PACKAGING MATERIALS FOR SHRIMP, FISH AND FISH PRODUCTS, THEIR PROPERTIES, SELECTION AND EFFECT OF DIFFERENT PACKAGING MATERIALS ON THEIR SHELF LIFE

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CERTIFICATE

This is to certify that this thesis entitled "Packaging materials for shrimp, fish and fish products, their properties, selection and effect of different packaging materials on their shelf life" embodies the results of original work conducted by Shri T.K.Srinivasa Gopal under my guidance from 19.7.1989 to 28.4.1993. I further certify that no part of this thesis has previously been formed the basis of the award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other University or Society. He has also passed the Ph.D. qualifying examination of the Cochin University of Science and Technology, Cochin-682022 held in January, 1991.

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DECLARATION

I, Sreenivasa Gopal, T.K. do hereby declare that the thesis entitled "Packaging materials for shrimp, fish and fish products, their properties, selection and effect of different packaging materials on their shelf life" is a genuine record of bonafide research carried out by me under the supervision of Dr. C.Hridayanathan, Reader, Department of Industrial Fisheries, Cochin University of Science and Technology and has not previously formed the basis of award of any degree, diploma, associateship, fellowship or other similar titles in any of the University or Institution.

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CONTENTS

LIST OF ABBREVIATIONS

ADI	-	Acceptable daily intake
AOAC	-	Association of official analytical chemists
AOCS	-	American oils chemists' society
ASTM	-	American society for testing and materials
BA	-	Barrier layer
BHT	-	Batylated hydroxytoluene
BIS	-	Bureau of Indian Standards
Cal	-	Calories
CFB	-	Corrugated fibreboard
CIFT	-	Central Institute of Fisheries Technology
CO_2	-	Carbon dioxide
CPP	-	Cast polypropylene
DEHP	-	Di-2-ethylhexylpthalate
DRD	-	Drawn & redrawn
DWI	-	Drawn & wall ironed
EDI	-	Estimated daily intake
EDTA	-	Ethylene diamine tetra acetic acid
ERH	-	Equilibrium relative humidity
EVA	-	Ethylene vinyl acetate copolymer
FAO	-	Food and Agriculture Organisation
FDA	-	Food and Drug Administration
FEFCO	-	Federation Europeenne Des Fabricants De Carton Ondule
g	-	Gram
GSM	-	Grams per square metre
h	-	Hour
HDPE	-	High density polyethylene

HM-HDPE	-	High molecular weight high density polyethylene
HTF	-	High tin fillet
ICAR	-	Indian Council of Agricultural Research
IFT	-	International Food Technologists
IQF	-	Individually quick frozen
IS	-	Indian Standards
kg	-	Kilogram
LDPE	-	Low density polyethylene
LD-HD	-	Low density high density polyethylene co-extruded film
LLDPE	-	Linear low density polyethylene
LTS	-	Low tin coated steel
M	-	Micron
M^2	-	Square metre
Metmb	-	Metmyoglobin
Met. PEST/ LDPE	-	Metallised polyester laminated with low density polyethylene
MSAT	-	Moisture proof heat sealable anchored transparent film
MVTR	-	Moisture vapour transmission rate
MXXT	-	Moisture proof PVDC coated on both sides transparent cellophane film
NPN	-	Non protein nitrogen
O_2	-	Oxygen
OAA	-	Orient Airlines Association
OECD	-	Organisation for Economic Co-operation and Development.
OPP	-	Oriented polypropylene
PA	-	Polyamide (nylon)

PEST	-	Polyethylene terephthalate (Polyester)
ppb	-	Parts per billion
ppm	-	Parts per million
PS	-	Polystyrene
PVC	-	Polyvinylchloride
PVDC	-	Polyvinylidene chloride
RH	-	Relative humidity
RSC	-	Regular slotted container
SSN	-	Salt soluble nitrogen
TFS	-	Tin free steel
TMA	-	Trimethylamine
TMAN	-	Trimethylamine nitrogen.
TMA-O	-	Trimethylamine Oxide
TVBN	-	Total volatile base nitrogen
UNDP	-	United Nations Development Programme
WSN	-	Water soluble nitrogen
WVTR	-	Water vapour transmission rate

1. INTRODUCTION

1. INTRODUCTION

Food packaging like any other packaging is an external means of preservation of food during storage, transportation and distribution and has to be provided at the manufacturing/production centre. Hence it forms an integral part of the product manufacture/production and has an important function in the distribution of foodstuffs. In today's consumer oriented economy a package is an extremely vital link between the manufacturer of the product and the ultimate user. There is great awareness among the consumers today regarding their right to obtain proper quality and correct quantity of the product at a fair price in an aesthetic and hygienic package (Toley, 1986). India is predominantly dependent on its agricultural economy, often leading to severe shortages. It is realised that one of the important causes of food shortage is high post harvest losses and spoilage, estimated to be around 20% (Veerraju, 1974). Packaging of foodstuffs becomes all the more important in countries like India where the climatic conditions vary considerably (temperature from subzero to over 50°C and relative humidity from 10% to 90%) and handling facilities are grossly inadequate.

Fisheries have an important place in the national economy, as they provide jobs to fishermen and bring in foreign exchange for the country. Fish play a very important role in human nutrition. In developing countries fish provides the primary source of animal protein for over one billion people (FAO/Word Bank/UNDP/CEC (1989)). Fishing is the main source of income for some 100 million people, about 80% of whom are in low income group. The demand for fish has been constantly growing and is expected to be around 100 million tonnes by 2000 A.D. (FAO (1981b)). India ranks 7th among the 10 fish producing countries and occupies topmost position in shrimp production as per the FAO statistics. India exported 1,39,419 tonnes of marine products valued at Rs.894 crores in 1990-91 registering an increase of 41% value wise over the exports during the previous year (Anon, 1992). The bulk of this export takes place in frozen form and export in canned form is less than 0.2%. Major markets for marine products are developed countries like Japan, U.S.A., Europe and Australia where there are statutory laws laying down specific norms of packaging and good manufacturing practice from the point of view of public health protection to consumers. Although India harvests about 2.93 million metric tonnes of fish annually, very little attention has been paid to the technology of packaging of fish and processed fishery products. Packaging as an effective tool of marketing has created a new standard of living in the developing countries. During the past decade in India there is almost a packaging revolution with the availability of varieties of packaging materials, thus generating better packaging consciousness in other producer/manufacturing food industries. But unfortunately such realisation is not forthcoming in the fisheries sector and packaging techniques for local and export trade continues to be on traditional lines with their inherent drawbacks and limitations (Govindan and Rao, 1987). This is probably due to the wrong notion that introduction of any new material would further escalate the cost of fish. First and foremost need of the hour is to educate the industry on modern packaging methods and right handling procedures and demonstrate to them that the packaging could be cost effective. Traditional packaging materials like bamboo baskets, wooden boxes, second hand plywood cases, gunnies, palmariah leaves, screw pine mats etc. are used for packaging of fresh and processed fish for local markets and to a limited extent for the export trade (Rao, 1975). It is of paramount importance to adopt scientific and functional method of packaging for a perishable product like fish, since our packaged products have to compete in the international market with similar products imported from other countries and act as their own salesman when displayed along with others. Instances are not lacking where due to the substandard method of packaging adopted, export commodities have been rejected at the other end.

In the year 1990-91 India exported 1,34,598 tonnes of frozen prawns, fish and cuttle fish together employing 6.73 crores of waxed duplex cartons, as many as 6.73 millions of corrugated fibre board, and 419 tonnes of plastic materials in the form of film. The approximate expenditure on packaging is estimated to be around 11 crores of rupees. And yet between 20 to 25% of the packaging used by the trade presently are damaged which may be at times be responsible for the damage to the contents (Subramanyan, 1984). These figures again do not reflect the loss in terms of value because of the inadequacy of the packaging standards adopted by this trade in the face of stiff international competition in packaging alone. It is known that the prices realised by India are not the highest. Perhaps product quality may be as much to blame as the packaging quality itself. A good packaging never improves quality of product but it can prevent deterioration to some extent (Gopakumar, 1993). It has been estimated that nearly 1/3rd of the exports originating from developing countries are either damaged or spoiled in transit. In case of India the proportion may not be that high, but is definitely large enough to cause concern to all (Gangadharan, 1982). Two of the common defects reported in the master cartons exported from India are low mechanical strength and tendency to get wet. They are weakened easily by deposits of moisture caused by temperature fluctuations during loading, unloading and other handling stages (Gopal, 1993). No attempt has been made by the industry to use sophisticated machinery for beheading, grading, packaging etc. The inner cartons and master cartons used were not strong enough to withstand the stress and strains of goods transit. The above comments were generally received along with many other from the Japanese buyers regarding our products (Anon, 1979). Among several packaging materials used in fishery industry, ISI specifications have been formulated only for corrugated fibre board boxes for export of frozen seafoods and froglegs (IS: 6715, 1972). This standard was formulated before containerisation came into existence in the export of marine products. Before containerisation the standards were stringent in view of the rough handling, transportation and storage. In the present study extensive investigations were carried out to evolve the code of practice and steps for the packaging of shrimp for export, development of suitable packaging materials for fishery products of commercial importance for local and export trade replacing the conventional packages, to improve the shelf life of fish/ fishery products and its suitability for food contact application.

2. REVIEW OF LITERATURE

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2.1 HISTORY OF DEVELOPMENT OF PACKAGING MATERIALS

Packaging development begins with man's earliest beginnings. The use of packaging has its foundations in antiquity, when man first learned to adopt natural containers to his own use for the storage, protection and transportation of foodstuffs and other goods. Many of these are early forms of packaging such as gourds, shells, the hollow stems of bamboo and the use of leaves for wrapping may still be seen today. These ancient forms of packaging were largely made as and when required by the user rather than being produced by a specialist manufacturer. The first blossoming of an actual packaging industry probably occurred when pottery jars began to be widely used for the storage and transportation of wine, oil and grain. The production of these jars became concentrated in areas where good clay and fuel were available and where the climatic conditions were ideal for their manufacture. In certain places in the world such as African island of Djerba, pottery jars have been produced for over 2000 years.

During the last 2000 years the products of the packaging industry became more diversified but were largely dependent on the use of natural materials. Typical products were wooven sacks and baskets and wooden crates and casks (Sacharow & Griffin, 1980). The invention of wooven cloth and clay pottery took place before 8000 B.C and crude glassware appeared not long after that period. Metals date from the end of the stone age. Wooden chests, kegs, barrels and boxes were known in early Greek and Roman days (Roger *et al.*, 1985). The utilisation of coal fired furnaces enabled glass bottles to be used for packaging rather than being luxury items, although these were still hand made. Automatic machines for the manufacture of paper and board made these available for packaging for the first time. The turn of the century saw many important packaging developments including the development of automatic processes for the manufacture of glass containers and cartons and the development of metal containers for food products. The first packaging films were developed starting with regenerated cellulose films(cellophane) and followed by cellulose acetate and rubber hydrochloride (pliofilm) films. The aluminium foils also became available for packaging. These changes led to the development of automatic packaging machinery including bottling lines. Transwrap and flowpack machines were developed to handle the new packaging films and various overwrap machines were produced to handle foil based materials.

The next big change in the packaging industry was brought about by the development of plastics. This resulted in the development of many new types of packaging products including plastic bottles, jars, tubes, drums, crates, injection moulded tubs, thermoformed trays and a wide range of packaging films. Other changes in the packaging industry were caused by developments in retailing and manufacturing industries. New methods of retailing gave rise to demands for products to be pre-portioned and pre-packaged. Increasing centralisation of production in the manufacturing industry made in line packaging operations economically feasible. These changes led in turn to the development of a wide range of high speed packaging machines which would keep pace with the production processes. The products of the packaging industry are now diverse with many different forms of packaging being available. These include

Rigid containers	:	Glass bottles, cans, cases, drums, injection moulding etc.
Semi rigid packs	:	Plastic bottles, cartons, thermoformings, blister packs etc.
Non rigid packs	:	Overwraps, bags, sacks, sachets, pouches etc.

It is the group of non rigid packs which are collectively known as flexible packaging. The Indian economy is predominantly agricultural and very often food shortages occur. One of the reasons attributed to this is the high losses due to post harvest spoilage. It is estimated that about 30% of the fruits and vegetables, 10% of food grains, 3% of flour and 5% of sugar and tea were wasted which resulted heavy losses to the economy of the country. (Dordi, 1983). Fish transport, distribution and marketing is unfortunately at the lowest technical standard in India and this is so particularly in the domestic sector. About 25-30% of the fish landed in India is used for dried fish production. Due to lack of adequate storage and packaging methodology, the dried fish losses are often as high as 30-40% (Dehadri, 1993). These alarming losses can be substantially minimised by adoption of proper packaging practices. Proper packaging can not only help in distribution of the product over a wider area, but can also preserve the product for a longer time by lessening contamination by maintaining high hygienic conditions and minimising the chances of adulteration.

2.2 STATUS OF PACKAGING IN INDIA

A significant development has taken place in the industrial sector in India since independence, particularly in recent years. With more and more industrialisation coupled with the increased sophistication and rising standards of living, the demand for industrial and consumer products has also increased immensely. Tin plate which is a very commonly used material is now indigenously manufactured, although tin is still imported. Electrolytically coated tin plate which was hitherto 100% imported is now produced in the country in smaller quantities(Bhatt, 1974). Traditional glass containers have a very wide application in the field of packaging. These are presently available to the packers in a variety of shapes, designs and colours (Vaziralli, 1974). Aluminium is yet another material which is used in large quantity in packaging industry. This metal is produced indigenously and is used as container sheets, slugs for collapsible rigid tubes and foils in a laminate with other flexible packaging materials. Machinery required for conversion of the basic raw material into various converted forms to suit the end use requirements are also available indigenously (Bulchandani, 1974).

Polystyrene was the first thermoplastic material to be manufactured in the country in 1957 followed by LDPE in early 60's and high density polythene in mid 60's. Polyvinyl chloride particularly as rigid films and bottles made its appearance in early 70's. India also produces thermoset plastics such as urea and phenol formaldehyde. These two latter materials were commonly used for caps and closures, but in the recent past these have been slowly replaced by the thermoplastic materials like polyethylene and polystyrene. The plastic material enjoy a good share of the total consumption of the packaging materials in the country due to their versatile properties. Among these materials in India as is true the world over, polythene enjoys the lions share. Low density polythene, HDPE. PVC, Polystyrene (PS), PVC resin etc. have brought tremendous change in the pattern of industrial life of our country. The world per capita consumption of plastics is around 3.3 kg. in a year while the Indian consumption is 0.27 kg. (Subramanyan, 1988). The other areas where in this industry has made break through are the manufacture of plastic sacks, various laminates, shrinkable films and thermoformed articles. The development of these has led to more sophisticated method of packaging viz. the shrink, skin and blister packaging. Another important flexible material manufactured in the country is cellulosic films in different forms. Saran coated films are now produced in India with imported PVDC. Kraft paper as well as paper made by mechanical pulping and a variety of speciality papers are also produced in the country. The corrugated board industry entered the field of packaging in the early 50's and different varieties of board are now produced in the country. The other allied materials viz. solid fibre board, moulded corrugated fibre board also are manufactured in the country. The solid board industry entered the field in late 60's. The moulded corrugated board made its appearance in the early 70's. The sack kraft required for the manufacture of multiwall paper sack is also now indigenously manufactured though not in sufficient quantities to meet the demand of this country. One of the latest developments in flexible packaging technology is the advent of co-extrusion technology. With this technique it is possible to produce multilayer films of high quality and desired properties. Various combinations of multilayer films are produced in this country like metalised nylon/low density polyethylene, high density polythene/LDPE/HDPE, LDPE/LDPE, PEST/LDPE/HDPE, Nylon/Ionomer, HDPE/LDPE and LDPE/Nylon/LDPE etc.(Srivatsava *et al.*, 1989).

Due to inherent advantages of the co-extrusion technology it is possible to extrude a film of low thickness which is not possible by lamination. This imparts substantial economic advantages in using co-extruded film and offers scope for economizing on the packaging for various types of foods.

The other conventional materials used for packaging purpose are jute, wood and plywood. These continue to enjoy their share in the field of packaging. Much research work is done in the filed of jute as a packaging medium. Jute in laminated form in combination with polythene and paper has found wide application in the packaging of variety of industrial and consumer products. The necessary laminating techniques and the machinery required therefore are also indigenously made available. In the recent past there is a growing tendency among the industries to switch over from wooden containers to other types of containers like the corrugated and solid fibre board boxes (Narayanan and Viswanathan, 1974). While the primary packaging materials have shown substantial growth year after year both in their production and areas of usage, the ancillary materials like the adhesives, cushioning materials, strappings, hoop iron, wire nails, printing inks, lacquers, lining compounds and solders also have their share both in the conversion of the basic materials as well as in the end use of packages. It may be added that the printing industry in the country has recorded a high level of technological growth and is in a position today to produce inks suited to most of the requirements demanded by the printing industry.

2.3 DEVELOPMENTS IN FOOD PACKAGING

Rising living standards and greater emphasis on production of food and other consumer items for export placed an immediate demand for more widespread use of packaging. Packaging extends the shelf life of foodstuffs and other consumable products and protect them against adulteration and provides an aesthetic appeal to these products. Packaging materials should be selected judicioulsy so as to withstand the storage conditions and transportation. In order to meet the International requirements of packaging the use of modern packaging is essential. Industrialisation and urabinsation have led to newer developments in packaging of foods like spices, convenience foods, ready to serve beverages, oils and fats, thermally processed foods and asceptic packaging of food products. Apart from its chief function of protection of the contents during storage,transportation and distribution, packaging plays vital role in marketing of these foods. Improvement of the existing packaging can substantially brings higher returns. Flexible packaging has been gaining a lot of importance as compared to blow moulded containers of similar size, primarily because of weight reduction and improved barrier properties which result from the use of different polymers in a multilayer laminate. Plastic packaging is becoming more popular in recent years due to logistic advantages like cheapness, functionality, light weight and saving of freight charges. The problems involved in the packaging of some of the food products are discussed in this review.

2.4 PACKAGING OF PERISHABLE FOODS

Perishable foods include both fresh and processed foods. They are characterised by a short shelf life normally terminated by microbial spoilage and by their storage under refrigeration just above the freezing point. The choice of packaging materials for such systems will depend on the nature of their storage properties. However keeping the moisture at a desired level and controlling the availability of oxygen to retard microbial and biochemical reactions are common denominators.

2.4.1 FRESH MEAT

In fresh meat most of the biological activities continue post mortem. Under normal atmospheric conditions the water activity of fresh meat is around 0.99. This is an ideal condition for the development of chemical and microbial deteriorative process. This deterioration is revealed by an increase of microflora, discoloration, rancidity (particularly for fatty meat) and dehydration. Good sanitation, controlled atmosphere and low storage temperature are key elements in increasing the shelf life of fresh meat. Meat colour provides the most obvious index to fresh meat quality to consumers and is determined by the relative abundance of three forms of its heme pigment. These include the purple red myoglobin (mb), the bright red oxygenated myoglobin (O_2mb) and the brown oxidised metmyoglobin (metmb). The dynamics of interconversion and relative proportions of myoglobin, oxymyoglobin and metmyoglobin control meat colour. The reduced myoglobin in the presence of oxygen is converted to bright red oxymyoglobin (O_2mb), the familiar "bloom" of fresh meats packaged for retail stores. This reaction is favoured by high oxygen pressures (>40 torr) (Rizvi, 1981). At reduced oxygen pressure of 1 to 1.4 torr oxidation of reduced heme ion (Fe^{2+}) to its Ferric state occurs giving rise to metmyoglobin (metmb) and brown colour. At about 50%

conversion of O_2mb to metmb, the meat becomes unacceptable to most consumers (Oord and Wesdrop, 1971). In fresh meat tissue, enzymatic oxidation of endogenous substrates particularly glucose produces reducing coenzymes which continually reduce memyoglobin back to myoglobin form and the cycle continues if the oxygen is present. As soon as the oxidisable substrates are used up, the reducing power of the muscle is lost and the iron of the heme pigment is oxidised to the brown metmyoglobin (metmb). In freshly cut piece of meat, a sufficient amount of metmyoglobin is formed within 2 to 4 days to give it a brown appearance. This oxidation is accelerated by increasing temperature and bacterial growth. Permeability of films to oxygen is important in fresh meat packaging. As the permeability of films to oxygen decreases, a partial pressure is reached where oxygen utilization by the tissues balances oxygen penetration at a level which favours the oxidation reaction (Fox, 1966). A packaging film must have an oxygen permeability of at least 5 litre/m^2/24 hr/atmosphere at 24°C to prevent such browning (Landrock, 1955). Commercially, however a permeability value of 8 to 12 litre/m^2/24 hr/atmosphere is more common. Solubilization of oxygen in the meat surface fluid and subsequent diffusion is required for oxygen to react with meat pigments. Inverse solubility of oxygen in water makes maintenance of lower temperature highly desirable. Packaging film should also be impermeable to water vapours or else meat will darken in colour due to pigment concentration in the dehydrated surface tissues when stored in a low humidity environment. Control of moisture is one of the most important factors in fresh meat packaging. Loss of moisture or dehydration has a significant darkening effect on the surface colour of fresh meat resulting from the concentration of pigment. Surface dehydration also results in loss of weight and possible shriveling thereby affecting the texture and juiciness of meat. Freezer burn has to be checked if meat is to be subjected to prolonged frozen storage. Many researchers in recent years have reported that light is also a contributing factor in the discoloraction of fresh meat (Rizvi, 1981). Meat stored at -1°C under direct illumination deteriorated at a faster rate than did meat stored in the dark and the colour change has attributed to enhanced bacterial growth (Marriott *et al.*, 1967). Similar observations were made by other workers (Leward *et al.*, 1971). Beef samples exposed to illumination at varying wavelengths showed significant increases in metmyoglobin production in the ultraviolet (250 nm) and low wavelength visible (405 to 577 nm) lights over similar samples exposed to light of 630 to 685 nm wavelength (Sester *et al.*, 1973). Both incandescent and fluorescent lights of 5375 lx intensities have been reported to enhance the destruction of surface oxymyoglobin of beef with the soft white fluorescent being most detrimental and incandescent the least (Satterlee and Hansmeyer, 1974). A maximum of 550 lx lighting system usually required for display of fresh meat is small enough not to have any commercially significant effect on meat colour. Therefore packaging of fresh meat is primarily intended to prevent moisture loss and offer this commodity to the consumers in the most desirable bright red colour. It should further prevent bacterial contamination and pick up of foreign flavour and odour by meat. Proper storage conditions and selection of a good packaging film can help accomplish these objectives. Meat should be stored at a temperature of 4°C to prevent its spoilage from bacterial or mould and consequent development of off odour. Low temperature storage is also helpful in markedly checking the rate of lipid oxidation. A relative humidity of 85-90% should be maintained to prevent surface desiccation. The most common packages for retail fresh meat cuts in western countries are polystyrene foam or clear plastic trays overwrapped with a transparent film. These trays offer an aesthetically appealing background. The use of blotters underneath eliminates the chances of excessive meat juice accumulation. Meat thus wrapped may be kept for approximately 10 days at a temperature of 0°C before it becomes microbiologically unacceptable. However it can retain the desirable bright red colour only for about 5 days (Sharma and Padda, 1986). Fresh red meat in retail sale units in U.K. is normally packed in specially formulated plasticised PVC which has high permeability to oxygen (over 5000 $ml/m^2/day$) which is necessary to retain the bright red colour due to oxymyoglobin which customers expect (Palling, 1980). In USA until 1966, quarters, primal and subprimal cuts were shipped unwrapped from packing plants to retail stores with an average of 4 days of transportation time and were subjected to 0.5% shrinkage per day (Weatherly *et al.*, 1968). Additionally millions of pounds of beef were condemned annually as a result of being putrid, sour or contaminated (Rhea *et al.*, 1972). For better product protection, longer product life, reduced waste, improved sanitation and economy in labour and transportation, distribution of fresh beef has changed from shipment of carcasses to that of packaged primal and subprimal cuts. This trend accounted for approximately 57% of total US retail fresh beef receipts and is predicted that an estimated 71% of supermarket fresh beef receipts will be primal subprimal cuts (Anon, 1978b). Of the several packaging methods for packaging of fresh meat, vacuum packaging has become the pacesetter. In seventies in USA nearly 60% of all primals and subprimals received at retail were vacuum packaged and in eighties it accounted nearly 76% of the prefabricated volume. In vacuum packaging of fresh meat, air is removed from the system contained in an oxygen impermeable film. This process creates an anaerobic/ microaerophillic ecosystem within the package with the heme pigments in reduced Mb-form. This oxygen remaining in vacuum package is converted to CO_2 by respiration of meat tissue and retards bacterial activity (Ingram, 1962; Johnson, 1974). Anaerobic conditions and inhibitory effects of Co_2 suppress the growth of common meat spoilage bacteria of Pseudomonas and Achromabacter species and allow the growth of facultative anaerobes such as Lactobacilli and Leuconostoc species (Baltzer, 1969; Pierson *et al.*, 1970).

Packaging films used for packaging of primals and sub-primals in USA are co-extruded EVA/PVDC/irradiated EVA, shrink bags, polyvinylydene chloride (saran), Nylon/LDPE and Nylon/Surylyn laminates.

In India the quantity of packaged meat and meat products is very low. Of this the processed meat which is canned is much smaller but with the development of poultry and piggery in the country, fresh meat chilled or frozen is sold in the big cities some times in prepackaged unit quantities. Among meat products, the production of sausages is going up and these are packed in natural casings. The method of preparation of these casings in dry and wet form is very well developed in our country but synthetic casings are not indigenously available (Veerraju, 1974).

Poultry foods are very susceptible to bacterial spoilage, evaporation loss, off odour, discoloration and biochemical deteriorations. The sterile poultry tissue gets contaminated during the evisceration process. Low temperature refrigeration retards microbial and biochemical changes. Prechilling of poultry, shrink and strech packaging to reduce headspace, flash chilling to freeze the surface and storage at -1 to -2°C has become a practice of poultry packaging (Brody, 1970). Oxidation of unsaturated poultry fat is not very critical because very little fat runs through the muscle tissue and oxidation follows other defects. Dehydration and evaporative losses result in weight loss and in textural defects and control is exercised through the use of packaging film with moisture barrier properties. In USA the commercially attractive method of packaging poultry and frozen turkeys consists of vacuum packaging in shrink films like Biaxially oriented irradiated LDPE (Rizvi, 1981). In UK the frozen poultry is sealed by clips or heat seals under partial vacuum into laminated bags of EVA/PE or similar construction which may be heat shrunk and then quickly frozen (Goddard, 1980).

In India the packaging materials used for frozen poultry are LDPE film or polyamide coated LDPE. Bulk packaging consists of wooden boxes or corrugated fibre board boxes.

2.5 PACKAGING OF FISHERY PRODUCTS

2.5.1 PACKAGING OF FRESH FISH

Fresh fishes are one of the most perishable of all foods. The rate of spoilage doubles every 5.5°C rise in temperature (OECD, 1970). They must be chilled or frozen immediately after harvest and kept refrigerated until eaten. Its quality deteriorates rapidly if it is not handled and stored properly. Much of the fish landed are subjected to fairly rough handling from the time of catching till it reaches consumer (OECD, 1970). Dehydration, onset of autolysis and microbial growth cause fresh fish to spoil rapidly. The initial step in deterioration of fish consists of hydrolytic reactions which are catalysed by enzymes from fish tissue themselves, thereby the penetration of microorganisms is facilitated and nutrients are formed which would promote bacterial growth. Microbial growth causes primarily break down of nitrogen containing materials and terminal oxidation of endogenously produced nucleotide products. They produce foul odour - mainly ammonia, amines, various keto acids and carbonyl compounds (Liston, 1965). Fish is moved through the various stages of storage, auction, processing and distribution in a variety of containers, many of which lack good hygienic standards. Any departure from immediate and continued refrigeration lead to flavour and texture losses. If the fish are of poor quality to start with, the quality loss is even more pronounced.

The package cannot improve the quality of the contents. The fish must be of high quality prior to packaging. A suitable fresh fish package must (1) reduce fat oxidation (2) reduce dehydration (3) provide for less bacterial and chemical spoilage (4) eliminate drip and prevent odour permeation (Sacharow and Griffin, 1980). The Orient Airlines Association (OAA) which represents eleven countries in Asia and Pacific has spelled out packaging standards for 'wet' shipments. This is applicable to (A) Marine products which incorporate salt water (brine)-ice-fresh water (B) Shell fish and (C) Other products which incorporate water or fluids. The airlines basic requirement is that all seafood carrying fresh, salted or frozen and salted casings must be sealed into absolutely water tight packaging. Further more these packages must withstand not only the relatively gentle treatment they would incur during air transport, but the rough handling expected before they arrive at the airport. A second requirement is that packaging be strong enough to allow stacking on pallets for storage or for loading (OAA, 1979). OAA requires too, that fibre board containers be impregnated with wax and recommends the use of containers with folded corners as a further defence against leakage or contamination that could lead to spoilage of fish from outside. Containers should be of telescopic design with a maximum gross weight per carton of 20 kg. In addition to the main container the product must be completely enclosed in a second sealed polythene bag thick (over 0.1 mm) and tough enough to resist puncture by bones or other parts of the fish. In some cases this may require the use of protective padding. Styro foam containers may be used only if their contents are packed in inner containers of polyethylene foil of the required thickness and must themselves be contained in strong cardboard cartons for additional protection. Maximum gross weight per styrofoam box is 20 kg. If kegs are used they must not be constructed of plywood. Wooden kegs must be iron hooped with grooves for the bottom and the lid and all joints must be sealed with caulking, oakum or similar material. Kegs are not be filled beyond 9/10th of their capacity and their gross weight must not exceed 30 kg (Anon, 1982).

Solid fibre board cases are being used by Devonshire fishermen to pack live shellfish for export to France and Belgium (Anon, 1977a). Shellfishes are packed in solid cases, and each case holds upto 56 lbs of lobsters and crabs packed in layers of straw. The boxes are delivered flat with sidestitching only to the fishermen's co-operative.

The case bottoms are then stitched, the live cargo packed and the tops tape sealed. Depending on their destination the sealed packs are subsequently shipped by air, sea or road (OECD, 1970). In USA or UK formerly iced fresh fish were shipped in wooden boxes by rail. In order to ship fresh fish to markets with greater speed air transport is used. The corrugated master cartons with wax coating on both sides is an emerging trend in fresh seafood distribution. Wax coated cartons with polystyrene foam is used in the fresh fish transportation (Sacharow & Griffin, 1980). In UK fish is unloaded at ports, some times into wooden boxes holding about 50-60 kg of fish or more usually into aluminium tubs which are normally maintained and kept clean by the authorities. For distribution from the ports, the returnable wooden box once universally employed has declined because of hygienic problems, difficulties of securing return and the cost of carriage (Paine & Paine,1983). Non returnable light weight boxes are being increasingly used. Larger companies with their own transport facilities often use returnable aluminium boxes. Injection moulded high density polythene and expanded polystyrene containers have also been used. Before packing, the fish is auctioned on the dock to the fish merchants who send the bulk of it away packed in ice to inland markets, retailers and large scale users. Transport is by rail and road. Various types of rail van are used to carry fish on trains which run rapidly from the ports to the principal inland towns, and most vans are insulated with air freight doors. Fresh fish also travels from the ports direct to the consumer by road. The best vehicles have 8-12 mm insulation but for frozen fish 10-15 mm insulation is required and the vehicles often carry a built in refrigeration unit. Solid carbon dioxide is employed in some places for precooling and during transit.

Prepackaging of fresh fish for retail sale was slow to develop. Sales of fresh fish in UK have declined over last three decades probably due to poor presentation. Other protein foods are commonly sold prepacked. Although prepackaging is unlikely to extend the shelf life of fish, it keeps it clean and free from flies, reduces odour and makes self service possible. The containers used for icing fish either at sea or at the market or distribution outlet are merely all returnable, that is to say they are used more than once to convey fish from one place to another. They are constructed in either wood, aluminium alloy or plastic, in a variety of shapes and dimensions. Other containers which are used more than once are to be found in individual processing factories. No container has as yet been produced which will satisfy the requirements of an industry where many individuals hold different views on what is more suitable for their particular needs or area of population. Indeed this situation can apply in relatively small ports, let alone particular countries and as yet it has been found extremely difficult to introduce a container which is standard in either dimensions, capacity or material. In the Scandinavian countries where 80 to 90% of the total catch is exported, regulations are in force regarding dimensions and materials of containers and wooden ones are normally classified as non-returnable. But in many of the importing countries there exists a trade in these ready made boxes (OECD, 1970). For example many are used two or three times for boxing fish at sea and as transport and distribution boxes before they are finally destroyed and as long as there are no regulations prohibiting this practice it is likely to continue.

The function of fresh fish containers in general and fish boxes in particular is to make possible the efficient and economical handling of fresh fish from catch to the retail market. These containers should protect fish from such undesirable influences as crushing, spoilage, environmental pollution and pilferage. They should facilitate storage, effective chilling, fast transfer, internal and long distance transport, easy determination of quantities and display in wholesale and retail markets. These requirements should be met at the lowest possible cost (Suwanrangsi, 1989b).

In India the physical flow of fish for domestic trade indicates that about 50% of the catches is consumed within a distance of 40 kms, another 45% within 200 kms and balance of 5% beyond 200 kms from the coastal line (Gupta, 1984). In general in this maritime state about 87.5% of the catch is consumed within the state and interstate flow is only 12.5%. For short distances, by and large road transport is resorted to. Though transportation by road is costlier, this happens to be the mode of transport for fresh fish upto 200 kms or even beyond as it is quicker than rail transport. Rail transport is adopted for smaller consignments and for long interstate distribution. The flow of fish by rail and road within a state is 20% and 80% and interstate is 45% and 55% respectively. Consumption of fish in the rural sector is 30-45% and urban and metropolitan areas account for the balance. Nearly one lakh metric tonnes of marine fish reach Bombay city in a year from within and neighbouring states while in Calcutta total inflow of fish is 1.34 lakhs metric tonnes of which 90% is inland fish variety. About 85,000 tonnes of fish are transported by rail wagons. Open lorries covered with tarpaulin, insulated/refrigerated trucks for longer distances and hand carts, bicycles, tempo vans etc. are used for short distance transport. While the fish sent by rail wagons are packaged, in road transport fish is despatched in packed or unpacked conditions. There is no fixed ratio of ice to fish used and varies according to its availability, cost and transit time. For shorter time intervals of 4 hours or less no icing is done. Domestic fish trade is mostly by private agencies and fish changes two to eight hands through commission agents, auctioners, wholesalers, retailers before it reaches the ultimate consumers. The average transit time of fish is 4-20 hrs and it is upto 65-70 hrs in long distance transport by train. The average fish sales by vendors and retailers is of the order of 30 to 60 kgs per day.

Methods of preserving the quality of fish from the time they are caught until they pass through the distribution net work and reach the consumer have been studied by technologists the world over. Tremendous advances have been made in developed countries as regards packaging and transportation of fish and fishery products. But in India the packaging of fish and fish products is still the foremost problem and the weakest link in fish processing industry. It is estimated that two thirds of India's fish catches are used afresh after having chilled with crushed ice (Govindan, 1988). Iced fish is often transported over long distances before it reaches the consumers. Packaging of fresh iced fish is probably the most neglected area under existing conditions in the country, even though it calls for maximum attention due to the highly perishable nature of the commodity. Baskets made of split bamboo and similar plant materials are invariably used for packing fresh iced fish. These baskets are popular in southern states. They are considered cheapest and cleanest non-returnable single service type containers by the fishing community. They are large shallow or deep types, varying in size, shape, capacity (40-110 kgs) and hence in their cost and strength properties. After packing they are wrapped in a gunny outside and stitched. However they have certain drawbacks. They do not possess adequate mechanical strength and get deformed under stacking loads, transferring the compressive loads to the fish which get crushed. Sharp edges of bamboo are also known to cause bruises on the skin of fish. The cost of basket varies from Rs.7 to 15 and average packaging costs including palmariah leaves/gunny/labour would be Rs.0.35-0.45/kg of fish. Empty baskets weigh 2-4 kgs depending on the size.

Wooden boxes and used plywood boxes of 20 - 120 kg capacity are used in western parts of the country for transport of fish by rail and road commission agents and wholesalers. The boxes are auctioned off by their agents at the receiving points and about 25-30% of the packaging costs are recovered. Generally these boxes are further reused for transport of fish at the receiving point to other places. The disadvantages of these packages are that they are not easily cleaned or dried, thus harbouring bacteria in the crevices, posing problem for reuse. The boxes specially lose their insulation value on becoming wet and tend to become heavy. Collection and return of empty boxes cause additional costs. The cost of container per use is Rs.0.50 to 1 kg of fish and empties weigh 5-7 kgs. Recently Marine Products Export Development Authority introduced insulated galvonised iron boxes for multipurpose use on boats and processing centres of capacity 40 kg and costing Rs.700 at current rates. They are supplied at 50% subsidy to the trade. They have not become popular with the trade in view of high tare weight (27 kgs), corrosion of metal parts in sea atmosphere etc. (Prabhu, 1993). The greatest disadvantage of the traditional transport packages is that with normal 1:1 ice fish ratio, they are capable of keeping fish in fair to good condition only upto a maximum period of

20 hours and are suitable for a journey of 500-700 kms, unless steps are taken to replenish ice enroute. They have poor insulation property thus affecting the rate of melting of ice considerably.

