask of 100 ml capacity. A few glass beads and a pinch of digestion mixture and 10 ml of concentrated sulphuric acid were also added. It was digested over a burner until the solution turned colourless. To the digested and cooled solution distilled water was added in small quantities with intermittent shaking and cooling until the addition of water generated heat. It was transferred quantitatively into a100 ml standard flask and made up to the volume. With a 2 ml pipette made up solution was transferred to the reaction chamber if the Micro-Kjeldahl distillation apparatus.2 drops of phenolphthalein indicator and 40% sodium hydroxide were added till the indicator changed to pink. Distillation was done for 4 minutes and ammonia liberated was absorbed into 2% boric acid containing a drop of Tashiro's indicator. The amount of ammonia liberated was determined by titration with 0.01 N standard sulphuric acid. Crude protein was calculated by multiplying total nitrogen content with conversion factor of 6.25 and expressed as percentage (A.O.A.C, 2000).

### 4. 3. 5. Test for Lacquer:

The lacquer was found not extractable with any of the solvents normally used. Therefore the lacquer coating thickness was determined by dissolving out the metal of a known weight and area in concentrated HCl and then weighing the lacquer film after washing it free of acid and then drying it. Tests for phenolic and epoxy resins were also done (Anon, 1992).

### 4. 3. 6. Air pressure test:

Air pressure test was done according to IS: 9396 (1979). A valve for pumping the air was previously fixed to the can by making a hole with the help of can punch. Then with an air pump air was pumped into the can through the valve when the can was immersed in the water. When the air pressure inside the can reached 25 psig pumping of air was stopped and observed for any leakage of the can.

### 4. 3. 7. Resistance to Sulphur Staining and Impermeability:

Aluminium cans were cut into pieces of 50 x 50 mm and edge of the cut pieces were coated with a suitable protective materials (nail polish) and some panels were uncoated to test whether blackening was there or not. These panels were placed inside the open top Sulphur resistant Lacquered tin cans. About 100 g of chopped fresh cauliflower was added into the can and filled with 2% hot brine leaving a head space of 6 mm. The can was seamed and heat processed in steam at 121.1°C for 2 hours. After processing and cooling in water, the cans were stored at room temperature for 48 hours before examination. (IS: 5818-1970)

#### 4. 3. 8. Test for suitability of can for food contact applications:

Suitability of the can for food contact application was found out by determining the water extractives at 121°C for 2 hrs and soluble chloroform extractives as per the methods of FDA (1983).

The cans were filled with 200ml of hot glass distilled water and immediately heat-sealed. The sealed cans were heat processed at 121.1°C for 2 hrs. After processing the processed water was transferred into clean beakers and evaporated up to 50ml.The contents of the beaker were transferred into another clean pre weighed tared platinum dish and evaporated to dryness. After cooling the weight of the dish is again taken to the nearest 0.1 mg to find out the amount of water extractives. To those dishes containing water extractives 50 ml of chloroform is added to dissolve all the chloroform extractives. The contents are filtered and evaporated to dryness in a clean pre weighed tared platinum dish. After drying the weight of the dish is again taken to the nearest 0.1 mg to determine the amount of chloroform extractives.

#### 4. 3. 9. Cut out analysis:

Cut out analysis was carried out to find out the seam integrity (Balachandran,1993). Samples were cut from the can and the seam length (L), seam thickness (T), and the countersink depth (CS), were determined using a micrometer. Body hook, cover hook, body thickness ($t_b$), and the end plate thickness ($t_c$) were also measured. Percentage overlap was calculated based on the above observations using the following equation.

$$\text{Overlap} = \frac{BH + CH + 1.1tc - L}{L - (2.2tc + 1.1tb)}$$

Where

BH = body hook length

CH = cover hook length

tc = cover plate thickness

tb = body plate thickness

L = seam lenth.

### 4. 3. 10. Determination of Vacuum

The vacuum in the can was determined with a vacuum gauge of the piercing type (IS: 3336-1968).

### 4. 3. 11. Canning of tuna in oil

Freshly collected yellow fin tuna (Thunnus albacores) of size 80±5 cm were used for the study. Fresh fish were collected from the fish market and brought to the laboratory in iced condition. After removing the head, gut and fins it was kept in running water for bleeding. After thorough bleeding, fish was precooked in steam at 10 pounds pressure for 90 min, cooled and kept at 10°C in the chill room overnight. Bones and red meat were removed from the precooked cooled fish and uniform pieces of 1.5 inches length were cut. The cans are thoroughly washed to remove adhering impurities and dried well to remove traces of water. Then cans are filled with 140 gms of tuna meat, 2.5% salt was sprinkled over and 60ml of hot refined oil was added. The filled cans were then steam exhausted in free flowing steam for 10-12 min and immediately double seamed in a seaming machine. The filled and sealed cans were thermally processed to the required Fo values at 121.1°C. At the end of the process cans are cooled immediately. The cooled cans are dried, labeled and stored.

### 4. 3. 12. Canning of tuna in brine:

Freshly collected yellow fin tuna (Thunnus albacores) of 80±5 cm size were used for the study. Fresh fish were collected from the fish market and brought to the laboratory in iced condition. After removing the head, gut and fins it was kept in running water for bleeding. After thorough bleeding, fish was brined in 10% brine for 15 minutes and precooked in steam at 10 pounds pressure for 90 min, cooled and kept at 10°C in the chill room overnight. Bones and red meat were removed from the precooked cooled fish and uniform pieces of 1.5 inches length were cut. The cans are thoroughly washed to remove adhering impurities and dried well to remove traces of water. Then cans are filled with 140 gms of tuna meat and 60ml of 2.5% hot brine solution were added. The filled cans were then steam exhausted in free flowing steam for 10-12 min and immediately double seamed in a seaming machine. The filled and sealed cans were thermally processed to a Fo value of 10 at 121.1°C. At the end of the process cans are cooled immediately. The cooled cans are dried, labeled and stored.

### 4. 3. 13. Canning of tuna in curry:

Freshly collected yellow fin tuna (Thunnus albacores) of 80±5 cm size were used for the study. Fresh fish were collected from the fish market and brought to the laboratory in iced condition. After removing the head, gut and fins it was kept in running water for bleeding. After thorough bleeding it was then cold blanched in 10% brine for 15 minutes. The cold blanched fish was precooked in steam at 10 pounds pressure for 90 min, cooled and kept at 10°C in the chill room overnight. Bones and red meat were removed from the precooked cooled fish and uniform pieces of 1.5 inches length were cut. The cans are thoroughly washed to remove adhering impurities and dried well to remove traces of water. Then cans are filled with 140 gm of tuna meat and 60ml of hot curry medium were added.

The filled cans were then steam exhausted in free flowing steam for 10-12 min and immediately double seamed in a seaming machine. The filled and sealed cans were thermally processed to a Fo value of 10 at 121.1°C. At the end of the process cans are cooled immediately. The cooled cans are dried, labeled and stored.(IS: 10273,1983).

**4. 3. 14. Canning of Mackerel in oil:**

Freshly collected Mackerel (*Rastelliger kanagurta*) of size 17±3 cm size were used for the study. Fresh fish were collected from the fish market and brought to the laboratory in iced condition. The head, tail tips, fins and entrails were removed from the fish. Black tissue or membrane adhering to the flesh were also removed. Fishes were then cut into three uniform pieces and washed well in chilled water. The fish pieces were then blanched in 10% brine for 15 min and precooked in free flowing steam for 30 min. and cooled thoroughly to remove water. Cans are thoroughly washed to remove adhering impurities and dried well to remove traces of water. Then cans are filled with 140 gms of fish pieces, and 60ml of hot refined oil was added. The filled cans were then steam exhausted in free flowing steam for 10-12 min and immediately double seamed in a seaming machine. The filled and sealed cans were thermally processed to the required Fo values at 121.1°C. At the end of the process cans are cooled immediately. The cooled cans are dried, labeled and stored. (IS: 2420-1971).

**4. 3. 15. Canning of mackerel in brine:**

Freshly collected Mackerel (*Rastelliger kanagurta*) of 17±3 cm size were used for the study. Fresh fish were collected from the fish market and brought to the laboratory in iced condition. The head, tail tips, fins and entrails were removed from the fish. Black tissue or membranes adhering to the flesh were also removed. Fishes were then cut into three uniform pieces and washed well in chilled water. The fish pieces were then blanched in 10% brine for 15 min. Cans are thoroughly washed to remove adhering impurities and dried well to remove traces of water. Then cans are filled with 140 gms of fish pieces, and 60ml of hot brine solution were added. The filled cans were then steam exhausted in free flowing steam for 10-12 min and immediately double seamed in a seaming machine. The filled and sealed cans were thermally processed to a Fo value of 9 at 121.1°C. At the end of the process cans are cooled immediately. The cooled cans are dried, labeled and stored. (IS: 3849-1976)

### 4. 3. 16. Canning of mackerel in curry:

Freshly collected Mackerel (*Rastelliger kanagurta*) of 17±3 cm size were used for the study. Fresh fish were collected from the fish market and brought to the laboratory in iced condition. The head, tail tips, fins and entrails were removed from the fish. Black tissue or membranes adhering to the flesh were also removed. Fishes were then cut into three uniform pieces and washed well in chilled water. The fish pieces were then blanched in 10% brine for 15 min. Cans are thoroughly washed to remove adhering impurities and dried well to remove traces of water. Then cans are filled with 140 gms of fish pieces, and 60ml of hot curry were added. The filled cans were then steam exhausted in free flowing steam for 10-12 min and immediately double seamed in a seaming machine. The filled and sealed cans were thermally processed to a Fo value of 9 at 121.1°C. At the end of the process cans are cooled immediately. The cooled cans are dried, labeled and stored. (IS: 9319-1979)

**Plate-5**


Aluminium cans after processing

### 4. 3. 17. Determination of cold spot:

Thermocouple glands were fixed at different position of the cans filled with liquid and solid to determine the cold spot. Glands were fixed at the extreme bottom, one-third from the bottom, one half from the bottom and one-fourth from the bottom of the cans. Thermocouples were pierced through the glands to the product and the heat penetration determined with the help of Ellab data recorder.

### 4. 3. 18. Heat penetration studies:

Heat penetration studies were done for tuna in oil, tuna in brine, tuna in curry, mackerel in oil, mackerel in brine and mackerel in curry. Tuna products filled in aluminium cans were heat processed to different Fo values; 5, 7 and 10 in the case of tuna in oil and to Fo 10 in the case of tuna in brine and tuna in curry in a stationary retort. And the mackerel products filled in aluminium cans were heat processed to different Fo values; 5, 7 and 9 in the case of mackerel in oil and to Fo 9 in the case of mackerel in brine and mackerel in curry. Before filling the cans, a packing gland is fixed at about one third from the bottom of the can. Then the thermocouple is pierced to the product through this packing gland. Processing were done at 121.1°C in an over pressure autoclave (John Fraser and sons Ltd, Model. No 5682). In the next stage cans filled with tuna in oil and mackerel in oil were subjected to different rotational speeds (2,4 and 6 rpm) by the rotation of the cage of the retort to study the effect of rotation on heat penetration.

The thermal data were taken by inserting thermocouple needles into the product. Thermocouple output was measured by using an Ellab CTF 9008 data recorder. Time–temperature data were taken at an interval of one minute and the print out was taken. The recorded data were analyzed using a computer. The heat penetration data were plotted on a semi log paper with temperature deficit (RT-CT) on log scale against time. Lag factor for heating ($J_h$), slope of the heating curve ($f_h$), time in minutes for sterilization at retort temperature (U) and lag factor for cooling (Jc) were determined. The process time was calculated by mathematical method (Stumbo, 1973). The graph for Fo value, cook value, retort temperature and product temperature were drawn from the time-temperature data. Actual process time is determined by adding process time (B) and the effective heating period during come up time i.e. 42% of the come up time.

**4. 3. 19. Sterility test:**

The thermally processed samples to different Fo were incubated at 37°c for 15 days. The incubated cans were aseptically opened and 1-2 gms of the samples were taken by a sterilized forceps and inoculated into the sterilized fluid thioglycolate broth in test tubes. Little sterilized liquid paraffin was put on to the top of the broth and incubated at 37°C for 48 hrs and at 55°C for 4 days (IS: 2168-1971).

**4. 3. 20. Shelf life studies:**

Tuna in oil, tuna in brine and Tuna in curry medium were heat processed to Fo10 and mackerel in oil, mackerel in brine and mackerel in curry were heat processed to Fo 9 and stored at room temperature and at 37°c to determine the shelf life. The canned products stored at room temperature and at accelerated temperature were periodically analyzed by chemical methods like Thiobarbituric acid (TBA) value, . pH and by sensory methods.

**4. 3. 21. Teture profile analysis:**

Instrumental Texture Profile Analysis was carried out Using a Food Texture Analyzer (Model LRX plus). The test was done at a speed of 12mm/second using 500N load cell. The probe used for the experiment was a 50 mm diameter cylindrical probe. The samples were allowed for a compression of 40% with a trigger force of 0.5 Kg. From the double compressions parameters such as hardness1, hardness2, cohesiveness, springiness, gumminess, chewiness were determined.

### 4. 3. 22. Estimation of TBA value:

About 10 gms of the sample were macerated with 2.5 ml 4 N Hcl diluted to 100ml with distilled water. The macerated sample was distilled by steam distillation method and 50 ml of the sample was collected in 10 minutes. Accurately weighed 0.288 gms of TBA standard and dissolved in 100ml glacial acetic acid in hot water bath and cooled to room temperature.5ml of the samples were taken in test tubes and 5ml of the prepared TBA reagent was also added. A blank was also made with distilled water. Then the samples were kept in boiling water bath for 30 minutes for colour development. The developed colour was read at 538 nm wavelengths against blank in a spectrophotometer. (Tarladgis et al 1960). The TBA value is expressed as mg malonaldehde / kg of fish.

### 4. 3. 23. Determination of pH:

About 10 gm of the sample were homogenized with 10 ml distilled water and the pH was recorded using a digital pH meter.

### 4. 3. 24. Sensory evaluation:

Sensory evaluations of all the thermally processed products stored at room temperature and at accelerated temperature were carried out. Sensory evaluation was based on characterization and differentiation of the various sensory characters such as appearance texture, odour and flavour. Score was given based on a 10-point hedonic scale by trained taste panel members (**Annexure 1**), as per guideline given by IS: 6273[II]-1971. Scores 9-10, 6-8,4-5 and 1-3 were taken for excellent, good, fair and poor respectively for each of the sensory characteristic.

**25. Estimation of aluminium content in canned fish:**

jm sample was digested with 9:4 nitric acid and perchloric acid and the ion was made colorless by slow heating in a heat mantle. The colourles ion was made up to 100ml in a standard flask. About 2 ml of the sample injected into ICP-AES and compared with aluminium standard.

**I. 3. 26. Transportworthiness Tests:**

wolve the Code of practice for packaging of canned products CFB boxes of dimension 330mmX 320mmX 310mm(5ply) was used using virgin 120-gsm virgin 100-gsm kraft papers. Cans (16 Nos) were packed in the above-tioned CFB boxes. The master cartons were sealed with 12mm wide propylene straps with the help of a strapping machine. Packs were subjected olling, vibration and drop test. Rolling test in the filled package was carried as per IS: 7028(1973) part V. Vibration test was determined on the filled ages as per IS: 7028 (1973). Drop test was done as per ASTM (1986) D-80. Physical properties of the CFB cartons made out of 120 gsm like Bursting igth, Puncture Resistance and waterproof ness were studied as per IS: 1060 6).

## ANNEXURE 1: SENSORY EVALUTION OF CANNED FISH

Assessor…………………………………………… Date……………………….

**FLAVOUR**

*(Please score the sample by placing a cross (x) at the relevant point along the scale.)*

| Sl.no | Sample number | Score | A | B |
|---|---|---|---|---|
| 1. | Excellent | 10 | | |
| 2. | Very good | 9 | | |
| 3. | Good | 8 | | |
| 4. | Moderately good | 7 | | |
| 5. | Neither good not bad | 6 | | |
| 6. | Slightly rancid, bitter or other off-flavors | 5 | | |
| 7. | Moderate rancid, bitter or other off-flavors | 4 | | |
| 8. | Strong rancid, bitter or other off-flavors | 3 | | |
| 9. | Very strong rancid, bitter or other off-flavors | 2 | | |
| 10 | Extremely rancid, totally unacceptable. | 1 | | |

**TEXTURE**

*(Please score the following characteristics by placing the Sample Number on each of the following scales.)*

A. Succulence (JUICY)

Very succulent Juicy 10 9 8 7 6 5 4 3 2 1 Very Dry

B. Toughness (HARDNESS)

Very tender 10 9 8 7 6 5 4 3 2 1 Very Tough

C. Fibrosity (STRINGY TEXTURAL PROPERTIES)

Not fibrous 10 9 8 7 6 5 4 3 2 1 Fibrous

**OVER ALL ACCEPTABILITY**

10 9 8 7 6 5 4 3 2 1

**TEST FOR QUALITY ATTRIBUTES**

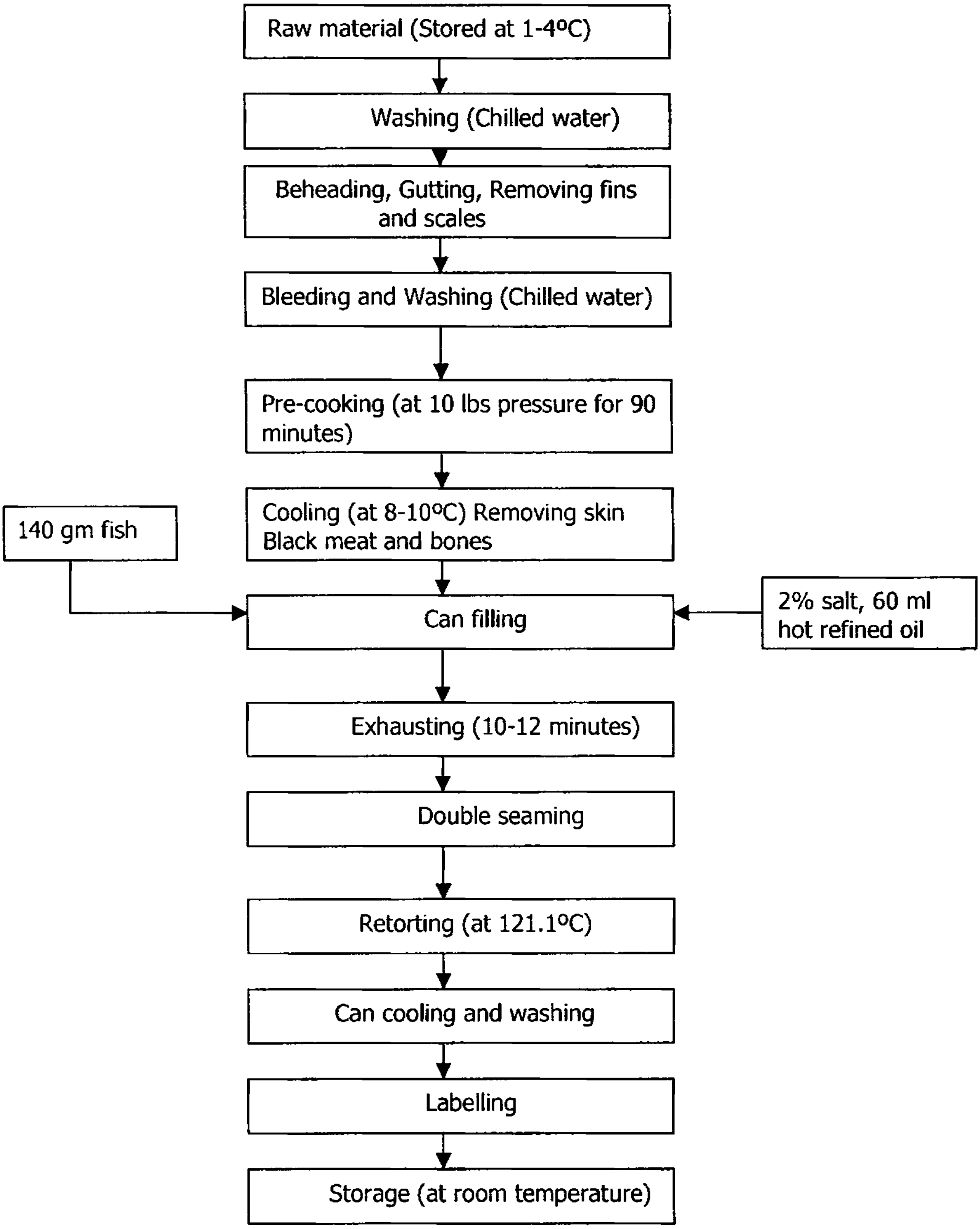
*(Please rate these sample for quality attributes to the following grade description and scoring.)*

QUALITY GRADE DESCRIPTION SCORE
Excellent ---------------------------------------- ------- 9-10
Good--------------------------------------------------------6-8
Fair--------------------------------------------------------4-5
Poor -------------------------------------------------------1-3

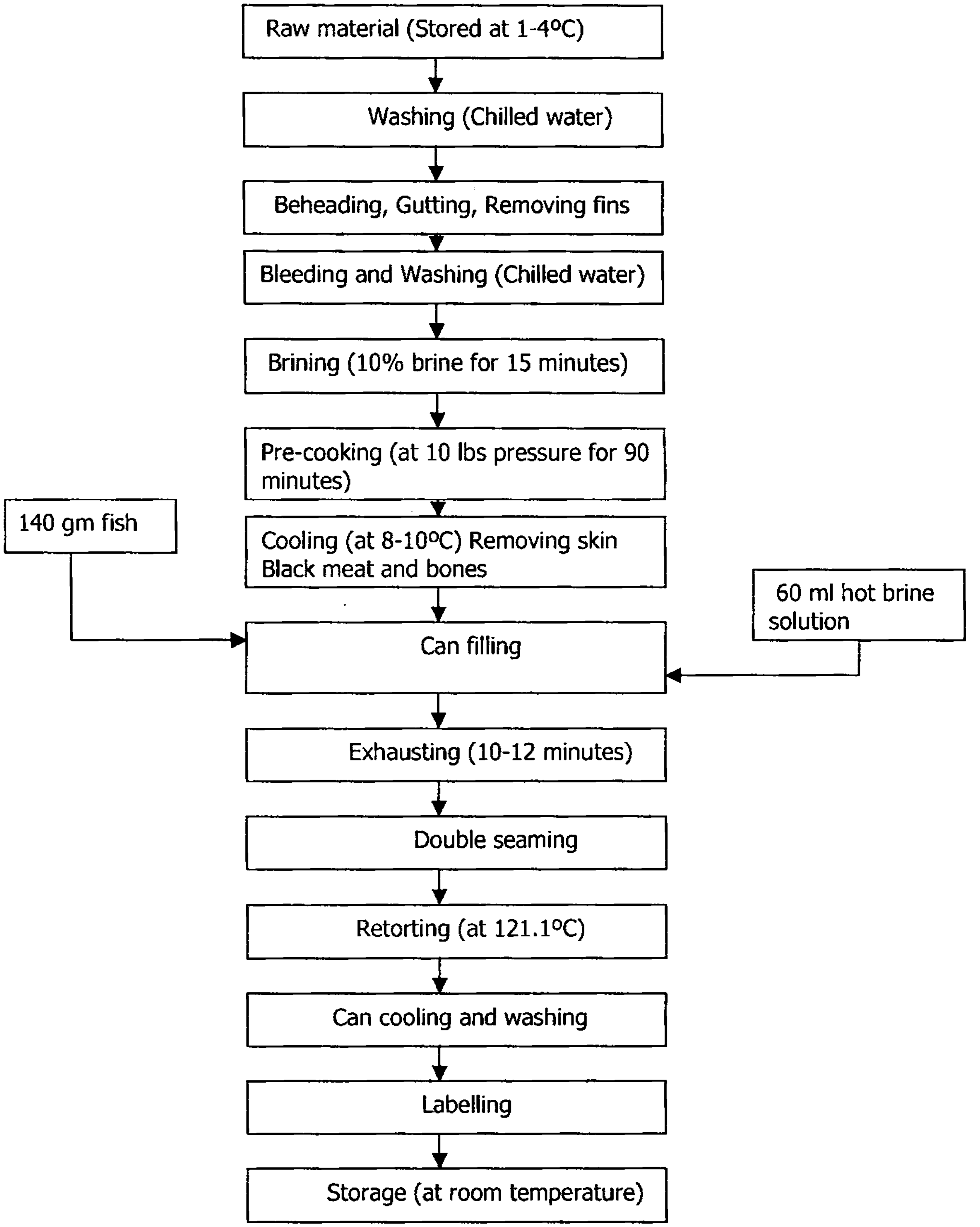
| CODE NO. OF SAMPLE | COLOUR | APPEARANCE | TEXTURE | TASTE | ODOUR |
|---|---|---|---|---|---|
| **A** | | | | | |
| **B** | | | | | |

**COMMENTS**

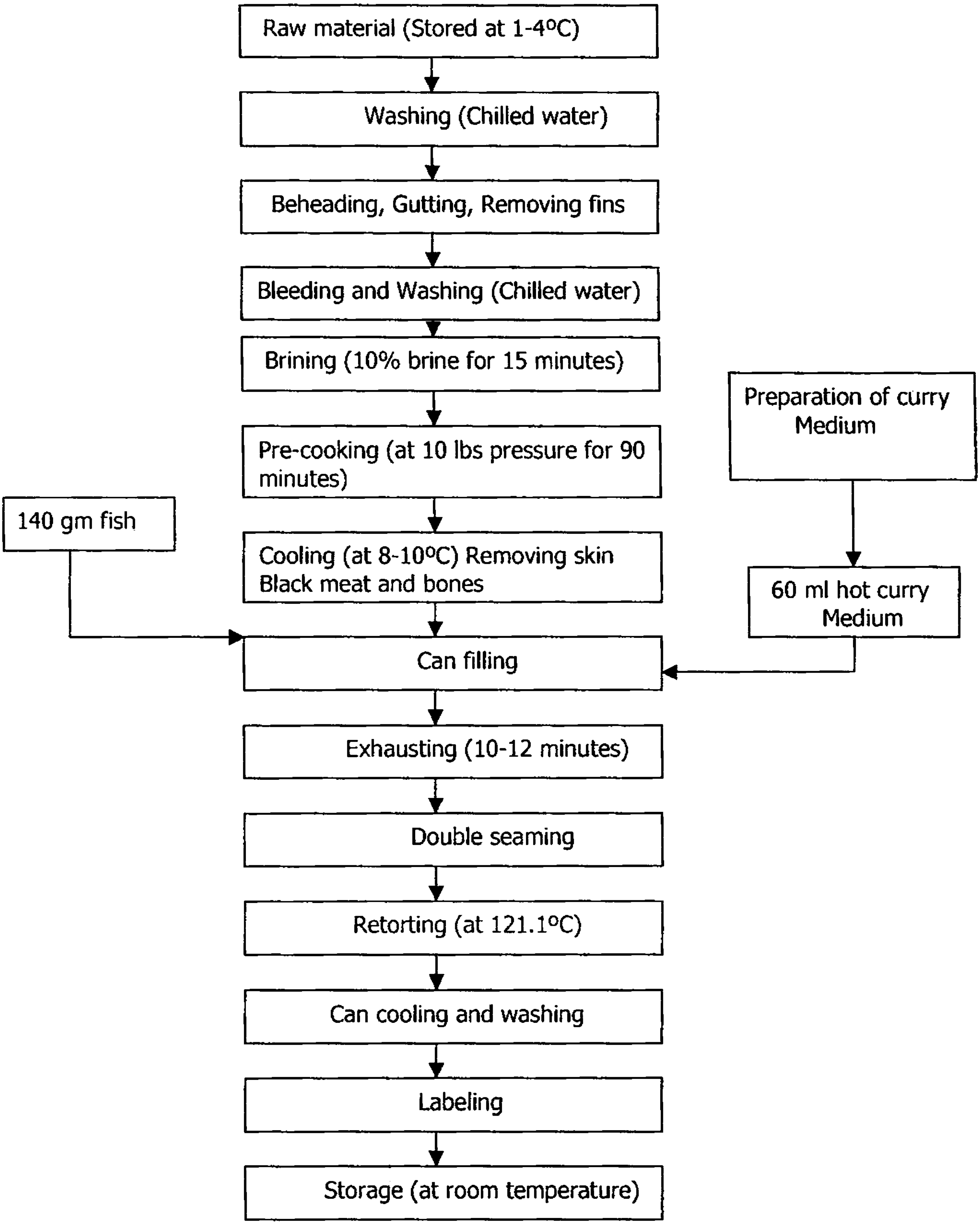
Flow Chart-1. **Canning of Tuna in Oil**



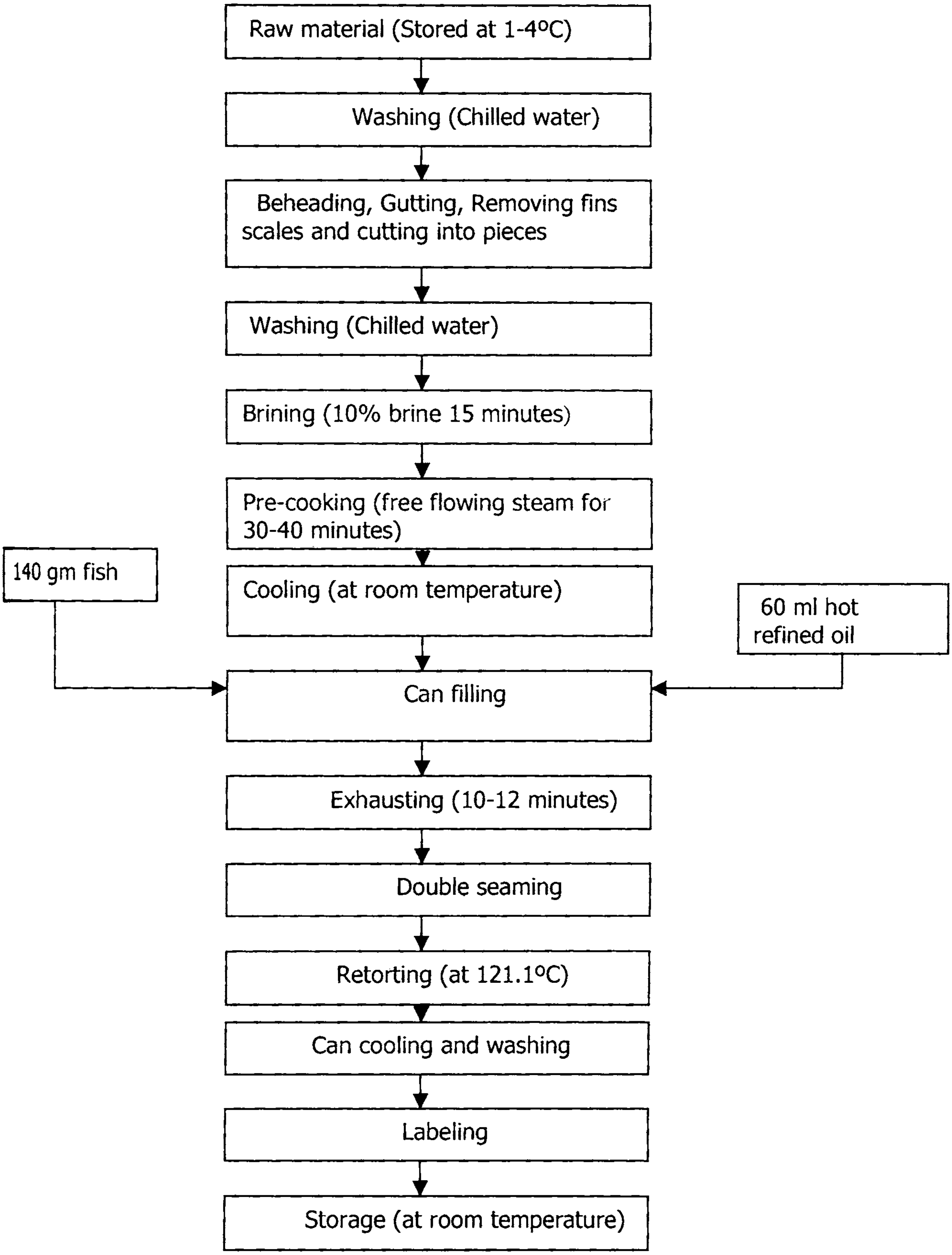
Flow Chart-2. **Canning of Tuna in brine**



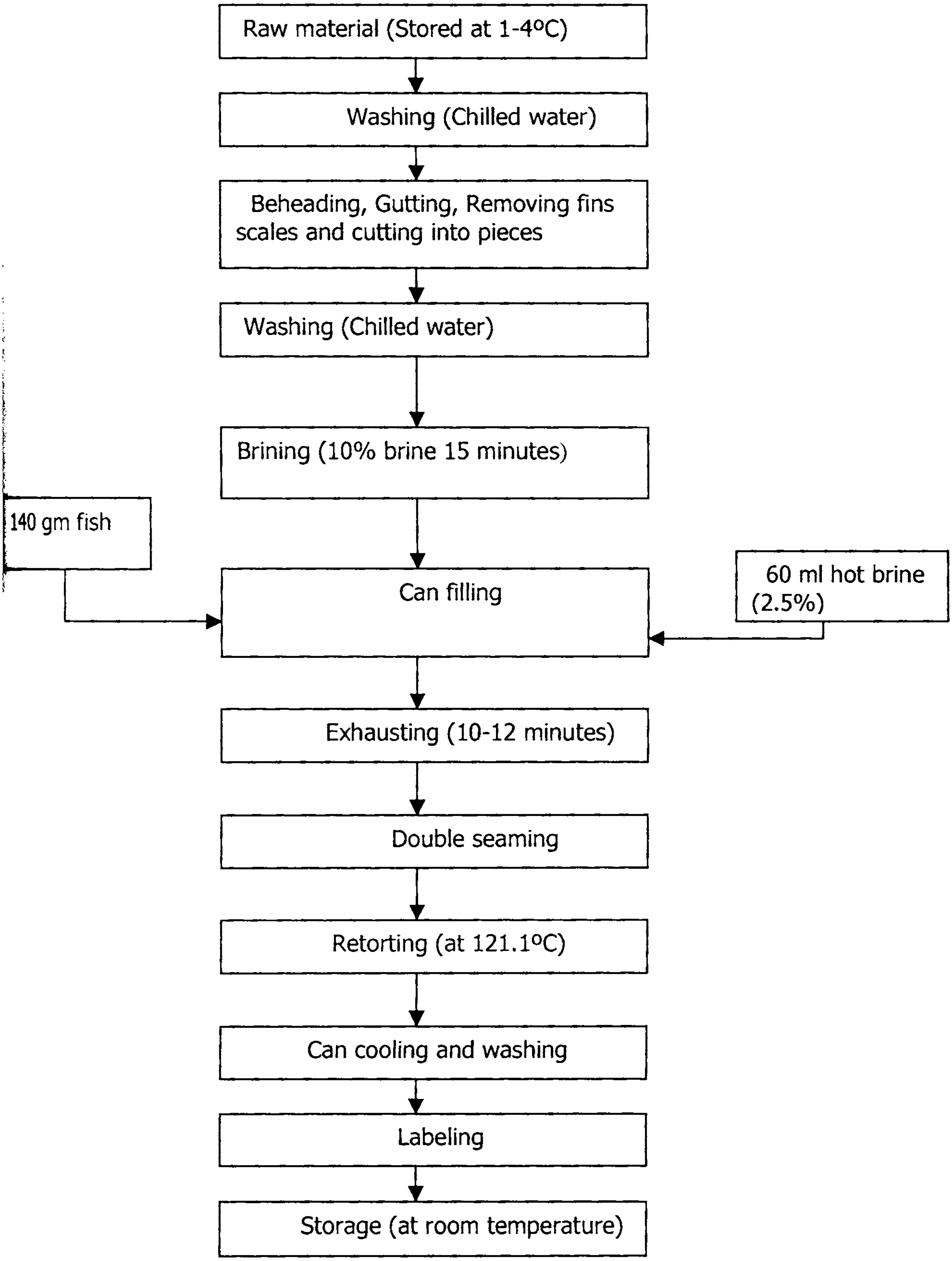
Flow Chart-3. **Canning of Tuna in Curry**



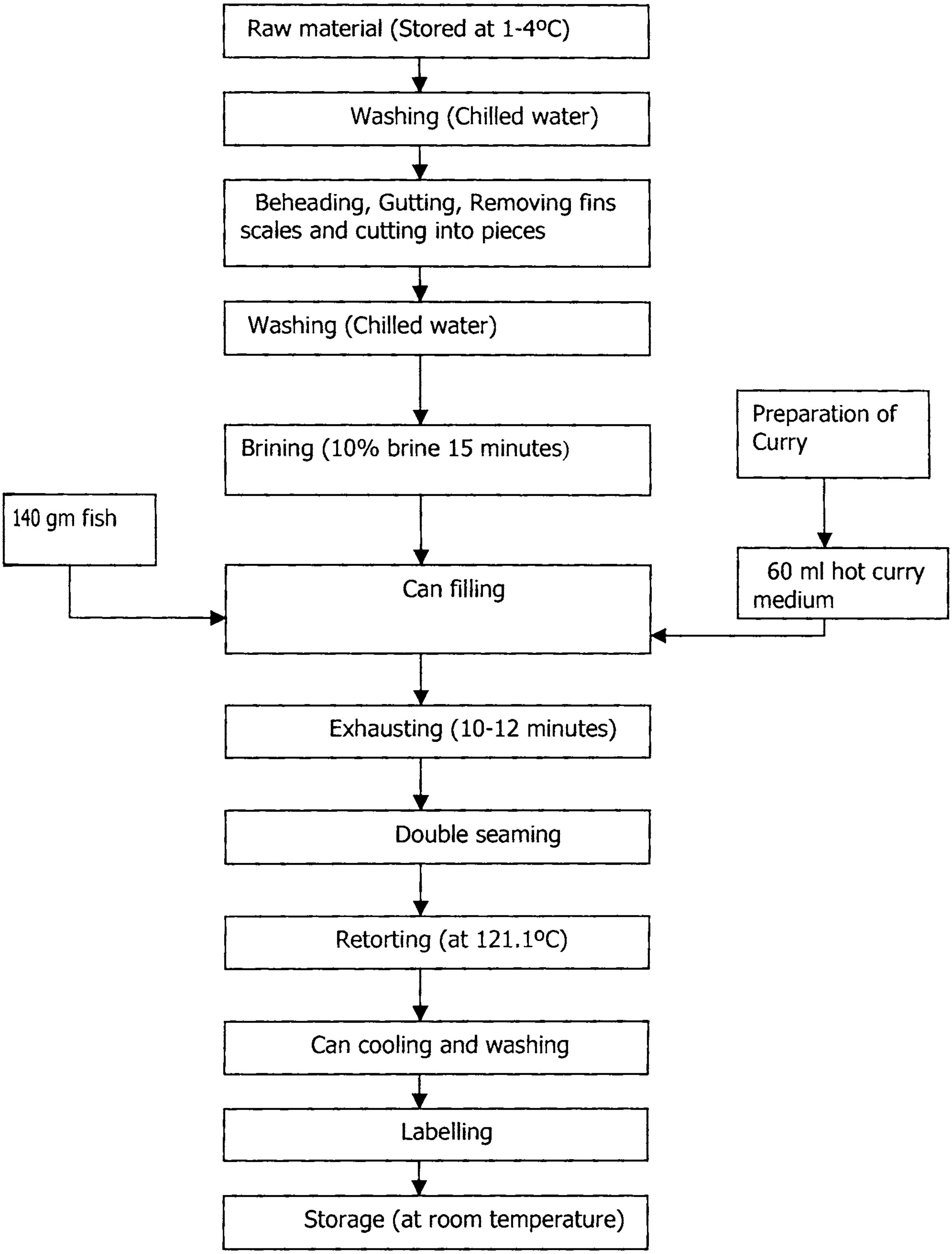
Flow Chart-4. **Canning of Mackerel in Oil**



Flow Chart-5.**Canning of Mackerel in Brine**



Flow Chart-6. **Canning of Mackerel in Curry**



# 5. RESULTS AND DISCUSSION

# 5. RESULTS AND DISCUSSION

Rigid containers have played a very significant role over several years in food processing and build up of consumer acceptance as well as confidence in preserved foods. The exploring studies to find an alternative container to tin cans resulted in the development of aluminium cans for food processing (Leymarie, 1972). India with it abundant aluminium resource developed indigenous aluminium cans suitable for heat processing. These cans were studied for their suitability for food contact applications. Type of lacquer and its thickness and usefulness as a protective coating etc. were studied. Heat penetration studies were done to find out a suitable $F_0$ value for different fish products. Shelf life evaluations were also done for various products processed in these cans. Studies were also done to find out a suitable packaging for the transportation or processed cans. Though extensive research has been carried out in the country on development of processes for fish and fish products, nothing much has been carried out using indigenous aluminium cans.