The first development work on the improvement of efficiency of bamboo baskets was undertaken at CIFT in early 60's by providing additional linings of polythene and gunny or water resistant kraft paper which reduced melting of ice considerably and thereby enhancing the shelf life of iced fish by 50-80% (Rao and Perigreen, 1964). The second hand tea chests commonly used in Veraval region of Gujarat, were provided with 2.5 cm thick foamed polystyrene (in polythene sleeving) slabs inside, to improve their insulation value. These containers were found to be extremely beneficial for transport of fish over long distances upto 60 hours duration. In a comprehensive study undertaken by ICAR under All India Co-ordinated Research Project on transportation of fresh fish, the various technological problems associated with transport of iced and frozen fish within the country, quality assessment of fish transported by various modes of containers in different regions of the country, thermal efficiencies of the existing and modified containers, amenability of various types of fish in round/filleted form for long distance transportation in iced or frozen state, economics of packaging and transportation systems etc. and far reaching recommendations on the standard to be adopted for handling fish and packing procedures for short and long distance transportation of fish were made. It recommended for short distance transportation of iced fish involving the journey less than 16 hours duration, the use of non-returnable, cheap containers and for distances involving duration upto 60 hours and beyond 16 hours the use of insulated plywood boxes with 25 mm thick foamed polystyrene. For long distance transport, packing the fish in the frozen state (at -18°C) in insulated plywood boxes was suggested so that at the receiving end they are received in thawed condition (below 5°C) (Nair, 1978). Govindan and Gupta (1978) developed a dismantleable insulated galvonised iron container for the transportation of different varieties of fish packed in different types namely fresh iced, chilled iced and frozen which were used in the transportation experiments conducted from Kakinada to Howrah, Kakinada to New Delhi and Paradweep to Howrah. In all the experiments the container performed exceedingly well and remained in very trim condition (Govindan and Gupta, 1978). The dismantleable container in double layer 22 gauge galvonised iron sheet sandwiching 25 mm thick expanded polystyrene slab as insulation material had internal dimensions of 457mm x 456mm x 457mm. This consisted of 6 pieces assembled together with bolts and nuts (Govindan and Gupta, 1978).

Rao *et al.* (1979) studied the comparative amenability of seer (*Scomboromorus species*) in round and fillet forms for transportation in 2.54 cm thick expanded polystyrene insulated plywood boxes from Kakinada to Calcutta and their consumer appeal in the Calcutta market. While both the forms withstood the rigors of transportation squarely, the fillets fetched only half the price of round fish in the auction conducted at Calcutta market. Rao *et al* (1980) studied the transportation of *Chanos chanos* with a view to device suitable methods of transportation of fresh and frozen fish to distant places by rail. Freshly harvested and frozen fish were transported to Calcutta, Delhi and Madras in different types of containers with different insulation materials. Plywood boxes with expanded polystyrene slab and multilayer gunny insulations, aluminium box with insulation and dismantable galvonised iron box with insulation were tried for transportation of the iced fish from Kakinada to Calcutta. The journey lasted 40 hours with one transshipment at Samalkot junction. The fish transported in all the above containers reached the destination in fair to good condition. Frozen *Chanos chanos* in the form of blocks were also transported successfully from Kakinada to Calcutta and Delhi,the later involving a journey of 50 hours and one transshipment at Vijayawada junction. Conventional bamboo baskets with palmariah leaf linings inside and gunny wrapping outside were found suitable for transporting iced fish to Madras by rail. Govindan *et al* (1977) investigated the long distance transportation of frozen fishes like oil sardine, mackerel, catfish, threadfin bream and ribbon fish frozen in glazed and unglazed blocks and packed in expanded polystyrene insulated plywood boxes with and without additional ice and dispatched in uninsulated parcel vans of trains from Cochin to Calcutta. The experiment revealed that fish in frozen form could be transported by rail in ordinary parcel vans from Cochin to Calcutta in 2.5 cm thick expanded polystyrene insulated plywood cases without reicing enroute. Even in the absence of glaze and additional ice the frozen fish withstood the transportation.

Rao (1975) reviewed the present status of packaging in fishing industry and outline the scope for further improvements in some areas for internal and external trade. Venkataraman *et al.* (1975) suggested the use of 25 and 15mm thermocole lined with polythene for insulation of plywood boxes for transportation of fresh fish during summer and winter respectively. By using these types of insulated boxes the initial fish to ice ratio of 1:1 could be brought down to 1:0.75 and still further 1:0.5 at the height of winter in January and February. Second hand tea chests were found to be robust and it could withstand a minimum of 5 trips to and fro. Moulded polystyrene boxes are found not suitable for long distance transport. In the non-insulated boxes the loss due to spoilage ranged from 10 to 25% and this could be completely eliminated by the use of insulated boxes. Perigreen and Nair (1976) suggested methods of handling and transportation of frozen prawns, the most important fishery product exported from the country. One of the drawbacks of bamboo basket is that they do not possess enough rigidity and go out of shape during transit thereby damaging the fish. Whatever insulation property that the jute liner possesses is lost once it becomes wet. Considerable time is required to stitch the jute liner over the basket, and the plywood boxes too on becoming wet, loose their strength. Second hand tea chests normally used by the fishing trade are not freely available as the tea industry is switching on to other packaging systems for bulk handling of tea. Now plywood boxes work out to be too costly for economic transportation of iced fish. To overcome the above problems CIFT has developed an insulated corrugated plastic container which is the lightest of all packages available in the country for iced fish transport. A package for holding 30 kgs of iced fish weighs less than 2 kgs and keep chilled fish fresh for 60 hours. It is reusable for 5 trips and being of collapsible design and light weight, return of empties is very much cheaper (Rao and Antony, 1989).

Chattopadhyay *et al* (1987) studied the transportation of wet fish using liquid nitrogen as a secondary refrigerant. Using a laboratory model having 2 mm thick aluminium sheet with 4 inch polyurathane foam slab insulation a temperature of 4°C was maintained from an initial temperature of 33°C, by allowing liquid nitrogen (LN) to evaporate from an insulated container. As the fish temperature cannot be brought down so quickly with cold nitrogen gas due to the poor heat transfer between stagnant nitrogen gas and fish, a combination of ice and liquid nitrogen was found to bring down the temperature to 4°C within 1 hour which would have been dropped to 9°C only with ice alone. It is concluded that ice melting rate can be reduced to about 50% with polyurathane foam insulation. Chattopadhyay and Bose (1978b) studied the cost of transportation in India of wet fish in iced and frozen condition in different types of returnable and non-returnable containers. Transportation of wet fish under frozen condition was found to be less economical compared to iced fish over short distances (below 1000 km) irrespective of the type of container used for transport. As no economic benefit can be derived from large containers it is recommended that the capacity of the container should be about 50 to 70 kg. Chattopadhyay and Bose (1978c) studied the bacteriological condition of vehicles and containers used in fish transport in India. Detection of pathogenic organisms indicated the insanitory conditions under which fish is transported. This can be avoided using disposable fish containers like fibre board boxes. Bacteriological condition of fish both in iced (1:1) and in frozen state transported in such containers were compared with that of fish transported in reusable containers. Chattopadhyay and Bose (1978a) also experimented the use of fibre board containers for the transportation of marine and fresh water fish in iced (1:1 by weight fish) and frozen state. The fish quality was evaluated after transportation and compared with that of fish transported in conventional baskets. They have found that the fishes could be transported in good condition for 60 hours covering a distance of 1700 kms in fibre board (three ply CFB moisture proof) containers and the woodwool used in between two walls of container was found to provide effective insulation.

In unfrozen seafood, bacterial activity is responsible for the offensive odour and flavour. Lipid oxidation in fish with a high fat content results in rancidity. Fish such as herring, clupea species, trout and salmon species can become rancid before microbial spoilage is evident (Hansen, 1963). Refrigeration has for many years been successfully used to retard spoilage of fresh fish. However at 0°C the shelf life of lean fish such as Atlantic cod, *Gadus morhua* is about 14 days and at 5°C the shelf life is only about 6 days (Ronsivalli and Charm, 1975). After a short storage period the product must be discarded.

From an economic view point the ability to preserve the quality and nutritional value of non-frozen fish for extended periods of time could be greatly rewarding in terms of reduced waste, increased value of the product and increased sales (Gorga *et al*, 1979). As a supplement to refrigeration, vacuum packaging and modified atmosphere packaging have been proposed as methods of extending the fresh storage life of fishery products. Vacuum packaging represents a static form of hypobaric storage which is widely applied in the food industry due to its effectiveness in reducing oxidative reactions in the product at relatively low cost. There are several reasons why vacuum packed fish may not become toxic to the consumer. *Clostridium botulinum* requires a reduced substrate on which to grow. Eliminating oxygen from the environment can create this condition. But Johansen (1965) noted that there are many other naturally available oxidising agents which can counteract the effect of low oxygen levels. Secondly competing microorganisms like lactobacilli may have an inhibitory effect on clostridia. Johansen (1965) mentions that the lactobacilli form peroxides and acids which inhibit the growth and toxin formation of *Clostridium botulinum.* Also the fish flesh may contain antimicrobial agents. Zak (1970) has found that Haddock, *Melanogrammus aeglefinus* contains an antimicrobial peptide which inhibits the growth of *Clostridium botulinum.* It may also be present in other lean fishes. Johansen (1965) states that it is the condition of the product itself and not vacuum packaging which determines whether or not botulinum toxin will form. Bramsnaes and Sorenson (1960) reported much improvement in the keeping quality of fatty fish when it is vaccum packaged in oxygen impermeable film. Huss (1972) compared the quality of plaice, *Pleuronectes platessa* and haddock held in ice without packaging, with fish packed in polythene without vacuum, in vacuum sealed polythene and in vacuum sealed polyamide (Nylon 11) pouches held in ice. During the 20 days storage period the plaice packed in evacuated bags had the lowest oxygen content, the lowest bacterial count and the highest quality score. Compared to the unwrapped plaice a 6 day extension of shelf life was obtained. Packaging without vacuum was judged as not advantageous for either plaice or haddock. Licciadello *et al* (1967) identified the spoilage bacteria of irradiated (150 krad) and non-irradiated, vacuum packed (74 mm Hg) haddock fillets after storage at -2°C in metal containers. With the non-irradiated fillets, the spoilage bacteria after 13 days storage was predominantly proteolytic pseudomonas. At that time the fillets had only a slight fishy odour, but 6 days later the odour became stronger, indicating the breakdown of TMAO to Trimethylamine (TMA). With the irradiated fillets the spoilage bacteria were chiefly lactobacilli. The odour of fillets at 48 days storage was slightly fishy. Air packed control fillets became putrid within 13 days. Spoilage of vacuum packed sole, *Eapsetta Jordani* fillets by pseudomonas has also been reported by Pelroy and Eklund (1966). Hansen (1972) found that Atlantic herring, *Clupea harengus* and trout, *Salmo irideus* stored directly in ice became rancid in 6 days. Fish stored in evacuated polyamide bags did not become rancid during 20 days of storage, but they did develop an objectionable odour and flavour due to bacterial activity. Jorgensen and Hansen (1966) reported that by irradiating (50, 100 and 200 krad) herring and trout before vacuum packaging, the storage life could be extended to 4 weeks. Use of bacteriostat Ethylenediaminetetra acetic acid (EDTA) with vacuum packed petrole sole and ocean perch, and *Sebastes alutus* fillets was investigated by Pelroy and Seman (1969). Non-vacuum packaged ocean perch spoiled in 5 days and vacuum packaged fillets spoiled in 6 days due to TMA production by pseudomonas. Application of disodium EDTA resulted in a 9 day extension of shelf life for the vacuum packaged fillets. Vacuum packaged petrole sole fillets spoiled after 7 days, while treatment with EDTA extended the shelf life at least 2 days more. At that time the predominant flora consisted of coliforms and lactic acid bacteria. Air packaged petrole sole fillets treated with EDTA had a shelf life of 6 days. In India no work has been done on the effect of vacuum packaging on fishery products.

2.5.2 PACKAGING OF FROZEN FISHERY PRODUCTS

Packaging of frozen fish is a well established practice and is used both as an aid to preservation and as a means to enhance preservation. The wide range of materials and methods available in UK and or continuous development of new materials and method make packaging a very difficult and complex subject (OECD, 1970). Frozen storage of foods is the most satisfactory method of long term preservation of perishable foods. A temperature of -18°C is commercially practiced for storage of frozen foods, although fish, pork, butter, ice cream and other fatty foods are kept between -20°C to -30°C (Rizvi, 1981). In spite of low temperature food materials are never completely frozen during normal commercial storage and deteriorative physical and chemical changes continue at a rate governed by product characteristics and storage temperature. Proper packaging for frozen fish is essential.

The advantages of packaging frozen fish are (OECD, 1970).

1) It prevents drying of the product during low temperature storage.
2) It prevents fatty fish from becoming rancid.
3) It protects the contents against physical damage and prevents contamination during handling.
4) It makes the product convenient to handle.
5) It makes the product attractive and arouses consumer interest.

6) It makes colour change or loss of gloss resulting from the freezing and cold storage process but not necessarily indicative of poor quality.

7) If required it provides for cooking in the wrapper either for convenience or to reduce cooking smells.

8) It provides with interleaving and with individual wrapping, a product which is easily separated into individual portions and permits direct cooking and without thawing.

9) It provides for quick thawing in water.

Under characteristic frozen storage conditions, foods tend to loose moisture rapidly and undergo desiccation. Fluctuations in storage temperatures during the distribution cycle further aggravate the situation. The initial quality advantages of quick frozen foods also disappear due to recrystallisation. Sublimation of ice during frozen storage of foods leads to rapid moisture loss from the surface, desiccation and objectionable appearance. This phenomenon is commonly described by a defect known as freezer burn. Other deleterious effects of freezer burn are loss of texture, palatability due to irreversible dehydration of proteins, increased oxidation rates in fatty foods, discolouration, destruction of vitamins and other nutrients and mechanical damages. Recommendations to minimize such defects include storage at higher humidity, surface coating and packaging in materials impermeable to water vapour (Fennema, 1975). Many of the polymeric films and plastic coated paper board commercially used for frozen foods have excellent moisture barrier properties and still package descication occurs. A build up of frost on the inside surface of the product can be observed in frozen fish packages. During the past few years various methods, including edible and inedible coatings and the use of films of extremely low moisture permeability have been tried to prevent in package desiccation. A general consensus points to the need for intimate contact between the packaging material and the food product. This has been achieved through the use of vacuum packaging, the application of which is spreading rapidly. Frozen fish are subject to two principal oxidative deteriorations, rancidity and rusting. The latter is light yellow to brown discolouration which occurs on the exposed surface. The phenomenon of rusting involves two factors (1) auto-oxidation of fish oils and (2) volatile basic nitrogenous compounds (Nonaka, 1957). Both oxidative defects can be delayed by preventing access of oxygen to the product surface. This may be temporarily achieved by covering the fish with a glaze of ice or by vacuum packaging in oxygen barrier films (Nonaka, 1957). The fundamental requirement for packaging material is its ability to withstand -18°C and lower temperatures without undergoing structural breakdown. Other requirements include impermeability to water vapour and oxygen, resistance to flavour transport, grease and mechanical damage and also heat resistance for packages that are intended for heating. Influence of packaging on the shelf life of frozen foods has been studied by Achvenainen *et al.* (1983). The significance of different packaging in improving the preservation of the quality of frozen foods and possibilities to increase storage temperatures in retail stores by improved packaging has been studied by Achvenainen *et al* (1983). The packaging tested included 23 different packagings or combinations of plastics, laminate, cardboard, aluminium foil, laminated and metallised packagings. In a part of the packaging the air was replaced by nitrogen. The foods tested were carrot cubes, fish fillets of Baltic herring and ice cream. Products stored in the top layer of an open display cabinet retained their quality best in aluminium foil laminate and metallised packaging and the shelf life was 2-3 times more than that in packaging without aluminium layer. Metallised layer protected against light and fluctuating temperature as well as aluminium foil. The packaging had significant influence also on preserving the quality of frozen foods stored in vertical cabinets. Herring fillets had the longest shelf life in vacuum packaging of low oxygen. Nitrogen did not improve the preservation of the quality of herring fillets. The study showed also that the coating of card board boxes must be tight enough to prevent any off flavour from card board migrating to the frozen foods. According to the study it is possible to increase frozen storage temperatures in retail stores by at least 3°C if frozen foods are protected by aluminium foil laminate or metallised packages although cost savings are insignificant.

The packaging used for frozen foods should be of good quality as well as odour and taint free in order to prevent contamination of the product by exposure or handling. Thus the product should be totally enclosed and the container should not be capable of being opened without recognisable damage. It should also protect the product against normal transit and storage hazards and inhibit dehydration by incorporating a moisture vapour barrier. All outer packaging should carry clear product identification and should be coded so that stock rotation can be carried out. The inner pack or carton should be marked with an appropriate identification code which should enable the producer concern to establish date of production, the location of the production factory, easy reference to daily production records and other conditions of manufacture. The information referred to date of production and the location of the production factory together with relevant product details should be available in relation to any individual packet and hence accessible to any retailer, caterer or enforcement officer having reasonable causes to require such information in relation to the quality of the product. The inner pack or carton should also carry details of recommended storage times thawing times and cooking instructions (Boast, 1985). The freezing process can be carried out with the product packed or unpacked but freezing times will be quicker if no wrapping is around the product. Any packaging acts as an insulator and reduces heat transfer. When a product is wrapped the inner layer must have excellent contact with the actual food and all air must be removed if reasonable cooling rates are to be obtained.

If an additional outer packing is used the individual items should be arranged to make a regular shape and hence establish good contact with the surrounding material. Heiss (1969) surveyed the packaging material in UK used for frozen fish products. The author mentioned that modern packaging materials had little influence on the freezing temperature required for fish fillets. The author discussed the technical requirements for the packaging of frozen fish, in relation between water vapour permeability of the packaging material and the occurrence of freezer burn. If a storage time of nine months at -20°C and a relative humidity of 75% are required water vapour permeability of the packaging material should not exceed 0.22 to 0.37 g/m^2 in 24 hours. Polythene films and cartons waxed on both sides and wrapped in heat sealable waxed paper are very satisfactory.

In UK the customary packaging methods for frozen fish blocks on board is that they are produced in various sizes ranging from 15 to 30 kg in weight. If vertical plate freezers are used the fillets are packed in cartons previously placed in the freezer compartments (Heiss, 1969). The cartons are made from sulphate box board which has both sides either waxed or polythene coated. In case of horizontal plate freezers a frame of corrugated card board and sheets of polythene film or paper waxed on both sides are used to separate the fillets from the freezer plates. The prepackaged frozen fish are then stored on board until the vessel reaches port, possibly upto three months time. The blocks are subsequently sawn into portions on shore and repackaged in small consumer packages. Tuna and other large fishes are glazed with water after freezing and are stored whole. Saw fish portions are wrapped in a shrunken biaxilly oriented plastic film such as polyvinylydene chloride or polythene as a substitute. Occasionally the fish portions are placed by machines between two cellophane polythene sheets and then sealed (flow pack). Polythene pouches or highly moisture proof grade cellophane (MSAT) or polypropylene film wrappings are generally used for unfrozen or thawed fillets. The outer package is a duplex carton the outside white and waxed, the inside grey and coated only when the fish is loosely wrapped. It is not hermetically sealed. Different types of duplex cartons are used for frozen fish packaging. The most commonly used are one piece folding carton with hook and slit design. Another method is the use of one piece flat carton with PE coated bottom which can be heat sealed so that drip tight corners are produced. The third one is a one piece carton top opening tuck on type with wax coating on both sides.

2.5.3 PACKAGING REQUIREMENTS IN RELATION TO FREEZING

The different packaging materials in common use now-a-days have little influence on freezing times for fillets of customary thickness. The freezing times are extended if air pockets form between freezer plate and wrapping material or wrapping material and fillets. Since the thermal conductivity of air is low (0.018 K cal/m^2h°C at -30°C) its heat transmission resistance is very high. The influence of air pockets is greater for thinner blocks and high freezing rate (Kiermeier *et al*, 1944). Excessive water vapour permeability is one of the causes of freezer burn. To avoid freezer burn the weight loss in the course of the turn over time should be kept down to about 60 to 110 gm/m^2. Assuming 9 months storage at -20°C and a relative humidity of 75% in the cold store, water vapour permeability should not exceed 0.22 to 0.37 g/m^2/24 hr (Heiss, 1963). Under the above mentioned storage conditions, a 30 micron polythene film has a WVTR of only 0.25 to 0.04g/m^2/24 hr which is very satisfactory. The corresponding values for cartons waxed on both sides wrapped in heat sealed waxed paper are only slightly higher 0.05 to 0.06 g/m^2/24 h. These figures presuppose heat sealed packages, mere wrapping without sealing results in a much higher water vapour permeability and does not afford sufficient protection against freezer burn and hence should be avoided. Waxed cartons without overwrap have a water vapour permeability of 3.1 to 3.4 g/m^2/24 hrs which is unsatisfactorily high. Little scientific literature is available on the possibilities of increasing the shelf life of frozen fish sensitive to oxidation by packaging. But temperature has a significant effect on enhancing the shelf life. Fishes like herring, mackerel, sardines, salmon and ocean perch have a high quality shelf life of 2 to 3 months at -18°C and 6 months at -30°C (Anon, 1964). The experiments with perch have shown that storage at low oxygen partial pressure does appreciably lengthen the shelf life of fish. Bramsnaes and Sorenson (1960) have demonstrated that rainbow trout which very quickly becomes rancid on the inside of the belly flaps and particularly along the fine blood vessels will keep for 9 months when vacuum packaged in polythene laminated cellophane and stored at -20°C. Anon (1977b) used a tubular film laminate (surylyn and polyamide) for packaging frozen fish under vacuum. The fish are packed automatically side by side and the package is sealed around them under vacuum. Any desired number of fish can then be cut from the strip by the retailer without unsealing the remaining fillets. Lindsay (1977) studied the effects of film packaging on oxidative quality of fish fillets made from lake trout (*Salvelinus mamoyosh*), packaged and frozen at -18°C for 10 months. Protection against oxidative rancidity in the fish afforded by vacuum sealed oxygen barrier (Surylyn/PVDC/ Surylyn and Nylon/Surylyn) pouches was assessed. Results clearly indicated that vacuum packaging in low oxygen permeable films such as Nylon/Surylyn and Surylyn/PVDC/ Surylyn protected the fish from oxidation and desiccation during prolonged frozen storage. The high price of shrimp justified the use of cans for added protection of quality (Anon, 1977b). Advantages claimed include prevention of icing up and dehydration of the IQF shrimp during defrost cycles after which polythene or paper packaged shrimp might start to stick together. Holm (1978) emphasised the need of moisture resistant fiberboard packages for storage and transport of chilled or frozen meat and fish using different types of coatings like microcrystalline waxes, mixed plastics and wax polythene coating etc. Achvenainen (1983) carried out a survey on packaging of deep frozen foodstuffs. Aluminium foil laminated containers were found to be best in preventing oxygen and water vapour penetration. Temperature could be maintained at between 4 and 6°C lower inside these containers. Vacuum packaging however is required for greasy products. Suwanrangsi (1989a) has identified the use of solid fibre board with wax coating or laminated with aluminium although traditional plastic lined box is still popular in most of the countries. Frozen fish packed directly into plastic lined master cartons, the whole encased in a jute bag has been found by exporters from Bangaladesh to be an economical way of shipment to Malaysia and Singapore. Frozen whole fish like tuna are normally packed in heavy duty, bulk pack corrugated fibre board cartons with gross weight of upto 1.5 tonnes. The institutional packaging consists of 3 to 6 kg, and the packaging material is board treated with either polyethylene or wax. Another popular method is to freeze blocks of products in trays wrapped with polyethylene film and after freezing the trays are packed in fibre board cartons. Blocks fillets are often protected by shrink wrapping and storage in master cartons. IQF products are normally packed in either sealed single layer polyethylene bags or laminated bags and put into outer master cartons. Retail packs are popular in western countries with housewives who prefer small portions that are easily opened, hygienic and can be released if necessary (Jeffs, 1988). Cartons for retail packaging are produced in top and end loading forms using materials such as solid white board, chip board or paper specially treated with wax, plastic or aluminium foil. This type of packaging is very popular for packing fish fillets, fish sticks and fish cakes. Products can be prewrapped, frozen or unfrozen before packing (Jeffs, 1988). Bags made of polythene are widely used for the packaging of frozen products. This type of packaging is suitable for relatively free moving products like IQF prawns and squid rings. Laminated packs are used for quick frozen products. Whilst many unsupported (single ply)packaging films are available, only polythene films find wide acceptance for the packaging of frozen products in Europe. Unmodified films are prone to splitting when subjected to impact forces under deep freeze conditions. To overcome this they usually use a co-polymer material like Ethylene/Vinyl acetate (EVA copolymers) containing 3-8% of vinyl acetate. Laminated materials are widely used for the packaging of frozen products where improved functional or display properties are required. The structures most commonly employed are polyester/polythene and nylon/ polythene. Most polyester/polythene laminates used for deep freezing packaging are based on 12 μ polyester film. The thickness of the polyethylene layer is between 40 and 70 μ. Thermoformed trays sealed with the lidding materials like PEST/PE are used for the packaging of frozen value added products. The materials most commonly used for the manufacture of single ply trays are PVC, polystyrene and polystyrene co-polymers. It is difficult to produce thermoformed trays from high density polythene and polypropylene. Thermoformed polyester trays can be obtained in both crystalline and amorphous forms (Jeffs, 1988). In USA greater amount of fish is sold in the frozen form in the super markets. In recent years sales of frozen battered fish portions sales have been on the increase. The package used is a polythene, wax or hot melt coated carton with or without a waxed paper overwrap. Waxed coated cartons were the first packages used. Problems were encountered in such packages with wax flaking off and with dehydration through the score lines on the package. Polythene coated paper board offers good flexibility and better moisture protection (Sacharow and Griffin, 1980). Over 2/3rd of the United States fish supply is imported. Copackers produce many varieties of frozen fish in plain cartons. They then wrap the cartons in paper overwraps supplied by their customers. The overwrap may be coated with wax, hot melts or polyethylene. Frozen fish is also found in overwrapped trays displayed in the frozen fish cabinet. Individual fillets are overwrapped with cellophane or PVC with or without paper board inserts. Vacuum packaging is not done because of the added expenses of operation and handling. In some cases frozen fish is vacuum packed at a low temperature and frozen. The most suitable packaging material used for the purpose is cellophane aluminium foil polyethylene or polyester PVDC polythene laminates. Rancidity formation decreases drastically in vacuum packs employing low oxygen permeable laminates. Overall shelf life is extended by almost 100%. Since vacuum packaging does not remove all the oxygen from the fish, lipid oxidation still occurs but at a much slower rate. Proper frozen storage is essential for all packaged fish, whether it be vacuum packed or overwrapped with a plastic film. An interesting frozen fish is frozen smoked salmon in tin plate or easy open aluminium cans. Each layer of the sliced fish is separated by a parchment paper insert. The conventional method of waxing that is done in India has already become outdated in developed countries. This is done by a process called high gloss or chilled waxing. This is carried out with a special wax application unit downstream of which is wax chilling bath through which the flat carton pass. This greatly enhances the aesthetic shelf appeal of the carton. The effect is improved further by the use of a special grade wax possibly microcystalline wax type, and certainly by a superior quality board (Rewri, 1982). The initial printing on the board is carried out in the continuous web form and the reel is then coated with polyethylene on either side. These diotite cartons are supplied flat to the customer where they have to be erected on special semiautomatic or fully automatic machines meant for the purpose. The flat is erected into a carton to first form the bottom, on which the below corners are heat sealed with the help of hot air which is blown into the four corners. After filling the product, the top is folded and closed and all the sides are again heat sealed. When a product such as fish sticks or fish cakes is packed in a carton unwrapped, the carton is coated on both sides with polythene so that any damage to the inner barrier due to the abrasive breadcrumbs does not result in a a strain on the outer surface of the carton. Cartons are made from either pure white board or duplex board depending upon whether product is prewrapped or not. Gopal *et al.* (1981) have given an account of the status of the packaging of fishery products in India. The present method of packaging of frozen shrimp compries an LDPE liner, a waxed paper board (usually duplex board) carton and waxed or unwaxed corrugated fibre board box closed with plastic strapping. The carton may be a one piece top opening(stapled or interlocked for setting up) or less often a two piece (tray and lid) carton. 300 to 400 gm/m^2 board is used for the carton and the wax coating may be 40-50 gm/m^2. Dimensions of the carton vary from packer to packer. There are no ISI specifications for these duplex cartons. Ten of such 2 kg (or 5 lb) cartons are packed in corrugated fibre board boxes. Of all the packaging materials used in the fish processing industry, Bureau of Indian Standards had laid down quality specifications for the corrugated fibre board boxes for export of seafoods and froglegs (IS : 6715-1972). These stipulate that the master cartons should be made of corrugated/solid fibre board the external liners of which shall be water proof. A task force set up by the Govt. of India recently observed that the CFB master cartons are subjected to severe stress and strain in the process of transport from factories to ships and lack of facilities for mechanical handling results in rough handling which causes damages, dents or tears in the cartons(Govindan *et al.*1988).

2.5.4 PACKAGING OF DRIED FISHERY PRODUCTS

Salt cured and dried fish occupies an important position because curing is one of the easiest methods of preservation. Salted and dried fish is infested by insects and pests, susceptible to oxidation and becomes hygroscopic. The moisture varies from 22.5-49% and salt content varies from 7.6-37.5%. In Britain only a small amount of fish is salt cured such as dried salt cod and pickled herrings. Fatty fish is not dry salted because the fat becomes rancid during exposure to air but they are immersed in a saturated solution of brine pickle where they are protected by a liquid barrier. There is still a limited market for small packs of special cures including vinegar and spices. These products are generally sold in glass jars or cans which are not sterilised and therefore require refrigeration. Bacterial spoilage can occur from halophillic bacteria (FAO, 1983). In USA most cured fish like klippers, smoked white fish, smoked haddock etc. are packed in wooden boxes for wholesale storage. The cured klippers are packed for consumer sale in overwraps of cellophane (Sacharow and Griffin, 1980). Hygienic protection is obtained as well as brand identification. In addition condensation within the package is reduced. Recent developments in cured fish packaging include the use of polyamide polythene laminated film and smoked fish in polyester polythene pouches. Packaging of salted fish is discussed with reference to suitable packaging materials and their characteristics by Ortiz *et al.* (1980). The packaging materials studied included tin plate, aluminium, glass, paper, plastic films and wood. Types of packs, their manufacture, characteristics applications, storage conditions and keeping quality of salted fish products are also discussed. Although dried fish has been processed in Malaysia for ages, improvement in the quality has not undergone any significant change (Hanausek, 1970). Dried fish in Malaysia are packed in any type of container available such as hessain or gunny sack, card board cartons, wooden boxes, bamboo and rattan baskets. At the retail shop, dried fish is displayed in boxes, rolled down paper bags, LDPE baskets etc. (FAO,1983). Biede *et al.* (1982) stored sundried shrimp from Taiwan and Lovistana at 22°C for 8 months in modified atmosphere or vacuum.

2.5.5 PACKAGING OF DRIED FISHERY PRODUCTS IN INDIA

One fifth of India's fish catches of 2.8 million tonne per annum is salted and dried for future consumption in the country and for export to neighbouring countries (Govindan *et al.*,1988). In 1988-89, 4175 tonnes of dried fish were exported earning foreign exchange worth Rs.52.2 million, the most important outlet for the product being Srilanka. A suitable dried fish packaging should be inert, leakproof, impermeable to oxygen and moisture, less transparent, resistant to mechanical abrasion and puncture and inexpensive (Gopal *et al.* 1981). The packaging materials employed for this product is highly unsatisfactory, leaving much to be desired from the scientific and hygienic points of view. Baskets improvised with braided coconut fibres or palmyrah leaves are the containers exclusively used for packaging this product both for export and internal distribution. An overwrap with gunny fabric is given as reinforcement in the case of products meant for export and those which have to be transported over long distances inside the country. The main disadvantages of these packages are easy entry of insects, rodents and other similar pests. the product is highly sensitive to changes in relative humidity. The shelf life of these commercially packed products is only about 2 to 3 months due to high initial moisture contents and its subsequent gain during storage resulting in high microbial attacks including red halophiles. The packages do not possess sufficient mechanical strength to withstand rough handling and go out of shape on stacking (Rao,1975). Indian Standard Institution (IS : 2884, 1979) specifies the packaging materials to be used for dried and laminated Bombay duck. Packaging of two types of Bombay duck shall be done as follows:

Dried Bombay Duck: The dried fish shall be tied in rolls of 2000 pieces. Each roll shall be tied with the rope placed equidistantly. The rolls shall be tied in such a manner that no piece falls off during handling. One or more such rolls shall be wrapped in mats and then such rolls shall be further wrapped in a hessain cloth and properly tied or as agreed to between the buyer and the supplier.

2.5.6 PACKAGING LAMINATED BOMBAY DUCK

The laminated pieces shall be tied in bundles of 25 pieces each. Each bundle thus formed shall be fastened by twine passing round uniformly so that it shall hold the pieces firmly and packed in suitable polyethylene bags and sealed air tight. The small bundles or packages shall then be packed in master cartons as agreed to between the purchaser and the vendor for internal marketing as well as for export.

2.5.7 PACKAGING OF DRY SALTED THREAD FIN (DARA) AND JEW FISH (GHOL)

Dry salted threadfin and jew fish shall be packed in leaf mats in the form of bundles overwrapped with hessain cloth, stitched and secured by coir ropes or any other suitable manner as agreed to between the purchaser and the vendor. Export inspection rules states that dried shark fins and dried fish maws shall be packed in a manner as agreed to between the exporter and the foreign buyer (Anon, 1969). In the absence of any agreement the material shall be packed in sound gunny bags (Anon, 1978a). Packaging of dried mackerel has been reported by Sen *et al.* (1961) who observed that packed dried fish developed mould growth in 62 days when stored at 78°F and 75% RH when the initial moisture content was 39.68%. According to them MST cellophane alone and in combination with polythene were found to preserve the original colour of the product to a great extent. Venkataraman and Vasavan (1955) have reported that sundried salted mackerels when stored in teak wood boxes lined with butter paper turned red or moldy in a period of 30-90 days. Velankar (1952) observed that market samples of sundried fish became spoiled and discoloured in about 2-5 months. Use of hessain bags with polythene lining has also been suggested as moisture barrier package for the storage of dry fish (Anon 1957). The shelf life of dried and packed fish is limited not by bacterial decomposition but by fungal attack, off odour and bitter taste. It was also reported by Venkataraman and Vasavan (1954-55) that dried mackerel packed in teakwood cases lined with butter paper turned moldy in 30 to 90 days. Shrivastava and Anandavally (1974) studied the storage life of dried prawns at room temperature. Without the treatment of any preservative they reported 2 months storage of prawn stored at room temperature. Kandoran and Valsan (1974) studied the bulk packaging of cured mackerel (*Rastrelliger kanagurta*) in different types of packaging materials like dealwood boxes, plywood boxes, tarpolythene lined gunny bags, palmirah leaf mats, gunny bags, card board boxes, split bamboo baskets and coconut palm leaf mat with an inner lining of polythene. Studies carried out by Antony and Govindan (1983) on dried lizard fish with moisture content of 25% showed that it became prone to fungus growth in packaging films within about 115 days while under low humidity and temperature conditions it kept well for pretty long time in packaging films. Salted and dried lizard fish sealed in pouches of low density polyethylene of thicker gauges (300 gauge and 400 gauge) and 400 MXXT cellophane film kept in good condition at ambient temperature for 3 to 4 months. 400 MXXT cellophane was found to be prone to easy attack by insects which found entry into the product in the 4th month. The shelf life almost trebled by storage at lower controlled temperature and humidity conditions in all the films used.

Christiansen (1951) observed that a cured fish sample became moldy in a package if it had an initial moisture content that equilibrated to 70% RH level and therefore such material would not lend itself to packaging whatever be the packaging material applied. Sen *et al.* (1961) observed that 70% RH equilibrates to 37.5% moisture content in cured mackerel (*Rastrelliger kanagurta*). Rao *et al.* (1962) reported that excessive drying of salted fish to 25% level would be necessary to prevent mold growth in a package. Govindan (1975) studied the storage life of freeze dried fishery products in hermetically sealed tin containers in an atmosphere of nitrogen and stored at ambient temperature. Storage life of freeze dried products can be reckoned in years at ambient temperatures. The effect of bulk packaging on the storage of salted and dried fish was studied at ambient conditions by Antony *et al*. (1988). Among four different packaging systems studied, gusseted type high density polythene wooven sacks having either circular loom or traditional loom laminated with 100 gauge LDPE were found to be best suited for dry fish packaging as they could withstand the hazards of handling, transportation and storage. Method employed for dry fish packaging at present is mostly the bulk type of10 kgs and above (FAO, 1981a) and hence the product fetches less price to the producers. Bulk packages render handling of the material and maintenance of proper hygienic conditions in retail distribution rather difficult. The dry fish can be processed, transported and passed on to the ultimate consumer by using consumer packages. Antony *et al* (1986) has found that whole dry prawns having 14.2% moisture content puncture any type of film or laminate. He has found out that first packing in duplex cartons and outer packing in 300 MXXT/150 gauge LDPE, can keep the product in good condition for more than 8 months without any treatment or preservative. Shell on dry prawn can be kept more than 8 months without the use of duplex cartons at room temperature.

2.5.8 PACKAGING OF CANNED FISH

Cans are traditionally used for heat sterilisable products. A suitable canned fish package should be hermetically sealable, thermally conductive, inexpensive and not affecting odour, flavour, texture, colour and food value of the contents. Sulphur resistant lacquered cans are generally used for fish products. Cans made of aluminium are also used occasionally and these are less expensive than tinned mild steel cans in western countries. Today there are several choices available such as standard tin plate, light weight tin plate, double reduced tin plate, tin free steel, vacuum deposited aluminium on steel and aluminium (Sacharow and Griffin, 1980). Fish canning is a method for industrial processing of raw fish and other edible aquatic products which enables to keep the product suitable for consumption at ambient temperatures over a longer period of time than any other commercial fish processing would do. The most common material used for manufacturing containers for fish products in the world are tin plate, aluminium and lacquered steel plate (TFS). Minimum thickness of tin plate for can making is 0.15 mm (Palling, 1980). For low acid products and fish, the steel type has no important influence on corrosion and any of the available types may be used although MR steel is usually preferred (FAO, 1985). Formerly tin plate was made by immersing sheets of black plate in molten tin. Now-a-days electrolytic plating techniques are used to apply tin to the base steel plate. The electrolytic tinning process permits a close control over deposition of the tin coating layer (Ellis, 1975). For canning shrimp C-enamel cans are recommended. This enamel is an oleoresinous type containing zinc oxide pigment which counteracts the action of the sulphur in the food and prevents blackening (Sacharow and Griffin, 1980). The canning of crab meat from blue crabs and lobster meat encountered difficulties in the early days as plain tin plate cans react with the hydrogen sulphide released by the fish to produce a black discolouration. Parchment liners helped to solve the problem. Acid dipping of the shell fish prior to canning also is helpful. Aluminium alloys are finding increasing use in the can making industry in USA and U.K. Advantages of aluminium include the light weight of the material, resistance to atmospheric corrosion and to sulphide bearing products (commonly found in fish products) and versatility for making containers by different methods. Dis-advantages include difficulties in closing the body seam by soldering and the necessity for heavier gauges which are required to obtain strength comparable with tin plate. Sheet made with pure aluminium has mechanical and physical properties which limits its use as a can making material. Increased strength is obtained by alloying aluminium with one or more other metals such as magnesium and manganese. Minimum thickness of aluminium for use in fish cans is 0.28 mm. Aluminium as a material can only be used for drawn can manufactured by deep drawing process as opposed to side seam soldered/ welded can normally made of tin plate. In Europe and USA aluminium has found its use mostly in the field of beverage processing industry. The metal has been found to be very prone to corrosion and because of limitations in terms of can diameter and heights it is not favoured as a potential replacement for tin plate (Anon, 1989). Most canning in the past in western countries were done in "tin cans"' cans made of steel with a very thin and even coating of tin. The aluminium plated can is now used quite extensively particularly in Scandanavian countries where aluminium has largely replaced the tin can in fish canning (Broek, 1965). The material is much softer than tin plate and is used only on small to medium cans which will not be subjected to rough handling. Shallow drawn aluminium cans are being used for canned tuna, sardines, crab meat, lobster, salmon and oysters (Lopez 1975). Glass has the advantages of being pure, easy to clean, corrosion free, leak proof and transparent, but it is of limited use with heat processed foods (Gray, 1956). The chief disadvantages here are breakage and the blowing off the lids when heat is applied. These problems may be overcome by careful handling, careful and proper regulation of pressure and the application of a special cooling spray during the heat process (Broek, 1965). With many foods especially seafoods a condition known as iron sulphide discolouration occurs. The iron sulphide (FES) is formed by the reaction of iron with free sulphides particularly H_2S in fish flesh. The main source of iron is the steel plate in the can. The problem of iron sulphide discolouration may be reduced to some extent by the use of aluminium cans or by the use of cans coated on the inside with an organic, oleoresinous lacquer. Many types of coatings are available but the 'C' enamels are the most commonly used for seafoods (Broek, 1965). C-enamels contain about 15% zinc oxide in suspension which reacts with the sulphides formed during heat sterilization to produce harmless white or colourless zinc compounds. Paper parchment liners are also some times added to cans to prevent the product from sticking to the can and also to prevent chunks of fish or whole fish from sticking to one another (Wheaton and Lawson, 1985). There are two main causes of spoilage of aquatic food products, bacterial and chemical. Bacterial spoilage may be caused by the use of poor raw material, under processing, infection of the can contents with polluted water or improper sealing of the can. Chemical spoilage is caused by the leaching of compounds and or metals from the can walls into the product (Burgers *et al* 1967). In recent years a lot of new develop-ments have taken place in the field of canning technology. Among them is the introduction of drawn and wall ironed (DWI), drawn and redrawn(DRD), easy open ends and alternative package materials such as tin free steel (TFS) and different types of rigid and flexible packaging materials (Mahadeviah, 1985). The development of welded side seam is a more recent innovation. Three piece cans have been replaced with two piece cans mainly for soft drinks and beverages. Two types of two pieces can have been recently introduced for packing soft drinks and beer. They are known as drawn and wall ironed (DWI) cans and drawn and redrawn cans (DRD). A new type of can known as high tin fillet (HTF) can has been developed for canning high detinners such as green asparagus, tomato products, dried prunes, green beans, wax beans and carrots. A steel company in Australia has developed a low tin coated steel (LTS) with a nominal tin coating mass of 1.1 g/m^2. LTS tin plate cans compare well with tin plate cans with tin coating of 2.8 g/m^2 (E 25) (Mahadeviah, 1985). To improve the shelf life of canned products a new type of tin plate known as grade K tin plate has been developed in USA (Londov and Manheim, 1970). A new type of tin container called "High tin fillet can" has been developed for canning high detinners such as asparagus, spinach etc. (Hotchmer and Kamm, 1967). Among the recent developments in the can making, the new welded can has been described as the world's fastest can for food and beverage containers (Laad,1985). This technology involves low capital expenditure compared to the other technologies like DW1, DR1 etc. The existing pre and drawn line equipment can be used and size can be changed easier for smaller cans. New materials have been developed for use in OTS cans. Tin free steel (TFS) developed in Japan for example has a steel base with a chromium/chromium oxide surface replacing the tin in conventional tin plate. This new surface provides an excellent substrate for lacquer adhesion which ensures superior performance in terms of product compatibility for many food products. Another new material Litewel-N (LTW-N) is being marketed by a Japanese company for use in welded food and beverage cans. It consists of a steel sheet thinly plated with tin and tin nickel alloy. LTW-N is claimed to have corrosion resistance, weldability and lacquer adhesion properties comparable to tin plate despite containing less tin (Anon, 1989). A flexible pouch made from thermoplastic and aluminium foil laminate has been developed as an alternative to rigid or semi rigid containers for packing processed food products. These are widely used in some of the advanced countries like USA, Europe, Japan etc. The retort pouch is a multilayer flexible package consisting mainly of polypropylene, aluminium foil and polyester. Exploratory research on thermal processing of food in retort pouches was first conducted in the mid to late 1950s (Lampi, 1978). Pouch processing technology moved ahead rapidly (Mermelsten, 1978) and commercial retort pouch processing systems are currently available from a number of equipment manufacturers. Retortable pouches are used extensively in foreign markets and are being adopted by the US Department of Defence to replace the traditional C-ration (Bannar, 1979). A study was first carried out in USA on the retortable foods packed in pouches. It was in Japan that retort pouch packed foods were first marketed on the commercial production basis in the world. Japan ranks the first in production and processing technique of retortable foods in the world. Oiled tuna was packed in retortable pouches in 79 in Japan and its production accounted for 653 tonnes in 79. Institutional size 500 gm or 1 kg contained products commanded a major share in the retortable tuna market. The retort pouch which is a flexible package for thermally processed food is a laminated food package that combines the advantages of the metal can and the boil in bag and is a significant advance since the development of metal can. It is a laminated flexible container capable of being heat processed in a conventional retort explored since mid fifties. Commercial application has taken place in Japan, Europe and USA. Some advantages of retort pouch are rapid heat penetration resulting in the reduction of processing time by 35-50%, improved quality of products with significant reduction in the loss of heat labile vitamins, lower package cost and saving in freight, less requirement of space, convenience to use and savings in energy (Lampi, 1977). The combination of shelf stability without refrigeration, resistance to handling abuse and light weight make foods packed in retortable pouches ideal for military use, recreational camping, institutional feeding and general public. Long (1962) listed the following requirements for retort pouch film (1) Gas permeability less than 15 $ml/m^2/$ 24 h/atmosphere (2) Water vapour transmission rate (WVTR) less than 0.8 $g/m^2/24$ h (3) Resistance to temperature from below 32°F to at least 250°F (4) High hydrophobic properties (5) Low cost of material and package fabrication (6) Suitability for food use (7) Resistance to fats, oils (8) Heat sealability over wide range of temperatures (9) Chemical inertness and dimensional stability (10) Capacity of being handled on automatic fabricating and filling equipment and good heat permeability (11) Physical strength to resistant handling abuse (12) Good ageing properties, printability and consumer appeal. The first laminate was made of polyester/foil/PVC. This was soon followed by a wide range of laminates like polyester/foil/modified polyolefin, polyester/foil/HDPE, polyester/Al foil/nylon and polyester/foil/polypropylene. Current ones are based on polyamide/cast PP or modified poly or polyester/Al foil/polyester/polypropylene co-polymers or polyester/oriented polyamide or polypropylene. Range of current performance requirements for sterilisable materials are (Lampi, 1979).

(1) Sterilisation temperature 116-145°C

(2) Oxygen permeability 0 CC/m^2/24 h

(3) WVTR 0 gm/m^2/24 h

(4) Seal strength 2-3.5 kg/10 mm

(5) Bond strength 150-500 gm/10 mm

(6) Heat seal range 160-260°C

(7) Thickness tolerance ± 2 μ

(8) Burst strength 7.5 kg/15 mm seal or 17.2×10^4 pa for 30 seconds

(9) Residual solvent, (taint) 30 mg/m^2

Advantages of retort pouch has been listed by Jimenez and Griffin (1981). He has listed 5 advantages over other packs. The thermal process time for a retort pouch can be significantly shorter than for a metal or glass container of the same capacity and in many instances this leads to improved quality (less over cooking). The shelf life of a pouched product is generally as long as if not longer than the equivalent frozen product and does not require the frozen storage and distribution chain and marketing restrictions that this imposes. Product/container interaction is less of a problem than with cans. Vacuum sealing in retort pouches without brine, syrup or sauce permits upto 40% saving in weight and volume and allows some products to be packed which are difficult to can successfully. Materials supplied in reels or pouches offer significant savings in storage space and weight compared to rigid containers. The retort pouch is easy to open with scissors and it can be provided with a tear notch (Jimenez and Griffin, 1981). Retortable thermoformed blow moulded plastic containers has come into existence as a retortable/ sterilisable material for food products. This container is claimed to offer substantial economies over metal cans, as well as attractiveness and easy opening. It will have some what slower heat transfer properties during retorting and retains the disadvantage of the cylindrical shape versus the thinner retort pouch (Griffin, 1987).

2.5.9 STATUS OF PACKAGING OF CANNED FISH IN INDIA

In India canning of shrimps is done in 803 (301x206 size) open top sanitary tin plate cans which are lacquered internally and externally so as to be sulphur resistant. Mackerel and sardines in oil are packed in aluminium tall cans and dingely rectangular 3 piece cans of size 407x207x 102 respectively. In India the manufacture of tin plate was started during 1923. But still open top sanitary quality tin plate is being imported from other countries spending huge amount of valuable foreign exchange. CFTRI in collaboration with M/s.Hindustan Steel Ltd., Rourkela has shown the possibility of introducing indigenous tin plate for canning processed food products (Mahadeviah, 1986). Tin plate is a low carbon steel plate coated with a layer of tin. Steel base plate is manufactured either by hot rolling or by cold rolling process. Ninety percent of the steel plate used for tin plate is manufactured by cold rolling process. The thickness of the steel plate varies from 0.18 mm to 0.3 mm depending on the size of the can required. Type MR quality steel plate with maximum phosphorous content of 0.02% is used for OTS cans. Of late double cold rolled tin plate with about 50% reduction in thickness and in fully hard state to give strength to the can has been developed to reduce the cost of the container. The thickness of tin coating varies from 5.6 g/m^2 to 22.4 g/m^2. Differential tin plate with different thickness of tin coating on either side are also available. As per ISI specifications differential tin plate of 11.2/5.6 with lacquer coating on the external surface (5.6 g/m^2) is used for processed food products. IS:9396(1979) lays down the material and lacquering requirements along with the diameters and capacity of round cans for packing processed foods. The requirements covered for round cans are definitely be very useful in preserving the packaged seafood and fish and to the required levels of product quality in the overseas market. The tins are largely imported so far as the tin sheets with such a low coating of sulphur and phosphorous (0.05% and 0.02% maximum respectively) are not manufactured in the country. IS:4638 (1981) provides requirement of a retail pack of 100 gm sardines. The use of tin plate with differential tin coating of D 84/56 grade (inside 8.4 g/m^2 and outside 5.6 g/m^2) and aluminium as material are specific features of this standard. Nearly 70% of the tinplate used in the country is consumed for food packaging. Most of the tin plate is imported and includes the entire quantity used for canning of fruits and vegetables and to some extent meat and fish products (Gulati, 1982). IS:5818 (1970) specifies the type of lacquer to be used for food cans. Studies have been made on packaging of products like stuffed parotas and cutlets using indigenous material for retort pouch application (Ghosh *et al* 1974a, 1974b and 1979). Stuffed parotas were packed in MST cellophane followed by (1) 60 g/m^2 kraft/0.04 mm foil/150 gauge polyethylene (2) sorbic acid treated paper and (3) 300 gauge HDPE sacks. Due to basic weakness of foil laminate, large number of pin holes were noticed and spoilage as high as 20% has been observed.

Also ready to eat foods packed in 60 μ polypro-pylene and processed at 121°C for 30 minutes was found to withstand processing temperature and transportation hazards. Antony *et al* (1985) studied the application of indigenous synthetic films for retortable pouches for preserving prawns by heat processing. Polypropylene pouches 250 gauge were found to withstand heat processing of prawns in brine. The processed pouches were further sealed in tight fitting bags of 12 μ metallised polyester/150 gauge LDPE laminate. The product had a life of 3 months at ambient temperature. Subramanyam *et al* (1985) studied the performance of indigenously available polypropylene film of thickness 60-75 μ which was found to be suitable for retort processing of Indian foods. To attain complete sterility, foods are sterilised with steam and air mixture at 1.4 kg/ sqcm. so as to reach F value of more than 4.0. Instead of the die cut protective system and 45 gsm grease paper outer covers, E-fluted 3 ply corrugated board made out of 130-140 gsm kraft paper was found to be more successful.

2.5.10 MODIFIED ATMOSPHERE PACKAGING

As an alternative to vacuum packaging atmosphere inside the package can be controlled to extend the shelf life of fish. In recent years considerable interest has been envinced in many countries in research on storage of fresh fish in modified or controlled atmosphere packaging. In the literature the term "modified atmosphere" is usually limited to those storage conditions where the atmosphere gas concentrations are altered before store. In controlled atmosphere systems the selected atmosphere concentration of gases are actively maintained throughout storage (Wilhem, 1982). However in a general sense atmosphere modification may include any deviation from normal atmospheric pressure or composition. Modifications of atmospheric compositions include storage under levels of carbon dioxide, oxygen, nitrogen and other gases which differ from normal air. Modified atmosphere packing (MAP) systems hold out great potentialities as a valuable technological tool for handling, preservation and distribution of seafoods. Such systems can be created through a simple distribution of atmospheric gases in the immediate storage environment of the product. It is primarily the enrichment of carbon dioxide in storage atmosphere as a means of controlling microbial growth that results in the preservation of the product. The gases used for these systems are produced inexpensively, the important ones viz. nitrogen and oxygen being natural components of atmospheric air. All these systems are generally simple to administer and maintain. Research on the effect of Co_2 on the storage life of fish began in the 1930's. Killefer (1930)briefly noted that fish stored in 100 percent Co_2 kept fresh two to three times longer than controls in air at the same temperature. Coyne (1932, 1933) was one of the early investigators to apply modified atmospheres to fishery products. In a preliminary study with pure cultures of bacteria isolated from fish products, he found that Co_2 atmosphere markedly inhibited their growth, while normal growth patterns were observed under air or nitrogen atmospheres. He also observed that 20 to 100% CO_2 atmospheres were very effective in the preservation of fresh haddock, cod, sole, whiting and plaice in the round as well as fillet forms, best results being obtained with 40 to 50% Co_2 systems. Stansby and Griffiths (1935) found that whole haddock stored under 25% carbon dioxide had a shelf life approximately twice that of products handled by conventional methods. Shewan (1950) suggested the use of 30 to 40% Co_2 atmosphere for optimal benefits of modified atmosphere storage. He suggested the use of 30 to 40% Co_2 atmosphere for optimal benefits of modified atmosphere storage. Tarr (1954) made observations similar to those of Shewan and advocated Co_2 contents of the order of 50% indicating that its preservative effect may be negligible below concentrations of 40%. Yokoseki *et al* (1956) found Co_2 atmospheres to be beneficial for storage of fish cakes. Brown *et al* (1980) found out that chemically and microbiologically 40% Co_2 is more effective in controlling the undesirable changes in rock fish fillets and silver salmon (*Oncorhynchus kisurch*) steaks. Fey and Regenstein (1979) found that 60% Co_2 atmosphere has been found to be very advantageous in extending the shelf life of fresh red hake (*Orophycischuss* species) packed in gas impermeable bags. Recent studies (Banks *et al* 1980, Brown *et al* 1980) on vermillion rock (*Sebastes* species), Coho salmon (*Oncornhynchus* species), Gulf trout (*Cynoscion* species) and croaker (*Micropagon* species) have shown that while Co_2 is effective in inhibiting the growth of gram negative bacteria pseudomonas, which produce trimethyl amine and ammonia, growth of gram +ve bacteria such as Lactobacillus is stimulated. These latter bacteria produce acid causing souring of fish during storage. Although the fundamental functions of Co_2 have not yet been fully elucidated, it is apparent that when exposed to an atmosphere containing at least 20% Co_2, bacterial activity is inhibited although autolytic changes proceed at the normal pace. Packaging materials generally employed for the purpose are flexible films of nylon/surylyn laminates, plastic moulded trays and overwrap with 75 gauge PVC strech film, polyacrylonitrile/ polythene film laminate etc. In Norway cod fillets are packed in PVC moulded tray laminated with 100 μ LDPE and sealed with 50 μ PVC laminated with 100 μ LDPE film with 50% O_2 and 50% Co_2 and has the shelf life of 19 days at 0-2°C compared to 11 days in air. At 5-7°C the fillet could be kept in acceptable condition for a period of 11 days compared to air packed sample which kept well for a period of 5 days only (Gopal *et al.* 1985). In India not much work is done on the modified atmosphere storage of fish. Gopal *et al* (1990) studied the modified atmosphere storage of fresh water fish fillets (Catla catla) using 12 μ plain polyester laminated with 230 gauge low density polythene. They found that 80% Co_2 and 20% O_2 had the shelf life of 27 days, whereas the sample held in air had the shelf life of only 12 days at 0-4°C. At the time of spoilage the bacterial flora in air was constituted by

Aeromonas (87%) with 3% Vibrio and Enterobacteriaceae and 6% Lactobacillus. The bacterial flora in case of sample stored with 80% Co_2 and 20% O_2 consisted of 48% Aeromonas, 33% Lactobacillus, 5% Vibrio, 5% Bacillus and 9% Pseudomonas.

3. MODERN PACKAGING MATERIALS AND THEIR BASIC CHARACTERISTICS

3. MODERN PACKAGING MATERIALS AND THEIR BASIC CHARACTERISTICS

3.1 MODERN PACKAGING MATERIALS

3.1.1 GLASS CONTAINERS

Glass containers have been used for many centuries and still are one of the important in food packaging.

Glass is made from limestone, sand, soda ash and alumina. Physically it is a super cooled liquid of very high viscosity. Chemically, it is a mixture of inorganic oxides.

Due to its certain properties, glass has its unique place in food packaging. It is strong, rigid and chemically inert. It does not appreciably deteriorate with age and is an excellent barrier to solids, liquids and gases, and gives excellent protection against odour and flavour contamination. The transparancy of glass provides product visibility. Glass can also be moulded to variety of shapes and sizes. But it has disadvantages like fragility, photo oxidation, heavier in weight etc.(Sacharow and Griffin,1980)

Glass containers includes bottles, jars, tumblers and jugs.

3.1.2 METAL CANS

Cans are traditionally used for heat sterilized products. Today there are several choices available: standard tin plate, light weight tin plate, double reduced tin plate, tin-free steel, and vacuum deposited aluminium on steel and aluminium.

Cans are coated inside and/or outside to get desirable properties like acid resistance and sulphur resistance. But care has to be taken to avoid tainting of the lacquer.

Metal cans are advantageous as packages because of superior strength, high speed manufacturing and easy filling and dosing. Disadvantages of metal cans are weight, difficulty in reclosing and disposal.

3.1.3. PAPER

A very considerable proportion of packaged foods is stored and distributed in packages made out of paper or paper based materials. Because of its low cost, ready availability and great versatility, paper is likely to retain its predominant packaging position.

Paper is highly permeable to gases, vapours and moisture and loses its strength when wet. Ordinary paper is not grease and oil resistant, but can be made into grease and oil proof by mechanical process during manufacturing.

3.1.3.1 KRAFT

Kraft papers are extremely strong and is used in bleached or unbleached forms.

3.1.3.2 GLASSINE

They are supercalendered chemical pulp sheet. They have high resistance to air and grease, and are stronger and stiffer than other types and have smooth and glossy surface.

In order to reduce the moisture permeability of grease proof glassine, they are sometimes waxed. Silicone coated glassine is useful when non stick properties are desired.

3.1.4 PAPER BOARD

Thicker paper is called as paper board. There is not a clear cut dividing line between the heaviest grade of paper and the lightest board. Moreover the lightest standard board is 0.19 mm thick (7.5 points) and heavy papers are of 0.125 mm thickness (5 points) (Sacharow, 1977a). Paper boards are used for carton making.

3.1.5 CELLOPHANES

Cellophane was the first commercial film. Cellophane is manufactured from highly purified cellulose derived from bleached sulfite pulp. By incorporating various coatings and modifications, over 100 different grades of cellophane are available now (Sacharow, 1976b).

Uncoated cellophane is flexible, strong, transparent, grease proof, hygroscopic and highly permeable to water vapour. When both sides of the film are coated with moisture resistant lacquers such as nitrocellulose, permeability to water vapour and other gases is greatly reduced. But complete permeability cannot be achieved by nitrocellulose. Saran coated cellophane (polymer coated cellophane) have superior product protection and provide an excellent gas, moisture and oil barrier. Saran coated cellophane is cheaper. Polyethylene coated cellophane is also available. Cellophane is used in lamination also. A transparent lamination used in food industry is Cello-Adhesive-Saran-Adhesive-PE.

But cellophane has very low permeability to odours, especially the vapours of essential oils so that aroma is retained well in packages which incorporate a layer of this films (Bomer, 1957).

3.1.6 POLYETHYLENE (PE)

Polyethylene is the largest volume single film used in the flexible packaging industry. It is available in 4 forms:

(1) Low density

(2) Medium density

(3) High density

(4) Shrink film

Polyethylene is a crystalline polymer with density between 0.915 and 0.960 gm/ml. All PE films are excellent water barrier but fairly poor barriers to nitrogen, oxygen and carbon dioxide. PE is inert to most chemicals. However, animal, vegetable and mineral oils are absorbed by it and may cause it to swell and discolour. Permeability to water vapour and gas decreases as density increases.

Polyethylene is appreciably permeable to a number of organic liquids and their vapours. It is permeable to a number of essential oils which may be disadvantageous when certain materials are packed in polyethylene owing to the gradual loss of odour and flavour (Wight, 1953).

3.1.7 PE MODIFICATIONS

Ionomers are constructed of both covalent and ionic bonds. For example Surlyn A is obtained by cross linking the copolymerised acid groups of polythene with Zinc or Sodium ions (Briston and Katan, 1974). Based on low density

PE, the ionic bonds in ionomers serves to increase overall bond strength and yield superior oil, grease and solvent resistance.

By copolymerizing low-density PE with vinyl acetate, ethylene vinyl acetate is obtained (EVA). EVA is more flexible than PE.

Irradiated PE is produced by irradiation of low density PE with high energy electrons. It has the effect of increasing the strength and heat resistance as well as decreasing the permeability to gases and vapours but permeability to larger organic solvent vapours molecules increases (Kelly *et al.*, 1957).

LDPE has the advantage of maximum flexibility of low cost and is widely used for packaging of tools in bags or as an overwrap. HDPE is used in film form as well as for production of rigid plastic containers. PE are also widely used in laminations where they provide the inner layer requiring heat sealability.

3.1.8 POLYPROPYLENE - (PP)

Polypropylene is produced by the polymerization of propylene. All PP films have permeability about 1/4 to 1/2 that of polyethylene. It is more stronger, rigid and lighter than polyethylene (Sacharow, 1976c).

3.1.9 TYPES OF PP

Cast PP: It is extruded, non oriented film and is characterized by good stiffness, grease and heat resistance and also has good moisture barrier. However, it is not a good gas barrier (Sacharow, 1976a).

Oriented, Heat set (OPP) : Orientation can be in one direction (unbalanced) or in two directions equally (balanced). The resulting film is characterized by good low temperature durability, high stiffness and excellent moisture vapour transmission rate. One drawback of OPP is its low tensile strength.

Coated PP: These newer types of PP are available as heat seal coated or saran (PVDC) coated. They are used when moisture and gas protection is necessary.

Composite PP: This has outer polyethylene plies around PP core. This material can be readily heat sealed and has excellent cold temperature characteristics.

3.1.10 POLYVINYLIDENE CHLORIDE (SARAN) PVDC

PVDC is usually produced as a copolymer with 5-50% vinyl chloride. The higher copolymers are used as coatings and provide an excellent moisture barrier. PVDC is more impermeable than PE. These extremely good protective characteristics have made PVDC an important component of many laminates. It is resistant to oils, grease and alcohols. Properties of PVDC can be changed by varying the degree of polymerization, the proportion of copolymer present and the addition of plasticizers (Sacharow, 1976a).

PVDC is available as shrink and non shrink film. Heat sealing is quite difficult due to its sharp melting point.

PVDC is used in its film form or as a coating or paper film or foil. Laminates of PVDC are excellent barrier and are heat sealable. Usually laminates includes paper - foil-PVDC and cello-PVDC.

3.1.11 POLYESTER (PEST)

The most widely used polyester film in packaging is formed by the condensation polymerization of ethylene glycol and terepthalic acid. These films are characterized by exceptional strength and chemical resistance. Polyester film has gained recognition rapidly for its versatility as packaging film because of its outstanding strength, barrier to gases, aroma retention and inertness to chemicals. It is used in laminates which are expected to be heated (Retort pouch application or boil in a bag pouch). Laminated polyester polythene has unique combination of properties which makes it ideal for high speed vacuum packaging of meat, cheese, coffee etc. (Basu, 1992).

Coated polyster film with PVDC are heat sealable. These coatings also serve to improve moisture vapour rate (MVTR) of the polyester film.

3.1.12 METALIZED POLYESTER

It has very low gas and moisture permeability. Many attempts have been made to replace aluminium foil by metalized polyester. But it does not have the functional barrier properties of aluminium foil. Metalized polyester have advantages like good handling properties and light barrier which prevents oxidative rancidity (Sacharow,1977c).

3.1.13 NYLON (PA)

Nylon (Polyamides) are obtained by polycondensation of diamines with diacids or amino acids. Nylon is available over 100 different film formulations.

Although each variety of nylon film has its own characteristic properties, certain similarities exist. They have excellent thermal stability, highly permeable to moisture but low to oxygen and other gases. Odour retention is excellent and the film is tasteless, odourless and nontoxic. Nylon films are considered to be about 3 times as strong as polyethylene. Nylon/PVDC/PE laminates have good oxygen, water vapour barrier properties, bursting strength, tensile strength and extensibility.

Plastic films like polystyrene, polycarbonate, rubber hydrochloride and cellulose acetate are rarely used for packaging of spices.

3.1.14 ALUMINIUM FOIL

Aluminium foil is defined as a solid sheet section rolled to a thickness less than 0.006". Aluminium has excellent properties like reflectivity, emissivity, thermal conductivity, light weight, corrosion resistance, workability, non-sparking, grease and oil resistant, tasteless and odourless, heat and flame resistance, capacity, non-toxicity and strength account for its popularity as a packaging material. The most outstanding property is barrier. Aluminium foil free from defects is a perfect moisture and oxygen barrier (Sacharow, 1977b).

In all flexible packaging applications using aluminium foil where good moisture and oxygen barrier properties are important, the foil is almost always combined with heat sealing media such as polyethylene. Considering its barrier properties, it is the cheapest material to use for the properties obtained.

3.1.15 LAMINATES

Lamination is a means for producing films or wrapping material which combine the properties of two or more individual components.

The combination of polyester/aluminium foil/polyethylene has been described as practically the most impermeable to all gases and vapours (Selby, 1967).

3.2 BASIC CHARACTERISTICS

3.2.1 MECHANICAL AND PHYSICAL PROPERTIES

Heat sealing : Heat sealing (Paine, 1956) is a process in which two or more films or flexible materials are sealed by the application of heat. It depends usually on the application of heat and pressure simultaneously to the overlapping edges of the wrapper, when fusion and welding take place. Some plastic films such as polythene will seal in this way without the application of any adhesive. Others such as regenerated cellulose films, require to be coated with a special film of lacquer varnish before they can be heat sealed. Some films cannot be heat sealed at all readily owing to their possessing too high or too sharp melting point, or on account of their tendency to shrink when heated as described above.

With many types of foods there is liable to be spillage or contamination of the film pouch along the sealing edges, and this may result in a failure to seal properly. This difficulty is minimized by spreading the seal over a strip of upto 1/4 inch or more in width and various devices such as crimping are helpful. Sometimes, if the temperature is not correctly adjusted or if film is pulled at the moment of sealing, it may become weakened at the seal and subsequently tear or burst.

3.2.2 PERMEABILITY

It relates to its permeability of various volatile and liquid substances. As far as the transmission of volatile substances is concerned, two types of permeability may be distinguished: (i) A solubility effect, by which the gas dissolves in the material of the film on one side, diffuses through and evaporates from the other side. This may be described as true permeability (ii) A pore effect, in which the gas flows through microscopic holes or channels in the membrane.

Most organic films when sufficiently thin exhibit both forms of permeability; metal foils, on the other hand exhibit only the second effect. Porosity falls very sharply as the thickness of the foil is increased, reaching virtually zero with many of the thicker types of commercially available material. For example, aluminium foil of thickness 0.035 mm is said to be practically pore free. True permeability, however, varies inversely as the thickness of the film and hence cannot be effectively eliminated merely by increasing the film thickness in the lower ranges.

The importance of the gas and vapour permeability characteristics of the various plastic film materials is reflected in the large amount of published research work on this subject. The theory of permeability of films to gases has been expounded by Barrer (1941) who defines permeability P by the equation $P = \frac{qx}{At\ (P_1 - P_2)}$

where q is the quantity of gas diffusing through a film of surface area A and thickness x in time t, with a difference $(P_1 - P_2)$ between the partial pressures of the diffusing gas on the 2 sides of the membrane. He shows further that -

$$P = DS$$

where D is the diffusion constant of the gas in the film and S is the solubility coefficient.

3.2.3 WATER VAPOUR PERMEABILITY

The degree of permeability to water vapour is probably the most important consideration governing the selection of a wrapping material for food products, some requiring complete exclusion of moisture and others keep better when the wrapper is permeable to water vapour.

Water vapour permeability is a special case of gas permeability and it follows the same general principles as applied to the latter, within the limitations imposed by the readily condensable nature of water vapour and the nature of the films. In general, hydrophilic films show predictable water vapour permeability over a fairly wide range of temperatures and partial pressure differences, whereas hydrophobic films do not.

3.2.4 PERMEATION OF THE PACKAGE

In practice the shelf life of a food product is controlled by the overall permeation of the package. This depends on a number of factors besides the inherent permeability of the wrapping materials. In particular, the amount of greasing of the wrapper and the method of sealing make important contribution to the efficiency.

3.2.5 SELECTION OF THE TYPE OF MOISTURE BARRIER REQUIRED

The choice of barrier material required for a particular product is generally fairly easily made by analogy with some similar product. However, it is necessary to calculate the permeability of the wrapping material required. A simplified method of doing this is based on the assumption that the materials used are not affected by greasing and seal perfectly as described by Paine (1956). In actual practice this assumption is not true, and due allowance for imperfect sealing and the effect of greases on permeability must be made.

Low permeability to odours (Lehman 1956) of a wrapping material may be important for two reasons, viz., in order that the contents of package shall be protected from the absorption of foreign odours and also to prevent the loss of essential aromas. Therefore some knowledge of the permeability to odour of a packaging material is very desirable. Since there is no satisfactory method for measuring odour, most of the work on this subject has dependence on measurement of the permeability to selected volatile organic materials whose behaviour might be expected to simulate that of the essential oils responsible for aroma. Muldoon and Sylvester (1951) for example have described a method based on the use of methyl furoate, while (Karel *et al*, 1957) used acetone, ethanol and trimethylamine vapours for tests on a number of films. Others have used allyl-isothiocyanate as the test vapour.

3.2.6 CHEMICAL PROPERTIES

The chemical properties of a wrapping material are important only in so far as they can affect the foodstuff which it contains. Paper, consisting mainly of cellulose and most polymers are relatively inert. Aluminium foil is liable to be attacked by salts and alkalies particularly and to some extent by acids, plasticizers, stabilizers & antioxidants, etc. Solvents, plasticizers, accelerators, stabilizers, antioxidants, fillers, dyes, pigments are all liable to be used in certain cases in order to produce a film possessing the right physical characteristics. Various adhesives and varnishes are also used from time to time to produce laminates & coated films.

Many of these substances are not in a polymerized form and therefore are more or less easily leached out by appropriate solvents, particularly when they are liable to be extracted by fatty foods.

Regarding toxicity considerable guidance has been given by Lehman (1956); Crompton (1979); Figge *et al.,* 1978; Murthy & Veeraju (1989) on the types of resins, plasticizers and other additives which may be regarded as safe for use in food wrappings. Safety of the plastics for food contact application has been dealt in detail in the chapter **5**.

4. MANUFACTURE OF CORRUGATED FIBRE BOARD AND PLASTIC FILMS

4. MANUFACTURE OF CORRUGATED FIBRE BOARD AND PLASTIC FILMS

4.1 CORRUGATED FIBRE BOARD

In the modern world corrugated fibre boards and boxes are being used for a wide variety of packaging needs and have become the largest used packing material. Corrugated paper board consists of two structural components namely the liner and the fluting media. These are in required numbers, joined together with special adhesives. Corrugated boxes though simple in appearance are formed with the help of combination of technical skills like engineering, design and graphics and hazard and transportation analysis(Paine and Paine 1983).