## 5. 1. Proximate Composition of Fishes

Fish protein is a very rich source of the essential amino acid lysine, which is absent in vegetable proteins. Fish protein can therefore be used to supplement vegetable proteins to provide a nutritionally balanced protein source in the diet (Balachandran, 2001). Proximate composition of the fish will give an idea about the nutritional quality of the fish. Table-4 shows the proximate composition of mackerel and tuna used for the study. From the table it can be seen that fat is high in mackerel compared to that of tuna. Fat content of mackerel is about 5.37% while that of tuna is about 3.23%. Moisture content of tuna is about 75.32% while that of mackerel is 72.64% with tuna showing maximum amount. Protein content is almost same in both the fishes with tuna having 18.88% and mackerel 19.31%. The ash content of mackerel is 1.89% while that of tuna is 1.57%.

Table-4.

Proximate composition of tuna and mackerel

| **Component** | **Percentage** |
|---|---|
| **Mackerel** | |
| Moisture | 72.64±0.16 |
| Fat | 5.37±0.37 |
| Protein | 19.31±0.24 |
| Ash | 1.89±0.08 |
| **Tuna** | |
| Moisture | 75.32±0.21 |
| Fat | 3.23±0.21 |
| Protein | 18.88±0.17 |
| Ash | 1.57±0.07 |

## 5.2. Physical Tests for Aluminium Cans

Physical tests were done to study the suitability and strength of the cans for the thermal processing of the foods. Generally thermal processing is done at higher temperatures and high pressure is also developed inside the can during the processing. Results of physical tests are presented in the Table-5.

Table-5
Physical properties of aluminium cans

| Test | Result |
|---|---|
| Air pressure test | 25 ± 1.00 psig |
| Lacquer thickness | 4.2 ± 0.16 $gm/m^2$ |
| Water extractives | 0.075 ± 0.002 mg/ sq. inch |
| Chloroform extractives | 0.039 ± 0.002 mg/ sq. inch |

The test cans had a dry lacquer film weight of 4.2 $gms/m^2$. The dry film weight of phenolic and epoxy lacquers considered satisfactory for food cans is in the range of 1.5- 5 $gms/m^2$. The lacquer also gives positive results for phenolic epoxy resins. The test for resistance to sulphur staining indicated that there was no blackening on the test panels and the cans were sulphur resistant The air pressure test showed that the cans withstood internal pressure of 25 psig. Fish cans are normally processed at 15 psig. So the mentioned aluminium cans have got the required strength to with stand the processing conditions. Results of experiments also showed that 8 oz aluminium cans used for the study do not require overpressure during thermal processing. Filled cans remain in their normal shape without distortion, when processed at 121.1C without overpressure.

Another major consideration was the migration of lacquer components to the can contents during processing and storage. It may happen that if the lacquer is not of the appropriate quality, the lacquer components may migrate to the can contents during processing and storage. The extent of migration depends upon the temperature of storage. Code of Federal regulations of the US, has prescribed specific regulations for the safe use of resinous and polymeric coatings as the food contact surfaces in metal containers. The extraction limit prescribed for coated container is generally 0.5 mg/ sq. inch of food contact surface when tested by the method suggested by FDA 175:300. The test aluminium cans had water extractives of 0.075 mg/ sq. inch and chloroform extractives of 0.039mg/ sq. in. The extractive values are much below those specified by FDA, which implies that the test aluminium cans are quite suitable for food contact applications. These studies confirm to the earlier studies by Balachandran et al (1998).

The success of the entire canning operation depends upon the proper seaming of the cans. The results of cutout analysis are presented in Table-6. The ideal overlap for cans should be 60% (Balachandran 1993). The tested aluminium cans had got an overlap of 62.16%. The lengths of the body hook and cover hook are 0.1596 cm and 0.1501 cm respectively. The studied aluminium cans have got a cover plate thickness of 0.028 cm and body plate thickness of 0.0411 cm. Results of the cut out analysis gives the indication that the seaming of individual aluminium cans is proper and suitable for thermal processing of fish products.

Table- 6
Results of Cut out Analysis

| Parameter | Result |
|---|---|
| Countersink depth | 0.27 ± 0.002 cm |
| Cover plate thickness | 0.027 ± 0.002 cm |
| Body plate thickness | 0.0411 ± 0.002 cm |
| Seam length | 0.251 ± 0.002 cm |
| Body hook length | 0.1596 ± 0.002 cm |
| Cover hook length | 0.1501 ± 0.002 cm |
| Over lap % | 62.16 ± 2.77 |

### 5. 3. Determination of Cold Spot:

The coldest spot in a container was defined according to Zechmann and pflug (1989) as the location in the container, which receives the lowest sterilization value (Fo) from the process. For non-homogenous foods, where non uniform heating was found to occur, the slowest heating could only be taken as the location with the smallest Fo value for the heating portion of the process as determined by the general method of Stumbo (Lu et al, 1991). Cold spot was determined for convection type of heating foods in 8 oz aluminium cans by inserting thermocouple needles at different positions of the 8 oz can. For 8 oz aluminium cans with convection heating the cold spot was found to be 1/3$^{rd}$ from the bottom of the can. Determination of the cold spot is essential and required to carry out accurate heat penetration studies. It will vary depending upon the nature of heat penetration.

## 5. 4. Heat Penetration Studies of Tuna in Different Media:

Severe sterility heat treatments are most often applied to low acid foods (pH > 4.6) packaged in hermetically sealed containers. Temperature of treatment in the case of low acid foods ranges from about 115°C to 150° C (Jaiswal, 2002). For the low acid canned foods, commercial sterility is necessary ie, foods must be free of pathogens as well as micro organisms capable of growing in the food under normal non-refrigerated conditions of storage. Severe heat processes commonly applied were the hazard of bacterial growth are expected to be high, as in foods destined for markets in tropical countries.

Tuna in oil were thermally processed to Fo 5, 7 and 10. The F0 recommended for fish and fish products ranges from 5-20 (Frott & Lewis, 1994). Heat penetration characteristics and Fo value of Tuna in oil processed to Fo 5 is presented in Fig 1 and that of cook value in Fig 2. Figures 3 and 4 represents the Fo value and cook value of Tuna in oil processed to Fo 7. Heat penetration characteristics and Fo value of Tuna in oil processed to Fo 10 is presented in Figure 5 and that of cook value in Figure 6. Initial temperature of the products were maintained at 40±3° C. The come up time varied between 3-6 minutes. The come up time should be as short as possible (Anon, 1968). Heat penetration characteristics at the coldest spot should be specific, if parameters such as filled weight, head space, type of container, dimension of container, come up time of the retort, heating media and initial temperature (Vanloey, 1994) were uniform for a given product.

Table-7. Heat penetration of tuna in oil processed to Fo 5 showing Fo value and cook value.

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 38.4 | 31.3 | 5.37E-09 | 0.013594 |
| 1 | 38.4 | 32.4 | 1.07E-08 | 0.027187 |
| 2 | 38.7 | 72.3 | 1.65E-08 | 0.041068 |
| 3 | 39.2 | 100.2 | 2.3E-08 | 0.055442 |
| 4 | 39.8 | 112.5 | 3.04E-08 | 0.070431 |
| 5 | 40.4 | 120.9 | 3.89E-08 | 0.08606 |
| 6 | 41.2 | 119.9 | 4.91E-08 | 0.102586 |
| 7 | 44.4 | 119.8 | 7.05E-08 | 0.123247 |
| 8 | 48.1 | 121.2 | 1.21E-07 | 0.149994 |
| 9 | 51.9 | 121.1 | 2.41E-07 | 0.184862 |
| 10 | 55.8 | 119.9 | 5.36E-07 | 0.230635 |
| 11 | 59.6 | 120.6 | 1.24E-06 | 0.290305 |
| 12 | 63.1 | 120.9 | 2.83E-06 | 0.366481 |
| 13 | 66.7 | 120.8 | 6.46E-06 | 0.464409 |
| 14 | 69.9 | 121.1 | 1.4E-05 | 0.586837 |
| 15 | 73 | 121 | 2.95E-05 | 0.738828 |
| 16 | 75.9 | 120.8 | 5.97E-05 | 0.924907 |
| 17 | 78.8 | 120.7 | 0.000119 | 1.152718 |
| 18 | 81.4 | 119.9 | 0.000226 | 1.425845 |
| 19 | 83.8 | 119.9 | 0.000412 | 1.748762 |
| 20 | 86.2 | 120.5 | 0.000736 | 2.130546 |
| 21 | 88.3 | 120.8 | 0.00126 | 2.572579 |
| 22 | 90.3 | 120.9 | 0.002092 | 3.080809 |
| 23 | 92.2 | 121.3 | 0.00338 | 3.661088 |
| 24 | 94 | 121.1 | 0.00533 | 4.319021 |
| 25 | 95.6 | 120.9 | 0.008149 | 5.054663 |
| 26 | 97.2 | 120.8 | 0.012222 | 5.877193 |
| 27 | 98.6 | 120.5 | 0.017846 | 6.784127 |
| 28 | 100 | 119.9 | 0.025608 | 7.784127 |
| 29 | 101.3 | 120.4 | 0.03608 | 8.879076 |
| 30 | 102.5 | 121 | 0.049883 | 10.06965 |
| 31 | 103.7 | 121.1 | 0.06808 | 11.36421 |
| 32 | 104.7 | 120.9 | 0.090989 | 12.75232 |
| 33 | 105.7 | 120.9 | 0.119829 | 14.24075 |
| 34 | 106.6 | 120.9 | 0.155311 | 15.82564 |
| 35 | 107.5 | 119.9 | 0.198962 | 17.51325 |
| 36 | 108.3 | 120.5 | 0.251443 | 19.29775 |
| 37 | 109 | 120.7 | 0.313103 | 21.17156 |

| | | | | |
|---|---|---|---|---|
| 38 | 109.8 | 120.9 | 0.387234 | 23.15295 |
| 39 | 110.4 | 120.9 | 0.472347 | 25.21905 |
| 40 | 111 | 121.2 | 0.570071 | 27.37349 |
| 41 | 111.5 | 121.1 | 0.679719 | 29.60441 |
| 42 | 112.1 | 121 | 0.805612 | 31.93072 |
| 43 | 112.6 | 120.8 | 0.946865 | 34.33962 |
| 44 | 113 | 120.5 | 1.101747 | 36.81669 |
| 45 | 113.6 | 120.3 | 1.279575 | 39.39967 |
| 46 | 113.9 | 120.3 | 1.470121 | 42.03729 |
| 47 | 114.3 | 120.5 | 1.679051 | 44.74956 |
| 48 | 114.7 | 120.6 | 1.908137 | 47.5386 |
| 49 | 115.1 | 120.6 | 2.159326 | 50.40658 |
| 50 | 115.4 | 121 | 2.428479 | 53.33523 |
| 51 | 115.7 | 121.3 | 2.716883 | 56.32582 |
| 52 | 116 | 121.1 | 3.025912 | 59.37968 |
| 53 | 116.3 | 120.6 | 3.357043 | 62.49813 |
| 54 | 116.5 | 120.8 | 3.70378 | 65.66041 |
| 55 | 116.7 | 120.9 | 4.066858 | 68.86712 |
| 56 | 117 | 121 | 4.455903 | 72.14167 |
| 57 | 116.6 | 45.6 | 4.810717 | 75.32609 |
| 58 | 113.8 | 44.2 | 4.996925 | 77.94537 |
| 59 | 104.9 | 44 | 5.020914 | 79.35299 |
| 60 | 104 | 39.8 | 5.040412 | 80.67493 |
| 61 | 103.1 | 37.5 | 5.056261 | 81.91641 |
| 62 | 100.1 | 36.5 | 5.064204 | 82.92341 |
| 63 | 97.5 | 38 | 5.06857 | 83.76334 |
| 64 | 93.5 | 37.5 | 5.070307 | 84.39872 |
| 65 | 90.3 | 34.2 | 5.071139 | 84.90695 |
| 66 | 87.2 | 35.6 | 5.071547 | 85.31632 |
| 67 | 84.4 | 35.4 | 5.07176 | 85.65305 |
| 68 | 81.7 | 35.1 | 5.071875 | 85.93195 |
| 69 | 79.1 | 34.7 | 5.071938 | 86.16458 |
| 70 | 76.5 | 34.9 | 5.071973 | 86.35861 |
| 71 | 74.4 | 35.1 | 5.071994 | 86.5262 |

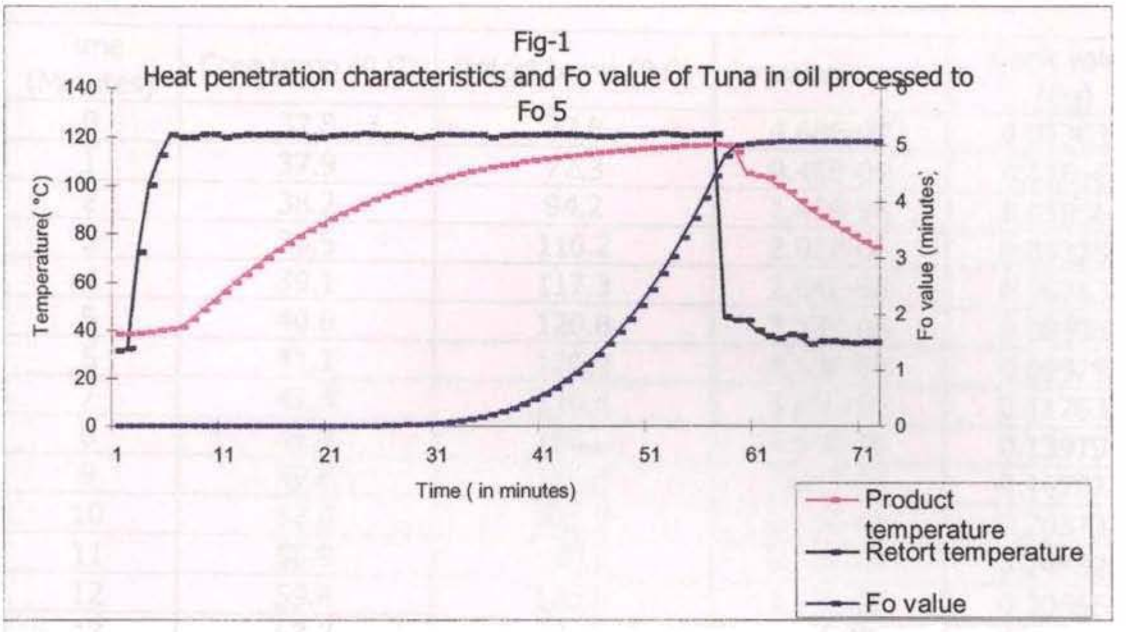


Fig-1
Heat penetration characteristics and Fo value of Tuna in oil processed to Fo 5
Temperature( °C)
Fo value (minutes)
Time ( in minutes)
Product temperature
Retort temperature
Fo value

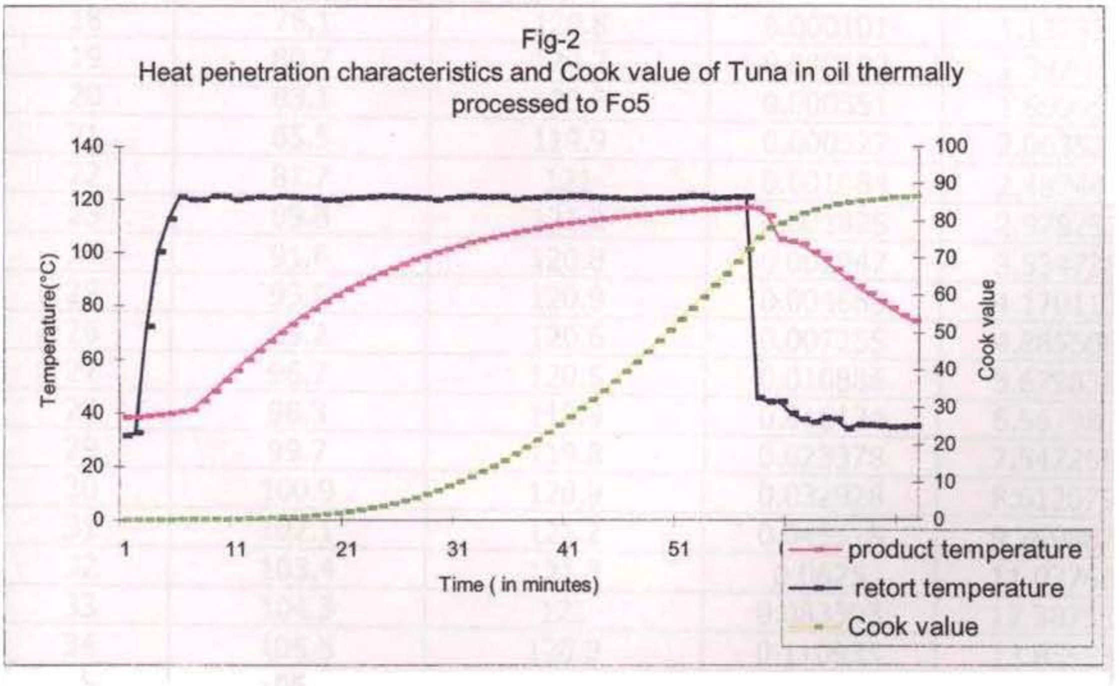


Fig-2
Heat penetration characteristics and Cook value of Tuna in oil thermally processed to Fo5
Temperature(°C)
Cook value
Time ( in minutes)
product temperature
retort temperature
Cook value

ble-8. Heat penetration of tuna in oil processed to Fo 7 showing Fo value and ok value

| Time Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 37.8 | 32.8 | 4.68E-09 | 0.013036 |
| 1 | 37.9 | 72.3 | 9.46E-09 | 0.026164 |
| 2 | 38.2 | 94.2 | 1.46E-08 | 0.039569 |
| 3 | 38.5 | 110.2 | 2.01E-08 | 0.053258 |
| 4 | 39.1 | 117.3 | 2.64E-08 | 0.067532 |
| 5 | 40.6 | 120.8 | 3.53E-08 | 0.083381 |
| 6 | 41.1 | 120.9 | 4.53E-08 | 0.099792 |
| 7 | 42.3 | 120.4 | 5.85E-08 | 0.117637 |
| 8 | 45.4 | 120.6 | 8.54E-08 | 0.139791 |
| 9 | 48.8 | 120.8 | 1.44E-07 | 0.167877 |
| 10 | 52.3 | 121.2 | 2.76E-07 | 0.203732 |
| 11 | 55.9 | 120.6 | 5.78E-07 | 0.249825 |
| 12 | 59.4 | 120.5 | 1.25E-06 | 0.308668 |
| 13 | 62.7 | 120.1 | 2.7E-06 | 0.382747 |
| 14 | 66 | 119.8 | 5.79E-06 | 0.476008 |
| 15 | 69.3 | 121.1 | 1.24E-05 | 0.593415 |
| 16 | 72.3 | 121 | 2.56E-05 | 0.738161 |
| 17 | 75.2 | 120.8 | 5.13E-05 | 0.91537 |
| 18 | 78.1 | 120.8 | 0.000101 | 1.132322 |
| 19 | 80.7 | 120.7 | 0.000193 | 1.392429 |
| 20 | 83.1 | 120.6 | 0.000351 | 1.699952 |
| 21 | 85.5 | 119.9 | 0.000627 | 2.063538 |
| 22 | 87.7 | 121 | 0.001084 | 2.487447 |
| 23 | 89.8 | 121.2 | 0.001825 | 2.978252 |
| 24 | 91.6 | 120.8 | 0.002947 | 3.534738 |
| 25 | 93.5 | 120.9 | 0.004685 | 4.170113 |
| 26 | 95.2 | 120.6 | 0.007255 | 4.885508 |
| 27 | 96.7 | 120.5 | 0.010886 | 5.679836 |
| 28 | 98.3 | 119.9 | 0.016134 | 6.567983 |
| 29 | 99.7 | 119.8 | 0.023378 | 7.547268 |
| 30 | 100.9 | 120.9 | 0.032928 | 8.612079 |
| 31 | 102.1 | 121.2 | 0.045518 | 9.769887 |
| 32 | 103.4 | 121.3 | 0.0625 | 11.03763 |
| 33 | 104.3 | 121 | 0.083393 | 12.38753 |
| 34 | 105.5 | 120.9 | 0.110935 | 13.85533 |
| 35 | 106.2 | 120.8 | 0.143295 | 15.3966 |
| 36 | 107.1 | 120.8 | 0.183105 | 17.03776 |
| 37 | 107.9 | 120.6 | 0.230968 | 18.77314 |

| | | | | |
|---|---|---|---|---|
| 38 | 108.7 | 120.8 | 0.288512 | 20.60814 |
| 39 | 109.4 | 120.9 | 0.356121 | 22.53499 |
| 40 | 110 | 121 | 0.433745 | 24.54423 |
| 41 | 110.6 | 120.8 | 0.52287 | 26.63936 |
| 42 | 111.1 | 120.9 | 0.62287 | 28.80888 |
| 43 | 111.7 | 120.9 | 0.737686 | 31.07116 |
| 44 | 112.2 | 121.2 | 0.866511 | 33.41375 |
| 45 | 112.6 | 121 | 1.007764 | 35.82265 |
| 46 | 113 | 119.9 | 1.162646 | 38.29973 |
| 47 | 113.5 | 119.7 | 1.336426 | 40.86475 |
| 48 | 113.9 | 120.5 | 1.526972 | 43.50237 |
| 49 | 114.2 | 120.8 | 1.731146 | 46.19578 |
| 50 | 114.6 | 120.9 | 1.955018 | 48.96542 |
| 51 | 114.8 | 120.5 | 2.189441 | 51.77399 |
| 52 | 115.1 | 120.4 | 2.44063 | 54.64197 |
| 53 | 115.4 | 120.6 | 2.709783 | 57.57061 |
| 54 | 115.7 | 121.1 | 2.998186 | 60.56121 |
| 55 | 115.9 | 121.1 | 3.300182 | 63.59383 |
| 56 | 116.2 | 121 | 3.623775 | 66.6906 |
| 57 | 116.4 | 121.5 | 3.962619 | 69.83089 |
| 58 | 116.6 | 121.1 | 4.317433 | 73.01531 |
| 59 | 116.8 | 120.8 | 4.688968 | 76.24448 |
| 60 | 116.9 | 120.7 | 5.069157 | 79.49626 |
| 61 | 117.1 | 120.6 | 5.467265 | 82.79374 |
| 62 | 117.3 | 121 | 5.884134 | 86.13755 |
| 63 | 117.1 | 73.3 | 6.282241 | 89.43503 |
| 64 | 116.3 | 61.2 | 6.613372 | 92.55349 |
| 65 | 114.2 | 44.5 | 6.817546 | 95.2469 |
| 66 | 111.5 | 41.5 | 6.927194 | 97.47782 |
| 67 | 108.5 | 38.9 | 6.982148 | 99.2874 |
| 68 | 105.4 | 37.6 | 7.009063 | 100.745 |
| 69 | 102.2 | 36.4 | 7.021946 | 101.9109 |
| 70 | 99.2 | 38.9 | 7.028402 | 102.8566 |
| 71 | 95.9 | 39.3 | 7.031422 | 103.6078 |
| 72 | 92.5 | 36.4 | 7.032803 | 104.2004 |
| 73 | 89.1 | 35.4 | 7.033434 | 104.6678 |
| 74 | 85.9 | 34.2 | 7.033736 | 105.0417 |
| 75 | 82.7 | 35.4 | 7.03388 | 105.3407 |
| 76 | 79.7 | 34.5 | 7.033953 | 105.5833 |
| 77 | 76.9 | 34.8 | 7.033991 | 105.7828 |

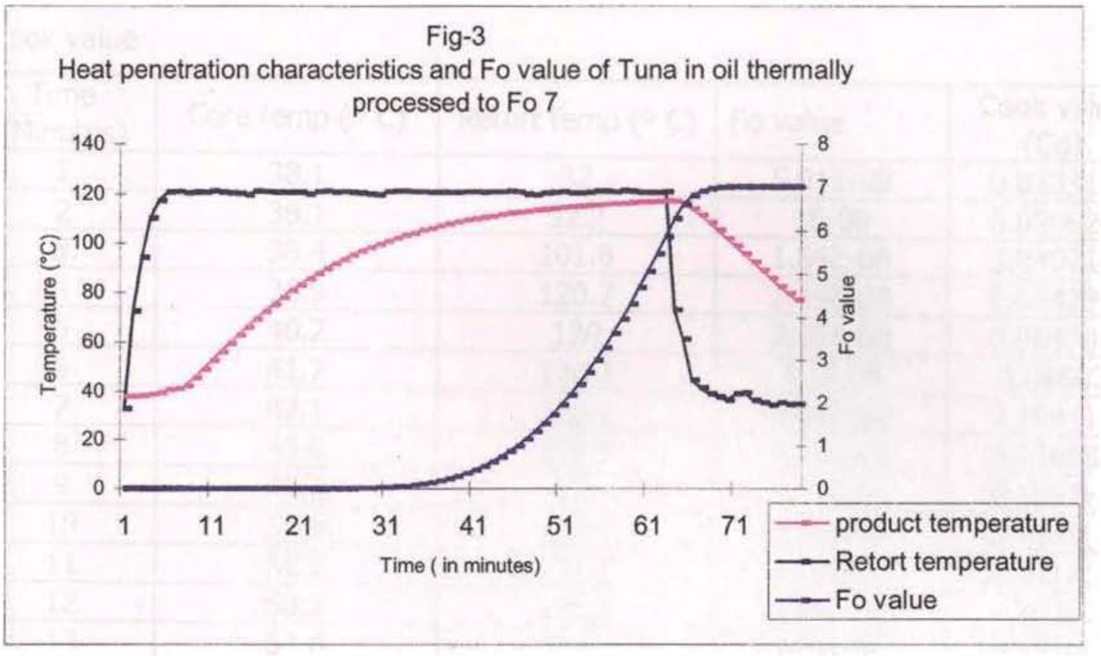


Fig-3
Heat penetration characteristics and Fo value of Tuna in oil thermally processed to Fo 7
140
120
100
80
60
40
20
0
Temperature (°C)
8
7
6
5
4
3
2
1
0
Fo value
1
11
21
31
41
51
61
71
Time ( in minutes)
product temperature
Retort temperature
Fo value

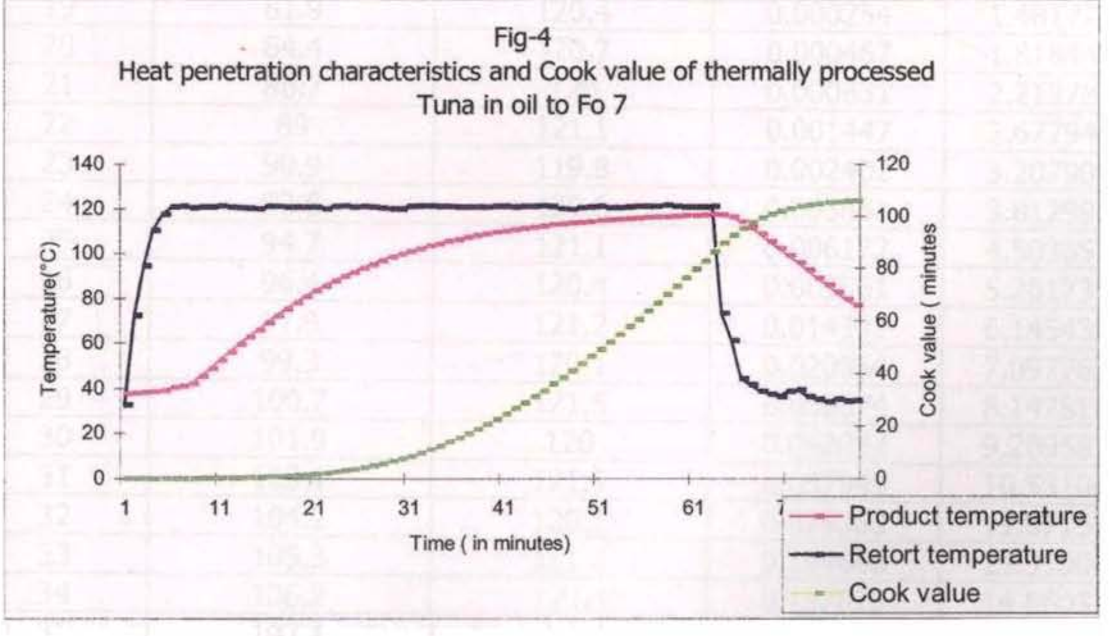


Fig-4
Heat penetration characteristics and Cook value of thermally processed Tuna in oil to Fo 7
140
120
100
80
60
40
20
0
Temperature(°C)
120
100
80
60
40
20
0
Cook value ( minutes
1
11
21
31
41
51
61
Time ( in minutes)
Product temperature
Retort temperature
Cook value

ɔle-9. Heat penetration of tuna in oil processed to Fo 10 showing Fo value and ɔk value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 1 | 38.1 | 32 | 5.01E-09 | 0.013312 |
| 2 | 38.1 | 92.2 | 1E-08 | 0.026624 |
| 3 | 38.4 | 101.8 | 1.54E-08 | 0.040218 |
| 4 | 38.9 | 120.7 | 2.14E-08 | 0.054294 |
| 5 | 40.2 | 120 | 2.95E-08 | 0.069706 |
| 6 | 41.7 | 120.2 | 4.1E-08 | 0.08682 |
| 7 | 42.1 | 120.1 | 5.36E-08 | 0.104417 |
| 8 | 45.6 | 120.9 | 8.18E-08 | 0.126883 |
| 9 | 49.2 | 120 | 1.46E-07 | 0.155763 |
| 10 | 52.9 | 119.7 | 2.98E-07 | 0.193151 |
| 11 | 56.5 | 121.1 | 6.44E-07 | 0.241215 |
| 12 | 60.3 | 120.2 | 1.48E-06 | 0.303872 |
| 13 | 63.8 | 120.1 | 3.34E-06 | 0.383861 |
| 14 | 67.2 | 121 | 7.41E-06 | 0.485266 |
| 15 | 70.5 | 120.4 | 1.61E-05 | 0.612928 |
| 16 | 73.5 | 120.2 | 3.35E-05 | 0.770315 |
| 17 | 76.4 | 121.1 | 6.74E-05 | 0.963 |
| 18 | 79.3 | 119.8 | 0.000133 | 1.1989 |
| 19 | 81.9 | 120.4 | 0.000254 | 1.481723 |
| 20 | 84.4 | 120.7 | 0.000467 | 1.818446 |
| 21 | 86.7 | 120 | 0.000831 | 2.213785 |
| 22 | 89 | 121.1 | 0.001447 | 2.677944 |
| 23 | 90.9 | 119.8 | 0.002402 | 3.207903 |
| 24 | 92.8 | 120.6 | 0.003881 | 3.812991 |
| 25 | 94.7 | 121.1 | 0.006172 | 4.503857 |
| 26 | 96.4 | 120.4 | 0.009561 | 5.281731 |
| 27 | 97.9 | 121.2 | 0.014347 | 6.145432 |
| 28 | 99.3 | 120.1 | 0.020954 | 7.097763 |
| 29 | 100.7 | 121.5 | 0.030074 | 8.147818 |
| 30 | 101.9 | 120 | 0.042097 | 9.289581 |
| 31 | 103.1 | 121.5 | 0.057945 | 10.53106 |
| 32 | 104.2 | 120.2 | 0.078363 | 11.87158 |
| 33 | 105.3 | 121.2 | 0.104666 | 13.31904 |
| 34 | 106.2 | 120.4 | 0.137025 | 14.86031 |
| 35 | 107.1 | 120.4 | 0.176836 | 16.50147 |
| 36 | 107.9 | 120.7 | 0.224699 | 18.23685 |
| 37 | 108.7 | 120 | 0.282243 | 20.07185 |
| 38 | 109.5 | 121.3 | 0.351426 | 22.01219 |

| | | | | |
|---|---|---|---|---|
| 39 | 110.1 | 120.2 | 0.430859 | 24.03549 |
| 40 | 110.7 | 121.5 | 0.52206 | 26.1453 |
| 41 | 111.3 | 120.4 | 0.626772 | 28.34531 |
| 42 | 111.8 | 120.5 | 0.744262 | 30.62342 |
| 43 | 112.3 | 120.6 | 0.876088 | 32.98242 |
| 44 | 112.9 | 119.9 | 1.027444 | 35.44227 |
| 45 | 113.3 | 121.1 | 1.193403 | 37.97175 |
| 46 | 113.7 | 120.2 | 1.375373 | 40.57281 |
| 47 | 114.1 | 121.4 | 1.574899 | 43.2475 |
| 48 | 114.5 | 120.4 | 1.793675 | 45.99789 |
| 49 | 114.8 | 120.6 | 2.028098 | 48.80645 |
| 50 | 115.1 | 120.9 | 2.279287 | 51.67443 |
| 51 | 115.5 | 120 | 2.55471 | 54.62358 |
| 52 | 115.8 | 121.5 | 2.849831 | 57.63512 |
| 53 | 116 | 120.4 | 3.15886 | 60.68897 |
| 54 | 116.3 | 120.5 | 3.489991 | 63.80743 |
| 55 | 116.5 | 120.8 | 3.836728 | 66.9697 |
| 56 | 116.8 | 120 | 4.208263 | 70.19887 |
| 57 | 117 | 121.5 | 4.597308 | 73.47342 |
| 58 | 117.2 | 120.3 | 5.004689 | 76.79399 |
| 59 | 117.4 | 120.2 | 5.431268 | 80.16122 |
| 60 | 117.5 | 121.2 | 5.867784 | 83.55203 |
| 61 | 117.7 | 120 | 6.324872 | 86.99048 |
| 62 | 117.8 | 119.9 | 6.792607 | 90.45302 |
| 63 | 117.9 | 121.5 | 7.271237 | 93.93979 |
| 64 | 118 | 120.4 | 7.761016 | 97.45099 |
| 65 | 118.1 | 120 | 8.262204 | 100.9868 |
| 66 | 118.3 | 119.2 | 8.787011 | 104.5722 |
| 67 | 117.8 | 43.7 | 9.254746 | 108.0348 |
| 68 | 116.3 | 40.9 | 9.585877 | 111.1532 |
| 69 | 114.8 | 41.6 | 9.8203 | 113.9618 |
| 70 | 112.3 | 46 | 9.952126 | 116.3208 |
| 71 | 109.4 | 40.7 | 10.01973 | 118.2476 |
| 72 | 106.1 | 39.9 | 10.05136 | 119.7782 |
| 73 | 102.9 | 40.6 | 10.06649 | 121.0025 |
| 74 | 99.6 | 41.2 | 10.07357 | 121.9749 |
| 75 | 96.4 | 35.9 | 10.07696 | 122.7528 |
| 76 | 93.2 | 34.2 | 10.07858 | 123.375 |
| 77 | 90 | 34.7 | 10.07936 | 123.8727 |
| 78 | 86.9 | 35.6 | 10.07974 | 124.2736 |
| 79 | 83.9 | 36.1 | 10.07993 | 124.5988 |
| 80 | 81.1 | 36.3 | 10.08003 | 124.8663 |
| 81 | 78.5 | 36.4 | 10.08008 | 125.65 |

Fig-5
Heat penetration characteristics and Fo value of thermally processed Tuna in oil to Fo 10

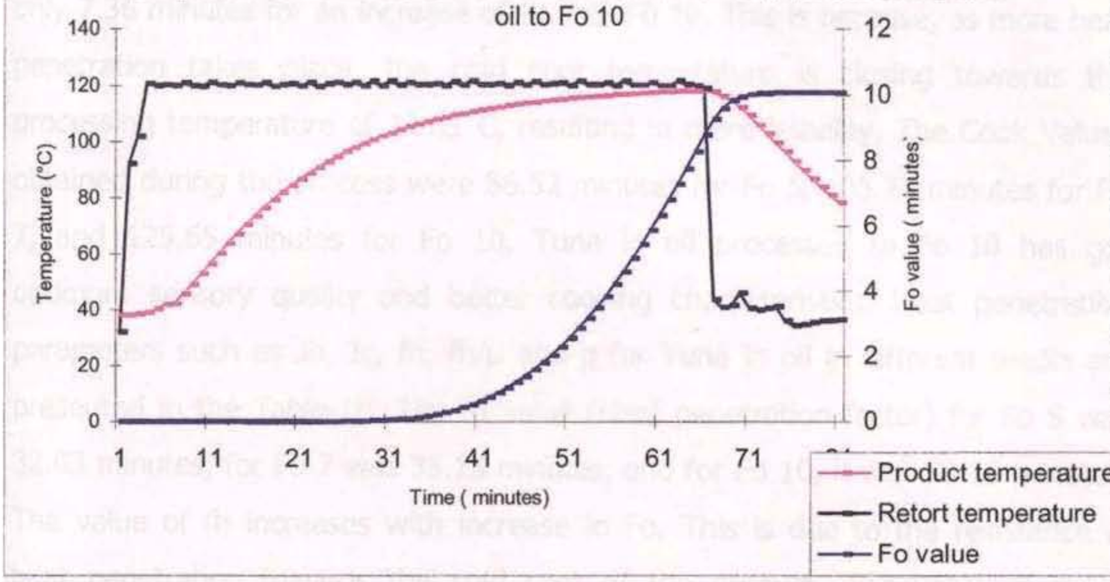
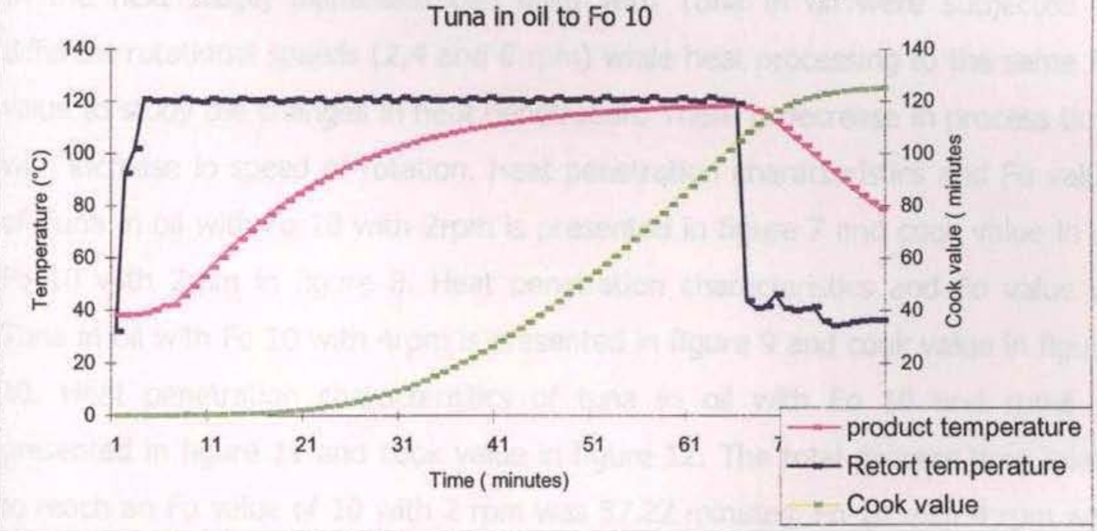



Fig-6
Heat penetration characteristics and Cook value of thermally processed Tuna in oil to Fo 10



Total process time (B+0.42 of come up time) taken to reach an Fo value of 5 was 44.31 minutes, Fo 7 was 57.07 minutes and for Fo 10, it was 64.43 minutes. Although it has taken 12.76 minutes for an increase of Fo 5 to F0 7, it has taken only 7.36 minutes for an increase of Fo 7 to F0 10. This is because, as more heat penetration takes place, the cold spot temperature is closing towards the processing temperature of 121.1 C, resulting in more lethality. The Cook Values obtained during the process were 86.52 minutes for Fo 5, 105.78 minutes for Fo 7, and 125.65 minutes for Fo 10. Tuna in oil processed to Fo 10 has got optimum sensory quality and better cooking characteristics. Heat penetration parameters such as Jh, Jc, fh, fh/u and g for Tuna in oil in different media are presented in the Table-10. The fh value (Heat penetration factor) for Fo 5 was 32.03 minutes, for Fo 7 was 35.13 minutes, and for Fo 10, it was 38.15 minutes. The value of fh increases with increase in Fo. This is due to the resistance in heat penetration towards the cold spot of the product. The value of fh/ U decreases with increase in Fo values. Value of fh/ U for Fo5 was 6.34, for Fo 7 was 4.97 and for Fo 10, it was 3.82. Final temperature deficit (g) also decreases with increase in Fo value.

In the next stage, aluminium can filled with Tuna in oil were subjected to different rotational speeds (2,4 and 6 rpm) while heat processing to the same Fo value to study the changes in heat penetration. There is decrease in process time with increase in speed of rotation. Heat penetration characteristics and Fo value of Tuna in oil with Fo 10 with 2rpm is presented in figure 7 and cook value in of Fo 10 with 2rpm in figure 8. Heat penetration characteristics and Fo value of Tuna in oil with Fo 10 with 4rpm is presented in figure 9 and cook value in figure 10. Heat penetration characteristics of tuna in oil with Fo 10 and rpm6 is presented in figure 11 and cook value in figure 12. The total process time taken to reach an Fo value of 10 with 2 rpm was 57.22 minutes, Fo 10 with 4 rpm was 56.16 minutes and Fo 10 with 6 rpm was 55.38 minutes. Compared to Tuna in oil

Table-10

## Heat penetration data of tuna products

| Io | Jh | Jc | fh | Fh/U | g | Cg | B | Total Process Time |
|---|---|---|---|---|---|---|---|---|
| TIO 5 | 0.7993±0.06 | 1.0390±0.02 | 32.03±0.49 | 6.3426±0.09 | 3.5262±0.04 | 86.52±0.90 | 41.3±0.80 | 44.31±0.66 |
| TIO 7 | 0.9449±0.03 | 1.1325±0.07 | 35.13±2.10 | 4.9689±0.14 | 3.1041±0.08 | 105.78±1.47 | 53.38±1.42 | 57.07±1.30 |
| TIO 10 | 1.3032±0.14 | 1.1683±0.09 | 38.15±0.86 | 3.815±0.15 | 2.4555±0.06 | 125.65±5.03 | 62.09±0.42 | 64.43±1.20 |
| TIO10 rpm2 | 1.3658±0.04 | 1.2973±0.02 | 33.36±1.58 | 3.3293±0.17 | 2.2321±0.07 | 115.35±1.93 | 54.17±1.45 | 57.22±1.42 |
| TIO 10 rpm4 | 1.4403±0.14 | 1.1845±0.02 | 32.37±1.38 | 3.2111±0.19 | 2.0616±0.12 | 114.45±1.74 | 54.02±1.02 | 56.15±1.26 |
| TIO10 rpm 6 | 1.4619±0.12 | 1.2176±0.05 | 32.09±1.47 | 3.2026±0.15 | 2.0679±0.12 | 110.93±1.49 | 53.75±1.59 | 55.38±1.60 |
| TIB 10 | 1.2509±0.06 | 1.3290±0.11 | 20.39±1.03 | 1.9969±0.08 | 1.1788±0.06 | 96.60±1.70 | 39.03±1.26 | 41.03±1.62 |
| TIC | 1.1175±0.03 | 1.2760±0.02 | 36.23±1.04 | 3.5785±0.12 | 2.4554±0.12 | 113.42±1.23 | 56.32±0.82 | 58.33±0.83 |

TIO-Tuna in oil

TIB-Tuna in brine

TIC-Tuna in curry

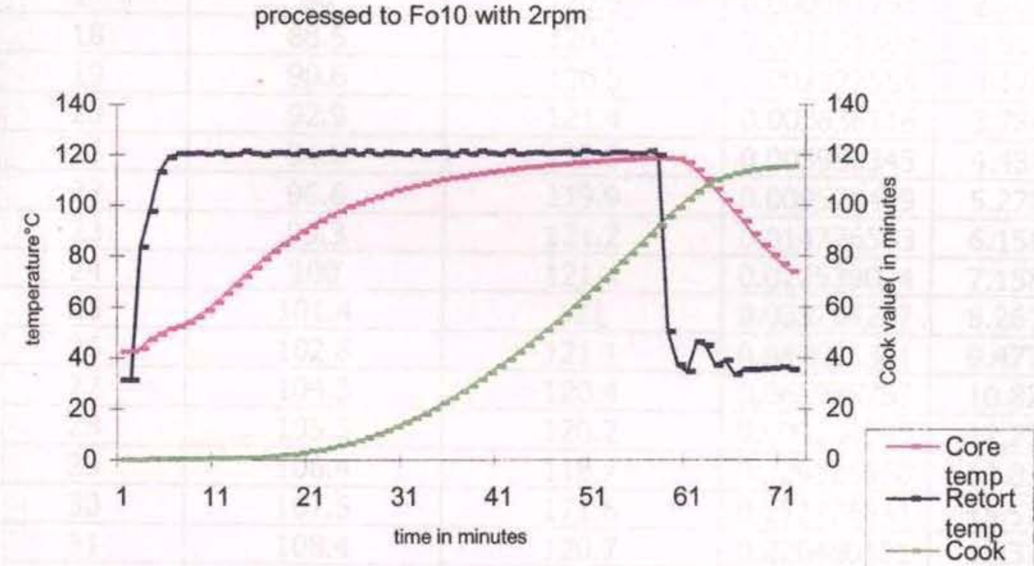
Table-11. Heat penetration of tuna in oil processed to Fo 10 and 2 rpm showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 42.3 | 31.2 | 1.32E-07 | 0.035855 |
| 1 | 42.6 | 31.1 | 2.52E-07 | 0.070722 |
| 2 | 43.5 | 83.6 | 3.64E-07 | 0.104868 |
| 3 | 47.2 | 97.6 | 4.69E-07 | 0.138306 |
| 4 | 49.2 | 113.2 | 5.71E-07 | 0.171512 |
| 5 | 51.4 | 119 | 6.78E-07 | 0.205184 |
| 6 | 52.4 | 120.5 | 8.13E-07 | 0.24129 |
| 7 | 53.8 | 120.6 | 1E-06 | 0.2811 |
| 8 | 56.1 | 120.7 | 1.32E-06 | 0.327841 |
| 9 | 58.8 | 120.2 | 1.9E-06 | 0.384272 |
| 10 | 61.9 | 121.1 | 3.11E-06 | 0.454329 |
| 11 | 65.2 | 120 | 5.68E-06 | 0.542527 |
| 12 | 68.7 | 120.4 | 1.14E-05 | 0.655121 |
| 13 | 72.1 | 121.6 | 2.4E-05 | 0.797861 |
| 14 | 75.5 | 120.6 | 5.16E-05 | 0.978818 |
| 15 | 78.8 | 120.1 | 0.00011 | 1.206629 |
| 16 | 81.7 | 120.9 | 0.000225 | 1.485533 |
| 17 | 84.7 | 121.1 | 0.000454 | 1.829379 |
| 18 | 87.2 | 120.2 | 0.000862 | 2.238754 |
| 19 | 89.7 | 121.6 | 0.001586 | 2.726146 |
| 20 | 91.8 | 120 | 0.002761 | 3.290453 |
| 21 | 93.9 | 120.7 | 0.004667 | 3.943811 |
| 22 | 95.9 | 121.1 | 0.007686 | 4.695015 |
| 23 | 97.7 | 120.3 | 0.012257 | 5.546747 |
| 24 | 99.5 | 121.6 | 0.019176 | 6.512461 |
| 25 | 100.8 | 120.2 | 0.028508 | 7.569868 |
| 26 | 102.2 | 121.6 | 0.041391 | 8.735783 |
| 27 | 103.5 | 120.4 | 0.058769 | 10.0124 |
| 28 | 104.7 | 120.9 | 0.081677 | 11.40051 |
| 29 | 105.8 | 120.8 | 0.111189 | 12.89936 |
| 30 | 106.9 | 120.2 | 0.149208 | 14.51778 |
| 31 | 107.8 | 121.6 | 0.195982 | 16.24109 |
| 32 | 108.7 | 120.3 | 0.253526 | 18.07609 |
| 33 | 109.6 | 121 | 0.324321 | 20.03002 |
| 34 | 110.2 | 120.9 | 0.405604 | 22.06749 |
| 35 | 111 | 120 | 0.503327 | 24.22192 |
| 36 | 111.6 | 121.6 | 0.615529 | 26.46847 |
| 37 | 112.2 | 120.4 | 0.744354 | 28.81106 |

| | | | | |
|---|---|---|---|---|
| 38 | 112.8 | 121.5 | 0.892265 | 31.25381 |
| 39 | 113.3 | 120.8 | 1.058224 | 33.78329 |
| 40 | 113.8 | 120.3 | 1.244432 | 36.40256 |
| 41 | 114.3 | 121.5 | 1.453362 | 39.11484 |
| 42 | 114.8 | 120.4 | 1.687785 | 41.9234 |
| 43 | 115.1 | 120.7 | 1.938973 | 44.79138 |
| 44 | 115.5 | 121.1 | 2.214396 | 47.74053 |
| 45 | 115.8 | 120.5 | 2.509517 | 50.75207 |
| 46 | 116.2 | 120.7 | 2.833111 | 53.84884 |
| 47 | 116.5 | 121 | 3.179848 | 57.01112 |
| 48 | 116.8 | 120.3 | 3.551383 | 60.24029 |
| 49 | 117.2 | 121.4 | 3.958763 | 63.56085 |
| 50 | 117.4 | 120.9 | 4.385343 | 66.92808 |
| 51 | 117.6 | 120.3 | 4.832026 | 70.34263 |
| 52 | 117.8 | 121.1 | 5.299762 | 73.80516 |
| 53 | 118.1 | 121.1 | 5.800949 | 77.34094 |
| 54 | 118.2 | 120.5 | 6.31381 | 80.90148 |
| 55 | 118.4 | 120.5 | 6.850842 | 84.51204 |
| 56 | 118.6 | 121.5 | 7.413183 | 88.17335 |
| 57 | 118.7 | 119.9 | 7.988623 | 91.8603 |
| 58 | 118.6 | 50.1 | 8.550965 | 95.52161 |
| 59 | 118.3 | 37 | 9.075772 | 99.10707 |
| 60 | 116.9 | 34.6 | 9.455961 | 102.3589 |
| 61 | 114 | 46 | 9.725115 | 105.2875 |
| 62 | 110.4 | 44.8 | 9.920099 | 107.9436 |
| 63 | 106.4 | 36.9 | 10.00521 | 110.0097 |
| 64 | 102 | 39 | 10.0391 | 111.5726 |
| 65 | 97.7 | 33.4 | 10.0514 | 112.7224 |
| 66 | 93.8 | 35.3 | 10.05597 | 113.5741 |
| 67 | 88.7 | 35.2 | 10.05783 | 114.2229 |
| 68 | 84.2 | 35.5 | 10.05841 | 114.6775 |
| 69 | 80.3 | 35.9 | 10.05861 | 115.0095 |
| 70 | 76.9 | 36.3 | 10.0587 | 115.2625 |
| 71 | 73.8 | 35.3 | 10.05873 | 115.3521 |

Fig-7
Heat penetration characteristics of Tuna in oil processed to Fo 10 with 2 rpm


Fig-8
Heat penetration characteristics and Cook value for Tuna in oil processed to Fo10 with 2rpm



-12. Heat penetration of tuna in oil processed to Fo 10 and 4 rpm showing alue and cook value

| Time (minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 43.4 | 39.4 | 2.45471E-07 | 0.043288 |
| 1 | 45.6 | 93.2 | 4.79894E-07 | 0.085975 |
| 2 | 47.7 | 100.3 | 7.03766E-07 | 0.128071 |
| 3 | 49.8 | 120.4 | 9.17562E-07 | 0.169584 |
| 4 | 53.2 | 120.2 | 1.14143E-06 | 0.21168 |
| 5 | 55.4 | 117.9 | 1.41059E-06 | 0.256193 |
| 6 | 56.6 | 120 | 1.7654E-06 | 0.304594 |
| 7 | 58.6 | 120.5 | 2.32774E-06 | 0.360242 |
| 8 | 60.9 | 121.2 | 3.28273E-06 | 0.425578 |
| 9 | 63.4 | 119.7 | 4.98098E-06 | 0.503365 |
| 10 | 66.3 | 120.9 | 8.29229E-06 | 0.598599 |
| 11 | 69.2 | 119.9 | 1.47488E-05 | 0.71519 |
| 12 | 72.2 | 120.4 | 2.76313E-05 | 0.858929 |
| 13 | 75.2 | 119.8 | 5.33353E-05 | 1.036138 |
| 14 | 78.1 | 119.9 | 0.000103454 | 1.25309 |
| 15 | 80.9 | 121.2 | 0.000198953 | 1.516852 |
| 16 | 83.5 | 121.3 | 0.000372733 | 1.83308 |
| 17 | 86 | 120.5 | 0.000681763 | 2.209573 |
| 18 | 88.5 | 120.3 | 0.001231304 | 2.657818 |
| 19 | 90.6 | 120.8 | 0.002122555 | 3.176799 |
| 20 | 92.9 | 121.4 | 0.003636116 | 3.786123 |
| 21 | 94.8 | 121.3 | 0.005980345 | 4.481827 |
| 22 | 96.6 | 119.9 | 0.009528479 | 5.270632 |
| 23 | 98.3 | 121.2 | 0.014776553 | 6.158779 |
| 24 | 100 | 121.4 | 0.022539024 | 7.158779 |
| 25 | 101.4 | 121 | 0.033254217 | 8.261395 |
| 26 | 102.8 | 121.1 | 0.048045301 | 9.477157 |
| 27 | 104.3 | 120.4 | 0.068938263 | 10.82706 |
| 28 | 105.3 | 120.2 | 0.095240943 | 12.27452 |
| 29 | 106.4 | 118.7 | 0.129125358 | 13.83745 |
| 30 | 107.5 | 121.6 | 0.172776941 | 15.52506 |
| 31 | 108.4 | 120.7 | 0.226480121 | 17.32205 |
| 32 | 109.3 | 121.5 | 0.292549466 | 19.23551 |
| 33 | 110.1 | 119.8 | 0.371982289 | 21.25881 |
| 34 | 110.8 | 120.5 | 0.465307719 | 23.38338 |
| 35 | 111.5 | 121.6 | 0.574955539 | 25.61431 |
| 36 | 112.2 | 120.7 | 0.703780494 | 27.9569 |
| 37 | 112.8 | 120.3 | 0.851691333 | 30.39965 |

| | | | | |
|---|---|---|---|---|
| 38 | 113.4 | 122.3 | 1.021515698 | 32.94684 |
| 39 | 113.9 | 120 | 1.21206177 | 35.58446 |
| 40 | 114.4 | 121.1 | 1.425857979 | 38.31572 |
| 41 | 114.8 | 120.6 | 1.660280861 | 41.12429 |
| 42 | 115.3 | 121 | 1.92330766 | 44.03257 |
| 43 | 115.7 | 121.2 | 2.21171081 | 47.02316 |
| 44 | 116.1 | 120.4 | 2.527938576 | 50.0984 |
| 45 | 116.4 | 121.4 | 2.866782732 | 53.23869 |
| 46 | 116.7 | 120 | 3.229860787 | 56.44541 |
| 47 | 117 | 121 | 3.618905932 | 59.71996 |
| 48 | 117.3 | 120.4 | 4.035775315 | 63.06377 |
| 49 | 117.6 | 121.6 | 4.482458908 | 66.47832 |
| 50 | 117.8 | 120.1 | 4.950194049 | 69.94086 |
| 51 | 118 | 121.6 | 5.439972868 | 73.45205 |
| 52 | 118.2 | 119.9 | 5.952834252 | 77.01258 |
| 53 | 118.4 | 121.6 | 6.489866049 | 80.62315 |
| 54 | 118.5 | 120.4 | 7.039406922 | 84.259 |
| 55 | 118.7 | 121.3 | 7.61484686 | 87.94595 |
| 56 | 118.7 | 108.3 | 8.190286797 | 91.63289 |
| 57 | 118.5 | 40.7 | 8.739827671 | 95.26874 |
| 58 | 118 | 38 | 9.22960649 | 98.77994 |
| 59 | 116.6 | 38.9 | 9.58441988 | 101.9644 |
| 60 | 114.3 | 37 | 9.793349493 | 104.6766 |
| 61 | 111.4 | 32 | 9.900501423 | 106.892 |
| 62 | 108.3 | 33.4 | 9.952982169 | 108.6765 |
| 63 | 104.8 | 34.8 | 9.976424457 | 110.0744 |
| 64 | 101 | 32.2 | 9.98619683 | 111.1466 |
| 65 | 97.3 | 32.5 | 9.990365523 | 111.9749 |
| 66 | 93.6 | 31.9 | 9.992143803 | 112.6147 |
| 67 | 90.1 | 32.5 | 9.992938131 | 113.1159 |
| 68 | 86.6 | 33 | 9.993292944 | 113.5085 |
| 69 | 83.3 | 33.3 | 9.993458903 | 113.8204 |
| 70 | 80.1 | 33.5 | 9.993538336 | 114.0698 |
| 71 | 77.2 | 37.4 | 9.993579074 | 114.2736 |
| 72 | 75.2 | 32.8 | 9.993604778 | 114.4508 |

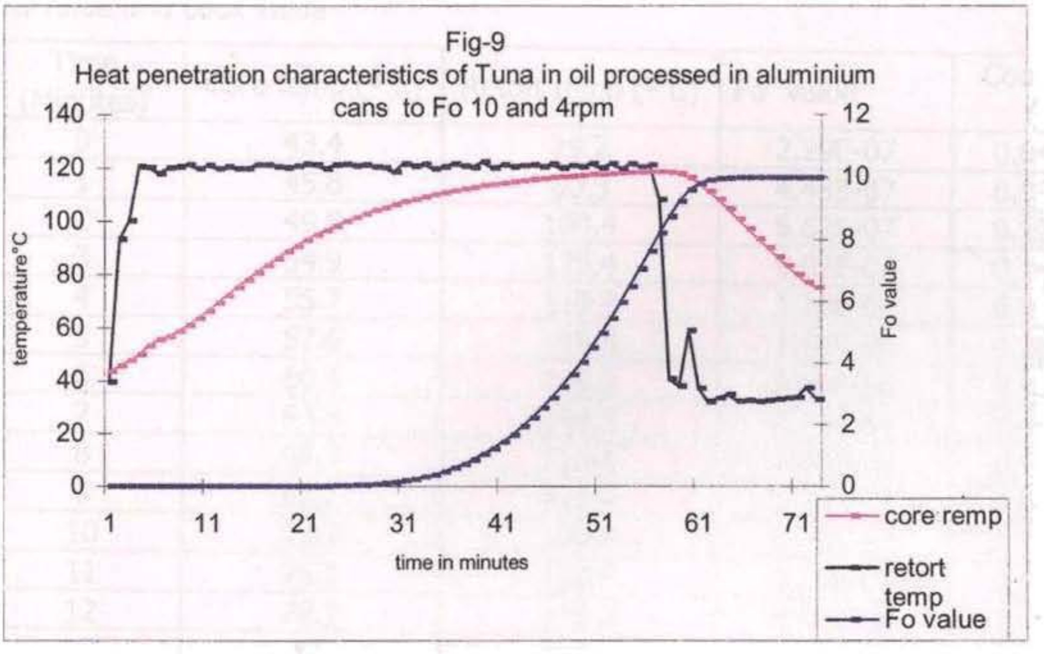


Fig-9
Heat penetration characteristics of Tuna in oil processed in aluminium cans to Fo 10 and 4rpm
temperature°C
Fo value
time in minutes
core remp
retort temp
Fo value

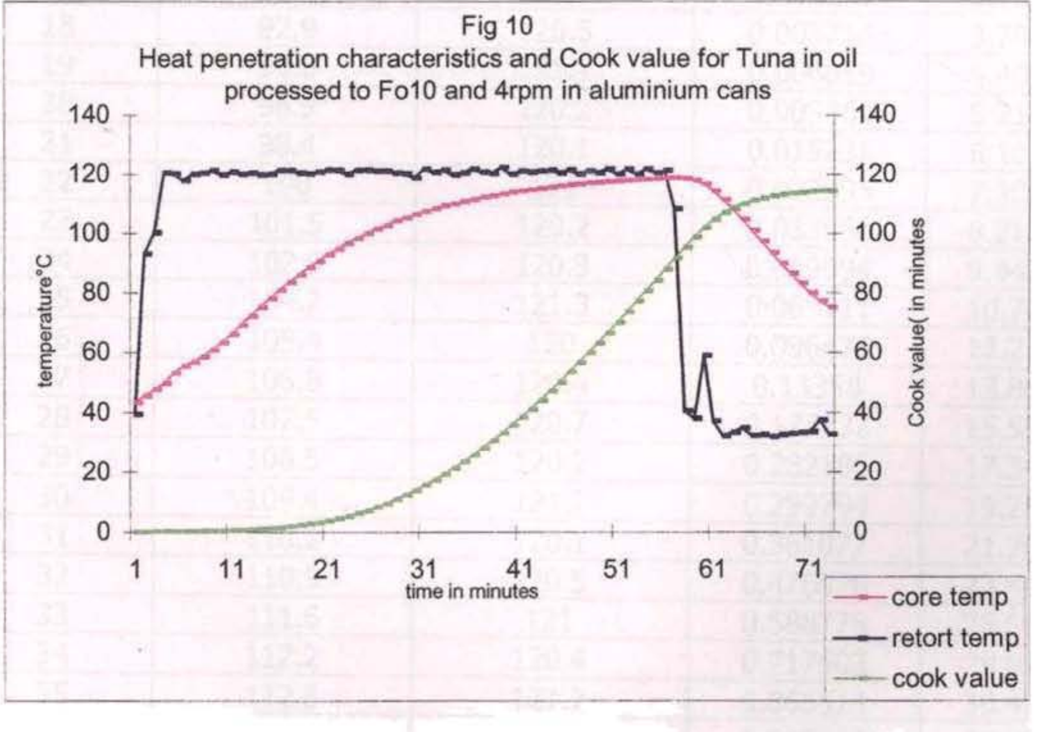


Fig 10
Heat penetration characteristics and Cook value for Tuna in oil processed to Fo10 and 4rpm in aluminium cans
temperature°C
Cook value( in minutes
time in minutes
core temp
retort temp
cook value

Table-13. Heat penetration of tuna in oil processed to Fo 10 and 6 rpm showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 43.4 | 29.2 | 2.29E-07 | 0.042391 |
| 1 | 45.8 | 80.3 | 4.43E-07 | 0.083904 |
| 2 | 49.8 | 100.4 | 6.62E-07 | 0.125707 |
| 3 | 54.9 | 125.4 | 9.02E-07 | 0.168694 |
| 4 | 55.7 | 119.9 | 1.19E-06 | 0.214148 |
| 5 | 57.6 | 119.8 | 1.64E-06 | 0.266046 |
| 6 | 60.4 | 119.2 | 2.49E-06 | 0.329142 |
| 7 | 63.3 | 119.5 | 4.15E-06 | 0.406388 |
| 8 | 66.3 | 118.9 | 7.46E-06 | 0.501622 |
| 9 | 69.2 | 119.4 | 1.39E-05 | 0.618213 |
| 10 | 72.2 | 120.9 | 2.68E-05 | 0.761952 |
| 11 | 75.1 | 120.8 | 5.19E-05 | 0.937929 |
| 12 | 78.1 | 120.2 | 0.000102 | 1.154881 |
| 13 | 81 | 120.2 | 0.0002 | 1.42049 |
| 14 | 83.7 | 120.7 | 0.000382 | 1.741161 |
| 15 | 86.2 | 121.1 | 0.000705 | 2.122946 |
| 16 | 88.6 | 121 | 0.001268 | 2.574329 |
| 17 | 90.8 | 120.2 | 0.002201 | 3.100603 |
| 18 | 92.9 | 120.5 | 0.003714 | 3.709927 |
| 19 | 94.8 | 121.1 | 0.006059 | 4.405631 |
| 20 | 96.9 | 120.2 | 0.009861 | 5.211122 |
| 21 | 98.4 | 120.1 | 0.015231 | 6.105488 |
| 22 | 100 | 121 | 0.022993 | 7.105488 |
| 23 | 101.5 | 120.2 | 0.033958 | 8.215824 |
| 24 | 102.9 | 120.3 | 0.049094 | 9.440098 |
| 25 | 104.2 | 121.3 | 0.069511 | 10.78062 |
| 26 | 105.4 | 120 | 0.096427 | 12.23821 |
| 27 | 106.8 | 120.4 | 0.13358 | 13.84538 |
| 28 | 107.5 | 120.7 | 0.177232 | 15.53299 |
| 29 | 108.5 | 120.2 | 0.232186 | 17.34256 |
| 30 | 109.4 | 121.2 | 0.299794 | 19.26941 |
| 31 | 110.2 | 120.1 | 0.381077 | 21.30688 |
| 32 | 110.9 | 120.5 | 0.476576 | 23.44633 |
| 33 | 111.6 | 121 | 0.588778 | 25.69288 |
| 34 | 112.2 | 120.4 | 0.717603 | 28.03547 |
| 35 | 112.8 | 121.2 | 0.865514 | 30.47822 |
| 36 | 113.4 | 120.1 | 1.035338 | 33.02541 |
| 37 | 113.9 | 120.7 | 1.225884 | 35.66303 |

| | | | | |
|---|---|---|---|---|
| 38 | 114.4 | 120.3 | 1.439681 | 38.39429 |
| 39 | 114.8 | 120.7 | 1.674103 | 41.20286 |
| 40 | 115.2 | 120.4 | 1.931143 | 44.09092 |
| 41 | 115.6 | 120.4 | 2.212981 | 47.06072 |
| 42 | 116 | 120.7 | 2.522011 | 50.11457 |
| 43 | 116.3 | 120.4 | 2.853142 | 53.23303 |
| 44 | 116.6 | 121.4 | 3.207955 | 56.41745 |
| 45 | 117 | 120.2 | 3.597001 | 59.692 |
| 46 | 117.2 | 121.1 | 4.004381 | 63.01256 |
| 47 | 117.5 | 120.2 | 4.440897 | 66.40337 |
| 48 | 117.7 | 121 | 4.897985 | 69.84183 |
| 49 | 118 | 119.9 | 5.387764 | 73.35302 |
| 50 | 118.2 | 120.9 | 5.900625 | 76.91355 |
| 51 | 118.4 | 120.1 | 6.437657 | 80.52412 |
| 52 | 118.6 | 121 | 6.999998 | 84.18543 |
| 53 | 118.7 | 120 | 7.575438 | 87.87238 |
| 54 | 118.9 | 116.4 | 8.177998 | 91.61113 |
| 55 | 118.7 | 47.4 | 8.753438 | 95.29808 |
| 56 | 117.7 | 37.5 | 9.266299 | 98.73654 |
| 57 | 115.3 | 62.5 | 9.723387 | 101.6448 |
| 58 | 112.3 | 47.1 | 9.986414 | 104.0038 |
| 59 | 108.7 | 33.8 | 10.11824 | 105.8388 |
| 60 | 104.8 | 43.7 | 10.17578 | 107.2366 |
| 61 | 100.7 | 42.2 | 10.19923 | 108.2867 |
| 62 | 96.7 | 35.9 | 10.20835 | 109.081 |
| 63 | 92.5 | 33.6 | 10.21198 | 109.6736 |
| 64 | 88.6 | 32.5 | 10.21336 | 110.125 |
| 65 | 84.8 | 32.9 | 10.21392 | 110.4712 |
| 66 | 81.2 | 33.3 | 10.21415 | 110.7406 |
| 67 | 77.1 | 33.7 | 10.21426 | 110.9429 |

Fig-11
Heat penetration characteristics of Tuna in oil processed to fo 10 and rpm6 in aluminium cans

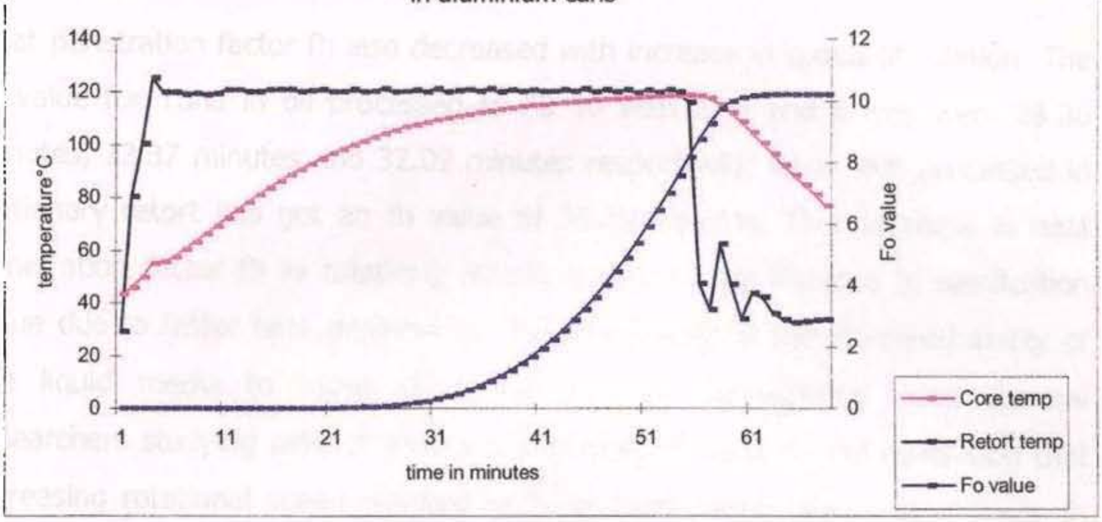
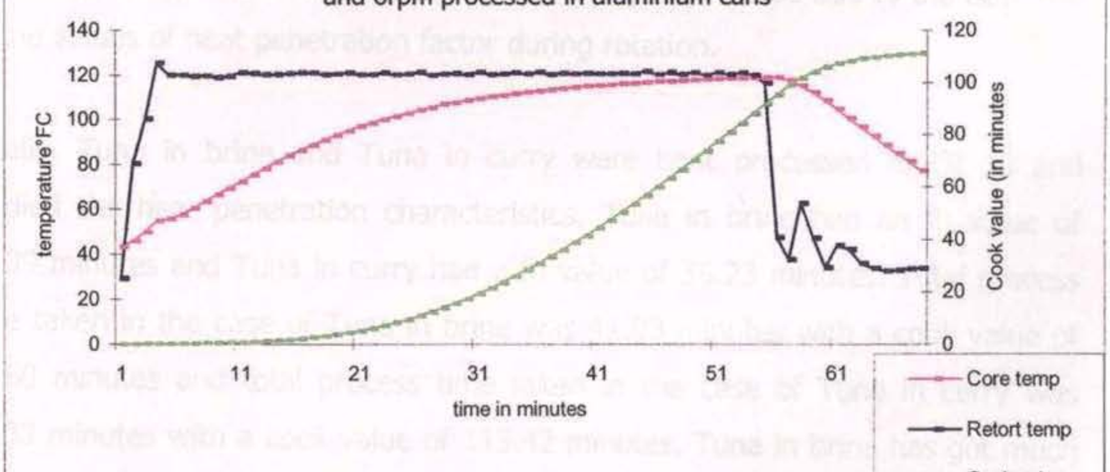



Fig-12
Heat penetration characteristics and Cook value for Tuna in oil with Fo 10 and 6rpm processed in aluminium cans



processed to an Fo value of 10 in stationary retort, Fo 10 with 2 rpm has got 7.21 minutes reduction in process time. Thereafter, although process time is decreasing, the reduction in time is also decreasing.

Heat penetration factor fh also decreased with increase in speed of rotation. The fh value for Tuna in oil processed to F0 10 with 2, 4 and 6 rpm were 33.36 minutes, 32.37 minutes and 32.09 minutes respectively; while that processed in stationary retort has got an fh value of 38.15 minutes. This decrease in heat penetration factor fh in rotationg retorts is due to the increase in sterilization value due to faster heat penetration. This is because of the increased ability of the liquid media to move effectively through the agitated cans. Several researchers studying axial or end-over-end rotation came to the conclusion that increasing rotational speed resulted in faster heat penetration, that is lower fh values. (Berry and Bradshaw, 1980; Naveh & Kopelman, 1980; Berry & Dickerson 1981; Berry & Bradshaw 1982; Berry & Kohn horst 1985). However, the influence of rotational speed on heat penetration rate is limited. Moreover, increase in rotational speed above 20 rpm resulted in breakage of the product (Vanloey, 1994). The value of fh/U showed a slight decrease due to the decrease in the values of heat penetration factor during rotation.

Finally, Tuna in brine and Tuna in curry were heat processed to F0 10 and studied the heat penetration characteristics. Tuna in brine had an fh value of 20.39 minutes and Tuna in curry had a fh value of 36.23 minutes. Total process time taken in the case of Tuna in brine was 41.03 minutes with a cook value of 96.60 minutes and total process time taken in the case of Tuna in curry was 58.33 minutes with a cook value of 113.42 minutes. Tuna in brine has got much faster heat penetration compared to Tuna in oil and Tuna in curry and resulted in a less total process time. This may be due to the less viscosity of brine solution leading to faster heat penetration. In oil medium heat penetration is slower due to the high viscosity of the oil medium Heat penetration characteristics and Fo value of Tuna in brine is presented in the Figure-13, and the Cook value in figure-14. Figures15 and 16 represent Fo value and Cook value of Tuna in curry processed to the Value of Fo 10. Among the three products, Tuna in Brine has got the least fh, fh/U and g values.