4.1.1 MATERIAL

Board consisting of one or more sheets of fluted paper stuck to a flat sheet of paper or board or between several liners usually kraft. This has the following classifications:

a. Single face corrugated

b. 3-ply corrugated

c. 5-ply corrugated

d. 7-ply corrugated

Clearly the material is manufactured from paper as an alternative to wood. The origin, however, is wood as shown below:

Wood

↓

Wood pulp (Sulphate process)

↓

Kraft paper

↓

Corrugated board

↓

Recyclable to paper pulp and back to board

4.1.2 SINGLE FACING

4.1.2.1 SINGLE FACING MACHINE

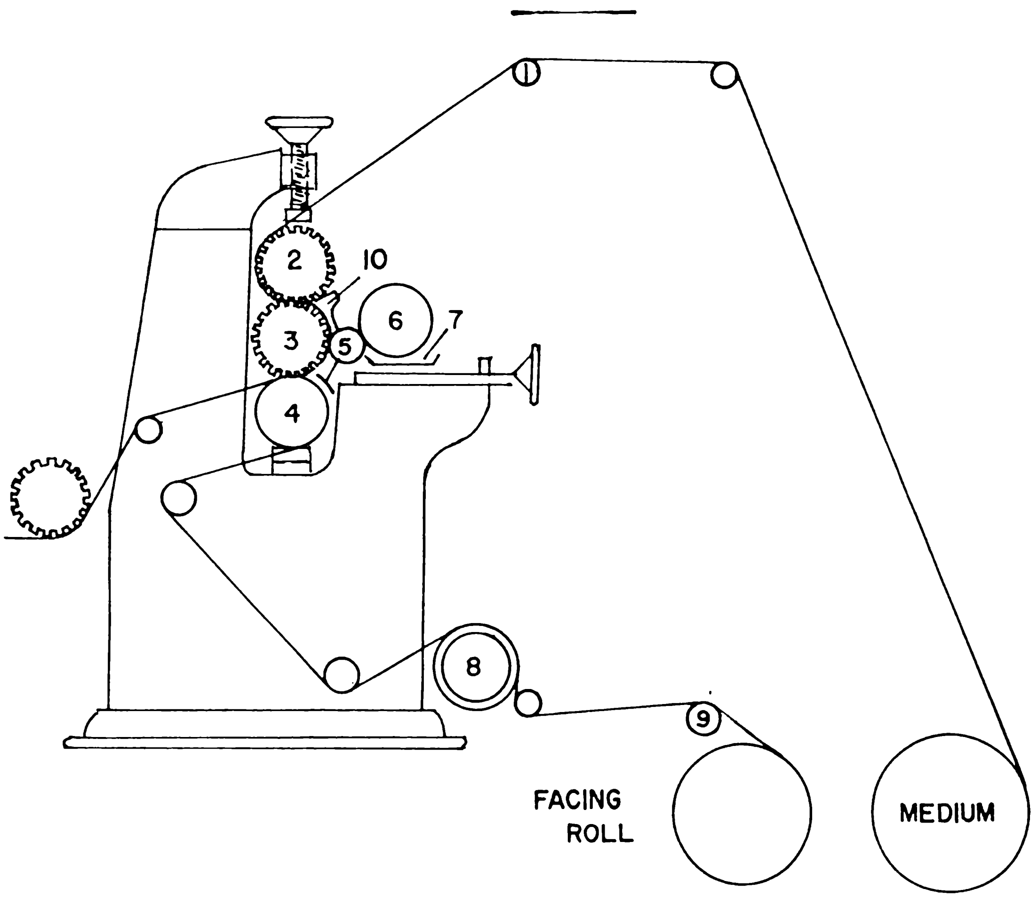
Fluting media are passed through two heated matching corrugated rolls. Adhesives are applied to the tips of the flutes. **(Figure I)** Liner sheet are pressed on to the glued tips of the corrugated sheet. The combined board (single faced corrugated board) is rolled up for subsequent use. Pretreatment like moistening, heating are given to corrugating medium and to the liner. The optimum moisture content of fluting media vary from 6 to 9% and that for liner around 8%. Corrugated rollers are so chosen as to have a particular type of flute contour, say A, B and C. These three types of flutes are common. They have been standardised on the basis of flute height and number of flutes per unit length of board. They are:

Flute	Corrugations per 30 cm.	Height of corrugation (Exclusive of liner)
A flute (Broad)	32 to 38	4.5 to 4.7 mm
B flute (Narrow)	50 to 56	2.1 to 2.8 mm
C flute (medium)	38 to 44	3.6 to 3.8 mm

In addition E flute of height about .9 mm and about 92 per 30 cm length is also used as alternative to duplex board.

In India jumbo flute using higher grammage liner and fluting has been made with a flute height of about 7 mm and about 20 flutes/30 cm. The broader the flute the better is the cushioning and resistance to bonding. The narrower the flute the better is the resistance to flat crush (the column is supported at number of points). Resistance to tear increases with reduction in flute height.

Figure. I.



1. Medium spreader.
2. Upper corrugatting roll.
3. Lower corrugatting roll.
4. Pressure roll.
5. Glue applicating roll
6. Glue Doctor roll.
7. Glue Pan.
8. Pre - beating roll.
9. Liner spreader.
10. Finger.

SINGLE FACING MACHINE

The depth of corrugation ie. flute height depends on the wear and closeness of matching of the teeth. Doctor roll limits the adhesive uptake. Finger guides hold the medium into the flutes of the bottom roll and guide it between bottom roll and glue applicator roll and another to the pressure roll where it meets the liner. Proper adjustment keeps the medium touching the corrugating roll and reduces the excessive fluff out at high speeds till it meets the liner. This increases heat transfer and gives better bond. Finger provides cut into the glue applicator roll and also top corrugator roll in which slots are provided. The tensile strength of the liner can deteriorate at the nip between the corrugating roll and the pressure roll due to excessive pressure (Veerraju, 1990). The liner undergo excessive elongation while under tension between the roll stand and the pressure roll and subsequent shrinkage may distort the flutes. Single faces in India are designed for speeds of 15 to 20 m/sec of corrugated sheet, which means that the dwell time at the pressure nip is very low from 0.03 sec to 0.04 sec (whereas in the modern fast machines it will be only one tenth of this time). The pressure and temperature should be optimum to produce sufficiently strong bond to hold the flute tips to the liner. In the modern machines which run at 200 m/sec the dwell time is only one tenth of this.

Hence the adhesive is to be of a proper quality and consistency to give adequate tack. The quantity of adhesive transferred is controlled by the nip between the doctor roll and the applicator roll. Adhesive consumption can be reduced by gravured applicator roll instead of smooth polished roll (Anon, 1973).

4.1.3 DOUBLE FACING

Double facing is to bond a second liner to the single face corrugated board.

4.1.3.1 MANUAL PROCESS

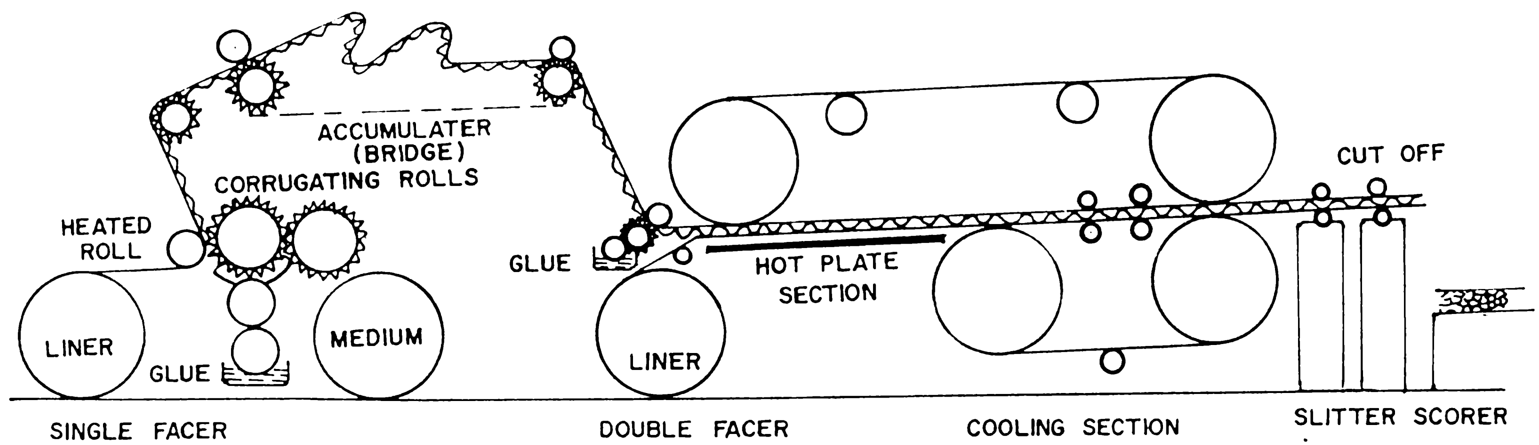
Sheet pasting (gluing) machine and a sheet pressing machine are used in this process. The out sheets of single face corrugated board is passed between a glue applicator roll and a backing roll with corrugations down towards the glue applicator roll **(Figure 2)**. Adhesive sticks to the tips of the corrugations. A precut double back liner is placed on the corrugations and the sheet thus stuck are stacked one over the other. The stack is pressed under the sheet press and left for few hours till the adhesive sets and the board dries. For 5 ply board another single faced board with glue on the corrugation is glued to the 3 ply board in a similar way. High humidity in the atmosphere delays adhesive drying and setting and may lead to fungus growth. Preheating of liners and use of hot adhesive can reduce time. Excessive pressure in sheet press leads to loss of flute height. Too low a pressure results in weak bond. In this process the double back liner being precut can be printed and used, avoiding the difficulty of good printing on the combined board.

4.1.3.2 DOUBLE FACE MACHINE

As the double faced CFB cannot be rolled, it should be cut to the sizes required simultaneously. This is

Figure. 2.

DOUBLE FACE CORRUGATOR



DOUBLE FACER MACHINE

achieved by rotary sheer and can be coupled to printer slotter to set the ready box blanks out of the machine. Ninety percent of the CFB manufacturers use only the single facer and the sheet pasting machine because it is cheaper and has more flexibility to handle small quantities. It is noticed that the board imperfections do not affect printing, as the printing is done on the liner before pasting (Veerraju, 1990).

4.1.4 QUALITY CONTROL IN CORRUGATED FIBRE BOARD

Quality control is the most significant factor for the total performance of the package. The major achievement to be derived from quality control is to correctly predict the performance of the box in various situations and to provide it with necessary strength. George (1993) observed that some of the hazards the corrugated cases may face are:

i. Crushing:- Encountered during stacking and shifting of load in transit.

ii. Impact or shock:- Due to dropping, throwing etc.

iii. Vibration:- Causes loosening and rubbing

iv. Puncture:- Outside contact with projectiles results in punctured surface.

v. Water/moisture:- Exposure to rain and due to condensation on removal from deep freeze; humidity conditions in stores or in transit.

vi. Contamination:-Penetration of or contamination by foreign substances from surroundings like gases or insects.

vii. Temperature change:- Movement from hot to cold or vice versa.

viii. Misplacement:- Can get misplaced in transit or in stores.

ix. Pilferage:- Theft of whole package or portion of contents.

The total quality control must start from the quality control analysis of raw materials. Since the basic component of the corrugated box is the kraft paper, it is essential to have quality control analysis on this material and equally important is the adhesive.

The standard quality checks on kraft paper are as follows:(George 1993)

1. Shade:- The shade should be pleasing, and that of liner should be suitable for printing.
2. Cleanliness:- The paper should be free from dirt and excessive shives.
3. Porosity:- Paper is a porous film. It is generally measured as the resistance of paper to the passage of air. Porosity is reported as the number of seconds required for displacing 100 CC of air. Porosity affects the absorption of adhesive and moisture.
4. Stiffness:- Stiffness is the rigidity of paper. It is related to caliper fibre strength etc. Stiffness is important because the utility of a box partly depends on its ability to resist bulging in filled condition. The stiffness of paper can be measured under the ring stiffness or ring crush test.

5. The uniform basis weight:- This is achieved by the uniform spread of pulp.

6. Bursting strength:- Bursting strength is a complex function of tensile strength and stretch and reveals the interfibre bonding and the pulp formation.

7. Uniform caliper:- The paper should have uniform thickness.

8. Stretch:- Stretch is the amount of distortion which paper undergoes under tensile stress. It is a factor in the bursting strength and initial tearing resistance of paper. Also it is an important factor in the folding endurance.

9. Tensile strength:- When corrugated board is manufactured a high tensile strength helps in resisting web breaks.

The chemical properties of paper are also very important. This directly affects the physical and other properties. Kumar (1990) has pointed out some of the chemical properties to be checked.

1. Moisture content:- Moisture content in paper affects its physical strength and flexibility. It also affects weight, dimensional stability, rigidity, tearing strength, tensile strength, folding endurance and elasticity.

2. pH:- High pH value adversely affects printing. Low pH would accelerate corrosion and pH also affects bursting strength of the paper.

3. Sizing:- Chemical agents are used for sizing while manufacturing the paper. Some of them affects the absorption of adhesives and also may react with adhesives when board is made.

4. Cobb test:- Cobb test is the test carried out to measure the water absorption of paper expressed as Cobb value. Cobb value reflects the sizing and similar properties.

5. Ash content:- Low ash content is essential for high strength in paper. High ash from the residual chemicals left over from bleaching and or dyeing are harmful to the strength and performance of paper.

4.1.4.1 ADHESIVES

There are many types of adhesives, but in fibre board industry the most widely used adhesives are starch based and sodium silicate. Some of these are available as ready mix liquid, as powder to be mixed with water, as powder to be cooked after mixing with water or gel (Murthy, 1972). Following are some of the properties to be checked for the purpose of quality control on adhesives.

(a) Tackiness:- Tackiness refers to the stickiness of the adhesive. It is a combination of plasticity, adhesion and cohesion. There is no specific method to measure tackiness. The practical method is the finger test by which an experienced person gets the indication. Modern synthetic and even some starch based glues are far better in bonding strength with little or no tackiness and therefore in these cases tackiness is not an essential test.

(b) Viscosity:- The viscosity of an adhesive must fall within certain limit. The viscosity directs the amount of adhesive transferred through the glue roll on to the paper. Viscosity is measured by viscometer.

(c) pH:- The pH of the adhesive affects the pH of the combined board. The use of highly alkaline adhesives should be avoided, especially for the outer liner since it affects the printing.

(dO Solid content:- Solid content is another important point while selection of adhesive. Solid content in the adhesive affects bond strength, setting time and stiffness.

4.1.4.2 QUALITY CONTROL IN PROCESSING STAGES

During the manufacture of CFB, different factors must be carefully checked to produce good quality board. The poor quality of CFB results in unsatisfactory functional characteristics in containers. The quality control tests in processing are mostly non-destructive and hence could be carried out on a continuous basis. The following are some of the defects that may occur during conversion (George, 1993).

1. Liner and medium not properly aligned:- This defects occur when the webs are not properly aligned on reel stands and on the rolls. This results in wastage and naked flutes.
2. Corrugation leaning:- Leaning corrugation is responsible for poor flat crush and poor cushioning ability.

3. Blisters:- Due to variable viscosity of adhesives or due to too much heat or speed, the bonding would be intermittent. It affects the bursting strength, flat crush and edge values of the board.

4. Spotty application pattern of adhesives:- This defect occurs when the adhesive is not of proper quality or the transfer roll is defective.

5. Low formation of flutes:- Lack of appropriate moisture content or low pressure on corrugating rolls, can result in low flutes in corrugated board. Also flute rolls must be checked for wear and tear. The finished board will fail in flat crush and edge crush.

4.1.4.3 QUALITY CONTROL ON FINISHED PRODUCTS

CORRUGATED BOARDS/BOXES

The usual tests conducted on corrugated board and boxes are bursting strength, flat crush (for 3 ply board only), puncture resistance, edge crush test, bending stiffness test, pin adhesion (Liner adhesion), water resistance of glue bond, vibration test, compression strength, print quality and the strength of manufacturer's joint. These tests are carried out to ensure production of corrugated fibre board with specified quality standards.

BENDING STIFFNESS TEST

It gives the resistance of the board against bending in the selected area. However it is not related to the buckling resistance or ultimate failure of the board or box.

PUNCTURE RESISTANCE TEST

The puncture resistance value represents the energy necessary for penetrating the board by a pointed head. It is a physical property and gives an idea of the required material strength to withstand an instantaneous application of force. It is dependent both on the basic materials and construction.

EDGE CRUSH RESISTANCE TEST

This test is intended to measure the edgewise compression strength of corrugated fibreboard. This test can be used to compare different material combinations. The test can also be considered to be an index of compression strength of finished boxes along with the bending stiffness of the board.

FLAT CRUSH TEST

The flat crush test is a measure of the resistance of the flutes in CFB to a crushing force applied perpendicular to the surface. Although not directly correlating with box compression tests, flat crush value is a measure of some of the factors involved in the operation of fabricating the board and of the material used to form the corrugations.

PIN ADHESION (LINER ADHESION)

It is the minimum force per unit length of a glued tip necessary for separating the adhesive bond between the liner and fluting under the prescribed conditions. This test reveals the quality of adhesion, which if not satisfactory, would result in delamination of substrates.

BURSTING STRENGTH TEST

It is defined as the peak pressure developed in a hydraulic or pneumatic system in forcing a rubber diaphram through a circular area of a board or paper under specific conditions. It is a physical property and gives an idea of the material. It is easy to understand and record and so is adopted as a standard and common quality control test for paper and board. The bursting strength property depends on the basic material and its construction. The moisture content in the board has direct bearing on bursting strength and with increasing moisture content the bursting strength decreases.

VIBRATION TEST

This test helps to determine the ability of the box including the inner fitments as well as the means of closure adopted to withstand given vibrations. It becomes more significant when sensitive products are packed inside the box.

WATER RESISTANCE OF GLUE BOND

The bond developed between the fluting and the liner should have adequate resistance to water or humidity conditions to avoid easy delamination. Also the outer liner especially must not get easily damaged by an unexpected exposure to rain.

COMPRESSION STRENGTH: This test gives the measure in terms of stackability of the box both under dynamic and static conditions. Compression strength is influenced by all the component materials in the box and the complete manufacturing practice. Almost all aspects that make a box directly influence the value of the compression strength. For example, substance and stiffness of the liner and the corrugating medium, formation and type of corrugation, combination of corrugations, quantity and uniformity of bonding medium, combination of plies, bending stiffness of the board, cutting and creasing of the board, moisture content, style of the box as well as the inner fitments all have a tangible influence on the compression strength. The compression strength is measured under standard conditions of temperature and humidity using a Universal Compression Strength tester with the platten movement fixed at a given speed. The compression strength comes from the load carrying capacity of the vertical panels. The load is generally concentrated only at the corners. The box fails when the lateral bulge becomes sufficiently large and failure lines transmit into the centre of the panel usually beginning from the corners. When flutes run vertically in the direction of the stacking the box will have better load carrying capacity. For combinations it is better that the heavier liner may be placed inside. For superior compression strength it should be ensured that the flutes are not crushed during conversion or printing and the ventilation holes if any must be punched away from the areas of higher stress.

The compression strength measures the load at which the board collapses under laboratory conditions. Such values are generally higher than the load when the box is stacked under sustained load in a warehouse. Therefore such practical working load in the warehouse have to be related to the lab compression strength by a safety factor. This safety factor would be necessarily influenced by the method of stacking, storage time, presence and effect of moisture etc. It can generally vary between 2 and 5.

STRENGTH OF MANUFACTURER'S JOINT

Manufacturer's joint in a box can either be stitched with suitable wire or laminated with tapes. Stitching would ensure a total grip on all plies while taping gives contact only on outer liners. For heavy duty cartons stitching with steel wires would be better. The wire must be rust proof. Number of stitches would depend on the height of the box and the weight and nature of the content.

PRINT QUALITY

Corrugated fibre board have become very important as an advertisement medium. Multicoloured beautifully printed boxes are an attraction on any supermarket shelf. Whether it is heavy duty boxes or carry pack mono cartons, printed display has a valuable role. It also helps identification. Another important point is that probably it is the cheapest advertisement medium. So the quality of the printing must be ensured to withstand transit hazards and must be legible and appealing until the box safely and satisfactorily reaches the consumer. The shipping container need not have printed display value for frozen shrimp for export as it is not kept on the supershelves of the super market. Shrimps are taken out from the duplex cartons and processed and packed in their own cartons at the other end.

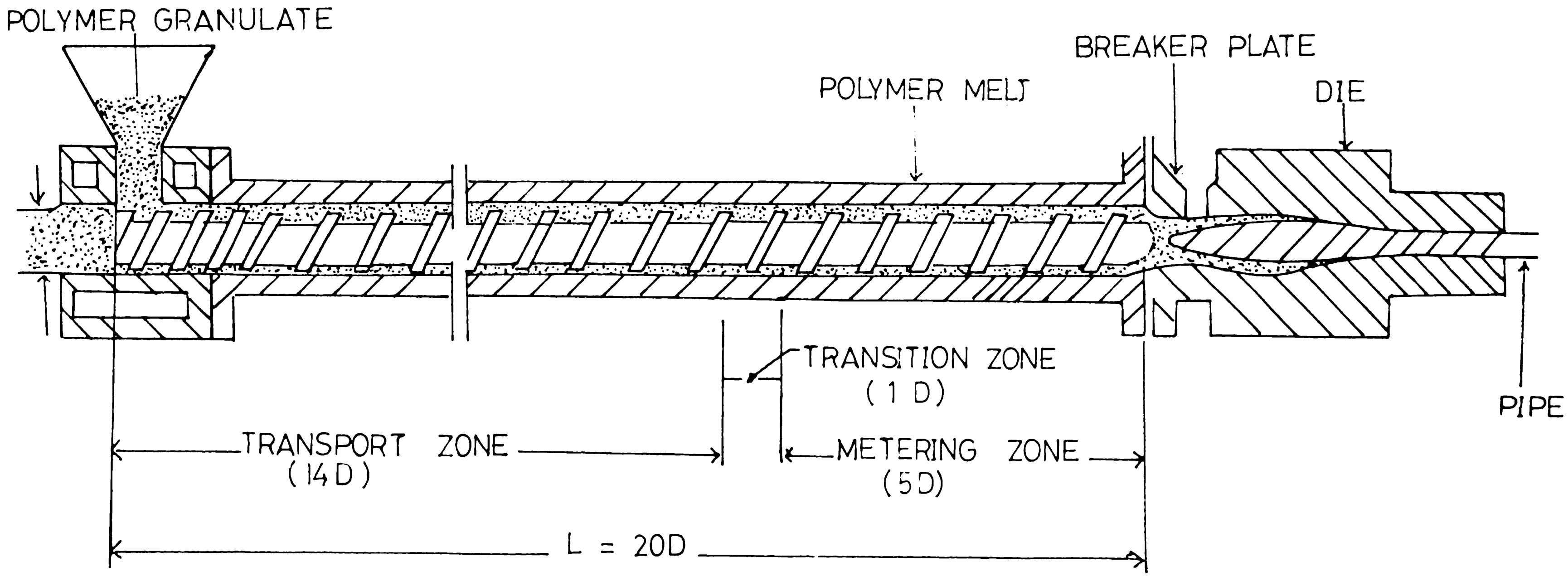
4.2 PLASTICS

4.2.1 EXTRUSION OF FILM

There are fundamentally two different methods of extruding film namely blow extrusion and slit die extrusion (Joseph, 1993). The equipment for film extrusion consists of an extruder fitted with a suitable die, equipment to cool the molten film, haul off machinery and a wind up unit. Blow extrusion and slit die extrusion vary in the design of die used and in the type of cooling. The haul off and wind up equipment is also different. The basic extrusion process is designed to convert continuously a thermoplastics material into a film.

A typical extruder is shown in figure 3 and consists essentially of an Archimedean screw which revolves within a close fitting heated barrel. The plastics granules are fed through a hopper mounted at one end of the barrel by the action of the screw. As the granules move along the screw, they are melted by contact with the heated walls of the barrel and by the heat generated by friction. The screw then forces the molten plastic through the die which determines its final form. The most important component of the extruder is the screw and different designs of screw are used for extruding different polymers. Extruder screws are characterised by their length to diameter ratio (commonly written as L/D ratio) and their compression ratios. The compression ratio is the ratio of the volume of one flight of the screw at the hopper end to the volume of one flight at the die end. L/D ratios most commonly used for single

Figure. 3.

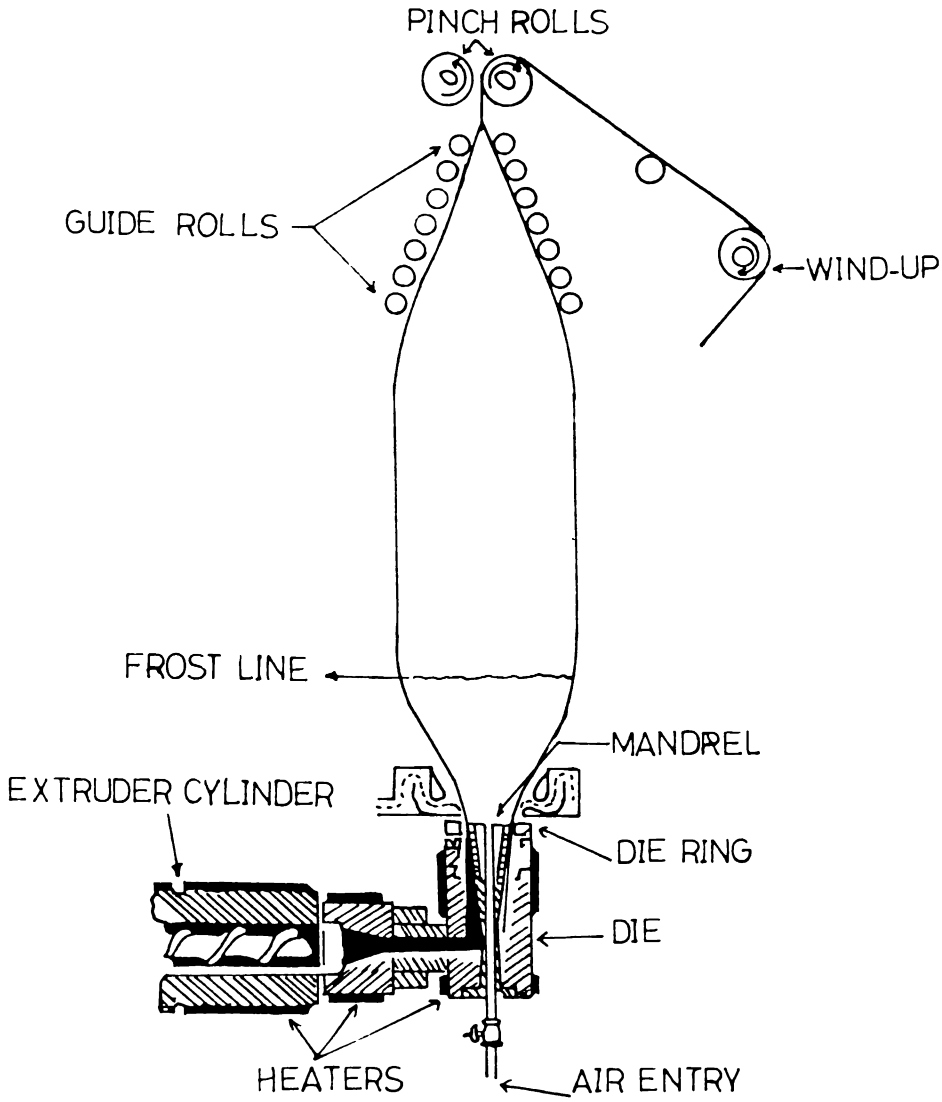


SCHEME FOR A TYPICAL SINGLE SCREW EXTRUDER (L/D = 20) SHOWN EXTRUDING PIPE screw extruders are between 15:1 and 30:1 while compression ratios can vary from 2:1 to 4:1. An extruder screw is usually divided into three sectors, namely, feed, compression and metering. The feed section transports the material from under the hopper mouth to the hotter portion of the barrel. The compression section is that section where the diminishing depth of thread causes a volume compression of the melting granules. The main effect of this is an increase in the shearing action on the molten polymer due to the relative motion of the screw surface with respect to the barrel wall. This improves the mixing and also leads to an increase in frictional heat and a more uniform heat distribution throughout the melt. The function of the final section of the screw is to homogenise the melt further, meter it uniformly through the die and smooth out pulsations. Just prior to the die is fitted a breaker plate supporting a screen pack consisting of a number of fine or coarse mesh gauges. The screen pack filters out any contamination which might be present in the raw material. This is particularly important in the case of thin film extrusion where even the smallest of contaminating particles could cause holes or even breaks in the film. The screen pack also increases the back pressure in the extruder and this improves the mixing and homogenisation of the melt.

4.2.2 BLOW FILM EXTRUSION

A typical set up for blow film extrusion is shown in Figure 4. In this instance the molten polymer from the extruder enters the die from the side but entry can also be

Figure. 4.



BLOWN FILM EXTRUSION

effected from the bottom of the die. Once in the die, the molten polymer is made to flow round a mandrel and emerges through a ring shaped die opening, in the form of a tube. The tube is expanded into a bubble of the required diameter by an air pressure maintained through the centre of the mandrel. The expansion of the bubble is accompanied by a corresponding reduction in thickness. Extrusion of the tube is usually upwards but it can be extruded downwards, or even sideways. The bubble pressure is maintained by pinch rolls at one end and by the die at the other. It is important that the pressure of the air is kept constant in order to ensure uniform thickness and width of film. Other factors that affect film thickness are extruder output, haul-off speed and temperatures of the die and along the barrel (Brydson, 1987). These must be strictly controlled.

4.2.3 SLIT DIE EXTRUSION (FLAT FILM EXTRUSION)

In flat film extrusion the molten polymer is extruded through a slit die and then into a quenching waterbath or on to a chilled roller. In either case the essence of the process is rapid cooling of the extruded film and cooling is therefore applied within a very short distance of the die lips (usually between 25 and 65 mm). This short distance is also dictated by the necessity to reduce "neckling" of the film web, with consequent loss of width. In the chill roll casting method, the melt is extruded on to a chromium plated roller, cured for water cooling. The rapid cooling leads to the formation of small crystallites and this gives a clearer film. Where the quench bath method is used, the water temperature should be kept constant for best results. At constant extrusion temperature, lower quench temperatures improve slip and antiblocking properties and higher quench temperatures give film that is easier to wind without wrinkles and with better physical properties (Oswin, 1975).

4.2.4 CALENDERING

Calendering is a process for producing film or sheet by feeding a plastic mass into the nip between the two rolls where it is squeezed into a film which then passes round other rolls. It emerges as a continuous film, the thickness of which is governed by the gap between the last pair of rolls.

The first stage of calendering process is the compounding of the plastics mix fed to the calender rolls. The mix may be a simple hot melt where polyethylene is being calendered but in the case of PVC (which is the polymer most commonly converted by calendering) the procedure is more complex. One method is to premix the polymer in a ribbon blender with stabilizers, plasticizers etc. and then pass the blend to an internal mixer where the mass is gelled for about 5-10 minutes at about 120-160°C. The gelated lumps formed are made into a rough sheet on a two roll mill and the sheet is fed to the calender.

Calender may consist of two to five hollow rolls (or bowls) arranged for steam heating or water cooling and are characterised by the number of bowls and their arrangement, eg., I, Z or inverted L types. Four roll, inverted L and Z types are the most usual. Calendering usually produces film with a better uniformity of gauge compared with that obtained by extrusion. A number of factors contribute to this, one of which is the great care paid to the engineering of the calender bowls.The final gauge is very much dependent on the gap between the final two bowls whereas in extrusion the gauge is dependent more on blow up ratios (in the case of tubular film)or draw down speeds (in the case of slit die film). In addition in an extruder cross-head die there may be a range of path lengths which lead to preferential flow and induce variation in gauge. In the tubular die process there are complicating factors such as the structures supporting the mandrel in the die. This also has an effect on the melt flow, leading to gauge variations. Another advantage of calendering is that better mixing is obtained. The amount of energy available in a calendering line is very much more than in an extrusion line and therefore calendered film is less dependent on the uniformity of the feed stock.

4.2.5 SOLVENT CASTING

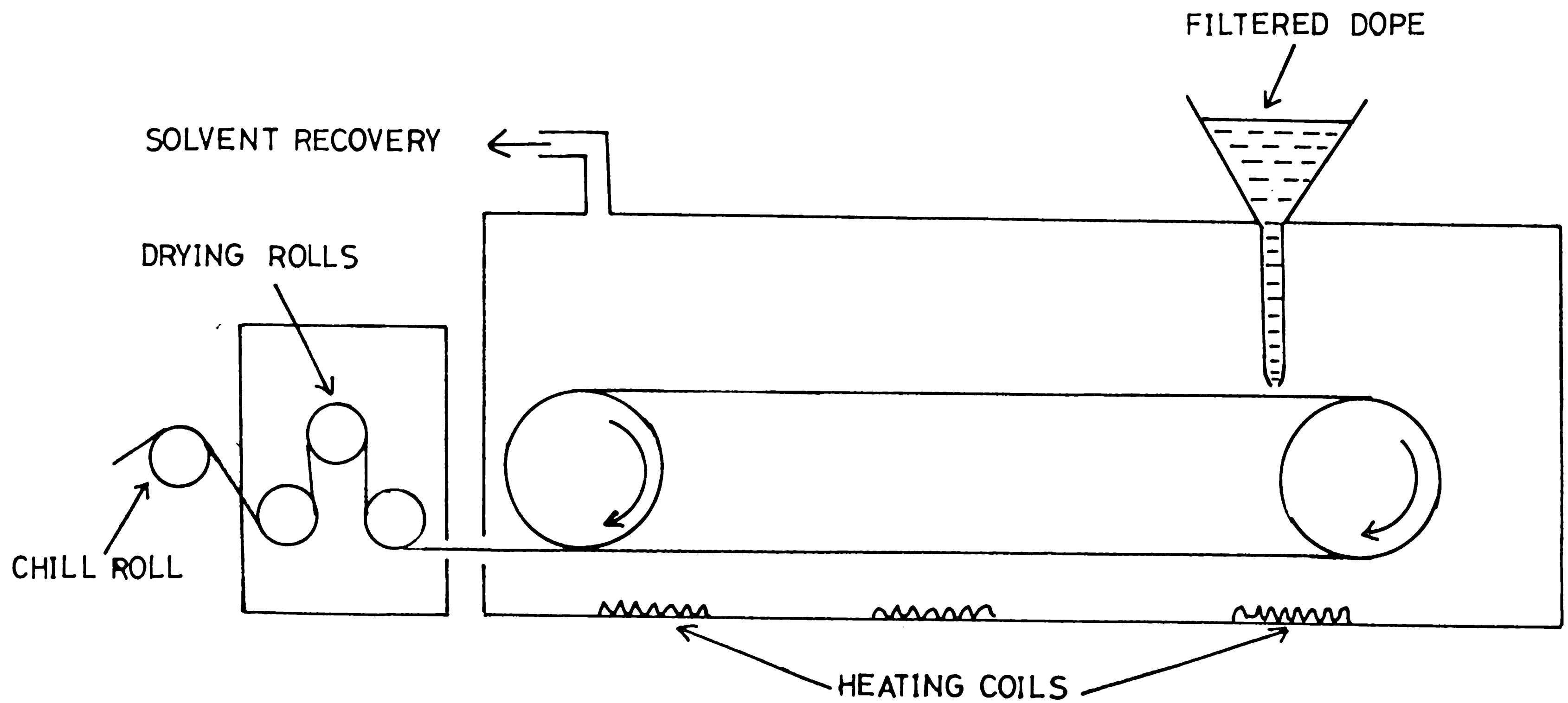
Solvent casting methods are expensive but cellulose nitrate film is made in this way because of the flammable nature of the film. A casting solution is prepared by dissolving cellulose nitrate and camphor (as plasticizer) in a 70:30 ether/alcohol mixture using paddle mixers. After 8-10 hours mixing the product is filtered through cellulose wadding and deaerated in vacuum at a temperature just under the boiling point of the solvent. The film casting is carried out on an endless belt, a smooth surface being obtained by depositing a layer of hard gelatine on a copper support. After being stripped from the casting surface the film is seasoned in a heated drying cabinet where it passes over a zig zag pattern of rollers. After a final passage over chilled rollers to cool the film, it is wound into reels. The general lay out of a film casting process is shown in Figure 5.

Some cellulose acetate film is produced by solvent casting, as well as by extrusion, and solution casting has also been used for producing vinyl chloride/vinyl acetate copolymer films (Parameshwaran, 1993).

4.2.6 CASTING OF REGENERATED CELLULOSE FILM

The basic raw material, cellulose is obtained from wood pulp or cotton linters. After soaking in caustic soda for an hour, the excess alkalie is pressed out. It is then shredded and allowed to age for 2-3 days and absorbs oxygen from the air. This reduces the length of the cellulose molecule chain and so reduces the viscosity of the solution during the next stage. Here the pulp is transferred to rotating chums and then sprayed with carbon disulphide. The solution is discharged into a tank and dispersed by stirring with dilute caustic soda solution. The resultant solution is known as viscose. Viscose solution is then allowed to ripen for 4-5 days. The ripening process consists of a slow hydrolysis the progress of which is followed by taking viscosity measurements. If ripening goes too far, a gel is formed which is useless. Air bubbles in the solution are removed by drawing a vacuum and a film is formed by casting on to a drum or endless metal band, which revolves in the

Figure. 5.



ENDLESS BELT METHOD OF CASTING CELLULOSE NITRATE FILM first of a series of tanks. The thickness of the film is regulated by varying the orifice at the base of the casting hopper or reservoir.

The first tank contains the coagulating solution consisting of sulphuric acid and sodium sulphate at a temperature of about 40°C. This solution not only coagulates the viscose but initiates its regeneration back to cellulose. The coagulated film is then led through further tanks by means of guide rolls. The tanks contain various solutions designed to complete the regeneration,wash out acid carried over from the coagulating bath, remove any elemental sulphur, carbon disulphide, hydrogen sulphide etc. and bleach the now transparent but still slightly colored film. The film is then run through a bath containing glycerol or ethylene glycol which act as plasticizers and confer flexibility on the film. Finally it is passed through a drying oven and reeled up.

At this stage, the film is extremely permeable to moisture vapour and is not heat sealable and a subsequent coating treatment must be given if moisture proofness or heat sealability are required. A typical coating consists of dibutyl pthalate plasticised cellulose nitrate, together with waxes and natural resins dissolved in organic solvents. Urea formaldehyde is also incorporated to anchor the coating and prevent it from floating off in damp conditions. The film is passed through the coating bath, dried to evaporate the solvent, then passed through a high humidity chamber to restore the flexibility. A coating of polyvinylidene chloride is applied when better barrier properties are required (Kumar, 1989).

5. SAFETY EVALUATION OF PLASTIC MATERIALS FOR PACKAGING

5. SAFETY EVALUATION OF PLASTIC MATERIALS FOR FOOD PACKAGING

In the field of food packaging plastics have been a relatively recent entry compared to such materials like glass and metals. While there has been adaptation of many of the traditional packaging materials eg. paper, glass and metals (tin, steel and aluminium), much of the growth has been due to the development of plastic or flexible packaging materials. Flexible plastic packages may be composed of a single component (usually one chemical substance in polymeric and building block form) or multiple components consisting of a variety of materials usually laminated in layers, offering many advantages not provided by single component packages.