Table-14. Heat penetration of tuna in brine processed to Fo 10 showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 44.5 | 33.1 | 2.19E-08 | 0.020806 |
| 1 | 44.3 | 87.6 | 4.28E-08 | 0.041323 |
| 2 | 44.4 | 99.9 | 6.42E-08 | 0.061984 |
| 3 | 45.1 | 117 | 8.93E-08 | 0.083679 |
| 4 | 47.3 | 120 | 1.31E-07 | 0.108974 |
| 5 | 51.3 | 120 | 2.36E-07 | 0.142412 |
| 6 | 57 | 119.4 | 6.25E-07 | 0.192182 |
| 7 | 62.9 | 120.3 | 2.14E-06 | 0.267303 |
| 8 | 68.5 | 119.3 | 7.63E-06 | 0.378336 |
| 9 | 74.1 | 119.9 | 2.76E-05 | 0.542453 |
| 10 | 79.3 | 120.4 | 9.37E-05 | 0.778352 |
| 11 | 83.8 | 120.9 | 0.00028 | 1.101269 |
| 12 | 88.1 | 120.3 | 0.000781 | 1.537176 |
| 13 | 92.2 | 119.6 | 0.002069 | 2.117455 |
| 14 | 95.4 | 120.1 | 0.004761 | 2.842902 |
| 15 | 98.2 | 120.7 | 0.009889 | 3.724874 |
| 16 | 100.8 | 120.6 | 0.019222 | 4.782281 |
| 17 | 103 | 119.6 | 0.03471 | 6.015128 |
| 18 | 104.9 | 120 | 0.058698 | 7.422746 |
| 19 | 106.8 | 121.1 | 0.095852 | 9.029912 |
| 20 | 108.5 | 120.2 | 0.150806 | 10.83948 |
| 21 | 109.7 | 120 | 0.22325 | 12.80709 |
| 22 | 110.5 | 120.7 | 0.310346 | 14.88766 |
| 23 | 111.6 | 120.2 | 0.422548 | 17.13421 |
| 24 | 112.7 | 120 | 0.567092 | 19.55997 |
| 25 | 113.5 | 121 | 0.740872 | 22.12499 |
| 26 | 114.2 | 120 | 0.945046 | 24.81841 |
| 27 | 114.8 | 120.4 | 1.179469 | 27.62697 |
| 28 | 115.3 | 120.9 | 1.442495 | 30.53525 |
| 29 | 115.9 | 119.9 | 1.744491 | 33.56788 |
| 30 | 116.3 | 120.9 | 2.075622 | 36.68633 |

| | | | | |
|---|---|---|---|---|
| 31 | 116.9 | 120.2 | 2.455811 | 39.93811 |
| 32 | 117.1 | 120.2 | 2.853918 | 43.23559 |
| 33 | 117.4 | 121.1 | 3.280498 | 46.60282 |
| 34 | 117.6 | 120 | 3.727181 | 50.01737 |
| 35 | 118 | 120.7 | 4.21696 | 53.52856 |
| 36 | 118.1 | 120.9 | 4.718147 | 57.06433 |
| 37 | 118.2 | 120.2 | 5.231009 | 60.62487 |
| 38 | 118.6 | 121 | 5.79335 | 64.28618 |
| 39 | 118.7 | 120.4 | 6.36879 | 67.97312 |
| 40 | 118.9 | 120.4 | 6.97135 | 71.71188 |
| 41 | 118.9 | 121.2 | 7.573909 | 75.45064 |
| 42 | 119.2 | 120.1 | 8.219564 | 79.26848 |
| 43 | 119.2 | 121 | 8.865218 | 83.08633 |
| 44 | 118.9 | 47.3 | 9.467777 | 86.82508 |
| 45 | 118.7 | 43.5 | 10.04322 | 90.51203 |
| 46 | 114.9 | 42.8 | 10.2831 | 93.34026 |
| 47 | 108.4 | 40.2 | 10.3368 | 93.741 |
| 48 | 100.8 | 39.4 | 10.34614 | 94.121 |
| 49 | 93.4 | 40.1 | 10.34783 | 94.6547 |
| 50 | 86.6 | 40.8 | 10.34819 | 94.9874 |
| 51 | 80.5 | 43.6 | 10.34828 | 95.1020 |
| 52 | 75.4 | 32.2 | 10.3483 | 95.5121 |
| 53 | 71 | 32.3 | 10.34831 | 95.8746 |
| 54 | 67.1 | 32.1 | 10.34832 | 96.1200 |
| 55 | 63.3 | 32.5 | 10.34832 | 96.4521 |
| 56 | 60.2 | 34.1 | 10.34832 | 96.6010 |

Fig-13
Heat penetration characteristics of Tuna in brine with Fo 10 processed in aluminium cans

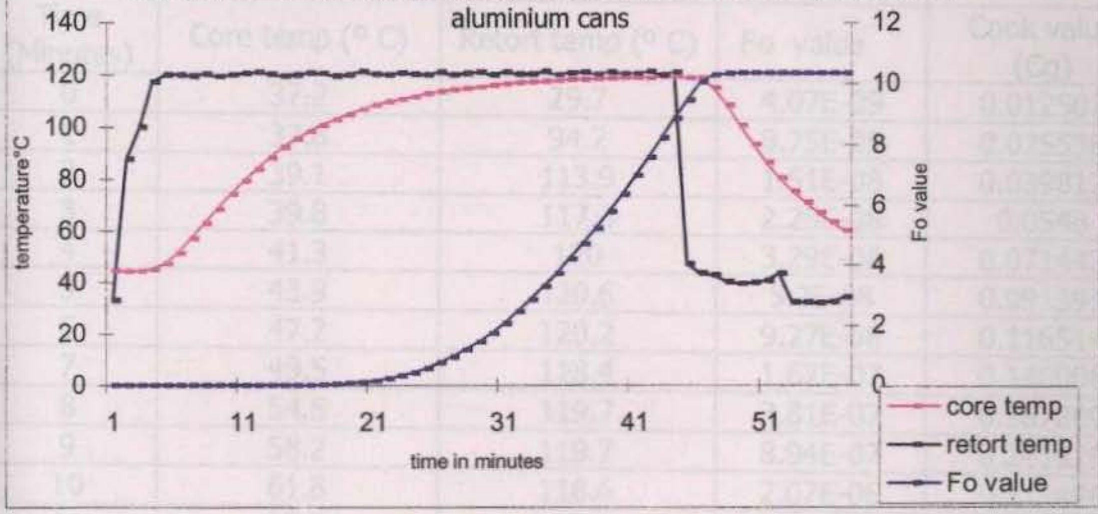
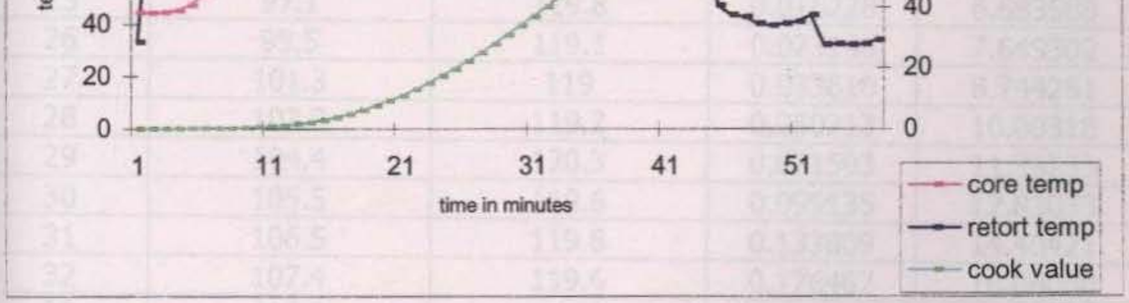



Fig-14
Heat penetration characteristics and Cook value of Tuna in brine with Fo 10 in aluminium cans



ıble-15. Heat penetration of tuna in curry processed to Fo 10 showing Fo ılue and cook value

| Time Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 37.2 | 29.7 | 4.07E-09 | 0.012502 |
| 1 | 37.8 | 94.2 | 8.75E-09 | 0.025538 |
| 2 | 39.1 | 113.9 | 1.51E-08 | 0.039812 |
| 3 | 39.8 | 117.3 | 2.25E-08 | 0.0548 |
| 4 | 41.3 | 120 | 3.29E-08 | 0.071443 |
| 5 | 43.9 | 120.6 | 5.2E-08 | 0.091395 |
| 6 | 47.2 | 120.2 | 9.27E-08 | 0.116514 |
| 7 | 49.5 | 118.4 | 1.62E-07 | 0.146006 |
| 8 | 54.5 | 119.7 | 3.81E-07 | 0.187809 |
| 9 | 58.2 | 119.7 | 8.94E-07 | 0.241926 |
| 10 | 61.8 | 118.6 | 2.07E-06 | 0.311496 |
| 11 | 65.3 | 118.9 | 4.7E-06 | 0.400311 |
| 12 | 68.8 | 119.1 | 1.06E-05 | 0.513693 |
| 13 | 72 | 119.1 | 2.29E-05 | 0.655441 |
| 14 | 74.9 | 120 | 4.69E-05 | 0.828979 |
| 15 | 77.6 | 120.9 | 9.15E-05 | 1.038492 |
| 16 | 79 | 121 | 0.000153 | 1.269505 |
| 17 | 83.6 | 120 | 0.000331 | 1.587947 |
| 18 | 87.4 | 119.8 | 0.000758 | 2.003075 |
| 19 | 90.3 | 119.6 | 0.001589 | 2.511305 |
| 20 | 92.9 | 120.3 | 0.003103 | 3.12063 |
| 21 | 93.3 | 119.4 | 0.004763 | 3.7472 |
| 22 | 94.1 | 118.5 | 0.006758 | 4.40974 |
| 23 | 94.9 | 119.3 | 0.009157 | 5.110315 |
| 24 | 96 | 120.5 | 0.012247 | 5.866778 |
| 25 | 97.1 | 119.8 | 0.016228 | 6.683588 |
| 26 | 99.5 | 119.1 | 0.023146 | 7.649302 |
| 27 | 101.3 | 119 | 0.033618 | 8.744251 |
| 28 | 103.3 | 119.2 | 0.050213 | 10.00318 |
| 29 | 104.4 | 120.3 | 0.071593 | 11.36253 |
| 30 | 105.5 | 119.6 | 0.099135 | 12.83033 |
| 31 | 106.5 | 119.6 | 0.133809 | 14.40421 |
| 32 | 107.4 | 119.6 | 0.176467 | 16.08008 |
| 33 | 108.3 | 120.7 | 0.228948 | 17.86458 |
| 34 | 109.1 | 119.7 | 0.292043 | 19.75152 |
| 35 | 110.6 | 120.5 | 0.381169 | 21.84665 |
| 36 | 111.2 | 119 | 0.483498 | 24.03136 |
| 37 | 111.9 | 119.9 | 0.603724 | 26.32543 |

| | | | | |
|---|---|---|---|---|
| 38 | 112.4 | 120 | 0.738621 | 28.70094 |
| 39 | 112.9 | 120.6 | 0.889977 | 31.1608 |
| 40 | 113.4 | 120.4 | 1.059801 | 33.70798 |
| 41 | 113.9 | 119.8 | 1.250347 | 36.3456 |
| 42 | 114.3 | 118.9 | 1.459277 | 39.05787 |
| 43 | 114.7 | 119.7 | 1.688364 | 41.84691 |
| 44 | 115.1 | 119.5 | 1.939552 | 44.71489 |
| 45 | 115.4 | 120.7 | 2.208706 | 47.64353 |
| 46 | 115.7 | 120.7 | 2.497109 | 50.63413 |
| 47 | 115.9 | 119.9 | 2.799104 | 53.66675 |
| 48 | 116.3 | 119.8 | 3.130235 | 56.7852 |
| 49 | 116.6 | 119 | 3.485048 | 59.96962 |
| 50 | 116.8 | 119 | 3.856584 | 63.19879 |
| 51 | 117.1 | 119.4 | 4.254691 | 66.49627 |
| 52 | 117.3 | 120.4 | 4.67156 | 69.84009 |
| 53 | 117.4 | 120.1 | 5.09814 | 73.20732 |
| 54 | 117.6 | 119.9 | 5.544823 | 76.62187 |
| 55 | 117.8 | 119.6 | 6.012559 | 80.0844 |
| 56 | 118 | 119 | 6.502337 | 83.59559 |
| 57 | 118.1 | 119.7 | 7.003525 | 87.13137 |
| 58 | 118.2 | 119.6 | 7.516386 | 90.6919 |
| 59 | 118.4 | 119 | 8.053418 | 94.30247 |
| 60 | 118.5 | 119.7 | 8.602959 | 97.93832 |
| 61 | 118.6 | 119.6 | 9.1653 | 101.5996 |
| 62 | 118.4 | 117.6 | 9.702332 | 105.2102 |
| 63 | 114.2 | 115.1 | 9.906506 | 107.9036 |
| 64 | 109.2 | 93 | 9.971071 | 109.8038 |
| 65 | 94.7 | 76 | 9.973362 | 110.4946 |
| 66 | 92.1 | 54.4 | 9.974621 | 111.0709 |
| 67 | 87.1 | 38.7 | 9.975019 | 111.7864 |
| 68 | 77 | 36.3 | 9.975058 | 112.1216 |
| 69 | 73.2 | 37.4 | 9.975074 | 112.6448 |
| 70 | 67.4 | 40.2 | 9.975078 | 112.9894 |
| 71 | 63 | 38.8 | 9.97508 | 113.1212 |
| 72 | 58.4 | 34.1 | 9.97508 | 113.3120 |
| 73 | 54.3 | 35.2 | 9.975081 | 113.4216 |

Fig-15
Heat penetraation characteristics of thermally processed Tuna curry to Fo 10

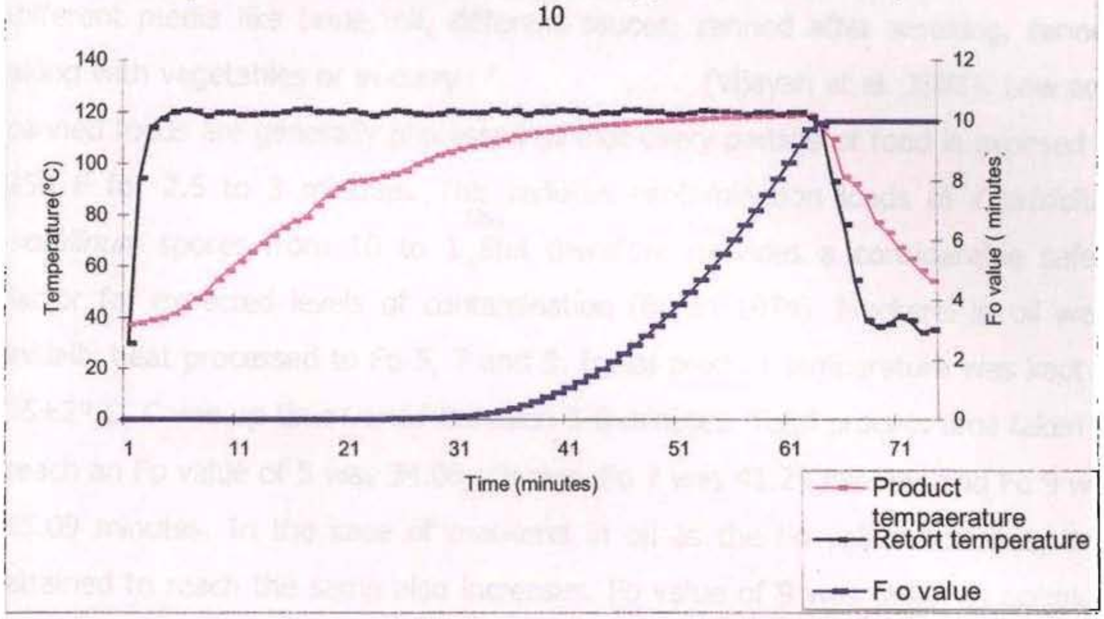



Fig-16
Heat penetration characteristcs and Cook value of thermally processed Tuna curry to Fo 10

### 5. 5. Heat Penetration Studies of Mackerel in Different Media:

Indian mackerel is a major fishery next to sardine and is commonly canned in different media like brine, oil, different sauces, canned after smoking, canned along with vegetables or in curry (Vijayan et al. 1985). Low acid canned foods are generally processed so that every particle of food is exposed to 250 F for 2.5 to 3 minutes. This reduces contamination loads of *Clostridium botulinum* spores from 10 to 1 and therefore provides a considerable safety factor for expected levels of contamination (Bryan 1974). Mackerel in oil were initially heat processed to Fo 5, 7 and 9. Initial product temperature was kept at $35\pm2^{o}$ C. Come up time varied between 3-6 minutes. Total process time taken to reach an Fo value of 5 was 34.06 minutes, Fo 7 was 41.29 minutes and Fo 9 was 45.09 minutes. In the case of mackerel in oil as the Fo value increases, time attained to reach the same also increases. Fo value of 9 was taken as optimum depending upon the sterility, cook value and also the softening of the bones. Mackerel in oil processed to an Fo 7 has taken 7.23 minutes more compared to Fo 5. But to attain Fo 9 it has taken only 3.40 minutes more compared to Fo 7. Heat penetration characteristics and Fo values of Mackerel in Oil processed to Fo 5 is presented in Figure 17 and cook value in figure 18. Heat penetration characteristics and Fo values of Mackerel in oil processed to Fo 7 is presented in Figure 19 and cook value in figure 20. Heat penetration characteristics and Fo values of Mackerel in oil processed to Fo 9 is presented in Figure 21 and cook value in figure 22. The values of heat penetration factor increases with increase in F0 values mainly due to the requirement of more heat penetration.

Cook value also shows a proportionate increase with increase in F0 values. Cook value for mackerel in Oil processed to F05 was 70.60 minutes, F0 7 it was 88.10 minutes and for mackerel in oil, processed to F0 9 was 100.53 minutes. Cook value represents the extent of cooking of the product. The fh value for F0 5 was 26.38 minutes, For F0 7 was 27.15 minutes and for F0 9 was 28.21 minutes. The value of fh/U decreases with increase in F0 value, mainly due to heat penetration

Table-16. Heat penetration of mackerel in oil processed to Fo 5 showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 33.7 | 33.4 | 3.64E-09 | 0.01945 |
| 1 | 34.1 | 64.4 | 5.64E-09 | 0.021456 |
| 2 | 35.1 | 82.8 | 8.66E-09 | 0.043428 |
| 3 | 38.4 | 101.3 | 1.24E-08 | 0.062448 |
| 4 | 41.1 | 117.7 | 2.87E-08 | 0.092969 |
| 5 | 46.8 | 120.6 | 1.48E-07 | 0.12468 |
| 6 | 52.4 | 121 | 2.98E-07 | 0.209025 |
| 7 | 58.7 | 121.1 | 2.54E-06 | 0.3248 |
| 8 | 65 | 120.3 | 5.21E-06 | 0.457321 |
| 9 | 71.4 | 120.8 | 4.58E-06 | 0.6876 |
| 10 | 76.4 | 120.6 | 7.3E-05 | 0.9391 |
| 11 | 81.4 | 120.5 | 0.000126 | 1.28874 |
| 12 | 85.9 | 120 | 0.000677 | 1.775169 |
| 13 | 89.4 | 120.8 | 0.001546 | 2.4876 |
| 14 | 93.2 | 120.7 | 0.003921 | 3.054817 |
| 15 | 95.8 | 12.9 | 0.009874 | 3.9876 |
| 16 | 98.8 | 120.7 | 0.015697 | 4.856073 |
| 17 | 100.8 | 121.2 | 0.028768 | 5.99468 |
| 18 | 101.9 | 121.1 | 0.036876 | 6.66784 |
| 19 | 103.2 | 120.2 | 0.048134 | 7.220671 |
| 20 | 106.7 | 120.4 | 0.120749 | 10.15627 |
| 21 | 108.1 | 120.8 | 0.198464 | 12.14568 |
| 22 | 109.3 | 120.2 | 0.252888 | 13.65133 |
| 23 | 110.5 | 121 | 0.34876 | 15.48762 |
| 24 | 111.4 | 121.2 | 0.467192 | 17.69793 |
| 25 | 112.2 | 120.4 | 0.57486 | 20.2486 |
| 26 | 113.1 | 119.9 | 0.78417 | 22.22248 |
| 27 | 113.8 | 120.4 | 0.98946 | 25.6874 |
| 28 | 114.4 | 120.7 | 1.211763 | 27.21132 |
| 29 | 114.9 | 120.9 | 1.54266 | 29.8464 |
| 30 | 115.4 | 120.8 | 1.75007 | 32.59815 |
| 31 | 115.9 | 121.1 | 2.00468 | 35.6486 |
| 32 | 116.3 | 120.3 | 2.412332 | 38.3341 |
| 33 | 116.6 | 120.8 | 2.7546 | 41.28468 |
| 34 | 116.9 | 121.1 | 3.172711 | 44.39935 |
| 35 | 117.2 | 120.8 | 3.7846 | 47.12168 |

| | | | | |
|---|---|---|---|---|
| 36 | 117.5 | 119.9 | 4.045743 | 50.76819 |
| 37 | 117.7 | 120.8 | 4.4624 | 53.4846 |
| 38 | 117.2 | 120.4 | 4.98462 | 57.40932 |
| 39 | 117.5 | 120.4 | 5.000024 | 60.2456 |
| 40 | 117.6 | 120.4 | 5.02534 | 64.23842 |
| 41 | 117.7 | 110.4 | 5.0253 | 65.48284 |
| 42 | 117.7 | 40.2 | 5.025357 | 66.84642 |
| 43 | 93.2 | 38.7 | 5.02536 | 67.2468 |
| 44 | 89.7 | 35.5 | 5.025364 | 68.02468 |
| 45 | 87.7 | 36.5 | 5.025365 | 68.8426 |
| 46 | 85.6 | 36.2 | 5.025367 | 69.99466 |
| 49 | 82.4 | 36.4 | 5.025368 | 70.2568 |
| 48 | 79.8 | 35.4 | 5.025368 | 70.48764 |
| 50 | 74.2 | 35.4 | 5.025368 | 70.61246 |
| 51 | 65.2 | 37.3 | 5.025368 | 70.61986 |
| 52 | 64.2 | 36.4 | 5.025368 | 70.62126 |

**Fig-17 Heat penetration characteristics and Fo value of Mackerel in oil processed to Fo 5**

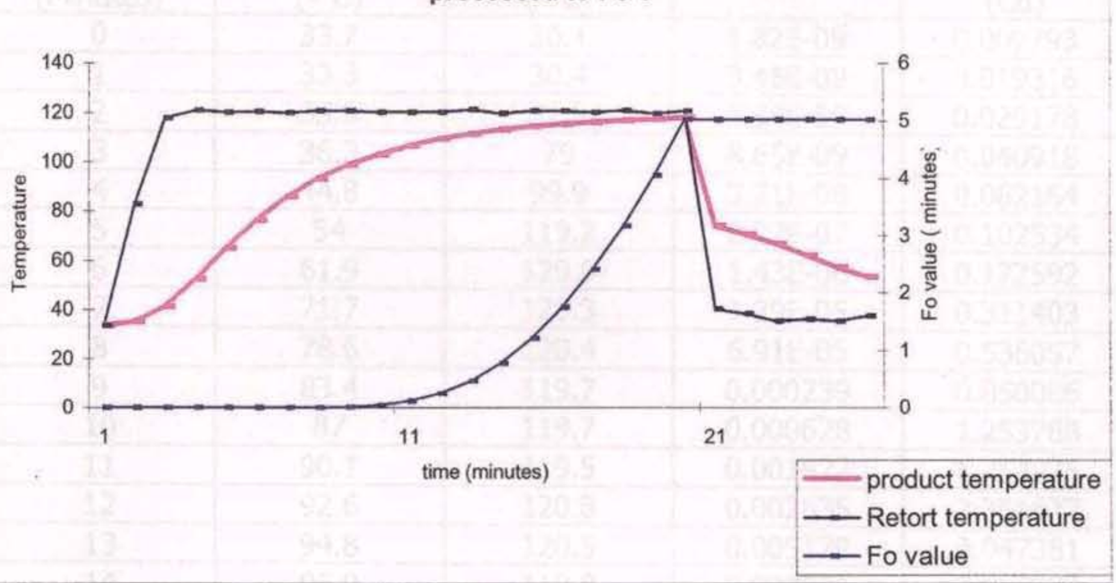
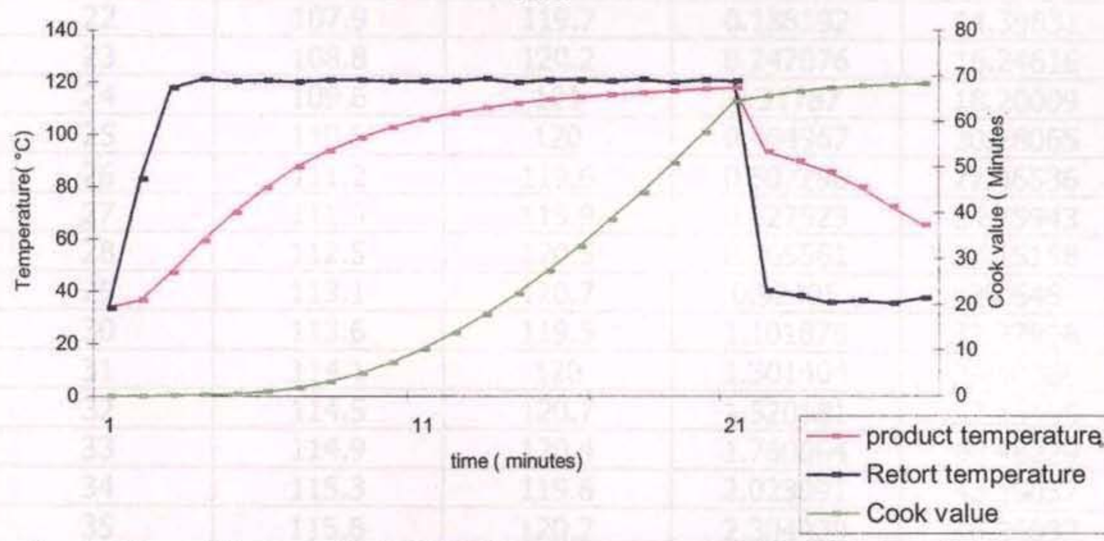



Fig-18
Heat penetration characteristics and cook value of Mackerel in oil processed to Fo 5



ble-17. Heat penetration of mackerel in oil processed to Fo 7 showing Fo lue and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 33.7 | 30.4 | 1.82E-09 | 0.009793 |
| 1 | 33.3 | 30.4 | 3.48E-09 | 0.019316 |
| 2 | 33.8 | 31.9 | 5.34E-09 | 0.029178 |
| 3 | 36.3 | 79 | 8.65E-09 | 0.040918 |
| 4 | 44.8 | 99.9 | 3.21E-08 | 0.062164 |
| 5 | 54 | 119.2 | 2.27E-07 | 0.102534 |
| 6 | 61.9 | 120.6 | 1.43E-06 | 0.172592 |
| 7 | 71.7 | 120.3 | 1.29E-05 | 0.311403 |
| 8 | 78.6 | 120.4 | 6.91E-05 | 0.536057 |
| 9 | 83.4 | 119.7 | 0.000239 | 0.850086 |
| 10 | 87 | 119.7 | 0.000628 | 1.253788 |
| 11 | 90.1 | 119.5 | 0.001422 | 1.754975 |
| 12 | 92.6 | 120.8 | 0.002835 | 2.351677 |
| 13 | 94.8 | 120.5 | 0.005179 | 3.047381 |
| 14 | 96.9 | 119.8 | 0.008981 | 3.852872 |
| 15 | 98.7 | 119.2 | 0.014735 | 4.766156 |
| 16 | 100.4 | 119.5 | 0.023247 | 5.79446 |
| 17 | 101.8 | 119.9 | 0.034996 | 6.928283 |
| 18 | 103.3 | 120.2 | 0.051592 | 8.187209 |
| 19 | 104.5 | 120.9 | 0.073469 | 9.556083 |
| 20 | 105.7 | 120.2 | 0.10231 | 11.04451 |
| 21 | 106.9 | 119.4 | 0.140328 | 12.66293 |
| 22 | 107.9 | 119.7 | 0.188192 | 14.39831 |
| 23 | 108.8 | 120.2 | 0.247076 | 16.24616 |
| 24 | 109.6 | 121 | 0.31787 | 18.20009 |
| 25 | 110.5 | 120 | 0.404967 | 20.28065 |
| 26 | 111.2 | 119.6 | 0.507296 | 22.46536 |
| 27 | 111.9 | 119.9 | 0.627523 | 24.75943 |
| 28 | 112.5 | 120.5 | 0.765561 | 27.15158 |
| 29 | 113.1 | 120.7 | 0.92405 | 29.646 |
| 30 | 113.6 | 119.5 | 1.101878 | 32.22898 |
| 31 | 114.1 | 120 | 1.301404 | 34.90366 |
| 32 | 114.5 | 120.7 | 1.520181 | 37.65405 |
| 33 | 114.9 | 120.4 | 1.760064 | 40.48229 |
| 34 | 115.3 | 119.6 | 2.023091 | 43.39057 |
| 35 | 115.6 | 120.2 | 2.304929 | 46.36037 |

| | | | | |
|---|---|---|---|---|
| 36 | 115.9 | 120.8 | 2.606924 | 49.39299 |
| 37 | 116.2 | 119.4 | 2.930518 | 52.48976 |
| 38 | 116.5 | 119.9 | 3.277255 | 55.65204 |
| 39 | 116.8 | 120.4 | 3.64879 | 58.88121 |
| 40 | 117 | 120.9 | 4.037835 | 62.15576 |
| 41 | 117.2 | 119.5 | 4.445215 | 65.47632 |
| 42 | 117.4 | 120 | 4.871795 | 68.84355 |
| 43 | 117.6 | 121 | 5.318478 | 72.2581 |
| 44 | 117.7 | 120.1 | 5.775567 | 75.69656 |
| 45 | 117.9 | 119.6 | 6.254197 | 79.18334 |
| 46 | 118 | 120.4 | 6.743976 | 82.69453 |
| 47 | 117.1 | 43.9 | 7.142083 | 85.992 |
| 48 | 100.4 | 35.7 | 7.150594 | 87.02031 |
| 49 | 86 | 34.5 | 7.150903 | 87.3968 |
| 50 | 76.9 | 46.6 | 7.150941 | 87.59633 |
| 51 | 73.7 | 30 | 7.150959 | 87.75593 |
| 52 | 68.4 | 30.3 | 7.150965 | 87.86619 |
| 53 | 63.4 | 30.1 | 7.150966 | 87.94398 |
| 54 | 58.6 | 28.7 | 7.150967 | 87.99962 |
| 55 | 58.1 | 33.2 | 7.150967 | 88.05336 |
| 56 | 57.5 | 31.3 | 7.150968 | 88.1049 |

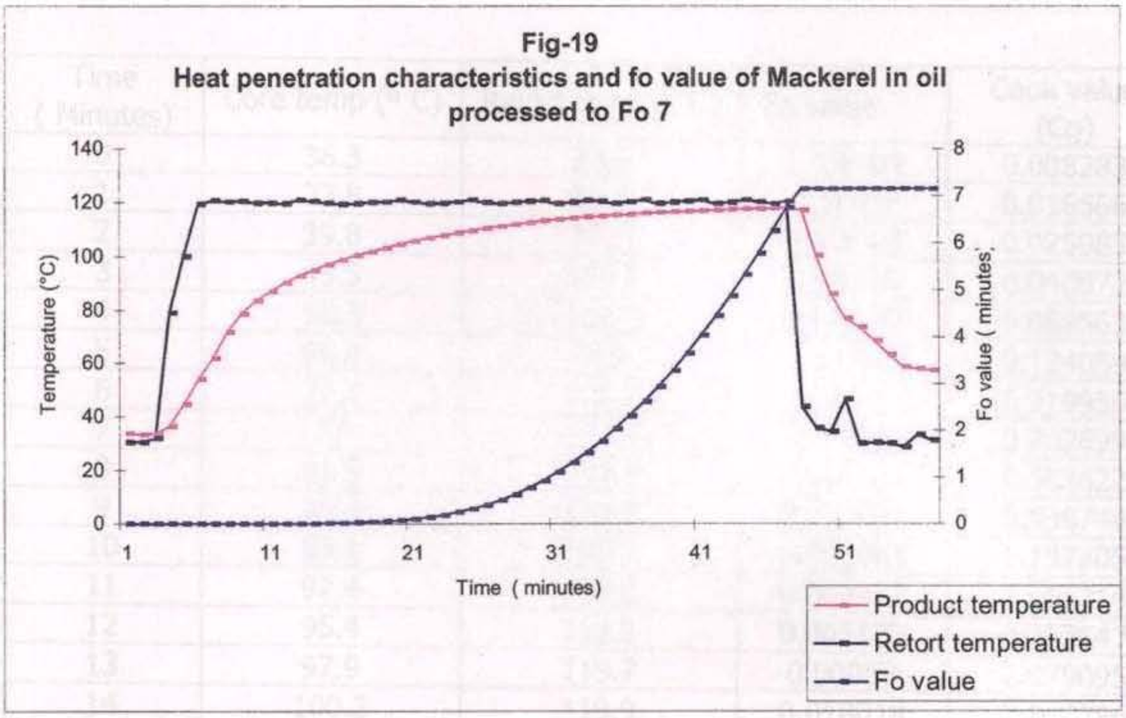



**Fig-19**
**Heat penetration characteristics and fo value of Mackerel in oil processed to Fo 7**

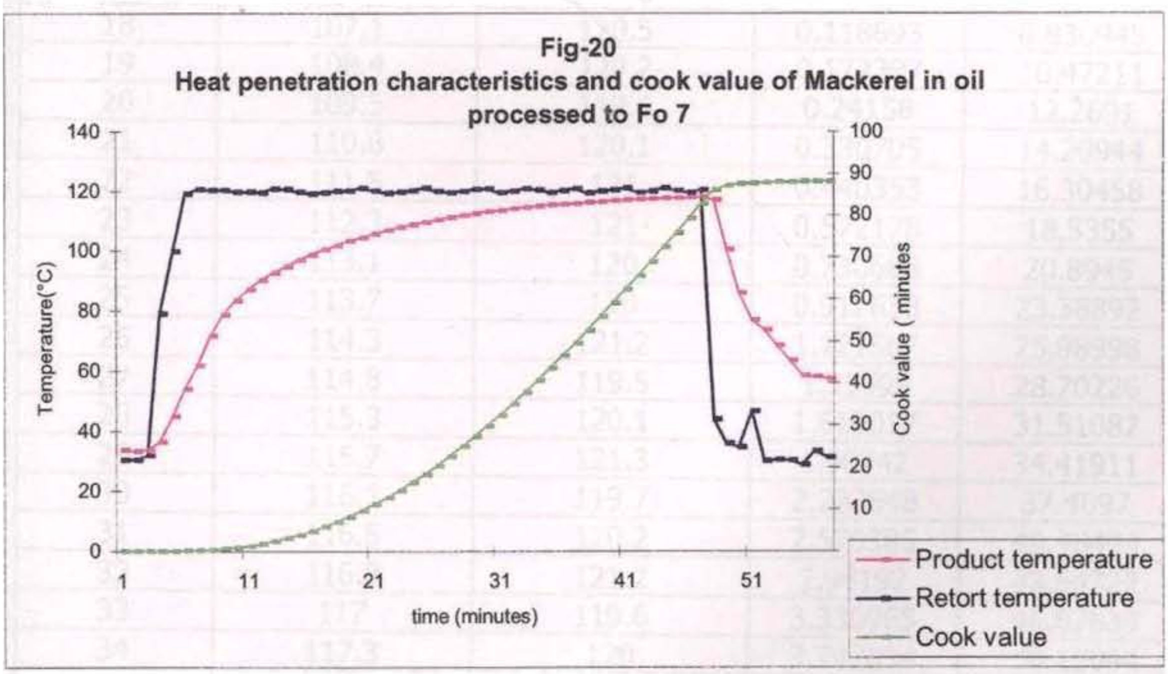



**Fig-20**
**Heat penetration characteristics and cook value of Mackerel in oil processed to Fo 7**

Table-18. Heat penetration of mackerel in oil processed to Fo 9 showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 36.3 | 29.6 | 1.05E-09 | 0.008283 |
| 1 | 37.8 | 80.4 | 2.2E-09 | 0.016566 |
| 2 | 39.8 | 97.1 | 9.61E-09 | 0.025083 |
| 3 | 49.5 | 107.7 | 7.88E-08 | 0.040072 |
| 4 | 58.3 | 119.9 | 6.04E-07 | 0.069563 |
| 5 | 66.4 | 120 | 3.99E-06 | 0.124059 |
| 6 | 72.1 | 120.4 | 1.66E-05 | 0.219959 |
| 7 | 77 | 118.4 | 5.55E-05 | 0.362699 |
| 8 | 81.4 | 119.8 | 0.000163 | 0.563622 |
| 9 | 85.4 | 120.8 | 0.000432 | 0.836748 |
| 10 | 89.1 | 120.3 | 0.001063 | 1.197805 |
| 11 | 92.4 | 119.6 | 0.002412 | 1.665214 |
| 12 | 95.4 | 119.5 | 0.005103 | 2.253647 |
| 13 | 97.9 | 119.7 | 0.00989 | 2.979095 |
| 14 | 100.2 | 119.9 | 0.018018 | 3.842796 |
| 15 | 102.3 | 120.6 | 0.0312 | 4.856849 |
| 16 | 104 | 120.7 | 0.050699 | 6.030927 |
| 17 | 105.6 | 119.6 | 0.078883 | 7.352868 |
| 18 | 107.1 | 120.5 | 0.118693 | 8.830945 |
| 19 | 108.4 | 120.2 | 0.172397 | 10.47211 |
| 20 | 109.5 | 119.6 | 0.24158 | 12.2691 |
| 21 | 110.6 | 120.1 | 0.330705 | 14.20944 |
| 22 | 111.5 | 121 | 0.440353 | 16.30458 |
| 23 | 112.3 | 121 | 0.572178 | 18.5355 |
| 24 | 113.1 | 120 | 0.730668 | 20.8945 |
| 25 | 113.7 | 120 | 0.912638 | 23.38892 |
| 26 | 114.3 | 121.2 | 1.121567 | 25.98998 |
| 27 | 114.8 | 119.5 | 1.35599 | 28.70226 |
| 28 | 115.3 | 120.1 | 1.619017 | 31.51082 |
| 29 | 115.7 | 121.3 | 1.90742 | 34.41911 |
| 30 | 116.1 | 119.7 | 2.223648 | 37.4097 |
| 31 | 116.5 | 120.2 | 2.570385 | 40.48494 |
| 32 | 116.8 | 121.2 | 2.94192 | 43.64722 |
| 33 | 117 | 119.6 | 3.330965 | 46.87639 |
| 34 | 117.3 | 120 | 3.747834 | 50.15094 |
| 35 | 117.6 | 121 | 4.194518 | 53.49475 |

| | | | | |
|---|---|---|---|---|
| 36 | 117.8 | 121.1 | 4.662253 | 56.9093 |
| 37 | 118 | 121 | 5.152032 | 60.37183 |
| 38 | 118.2 | 119.9 | 5.664893 | 63.88303 |
| 39 | 118.3 | 121.3 | 6.189701 | 67.44356 |
| 40 | 118.5 | 119.8 | 6.739242 | 71.02902 |
| 41 | 118.7 | 120.6 | 7.314682 | 74.66488 |
| 42 | 118.8 | 119.6 | 7.903525 | 78.32618 |
| 43 | 119 | 120.4 | 8.52012 | 82.01313 |
| 44 | 118.8 | 67.5 | 9.108964 | 85.72589 |
| 45 | 107.5 | 49.8 | 9.152616 | 89.49083 |
| 46 | 94.4 | 41.8 | 9.154754 | 93.25576 |
| 47 | 86.6 | 53.9 | 9.155108 | 96.96852 |
| 48 | 80.9 | 34.6 | 9.155204 | 98.65613 |
| 49 | 74 | 33.4 | 9.155223 | 99.33269 |
| 50 | 68.7 | 34.5 | 9.155229 | 99.72528 |
| 51 | 64.9 | 34.9 | 9.155232 | 99.98904 |
| 52 | 61.8 | 39.4 | 9.155233 | 100.152 |
| 53 | 59.9 | 37.1 | 9.155233 | 100.2646 |
| 54 | 58.1 | 31.3 | 9.155234 | 100.351 |
| 55 | 53.4 | 28.7 | 9.155234 | 100.4206 |

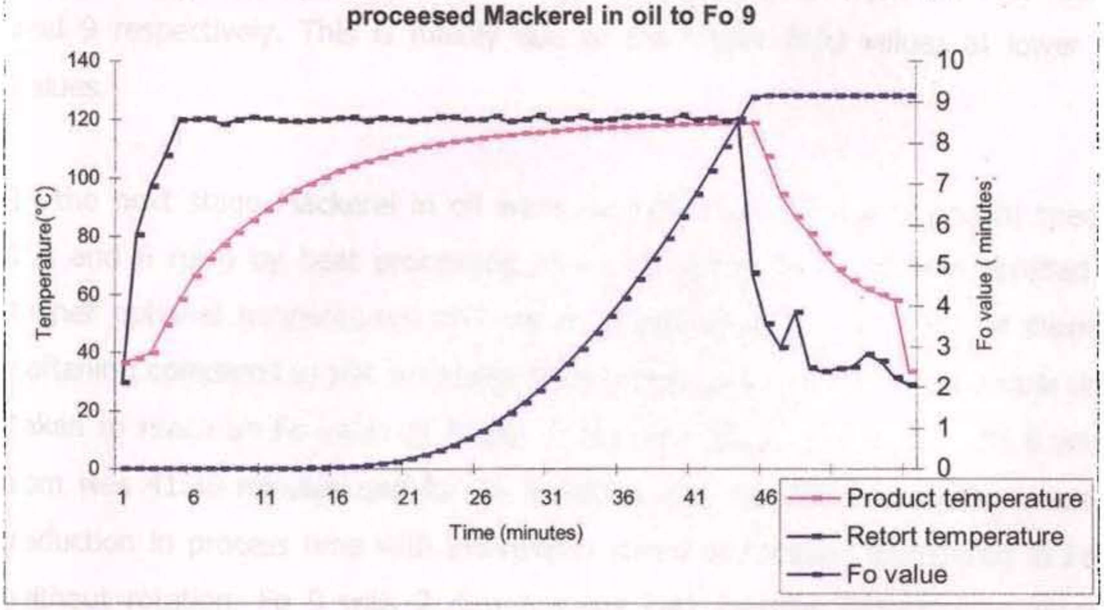



**Fig-21 Heat penetartion characteristics and fo value of thermally proceesed Mackerel in oil to Fo 9**

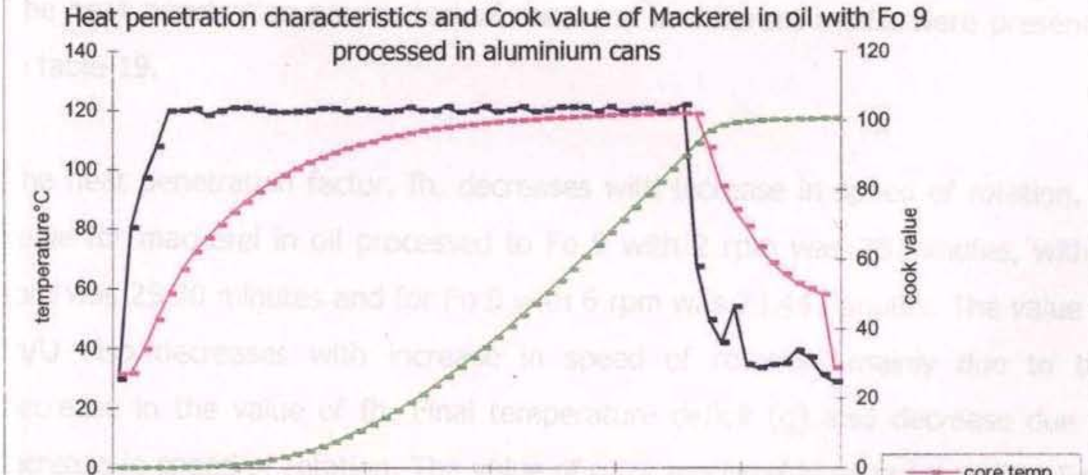



Fig-22
Heat penetration characteristics and Cook value of Mackerel in oil with Fo 9 processed in aluminium cans

which is low and increase in Fo values. When the processing temperature is 121.1 C, U=Fo (Stumbo 1973). Final temperature deficit (g) also decreases with increase in Fo values with corresponding values of 3.60, 2.38 and 2.02 for Fo5, 7 and 9 respectively. This is mainly due to the higher fh/U values at lower Fo values.