India is no exception to such onslaught by plastics in food packaging industry. The consumption of plastics in food packaging industry is estimated to be about 5.5 million tonnes compared to about 2 million tonnes during 1985-86 (Murthy and Veerraju, 1989). The impact of plastic has been so magnanimous particularly in the food packaging industry that they have revolutionized the science and art of packaging. Such an unparalleled versatality of plastics arises due to the host of important characteristics among which most important is their capability to provide a multitude of combinations and permit effects which is not possible with other materials.

Flexible packaging materials are often composites of functional additives, or processing aids, such as catalysts, antioxidants, heat stabilizers, plasticizers or colourants. Most of these additives are used in small amounts ie. 1-2% (Seymour,1986). Catalysts such as benzoyl peroxide are added to initiate polymerisation in film manufacture. Antioxidants such as butylated hydroxytoulene (BHT) prevent oxidative deterioration of packaging materials. Other additives such as calcium and zinc containing compounds and epoxidized soybean and linseed oils serve as stabilizers, preventing degradation of packaging materials when heated or exposed to ultraviolet (**UV**) irradiation. Colourants may be used to enhance the eye appeal of packages or they may provide more specific functions such as protection (screening) from UV irradiation. Plasticizers are substances used in some films, particularly in PVC and a few other brittle plastics, to soften and provide flexibility.

5.1 PLASTICIZERS

Accidental discovery in the early 1970s of tissue culture media contaminated with plasticizers triggered a series of investigations into the possible leaching of various chemical compounds out of PVC materials and into surrounding media(Carter,1977). Modern plastics Encyclopedia (Anon, 1980-81) lists 480 plasticizers, 100 of which are commercially important in the plastics industry (Sears *et al.* 1985) and even fewer of which are commercially important in food packages. Esters of pthalic acid (pthalates) constitute the major class of plasticizers permitted by FDA for use in food contact plastics. Several different forms of pthalates are available, some of the most common are referred to abbreviations such as DEHP (Di-2-ethylhexyl pthalate) and DOP (Dioctyl pthalate) (IFT, 1974). Migration of DEHP was observed in lipid extracts of plasma taken from plastic transfusion packs, in whole human blood and rat blood which had been circulated in PVC tubing and in blood which had been stored in plastic bags (Marcel and Noel, 1970; Jaeger and Rubin 1970a, b). Migration of plasticizers from PVC products was traced to cap liners (Dczeevw *et al*, 1975), blood tubing used in hemodialysis (Ono *et al*., 1975), blood bags (Jaeger and Rubin, 1972) and Umbilical catheters (Hillman *et al*., 1975).

On the basis of observations made upto 1974, the Institute of Food Technologists' Expert Panel on Food Safety and Nutrition reported that no evidence existed of toxicity in man due to pthalates from either foods, beverages or household products as ordinarily consumed or used (IFT, 1974). On the basis of this observation, coupled with the limited use of pthalate - containing food packaging materials and the low rate of migration of the plasticizers from package to food, the Expert Panel concluded that pthalates in food packages represent no significant hazard to human health. More recently, Giam and Wong (1987) reviewed the distribution and concentration of plasticizers in food and found that data on the occurrence of plasticizers in food were limited. In a study of the migration of di-2-ethylhexyl adipate (DEHA) into a variety of foods during inhome use of PVC films such as wrapping and covering of foods, use of film during marinading of meats and covering of food during microwave reheating of cooked foods. Startin *et al.*, (1987) found that migration of the compound did occur and it increased with length of contact time and temperature and levels of migration were highest when there was direct contact between the film and foods with a high fat content at the surface. Highest levels of migration were observed for microwave cooked meats (roast chicken 151 mg/kg and pork spareribs 351 mg/kg). Lower levels of migration were seen in microwave boiled carrots (3 mg/kg) and potatoes (4 mg/kg). Lowest levels were observed for fruits and vegetables (except avocado) wrapped in PVC film and in foods where PVC film was used for food preparation (including microwave reheating) with little or no direct contact between food and covering.

Castle *et al.* (1987) conducted a similar study of the migration of DEHA and PVC film but examined levels in retail foods wrapped in plasticized PVC film rather than in home use of the film. They also observed that levels of the migrant correlated with the extent of contact between the film and exposed fatty portions of the food. Levels ranged from 1.0 to 72.8 mg/kg in uncooked meat and poultry, 27.8 to 135 mg/kg in cheese, less than 2 mg/kg in fruits and vegetables and 11 to 212 mg/kg in baked goods and sandwitches.

5.2 VINYL CHLORIDE

In the mid 1970s, concern was expressed about the use of PVC in food and alcoholic beverages because residual vinyl chloride monomer was discovered within the PVC container and questions were raised about possible migration of the monomer into food (Cocco, 1986). PVC was prior sanctioned for use in general food contact applications. Also PVC resins are listed in a number of specific FDA regulations relating to food contact substances (Cocco, 1986). However since the vinyl chloride monomer did not have clearance at the time the questions arose, FDA proposed a ban on the use of vinyl chloride for PVC food packaging but did not issue a final rule. PVC film manufacturers have responded by reducing the levels of vinyl chloride monomer in PVC film and have demonstrated that the maximum potential migration at these new levels is less than the capability of measurement by the most sensitive methods currently available (Mathis, 1983). As a result FDA is expected to clarify its position on the use of PVC for food and alcoholic beverage packaging (Cocco, 1986). The codex committee on food additives and contaminants recently proposed guideline levels of 1 ppm for vinyl chloride monomer in PVC packages and 0.01 ppm for the monomer in food (Anon, 1988).

5.3 AMINE PRECUSSORS, NITROSAMINES

Potential nitrosamine formation from the reaction of nitrites commonly used in the preparation of cured meat products with amine precussors in rubber nettings used to package some cured meat products has received publicity. Sen *et al.* (1987) have recently shown that the use of rubber netting to hold hams and other cured products during processing could result in migration of upto 504 ppb of volatile nitrosamines. The theory is that amine precursors such as diethyl dithiocarbamate and dibutyl dithiocarbamate in the rubber netting react with the nitrites added to the meats. A concentration gradient of nitrosamines was observed in the meat, with levels higher in the outer layers of the meat products and lower or absent towards the center. Most unused rubber nettings contained only trace amounts of nitrosamines and cured meats packaged in plastic wrappings or cotton nettings contained no nitrosamines. Sen *et al.*, (1987) recommended that nettings other than those composed of rubber be used or that rubber netting components be improved.

Hotchkiss and Vecchio (1983) observed migration of traces of volatile nitrosamines from paper based packaging materials. Sen and Baddo (1986) found that migration from package components could explain the sporadic occurrence of nitrosamines in margarine and other edible oils. IFT expert panel on food safety and nutrition concluded that the significance, if any, to human health of the very low level of volatile nitrosamines in human foods is unknown and further that foods as currently known are minor contributors to overall exposure to these compounds (IFT, 1987).

5.4 OTHER MIGRANTS

Concern has been expressed about the potential health risk of stabilizers from soft plastic wraps and printing ink (Carter, 1977). The concern about printing ink focused on the potential for lead migration from the package to the food. Lead and other toxic materials are banned from use in inks used in food packages. Of greater concern now, however are preprinted packaging materials that are rolled after printing to be used in form, fill and seal processing machines. While on the roll, the inside of one package comes directly in contact with the outside of another package. The ink and the solvents that it may be dissolved in can readily contaminate the inside of the package.

Migration of substances in toxicologically insignificant amounts but at levels sufficient to affect product flavour and odour is of a more practical concern, from both a consumer stand point and an industry perspective. In general it is difficult to trace the source of off odours and flavours in food. Many compounds responsible for off flavours have low detection thresholds, often lower than the detection limits of the analytical instruments available. While these odour-active compounds may pose little or no health risk, they may cause much concern in the consumer's mind about product contamination. Despite their safety, food products will not be purchased if off flavours or odours are present. Several cases of off flavours in foods traced to packaging materials were reviewed by Passy (1983). An off flavour in fruit flavoured soft drinks packaged in pouches made of a polyester/ aluminium foil/polythene laminate resulted from the improper drying of the adhesive used in the lamination process. The off flavour was attributed to the presence of toluene in the faulty pouches at levels 26-68 times greater than that in good pouches. In another case chocolate and lemon cream cookies packed in polystyrene trays and overwrapped with cellophane developed off flavour due to migration of residual styrene monomer from the polystyrene trays. Analysis of the trays however showed residual monomer levels of 0.18-0.20% well below the specification maximum of 0.5%. The package was thus acceptable according to compositional limits but resulted in tainting of the food. This not only an example of an off flavour in food resulting from migration from the packaging material, but also a case in which the existing regulations guarantee the safety and wholesomeness of food but do not guarantee its quality.

5.5 AVOIDANCE OF POTENTIAL PROBLEMS THROUGH QUALITY CONTROL

Above mentioned few examples are the cases related to off flavours in foods that occur as a result of packaging materials. There are undoubtedly many more cases, reported and unreported as well as potential cases which have been averted by appropriate manufacturing quality control procedures. One recent report by McGorrin *et al.* (1987) detailed the detection of musty odour in a packaging film upon inspection by plant personnel. Analytical procedures narrowed the list of possible contaminants to four compounds. Further evaluation enabled identification of the responsible compound. It was postulated that formaldehyde from an unknown source reacted with the residual 2-methyl-2-4-pentanediol compound that had been used as a coating material to help ink adhere to the film. By limiting the amount of residual coating material, the film manufacture was able to prevent the formation of the musty odour.

5.6 REGULATION OF PACKAGE COMPONENTS

For regulating their use, many countries have formulated standards and codes for the manufacture and use of plastic materials in contact with foodstuffs appropriate to the conditions and situations in these countries. India too has made a beginning in that direction. The Bureau of Indian Standards (BIS) has formulated positive list of constituents in and specifications for plastics commonly used in food packaging, such as polythene, polypropylene, polystyrene, PVC, nylon and ethylene acrylic acid.

Basically regulations pertaining to food packaging materials comprise (Murthy and Veerraju, 1989);

1. Regulations for adjuvants (antioxidants, plasticizers etc.) used in food packaging materials. Generally in these regulations, control is placed on material composition ie. the amount of the adjuvant which can be used as well as the kinds of plastic in which it can be used are prescribed.
2. Regulations for the basic polymeric resins used in food packaging.
3. Regulations for the finished packaging material on the limits on global migration from the final food contact article. The limitations would thus include the contributions from all the adjuvants and processing aids used in making the food contact film, bottle etc. In these regulations, the time/temperature/solvent conditions for the short-term extraction experiments (well known as migration tests)used to test compliance are spelled out

All these regulations ultimately rest on a comparison between the acceptable daily intake (ADI) derived from animal feeding studies and the maximum estimated daily intake (EDI) for the additive. A knowledge of ADI is essential for fixing the limits for the amount of adjuvants that migrate from the packaging material. In order to determine the EDI, extraction experiments are required which simulate, to the extent possible, the most severe proposed conditions of use and the maximum user daily intake. In case of adjuvants, the results of these experiments are used to get limits on the concentration in the plastic so that exposure does not exceed acceptable limits.

The measurement or estimation of individual migrants (specific migration) in the foodstuffs is extremely difficult and laborious as against the estimation of all the migrants together (global migration) which is relatively simpler. Even this global migration is difficult to estimate in actual foodstuffs which are generally complex. Hence foodstuffs are categorised into few groups like high fat foods, alcoholic foods, acid foods, aqueous foods etc. and solvents to simulate the extractive character of each of the food types are chosen with appropriate simulation factor, to render easy estimation and reproducibility. The global migration includes the migration of non-toxic substances also. However if the limit for global migration does not exceed the limit of any of the migrants from the plastic it may still be safe. But the actual global migration limits generally agreed upon are only compromises.

Annexure A gives the global migration limits specified by a few of the important regulating agencies of the world. From the table it can be seen that the nature of the test and limits are not uniform in all the countries. Anon (1984) and FDA (1983a) have given different migration limits for different types of plastics. The regulation of Food and Drug Administration (FDA, 1983a) covers a wide range of plastics and clearly specifies for each plastic material either migration or extraction test depending upon the manner of their use for food. FDA(1983a) covers numerous polymers such as polyolefins, acrylics, nylons, polyesters, vinyls,thermosets, polycarbonates, ionomers, sealing gasket, cellophane, chlorosulphanates and others. Further parts 175 and 176 in FDA (1983b) gives specifications for adhesives, resinous coating, coated papers and other substances for use as components of coatings.

The FDA (1983a) and Anon (1981) specify only hexane and xylene extraction limits by refluxing for polyolefin resins when used singularly and only migration limits when used as coatings or laminates. IS (1974) prescribed this extraction requirement earlier, but substituted this requirement by global migration limit in its specification (IS, 1982). The reflux extraction tests are much simpler and can be expected to reflect the amount of degraded portions of the recycled materials in addition to other additives. Because of this, the reflux extraction test for polyolefins appears to be more relevant to Indian situation where there is likelihood of addition of too much of recycled material to the virgin polymer (as in the case of largest used plastic - the polyethylene).

Annexure B gives specific migration limits for heavy metals and volatile toxic monomers such as vinyl chloride in PVC, styrene from styrene based plastics, acrylonitrile from nitrile plastics and non-volatile monomers from thermosets. Even here the limits vary from country to country. Anon (1984b) has fixed limits for the migration of heavy metals for all plastics and monomers for some whereas ISI has fixed the migration of heavy metals only for PVC.

Annexure C gives categorisation of foods and the corresponding simulants to be used in the migration tests. FDA (1983) and Anon (1984a) have categorised foods into typical groups like acidic and non-acidic aqueous foods, oils and fats, fatty foods, dairy products, alcoholic beverages, dry solids with and without fat and specified typical simulants for these categories. IS (1981) has stipulated many food simulants but without categorising the Indian foods.

It has indicated that the choice of the simulating solvent shall be dependent on the nature of the food and in case of dispute, the threshold value of migration shall be satisfied for all solvents and with all test conditions. It is noted that IS is the only one to give hexane as one of the simulants, whereas FDA (1983) is the only one not to give acetic acid as a simulant. Thus there is a need to study and categorise Indian foods and specify right type of simulant for the migration tests.

Annexure D gives time-temperature conditions specified for migration tests. As can be seen from this table, the temperature-time combinations are highly divergent even for the same use condition from country to country. For example FDA (1983) specifies 120°C for 2 hours for high temperature-heat sterilisation, whereas Anon (1984) specifies 95°C for 30 minutes for sterilisation above 100°C and ISI has no suggestion for this condition. For room condition storage, FDA specifies 49°C for 24 hours whereas IS (1981) specified only 40°C for 24 hours for our hotter climate. Similarly for migration with heptane, Japan specifies 25°C for 60 minutes, whereas IS:9845 (1981) specifies 25°C for only 30 minutes. In the light of this, the test conditions given in Indian Standard appear to be lower. The migration of constituents increases exponentially with temperature (Crosby, 1981). The test temperature should always be equal or more than the worst use condition, whereas the longer time of contact (as in long storage) can be simulated by a lesser contact time (laboratory test time) using higher temperature.

Since the last few years there is spurt in the introduction of many more flexible plastic laminates and plastic bottles for consumer packaging of foodstuffs in India. Also the general awareness towards their safety for using them in direct contact with foods has increased very much. As a consequence, the formulation of regulatory measures has become the need of the day. However, these regulatory measures have to be preceded by the development of suitable methods (procedures and apparatus) to be incorporated into the regulations for effective control. IS 9845 (1981) covers only partially and even the existing standards as mentioned earlier are not very relevant to the Indian situation.

Annexure A

Global migration limits

Country	Global migration limits	Limits for extraction by refluxing
India	60 mg/kg or 60 mg/litre or 0.1 mg/cm^2 for containers of capacity less than 250 ml for polythene (IS:10146, 1982) PVC (IS:10151, 1982)and Polystyrene (IS:10142, 1982)	5.5% in hexane and 11.5% in xylene for polyethylene (Now discontinued)
Europe	60 mg/litre or 60 mg/kg or 0.1 mg/dm^2 for all plastics and laminates (EEC, 1978)	Nil
United Kingdom	3 micron formaldehyde/ sq.cm. in Melamine formaldehyde (BPF,1981)	5.5% in hexane and 11.5% in xylene for polyethylene. 6.5% in hexane and 10% for xylene for polypro-pylene
Japan	150 mg/litre for PE, PP & 30 mg/litre for container to be used above 100°C. 15.3 mg/ litre for Nylon 240 mgs/ litre for Polystyrene (Japan, 1984)	10 ppm of potassium permanganate consumption for water extract for all plastics
U.S.A	50 mg/litre or 0.5 mg/ inch^2(0.08/cm^2) for all plastics and coatings and for sizes below one gallon (FDA, 1983)	(i) 5.5% in hexane & 11.3% in xylene for PE. (ii) 6.4% in hexane & 9.8% in xylene for PP. (iii) 1.0% in ethyl acetate & benzene for nylon. (iv) 0.15% in water, 1.50% in alcohol and n-heptane for polycarbonates

Annexure B

Limits of Monomer & Heavy Metals in Plastics

Country	Limit for Monomer	Limit for heavy metals
India	VCM in PVC 1 ppm; in food migration 10 ppb; Styrene in polystyrene 2000 ppm	Pb 1 ppm and others 0.01 ppm in PVC
Europe	VCM in PVC 1 ppm	Nil
United Kingdom	VCM in PVC 1 ppm. Styrene in PS 5000 ppm	Nil
Japan	VCM in PVC 1 ppm. Volatile component in polystyrene 5000 ppm. Vinylidine chloride in PVDC 6 ppm. Caprolactum in Nylon 15 ppm.	i) 100 ppm dibutyletin and 1000 ppm cresyl phosphate in PVC. ii) Pb, Cd & Ba 100 ppm each in PVDC. iii) 0.05 ppm Antimony and 0.1 ppm Germanium in PET.
U.S.A	VCM not specified Styrene in PS 10000 ppm and fatty foods contact 5000 ppm. Acrylonitrile in ABS plastics 11 ppm.	Nil

VCM : Vinyl chloride monomer

PVC : Polyvinyl chloride

PVDC : Polyvinylidine chloride

PS : Polystyrene

Annexure C

Food Simulants and Categorization of Foods

Country	Simulants	Food classification
India	(a) Distilled water (b) 3% acetic acid (c) 8% alcohol (d) 80% alcohol (e) Hexane (f) Heptane	Make appropriate choice. Use all solvents in case of dispute
Europe	(a) Distilled water (b) 3% acetic acid (c) 15% alcohol (d) Rectified olive oil or sunflower oil or standard synthetic triglyceride	Nil
United Kingdom	Nil	Nil
Japan	(a) Distilled water	For all foods
	(b) 20% alcohol	For liquors and spirits
	(c) Heptane	For oils, fats and fatty foods
	(d) 4% acetic acid	For all other foods
U.S.A	(a) Distilled water	For acidic and nonacidic aqueous products, dairy products, non-alcoholic beverages and bakery products
	(b) Heptane	For oils, fats, dairy products and aqueous products containing free oil
	(c) 8% or 50% alcohol	For alcoholic beverages containing 8% or more of alcohol

Annexure D

Time-Temperature Conditions for Migration Tests

Country	Condition of test	
India (IS:9845, 1981)	(i) 60°C for 2 h, brief contact at high temperature (ii) 40°C for 24 h long contact at room temperature (iii) 40°C for 30 min (hexane) (iv) 25°C for 30 min (heptane)	Water, 3% acetic acid, 8% or 80% alcohol
Europe (EEC, 1978)	70°C for 2 h - Accelerated 40°C for 10 days - simulating long term room temperature storage for all simulants.	
United Kingdom (BPF, 1981)	Same as EEC	
Japan (Japan, 1984)	60°C for 30 min with acetic acid, alcohol, water 25°C for 60 min with heptane 95°C for 30 min for use above 100°C	
U.S.A (FDA, 1983)	121°C - 2 h with water sterilising temperature 66°C - 2 h with water & 8% alcohol - Hot filled or pasteurised below 150°F 49°C - 24 h with water - Room temperature and 8% alcohol filled and stored 38°C - 30 min. with heptane - Hot filled or pasteurised below 150°F 21°C - 30 min. with heptane - Room temperature filled and stored	

6. MATERIALS AND METHODS

6. MATERIALS AND METHODS

6.1 MATERIALS

6.1.1 FISH

The fishes used for the studies and its scientific names are given below:

Common name	Scientific name
Mackerel	*Rastrelliger kanagurta*
Seer fish	*Scomberomorus guttatus*
White prawn	*Penaeus indicus*

Mackerel, seer fish and prawns were collected from fisheries harbour, Kochi soon after landing. All the samples were iced immediately. Fishes were sorted and only extremely fresh and uniform sized samples were used for the studies.

6.1.2 PACKAGING MATERIALS

The packaging materials used for the studies are:

(1) Corrugated fibre board (CFB) or master cartons

(2) Kraft paper

(3) Waxed cartons (Duplex cartons)

(4) Recycled high density polythene strap

(5) Virgin high density polythene strap

(6) Polypropylene strap

(7) Rayon strap

(8) Low density polythene (LDPE)

(9) High molecular weight high density polythene (HM-HDPE)

(10) Cast polypropylene (CPP)

(11) Oriented polypropylene (OPP)

(12) Moisture proof saran coated on both sides of transparent cellophane (MXXT)

(13) Polyester (PEST or PET)

(14) Linear low density polythene (LLDPE)

(15) 12 μ polyester laminated with 300 gauge low density polythene (12 μ PEST/300 gauge LDPE)

(16) 12 μ metallised polyester/150 gauge LDPE (12 μ met PEST/150 gauge LDPE)

(17) 300 moisture proof saran coated on both sides of transparent cellophane laminated with 150 gauge low density polythene (300 MXXT/150 gauge LDPE)

(18) Glassine

(19) 250 gauge low density polythene - High density polythene co-extruded film (LD-HD)

(20) 90-100 μ low density polythene/Barrier/Nylon/Barrier/ Primacore.

(21) 150 gauge polyester tracing sheet

(22) Code slip made out of paper

(23) Nylon - 6 (PA)

(24) Moisture proof sealable transparent cellophane film

(25) 12 μ plain polyester laminated with LDPE-HDPE co-extruded film (12 μ PEST/LD-HD)

(26) 12 μ metallised polyester laminated with LDPE-HDPE co-extruded film (12 μ met PEST/LD-HD)

(27) 12 μ metallised Nylon/200 gauge LDPE co-extruded film

(28) 100 μ high density polythene/LDPE-HDPE coextruded film

(29) 90 μ LDPE/LDPE co-extruded film

(30) 12 μ polyester/118 μ LDPE-HDPE co-extruded film (12 μ PEST/118 μ LD-HD)

(31) 12 μ Nylon/ionomer co-extruded film

(32) 120 μ high density polythene/low density polythene

(33) 60 μ low density polythene/Nylon/low density polythene

6.1.3 REAGENTS

Analytical grade reagents supplied by B.D.H. (India) E.Merck (India) and Sarabai M. Chemicals and Qualigens (GR quality) were used for experiments.

6.2 METHODS

6.2.1 PHYSICAL AND CHEMICAL METHODS

Master cartons (corrugated fibre board) used in frozen shrimp processing factories in and around Kochi, Veraval, Kakinada, Bombay, Tuticorin, Kollam and Paradeep were used. The samples were conditioned before testing by the method described in IS : 1060 (1966). They were tested for different parameters as per IS specification (IS : 6715, 1972). Bursting strength and water proofness expressed in terms of cobb 30' value were determined as per IS : 1060 (1966). Puncture resistance, combined weight of liners and corrugating medium were determined according to IS : 4006 (1972). The wax content in the corrugated fibre board was determined by the method of IS : 3962 (1967). The type of flute was determined as specified in the IS : 2771 (1977).

To find out the effect of quality of kraft paper on the physical properties of corrugated fibre board, kraft paper samples were collected from the corrugated fibre board (CFB) box fabricators from 4 different factories. They were subjected to the conditioning as per IS : 1060 Part I (1966) at 27°C and 65% RH. Thickness, grammage, tearing strength, bursting strength and burst factor were determined as per IS: 1060 Part I (1966) and tensile strength in machine and cross directions as per IS : 1060 Part I (1966) by taking 18 cm length of the specimen. The tensile properties of virgin, non virgin and semi virgin kraft papers were tested in the Universal Testing Machine Zwick 1484. Ring stiffness value was determined as per ASTM (1968b).

A large number of samples of kraft papers of different manufacturers in the grammage 120-180 GSM normally used by the converter industry were collected from the CFB box fabricators in and around Cochin and their relevant properties like burst factor, breaking length, tear factor, ring stiffness and cobb value were studied as per the test methods laid down in IS : 1060 (1966), IS : 4006 (1972) and ASTM-D 1164 (1968b)and compared with specifications of kraft paper IS : 1397 (1967).

To study the effect of moisture absorption on the physical properties of kraft paper, both virgin and recycled papers were exposed to -20°C and 90% RH for three months and changes in physical properties were studied.

To find out the alternative package designs for 2 kg blocks of frozen shrimp, corrugated box of the size 47.5 cm x 31.5 cm x 21 cm using 120 GSM kraft paper conforming to the type Regular Slotted Container. Fefco 0201 and wrap around type of the same size were fabricated in a local firm at Kochi. CFB of the size 32 cm x 32 cm x 26 cm made out of 120 GSM kraft paper currently used by the frozen shrimp industry were also fabricated for comparison. The compression strength of the boxes were determined as per ASTM (1973a).

To find out the effect of regular fluting and cross fluting 5 ply corrugated fibre board box of the sizes 330 mm x 320 mm x 310 mm was prepared using 125 GSM kraft paper and 120 GSM kraft paper in a factory making corrugated fibre board. The physical properties of the boards were studied after conditioning the samples by the method described in IS : 1060 (1966). Bursting strength was determined as per IS : 1060 (1960). Puncture resistance was determined according to IS : 4006 (1972). Compression strength of the box was determined as per ASTM (1973a). Moisture was determined by drying the sample in an oven at 100°C till constant weight.

To evolve the code of practice for the packaging of frozen shrimp for export, corrugated fibre board box of the dimension 330 mm x 320 mm x 310 mm (5 ply) was prepared using virgin 120 GSM and virgin 100 GSM kraft paper in a factory making corrugated fibre board. Two kg lots of finely crushed ice were packed in the duplex cartons (grammage 300 GSM with wax coating of 10 GSM on each side) with 100 gauge low density polythene film lining inside. Ten such cartons were arranged in one master carton and wound with 12 mm wide polypropylene straps with the help of a strapping machine. The entire operation was carried out exactly as practiced in commercial shrimp freezing factories except the ice replaced the frozen shrimp. Twenty four such master cartons each made out of 100 GSM kraft paper and 125 GSM kraft paper were prepared and frozen stored. At the end of each month two master cartons were withdrawn from the storage and subjected to transport worthiness test. The first pack was tested for rolling, vibration and drop tests. Rolling test on the filled packages were carried out as per IS : 7028 Part V (1973). Vibration test was determined on the filled packages as per IS : 7028 (1973). The pack was kept on the vibration table and vibrated for one hour at a frequency of 120 c.p.m. and amplitude 2.54 cm. After the above two tests the pack was subjected to drop test as per ASTM D 775-80 (1986a). Compression strength of the empty box was determined using the second pack as per ASTM (1973a). The studies were continued upto 6 months of frozen storage.

Waxed cartons used in frozen shrimp export were collected at random from 33 frozen shrimp processing factories in and around Kochi, Veraval, Kakinada, Bombay, Tuticorin,Kollam and Paradeep. They were tested for bursting strength, puncture resistance, tearing strength (both in machine and cross directions), tensile strength and elongation, moisture content,grammage, water proofness(cobb value) and wax content. The samples were conditioned before testing by the method of IS : 1060 (1966). Moisture was determined by drying the sample in an oven at 100°C. Bursting strength and water proofness expressed in terms of cobb 30' value, tearing strength in both machine and cross directions, tensile strength and elongation were determined as per IS : 1060 (1966). Puncture resistance was determined according to IS : 4006 (1972). The wax content was determined by the method mentioned in the appendix B of IS : 3962 (1967).

Low density polythene films used in prawn freezing factories were collected at random from 20 frozen shrimp processing factories in and around Kochi, Veraval, Kakinada, Bombay, Tuticorin, Kollam and Paradeep. Samples were conditioned before testing by the method of IS:1060 (1966). They were tested for thickness variation, tensile strength and elongation at break in machine and cross direction and overall migration residues. For determination of thickness variation, five different areas were selected along the length of the film with a minimum distance of one meter. Measurements were carried out at the edges as well as in the middle of the area with a micrometer as given in IS : 2508 (1984). Tensile strength and elongation at break in machine and cross direction was determined as per IS : 2508 (1984). Suitability of the film for frozen fish packaging (Food contact application) was found out by following the methods of IS : 9845 (1981).

For evolving a suitable code slip for frozen fish packaging, paper used as a code slip procured from 4 different sources and polyester tracing sheet obtained from a local firm were subjected to the conditioning as per IS : 1060 - Part I (1966) at 27°C and 65% RH. The following tests were conducted as per the Indian Standards Institution methods indicated against each.

(1) Thickness, grammage, tearing strength, bursting strength and cobb value IS : 1060 - Part I (1966).

(2) Tensile strength in machine and cross direction were determined as per IS : 1060 Part I (1966) by taking 10 cm length of the specimen.

(3) Bursting strength (wet) and tensile strength (wet) IS : 1060 Part II (1960).

(4) Tearing strength (wet) was determined by keeping the sample in water for 4 hours. Wiped the excess water and determined the tearing strength as per IS : 1060 Part I (1966).

(5) Air permeability : IS : 4006 - Part I (1966).

(6) Suitability of the code slip (polyester tracing sheet) for food contact application was determined by the methods of IS : 9845 (1981) as indicated by water extractives at 40°C for 24 hours.

(7) Visual observation on the disintegration of code slip in water was found out by keeping the code slip after freezing in a 2 kg frozen ice block and repeated thawing and freezing for nearly 10 days.

Strapping materials were collected at random from 35 different prawn freezing factories in and around Calicut, Cochin, Mangalore, Bombay, Tuticorin, Kakinada and Veraval. They were tested for tensile strength (dry and wet) and elongation (dry and wet) using a tensile strength tester. The samples were conditioned before testing and the tensile strength (dry) and elongation at break (%, dry) were determined using a tensile strength tester as per IS : 1060 (1966). Tensile strength (wet) and elongation at break (%, wet) were determined after keeping the strapping material in water for 12-14 hours as followed in the case of synthetic fishing gear materials (IS : 5815 - 1971). For evolving the load elongation curve the tensile/elongation (dry) for polypropylene, high density polythene, recycled high density polythene and rayon straps were carried out using Zwick 1484 material testing system. The tensile/elongation characteristics of these materials were studied in detail. To find out the effect of frozen storage, recycled high density polythene straps (12 mm width), polypropylene (virgin), High density polythene (virgin) and Rayon straps were procured from a local manufacturer and kept in the frozen storage for 6 months at -20°C. At the end of each month, samples of the strapping materials were withdrawn from the frozen storage, the condensed water wiped dry using filter paper and analysed for tensile strength and elongation.

6.2.2 EFFECT OF FROZEN STORAGE ON THE PROPERTIES OF CFB AND DUPLEX CARTONS

For finding the effect of frozen storage on the physical properties of corrugated fibre board master cartons and waxed duplex cartons, commercial samples of corrugated fibre board master cartons (unwaxed 5 ply B flute 651 GSM) and waxed duplex cartons used in frozen shrimp export were procured from local manufacturers. They were subjected to complete analysis of the properties like moisture, bursting strength, puncture resistance and compression strength after conditioning the samples by the method described in IS : 1060 (1966). Bursting strength was determined as per IS : 1060 (1960). Puncture resistance was determined according to IS : 4006 (1972). Moisture was determined by drying the sample in an oven at 100°C till constant weight. Two kg lots of finely crushed ice were packed in the duplex cartons with 100 gauge low density polythene film linings inside. Ten such cartons were arranged in one master carton and wound with 12 mm wide polypropylene straps with the help of a strapping machine. The entire operation was carried out exactly as practiced in commercial shrimp freezing factories excepting for the fact that the ice replaced the frozen shrimp. Fifteen such master cartons were got ready and held in frozen storage at -18 to -20°C (RH 80-85%). At the end of each month two master cartons were withdrawn from the storage, opened, ice emptied and both the master cartons and duplex cartons were subjected to complete analysis. In duplex cartons, moisture uptake, bursting strength, puncture resistance, tensile strength and elongation (in the lengthwise direction of the carton) and tearing strength in both machine and cross directions were studied. The bursting strength, moisture uptake, puncture resistance and compression strength were determined in case of master cartons. The studies were continued upto 6 months of frozen were storage.

The following packaging materials were obtained from indigenous manufacturers:

(1) Low density polythene (LDPE)

(2) High density polythene (HDPE)

(3) Polypropylene (PP)

(4) MXXT cello (Saran coated cellophane)

(5) Glassine

(6) Polyester (PEST or PET)

(7) Polyester/LDPE

(8) Metallised polyester/LDPE

(9) Saran coated cellophane/LDPE

(10 Metallised Nylon/LDPE co-extruded film

(11) High density polythene/LDPE/HDPE

(12) LDPE/LDPE

(13) PEST/LDPE-HDPE co-extruded film

(14) Nylon/ionomer

(15) High density polythene/low density polythene co-extruded film.

(16) Low density polythene/Nylon/low density polythene

The physical properties such as thickness variation, tensile strength in machine and cross direction, elongation at break, tear resistance, water vapour transmission rate and oxygen permeability were determined after conditioning the sample. For thickness variation five different areas were selected along the length of the film with a minimum distance of one meter. Measurements were carried out at the edges as well as in the middle of the area with a micrometer as given in IS : 2508 (1984) and the value calculated as percentage. The tensile strength and elongation at break in machine and cross direction was determined as per IS : 2508 (1984). Elongation at break was carried out while determining the tensile strength. Tear resistance was determined as per IS : 1060 - Part I (1966) and the value calculated as g. Water vapour transmission rate was determined according to IS : 1060 - Part 2 (1960) and value calculated as $g/m^2/24$ h at 37°C and 95% RH. Oxygen permeability was determined by using a gas permeability tester as described in ASTM D (1975).

6.2.3 PACKAGING STUDIES OF PRAWN SOUP POWDER

Fresh prawn *Penaeus indicus* was collected from Fisheries Harbour, Kochi, washed in potable water and iced immediately and brought to the laboratory. It was peeled and devenied and washed in potable water containing 5 ppm chlorine. Prawn soup powder was prepared as per the method described by Shenoy *et al.* (1983). Prawn soup powder was packed in approximately 100 g lots in pouches of different synthetic films like 100 gauge low density polythene (LDPE), 60 gauge high molecular weight high density polythene (HM-HDPE), 100 gauge polypropylene (PP), 12 micron plain polyester laminated with 150 gauge low density polythene, 12 micron metallised polyester laminated with 150 gauge low density polythene, 12 micron plain polyester laminated with 128 μ LDPE-HDPE co-extruded film, 95 micron LD/BA/Nylon/BA/Primacore, 300 saran coated on cellophane on both sides laminated with 150 gauge low density polythene (300 MXXT/150 gauge LDPE) and 250 gauge Nylon/low density-high density co-extruded film (size of the pouch 12.5 x 9 cm) and heat sealed using peddle type heat sealing machine. The sealed pouches were kept for storage studies at ambient conditions, temperature 27-30°C and relative humidity 80-90%. Samples withdrawn periodically were analysed and overall acceptability evaluated by a panel of judges. The product was analysed for moisture, protein, fat, ash (AOAC, 1975) and free fatty acids (AOCS, 1956). The pH value of the soup powder was measured from a suspension of 1 g of the sample in 100 ml distilled water. The humidity moisture relationship was studied at room temperature (27-30°C) by exposing weighed quantities of sample to different relative humidities ranging from 11 to 92% in desiccators using appropriate saturated salt solutions (Funk, 1974). Brown discolouration was determined by extracting 1 gm of sample with 66% alcohol and measuring optical density at 420 μ (Kannur *et al.*, 1973). Water vapour transmission rates of films were determined as per ISI method (IS : 1060 - Part II, 1960) as modified by Gopal and Govindan (1981). Oxygen transmission rates were determined as per ASTM (1975) and tensile strength and elongation at break in machine and cross directions were determined as per IS : 2508 (1984). Heat seal strength was determined as per ASTM (1973b). The suitability of the pouches for packing soup powder (heptane extractives at 21°C for 30 minutes and 25°C for 30 minutes) was determined by following the methods of IS : 9845 (1981) and FDA 175 : 300 (1983)

6.2.4 SENSORY EVALUATION

A taste panel consisting of 12 expert members was selected. The selection was made on the basis of their ability to discriminate the difference in various samples and also to repeat the judgments. Ten members were called for each experiment.

Samples for testing was prepared by adding 5 g soup powder in 100 ml hot water. Precautions were taken to select materials so that it was representative of the product under study. Soup was served hot to the taste panel members to assess the appearance, flavour and overall acceptability based on the above factors. They were asked to represent their liking on a hedonic scale consisting of nine points, point 4 was taken as the acceptability limit (Amerine *et al.*, 1965). The results were analysed statistically as per ASTM (1968a).

6.2.5 PACKAGING OF FISH PICKLES IN OIL

Seer fish (*Scomberomorus guttatus*) was collected from Fisheries Harbour, Kochi, washed in potable water and iced immediately and brought to the laboratory. It was cut into small pieces after gutting and beheading. It was washed in potable water containing 5 ppm chlorine. Fish pickle was prepared as per the method described by Muraleedharan *et al.* (1982). The fish pickle in 380 g lots were introduced with the help of a glass funnel with long stem into different flexible pouches of size 16 x 15 cm and heat sealed. The pouches employed were 300 gauge polypropylene, 12 μ metallised polyester/300 gauge LDPE, Saran coated cellophane 300/150 gauge polythene, 85 μ Nylon-Surylyn film, 12 μ metallised polyester/118 μ LDPE-HDPE co-extruded film, 12 μ plain polyester/128 μ LDPE-HDPE co-extruded film, 95 μ LD/BA/Nylon/BA/Primacore and glass bottle for the preliminary screening. Out of them the following pouches were subjected to detailed study. 85 μ Nylon/Surylyn film, 12 μ metallised polyester/118 μ LDPE-HDPE co-extruded film, 12 μ plain polyester/128 μ LDPE-HDPE co-extruded film and 95 μ LD/BA/Nylon/BA/Primacore. Titrable acidity of the muscle was determined by AOAC method (1975). Total volatile nitrogen was determined from trichloro acetic acid extract of the meat following the Conway microdiffusion method (1947). Peroxide value of the meat was determined by AOAC method (1975). For the determination of pH, the fish muscle was made into a paste by thoroughly grinding in a waring blender. About 10-15 g of the paste was taken in a beaker and mixed well with 5 times by weight of distilled water. The pH of this blend was measured using a digital pH meter. Peroxide value was determined by AOAC method (1975) after wiping off the adhering substances from the fish muscle using filter paper. The water vapour transmission rates of packaging materials used were determined as per ISI method (IS : 1060 - Part II, 1960) as modified by Gopal and Govindan (1981). Oxygen transmission rates were determined as per ASTM (1975). Organoleptic values were judged by a trained taste panel. Transport worthiness test of the filled pouches was determined as per IS : 12265 (1987). For vibration test about 10 pouches filled with pickles in oil were kept in single layer and provided with arrangement to prevent the falling down of the pouches during testing. The amplitude and frequency of vibration tested were 2.54 cm and 120 cycles/minute respectively. For drop test, ten pouches were filled with pickles in oil and sealed in a pedal type impulse heat sealing machine. Five pouches were tested first. Each pouch was dropped four times, one drop on each flat surface (upper and lower) and one drop on each longer side. The pouches were dropped on a flat smooth surface of the drop tester from a height of 1.2 m (ASTM, 1986b). Each pouch was examined for any leakage of the contents after the test. If none of the five pouches selected for the test failed in the drop test, the lot was considered as passing. If just one pouch failed, the other set of 5 pouches were tested in the same manner as above. If none of the pouches failed again, the lot was accepted, otherwise the lot was rejected. The suitability of the pouches for fish pickle packaging as regards heptane and water extraction was determined by following the methods of IS : 9845 (1981) and FDA 175 : 300 (1983).

6.2.6 PACKAGING STUDIES OF FROZEN PRAWNS

Fresh prawn, *Peneus indicus* was collected from Fisheries Harbour, Kochi, washed in potable water and iced immediately and brought to the laboratory. It was peeled and deveined and count was determined. It was then washed in potable water containing 5 ppm chlorine and 500 g each was packed in waxed carton line inside with 100 gauge LDPE, 200 gauge LDPE, 200 gauge PP, 60 gauge LLDPE, 300 saran coated cellophane on both sides laminated with 150 gauge LDPE and 12 μ plain polyester laminated with 150 gauge low density polythene. Six packets each were prepared for each packaging material. They were frozen in a contact plate freezer at -35 to -40°C and kept in a cold storage maintained at -20 ± 2°C. Moisture, protein, non-protein nitrogen, salt soluble nitrogen, total volatile base nitrogen and sensory characteristics such as appearance, texture and flavour were analysed monthly for six months.

Flexibility at low temperature was determined by visual observation. The water vapour transmission rate of packaging materials used were determined as per ISI method (IS : 1060 - Part II, 1960) as modified by Gopal and Govindan(1981). Oxygen transmission rates were determined as per ASTM (1975). The suitability of the pouches for packing frozen shrimp was determined by estimating the water extractives at 21°C for 24 hours and 40°C for 24 hours as per FDA (1983) and IS:9845 (1981) respectively. Moisture, protein and non-protein nitrogen were determined by the method of AOAC (1984), total volatile base nitrogen by the method of Conway (1947) and salt soluble nitrogen by the method of Dyer *et al.* (1950). Sensory evaluation was conducted by a trained taste panel. The selection was made based on their ability to discriminate the difference in various samples and also to repeat the judgments (ASTM, 1968a). Prawn samples for testing were prepared by cooking them in 2% brine for 10 minutes and served moderately hot (45-60°C) independently to each member to assess the appearance, flavour and texture and hence the overall acceptability. They were asked to represent their liking on a hedonic scale consisting of nine points. Point 4 was taken as the acceptability limit (Amerine *et al..*, 1965). The data were analysed statistically (ASTM, 1968a).

6.2.7 PACKAGING STUDIES OF DRIED FISH

Freshly landed mackerel were collected from Cochin Fisheries Harbour, dressed, split ventrally. Viscera and gills were removed and washed free of blood, slime and other extraneous matter. Dry salting was carried out in the ratio of 1:5 (salt to fish) for 25 hours and the salted fish rinsed in fresh water to remove adhering salt. They were then dried in the sun until the moisture content reached to a level of 34%. The dried fish were divided into two equal portions. One portion containing 250 g of the product dusted with calcium propionate at 0.1% level were sealed in pouches of the different flexible packaging materials like 200 gauge LDPE, 100 gauge HM-HDPE, 200 gauge PP, 250 gauge LD-HD, 100 gauge LLDPE, 300 saran coated cellophane on both sides laminated with 150 gauge low density polythene (300 MXXT/LDPE), 12 μ metallised polyester laminated with 150 gauge low density polythene (Met PEST/LDPE) and 12 μ plain polyester laminated with 150 gauge low density polythene (plain PEST/LDPE) of dimensions 28 x 18 cm and stored at atmospheric condition (RH 65 to 95% and temperature 25 to 34°C). Another portion containing 250 g of the product without preservative were sealed in pouches of the same dimension and stored at atmospheric conditions (RH 65 to 95% and temperature 25 to 34°C). Control samples with or without treatments were kept unpacked. Estimations of initial moisture, sodium chloride, fat, protein and ash were conducted according to AOAC (1984) methods. Total volatile base nitrogen (TVBN) contents of the samples were estimated on rectified spirit extracts of the muscle by microdiffusion method of Conway (1947). Free fatty acid estimation was done as per AOCS (1956). Samples were withdrawn every month and tested for moisture content, TVBN, FFA and organoleptic evaluation. The humidity moisture relationship was studied at room temperature (27-30°C) by exposing weighed quantities of samples to different relative humidities ranging from 11 to 92% in desiccators using appropriate saturated salt solutions (Kumar *et al.*, 1974). Water vapour transmission rate of the packaging films was determined according to IS : 1060 Part 2 (1960) and the value calculated as $g/m^2/24$ h at 37°C and 90% RH. Oxygen permeability was determined by using a gas permeability tester as described in ASTM (1975).

7. RESULTS AND DISCUSSION

7. RESULTS AND DISCUSSION

The particulars of the master cartons collected from fifty two different factories are given in the Table 1. Values of bursting strength are shown in Table 2, values of puncture resistance in Table 3, waterproofness in Table 4 and analysis of the cartons for combined weight of liners in Table 5. Weights of substance for corrugating medium are presented in Table 6.

Table I

Particulars of master cartons

1. Total Number of cartons	52
2. Number of plies in the cartons	5
3. Number of waxed cartons	12
4. Number of unwaxed cartons	40
5. Number of cartons with B flutes	52
6. Wax content GSM	3 - 40
7. Saponifiable Matter, %	0.02 - 7.95

Table 2

Bursting strength of master cartons

Bursting Strength Kg/Sq cm	Cartons falling in each range
8.5-9.5	16
9.6-10.5	9
10.6-11.5	12
11.6-12.5	10
12.6-13.5	3
13.6-14.0	2

Table 3

Puncture resistance of master cartons

Punct. Rest., Beach Units	Cartons falling in each range
124-149	4
150-174	9
175-199	11
200-224	12
225-249	9
250-274	6
275-305	1

Table 4

Water proofness of master cartons

Water Proof., Cobb 30' value	Cartons falling in each range
24-60	3
60-120	16
121-321	14
322-522	10
523-723	1
724-1025	8

Table 5

Analysis of combined Weight liners

Comb. Wt of liners g/sq.m	Cartons falling in each range
300-349	1
350-399	23
400-449	10
450-499	10
500-549	2
550-599	4
600-649	2

Table 6

Weight of substance for corrugating medium in the master cartons

Wt. of the substance g/sq.m	Cartons falling in each range
102-117	4
118-133	22
134-149	9
150-165	10
166-181	4
182-197	3

It can be seen from Table 1 that no uniformity is maintained by the different manufacturers regarding waxing and saponifiable matter. The saponifiable matter is usually rosin, a sizing agent used in the manufacturing process of the paper boards which imparts waterproofness to them. In general the flute that is being used in the corrugating medium is of the B type (40-55 corrugations / 30 cm) and 2.1 to 2.9 mm flute height. Only one manufacturer has used a combination of B + C flute. "C" flute contains 36 - 44 corrugations/30 cm and 3.6 to 3.8 mm flute height. It is seen from the results that only some manufacturers wax their master cartons. Waxing is necessary to reduce the water absorbance and assists in the retention of various physical properties so that the strength of the cartons is not reduced while subjected to water spray / condensation, while shipping. The data shows that there is a variation in the wax content ranging from 3 to 40 gsm and saponifiable matter from 0.02 to 2.95 percent. Waxing alone is not sufficient to reduce the water absorption value. Some percentage of saponifiable matter (usually rosin) and probably other sizing materials should also be present in the paper to keep it down. However, ISI specifications (IS: 6715 - 1972), do not lay down any minimum requirements for these constituents in the carton material. Probably, the requirements for the waterproofness stipulated in the standards take care of these aspects indirectly, since in the absence of the required degree of glazing and probably external water proofing (by wax treatment) the former cannot be achieved.

It is observed from Table 2 that only 3.8 percent of the cartons studied conformed to ISI standards with respect to bursting strength, the minimum value of which stipulated for cartons meant for holding 20 - 30 kg of materials being 14 kg/sq. cm. Bursting strength is a complex function of tensile strength and stretch. It reveals the inter fibre bonding and the formation of paper, the latter meaning the uniformity with which fibres are distributed in the paper. The larger number of the cartons falling in the lower ranges of bursting strength, contribute to the low mechanical strength generally reported in the commercial samples of master cartons.

Indian Standards Specifications for puncture resistance of master cartons under study is 200 beach units. Only 54 percent of the cartons conformed to the standards for puncture resistance which was fixed at 200 beach units. The puncture resistance is reflective of the paper board quality. The resistance of paper board to puncture is of extreme importance in the manufacture of shipping containers because of the hazards involved in transportation, handling and storing. Containers are frequently punctured by the corners of other containers, lumbers, forks etc.

Cobb test is the test to measure the water absorption of the paper board. It reflects the efficiency of sizing and similar properties of paper and is particularly useful in assessing the suitability of corrugated fibre boards for the manufacture of master cartons to be used as shipping containers under conditions where they are likely to get exposed to water spray or subjected to water vapour condensation. Cobb value must be low when the paper is used for making shipping containers which are subjected to high humidity for a prolonged period. Table 4 shows that only 36.5 percent of the cartons used in frozen shrimp exports are conforming to the ISI standards of 120 Cobb 30 minutes, some values showing values as high as six to seven times the maximum stipulated. It is noted that low Cobb values are generally associated with high wax and saponifiable (rosin) contents. The sample which had a wax content of 3.12 percent and saponifiable matter of 2.85 percent showed the lowest Cobb value of 24 among the samples studied. Another one with 9.2 percent wax content and 6 percent saponifiable matter showed the Cobb value of 48. A sample with no wax coating and 7 percent saponifiable matter showed a Cobb value of 44. This means sizing agents used in manufacturing process of the board influence the water resisting properties. Hence the proper degree of sizing at the manufacturing stage and a superficial coating with wax help in enhancing the water proofness of the corrugated fibre board.

It is seen from Tables 5 and 6 that only 15 percent of the samples conform to the ISI specification of a minimum of 500 g/sq.meter for combined weight of liners while 32.7 percent samples satisfied the stipulation of a minimum of 150 g/sq.meter for corrugating medium. The basis weight is a very important property of paper and paper boards as they are customarily bought and sold on a weight basis, but are used on area basis. It also affects the burst factor and other physical properties of the board and the functional characteristics of the box. Besides, the basis weight can be used to a reasonable extent as an index of physical strength. Particularly in the case of shipping containers the basis weight has found a place in national and International specifications which are used as a guide by buyers in package design.

The weight of the carton is related to the grammage of the paper, type of adhesives and dimensions of the box. Most of the cartons are having the weight in the range of 601 - 651 g (Table 7). The weight cannot be specified to the manufacturer as it may increase if the adhesive used is silicate based. This may be the reason why the ISI standards do not stipulate any weights specifications for the corrugated fibre board master cartons.

Table 7

Total weight of master cartons

Total wt. (g)	Cartons falling in each range
550-600	7
601-651	25
652-702	8
703-753	5
754-804	6
805-855	1

Table 8 shows that there are wide variations in the dimensions of the master cartons. This is due to the variations in the dimensions of waxed duplex cartons (which are specified by the importers) used inside the master cartons, whose dimensions have to be adjusted to exactly pack ten numbers of the former. Nevertheless, dimension is an important property when exported to different countries as variation may affect the handling conditions.

Table 8

Volume of master cartons

Volume, cm^3	Cartons falling in each range
23,100-25,000	6
25,100-27,000	5
27,100-29,000	5
29,000-31,000	8
31,100-33,000	24
33,100-35,000	4

Table 9 shows the physical properties of virgin, non virgin and semi-virgin kraft paper that is generally used for the manufacture of corrugated fibre board. The bursting strength, ring stiffness and tensile strength are more in virgin kraft paper than in recycled kraft paper. In semi-virgin paper, the values lies in between virgin and non virgin paper. Burst factor is an important physical parameter of paper, which ultimately decides the load bearing capacity of the finished container. The values for the grade I paper as mentioned in IS : 1397 (1967) are above 30. The values obtained in the present study for the virgin kraft paper are between 20 and 30 which refer to grade II as per the above standard. Non virgin and semi-virgin kraft papers used in the analysis have burst factor below 20 which are classified as others as per the above standard. Fig. 6 indicates the tensile properties of different kraft paper in machine and cross direction. Virgin kraft paper possess higher tensile strength ranging from 70 to 110 newtons in machine direction and in the case of non virgin paper, it varies from 51 to 55 newtons in machine direction for the same rated 120 grammage kraft paper. As bursting strength is a combination of tensile strength and stretch, the bursting strength increases as the tensile strength increases. It is noted that the tearing strength is more or less independent of the virginity of the paper. Even in case of non virgin kraft paper, the tearing strength may be more than the virgin paper for the same grammage of kraft paper. The above results show that the use of non virgin paper yields poor quality corrugated fibre board with lower strength. Hence for the fabrication of the master cartons, for frozen sea foods, virgin grade kraft paper should be used.

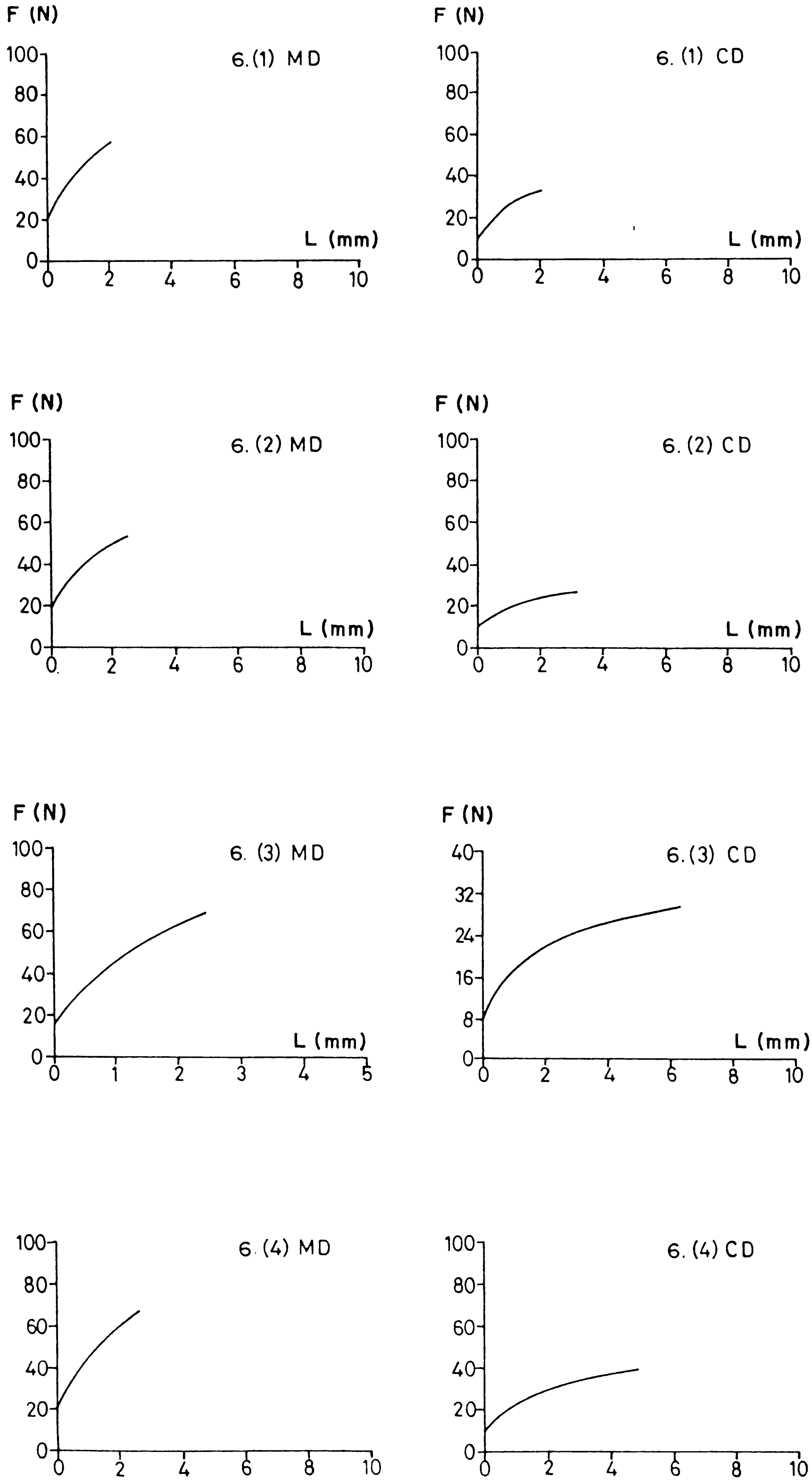
Table 9

Physical properties of recycled (non virgin), virgin and semi-virgin kraft paper

Details		Recycled	Recycled	Semi Virgin	Semi Virgin	Virgin	Virgin	Virgin	Virgin	Recycled	Recycled	Virgin	Virgin	Semi Virgin	Virgin
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Grammage, g/sq.m	Rated	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	100.00	90.00	100.00	150.00	150.00	140.00
	Actual	133.50	126.03	121.73	126.40	125.60	126.40	125.83	129.40	103.16	92.33	106.67	155.93	152.23	140.06
Caliper, mm		0.165	0.156	0.162	0.153	0.167	0.153	0.157	0.148	0.138	0.131	0.136	0.205	0.212	0.186
Bursting strength, kg/sq.cm		1.40	1.30	2.10	2.10	3.00	2.60	3.10	2.50	1.50	1.70	2.80	3.80	2.60	2.90
Burst factor		10.50	10.30	17.25	19.09	23.84	20.60	24.64	20.34	14.50	18.40	26.20	24.20	17.33	20.35
Ring stiffness,	MD	77.00	83.50	86.00	93.00	137.80	137.80	142.20	136.00	65.70	56.20	85.00	192.20	149.30	139.30
Newtons	CD	71.33	61.80	76.30	72.33	106.20	106.20	114.25	107.30	58.40	54.00	82.30	167.80	87.00	124.00
Tearing strength,	MD	107.00	86.40	80.00	112.00	144.00	144.00	100.00	96.00	56.00	56.00	100.00	232.00	135.00	128.00
g	CD	123.00	96.00	104.00	115.00	152.00	176.00	116.00	116.00	100.00	68.00	164.00	288.00	138.00	132.00
Tensile strength,	MD	55.38	51.57	72.90	73.50	70.00	108.05	84.11	91.30	30.53	32.20	90.12	128.60	99.00	104.50
Newtons/18 cm length/ 1.5 cm width	CD	30.95	27.94	31.20	37.50	35.00	46.03	55.90	60.65	20.60	21.48	32.50	53.40	56.23	60.70
	MD	1.30	1.56	1.30	2.06	1.60	1.83	1.77	1.88	0.98	1.10	1.46	1.57	2.24	2.83
Elongation, %	CD	1.30	1.84	3.57	2.49	3.80	6.53	3.18	2.89	1.31	1.56	4.68	4.50	4.37	5.70

MD - machine direction; CD - cross direction

Figure.6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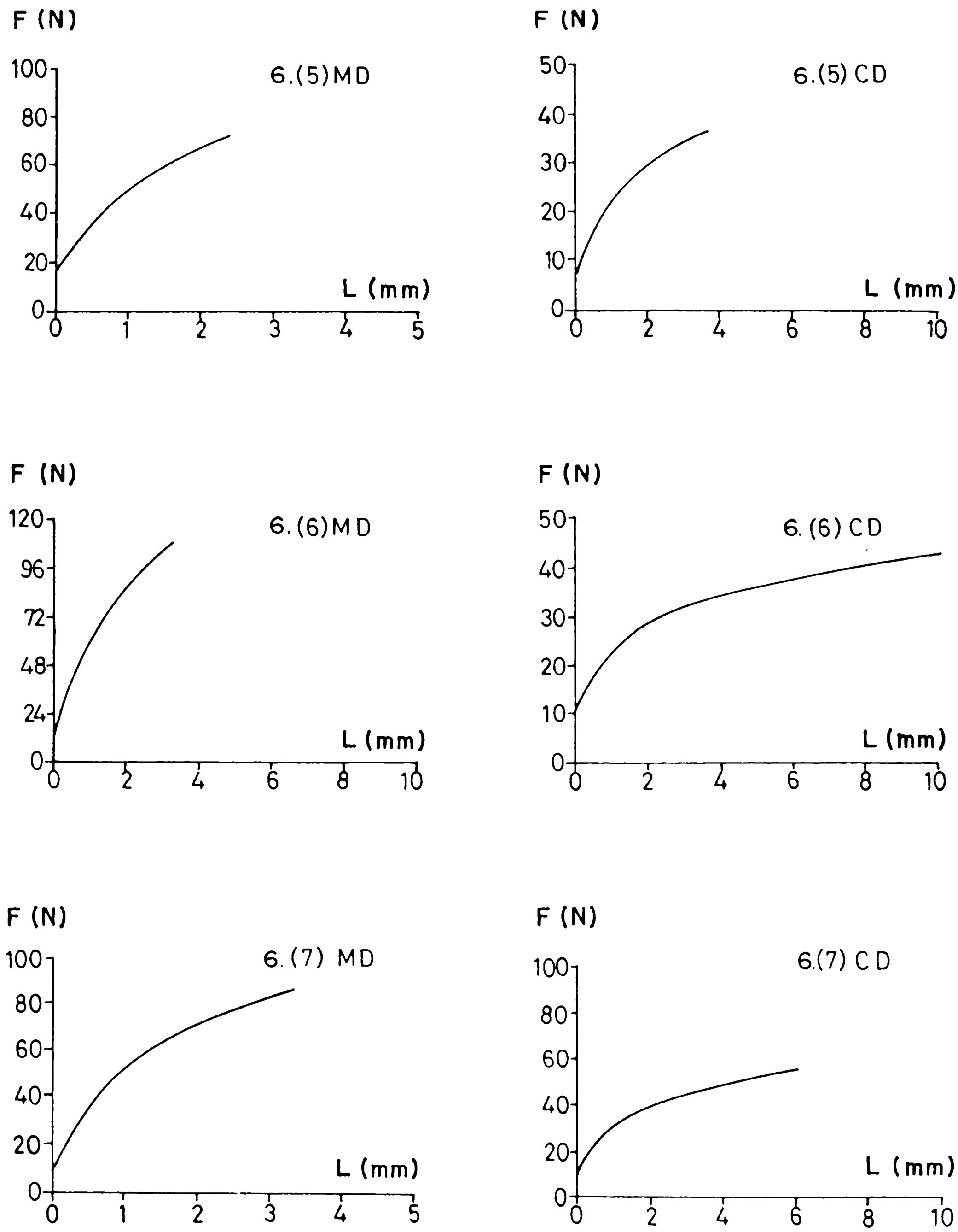
6.(1) MD
L (mm)
F (N)
6. (1) CD
L (mm)
F (N)
6. (2) MD
L (mm)
F (N)
6. (2) CD
L (mm)
F (N)
6. (3) MD
L (mm)
F (N)
6.(3) CD
L (mm)
6. (4) MD
6. (4) CD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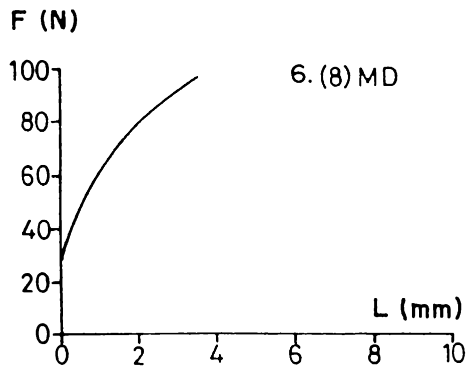
6.(5) CD
L (mm)
F (N)
6.(6) MD
L (mm)
F (N)
6.(6) CD
L (mm)
F (N)
6.(7) MD
L (mm)
F (N)
6.(7) CD
L (mm)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6. (8) MD
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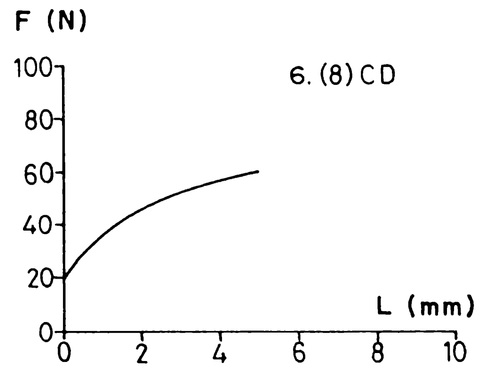
0 2 4 6 8 10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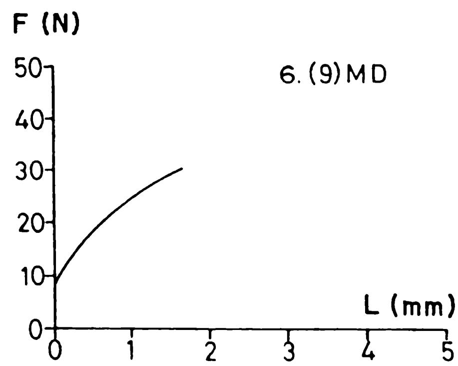
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6. (9) MD
L (mm)
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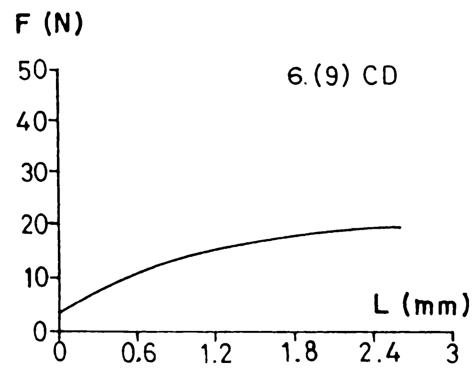
0 1 2 3 4 5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L (mm)
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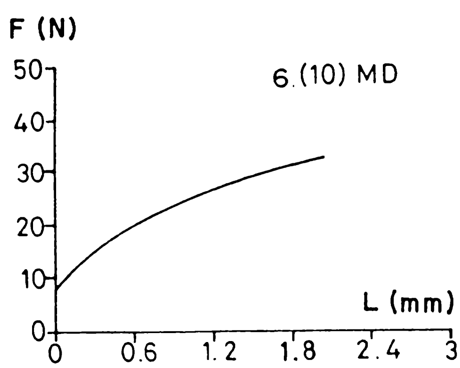
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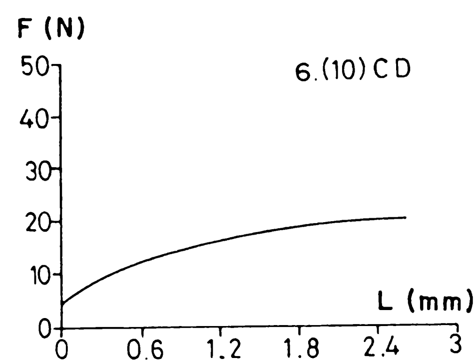
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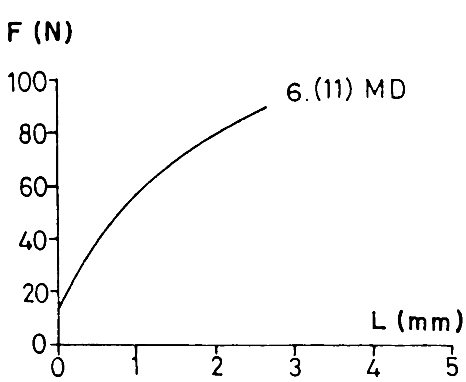
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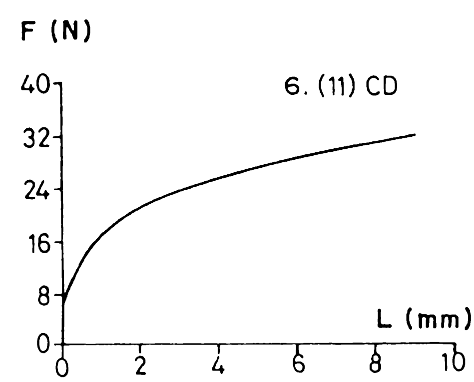
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L (mm)
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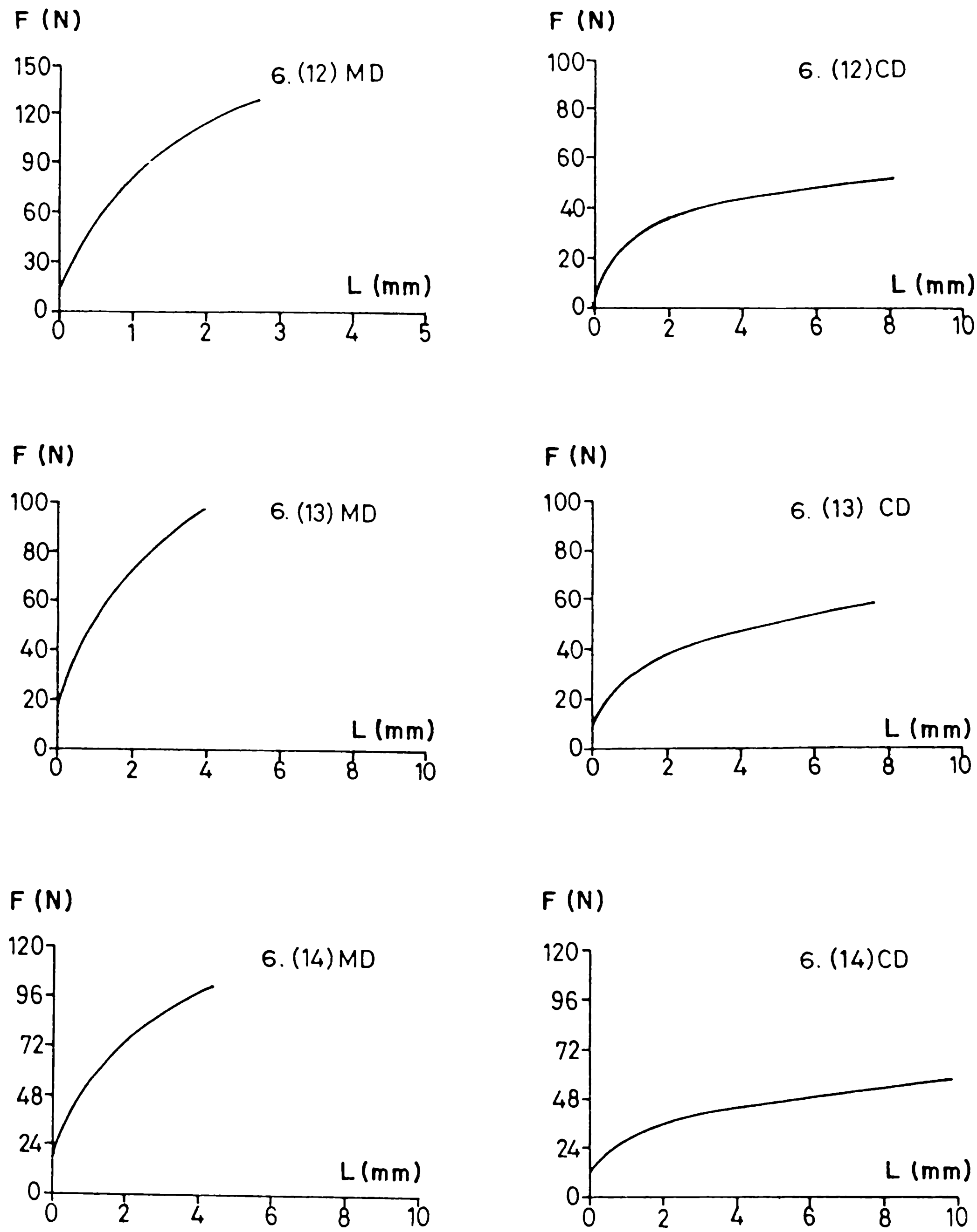


FIG: 6 Load elongation curve of virgin (5, 6, 7, 8, 11, 12 & 14) semi virgin (3, 4 & 13) and non-virgin (1, 2, 9 & 10) kraft papers used in the manufacture of corrugated fibreboard.

It was further observed that the kraft paper used in the fabrication of corrugated fibre board boxes was of two different grades viz. virgin and recycled. It is seen that only ten percent samples conformed to grade I as far as burst factor is concerned (Table 10), thirty percent in case of tear factor and nil in the case of breaking length and Cobb value. Less than sixty percent of the samples conform to grade II specifications.

Table 10

Physical properties of kraft paper

Property	Ranges and number of samples (in brackets) falling in them		
	A*	B**	C***
Burst factor	30 & above (2)	30-20 (12)	<20 (7)
Breaking length, m Machine Direction	7000 & above (Nil)	7000-4500 (6)	<4500 (15)
Tear factor	120 & above (6)	120-75 (12)	<75 (3)
Specific ring crush, Newtons Cross direction	75 & above (1)	75-50 (4)	<50 (16)
Cobb value 1 minute	15 & below (Nil)	15-20 (7)	>20 (14)

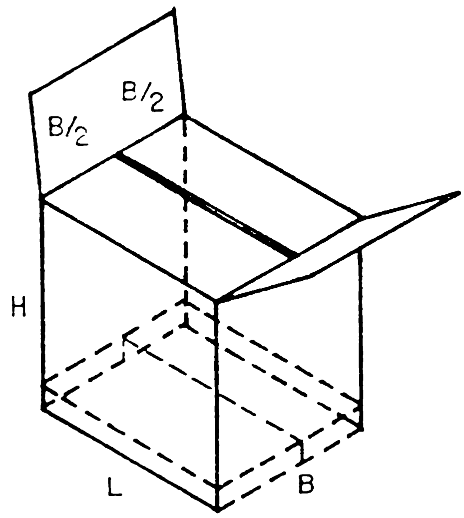
A* Grade I as per IS specifications
B** Grade II as per IS specifications
C*** Others

To study the effect of moisture absorption, on the physical properties of kraft paper, both virgin and recycled paper were exposed to - 20°C and 90 percent RH for three months and changes in physical properties were studied (Table 11). It is seen that both virgin grade and recycled paper have shown decrease in their physical strength and the changes are pronounced in case of recycled paper.

The present corrugated fibre box is a regular slotted container (RSC) conforming to style FEFCO 0201, which can hold 10 unit cartons in the fashion (2 x 5), two per layer and in five layers. In the two new designs proposed, the size and style of the transport packages are changed to hold twelve unit cartons in the fashion (3 x 4) to effect savings in the board area used and thus economising the packaging costs (Fig. 7). An added advantage of the new design of the boxes is that they are cuboid in shape, thus facilitating easier handling and better stacking which is indicated by higher compression strength (Figs. 8 and 9). The style of the construction of the first case (Fig. 7.2) is same as that of the one currently used (RSC) (Fig. 7.1) and the second one (Fig. 7.3) is similar to wrap around type adopting which further cost savings in packaging can be achieved.