In the next stage Mackerel in oil were subjected to different rotational speeds 2,4 and 6 rpm) by heat processing to an Fo value of 9. Agitation resulted in higher optional temperatures and better quality retention. In terms of thermal softening compared to still processes (Hendrickes et al, 1993). Total process time taken to reach an Fo value of 9 with 2 rpm was 42.28 minutes, for Fo 9 with4 rpm was 41.38 minutes and for Fo 9 with 6 rpm was 38.22 minutes. There is reduction in process time with increase in speed of rotation. Compared to Fo 9 without rotation, Fo 9 with 2 rpm has got 2.41 minutes reduction in process time. Corresponding Cook values were also decreased with increase in the speed of rotation. The cook value of Mackerel in oil processed withF0 9 with 2 rpm was 95.09 minutes, with 4 rpm was 94.49 minutes and for 6 rpm was84.60 minutes. The heat penetration parameters of mackerel in different media were presented in table-19.

The heat penetration factor, fh, decreases with increase in speed of rotation. fh value for mackerel in oil processed to Fo 9 with 2 rpm was 28 minutes, with 4 rpm was 25.30 minutes and for Fo 9 with 6 rpm was 23.44 minutes. The value of fh/U also decreases with increase in speed of rotation, mainly due to the decrease in the value of fh. Final temperature deficit (g) also decrease due to increase in speed of rotation. The value of g for mackerel in oil processed to Fo 9 with 2 rpm was 3.05, with 4 rpm were 2.79 and Fo 9 with 6rpm was 2.59. Value of g decreases because it depends upon the fh/U and lag factor in cooling. Heat penetration characteristics and Fo values of mackerel processed to Fo 9 with 2 rpm is presented in figure 23 and cook value in figure 24. Heat penetration characteristics and Fo values of mackerel processed to Fo 9 with 4 rpm is presented in figure 25 and cook value in figure 26. Heat penetration characteristics and Fo values of mackerel processed to Fo 9 with 6 rpm is presented in figure 27 and cook value in figure 28. Vanloey et al (1994) studied the effect of headspace in rotational speed on the heat penetration characteristics.

In the last stage, mackerel in brine and mackerel in curry were heat processed to Fo 9 to study the changes in heat penetration. Total process time taken to reach an Fo value of 9 in the case of mackerel in brine was 38.06 minutes and in case of mackerel in curry, it was 57.31 minutes. Heat penetration characteristics and Fo value of mackerel in brine is presented in Figure 29 and cook value in figure 30. Heat penetration characteristics and Fo value of mackerel in curry is presented in Figure 31 and cook value in figure 32. The cook value of mackerel in brine processed to Fo 9 was 92.83 minutes and mackerel in curry processed to F0 9 has got a cook value of 116.25 minutes. Gopal et al (2002) reported that mackerel fish curry processed to Fo 8.43 in retortable pouches gave an acceptable product with desired texture and sensory characteristics. In the present study, Fo 9 was taken as optimum in the case of Mackerel curry in aluminium cans. Among the three products, mackerel in brine processed to Fo 9 has got the least process time and also heat penetration factor. Heat penetration factor for mackerel in brine was 20.12 minutes, for mackerel in curry, it was, 35.17 minutes and for mackerel in oil it was 45.09 minutes when processed to Fo 9.

Table-19

**Heat penetration data of mackerel products**

| Fe | Jh | Jc | Fh ( mts) | Fh/U | g | Cg ( mts) | B ( mts) | TPT ( mts) |
|---|---|---|---|---|---|---|---|---|
| MIO 5 | 0.6037±0.16 | 1.1376±0.06 | 26.38±2.58 | 5.1827±0.87 | 3.0844±0.45 | 70.6±1.03 | 31.13±2.03 | 34.06±2.04 |
| MIO 7 | 0.7360±0.12 | 1.1135±0.03 | 27.15±3.40 | 3.7144±0.49 | 2.3080±0.26 | 88.10±1.88 | 38.49±1.45 | 41.29±1.56 |
| MIO 9 | 0.7130±0.03 | 1.2573±0.05 | 28.21±0.22 | 3.0932±0.02 | 2.0344±0.15 | 100.53±1.24 | 42.21±1.01 | 45.09±0.99 |
| MIO 9 Rpm2 | 0.6972±0.11 | 1.1211±0.06 | 28.00±2.02 | 2.4699±0.43 | 1.4819±0.36 | 95.09±3.03 | 41.06±1.88 | 42.28±1.54 |
| MIO 9 Rpm4 | 0.6305±0.16 | 1.2966±0.11 | 25.3±3.83 | 2.7453±0.43 | 1.7561±0.28 | 94.49±2.12 | 37.39±1.96 | 41.38±1.36 |
| MIO 9 Rpm6 | 0.6858±0.23 | 1.3226±0.03 | 23.44±1.91 | 2.5768±0.24 | 1.6377±0.16 | 84.6±2.28 | 36.19±1.32 | 38.22±1.70 |
| MIB | 0.8949±0.01 | 1.2203±0.07 | 20.12±1.12 | 2.2479±0.12 | 1.3349±0.05 | 92.83±0.69 | 35.57±1.00 | 38.06±1.29 |
| MIC 9 | 1.1728±0.01 | 1.2661±0.01 | 35.17±0.18 | 3.8961±0.03 | 2.5740±0.02 | 116.25±2.21 | 54.31±0.51 | 57.31±0.51 |

MIO – Mackerei in oil

MIB – Mackerel in brine

MIC – Mackerel in curry

Table-20. Heat penetration of mackerel in oil processed to Fo 9 and 2rpm showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 35.6 | 32.6 | 1.32E-09 | 0.008881 |
| 1 | 36.7 | 75.8 | 2.87E-09 | 0.018208 |
| 2 | 38.4 | 82.8 | 8.24E-09 | 0.031801 |
| 3 | 45.4 | 92 | 3.52E-08 | 0.053955 |
| 4 | 52.9 | 96.2 | 1.87E-07 | 0.091343 |
| 5 | 57.4 | 115.9 | 6.13E-07 | 0.142522 |
| 6 | 66.5 | 120.5 | 4.08E-06 | 0.239093 |
| 7 | 73.5 | 120 | 2.15E-05 | 0.39648 |
| 8 | 79.2 | 121.5 | 8.6E-05 | 0.63074 |
| 9 | 82.6 | 119.2 | 0.000227 | 0.92772 |
| 10 | 85.4 | 119.4 | 0.000496 | 1.288777 |
| 11 | 87.9 | 120 | 0.000975 | 1.718643 |
| 12 | 90.5 | 119.5 | 0.001846 | 2.234015 |
| 13 | 93 | 120.7 | 0.003395 | 2.847606 |
| 14 | 95.3 | 120.2 | 0.006025 | 3.56801 |
| 15 | 97.5 | 120.7 | 0.01039 | 4.407938 |
| 16 | 99.4 | 120.1 | 0.017151 | 5.366937 |
| 17 | 101.1 | 119.3 | 0.027151 | 6.446713 |
| 18 | 102.7 | 119.6 | 0.041605 | 7.654021 |
| 19 | 104.2 | 121.4 | 0.062023 | 8.994539 |
| 20 | 105.6 | 119.9 | 0.090207 | 10.47262 |
| 21 | 106.9 | 119.7 | 0.128226 | 12.09103 |
| 22 | 108 | 120.4 | 0.177204 | 13.83856 |
| 23 | 109.1 | 119.3 | 0.240299 | 15.7255 |
| 24 | 110 | 120 | 0.317924 | 17.73473 |
| 25 | 110.9 | 120.1 | 0.413423 | 19.87419 |
| 26 | 111.7 | 120.9 | 0.528239 | 22.13646 |
| 27 | 112.4 | 120.5 | 0.663135 | 24.51198 |
| 28 | 113.1 | 119.3 | 0.821624 | 27.0064 |
| 29 | 113.7 | 119.6 | 1.003594 | 29.60746 |
| 30 | 114.2 | 120.5 | 1.207768 | 32.30088 |
| 31 | 114.7 | 120.6 | 1.436855 | 35.08992 |
| 32 | 115.2 | 120.8 | 1.693894 | 37.97798 |
| 33 | 115.6 | 121.7 | 1.975733 | 40.94778 |
| 34 | 116 | 119.4 | 2.284762 | 44.00163 |
| 35 | 116.4 | 119.9 | 2.623606 | 47.14192 |

| | | | | |
|---|---|---|---|---|
| 36 | 116.8 | 120.3 | 2.995142 | 50.37109 |
| 37 | 117 | 121.6 | 3.384187 | 53.64564 |
| 38 | 117.3 | 119.7 | 3.801056 | 56.98946 |
| 39 | 117.6 | 119.6 | 4.24774 | 60.40401 |
| 40 | 117.8 | 119.8 | 4.715475 | 63.86654 |
| 41 | 118 | 121 | 5.205254 | 67.37773 |
| 42 | 118.2 | 120.2 | 5.718115 | 70.93827 |
| 43 | 118.4 | 119.7 | 6.255147 | 74.54883 |
| 44 | 118.5 | 121.1 | 6.804688 | 78.18469 |
| 45 | 118.7 | 119.7 | 7.380128 | 81.87163 |
| 46 | 118.8 | 119.7 | 7.968971 | 85.58439 |
| 47 | 118.9 | 121.1 | 8.571531 | 89.32315 |
| 48 | 118.7 | 93.1 | 9.146971 | 93.01009 |
| 49 | 97.1 | 56.2 | 9.150952 | 93.8269 |
| 50 | 88.4 | 47.4 | 9.151489 | 94.27203 |
| 51 | 81.8 | 45 | 9.151606 | 94.55289 |
| 52 | 76.5 | 41.9 | 9.151641 | 94.74692 |
| 53 | 71.9 | 41.1 | 9.151653 | 94.88769 |
| 54 | 68.7 | 40.6 | 9.151659 | 95.00028 |
| 55 | 66.4 | 34 | 9.151662 | 95.09618 |

Fig-23
Heat penetration characteristics of Mackerel in oil with Fo9 and 2 rpm in aluminium cans

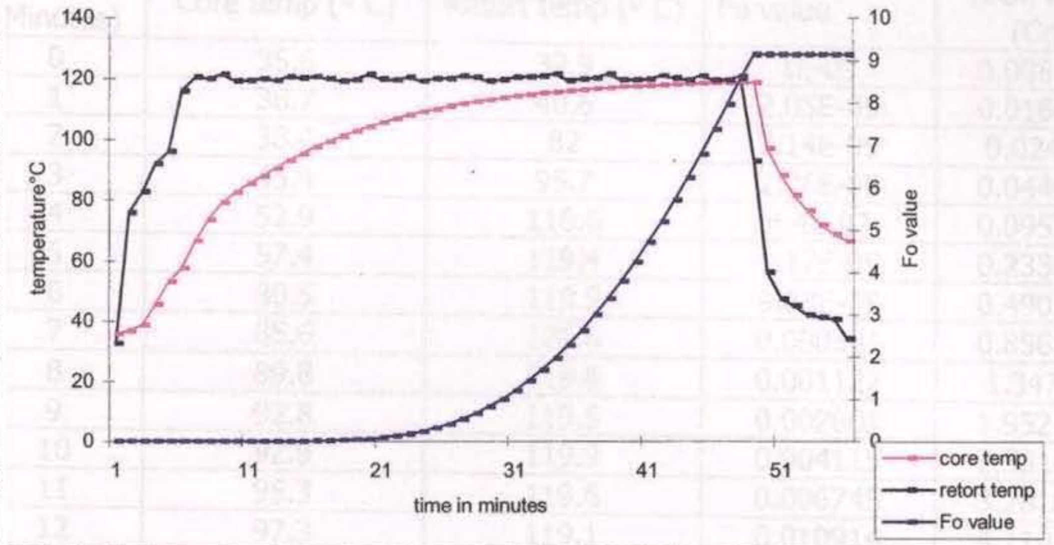



Fig-24
Heat penetration characteristics and cook value of Mackerel in oil with Fo 9 and 2rpm processed in aluminium cans

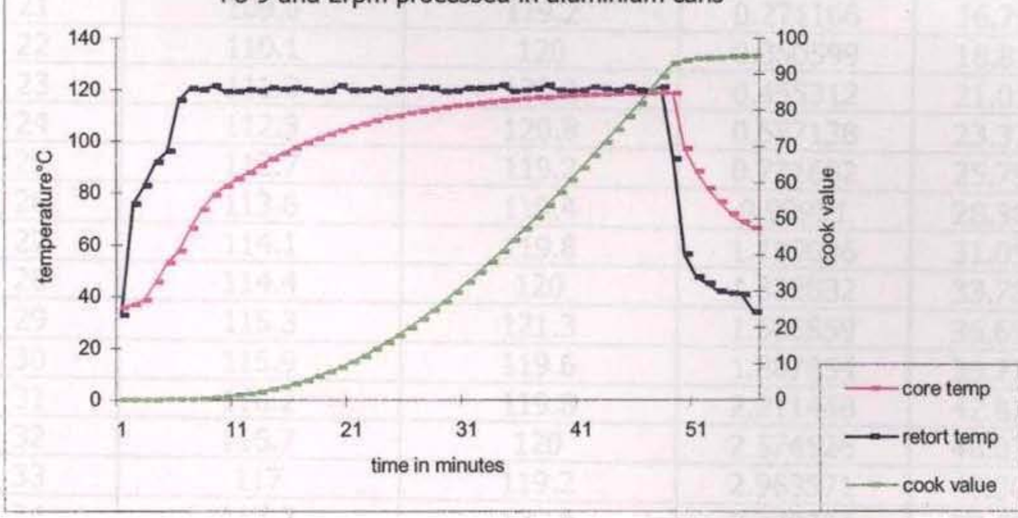


Table-21. Heat penetration of mackerel in oil processed to Fo 9 and 4rpm showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 35.6 | 32.9 | 1E-09 | 0.008168 |
| 1 | 36.7 | 40.6 | 2.05E-09 | 0.016451 |
| 2 | 38.4 | 82 | 3.14E-09 | 0.02485 |
| 3 | 45.4 | 95.7 | 2.26E-08 | 0.044943 |
| 4 | 52.9 | 116.6 | 4.4E-07 | 0.095766 |
| 5 | 57.4 | 119.4 | 1.17E-05 | 0.233612 |
| 6 | 80.5 | 119.9 | 9.88E-05 | 0.490114 |
| 7 | 85.6 | 120.6 | 0.000381 | 0.856245 |
| 8 | 89.8 | 119.6 | 0.001122 | 1.34705 |
| 9 | 92.8 | 119.5 | 0.002601 | 1.952137 |
| 10 | 92.9 | 119.9 | 0.004115 | 2.561461 |
| 11 | 95.3 | 119.6 | 0.006745 | 3.281865 |
| 12 | 97.3 | 119.1 | 0.010914 | 4.110154 |
| 13 | 99 | 120.3 | 0.017079 | 5.042757 |
| 14 | 100.7 | 120 | 0.0262 | 6.092812 |
| 15 | 102.1 | 120.4 | 0.038789 | 7.25062 |
| 16 | 103.5 | 120.7 | 0.056167 | 8.527237 |
| 17 | 104.7 | 121.2 | 0.079076 | 9.915348 |
| 18 | 105.9 | 120.5 | 0.109275 | 11.42469 |
| 19 | 107.1 | 119.3 | 0.149086 | 13.06585 |
| 20 | 108.2 | 119.4 | 0.200372 | 14.83794 |
| 21 | 109.6 | 119.2 | 0.271166 | 16.79187 |
| 22 | 110.1 | 120 | 0.350599 | 18.81517 |
| 23 | 111.3 | 120.2 | 0.455312 | 21.01518 |
| 24 | 112.3 | 120.8 | 0.587138 | 23.37418 |
| 25 | 112.7 | 119.2 | 0.731682 | 25.79994 |
| 26 | 113.6 | 119.4 | 0.90951 | 28.38292 |
| 27 | 114.1 | 119.8 | 1.109036 | 31.05761 |
| 28 | 114.4 | 120 | 1.322832 | 33.78887 |
| 29 | 115.3 | 121.3 | 1.585859 | 36.69715 |
| 30 | 115.9 | 119.6 | 1.887854 | 39.72977 |
| 31 | 116.2 | 119.8 | 2.211448 | 42.82654 |
| 32 | 116.7 | 120 | 2.574526 | 46.03326 |
| 33 | 117 | 119.2 | 2.963571 | 49.30781 |
| 34 | 117.2 | 120.3 | 3.370951 | 52.62837 |
| 35 | 117.8 | 120.7 | 3.838686 | 56.09091 |

| | | | | |
|---|---|---|---|---|
| 36 | 117.9 | 119.3 | 4.317317 | 59.57769 |
| 37 | 118 | 119.6 | 4.807095 | 63.08888 |
| 38 | 118.4 | 119.4 | 5.344127 | 66.69945 |
| 39 | 118.3 | 119.5 | 5.868935 | 70.28491 |
| 40 | 118.6 | 120.2 | 6.431276 | 73.94622 |
| 41 | 118.8 | 120.4 | 7.02012 | 77.65898 |
| 42 | 118.9 | 120 | 7.622679 | 81.39774 |
| 43 | 119.1 | 119.2 | 8.253637 | 85.18904 |
| 44 | 119.1 | 117 | 8.884594 | 88.98033 |
| 45 | 115.7 | 85.5 | 9.172997 | 91.97093 |
| 46 | 101 | 45.2 | 9.182769 | 93.0432 |
| 47 | 90.1 | 42.8 | 9.183564 | 93.54438 |
| 48 | 82.4 | 43.9 | 9.183699 | 93.83725 |
| 49 | 76.2 | 39.7 | 9.183731 | 94.02726 |
| 50 | 71.4 | 39.1 | 9.183742 | 94.1632 |
| 51 | 66.9 | 42.9 | 9.183745 | 94.2625 |
| 52 | 59.2 | 41.2 | 9.183746 | 94.32053 |
| 53 | 61.3 | 41.4 | 9.183747 | 94.38772 |
| 54 | 60.4 | 35.5 | 9.183748 | 94.45081 |
| 55 | 57.5 | 33.1 | 9.183748 | 94.46358 |
| 56 | 55.8 | 34.6 | 9.183748 | 94.47492 |
| 57 | 52.6 | 47.7 | 9.183748 | 94.48399 |
| 58 | 54.1 | 42.2 | 9.183748 | 94.49406 |

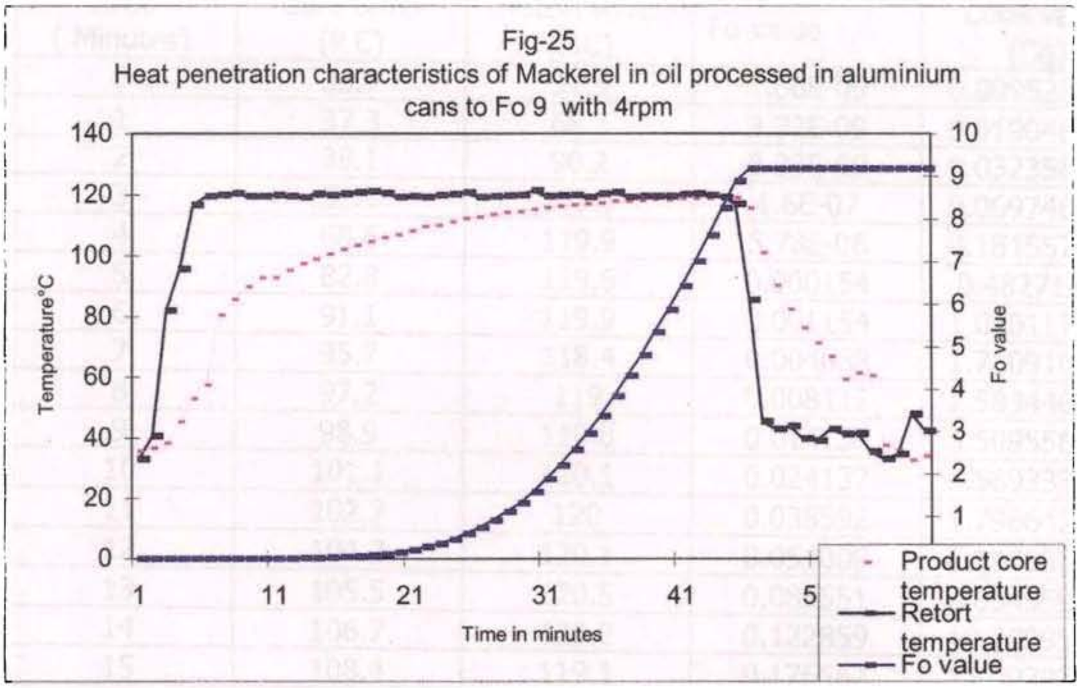


Fig-25
Heat penetration characteristics of Mackerel in oil processed in aluminium cans to Fo 9 with 4rpm
Temperature°C
Fo value
Time in minutes
Product core temperature
Retort temperature
Fo value

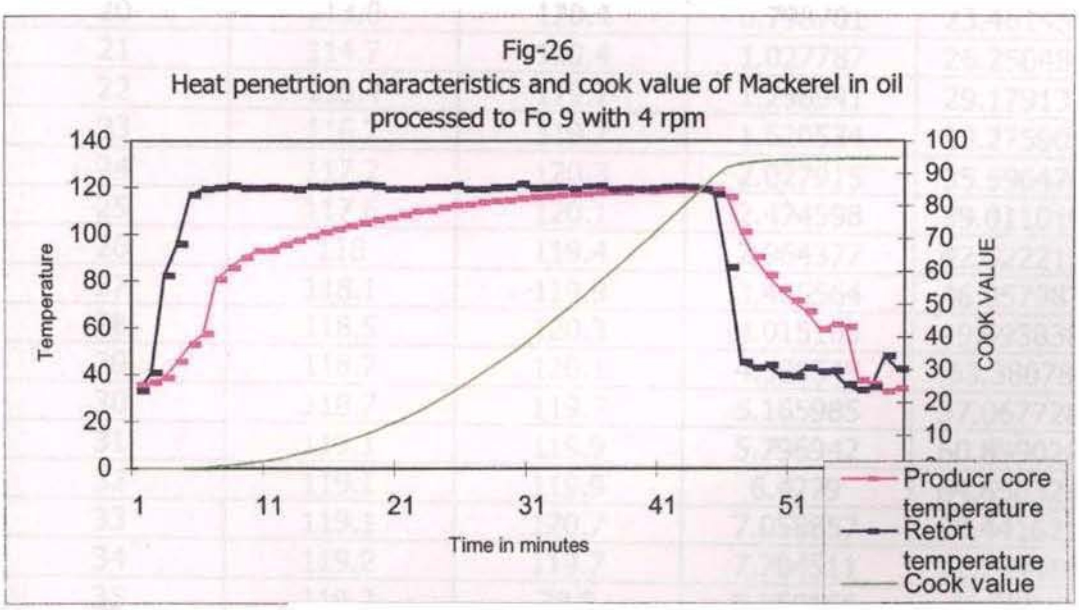



Fig-26
Heat penetrtion characteristics and cook value of Mackerel in oil processed to Fo 9 with 4 rpm
Temperature
COOK VALUE
Time in minutes
Producr core temperature
Retort temperature
Cook value

Table-22. Heat penetration of mackerel in oil processed to Fo 9 and 6rpm showing Fo value and cook value

| Time ( Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 36.7 | 31.3 | 1.66E-09 | 0.009523309 |
| 1 | 37.3 | 68.3 | 3.32E-09 | 0.019046618 |
| 2 | 38.1 | 90.2 | 8.33E-09 | 0.032358591 |
| 3 | 52.9 | 103.9 | 1.6E-07 | 0.069746164 |
| 4 | 68.6 | 119.9 | 5.78E-06 | 0.181557245 |
| 5 | 82.8 | 119.6 | 0.000154 | 0.48271072 |
| 6 | 91.1 | 119.9 | 0.001154 | 1.020117363 |
| 7 | 95.7 | 118.4 | 0.004038 | 1.760910533 |
| 8 | 97.2 | 119 | 0.008112 | 2.583440095 |
| 9 | 98.9 | 119.8 | 0.014137 | 3.509558823 |
| 10 | 101.1 | 120.1 | 0.024137 | 4.589333985 |
| 11 | 102.7 | 120 | 0.038592 | 5.796642272 |
| 12 | 104.2 | 120.1 | 0.059009 | 7.137160511 |
| 13 | 105.5 | 120.5 | 0.086551 | 8.604959779 |
| 14 | 106.7 | 120.2 | 0.122859 | 10.20095028 |
| 15 | 108.4 | 119.1 | 0.176562 | 11.99793943 |
| 16 | 109.5 | 120 | 0.245745 | 13.93828368 |
| 17 | 111.3 | 120.4 | 0.350458 | 16.13829159 |
| 18 | 111.8 | 119.5 | 0.467948 | 18.41640719 |
| 19 | 112.7 | 119.6 | 0.612492 | 20.84217084 |
| 20 | 113.8 | 120.4 | 0.798701 | 23.46145019 |
| 21 | 114.7 | 120.4 | 1.027787 | 26.25048892 |
| 22 | 115.4 | 119.2 | 1.296941 | 29.17913349 |
| 23 | 116.2 | 119.7 | 1.620534 | 32.27590448 |
| 24 | 117.2 | 120.3 | 2.027915 | 35.59647052 |
| 25 | 117.6 | 120.1 | 2.474598 | 39.01101939 |
| 26 | 118 | 119.4 | 2.964377 | 42.52221113 |
| 27 | 118.1 | 119.9 | 3.465564 | 46.05798798 |
| 28 | 118.5 | 120.3 | 4.015105 | 49.69383884 |
| 29 | 118.7 | 120.1 | 4.590545 | 53.3807839 |
| 30 | 118.7 | 119.7 | 5.165985 | 57.06772897 |
| 31 | 119.1 | 119.9 | 5.796942 | 60.85902659 |
| 32 | 119.1 | 119.9 | 6.4279 | 64.65032422 |
| 33 | 119.1 | 120.7 | 7.058857 | 68.44162184 |
| 34 | 119.2 | 119.7 | 7.704511 | 72.25946587 |
| 35 | 119.2 | 78.8 | 8.350166 | 76.0773099 |
| 36 | 119.4 | 61.7 | 9.026249 | 79.94880566 |
| 37 | 114.6 | 54 | 9.250121 | 82.71845152 |

| | | | | |
|---|---|---|---|---|
| 38 | 97.3 | 47.8 | 9.254289 | 83.54674038 |
| 39 | 85.7 | 43.7 | 9.254578 | 83.91543488 |
| 40 | 77.8 | 41.3 | 9.254625 | 84.12789271 |
| 41 | 71.7 | 39.3 | 9.254636 | 84.26670382 |
| 42 | 67.3 | 39.8 | 9.25464 | 84.36881914 |
| 43 | 64 | 40.5 | 9.254642 | 84.44993223 |
| 44 | 63.1 | 40.7 | 9.254644 | 84.52610823 |
| 45 | 62.7 | 40.2 | 9.254645 | 84.60018755 |

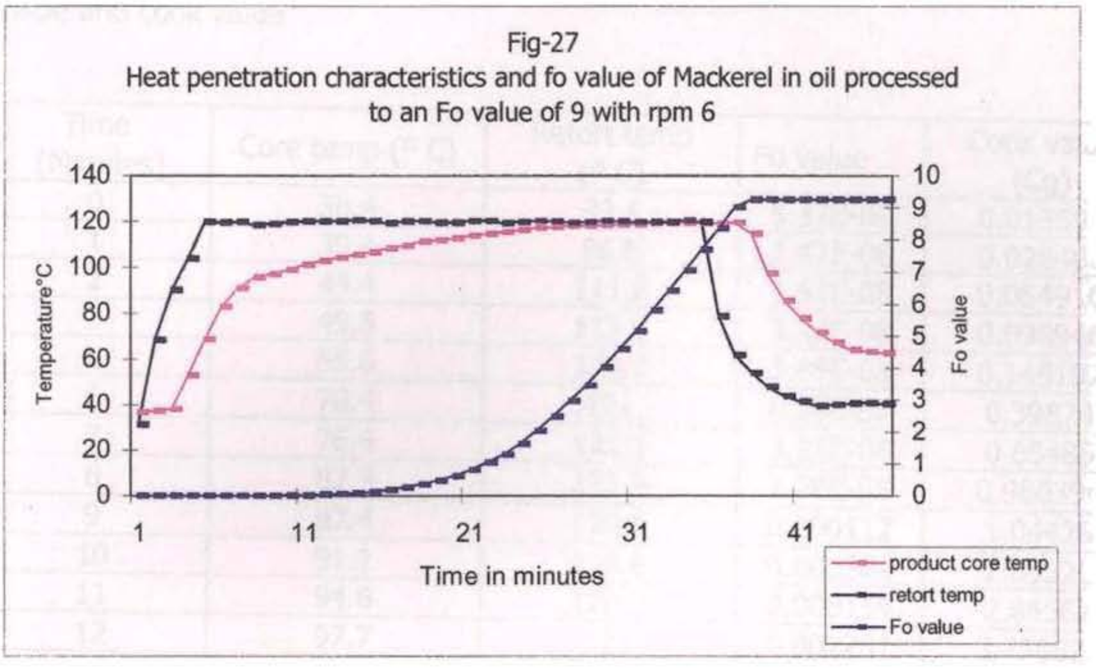


Fig-27
Heat penetration characteristics and fo value of Mackerel in oil processed to an Fo value of 9 with rpm 6
Temperature°C
Fo value
Time in minutes
product core temp
retort temp
Fo value

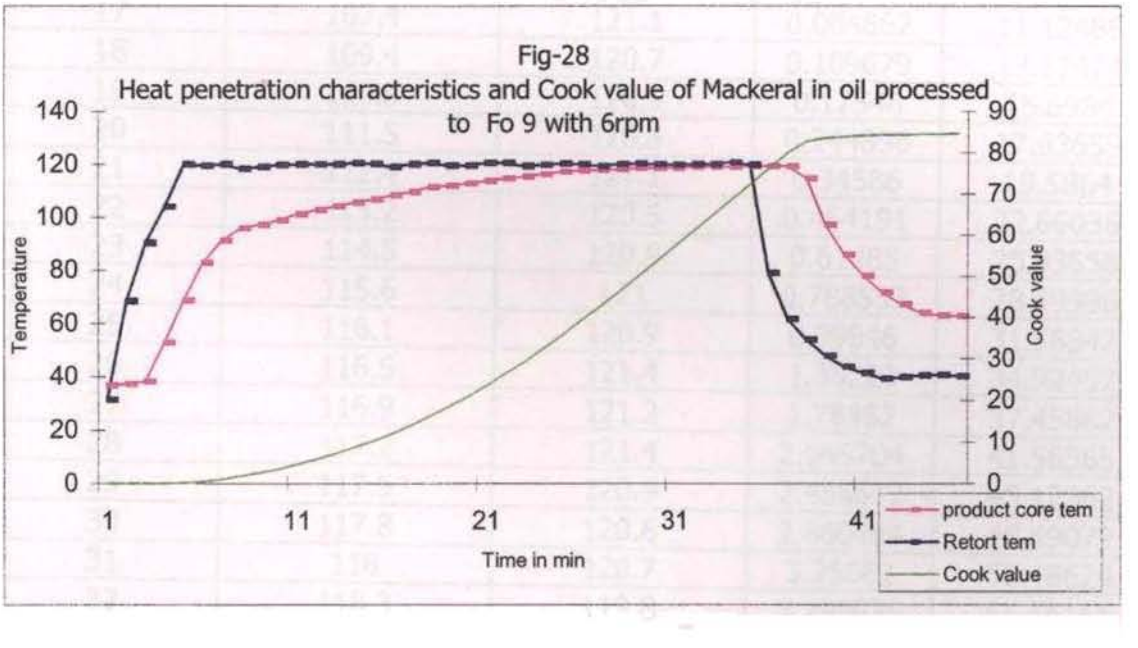


Fig-28
Heat penetration characteristics and Cook value of Mackeral in oil processed to Fo 9 with 6rpm
Temperature
Cook value
Time in min
product core tem
Retort tem
Cook value

Table-23. Heat penetration of mackerel in brine processed to Fo 9 showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 38.4 | 32.4 | 5.37E-09 | 0.013594 |
| 1 | 39.4 | 86.6 | 2.47E-08 | 0.028468 |
| 2 | 44.4 | 111.8 | 1.61E-08 | 0.054916 |
| 3 | 49.5 | 115.6 | 3.42E-08 | 0.098946 |
| 4 | 55.6 | 120.7 | 5.89E-08 | 0.145192 |
| 6 | 70.4 | 121 | 6.23E-07 | 0.39874 |
| 7 | 76.6 | 121.1 | 4.25E-06 | 0.65486 |
| 8 | 82.3 | 121.2 | 1.76E-05 | 0.980396 |
| 9 | 87.4 | 120.8 | 0.000112 | 1.04426 |
| 10 | 91.1 | 119.8 | 0.000281 | 2.05521 |
| 11 | 94.8 | 120.2 | 0.000159 | 2.84562 |
| 12 | 97.7 | 121 | 0.002281 | 3.758674 |
| 13 | 99.9 | 120.9 | 0.009846 | 5.12466 |
| 14 | 102.7 | 120.7 | 0.011423 | 6.173291 |
| 15 | 104.5 | 120.8 | 0.024246 | 7.45862 |
| 16 | 106.5 | 120.6 | 0.040332 | 9.321037 |
| 17 | 107.4 | 121.1 | 0.084862 | 11.12486 |
| 18 | 109.4 | 120.7 | 0.109679 | 13.17474 |
| 19 | 110.8 | 120.9 | 0.17548 | 15.6984 |
| 20 | 111.5 | 120.5 | 0.244896 | 17.63659 |
| 21 | 112.4 | 121.1 | 0.34586 | 19.5864 |
| 22 | 113.2 | 120.5 | 0.464191 | 22.66036 |
| 23 | 114.5 | 120.8 | 0.61485 | 25.43658 |
| 24 | 115.6 | 121 | 0.788553 | 28.59996 |
| 25 | 116.1 | 120.9 | 0.99846 | 31.56842 |
| 26 | 116.5 | 121.4 | 1.35223 | 34.92452 |
| 27 | 116.9 | 121.2 | 1.78962 | 37.45862 |
| 28 | 117.2 | 121.4 | 2.045704 | 41.56565 |
| 29 | 117.5 | 120.9 | 2.458612 | 45.12862 |
| 30 | 117.8 | 120.8 | 2.860464 | 48.49072 |
| 31 | 118 | 120.7 | 3.25862 | 52.48624 |
| 32 | 118.3 | 119.8 | 3.795935 | 55.66165 |
| 33 | 118.5 | 120.2 | 4.25642 | 58.84632 |
| 34 | 118.7 | 120.3 | 4.84555 | 63.03554 |
| 35 | 118.7 | 121.1 | 5.24862 | 66.54826 |
| 36 | 118.4 | 120.2 | 5.996429 | 70.25668 |

| | | | | |
|---|---|---|---|---|
| 37 | 118.4 | 121 | 6.45896 | 73.84562 |
| 38 | 118.2 | 121.1 | 7.070493 | 77.37775 |
| 39 | 117.4 | 120.1 | 7.5426 | 80.24582 |
| 40 | 116.4 | 119.8 | 8.096216 | 83.65832 |
| 41 | 113.2 | 82.4 | 8.38946 | 85.42682 |
| 42 | 110.3 | 57.9 | 8.773904 | 87.76179 |
| 43 | 106.4 | 52.4 | 8.88482 | 89.5268 |
| 44 | 103.2 | 45.2 | 8.940257 | 90.26214 |
| 45 | 95.6 | 43.2 | 8.962548 | 90.84526 |
| 46 | 90.2 | 41.1 | 8.972693 | 91.27153 |
| 47 | 85.4 | 39.6 | 8.973242 | 91.54872 |
| 48 | 81.4 | 37.4 | 8.974319 | 91.81778 |
| 49 | 80.5 | 37.4 | 8.974421 | 92.00456 |
| 50 | 79.2 | 36.4 | 8.974533 | 92.2863 |
| 51 | 75.4 | 36 | 8.974649 | 92.36482 |
| 52 | 67.9 | 35.4 | 8.974662 | 92.49926 |
| 53 | 65.1 | 35.4 | 8.974772 | 92.8312 |

Fig-29
Heat penetration characteristics of Mackerel in brine thermally processed to Fo 9

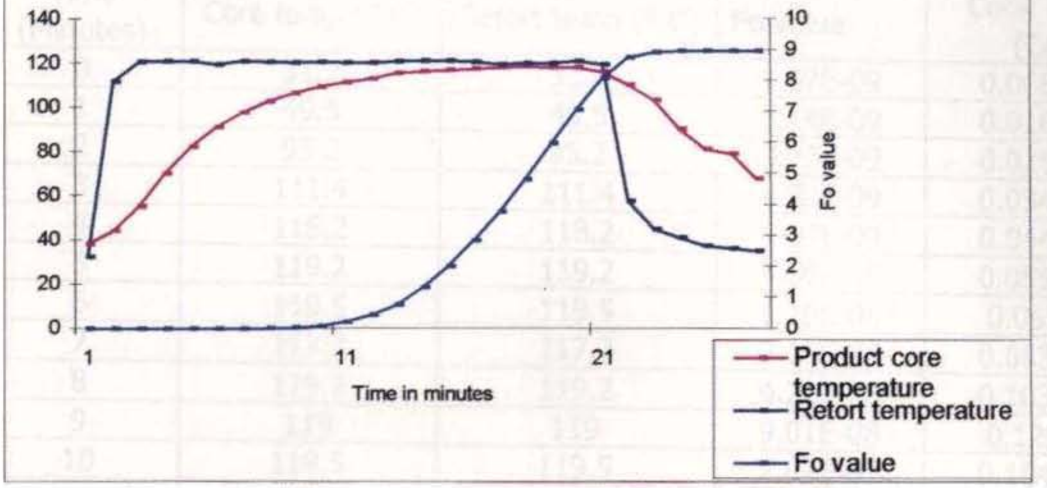



Fig-30
Heat penetration characteristics and Cook value of thermally processed Mackerel in brine to Fo9