Figure. 7

A. CURRENTLY USED MASTER CASE (Figure 7.1)



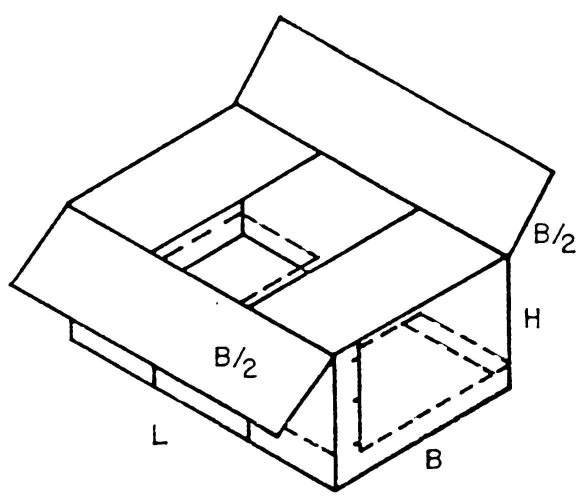
Size of master case.

32 x 32 x 26 cms.

R.S.C Fefco 0201

Arrangement of unit cartons 2 x 5

B.1 NEWLY SUGGESTED MASTER CASE (Figure. 7.2)



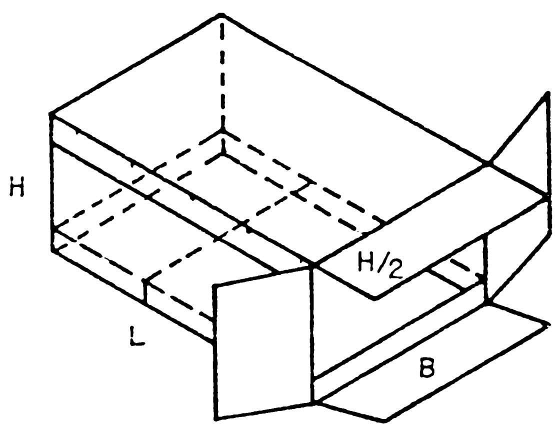
Size of master case

47·5 x 31·5 x 21 cms.

R.S.C FEFCO 0201

Arrangement of unit cartons 3 x 4

B. 2 (Figure. 7.3)



Size of master case

47·5 x 31·5 x 21 cms.

Wrap around type.

Arrangement of unit cartons 3 x 4

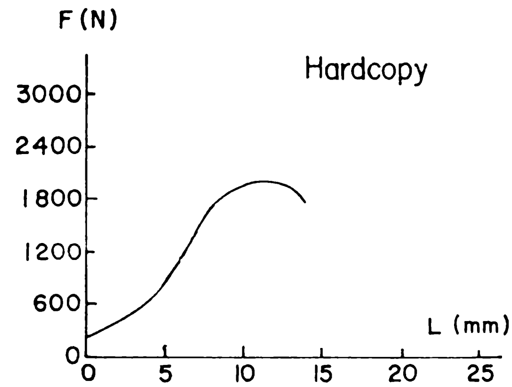
SIZE OF 2 KGS FROZEN SHRIMP (PEELED & DEVEINED) BLOCK

SIZE OF DUPLEX BOARD CARTON 31 x 15·5 x 5 cms. 2400 C.C

Figure. 8.

Load deformation curve of 5ply Corrugated Fibre Board box (CFB) of the size 320 mm x 320 mm x 260 mm RSC Fefco 0201 (currently used cartons)

Arrangement of unit cartons 2 x 5



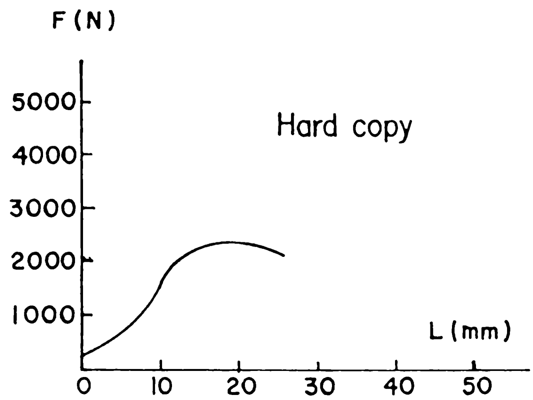
Grammage of the kraft paper used for fabricating CFB	120 GSM
Compression strength of the currently used CFB box to hold 10 unit cartons.	2280 N
Total work done under the curve.	18·94 N
Work done to reach the maximam compression strength.	13·25 N

Figure. 9.

Load deformation curve of 5 ply corrugated fiber board box (CFB) of the size 475 mm x 315 mm x 210 mm.

R.S.C Fefco 0201 type.

Arrangement of unit cartons 3 x 4



Grammage of the kraft paper used for fabricating CFB	120 GSM
Compression strength of the newly suggested box to hold 12 unit cartons	2711·2 N
Total work done unter the curve	43·73 Nm
Work done to reach the maximum compression strength	30·01 Nm

Table 11

Physical properties of kraft paper exposed to -20°C and 90% RH for three months

Property	Virgin grade			Non virgin grade (Recycled)		
	Before Exposure	After Exposure	% change	Before Exposure	After Exposure	% change
Grammage, GSM	123	130	+5.7	119	136	+14.2
Bursting Strength, Kpa	335	190	-43.2	230	65	-71.7
Tensile strength, Kgf/1.5 cm width	8.8	7	-20.5	5.2	3.8	-26.9
Tear strength, g Cross direction	8	7.5	-6.3	6.2	5.7	-8.0
Ring stiffness, Newtons	89	69	-22.5	60	42	-30

Consider a specific case of packing 60 nos of 2 kg nett, frozen peeled and deveined shrimp in duplex cartons. Each duplex cartons has a volume of 2400 cc and size of the duplex cartons 31 x 15.5 x 5 cm. Details of construction of the currently used master case and those of newly suggested ones are presented in the figures 7.1, 7.2 and 7.3. Details of the areas of corrugated fibre board required for the boxes are mentioned in Table 12. Taking the case of 40 million kg of frozen shrimp exported to Japan during 1990 the effective cost savings in the master cases, works out roughly at Rs. 1.47 million and Rs. 3.8 million respectively for the new designs (mentioned in the fig. 7.2 and 7.3).

Table 12 shows the effect of regular fluting and cross fluting of corrugated fibre boards on physical properties. Regular fluting and cross fluting boards do not have any effect in bursting strength and puncture resistance. But there is an improvement in the compression strength for the regular fluting compared to cross fluting (Figs. 10, 11, 12 and 13).

Table 12

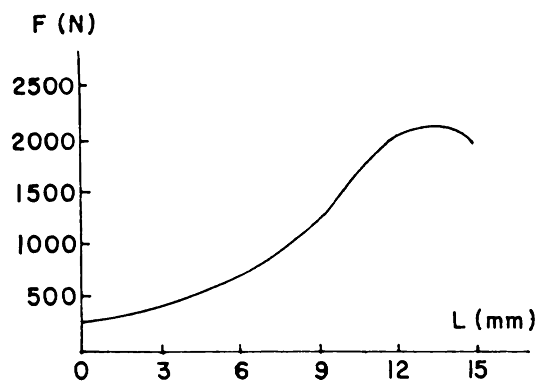
Physical properties of five ply corrugated fibreboard made out of 125 GSM and 120 GSM Kraft paper adapting regular fluting and cross fluting

Details	Regular fluting		Cross fluting	
	5 ply made of 125 GSM Kraft paper	5 ply made of 120 GSM Kraft paper	5 ply made of 125 GSM Kraft paper	5 ply made of 120 GSM Kraft paper
Moisture content	8.2	8.4	8.0	8.2
Bursting strength (Kg/sq.cm)	9	9.0	9.0	9.0
Puncture restistance (Beach units)	165	155	165	155
Compression Strength (Newtons)	2231	2110	1778	1720

Figure.10

Load deformation curve of 5ply corrugated fibreboard box (CFB) of the size 330 mm x 320 mm x 310 mm using regular fluting board.

Regular fluting (Ist batch)

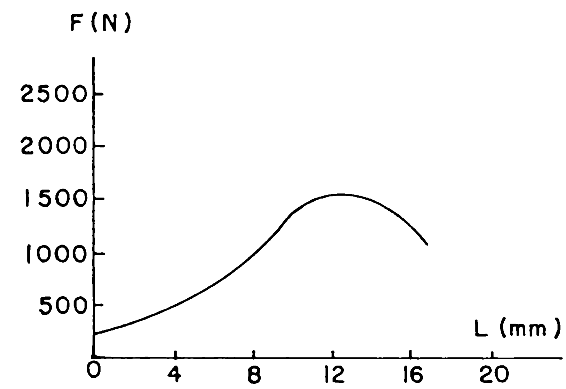


Grammage of kraft paper used.	125 GSM
Compression strength of the regular fluting CFB box.	2110 N
Total work done under the curve.	22·1 Nm.
Work done to reach the maximum compression strength	14·7 Nm.

Figure. II.

Load deformation curve of 5 ply corrugated fibreboard box (CFB) of the size 330 mm x 320 mm x 310 mm using cros fluting boards.

Cross fluting (I[st] batch)

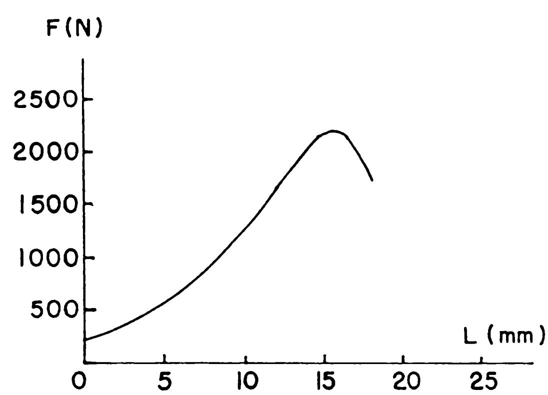


Grammage of kraft paper used.	125 GSM
Compression strength of the cross CFB box.	1778 N
Total workdone under the curve	16·8 Nm
Work done to reach the maximum compression strength	12·3 Nm

Figure. 12.

Load deformation curve of 5 ply corrugated fiberboard box (CFB) of the size 330 mm x 320 mm x 310 mm using regular fluting boards.

Regular fluting (IInd batch)

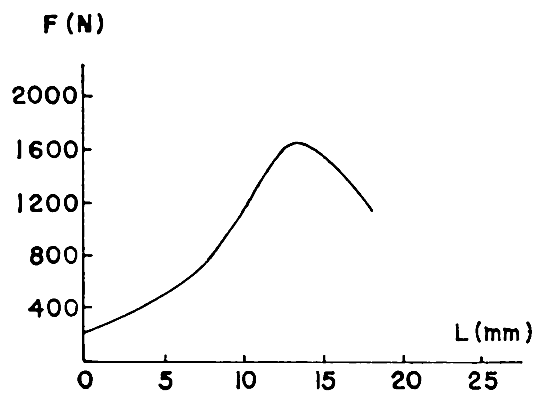


Grammage of the kraft paper used.	→	120 GSM
Compression strength of the regular fluting CFB box.	}	2231·5 N
Total workdone under the curve.	→	22 Nm.
Workdone to reach the maximum compression strength.	}	16·1 Nm.

Figure. 13.

Load deformation curve of 5 ply corrugated fibreboard box (CFB) of the size 330 mm x 320 mm x 310 mm using cross fluting boards.

Cross fluting (IInd batch)



Grammage of the kraft paper used.	→	120 GSM
Compression strength of the cross fluted CFB box.	}	1720 N.
Total work done under the curve.	→	17·3 Nm.
Work done to reach the maximum compression strength.	}	10·6 Nm.

Variations of moisture in 33 waxed duplex cartons are summarized in Table 14. Values of bursting strength are shown in Table 15 and those of puncture resistance in Table 16. Water proofness of the sample expressed in terms of Cobb 30 minutes value is presented in Table 17. The values of tensile strength expressed in terms of kgf / 1.5 cm width / 18 cm length and elongation expressed in terms of increase in length are presented in Table 18. Results of analysis of cartons for wax content are presented in Table 19. Tearing strength both in machine and cross directions are presented in Table 20.

It can be seen from Table 13 that there is considerable variation in the moisture of the cartons. Moisture in boards is a very important factor affecting physical strength, flexibility, sheet forming characterstics, weight, dimensional stability, rigidity, tearing strength, tensile strength, folding endurance and elasticity. Majority of the samples studied were found to have moisture of 6.5 percent to 8.8 percent. Very low moisture indicates the poor storage facility for these packaging materials in the factory. The higher the moisture, the poorer are the physical strength characterstics.

Table 13

Moisture content of cartons

Range of Moisture, %	Cartons falling in each range
6.5-7.7	24
7.8-8.8	9

It is observed from Table 14, that 61 percent of the cartons are having bursting strength above 5 kg./sq.cm. The waxed cartons should have a bursting strength as high as possible, so that it can withstand handling and storage conditions. It is seen from Table 15 that 67 percent of the cartons had puncture resistance above 25 beach units. The puncture resistance is reflective of the paper board quality. Usually in the primary package the problem of puncture does not arise. It is encountered only during handling conditions by corner hit on the container before filling in the master cartons.

Table 14

Distribution of bursting strength

Range of Burst.Strength, kg/sq.cm	Cartons falling in each range
3.6-4.0	4
4.5-5.0	8
5.25-5.75	12
6.0-6.5	5
6.75-7.00	3
7.25-7.50	1

Table 15

Puncture resistance of cartons

Range of Punct. resistance, Beach units	Cartons falling in each range
20.00-22.00	3
22.50-25.00	8
26.00-29.00	10
29.50-32.75	12

Table 16 shows that 88 percent of the waxed cartons are having Cobb value below 45. Cobb value must be low as the cartons are likely to come in contact with the moisture in the frozen storage due to water condensation. It is noted that the low Cobb values are associated with higher wax and saponifiable matter (rosin) contents. The sample which had 6.84 percent wax and 5.4 percent saponifiable matter showed the lowest Cobb value namely 2.84 among the samples studied. Another one with 9.65 percent wax and 2.5 percent saponifiable matter had a Cobb value of 4.65. This shows that with a higher saponifiable and less wax, low cobb values can be achieved. But some amount of wax should be present in the carton as otherwise the frozen product sticks hard to it with glaze water freezing in between. Hence the proper amount of wax and saponifiable should be present in the carton to achieve the desired Cobb value.

Table 16

Water proofness of waxed cartons

Range of Water proofness, Cobb 30'value	Cartons falling in each range
2.84-25.00	21
25.00-45.00	8
46.00-66.00	2
67.00-85.00	1
406.15	1

Table 17 shows the tensile strength of the carton and elongation expressed in terms of kgs/ 1.5 cm width / 18 cm length and elongation in cm respectively. In food packaging operations, tensile strength of a flexible packaging material is important as it determines the resistance to rupture when subjected to pulling force. High tensile strength for packaging materials are required to hold heavy packaged items. The values in Table 18 indicate that majority of the cartons are having tensile strength between 5.85to 20 kg/ 1.5 cm width / 18 cm length. Only one out of 33 cartons is having tensile strength above 20 kgf.

Table 17

Tensile strength and elongation of cartons

Range of Tensile strength kgf/1.5cm width / 18 cm length	Cartons falling in each range
5.85-09.08	24
9.10-12.10	1
12.20-15.20	3
15.30-18.30	4
18.40-19.40	0
>20 Kgf	1
Range of elongation, cm (increase in length / 18 cm)	**Cartons falling in each range**
0.30-0.50	10
0.55-0.85	11
0.86-1.16	9
1.20-1.50	2
1.60-1.83	1

Elongation property of a carton which is measured on the same machine as that for tensile strength, gives a measure of the toughness or resistance to rupture. Packages which are likely to undergo drops during distribution / processing requires cartons of high elongation. Table 17 indicates that two third of the cartons are having an elongation below 0.85 cm / 18 cm length.

It may be seen from Table 18 that no uniformity is maintained by the different manufacturers as regards to quantity of wax applied on the cartons. Variations in the wax may be attributed to wide differences in the temperature of the wax bath used as most of the manufacturers do not employ thermostats to control the temperature. Properly waxed cartons possess the advantages of being liquid proof and reducing the water vapour transmission rate while controlling the danger of sticking when in contact with freezer plate.

Table 18

Analysis of wax content

Range in GSM	Cartons falling in each range
8.00-10.00	1
10.10-20.00	5
20.10-30.00	17
30.10-40.00	6
40.10-43.00	4

The internal tearing resistance is a very important property in packaging of food stuffs especially when sharp edged products are packed, since even a slight tear in the material may result in the total failure of the packaging. Tearing strength is dependent on the orientation of the molecules or fibres in the packing materials. Table 19 shows that the tearing strength varied from 128 to 368 g in machine direction and 140 to 384 g in cross direction.

Table 19

Tearing strength of the cartons in machine and cross directions

Range of Tearing Strgth., g	Cartons falling in each range	
	Cross Dir.	Mach. Dir
128-178	2	7
179-229	19	20
230-280	5	3
281-329	4	1
330-370	2	2
371-384	1	

Table 20 shows the properties of low density polythene film used as an overwrap for the packages of frozen shrimp for export purpose. Food grade packaging materials must conform to distinctly different sets of standards in respect to:

a) Tolerance range in thickness

b) well defined physical properties

c) safety aspects against health hazards and

d) Flavour contamination.

From the results, it is seen that the thickness of the film is within the defined ranges. The permitted variation is ± 25 percent as per IS : 2508 (1984). Thickness of the film for food packaging should be within the defined ranges.

Table 20

Physical Properties of LDPE films used as an overwrap for frozen shrimp packaging

Source	Thickness (Stated)	Mean Thickness (Actual)	Overall Migration residue, mg/sq.dm	Deviation, %	Impact Strength, g	Tensile Str., Kg/sq.cm		Elongation at Break, %	
						Mach. Dir.	Cross Dir.	Mach. Dir.	Cross Dir.
1.	125 guage	120 guage	5.88	9.0	75	103	102	400	800
2.	100 guage	110 guage	5.32	5.0	80	100	68	266	322
3.	120 guage	118 guage	4.92	8.5	78	130	75	150	380
4.	125 guage	120 guage	5.64	3.8	70	122	120	135	90
5.	125 guage	119 guage	5.80	5.0	65	125	119	250	300
6.	100 guage	102 guage	4.92	11.2	63	100	85	265	310
7.	120 guage	118 guage	4.20	9.5	75	105	70	200	360
8.	125 guage	123 guage	6.20	8.9	82	120	90	105	300
9.	100 guage	102 guage	2.84	6.5	74	125	95	110	320
10.	125 guage	123 guage	3.24	7.5	63	112	90	200	300
11.	120 guage	124 guage	9.84	8.5	65	122	100	120	320

(Contd...2)

Source	Thickness (Stated)	Mean Thickness (Actual)	Overall Migration residue, mg/sq.dm	Deviation, %	Impact Strength, g	Tensile Str., Kg/sq.cm		Elongation at Break, %	
						Mach. Dir.	Cross Dir.	Mach. Dir.	Cross Dir.
12.	100 guage	110 guage	3.20	7.3	68	128	118	140	360
13.	120 guage	118 guage	5.40	6.8	80	121	86	150	360
14.	125 guage	123 guage	3.00	5.5	78	122	87	120	370
15.	120 guage	118 guage	3.12	9.8	71	118	85	110	365
16.	125 guage	120 guage	6.00	6.5	73	125	103	120	370
17.	120 guage	118 guage	9.96	8.0	75	118	75	150	360
18.	125 guage	118 guage	80.1	16.0	60	100	68	95	320
19.	120 guage	118 guage	4.80	4.8	85	120	80	200	350
20.	125 guage	128 guage	8.80	7.5	82	110	75	250	320

Non uniformity or wide variation in the thickness of the material will obviously affect the packed foods adversely and reduce its shelf life. It can be seen that mean thickness in most cases does not vary much from the stated thickness. The thickness variation is within the prescribed limit ($\pm$ 25 percent). This is too wide a variation and is undesirable for packaging foods, which can deteriorate when packed with such film.

Polymers used for manufacturing food packaging should have good mechanical properties. Commonly used polythene grade has a melt flow index of two corresponding to a molecular weight of 32,000 and a tensile strength of 128 kg/ sq.cm. (Borkar et al, 1982). Molecular weight of approximately 32,000 is necessary for the film to maintain its flexibility at extreme cold temperature. Tensile strength, which is dependent upon molecular weight thus plays an important role in defining the quality of production and also the state of degradation. IS : 2508 (1984) stipulates the minimum tensile strength as 120 kg/ sq. cm in machine direction and 85 kg / sq. cm in cross direction. Elongation at break should be 100 percent in machine direction and 350 percent in cross direction for the thickness of polythene varying from 50 to 300 guage. Table 20 indicates that many samples have not reached this laid down specification. It can also be observed that the above mentioned values are attainable by the industry, provided the correct grade polymer is used.

As shown in the Table 20, the overall migration residue of the most of the samples were within 10 mg/sq. dm as specified by IS:9845 (1981). One sample had an overall migration limit upto 80 mg / sq. dm. Also this sample had tensile strength and elongation percentage below the limit prescribed in IS: 2508 (1984). This may be due to the incorporation of excess amount of additives during the manufacturing stage. Migration residues are very important in view of the use of polymers in contact with food due to possible migration during storage.

The usual packaging procedure adopted in the frozen shrimp export industry in India is to provide an overwrap with a flexible synthetic film to the 2 kg frozen blocks before they are packed in the waxed duplex cartons. As per the practice in vogue in the industry each days production is given a code number and this code number indicates the year, month and day of production in addition to the size, grade etc. The code slip used is made of paper, with thickness varying from 0.07 mm to 0.215 mm. The code slips get mutilated while thawing the blocks for reprocessing and the mutilated fragments are estimated as filth. An attempt is made to develop a non mutilable, writable and printable synthetic film which is essential so that it is not counted as filth.

Table 21 shows the comparative properties of paper and polyester tracing sheet. As seen from the table, polyester tracing sheet possess high bursting strength, tensile strength, bursting strength (wet), tensile strength (wet) and nil Cobb value. Air permeability determination shows that it is non porous. Grammage of the paper used as code slip in the industry varies from 50 to 170 gsm. The differences observed in the strength properties of the paper from four different sources can be due to the differences in the quality of the raw material employed in their manufacture. Even though paper obtained from two different sources showed good tensile and tearing strength, the strength properties are reduced upon wetting. Paper is having high Cobb value and after it becomes wet, the strength properties are reduced. Polyester tracing sheet being non porous after wetting, it will not loose its original property as can be seen from the results of tensile strength (wet) and bursting strength (wet). The average water extractive values of polyester tracing sheet is within the limits of 10 mg/ sq. dm and hence suitable for food contact applications. There is no disintegration of the polyester tracing sheet in the frozen block even after ten days of repeated freezing and thawing. Disintegration of the code slip made out of paper was noticed in the frozen block kept for ten days when subjected to repeated freezing and thawing. Polyester tracing sheet kept in frozen shrimp block in four different industries around Cochin indicates its suitability to be used as a code slip without any disintegration / damage. All the existing printing / writing done on the paper code slip can be done on the polyester tracing sheet code slip also. Non brittleness of the code slip at frozen storage temperatures renders the code slip fit for use in the frozen shrimp for export.

Table 21

Physical properties of paper code slip and polyester tracing sheet code slip

	Details		Polyester Tracing sheet	Paper code Slip Source 1	Paper code Slip Source 2	Paper code Slip Source 3	Paper code Slip Source 4
1	Grammage, GSM		55	50	60	170	155
2	Thickness, mm		0.0375	0.07	0.07	0.175	0.215
3	Bursting Str., Kg/sq. cm.		11.5	2	1.5	3	2
4	Bursting Str. (Wet)		11.5	1.0	1.25	1.375	1.4
5	Tensile Str. Kgf/10cm length/ 1.5 cm width	Mach. Dir	9.7	2.1	3	9.5	5.9
		Cross. Dir	8.7	2	2.5	5.7	2.9
6	Tensile Str(wet) Kgf/10cm length/ 1.5 cm width	Mach. Dir	9.7	0.3	0.3	0.7	0.5
		Cross. Dir	8.7	0.2	0.2	0.6	0.3
7	Tearing Str.(g)	Mach. Dir	50	40	27	64	64
		Cross. Dir	55	45	42	80	85
8	Tearing Str.(g) (Wet)	Mach. Dir	50	10	8	16	24
		Cross. Dir	55	12	10	18	28
9	Cobb Value (1 min)		0	12	15	21	40
10	Air permeability Sec / 100 cc of air through the tracing sheet		No air can pass	47	6	76	26

Variations of tensile strength and elongation at break (dry) in 35 samples of strapping materials and effect of wetting on these properties are summarised in Table 22. It may be seen from the table that there is considerable variation in the dry tensile strength of the strapping materials. This property is important as it determines the resistance to rupture when subjected to pulling force and the extent of force that can be applied on the strapping materials by means of a strapping machine, before clinches the clip. Majority of the exporters (about 63 percent) uses recycled high density polythene straps, the tensile strength of which varies from 930 to 2520 kg/ sq.cm. Only one of the 22 recycled HDPE samples showed a stray value of tensile strength of 2518 kg / sq. cm. About 29 percent of the exporters use straps of polypropylene, the tensile strength of which varied from 940 kg / sq.cm to 3100 kg/ sq. cm. The tensile strengths of rayon strapping materials show variations from 1650 to 1800 kg / sq. cm. The tensile strength of the straps must be high so that they can be pulled tight enough to keep the master carton stable. The carton is strapped vertically, usually with two straps on a side, providing a stable and easily transported load. Narasimhan (1982) recommends that the tensile strength of the strapping materials should be around 1666 kg / sq. cm. (corresponding to 100 kgs tensile strength, 12 mm width and 0.5 mm thickness) and elongation at break of around 20 percent for frozen shrimp products. Polypropylene gives an elongation at break of less than 20 percent and one can produce polypropylene having tensile strength around 1666 kg / sq. cm.

Table 22

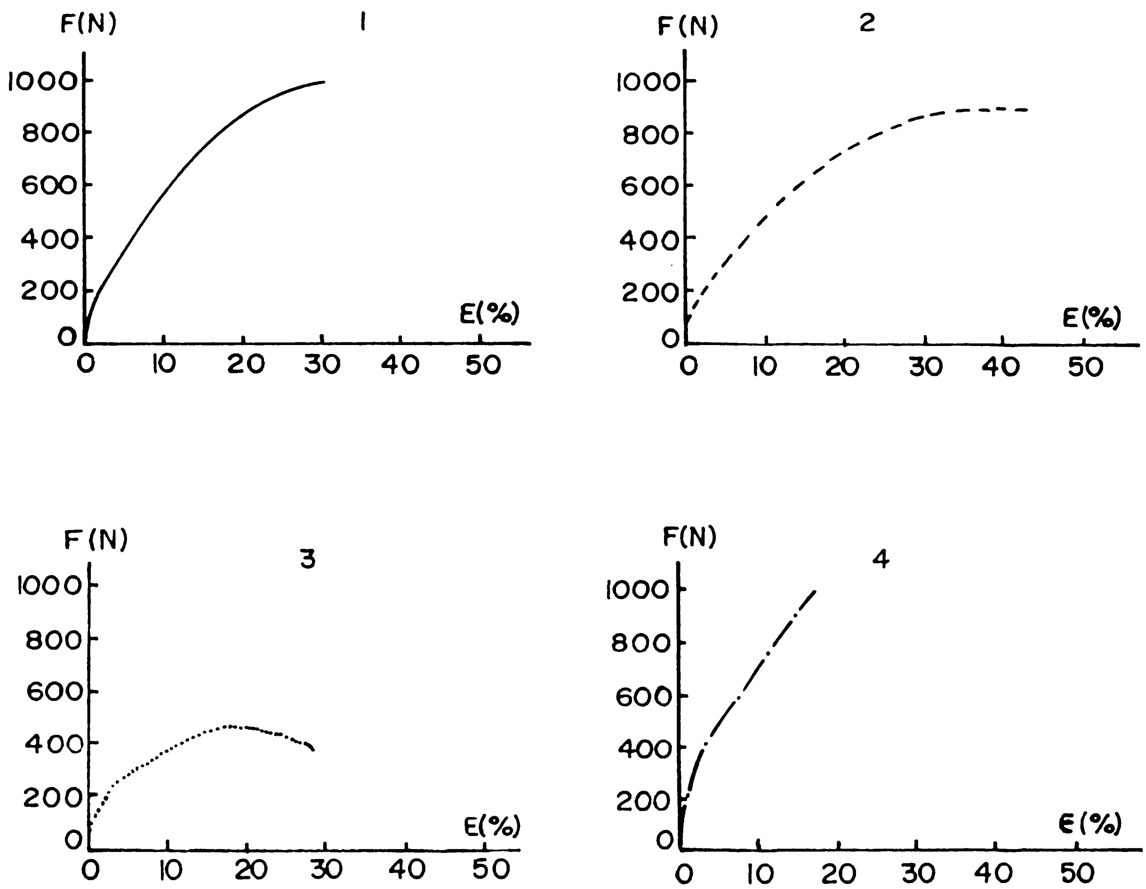
Tensile strength & Elongation of strapping materials

Sample	No. of samples	Range of Tensile str., kg/sq.cm	Range of Elongation at break, %
Polypropylene	10	940-3100	20-10
Rayon	2	1650-1700	18-17
Recycled HDPE	22	930-2520	60-25
HDPE	1	1575	50

Fig. 14. show the stress / strain relationship of the various strapping materials. The tensile strength of strapping materials must be great enough so that the strapping material will not break when subjected to the sort of load likely to be encountered in practice. The characteristics of the curve shows that HDPE and recycled HDPE materials can be classified as soft and weak, polypropylene as hard and brittle, rayon strap as hard and strong. These classifications have been done as referred by Briston and Katan (1974).

Wetting in water affects the above properties differently depending upon the material. In case of high density polythene and polypropylene , the tensile strength increases on wetting, whereas the tensile strength of rayon strap decreases on wetting. Rayon strap is not suitable for

FIG. 14



Load elongation curve of strapping materials used in frozen strimp for export.

1. Polypropylene strap 2. High density polythene strap
3. Recycled high density polythene strap 4. Rayon strap

reinforcement of master cartons which have to be kept in the frozen storage. Due to fluctuations in humidity in the frozen storage, rayon strap absorbs moisture and looses its strength. This has been conclusively proved by studying the changes in its properties during prolonged frozen storage. However, the elongation at break increases with the absorption of water. Also there are indications of splitting of cellulose fibres. The main advantages of rayon strapping are high tensile strength and display value. The brand name of the commodity exported can be easily printed on the rayon strapping material. In the case of high density polythene and reprocessed high density polythene, the elongation at break (dry) is high, but decreases due to wetting while in polypropylene there is no significant change in the elongation at break in dry and wet conditions.

Table 23 shows the fluctuations in the tensile strength and elongation at break (percentage) during frozen storage. In the case of polypropylene, the fluctuations in the tensile strength and elongation at break (percentage) are comparatively low. Hence polypropylene is more preferred compared to virgin HDPE or recycled HDPE, in which the tensile strength and elongation at break vary considerably during frozen storage and hence there are chances that it may give way / may not continue to have a good grip on the master carton during frozen storage, handling and transportation. According to Brydson (1987) polypropylene is having tendency to become brittle which is more than that of polythene. Products of improved strength

Table 23

Effect of frozen storage on the properties of strapping materials

Storage Period in months	Polypropylene		High density polythene		Recycled HDPE		Rayon	
	Tensile Str., Kg/sq.cm	Elongation, %	Tensile Str., Kg/sq.cm	Elongation, %	Tensile Str., Kg/sq.cm	Elongation, %	Tensile Str., Kg/sq.cm	Elongation, %
0	1440	20.0	1575	50.0	1335	62.0	1645	18.0
1	1455	18.0	1580	51.5	1350	65.5	1435	18.0
2	1461	16.5	1583	51.7	1373	67.0	1515	19.8
3	1460	16.5	1585	55.0	1415	68.0	1240	20.0
4	1474	16.6	1620	58.0	1416	68.0	1200	23.2
5	1490	16.6	1670	67.5	1460	69.0	1190	22.0
6	1504	18.0	1675	68.0	1465	70.0	1185	22.0

and lower brittle points can be obtained by block co-polymerisation of polypropylene with small amounts of (4-15 percent) of ethylene. Variations in the properties of polymers can be achieved by incorporating additives. In the case of rayon strap the tensile strength decreases drastically with frozen storage period and elongation at break increases. Due to fluctuations in humidity in the frozen storage the rayon straps absorbs moisture and looses its strength. Also there are indications of splitting of cellulose fibres.

Deteriorative changes taking place in master cartons during frozen storage for six months are presented in Table 24. A sudden spurt was observed in the moisture content even after one month of storage. This may be partly attributed to the fact that the cartons were not wax coated. Thereafter, the increase was not so marked, till the end of fifth month. After six months, a further steep increase was noticed. Corresponding decrease occurred in bursting strength and puncture resistance, significant changes in them being registered only after 2 to 3 months of storage. Alterations in these parameters are caused by condensation of moisture on the cartons due to fluctuations of temperature occurring during opening of the frozen store. Even though moisture uptake is comparatively quicker, the havoc done by it on the physical properties is slower. Moisture in the board is a very important factor affecting physical strength, flexibility, sheet forming characterestics, as also its weight, dimensional stability, rigidity, folding endurance, elasticity and above all its thermal properties. Fall in bursting strength is attributable to loss in strength and toughness of the fibres caused by the action of moisture. The decrease in puncture resistance is the root cause of frequent puncture of the master cartons held in frozen storage by corners of other cartons, lumbers and forks, when they are subsequently handled for transportation.

Table 24

Effect of frozen storage on properties of master cartons
(Grammage of board 651 GSM)

Period of Storage, months	Moisture, %	Bursting Strength, Kg/Sq.cm	Puncture Resistance, beach units
Nil	6.67	13.5	185
1	14.12	13.5	175
2	14.5	11.5	170
3	14.09	11.5	185
4	15.19	10.0	170
5	14.52	10.2	159
6	19.1	8.2	150

Table 25

Effect of frozen storage on physical properties of waxed duplex cartons
(Grammage of board 345 GSM, Wax content 8.5%, Saponifiable matter 2.94 %)

Period of Storage, Months	Moisture, %	Bursting Strength, Kg/sq.cm	Puncture Resistance, Beach units	Tearing Strength, g		Tensile Str., Kgf	Elongation, Cm/18 cm
				Cross Dir.	Mach. Dir		
Nil	5.45	3.75	21	180	168	16.26	0.6
1	9.19	3.75	20	152	128	10.97	0.6
2	9.54	3.50	20	160	128	11.08	0.6
3	9.60	3.50	20	128	112	9.05	0.6
4	9.60	3.25	20	144	120	10.95	0.6
5	9.70	3.25	19.5	144	120	10.75	0.6
6	9.79	3.25	19	144	120	10.70	0.6

Table 25 gives the changes in physical properties of waxed duplex cartons during frozen storage for six months. The increase in moisture was maximum after the first month in frozen storage. However the percentage increase was less than that in the corrugated fibre board, which may be attributed to the protection offered by the wax coating against moisture penetration and the comparatively lower grammage of duplex cartons (345 gsm). The fall in bursting strength in duplex cartons was only 13.3 percent after six months compared to 39 percent in master cartons. Puncture resistance decreased by 9.5 percent during storage. Tearing and tensile strength were the most affected. The tearing strength showed a fall of 20 percent in cross direction and 28.6 percent in machine direction in six months. Most drastic change was observed in tensile strength, a fall of 34.2 percent of the original.

Changes in moisture, bursting and puncture resistance occurring in plain corrugated fibreboards and moisture, bursting, tearing strength and puncture resistance occurring in duplex boards when exposed to moisture on one side for various period are presented in Table 26. Prolonged exposure to moisture and their consequent absorption drastically affects all the important physical properties. In commercial practice, duplex cartons are exposed to glazing both in the case of carton freezing and in tray freezing at the stage of packing. The absorption continues for varying lengths of time until all the free water freezes into ice. Master cartons are usually exposed inadvertently to occasional splashes of glaze water and to wetness of the surface on which they are placed. Condensation of water also occurs on the surface of master cartons due to fluctuations in temperatures of the frozen storage, dripping of water drops from the roof of the storage and during transshipment. Under all these circumstances, water is absorbed into carton material, causing deterioration in their physical properties.

Table 26

Changes in physical properties of plain corrugated fibre board and duplex board during prolonged exposure to moisture

Physical Properties	Corrugated Fibre Board				Duplex board			
	A	B	C	D	A	B	C	D
Moisture %	6.67	19.35	21.46	22.76	7.55	22.92	25.59	28.21
Bursting strength, kg/sq.cm	11.5	7.5	6.75	6.25	3.4	1.05	0.9	0.65
Puncture resistance, Beach units	210	127.5	117.5	115	20.5	10.5	8.5	6.75
Tearing Strength, g								
Cross Dir	---	---	---	---	176	64	48	40
Mach. Dir	---	---	---	---	165.5	56	40	32

A : Control (before exposure to water)

B : After one hour exposure to water

C : After two hour exposure to water

D : After three hour exposure to water

The changes in physical properties of corrugated fibre board and duplex board brought about by wax coating once, twice and thrice are presented in Table 27. Wax coating causes significant improvement in the moisture resistance as shown by the decreasing Cobb 30 minutes values. Wax content in the boards increase with the number of times they are waxed with simultaneous decrease in Cobb 30 minutes values. Two wax coating treatments appear to be sufficient to impart desirable degree of water resisting property to the board. The other characterestics of the boards namely moisture, bursting strength, puncture resistance and tearing strength are not however affected in any way by wax coating.