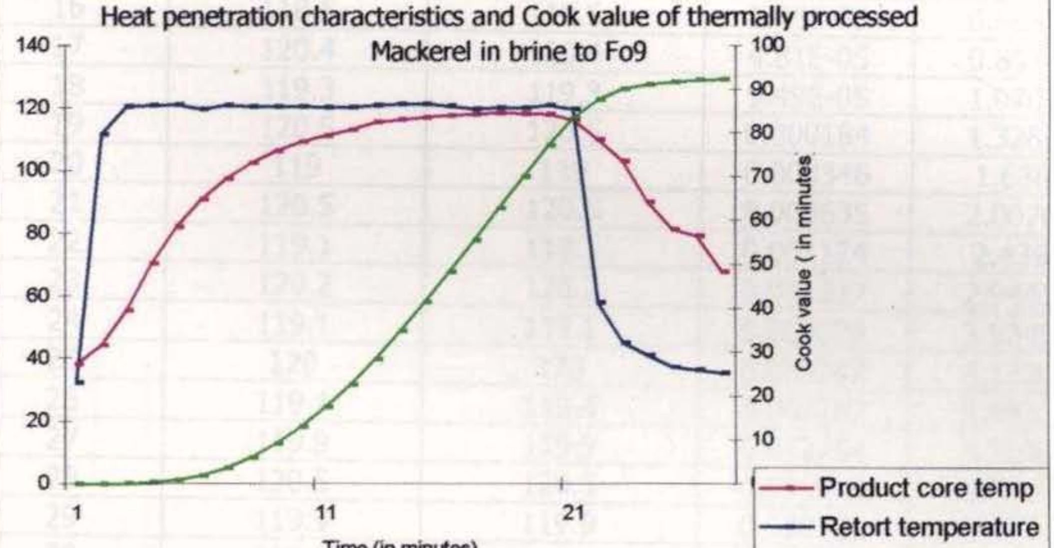


Table-24. Heat penetration of mackerel curry processed to Fo 9 showing Fo value and cook value

| Time (Minutes) | Core temp (° C) | Retort temp (° C) | Fo value | Cook value (Cg) |
|---|---|---|---|---|
| 0 | 31.7 | 31.7 | 1.07E-09 | 0.008341 |
| 1 | 49.5 | 49.5 | 2.14E-09 | 0.016682 |
| 2 | 95.2 | 95.2 | 3.37E-09 | 0.025379 |
| 3 | 111.4 | 111.4 | 4.82E-09 | 0.034512 |
| 4 | 118.2 | 118.2 | 6.64E-09 | 0.044305 |
| 5 | 119.2 | 119.2 | 9.09E-09 | 0.055028 |
| 6 | 119.5 | 119.5 | 1.29E-08 | 0.06727 |
| 7 | 117.2 | 117.2 | 2.18E-08 | 0.083119 |
| 8 | 119.2 | 119.2 | 4.22E-08 | 0.103494 |
| 9 | 119 | 119 | 9.01E-08 | 0.12987 |
| 10 | 119.5 | 119.5 | 2.02E-07 | 0.164016 |
| 11 | 118.3 | 118.3 | 4.59E-07 | 0.207912 |
| 12 | 119.3 | 119.3 | 1.05E-06 | 0.264342 |
| 13 | 115.4 | 115.4 | 2.34E-06 | 0.335882 |
| 14 | 120.4 | 120.4 | 5.22E-06 | 0.42721 |
| 15 | 119.2 | 119.2 | 1.12E-05 | 0.541386 |
| 16 | 118.5 | 118.5 | 2.35E-05 | 0.683134 |
| 17 | 120.4 | 120.4 | 4.81E-05 | 0.857887 |
| 18 | 119.3 | 119.3 | 9.49E-05 | 1.070344 |
| 19 | 120.5 | 120.5 | 0.000184 | 1.328643 |
| 20 | 119 | 119 | 0.000346 | 1.63832 |
| 21 | 120.5 | 120.5 | 0.000635 | 2.007014 |
| 22 | 119.1 | 119.1 | 0.001124 | 2.43989 |
| 23 | 120.2 | 120.2 | 0.001937 | 2.944587 |
| 24 | 119.1 | 119.1 | 0.003225 | 3.524865 |
| 25 | 120 | 120 | 0.005267 | 4.192044 |
| 26 | 119.4 | 119.4 | 0.008287 | 4.943248 |
| 27 | 119.9 | 119.9 | 0.012754 | 5.789058 |
| 28 | 120.5 | 120.5 | 0.019211 | 6.734767 |
| 29 | 119.9 | 119.9 | 0.028123 | 7.777521 |
| 30 | 119.4 | 119.4 | 0.040426 | 8.927278 |
| 31 | 120.5 | 120.5 | 0.056644 | 10.17745 |
| 32 | 119.5 | 119.5 | 0.078023 | 11.53681 |
| 33 | 120.5 | 120.5 | 0.104939 | 12.9944 |
| 34 | 120.1 | 120.1 | 0.138823 | 14.55733 |
| 35 | 119.3 | 119.3 | 0.18051 | 16.22155 |

| | | | | |
|---|---|---|---|---|
| 36 | 120.4 | 120.4 | 0.231796 | 17.99364 |
| 37 | 119.4 | 119.4 | 0.293456 | 19.86746 |
| 38 | 120.6 | 120.6 | 0.365899 | 21.83507 |
| 39 | 119.9 | 119.9 | 0.452996 | 23.91564 |
| 40 | 119.7 | 119.7 | 0.552996 | 26.08516 |
| 41 | 120.5 | 120.5 | 0.667811 | 28.34743 |
| 42 | 119.5 | 119.5 | 0.799637 | 30.70643 |
| 43 | 120.2 | 120.2 | 0.947548 | 33.14918 |
| 44 | 120.2 | 120.2 | 1.113506 | 35.67865 |
| 45 | 119.5 | 119.5 | 1.299715 | 38.29793 |
| 46 | 120.7 | 120.7 | 1.503889 | 40.99134 |
| 47 | 120 | 120 | 1.727761 | 43.76099 |
| 48 | 119.3 | 119.3 | 1.973232 | 46.60903 |
| 49 | 120.9 | 120.9 | 2.236259 | 49.51731 |
| 50 | 119.9 | 119.9 | 2.518097 | 52.48711 |
| 51 | 119.4 | 119.4 | 2.827126 | 55.54096 |
| 52 | 121 | 121 | 3.15072 | 58.63773 |
| 53 | 119.7 | 119.7 | 3.497457 | 61.80001 |
| 54 | 119.9 | 119.9 | 3.868992 | 65.02918 |
| 55 | 120.6 | 120.6 | 4.258037 | 68.30373 |
| 56 | 119.7 | 119.7 | 4.665418 | 71.6243 |
| 57 | 120.2 | 120.2 | 5.091997 | 74.99153 |
| 58 | 120.4 | 120.4 | 5.538681 | 78.40608 |
| 59 | 119.3 | 119.3 | 6.006416 | 81.86861 |
| 60 | 120.7 | 120.7 | 6.485046 | 85.35539 |
| 61 | 119.9 | 119.9 | 6.986233 | 88.89116 |
| 62 | 119.5 | 119.5 | 7.499095 | 92.4517 |
| 63 | 119.8 | 119.8 | 7.988873 | 95.96289 |
| 64 | 54.3 | 54.3 | 8.405743 | 99.30671 |
| 65 | 47.4 | 47.4 | 8.645626 | 102.1349 |
| 66 | 48.1 | 48.1 | 8.836172 | 104.7726 |
| 67 | 42.6 | 42.6 | 8.980716 | 107.1983 |
| 68 | 42 | 42 | 9.067812 | 109.2789 |
| 69 | 40.5 | 40.5 | 9.109499 | 110.9431 |
| 70 | 37.9 | 37.9 | 9.12812 | 112.2467 |
| 71 | 37.8 | 37.8 | 9.136064 | 113.2537 |
| 72 | 36 | 36 | 9.139452 | 114.0316 |
| 73 | 35.8 | 35.8 | 9.140897 | 114.6325 |
| 74 | 36.5 | 36.5 | 9.141543 | 115.1032 |
| 75 | 36.9 | 36.9 | 9.141838 | 115.4744 |
| 76 | 37.2 | 37.2 | 9.141976 | 115.7694 |
| 77 | 37.6 | 37.6 | 9.142045 | 116.0086 |
| 78 | 37.6 | 37.6 | 9.142115 | 116.2478 |

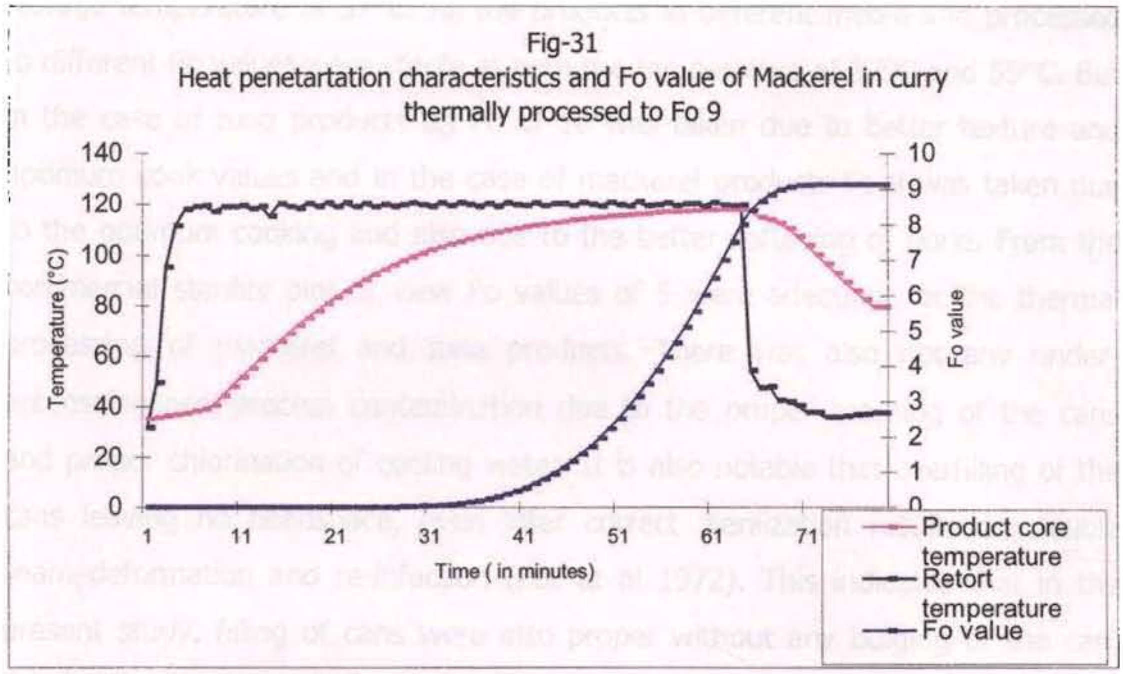



Fig-31
Heat penetartation characteristics and Fo value of Mackerel in curry thermally processed to Fo 9

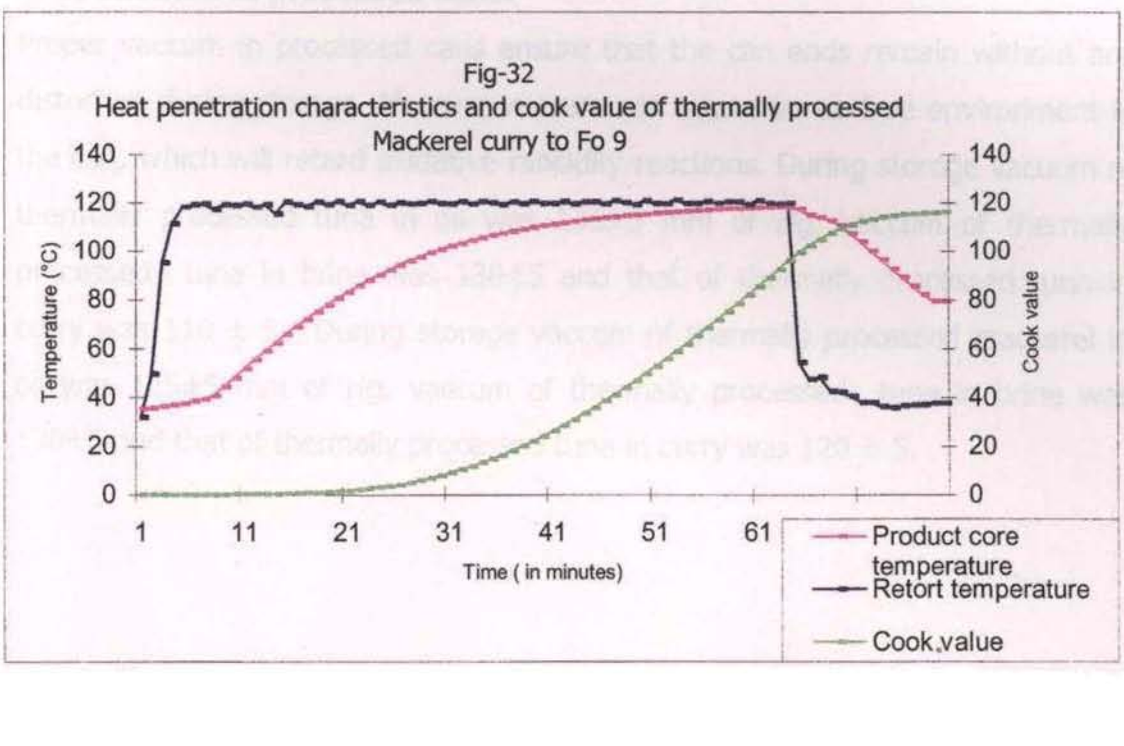



Fig-32
Heat penetration characteristics and cook value of thermally processed Mackerel curry to Fo 9

## 5. 6. Sterility Test:

Sterility tests were done for both tuna *in different media and for different* Fo values and for mackerel in different *media and for different* Fo values at a storage temperature of 37°C. All the products in different media and processed to different Fo values were sterile at both the temperature of 37ºC and 55ºC. But in the case of tuna products an Fo of 10 was taken due to better texture and optimum cook values and in the case of mackerel products Fo 9 was taken due to the optimum cooking and also due to the better softening of bone. From the commercial sterility pint of view *Fo values of* 5 were adequate for the thermal processing of mackerel and tuna products. There was also not any under-processing post-process contamination due to the proper seaming of the cans and proper *chlorination of cooling* water. It is also notable that overfilling of the cans leaving no headspace, even after correct sterilization results on double seam deformation and re-infection (Put et al 1972). This indicates that in the present study, filling of cans were also proper without any bulging of the can, resulting any leakage during processing.

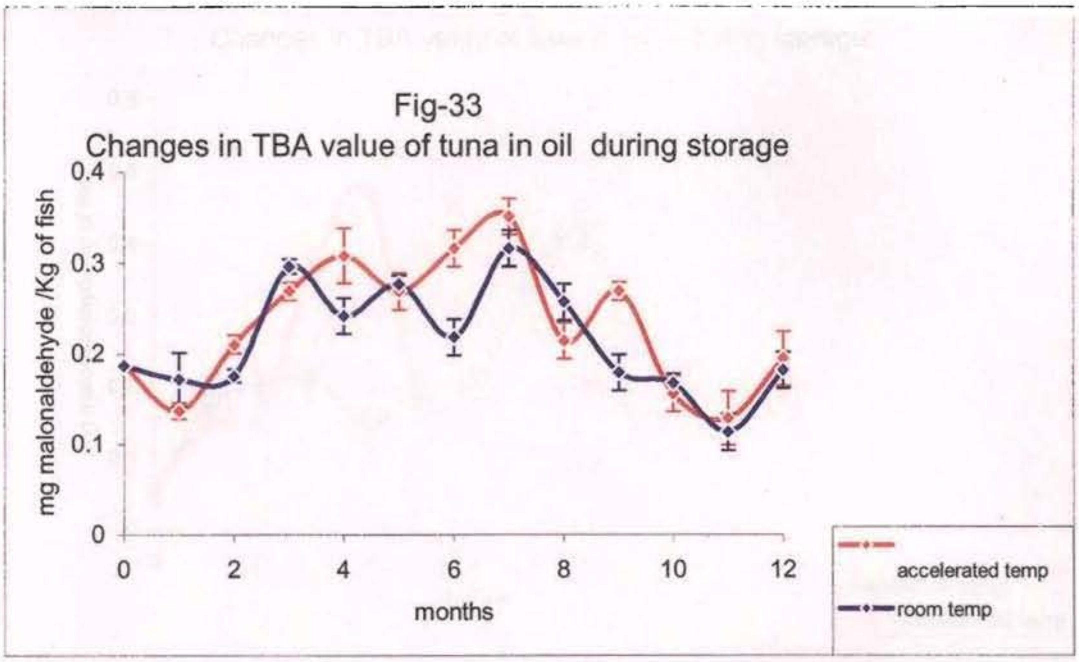
## 5. 7. Vacuum in processed cans:

Proper vaccum in processed cans ensure that the can *ends remain without* any distortion during storage. Morever vaccum will create an air free environment in the can, which will retard oxidative rancidity reactions. During storage vacuum of thermally processed tuna in oil was 135±5 mm of Hg, vaccum of thermally processed tuna in brine was 130±5 and that of thermally processed tuna in curry was 110 ± 5. During storage vaccom of thermally processed mackerel in oil was 125±5 mm of Hg, vaccum of thermally processed tuna in brine was 130±5 and that of thermally processed tuna in curry was 120 ± 5.

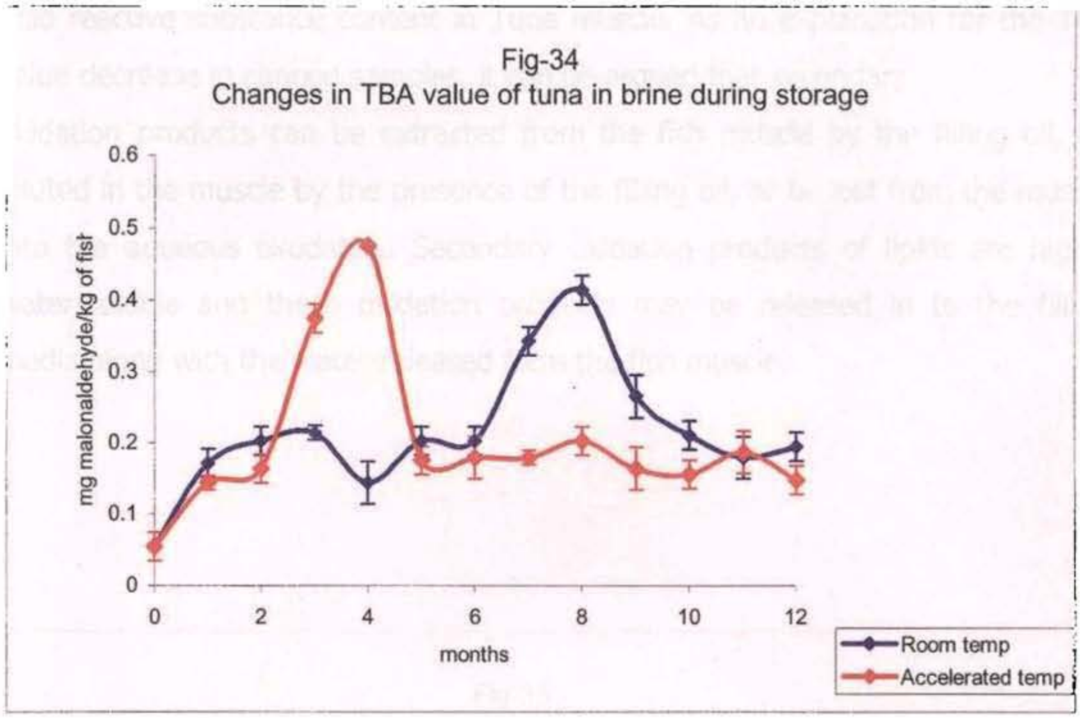
## 5.8. Changes in TBA Value:

The quality of canned product has a very close relationship with their lipid content and composition. Canned fishery products are especially susceptible to flavor and other changes due to high levels of polyunsaturated fatty acids (Maeda et al 1985; Ackman,1969). When marine species are processed at higher temperatures, damage to PUFA can lead to primary and secondary lipid oxidation products, which can result in browning (Aubourg,1999), formation of fluorescent compounds (Ramanathan and Das. 1992), flavour changes and loss of essential nutrients (Boyd et al,1993). TBA value analysis was done for tuna in different media and for mackerel in different media both at room temperature and at accelerated temperature.

Changes in TBA value of tuna in oil at room temperature and at accelerated temperature were presented in fig 33. In the case of tuna in oil TBA value increased upto 7 months of storage both at room temperature and at accelerated temperature. After this period TBA value decreased in tuna in oils stored at both temperatures. TBA value increased upto 0.32 mg malonaldehyde/ Kg of fish in the tuna in oil stored at room temperature and upto 0.35 mg malonaldehyde/ Kg of fish in the product stored at accelerated temperature starting from an initial value of 0.19 mg malonaldehyde/ Kg of fish. After 12 months of storage TBA value of tuna in oil stored at room temperature was 0.182 mg malonaldehyde/ Kg of fish and 0.195 mg malonaldehyde/ Kg of fish in tuna in oil stored at accelerated temperature. Decreasing TBA value in the case of tuna in oil during storage has been earlier reported by Medina et al (1999) and Aubourg et al (1997)

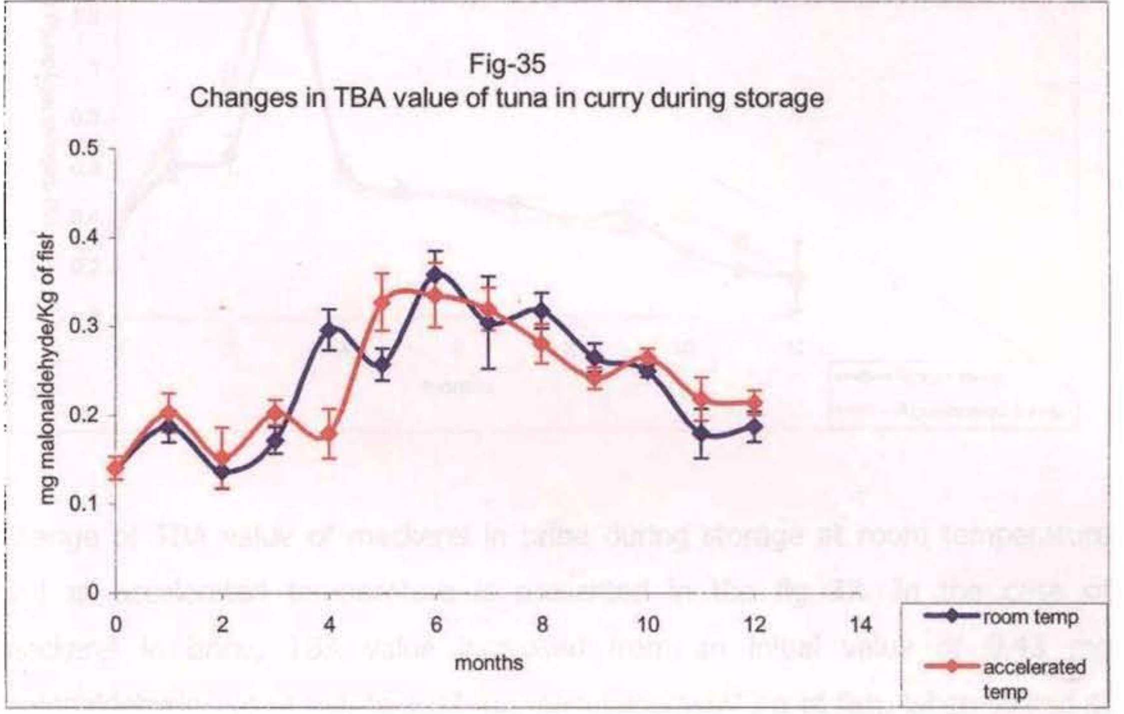



Changes in TBA value of tuna in brine during storage are presented in figure-34. In the case of tuna in brine TBA value showed maximum increase during storage. It increased upto 4 months when stored at 37C with a TBA value of 0.48 mg malonaldehyde/ Kg of fish and it increased upto 8 month at room temperature with TBA value of 0.41 mg malonaldehyde/ Kg of fish with an initial TBA value of 0.055 mg malonaldehyde/ Kg of fish. Medina et al (1998) stated that the highest TBA values were found in canned tuna muscle using brine as dipping medium. After 12 months of storage tuna in brine stored at room temperature had a TBA value of 0.19 mg malonaldehyde/ Kg of fish and that stored at 37°C had a TBA value of 0.15 mg malonaldehyde/ Kg of fish.




Changes in TBA value of tuna in curry during storage at room temperature and accelerated temperature are presented in figure-35. In the case of tuna in curry, TBA value increased upto 6 months of storage and thereafter it decreased when stored upto a period of 12 months. TBA value of tuna in curry increased upto a value of 0.338 mg malonaldehyde/ Kg of fish, when stored at room temperature and upto 0.335 mg malonaldehyde/ Kg of fish when stored at accelerated temperature starting from an initial value of 0.1404 mg malonaldehyde/ Kg of fish. After 12 months of storage TBA value of tuna in curry stored at room temperature was 0.19 mg malonaldehyde/ Kg of fish and that stored t 37C was 0.21 mg malonaldehyde/ Kg of fish. In all the tuna products, stored at room temperature, and at 37°C, TBA value were increasing upto a certain period of storage and decreasing after that when stored for a period of 12 months. Aubourg (1997) states that all the time and temperature conditions of sterilization followed by storage produced a large decrease in the Thiobarbituric

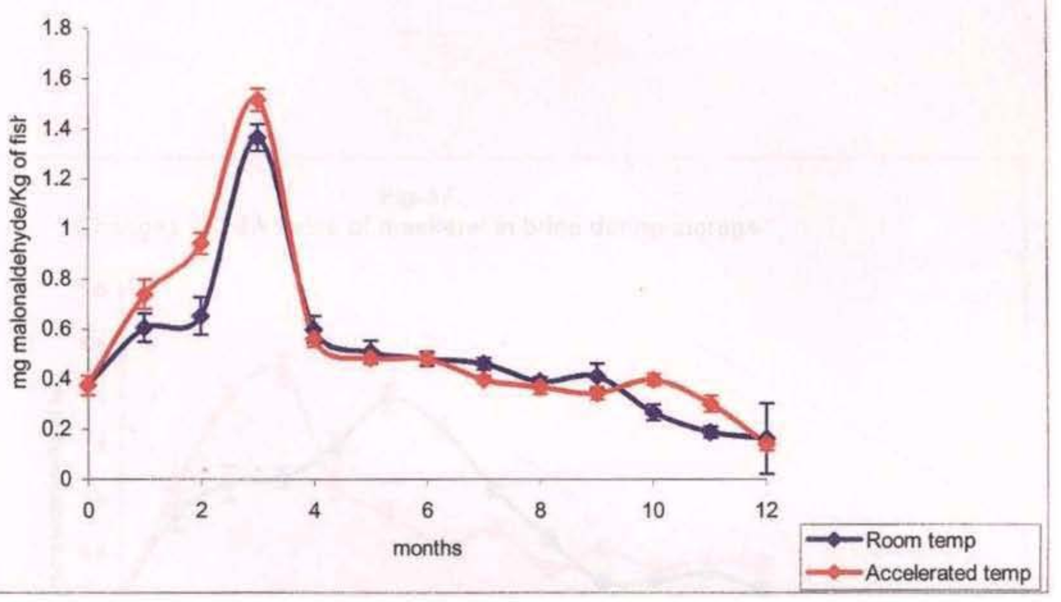
Acid reactive substance content in Tuna muscle. As an explanation for the TBA value decrease in canned samples, it can be argued that secondary oxidation products can be extracted from the fish muscle by the filling oil, be diluted in the muscle by the presence of the filling oil, or be lost from the muscle into the aqueous exudates.. Secondary oxidation products of lipids are highly water-soluble and these oxidation products may be released in to the filling media along with the water-released form the fish muscle.



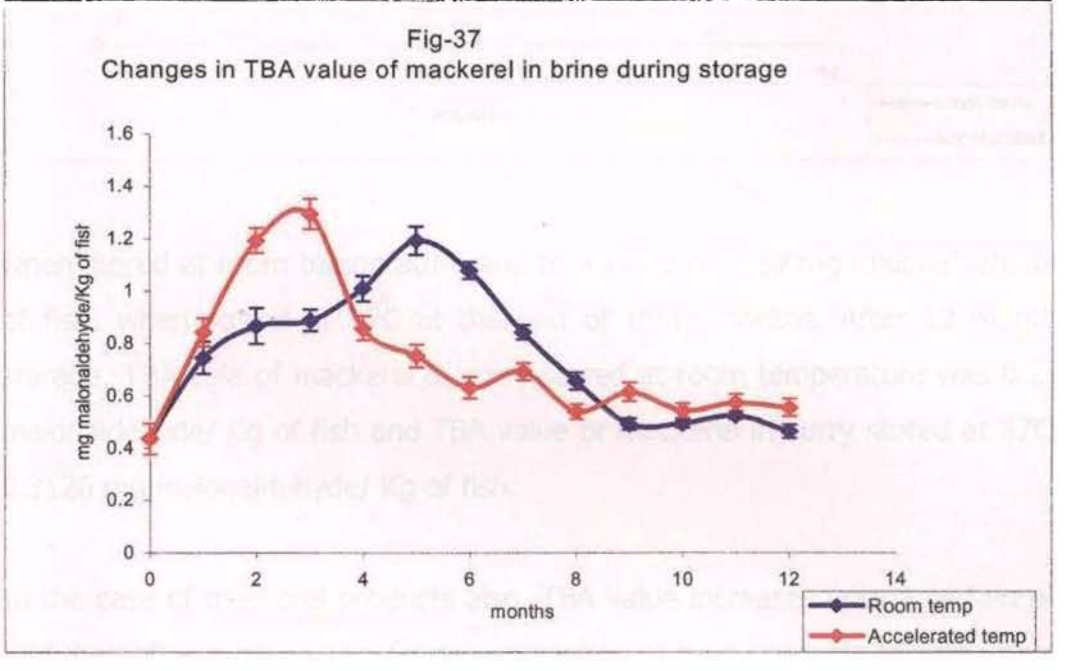

Change of TBA value of mackerel in oil during storage at room temperature and at accelerated temperature is presented in the fig-36. In the case of mackerel in oil, increase in TBA value was rapid. It increased from an initial value of 0.3744 mg malonaldehyde/ Kg of fish to 1.36 mg malonaldehyde/ Kg of fish in the mackerel in oil stored at room temperature at the end of three mo^n^ths and upto

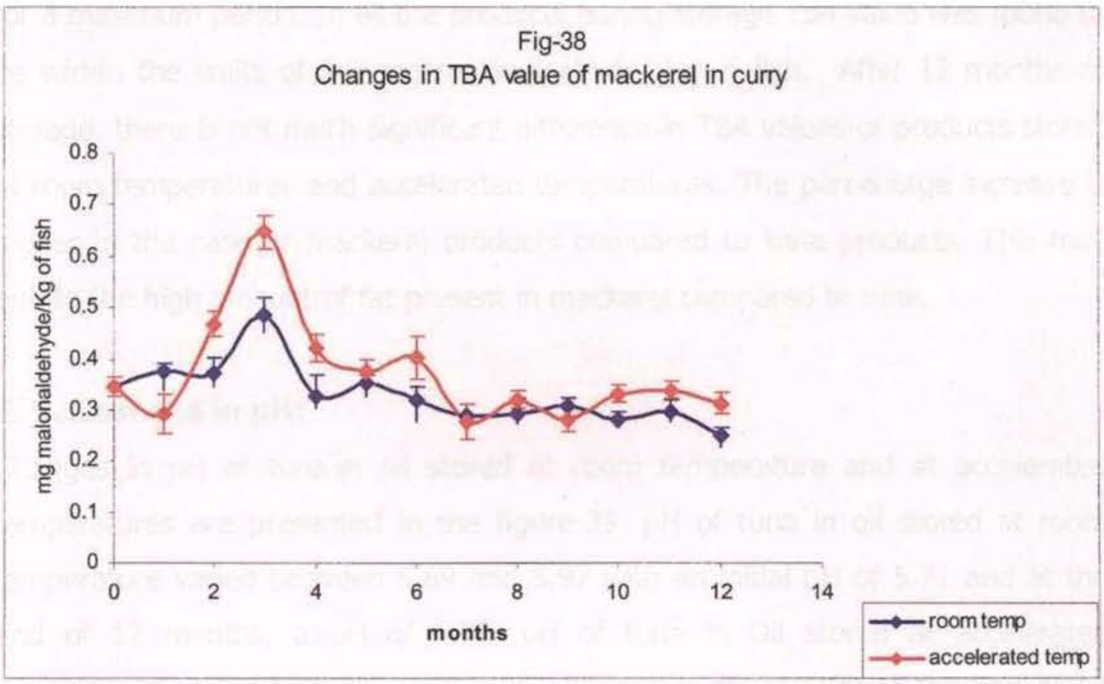
1.52 mg malonaldehyde/ Kg of fish when stored at 37ºC at the end of three months. Thereafter, TBA value decreased when stored upto a period of 12 months. After 12 months of storage, TBA value of mackerel in Oil stored at room temperature was 0.16mg malonaldehyde/ Kg of fish and TBA value of product stored at 37ºC was 0.14 mg malonaldehyde/ Kg of fish.

Fig-36
Changes in TBA value of mackerel in oil during storage




Change of TBA value of mackerel in brine during storage at room temperature and at accelerated temperature is presented in the fig 37. In the case of mackerel in brine, TBA value increased from an initial value of 0.43 mg malonaldehyde/ Kg of fish to 1.07 mg malonaldehyde/ Kg of fish, when stored at room temperature upto 5 months; and in the product stored at 37ºC, it increased upto a period of 3 months to a value of 1.29 mg malonaldehyde/ Kg of fish. Mackerel in brine showed maximum TBA value during storage. TBA value of Mackerel in brine stored at room temperature was 0.46 mg malonaldehyde/ Kg of fish and TBA value of products stored at 37C was 0.55 mg malonaldehyde/ Kg of fish after 12 months of storage. Change of TBA value of mackerel in curry during storage at room temperature and at accelerated temperature is presented in the fig 38. In the case of mackerel in curry, TBA value increased upto 3 months of storage in both the cases ie, at room temperature and 37° C, thereafter TBA value decreased when stored upto a period of 12 months. TBA value of mackerel in curry increased from an initial value of 0.32 mg malonaldehyde/ Kg of fish to a value of 0.48mg malonaldehyde/ Kg of fish



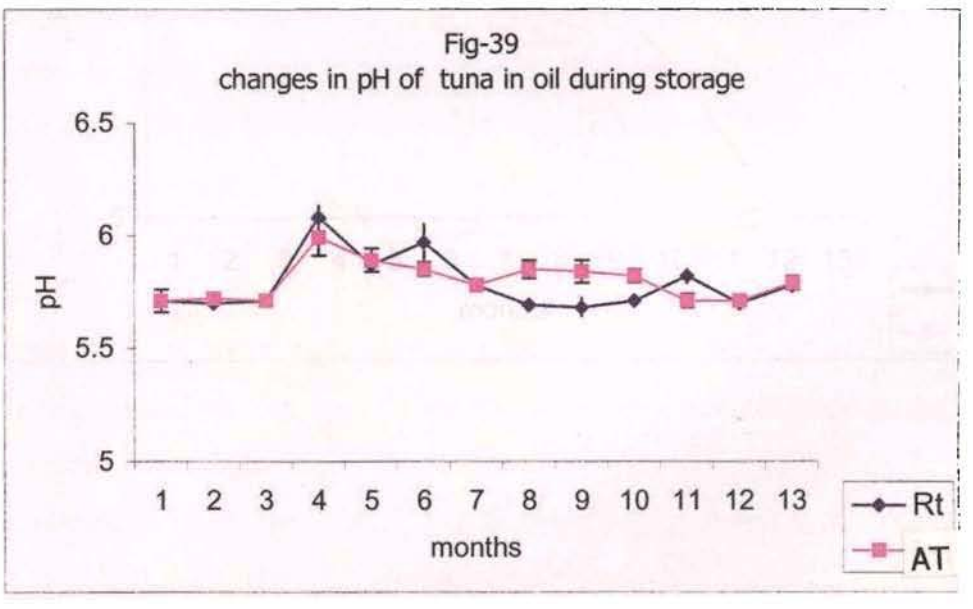



when stored at room temperature and to a value of 0.67 mg malonaldehyde/ Kg of fish, when stored at 37°C at the end of three months. After 12 months of storage, TBA vale of mackerel in curry stored at room temperature was 0.25 mg malonaldehyde/ Kg of fish and TBA value of mackerel in curry stored at 37C was 0.3120 mg malonaldehyde/ Kg of fish.

In the case of mackerel products also, TBA value increases upto a certain period and thereafter it decreases. Same explanation of tuna products can also be given in this case also. During storage, fish flesh releases water and this water contains secondary oxidation products of lipids which are highly water-soluble. Compared to tuna products, mackerel products showed maximum increase in TBA value due to the high amount of lipids in mackerel. It can be observed from both the cases, TBA value increases to a maximum period of 8 months and thereafter decreases. Both tuna in brine and mackerel in brine stored at accelerated temperatures showed rapid increase in TBA values. Similarly, tuna in brine and mackerel in brine stored at room temperature there was increase in TBA value for a maximum period. In all the products during storage TBA value was found to be wirhin the limits of 2-3 mg malonalgehyde/ kg of fish. After 12 months of storage, there is not much significant difference in TBA values of products stored at room temperatures and accelerated temperatures. The percentage increase is higher in the case of mackerel products compared to tuna products. This may due to the high amount of fat present in mackerel compared to tuna.

## 5. 9. Changes in pH:

Changes in pH of tuna in oil stored at room temperature and at accelerated temperatures are presented in the figure-39. pH of tuna in oil stored at room temperature varied between 5.69 and 5.97 with an initial pH of 5.71 and at the end of 12 months, a pH of 5.78. pH of tuna in Oil stored at accelerated temperature varied between 5.68 and 5.87 with a pH of 5.79 at the end of 12 months at storage. Changes in pH of tune in brine stored at room temperature and at accelerated temperatures are presented in the figure-40. During 12



months of storage, pH of tune in Brine stored at room temperature varied between 5.68 and 5.87 with an initial pH of 5.85 and at the end of 12 months, with a pH of 5.82. Meanwhile pH of tuna in brine stored at 37C varied between 5.65 and 5.87 with a pH of 5.82 at the end of 12 months. Changes in pH of tuna in curry stored at room temperature and at accelerated temperatures are presented in the figure 41. pH of tuna in curry stored at room temperature showed variation between 5.34 and 5.73 with an initial Ph of 5.61 and a final pH of 5.49 at the end of 12 months of storage. pH of tuna in curry stored t accelerated temperatures varied between 5.45 and 5.65 with a final pH of 5.51 at the end of 12 months of storage.

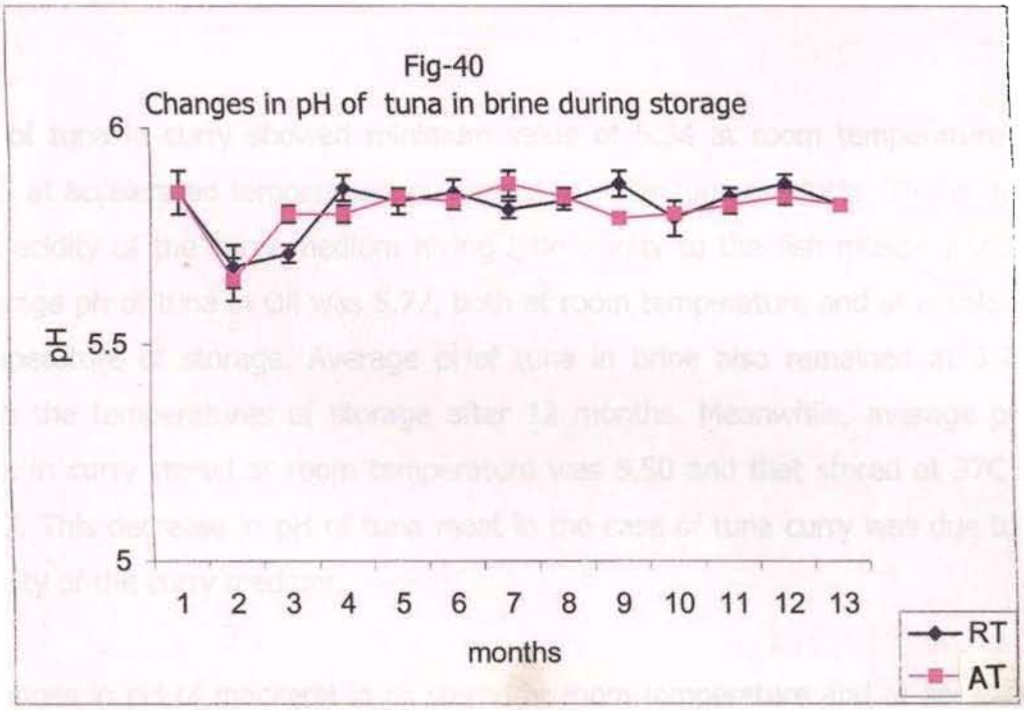
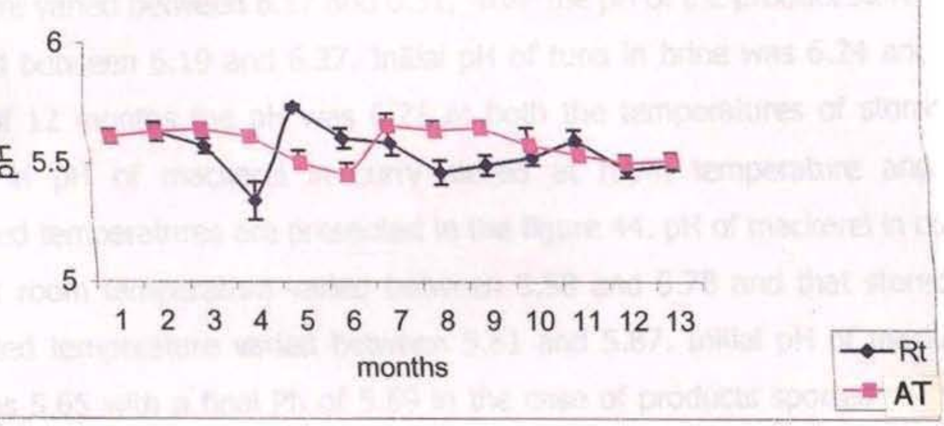


Fig-41
Changes in pH of tuna in curry during storage




pH of tuna in curry showed minimum value of 5.34 at room temperature and 5.45 at accelerated temperature compared to other tuna products. This is due to the acidity of the curry medium giving little acidity to the fish muscle also. The average ph of tuna in Oil was 5.77, both at room temperature and at accelerated temperature of storage. Average pHof tuna in brine also remained at 5.77 in both the temperatures of storage after 12 months. Meanwhile, average pH of tuna in curry stored at room temperature was 5.50 and that stored at 37C was 5.57. This decrease in pH of tuna meat in the case of tuna curry was due to the acidity of the curry medium.

Changes in pH of mackerel in oil stored at room temperature and at accelerated temperatures are presented in the figure 42. pH of mackerel in oil stored at room temperature varied between 6.14 and 6.43 and that stored at accelerated temperature varied between 6.19 and 6.48 during 12 moths of storage. Mackerel in oil stored at room temperature had an initial pH of 6.38 and a final pH of 6.22

at the end of 12 months of storage. The pH of mackerel in oil stored at accelerated temperature was 6.20 at the end of 12 months. Changes in pH of mackerel in brine stored at room temperature and at accelerated temperatures are presented in the figure 43. pH of mackerel in brine stored at room temperature varied between 6.17 and 6.31, while the pH of the product stored at 37C varied between 6.19 and 6.27. Initial pH of tuna in brine was 6.24 and at the end of 12 months the pH was 6.21 at both the temperatures of storage. Changes in pH of mackerel in curry stored at room temperature and at accelerated temperatures are presented in the figure 44. pH of mackerel in curry stored at room temperature varied between 5.58 and 5.78 and that stored at accelerated temperature varied between 5.61 and 5.87. Initial pH of mackerel curry was 5.65 with a final Ph of 5.59 in the case of products sported at room temperature and 5.64 for the products stored at accelerated temperature.

Fig-42
Changes in pH of Mackerel in oil during storage

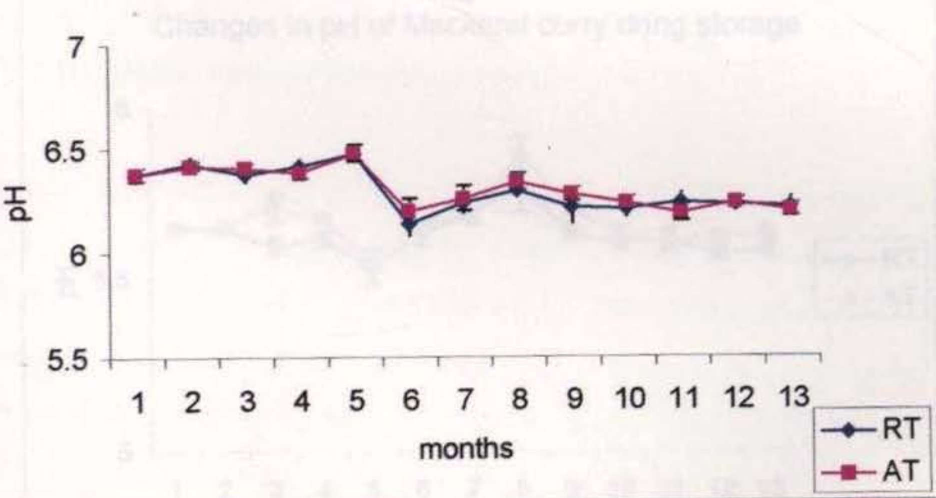


Fig-43
Changes in pH of Mackerel in brine during storage

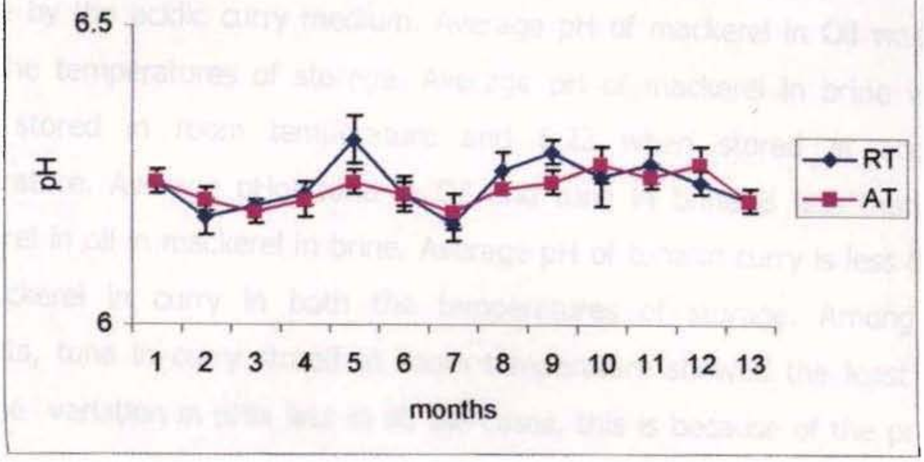
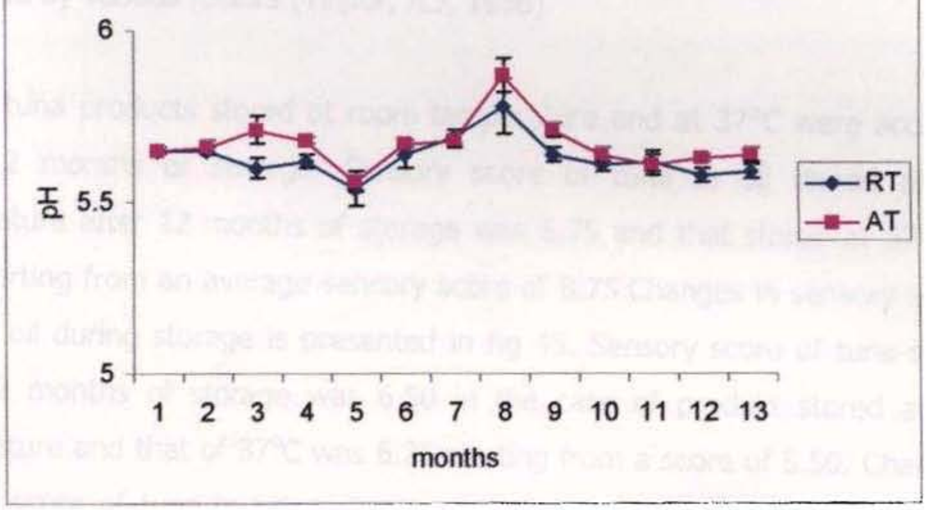



Fig-44
Changes in pH of Mackerel curry dring storage



Like tuna products, among mackerel products, mackerel curry has got the least average pH. Average pH of tuna curry was 5.68 when stored at room temperature and 5.72 when stored at 37°C. this acidic pH is imparted to the fish muscle by the acidic curry medium. Average pH of mackerel in Oil was 6.30 in both the temperatures of storage. Average pH of mackerel in brine was 6.23 when stored in room temperature and 6.22 when stored at accelerated temperature. Average pHof tuna in Oil and tuna in brine is less than that of mackerel in oil in mackerel in brine. Average pH of tuna in curry is less than that of mackerel in curry in both the temperatures of storage. Among all the products, tuna in curry stored at room temperature showed the least average pH. The variation in pHis less in all the cases, this is because of the prevention of bacterial and enzymatic action by high temperature treatment.

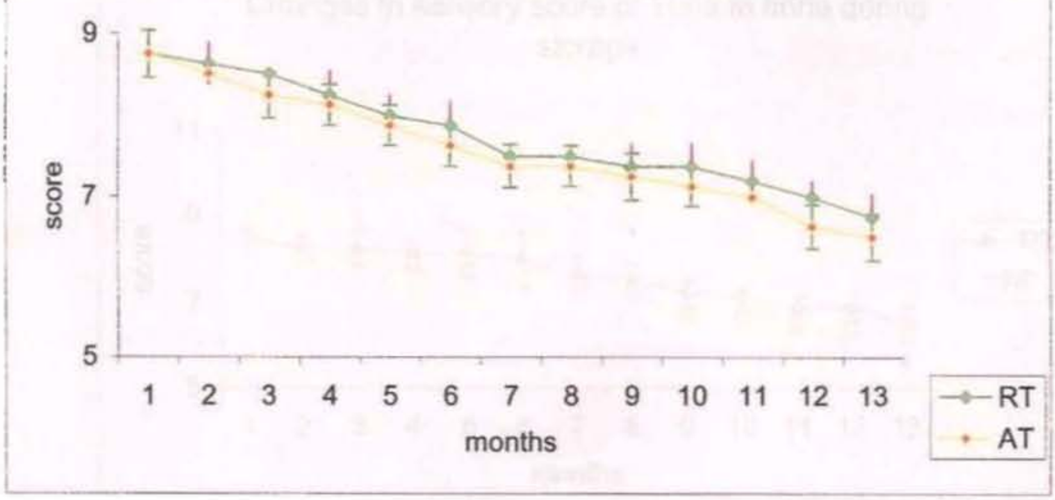
**5. 10. Sensory Scores:**

During sensory evaluation the human brain integrates all the signals and produces an overall perception of the product regarding texture, color, odour and flavour. The way in which these characters are present in the food and the manner in which they are retained during processing and storage, are all governed by various factors (Taylor, A.J, 1998).

All the tuna products stored at room temperature and at 37°C were acceptable after 12 months of storage. Sensory score of tuna in oil stored at room temperature after 12 months of storage was 6.75 and that stored at 37°C was 6.63 starting from an average sensory score of 8.75.Changes in sensory score of tuna in oil during storage is presented in fig 45. Sensory score of tuna in brine after 12 months of storage was 6.50 in the case of product stored at room temperature and that of 37°C was 6.25 starting from a score of 8.50. Changes in sensory score of tuna in brine during storage are presented in fig 46. Sensory score of tuna in curry stored at room temperature was 6.00 and that stored at 37°C was 5.50 at end of storage period with an initial sensory score of 8.28.

Fig-45

Changes in sensory scores of Tuna in oil during storage




Changes in sensory score of tuna in curry during storage are presented in fig-47. After 12 months of storage tuna in oil stored at room temperature was more acceptable compared to any other tuna products. The major components of canned foods , such as protein, fat and carbohydrates would not be expected to change during storage. Ascorbic acid and Thiamine are two, micronutrient most vulnerable to deterioration during processing and storage( Anon, 1998). After 12 months of storage not significant taste difference was observed among the tuna products. Tuna in oil retained the sensory characters throughout the storage period. There is slight degradation in color of tuna in curry ,but not any reduction in the flavour and texture.

Fig-46
Changes in sensory score of Tuna in brine during storage

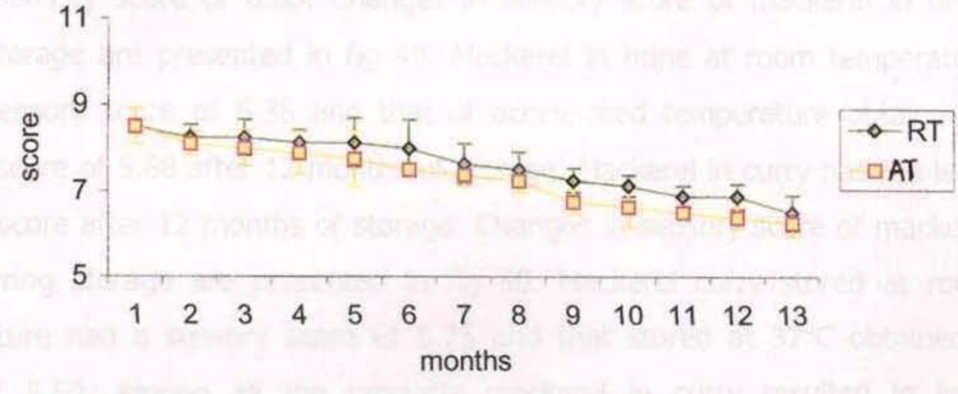
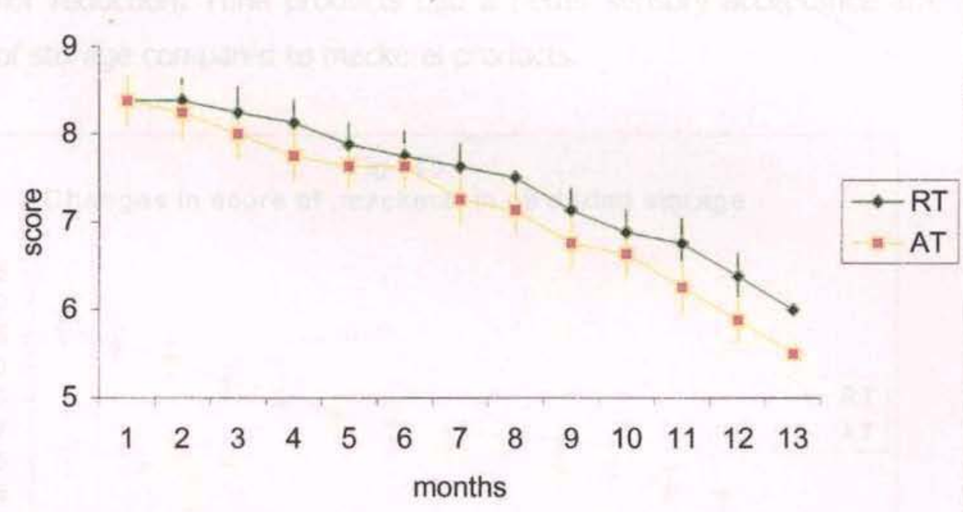
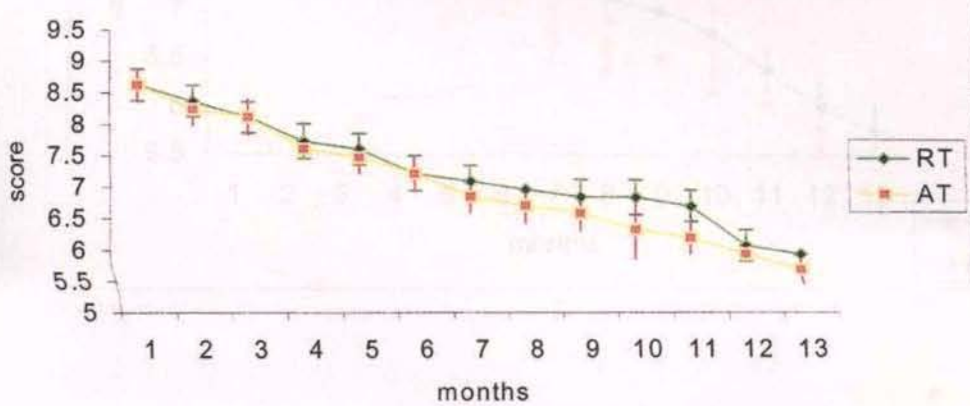



Fig-47
Changes in sensory score of tuna curry during storage



Changes in sensory score of mackerel in oil during storage are presented in fig-48. Mackerel in oil had a sensory score of 6.00 when stored at room temperature and stored at 37° C had a sensory score 5.75 after 12 months of storage starting from a sensory score of 8.63. Changes in sensory score of mackerel in brine during storage are presented in fig 49. Mackerel in brine at room temperature had a sensory score of 6.38 and that of accelerated temperature obtained a sensory score of 5.88 after 12 months of storage. Mackerel in curry has the least sensory score after 12 months of storage. Changes in sensory score of mackerel curry during storage are presented in fig 50. Mackerel curry stored at room temperature had a sensory score of 5.75 and that stored at 37°C obtained a score of 5.50. Among all the products mackerel in curry resulted in least acceptable sensory score according to sensory evaluation after 12 months of storage. Gopal et al (2001) reported that mackerel curry processed in retort pouches had an overall sensory score of 7.5 after 12 months of storage at room temperature.Mackerel products developed slight rancidity after 12 months of storage, especially mackerel in oil. Like tuna curry, mackerel curry also showed slight color reduction. Tuna products had a better sensory acceptance after 12 months of storage compared to mackerel products.

Fig--48
Changes in score of mackerel in oil during storage



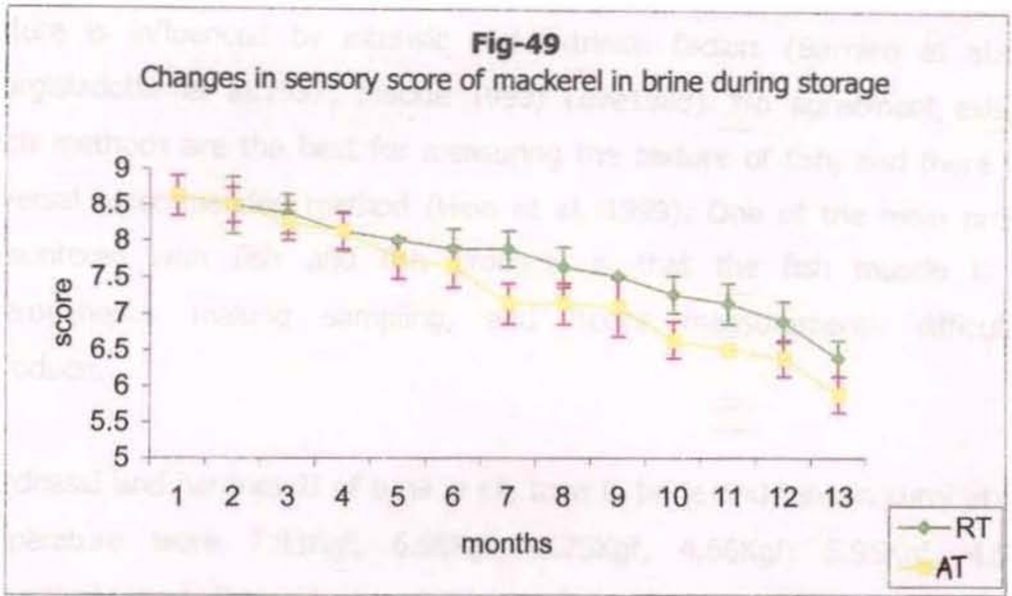


Fig-49
Changes in sensory score of mackerel in brine during storage
score
9
8.5
8
7.5
7
6.5
6
5.5
5
1 2 3 4 5 6 7 8 9 10 11 12 13
months
RT
AT

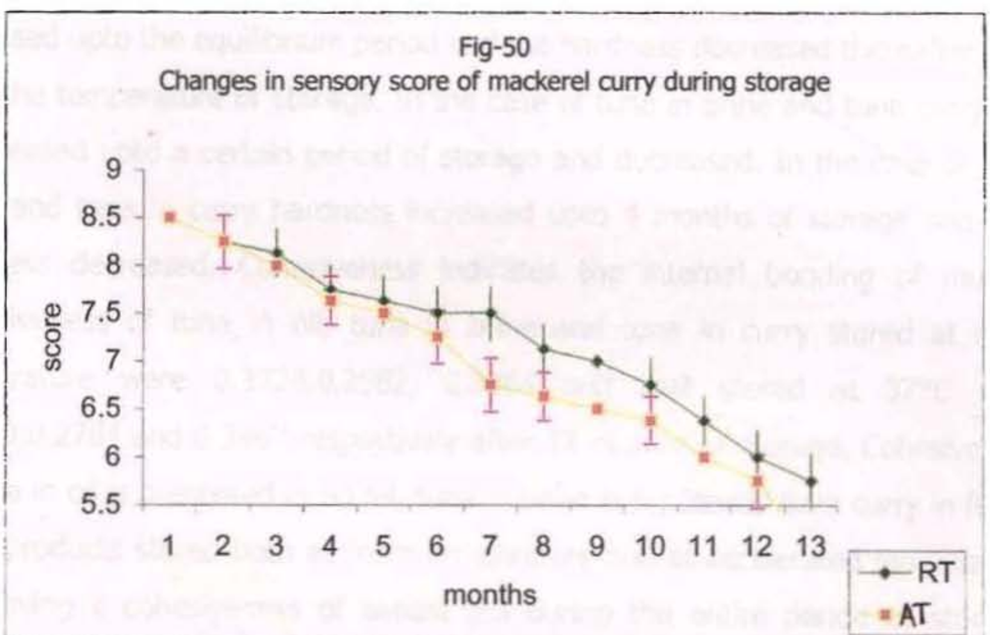
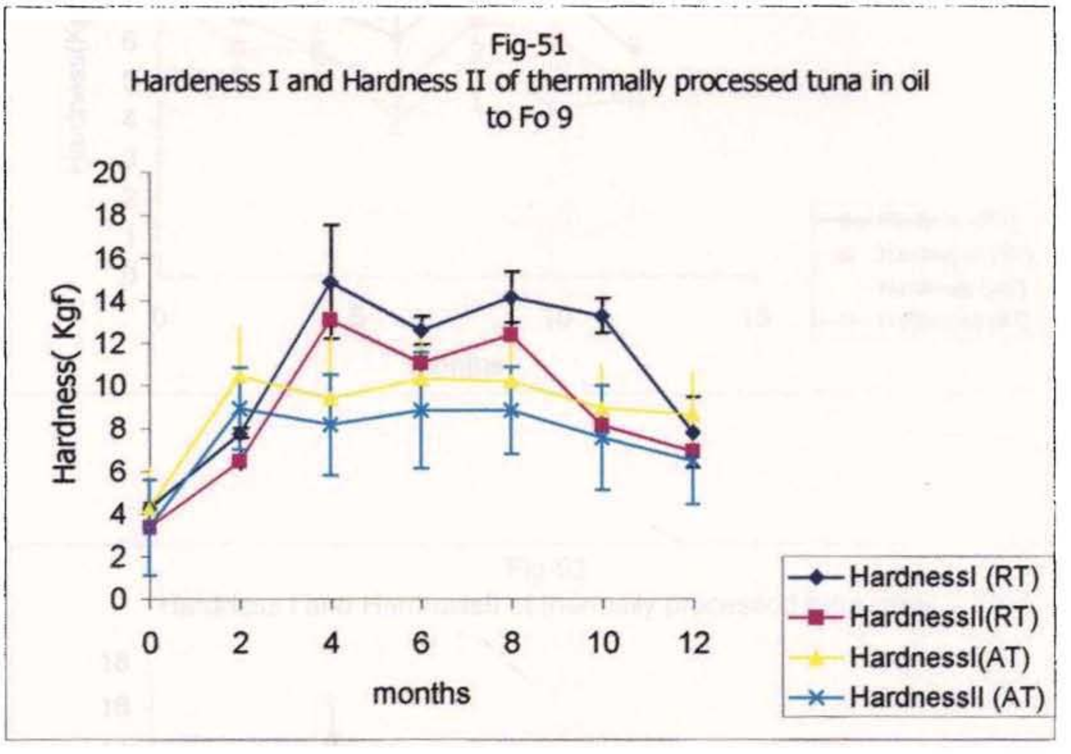


Fig-50
Changes in sensory score of mackerel curry during storage
score
9
8.5
8
7.5
7
6.5
6
5.5
1 2 3 4 5 6 7 8 9 10 11 12 13
months
RT
AT

## 5. 11. Texture Studies:

Texture is influenced by intrinsic and extrinsic factors (Barraro et al.1998; Sigurgisladottir et al.1997; Mackie 1993; Love1983). No agreement exists to which methods are the best for measuring the texture of fish, and there is no universal recommended method (Heia et al. 1999). One of the main problem encountered with fish and fish products is that the fish muscle is very heterogeneous making sampling, and hence measurements difficult to reproduce.

HardnessI and hardnessII of tuna in oil, tuna in brine and tuna in curry at room temperature were 7.83Kgf, 6.95Kgf; 5.75Kgf, 4.66Kgf; 5.95Kgf, 4.50Kgf respectively and that of stored at accelerated temperature were 8.69Kgf, 6.52Kgf; 5.41Kgf, 4.57Kgf; 5.65Kgf, 2.89Kgf respectively after 12 months of storage. Hardness on tuna in oil is presented in Fig51, hardness of tuna in brine infig 52 and that of tuna curry in fig 53. Hardness I and II of canned tuna in oil increased upto the equilibrium period and the hardness decreased thereafter at both the temperature of storage. In the case of tuna in brine and tuna curry also it increased upto a certain period of storage and decreased. In the case on tuna in oil and tuna in curry hardness increased upto 4 months of storage and then hardness decreased. Cohesiveness indicates the internal bonding of muscle. Cohesiveness of tuna in oil, tuna in brine and tuna in curry stored at room temperature were 0.3728,0.2982, 0.3064 and that stored at 37°C were 0.2969,0.2784 and 0.3467 respectively after 12 months of storage. Cohesiveness of tuna in oil is presented in fig 54, tuna in brine in fig 55 and tuna curry in fig56. Tuna products stored both at room temperature and at accelerated temperature are having a cohesiveness of almost 0.3 during the entire period of storage. Springiness is the elastic or recovering property of the fish muscle during compression. Its related to the amount of moisture present in the muscle during storage. Springiness of tuna in oil is presented in fig 57, tuna in brine in fig 58 and tuna curry in fig 59. Springiness of tuna in oil, tuna in brine and tuna in curry were 5.05mm, 4.12 mm, 4.16 mm and that stored at 37°C were 4.98mm, 4.01mm and 4.39 mm respectively.



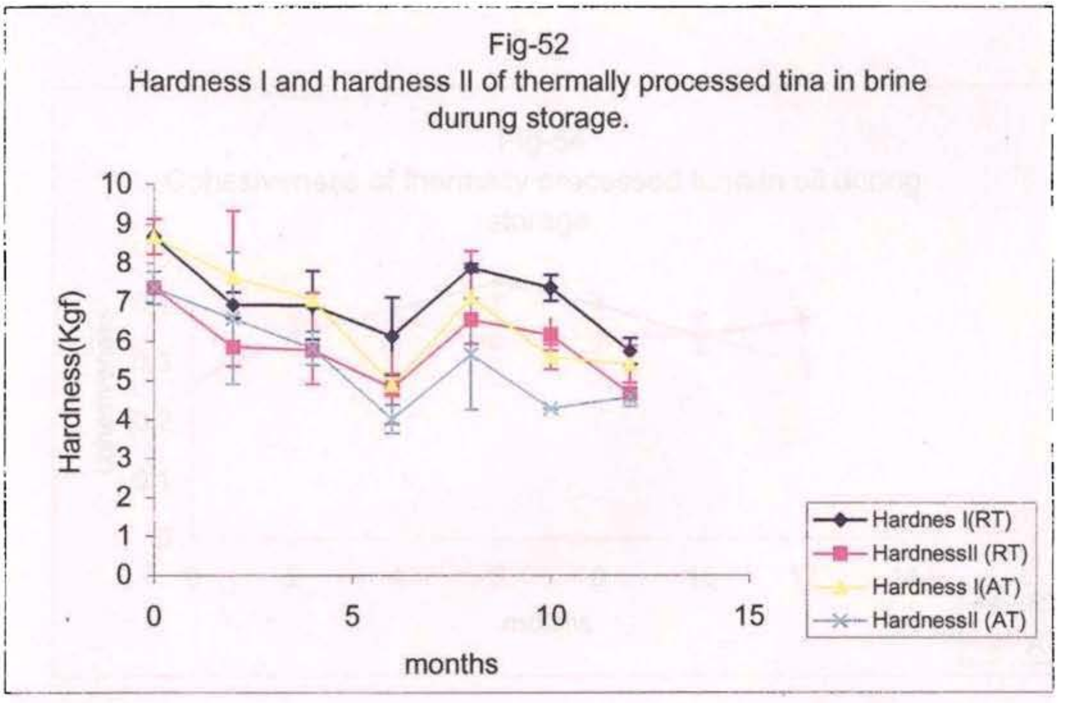


Fig-52
Hardness I and hardness II of thermally processed tina in brine durung storage.
Hardness(Kgf)
months
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
Hardnes I(RT)
HardnessII (RT)
Hardness I(AT)
HardnessII (AT)

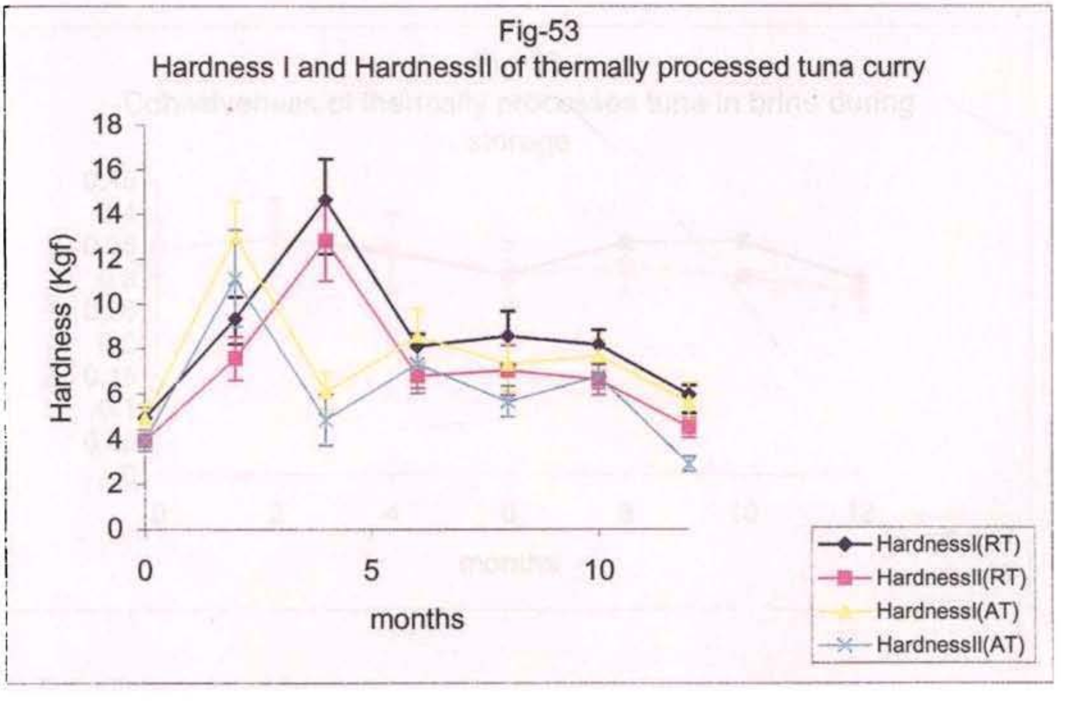


Fig-53
Hardness I and HardnessII of thermally processed tuna curry
Hardness (Kgf)
months
0
2
4
6
8
10
12
14
16
18
0
5
10
HardnessI(RT)
HardnessII(RT)
HardnessI(AT)
HardnessII(AT)

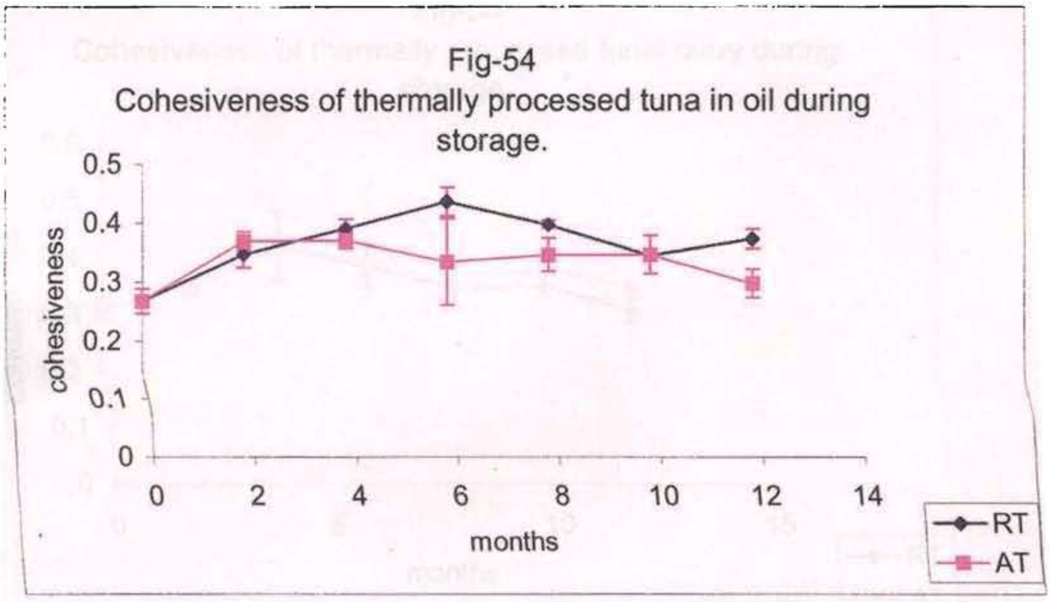


Fig-54
Cohesiveness of thermally processed tuna in oil during storage.
0.5
0.4
0.3
0.2
0.1
0
cohesiveness
0
2
4
6
8
10
12
14
months
RT
AT

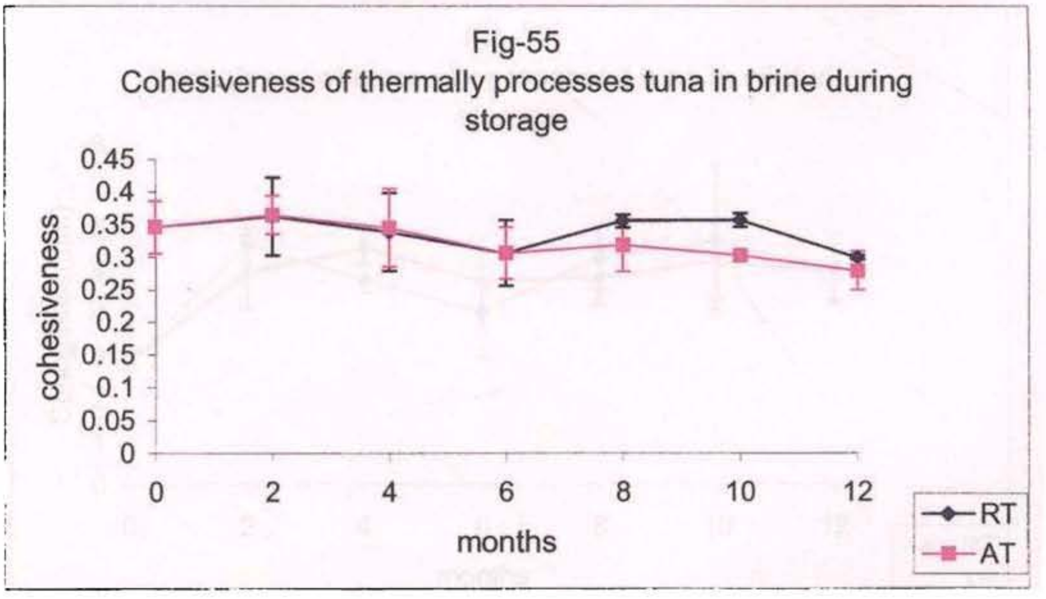


Fig-55
Cohesiveness of thermally processes tuna in brine during storage
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
cohesiveness
0
2
4
6
8
10
12
months
RT
AT

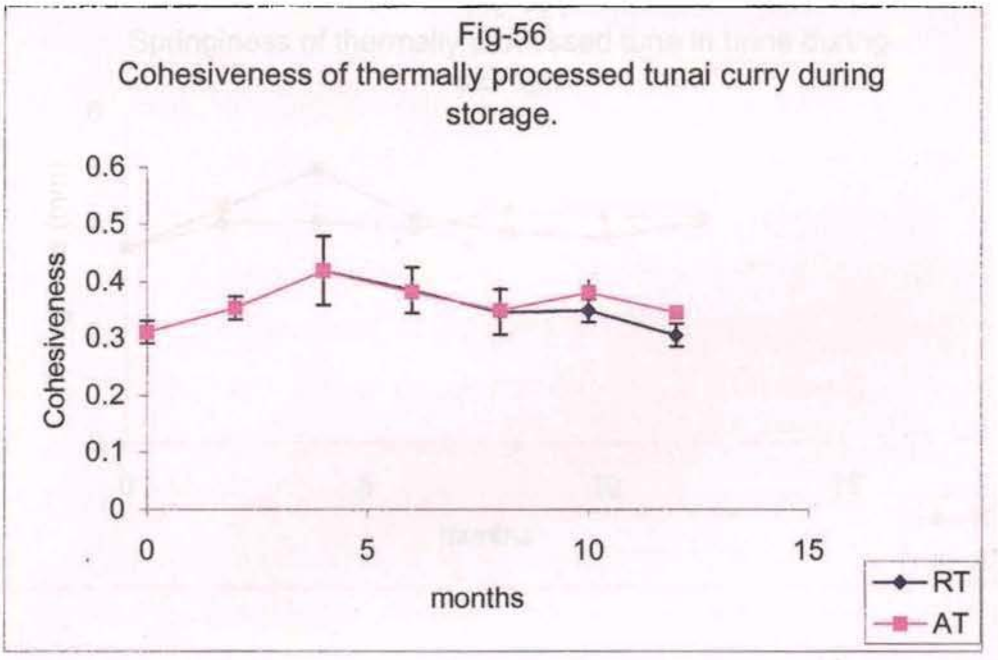


Fig-56
Cohesiveness of thermally processed tunai curry during storage.
Cohesiveness
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
months
RT
AT

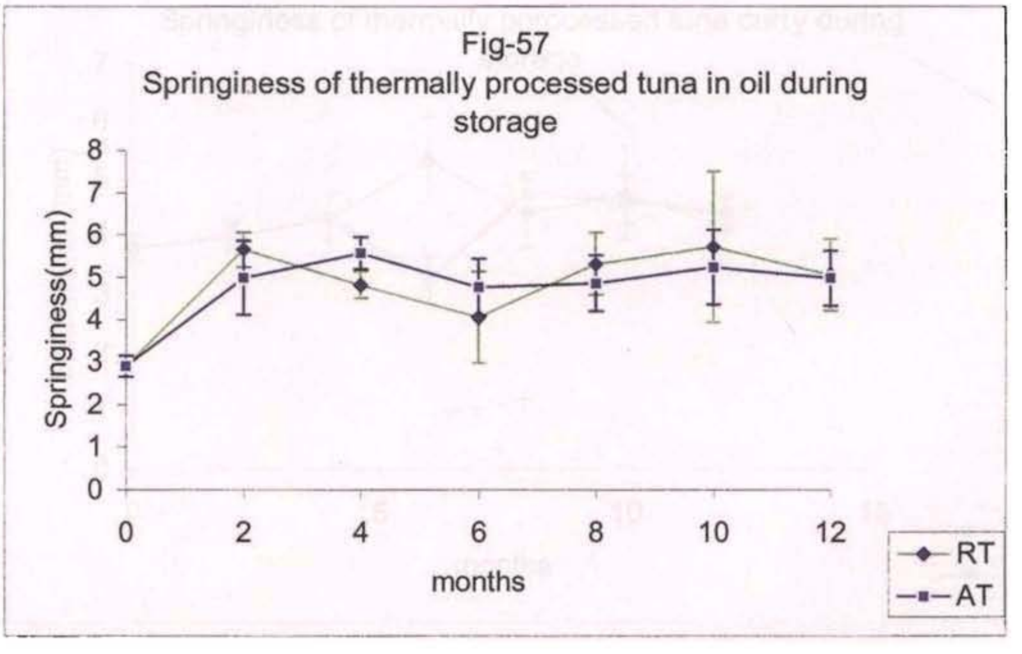


Fig-57
Springiness of thermally processed tuna in oil during storage
Springiness(mm)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
months
RT
AT

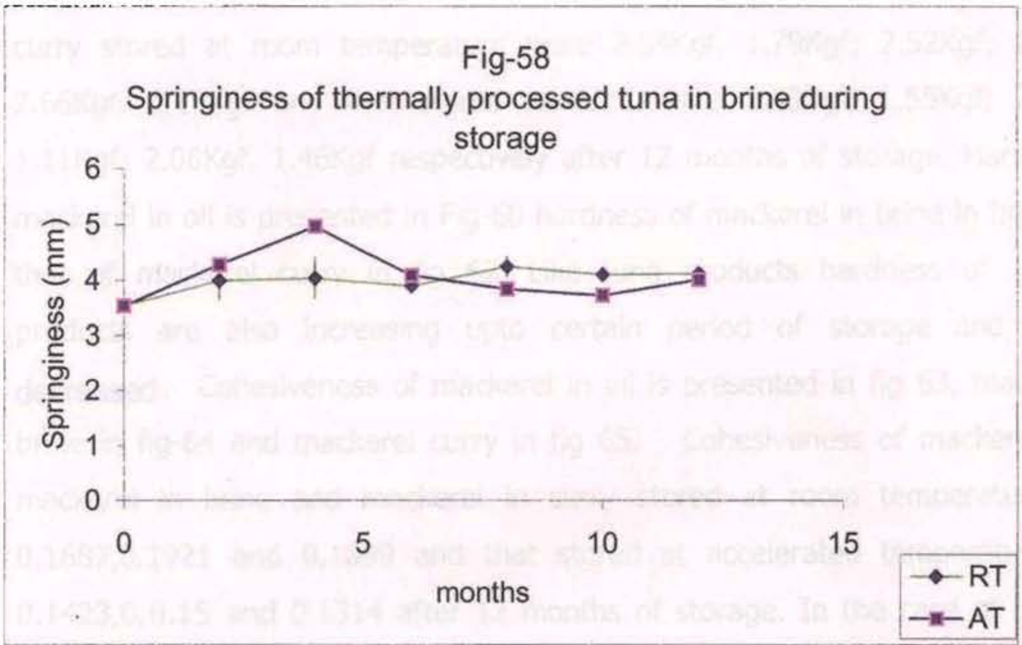



Fig-58
Springiness of thermally processed tuna in brine during storage

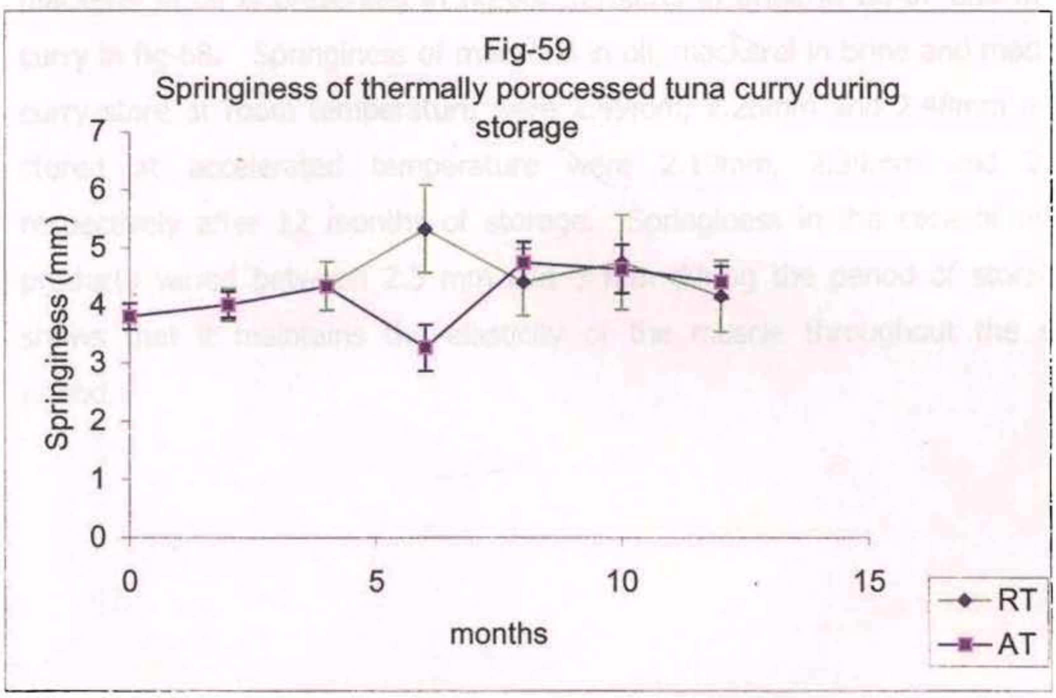



Fig-59
Springiness of thermally porocessed tuna curry during storage

Hardness I and Hardness II of mackerel in oil, mackerel in brine and mackerel in curry stored at room temperature were 2.54Kgf, 1.79Kgf; 2.52Kgf, 1.85Kgf; 2.66Kgf, 2.19Kgf and that stored at 37°C were 2.33Kgf, 1.55Kgf; 2.41Kgf, 1.11Kgf; 2.08Kgf, 1.46Kgf respectively after 12 months of storage. Hardness of mackerel in oil is presented in Fig-60 hardness of mackerel in brine in fig-61 and that of mackerel curry in fig 62. Like tuna products hardness of mackerel products are also increasing upto certain period of storage and they decreased. Cohesiveness of mackerel in oil is presented in fig 63, mackerel in brine in fig-64 and mackerel curry in fig 65. Cohesiveness of mackerel in oil, mackerel in brine and mackerel in curry stored at room temperature were 0.1687,0.1921 and 0.1899 and that stored at accelerated temperature were 0.1423,0.0.15 and 0.1314 after 12 months of storage. In the case of mackerel products cohesiveness is about 0.2 during the storage period and shows that , the products retain the cohesiveness throughout storage. Springiness of mackerel in oil is presented in fig-66, mackerel in brine in fig-67 and mackerel curry in fig-68. Springiness of mackerel in oil, mackerel in brine and mackerel in curry store at room temperature were 2.49mm, 2.26mm and 2.48mm and that stored at accelerated temperature were 2.19mm, 2.39mm and 2.23mm respectively after 12 months of storage. Springiness in the case of mackerel products varied between 2.5 mm and 3 mm during the period of storage.This shows that it maintains the elasticity of the muscle throughout the storage period.

Fig-60
Hardnessl and Hardnessll of thermally processed mackerel in oil during storage

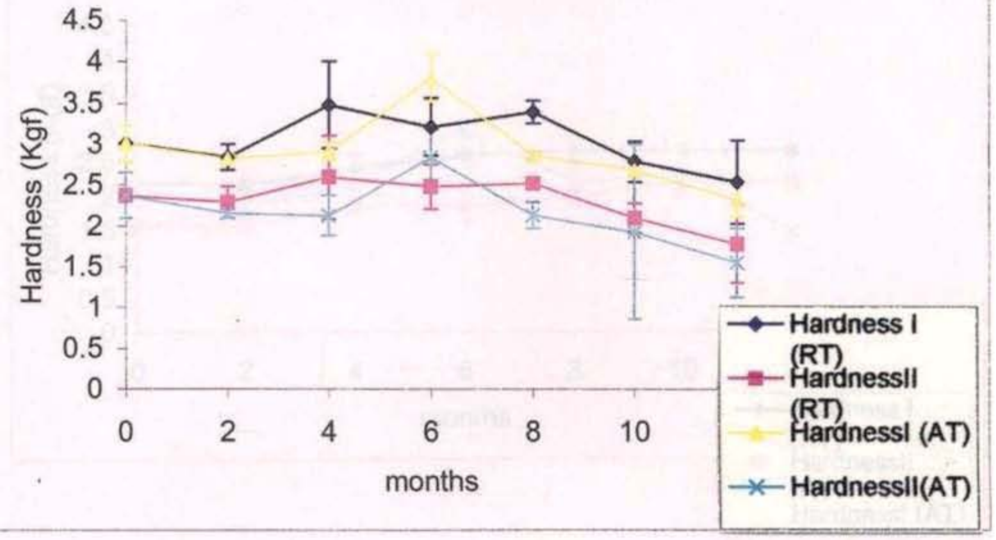
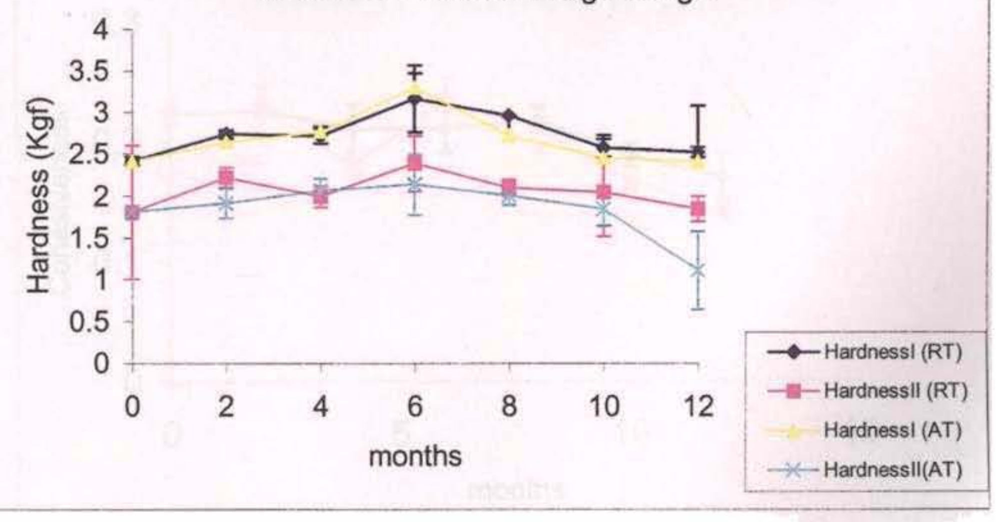



Fig-61
Hardness I and hardness II of thermally processed mackerel in brine during storage



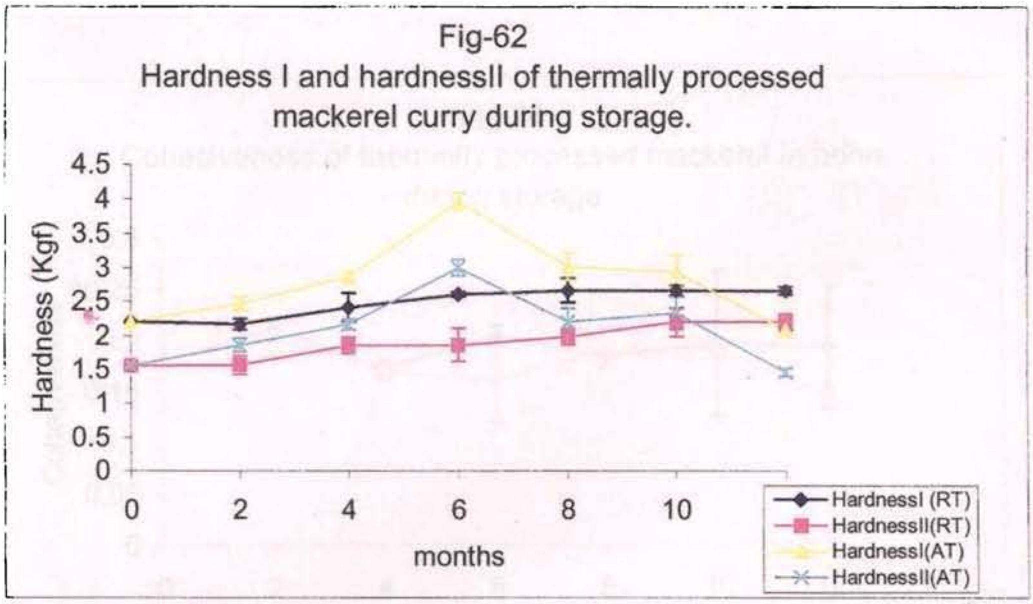


Fig-62
Hardness I and hardnessII of thermally processed mackerel curry during storage.
Hardness (Kgf)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
months
HardnessI (RT)
HardnessII(RT)
HardnessI(AT)
HardnessII(AT)

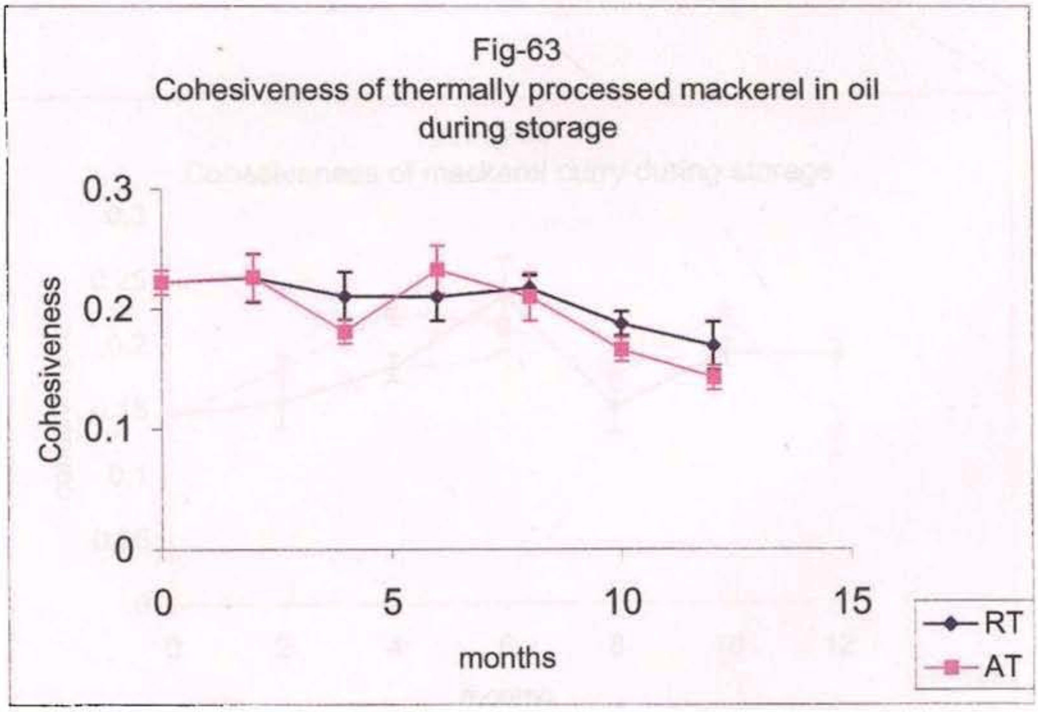


Fig-63
Cohesiveness of thermally processed mackerel in oil during storage
Cohesiveness
0.3
0.2
0.1
0
0
5
10
15
months
RT
AT

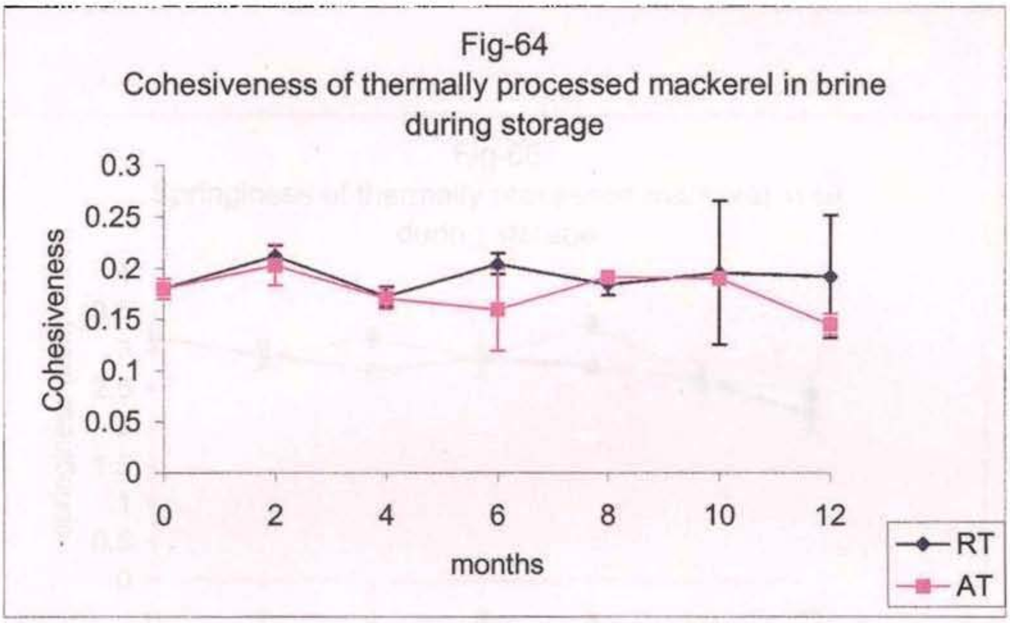


Fig-64
Cohesiveness of thermally processed mackerel in brine during storage
Cohesiveness
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
months
RT
AT

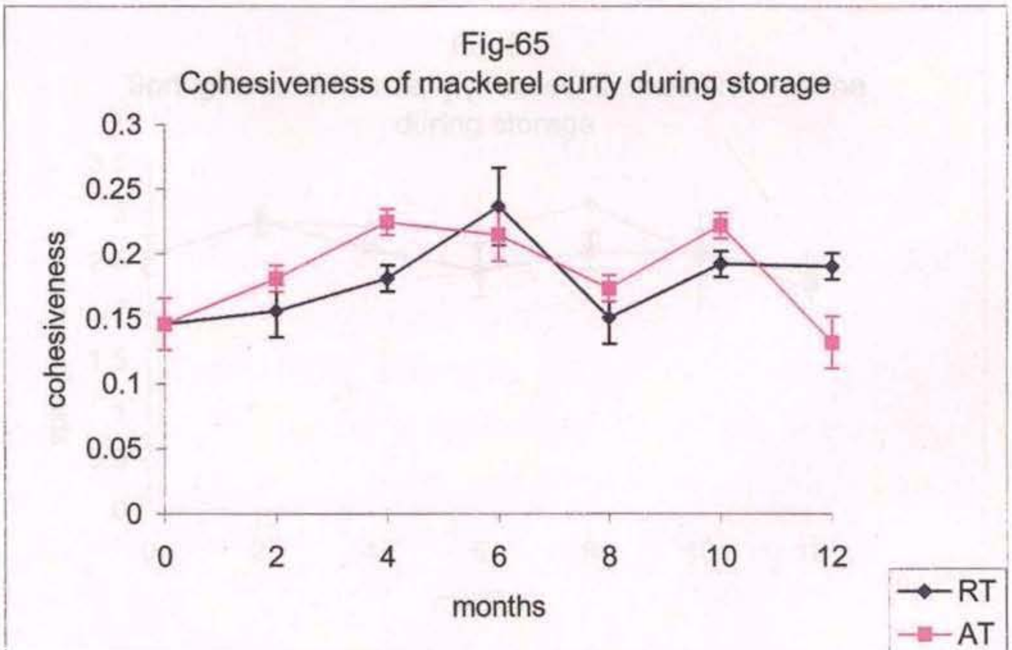


Fig-65
Cohesiveness of mackerel curry during storage
cohesiveness
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
months
RT
AT

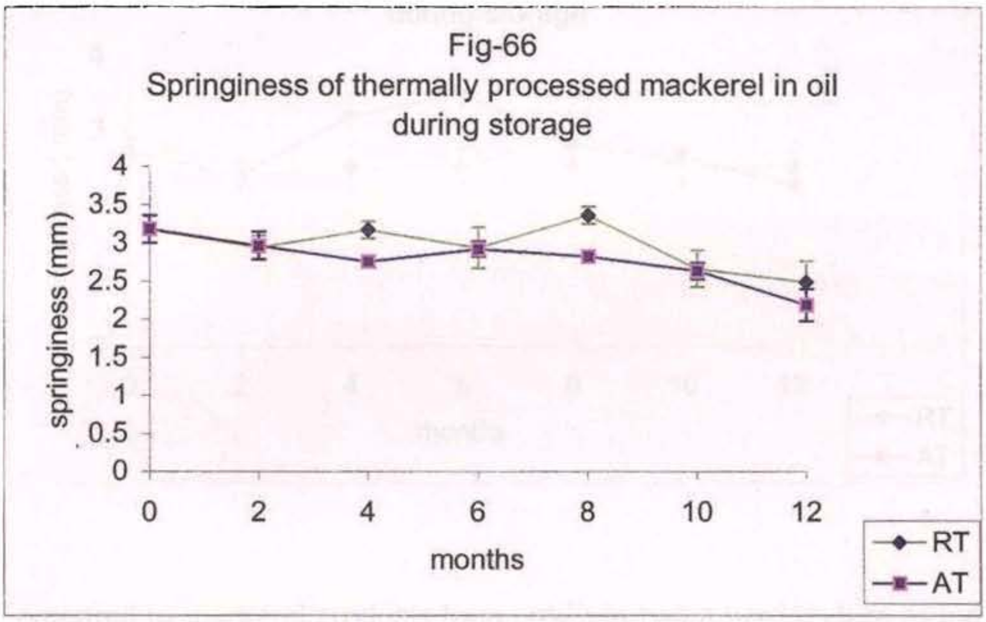


Fig-66
Springiness of thermally processed mackerel in oil during storage
springiness (mm)
months
RT
AT

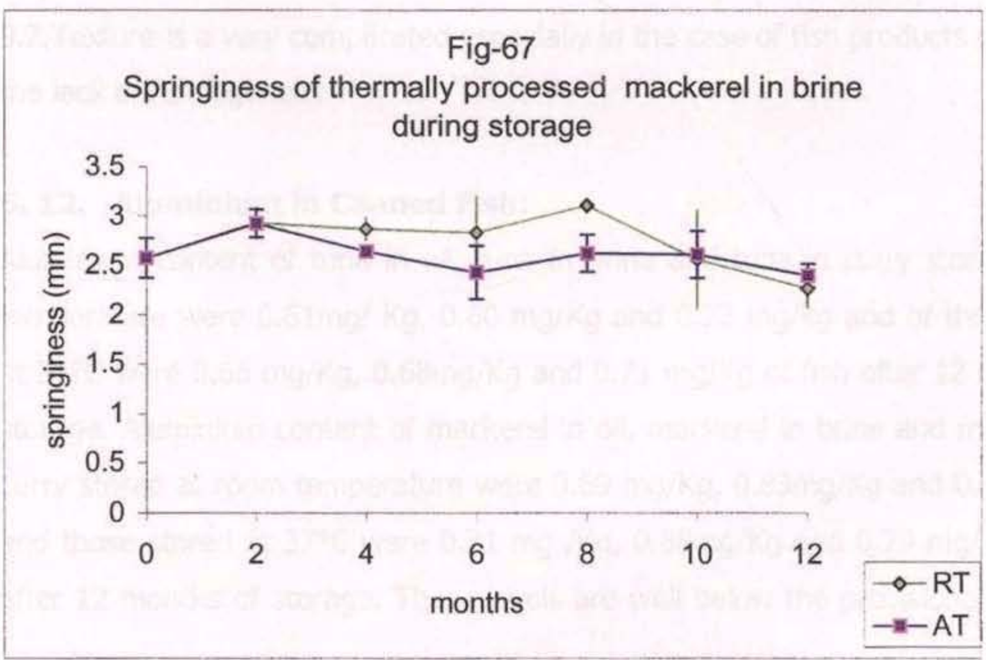


Fig-67
Springiness of thermally processed mackerel in brine during storage
springiness (mm)
months
RT
AT

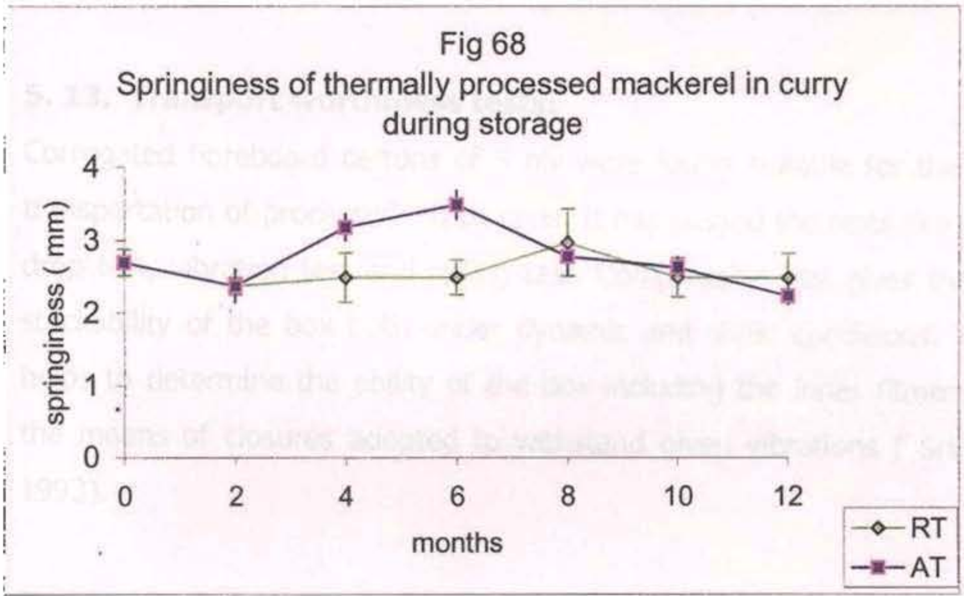


Fig 68
Springiness of thermally processed mackerel in curry during storage

Compared to mackerel products tuna products had a hard texture as indicated by the hardness. Hardness of mackerel is less than that of tuna as mackerel is having softer texture compared to tuna. Cohesiveness of tuna products varied between 0.2 and 0.3 while that of mackerel products varied between 0.1 and 0.2.Texture is a very complicated especially in the case of fish products due to the lack of homogeneity.

## 5. 12. Aluminium in Canned Fish:

Aluminium content of tuna in oil, tuna in brine and tuna in curry stored at room temperature were 0.61mg/ Kg, 0.60 mg/Kg and 0.72 mg/kg and of those stored at 37°C were 0.65 mg/Kg, 0.68mg/Kg and 0.71 mg/Kg of fish after 12 months of storage. Aluminium content of mackerel in oil, mackerel in brine and mackerel in curry stored at room temperature were 0.69 mg/Kg, 0.83mg/Kg and 0.73 mg/Kg and those stored at 37°C were 0.71 mg /Kg, 0.88mg/Kg and 0.79 mg/Kg of fish after 12 months of storage. These levels are well below the provisional tolerable daily intake of 1 mg/Kg body weight per day recommended by WHO (Ranau and Oehlenschlaeger, 1997).

### 5. 13. Transport worthiness tests:

Corrugated fibreboard cartons of 5 ply were found suitable for the Storage and transportation of processed 8 oz cans. It has passed the tests like compression; drop test, vibration test and rolling test. Compression test gives the measure of stackability of the box both under dynamic and static conditions. Vibration test helps to determine the ability of the box including the inner fitments as well as the means of closures adopted to withstand given vibrations ( Srinivasa gopal, 1993).

The CFB had a bursting strength of 12 Kg/cm$^2$ and Cobb 30' value of 85.The puncture resistance of the CFB was 240 beach units. Transport worthiness tests indicate the master carton prepared out of 120 gsm Kraft paper withstand all the transport worthiness tests like drop, rolling and vibration tests. CFB prepared out of 100gsm Kraft failed in the drop test of the transport worthiness indicates its unsuitability for packaging canned products. CFB with a bursting strength of 12 Kg/cm$^2$, Cobb value of 85 and puncture resistance of 240 beach units is found to be suitable for bulk packing of canned products in a shipping container.

# 6.SUMMARY AND CONCLUSIONS

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Fish occupies a prominent role in human nutrition. The value of fish for human nutrition lies in the relatively high protein content, good digestibility and high biological value of fish proteins. Fish is consumed in many forms in the developed countries; the value added fish products are consumed in substantial quantity. In today's affluent society, people prefer to buy ready-to-cook and ready-to-serve convenience products from supermarkets than buying raw fish, which is cumbersome to prepare for the table. All over the world, the tendency now is to take convenience foods, such as assembling meals, rather than preparing from basic ingredients. Besides exports, demand in internal market for convenience product is increasing in India . Among different value added food products, canned product is one of the most important one.

*Canning is defined as the process of heating hermetically sealed foods* to a temperature that kills harmful microbes. The containers may be made of metal, glass or any other material that is airtight and heatable. For the purpose of canning, different containers are used such as glass, tin, Tin-Free steel, aluminium etc . Several workers have tried to preserve the fish products in tin containers. As far as India is concerned tinplate for making cans is imported and hence it is disadvantageous economically. Many of these containers have the problems of disintegration of lacquers, expensive and are difficult to open. In the case of aluminium cans earlier studies were carried out using imported aluminium cans which are not cost effective. India exported very insignificant quantity of canned shrimps amounting to 3.5 tonnes valued at 4.4 lakh rupees in 1996. This quantity is less than 1% of the total seafood exports of 353675 tonnes during that year. There after no significant export of canned seafoods has taken place. Most of the canned seafood production is going for the defence supplies and small quantity to the domestic market. Global trade of canned seafoods during 2000-2001 worked out to be 9379 million US dollars. Export of canned seafoods reached its zenith in 1997-1998, which was found to be 9476 million US dollars. The USA, UK, France, Japan, Germany and Canada were the leading importers. Thailand is the major exporter of canned fishery products and become the market leader by exporting 2069 million US dollars of canned seafoods.

The fish like tuna, sardine, mackerel and others now being exported from the country to neighboring countries in the form of raw material could be canned with value addition. With our sound infra structure and availability of relatively cheap labour prospects for developing an export oriented canning industry are very bright. It is relevant to draw examples from Maldives, Mauritius and Seychelles where massive canneries bank only on their rich raw material base and successfully run a global trade in canned seafood by heavily relying on imported material and expertise inputs.

The canning industry got a boom in India in the late fifties, mainly intended for canning of prawns for the export market. Export of this commodity started in the year 1959 which after touching the highest record of 2,200 tonnes worth Rs.52.4 million in 1973 records a steep fall due to the very same reasons that caused the closing down of the first fish canning factory in the country. One of the major factors for downfall of the Indian canning industry is inadequacy of indigenous tin cans with respect to their quality and price. The quality of lacquer, the finish and diversity are the elements essential to ensure shelf life and consumer appeal. In India, the price of the can alone works out to nearly 30% of the cost. Added to the cost of labour, cartons and other items shoot up to 50% of the total production cost making it ill affordable to the average Indian consumers and not competitive in most of the overseas market. In India the most promising alternative to tin cans for fish canning is found to be aluminum cans since the basic ore of aluminium Bauxite is available in large quantities. Recently some companies had ventured in to the indigenous manufacture of aluminium cans. In India, only Klass Engineering Pvt. Ltd, Bangalore manufactures aluminium containers for food canning.

So the present study was aimed to find an alternative container to tin cans for fish canning with emphasis on the suitability of indigenous aluminium cans and heat penetration and process time calculations. The physical properties of the aluminium cans studied include Test for Lacquer, Air pressure test, Resistance to sulphur staining and impermeability, Test for suitability of can for food contact applications, and cut out analysis. The test cans had a dry lacquer film weight of 4.2 gms/$m^2$ · The lacquer also gives positive results for phenolic epoxy resins. The air pressure test showed that the cans withstood internal pressure of 25 psig. So the mentioned aluminium cans have got the required strength to with stand the processing conditions Results of experiments also showed that 8 oz aluminium cans used for the study don't require overpressure during thermal processing. The test aluminium cans had water extractives of 0.07 mg/ sq. inch and chloroform extractives of 0.04mg/ sq. in. The extractive values are much below those specified by FDA, which implies that the test aluminium cans are quite suitable for food contact applications. The cut out analysis showed that the indigenous aluminium cans have got a good overlap of 62.16% and the body hook and cover hook are 0.1596 cm and 0.1501 cm respectively. Cut out test revealed the double seaming suitability of aluminium cans.

Canning studies were carried out in aluminium cans (8 oz) using tuna in oil tuna in brine, tuna curry, mackerel in oil, mackerel in brine and mackerel curry. Tuna in oil were thermally processed to Fo 5, 7 and 10 and with Fo10 and rpm 2,4, and 6 to study the heat penetration. Total process time (B+0.42 of come up time) taken to reach an Fo value of 5 was 44.31 minutes, Fo 7 was 57.07 minutes and for Fo 10, it was 64.43 minutes. The Cook Values obtained during the process were 86.52 minutes for Fo 5, 103.78 minutes for Fo 7, and 121.65 minutes for Fo 10.From the study it was found that Fo 10 is found good for tuna according to cooking and sterility characteristics. Aluminium can filled with tuna in oil were subjected to different rotational speeds (2,4 and 6 rpm) by subjecting to heat processing to the same Fo value to study the changes in heat penetration. There is decrease in process time with increase in speed of rotation. *The total process time taken to reach an Fo value of 10 with 2 rpm was 57.22* minutes, Fo 10 with 4 rpm was 56.16 minutes and Fo 10 with 6 rpm was 55.38 minutes.*The corresponding cook values are 115.35 minutes,114.45 minutes, and* 108.93 *minutes. Finally, Tuna in brine and Tuna in curry were heat processed to* F0 10 and studied the heat penetration characteristics. Total process time taken in the case of Tuna in brine was 41.03 minutes with a cook value of 96.60 minutes and total process time taken in the case of Tuna in curry was 58.33 minutes with a cook value of 113.43 minutes. Tuna in brine has got much faster heat penetration compared to Tuna in oil and Tuna in curry and resulted in a less total process time.

Mackerel in oil were initially heat processed to Fo 5, 7 and 9. Total process time taken to reach a Fo value of 5 was 34.06 minutes, Fo 7 was 41.29 minutes and Fo 9 was 45.09 minutes. In the case of mackerel Fo value of 9 was taken as optimum depending upon the sterility, cook value and also the softening of the bones. *Cook value for mackerel in Oil processed to F05 was 70.60 minutes; F0 7 it was 86.23 minutes and for mackerel in oil, processed to F0 9 was 100.53* minutes. In the next stage mackerel in oil were subjected to different rotational speeds 2,4 and 6 rpm) by heat processing to a Fo value of 9 to study changes in heat penetration. Total process time taken to reach a Fo value of 9 with 2 rpm was 42.28 minutes, for Fo 9 with4 rpm was 41.38 minutes and for Fo 9 with 6 rpm was 38.22 minutes. The cook value of Mackerel in Oil processed withF0 9 with 2 rpm was 95.09 minutes, with 4 rpm was 94.49 minutes and for 6 rpm was84.60 minutes. In the last stage, mackerel in brine and mackerel in curry were heat processed to Fo 9 to study the changes in heat penetration. Total process time taken to reach an Fo value of 9 in the case of mackerel in brine was

38.06 minutes and in case of mackerel in curry, it was 57.31 minutes. The cook value of mackerel in brine processed to Fo 9 was 92.83 minutes and mackerel in curry processed to F0 9 has got a cook value of 116.25 minutes.

Sterility tests were done in all the cases and all the Fo values tried both in the case of mackerel and tuna were found to be sterile. But in the case of tuna products an Fo of 10 was taken due to better texture and optimum cook values and in the case of mackerel products Fo 9 was taken due to the optimum cooking and also due to the better softening of bone.

Tuna in oil, tuna in brine and Tuna in curry medium were heat processed to Fo10 and mackerel in oil, mackerel in brine and mackerel in curry were heat processed to Fo 9 and stored at room temperature and at 37°c to determine the shelf life. The characteristics studied include changes in TBA value, pH, Sensory characteristics and Texturecprofile analysis. In all the tuna products, stored at room temperature, and at 37ºC, TBA value were increasing upto a certain period of storage and decreasing after that when stored for a period of 12 months. In the case of mackerel products also, TBA value increases upto a certain period and thereafter it decreases. pH of all the products remain more or less unchanged during the 12 months period of storage. Sensory score of tuna in oil stored at room temperature after 12 months of storage was 6.75 and that stored at 37°C was 6.63. Sensory score of tuna in brine after 12 months of storage was 6.50 in the case of product stored at room temperature and that of 37°C was 6.25. Sensory score of tuna in curry stored at room temperature was 6.00 and that stored at 37°C was 5.50 at end of storage period. After 12 months of storage tuna in oil stored at room temperature was more acceptable compared to any other tuna products.

Mackerel in oil had a sensory score of 6.00 when stored at room temperature and stored at 37°C had a sensory score 5.75 after 12 months of storage. .

Mackerel in brine at room temperature had a sensory score of 6.38 and that of accelerated temperature obtained a sensory score of 5.88 after 12 months of storage. Mackerel curry stored at room temperature had a sensory score of 5.75 and that stored at 37°C obtained a score of 5.50. Among all the products mackerel in curry resulted in least acceptable sensory score according to sensory evaluation after 12 months of storage.

Hardness of the products increased upto a certain period of storage and then it decreased. In the case on tuna in oil and tuna in curry hardness increased upto 4 months of storage and then hardness decreased. Tuna products stored both at room temperature and at accelerated temperature are having a cohesiveness of almost 0.3 during the entire period of storage. Like tuna products hardness of mackerel products are also increasing upto certain period of storage and then it decreasing. In the case of mackerel products cohesiveness is about 0.2 during the storage period. Springiness in the case of mackerel products varied between 2.5 mm and 3 mm during the period of storage. Compared to mackerel products tuna products had a hard texture as indicated by the hardnes. Estimation of aluminium in the canned fish after 12 months of storage indicated that there is not any significant migration of aluminium into the product, indicating the very good lacquer quality.

Finally transportworthiness tests of finished products were carried out in master cartons. It has passed the tests like compression; drop test, vibration test and rolling test. Transport worthiness tests indicate the master carton prepared out of 120 gsm Kraft paper withstand all the transport worthiness tests like drop, rolling and vibration tests. The research findings can be summarized as follows.

• Indigenous aluminium cans are found suitable for the thermal processing of fish products.

• 8 oz aluminium cans do not require over pressure for thermal processing.

• Tuna products require a Fo of 10 for optimum sensory and textural characteristics.

• Mackerel products require a Fo of 9 for optimum sensory and textural characteristics.

• There is reduction in process time with the increase in the speed of rotation for the same Fo value (Fo 10 in the case of tuna and Fo 9 in the case of mackerel) .2 rpm is found to have a efficient reduction in process time.

•The three Fo values were found to be sterile in the case of mackerel and tuna products.

• Migration of aluminium from the can to the product is very insignificant.

• All the products were acceptable at the end of storage period. Comparitively curry products were least acceptable.

There are high prospects for canned seafood exports as the consumption of canned seafood abroad is on the increase. The advantages of reviving the seafood industry in the country will increase our export earnings. Similarly the fishing industry will also be benefited whenever the freezing sector reduces their production due to fluctuating overseas market. The reduction in cost of processed food may also increase domestic consumption of canned seafood. Therefore, the future for marketing canned seafood is very bright by using indigenous aluminium containers.

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