Table 27

Changes in physical properties of plain corrugated fibre board and duplex board after repeated wax coating

Stage of analysis	Corrugated fibreboard		Duplex carton	
	Cobb 30' Value	Wax Content %	Cobb 30' Value	Wax Content %
Initial (Before wax coating)	108.45	Nil	66.16	Nil
After wax coating once	87.05	6.68	39.80	11.90
After wax coating twice	25.06	9.01	32.54	13.77
After wax coating thrice	19.49	9.84	30.00	16.29

Table 28 depicts the changes in moisture, bursting strength and puncture resistance of the wax coated corrugated fibre board after exposure to water for 1, 2 and 3 hours at one side to a depth of 4 cm. The uptake of water is maximum in the control sample (Table 26). The moisture increasing more than three times in three hours, greatest increase occurring in the first hour of exposure. Moisture uptake in the first hour in both twice and thrice coated samples is comparable, while during subsequent continued exposure, the latter exhibits greater resistance (Table 28). This is a very important phenomenon to be reckoned with, since moisture condensation on the master cartons takes place to some extent due to fluctuations of temperatures and humidity in the frozen storage during opening and closing of doors and to considerably high degree while transporting the frozen cargo in insulated vans. The condensed moisture gets absorbed into the carton materials, weakening its physical properties. This causes the drastic fall in bursting strength and puncture resistance values along with increase in moisture content. It may incidentally be pointed out that wax coating does not alter these characterestics as they are the inherent properties of the material constituting the board and hence initial values of the control board hold good for the wax coated samples also prior to exposure to moisture.

Table 28

Changes in physical properties of corrugated fibreboard (wax coated) due to exposure to water

Sample	Moisture, %	Bursting strength, Kg/sq.cm	Puncture resistance, Beach units
Initial values	6.67	11.5	210.0
Wax coated once			
A	16.28	7.5	150.0
B	18.24	6.5	130.0
C	19.65	6.5	120.0
Wax coated twice			
A	7.78	10.0	190.0
B	16.18	8.5	150.0
C	16.58	7.5	138.0
Wax coated thrice			
A	8.09	9.0	197.5
B	10.22	9.0	185.0
C	12.29	9.0	175.0

A : After one hour exposure to water
B : After two hour exposure to water
C : After three hour exposure to water

Changes occurring in moisture, bursting strength, puncture resistance and tearing strength in both cross and machine direction in duplex boards coated with different percentages of wax on exposure to water to a depth of 4 cm for 1, 2 and 3 hours are presented in Table 29. The pattern of changes is similar to that in corrugated board. Moisture in the control sample multiplies nearly four times after exposure to water for three hours (Table 28). Even though the percentages of wax imbibed are comparatively more in duplex boards (Table 29), their water intake is more than that of the corrugated boards with smaller percentages of absorbed wax. Hence the amount of wax alone is not the decisive factor in the matter of fluid absorption. It is known that the amount of fibres, sheet density and ash content are some other factors over and above wax content which contribute towards building up resistance against fluid penetration in papers (Anon, 1973). Rates of deterioration in physical properties namely bursting strength, tearing strength and puncture resistance are comparatively more pronounced in the duplex board along with the absorption of water.

Transport worthiness tests conducted on the filled packages with ice with the different basis weights of kraft paper are presented in Table 30. Tests conducted on the filled packages proved beyond doubt that the master cartons prepared out of virgin 120 gsm kraft paper possess higher bursting strength than 100 gsm paper. Transport worthiness tests indicate that the master cartons prepared out of 120 gsm kraft paper withstand all the transport worthiness test like drop, rolling and vibration tests. Corrugated fibre board prepared out of 100 gsm kraft paper failed in the drop test of the transport worthiness tests indicating its unsuitability for packing frozen fishery products.

Table 29

Changes in physical properties of waxed duplex board due to exposure to water

Sample	Moisture, %	Bursting strength, kg/sq.cm	Puncture resistance, Beach units	Tearing strength, g Cross Dir.	Tearing strength, g Mach. Dir.
Initial values	7.55	3.40	20.50	176	165.5
Wax coated once					
A	16.28	1.75	17.75	120	114
B	19.93	1.40	13.75	104	96
C	22.28	1.25	12.25	100	88
Wax coated twice					
A	13.90	1.70	18.00	136	120
B	20.00	1.40	17.50	126	113
C	20.92	1.50	13.25	116	96
Wax coated thrice					
A	13.74	2.40	19.50	144	124
B	18.53	1.40	16.25	128	112
C	20.46	1.50	15.50	120	112

A : After one hour exposure to water
B : After two hour exposure to water
C : After three hour exposure to water

Table 30

Physical properties of packaging materials used for the study and endurance tests for filled packages

Description of the package with its physical properties	Net Weight	Endurance tests on filled packages		
		Drop test Height ->3 ft	Roll test 20 rolls along three different axis	Vibration test Frequency : 120 cpm Amplitude : 2.54 cm
(1) Corrugated fibre board of the dimension 33 x 32 x 31 cm with 120 GSM kraft paper (RSC type) Bursting strength 12 kg/sq.cm Puncture resistance 200 BU Compression strength 350 kg Type of flute B Adhesive used Starch based adhesives Duplex cartons used are of grammage 300 GSM with wax coatings 10 GSM on both sides Thickness of duplex cartons 0.42 mm Ring Stiffness 270 N Bursting strength 400 Kpa LDPE film used (as a overwrap)	23-24 Kg filled with duplex cartons containing ice blocks	No damage to the box CFB box intact.	No damage to the box	Melting of ice took place while vibration, but no damage to the box.

Contd.......2

<u>Physical</u> <u>properties</u> <u>of</u> <u>LDPE</u> <u>film</u> <u>used:</u> WVTR 18 g/sq.m/90% RH/24h/37°C Tensile strength MD: 120 Kg/sq cm CD: 85 Kg/Sq cm Elongation at break MD: 100% CD: 300% Impact strength 80 g	The cartons were strapped with 12 mm polypropylene having a tensile strength 75 kg/cm width			
(2) Corrugated fibre board of the dimension 33 x 32 x 31 cm with 100 GSM kraft paper Bursting strength 10 kg/sq.cm Puncture resistance 175 BU Compression strength 300 kg Type of flute B Adhesive used Starch based adhesives Duplex cartons, LDPE films and strapping materials used were of the same type as mentioned in (1)	23-24 Kg filled with duplex cartons containing ice blocks	With the first drop itself, corrugated fibre board box was damaged. Duplex cartons comes out of the corrugated fibre board box.	No damage to the box	No damage to the box

The various physico-chemical properties determined on a number of samples are given in Table 31. The water vapour transmission rate values of packaging materials are of paramount importance in selecting them to package specific food products since the shelf life of a moisture sensitive food is influenced by this property. Fish products such as dry fish, frozen fish, soup powder and other processed fishery products need packages with low water vapour transmission rate (WVTR) to prevent the absorption of moisture and at the same time preventing excessive desiccation. With a knowledge of the WVTR of a packaging material, the initial and critical moisture contents of the product and the humidity gradient between the inside and outside of the package, the shelf life of the product could be predicted to a fair degree (Heiss and Echner, 1971 ; Kumar *et al.* ,1974). The WVTR values in the tables indicate that LDPE of 100 guage on an average had a value of 18g/sq.m / 38°C/ 90 % RH. LDPE (200 guage) on average had a value of 8.29 sq.m/ 38°C / 90 % RH. High density polythene (HDPE) of corresponding thickness had a value of only 2.5 g /sq. m/ 38°C / 90 % RH. It was also observed that in the range of thickness tested between 100 guage and 200 gauges the water vapour transmission rate of LDPE were about three times more than HDPE. Polyester of 50 guage had a value of 39.6 g /sq.m /38° C/ 90 % RH, whereas laminates of polyester with polythene or metallised polyester show a less value. Papers such as MXXT cello (300 gsm) and glassine were found to have high WVTR but coating or laminating them with polythene has improved considerably their barrier property (Kumar, *et al.*, 1976). In case of the laminates it could be inferred that cellulose film alone is not an effective water vapour barrier at high humidity and temperature conditions and the effectiveness of the laminates to reduce WVTR is mainly due to PVDC coatings and PE films. Coatings of co polymers of PVDC (PVC Saran) on cellulose film was found to be very effective in reducing WVTR, the rate reduced from 17 to 6.7 g/ sq. m which could be advantageously used to package hygroscopic products (Kumar, *et al.*, 1976).

In food packaging operations, tensile strength of a flexible packaging material is important since it determines the resistance to rupture when subjected to a pulling force. High tensile strength for packing materials are required to hold heavy items and when packages are formed in semi automatic or automatic pouch forming and filling machines and also in operations such as laminations, coatings or printing. The tensile strength values given in Table 31, indicates that for majority of films and laminates they fall between 2 to 4 kN/m width in machine direction and 1.25 to 2 kN /m width in cross direction. Among the plastic films studied, polyester is having higher tensile strength compared to LDPE, PP or HDPE.

Elongation property of a flexible packaging material which is measured on the same machine as that of tensile strength gives a measure of the toughness or resistance to rupture. In food packages which are likely to experience drops during distribution, they require materials of higher elongation. In general papers are having low elongation values whereas plastic materials such as LDPE and co-extruded films showed more than 300 percent and upto 900 percent respectively.

Bursting strength values of flexible packaging materials are difficult to correlate with their actual performance in the package form during storage and distribution, but this gives an indication of the combined tensile strength properties (ASTM, 1963). Also burst values are a rough guide to compare the general strength properties of packaging materials. Most of the unsupported films had bursting strength values between 0.98 kg./ sq.cm. to 1.96 kg / sq. cm. Polyester possess higher bursting strength for the lower thickness of the film compared to LDPE or HDPE. Because of this property, polyester is laminated with multilayer film in order to set higher bursting strength. Laminates of metallised polyester with 150 guage LDPE had high burst values. of 5.16 kg / sq.cm.

Another property of a flexible packaging material, internal tearing resistance, is a very important property in food stuffs packaging especially when sharp edged products are packed since even a slight tear in the material may propagate and result in the total failure of package. Films of polyester and polypropylene (OPP) have poor tearing resistance values of only 10 to 12 g in machine direction and cross direction. Polyesters and co-extruded films had very high tear values, since high elongation is normally associated with high tear resistance. LDPE/LDPE coextruded film have very high tear strength in the region of 490 g. A very important property of packaging film is oxygen permeability. As can be seen from the table 31, low density polythene is having higher gas transmission rate compared to high density polythene and other laminates. Since the permeability to Oxygen of low density polythene is fairly high it is not advisable to use these films to pack oxygen sensitive products. The degree of crystallinity of the polymer affects the permeability (Paine, 1983). In the steady state, the quantity of gas or oxygen transmitted is inversely proportional to the thickness of the film. In case of laminates and multilayer film the gas transmission rates are much less compared to low density polythene or HDPE or PP.

Table 31

Physical properties of various packaging films used in the industry

DETAILS	Tensile Str., KN/M		Elongation at break, %		Bursting Strength, kg/sq.cm	Tearing resistance g		WVTR g/sq m/24 h 37°C at 90 % RH	OTR cc/sq m/24 h 20°C atmosphere
	Machine Dir.	Transverse Dir.	Machine Dir.	Transverse Dir.		Machine Dir.	Transverse Dir.		
LDPE 100 guage	3.70	2.00	300	175	0.980	27	32	18	9000
LDPE 200 guage	1.18	0.59	High	365	1.177	120	>120	8.2	4100
HDPE 200 guage	1.19	1.05	500	500	1.377	270	360	2.5	1450
Cast PP 200 guage	1.31	1.25	300	350	1.961	132	180	4.5	1700
OPP 200 guage	2.20	2.00	7	70	-	10	10	2	1240
MXXT cello 300 GSM	2.62	1.28	25	35	2.350	33	40	8.5	45
Glassine 40 GSM	2.55	1.43	5	5	1.170	48	83	1920	High
Polyester 12 u	1.83	1.37	22	20	3.138	12	12	39.6	160
12 u Plain polyester/ 300 guage LDPE	3.30	2.53	100	65	3.138	165	180	4.9	75
12 u Metallised PEST/ 150 guage LDPE	2.97	2.67	82	70	5.160	105	123	0.5	1
300 MXXT cello/ 150 g LDPE	3.14	1.43	30	75	2.740	120	128	6.4	6

(contd....2)

DETAILS	Tensile Str., KN/M		Elongation at break, %		Bursting Strength, Kg/cm^2	Tearing resistance g		WVTR g/sq m/24 h 37°C at 90 % RH	OTR cc/sq m/24 h 20°C atmosphere
	Machine Dir.	Transverse Dir.	Machine Dir.	Transverse Dir.		Machine Dir.	Transverse Dir.		
12 µ Metallised nylon / 200 g LDPE	8.25	5.3	240	190	3.4	43	52	2	5
100 µ HDPE/LDPE/HDPE	1.96	1.87	200	840	1.6	220	240	10	1000
90 µ LDPE/LDPE	2.6	2.55	900	800	0.8	375	490	15	2000
12 µ PEST/118 µ LDPE-HDPE coextruded film	3.09	2.85	950	750	3.9	185	206	0.4055	1250
85 µ Nylon/Ionomer	2.95	2.11	120	110	1.70	240	286	10.6	50
60 µ LDPE/Nylon/LDPE coextruded film	1.92	1.77	500	380	1.38	45	60	12	8
120 µ LDPE/HDPE coextruded film	2.3	1.72	970	980	2.45	280	310	8	1000

Table 32 gives the proximate composition of prawn soup powder. Sorption isotherm characterstics are shown in Fig.15. Under ambient storage conditions (Temperature 27°C to 30°C and relative humidity 80 to 90 percent), the product had a tendency to absorb moisture. It lost its free flowing characterestics when moisture content rose >= 9.89 percent. The packaging material should have low water vapour transmission rate for retaining this characteristic property for a longer period. The storage studies of prawn soup powder packed in different packaging materials are presented in Table 33. Moisture uptake was lower in the laminated polyester /LDPE and co-extruded films. This is due to their low water vapour transmission rates and pH decreased in all the pouches. FFA production was less in the products packed in laminated and co extruded films. Browning rate was more in LDPE, PP and HM-HDPE pouches. This may be due to high oxygen transmission rates of these films.

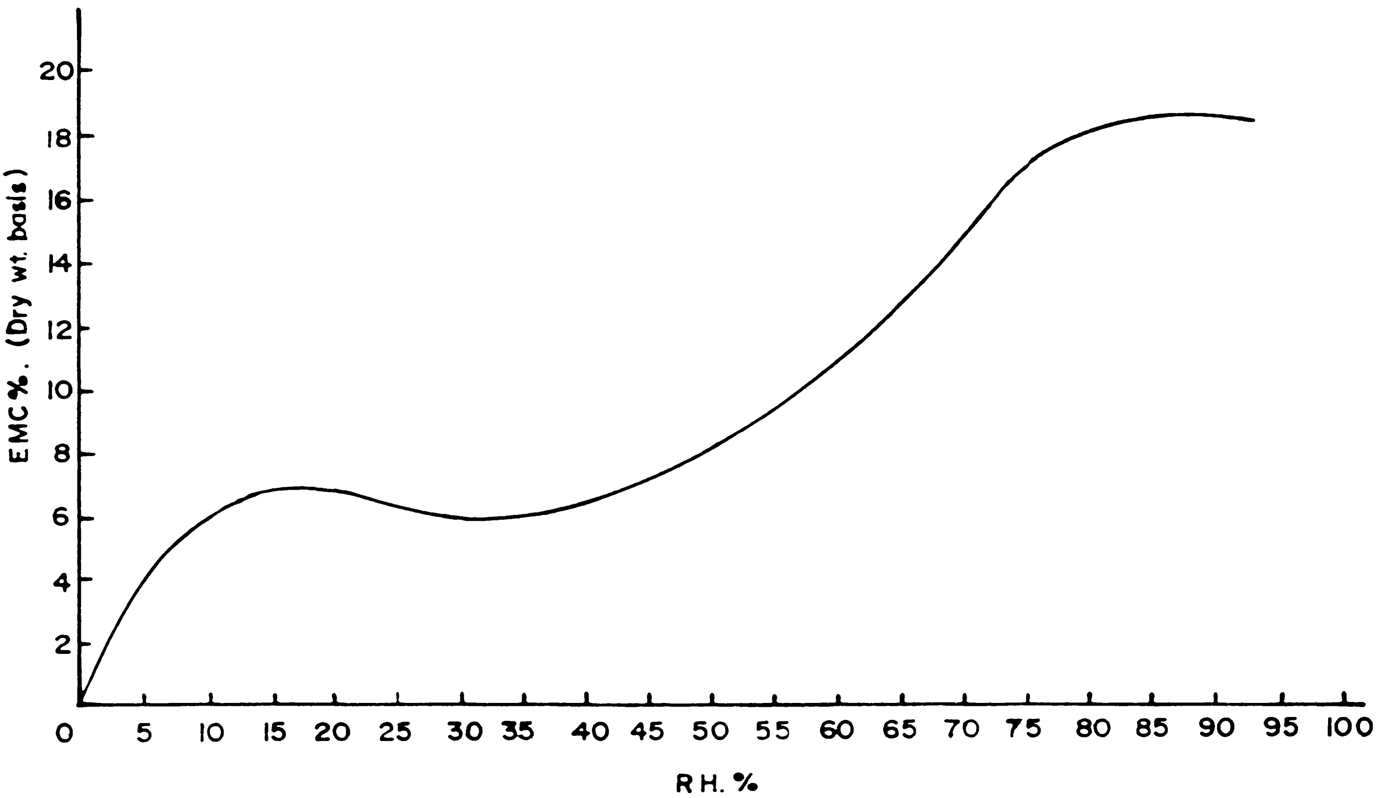
Table 32

Chemical composition of soup powder

Moisture %	5.1
Protein %	21.0
Fat %	14.6
Ash %	19.4

Figure. 15.

SORPTION ISOTHERM CHARACTERISTICS OF PRAWN SOUP POWDER



The physical properties of polyester laminated with LD-HD co extruded film, LD/BA/Nylon/ primacore and Nylon / LDPE-HDPE , which was found suitable for soup powder packaging are described in Table 34. 62.5 Nylon / LDPE-HDPE co extruded film, 12 micron polyester / LD-HD , 90 micron LD/BA/Nylon/BA/Primacore are the suitable packaging materials for fish soup powder. The pouch material enabled the soup powder to retain the flavour, odour and other desirable characterestics for a period of 180 days. Heat seal strength was also high in these pouches. The average heptane extractive of LDPE-HDPE co extruded film, 12 micron plain Polyester / LDPE-HDPE co extruded film and 90 micron LD/ BA/Nylon/BA/Primacore pouches were below the limit (50 mg / l and 60 mg / l) specified by FDA (1983) and IS :10146 (1982) respectively. Thus when viewed from FDA and IS specifications, the pouches used have overall extractive values below the specified limits and hence are suitable for soup powder packaging. For a longer shelf life, LDPE-HDPE co extruded film may be laminated with 12 micron metallised polyester.

Table 33

Storage of prawn soup powder in different packaging materials at room temperature

Parameters	Storage Period	HM/ HDPE	LDPE	PEST/ LDPE	Nylon LDPE- HDPE co-extruded	MXXT/ LDPE	PP	Metallised PEST/ LDPE	12μ plain PEST/ LDPE -HDPE	95 μ LD/ BA/Nylon/BA Primacore
		Packaging materials used								
Moisture	Initial	5.630	5.630	5.630	5.630	5.630	5.630	5.630	5.630	5.630
	After 2.5 months	8.000	8.000	6.000	6.000	7.000	8.100	5.740	6.000	5.950
	After 4 months	8.500	8.300	7.000	6.500	7.300	8.180	7.200	7.250	7.180
	After 5 months	*	*	*	6.700	*	*	*	8.020	7.950
	After 6 months	*	*	*	8.150	*	*	*	8.850	8.500
pH	Initial	6.930	6.930	6.930	6.930	6.930	6.930	6.930	6.930	6.930
	After 2.5 months	6.580	6.540	6.650	6.500	6.600	6.500	6.650	6.850	6.850
	After 4 months	6.130	6.180	6.480	6.500	6.200	6.180	6.200	6.700	6.750
	After 5 months	*	*	*	6.340	*	*	*	6.700	6.700
	After 6 months	*	*	*	6.280	*	*	*	6.700	6.700
O D at 420 mu	Initial	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
	After 2.5 months	0.035	0.040	0.035	0.035	0.035	0.040	0.035	0.035	0.035
	After 4 months	0.041	0.042	0.035	0.036	0.036	0.038	0.036	0.035	0.035
	After 5 months	*	*	*	0.042	*	*	*	0.036	0.035

(Contd....)

Parameters	Storage Period	Packaging materials used								
		HM/ HDPE	LDPE	PEST/ LDPE	Nylon LDPE- HDPE co-extruded	MXXT/ LDPE	PP	Metallised PEST/ LDPE	12μ plain PEST/ LDPE	95 μ LD/ BA/Nylon/BA Primacore
	After 6 months	*	*	*	0.048	*	*	*	0.038	0.036
FFA mg % Oleic acid	Initial	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	After 2.5 months	2.960	4.610	1.970	2.100	2.000	2.700	2.100	1.500	1.580
	After 4 months	4.110	5.800	2.470	2.050	2.120	4.500	2.060	1.950	1.850
	After 5 months	*	*	*	2.800	*	*	*	2.010	2.050
	After 6 months	*	*	*	4.850	*	*	*	2.850	2.700

Table 33 a

Organoleptic evaluation of prawn soup powder in different packaging materials at room temperature

Storage Period	Packaging materials used: HM/ HDPE	LDPE	PEST/ LDPE	Nylon/LDPE-HDPE co-extruded	MXXT/ LDPE	PP	Metallised PEST/ LDPE	12µ plain PEST/ LDPE-HDPE	95 µ LD/ BA/Nylon/BA Primacore
Initial	Good	Good	Good	Good	Good	Good	Good	Good	Good
After 2.5 months	Good	Good	Good	Good	Good	Good	Good	Good	Good
After 4 months	Not acceptable off taste, delamination took place		Acceptable No off taste, delamination took place	Acceptable No off taste No delamination	Acceptable No off taste, delamination took place	Not acceptable off taste, delamination took place	Acceptable No off taste, delamination took place	Good, No Off taste	Good, No Off taste
After 5 months	******	******	******	Acceptable No off taste No delamination	******	******	******	Good, No Off taste	Good, No Off taste
After 6 months	******	******	******	Good, no off taste.	******	******	******	Good, No Off taste	Good, No Off taste
After 7 months	******	******	******	Not acceptable, off odour	******	******	******	Not acceptable Slightly off odour	Not acceptable Slightly off odour

Table 33 b

Sensory score of prawn soup powder packed in different packaging materials at room temperature

Storage Period	Packaging materials used								
	HM/ HDPE	LDPE	PEST/ LDPE	Nylon/LDPE-HDPE co-extruded	MXXT/ LDPE	PP	Metallised PEST/ LDPE	12μ plain PEST/ LDPE-HDPE	95 μ LD/ BA/Nylon/BA Primacore
Initial	8.0±0.8	8.0±0.8	8.0±0.8	8.0±0.8	8.0±0.8	8.0±0.8	8.0±0.8	8.0±0.8	8.0±0.8
After 2.5 months	6.0±1.1	6.7±0.9	7.0±0.6	7.0±0.8	6.8±0.7	6.4±0.3	6.2±0.9	7.5±0.3	7.4±0.7
After 4 months	3.8±0.3	3.5±0.6	5.0±0.9	5.5±0.6	5.1±1.2	3.7±0.6	5.0±1.2	6.5±0.9	6.8±0.5
After 5 months	-	-	-	5.0±1.4	3.9±0.3	-	-	6.0±1.1	5.8±0.9
After 6 months	-	-	-	5.1±0.9	-	-	-	5.1±0.8	5.0±1.2
After 7 months	-	-	-	3.5±0.5	-	-	-	3.8±0.4	3.6±0.7

Table 34

Physical properties of PEST/LDPE-HDPE, LD/BA/Nylon/BA/Primacore and Nylon/LDPE-HDPE co-extruded film

Parameters	12 μ PEST/ LDPE-HDPE	95 μ LD/BA/ Nylon/BA/ Primacore	62.5 μ LDPE-HDPE/ co-extruded film
Water vapour transmission rate (g/sq.m/90% RH at 38 ±2°C/ 24 h)	0.4055	0.5	4.84
Oxygen transmission rate (cc/sq.m/24 h/ 20°C/atmosphere)	25.3	30	55.58
Tensile strength kg/sq.cm			
Machine Direction	315	299	201
Cross Direction	290	216	188
Elongation at break (%)			
Machine Direction	950	500	200
Cross Direction	750	380	842
Heat seal strength kg/sq.cm			
Machine Direction	250	230	150
Cross Direction	200	180	140
Heptane extraction (mg/litre)			
at 21.1°C for 30 min	15.28	18.05	18.5
at 25°C for 30 min	17.45	20.08	19.8
Drop test	No damage to the packaging material and withstood six drops		

Results of the physical observations on packaging materials during storage of fish pickle are presented in Table 35. It can be seen from Table 35, 85 micron Nylon / Surylyn film, 12 micron metallised polyester laminated with 118 micron co-extruded films of LDPE-HDPE, 12 micron plain polyester laminated with 128 micron co-extruded film of LDPE-HDPE film and 95 micron LD / BA /Nylon / BA /primacore are suitable for the packaging of fish pickles based on the physical observations on packaging materials during storage of pickles and transport worthiness tests like drop tests and vibration tests.

Results of the chemical analysis of fish pickle at different stages of storage at room temperature are presented in Table 36. Titrable acidity of the muscle increased on storage and attained equilibrium in 5 months. The TVN values remained somewhat steady during 7 months of storage at room temperature. Peroxide value of the muscle was very low in 7 months of storage. No rancid flavour could be detected organoleptically. No mould growth was observed in any of the sample throughout the storage period.

Table 37 shows the water vapour transmission rates and oxygen transmission rates of packaging films. It can be seen that plain polyester /LDPE-HDPE, Metallised polyester / LDPE-HDPE and LD / BA / Nylon /BA /Primacore are having low WVTR and oxygen transmission rates. Table 38 shows the result of sensory evaluations. The taste panel reported that the products were in good condition after 7 months of storage. The panel did not find any difference among the

Table 35

Physical observations on packaging materials during storage of pickle

Packaging materials used	Observations
Poly propylene film 300 guage	Leakage of pickles observed after 3 months of storage. Odour of the pickles perceptible externally. Leakage observed after one drop.
12 μ metallised polyester laminated with 300 guage low density polythene	Leakage was observed in most of the pouches in 7 months storage. Delamination of polythene from the metallised polyesters was observed in all cases. Leakage observed after 2nd and 3rd drop.
Cellophane polythene laminate 300 guage coated with Saran	Remained in good condition for a period upto 4 months. Delamination takes place after 5 months of storage. Insects started attacking cellophane and caused pin holes in polythene. Leakage observed after 2nd or 3rd drops.
85 μ Nylon/Surylyn film	Remained in good condition for 7 months without leakage,withstands drop test and vibration tests.
12 μ metallised polyester/ 118 μ LDPE-HDPE coextruded film	Remained in excellent condition for 7 months without leakage, withstands drop test and vibration tests.
12 μ plain polyester/ 128 μ LDPE-HDPE coextruded film	Remained in excellent condition for 7 months without leakage, withstands drop test and vibration tests.
95 μ LD/BA/Nylon/BA/Primacore	Remained in good condition for 7 months without leakage, withstands drop test and vibration tests.
Glass bottle	Remained in good condition for 7 months without leakage. Did not withstand drop test and vibration tests.

Table 36

Storage changes in fish pickle sealed in different packaging materials at room temperature

Details	Initial	After 7 months of storage				
		85 µ Nylon/ Surylyn film	12 µ metallised polyester/118 µ LDPE-HDPE	12 µ plain polyester/ 128 µ LDPE-HDPE	95 µ LD/BA/ Nylon/BA/ Primacore	Glass Bottle
Acidity of the Muscle (% acetic acid)	1.28	1.54	1.63	1.60	1.62	1.63
TVN (mg/100 g muscle)	16.00	19.20	19.23	19.25	19.20	16.40
Peroxide value (m eq/1000 g of fat)	0.16	1.38	1.76	1.71	1.02	1.03
pH	3.90	3.51	3.58	3.50	3.50	3.60

Table 37

Water vapour and oxygen transmission rates of packaging films used for fish pickle

Details	85 μ Nylon/ Surylyn film	12 μ metallised polyester/118 μ LDPE-HDPE	12 μ plain polyester/ 128 μ LDPE-HDPE	95 μ LD/BA/ Nylon/BA/ Primacore
WVTR (g/sq m/24 h/ 37°C/90% RH)	10.60	0.78	0.4055	0.50
Oxygen transmission rate (cc/sq m/24 h/ atmosphere)	55.60	18.50	27.00	30.00

products packed in glass bottle, plain polyester laminate with LDPE /HDPE, metallised polyester laminated with LDP /HDPE, Nylon / Surylyn and LD/BA/Nylon/BA/Primacor pouches. The product was in good condition as regard flavour and appearance after seven months of storage. The overall appearance of the product packed in Nylon / Surylyn became slightly dull after 7 months storage. This may be attributed to its high oxygen permeability and water vapour transmission rate. No rancidity was reported in any of the samples. This may be attributed to some spices used in the pickles which may possess antioxidant properties.

Table 38

Organoleptic evaluation of Seer fish pickle in Nylon/Surylyn, Met. PEST/LDPE-HDPE, LD/BA/Nylon/BA/Primacore and Polyester/LDPE-HDPE

Initial	5 months	7 months
In all the samples the muscle is moderately hard, acidic salty and had good taste. The gravy portion was slightly more acidic and salty	In all the samples packed on flexible pouches and glass bottle, the muscle was firm, sufficiently acidic, salty and spicy and had very good taste, highly palatable gravy. The saltiness and acidity reduced in the gravy	In all the samples packed in flexible pouches and glass bottle the muscle became moderately fibrous and tough, acidic and spicy. Palatable gravy, sufficient salt and acidity in the gravy. Only in Nylon/surylyn pouch the colour of the pickle had become dull

It can be seen from Table 39, that the average extractive values of Nylon / Surylyn, plain polyester / LDPE-HDPE, and metallised polyester / LDPE-HDPE, 95 micron LD/BA/Nylon/BA/Primacore are below the limit of 50 mg/l and 60 mg/l as specified by FDA and IS respectively. Thus when viewed from both FDA and IS specifications, the pouches used have overall extractive values below the specified limits for food contact application. Water extractives are also well below the limit. The results shows that all these pouches can be used for packaging of fish pickles.

Table 39

Results of the migrateion test of different packaging materials used in the study

Details of packaging materials	Amount of heptane extraction mg/l		Amount of water extractives mg/l
	21°C for 30 min	25°C for 30 min	48°C for 24 hours
12 u metallised polyester/118 u LDPE-HDPE	16.09	18.20	2.33
12 u plain polyester/ 128 u LDPE-HDPE	15.28	17.45	4.08
85 u Nylon/ Surylyn film	22.83	23.12	5.19
95 u LD/BA/ Nylon/BA/ Primacore	18.05	20.08	2.12

Maximum overall extractive specified as per FDA 175 : 300 : 50 mg/l

Maximum overall migration limit as specified by IS : 10146 - 1982 : 60 mg/l

Comparative costs of these packaging materials in relation to glass bottles are given in Table 40. It may be observed that a net quantity of 380 g of fish pickle needs a glass container costing Rs 3.00. Metallised polyester/ LDPE-HDPE pouch of the size 16 cm x 15 cm would cost just Rs. 1.10 to pack 380 g of pickle. The cost advantages in terms of costs of packaging materials are 1:3 in favour of flexible pouches compared to glass bottles. In transporting the finished product to the ultimate consumer, the gross weight of the packed product is to be taken into account. If a package adds more gross weight to the net weight of the product transported, then that package adds substantially to the cost of final product. Comparatively that material cannot be considered cost effective. From column 5 of the Table 40 it may be observed that the glass containers add 78.95 percent to the net weight of the product. This means the transport cost would escalate proportionately. As compared to the substantial addition to the weight of the product by glass containers, the flexible packaging materials studied have added less than 4 percent to the gross weight of the product. This would result in huge savings in transportation cost. Considering the various factors involved in material cost, labour cost as well as transportation cost, the flexible packaging materials prove to be highly cost effective compared to the traditional glass containers. Defence services already use flexible packaging materials based on regenerated cellulose films for the packaging of pickle in oil (Ghosh *et al.*, 1965).

Table 40

Comparative costs and weights of glass bottles and flexible packaging materials for fish pickles

Container	Net wt. of packed Pickle (g)	Wt. of packaging material(g)	Cost of contaier	Package wt. as a % of Product wt.
Glass bottle	350.00	300.00	Rs3.00	78.95
12 u metal-lised poly-ester/118 u LDPE-HDPE	380.00	12.00	Rs1.10	3.16
12 u plain polyester/ 128 u LDPE-HDPE	380.00	11.50	Rs1.00	3.02
85 u Nylon/ Surylyn film	380.00	9.00	Rs1.10	3.21
95 u LD/BA/ Nylon/BA/ Primacore	380.00	10.50	Rs1.25	3.5

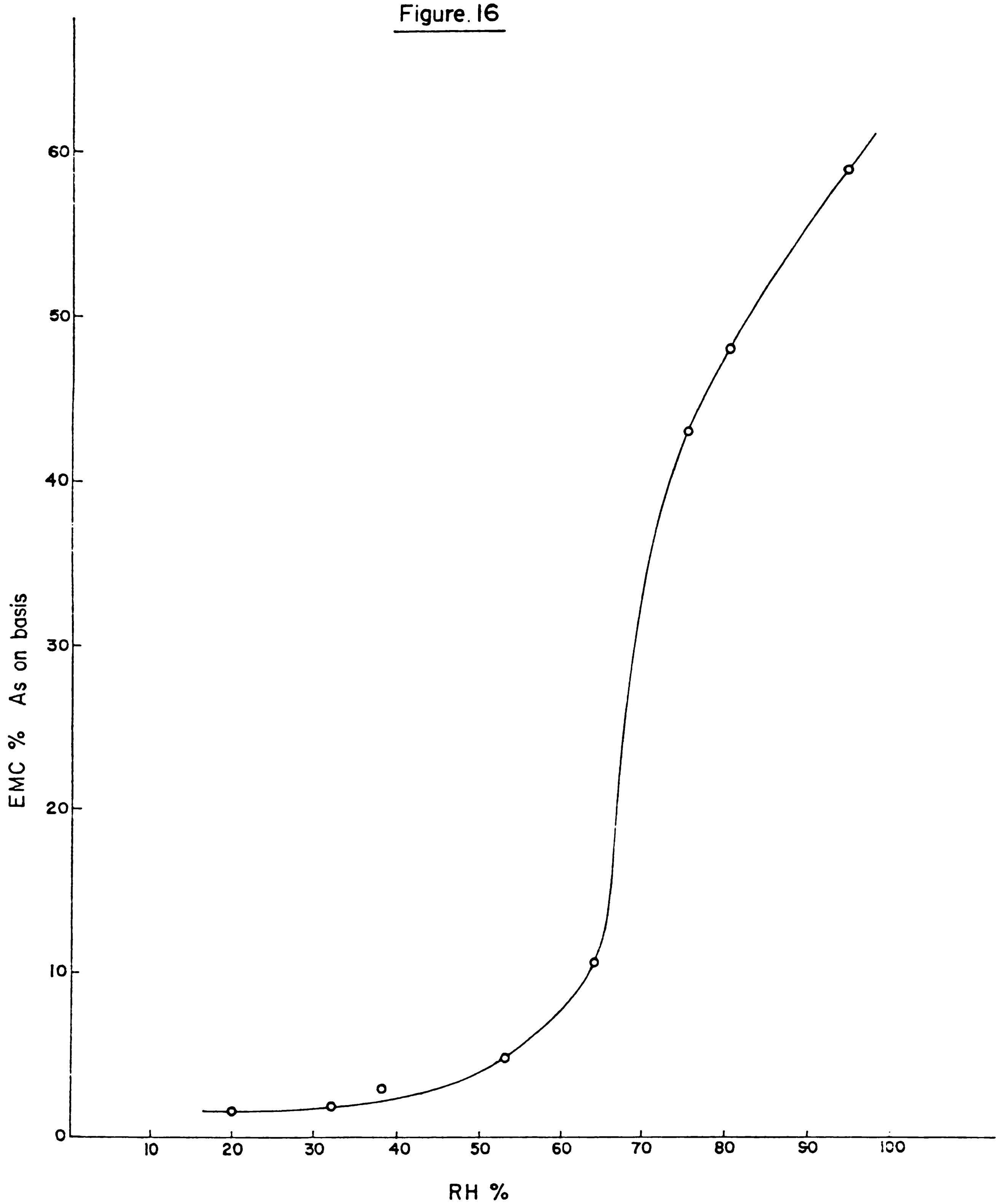
Cost of flexible packaging materials are based on the selling price in market 1990.

Size of the pouch : 16 x 15 cm

Details of the samples of cured, dried, treated and packed Mackerel stored at ambient conditions are presented in Table 41. The sorption isotherm characteristic of cured, dried and treated mackerel are presented in Fig. 16. The results of initial analysis immediately after drying and treatment with preservative mixture are given in Table 42. Table 43 presents the physical properties of the films like water vapour transmission rate and oxygen transmission rate used for the studies. The changes in moisture, TVN, FFA and organoleptic ratings during storage are shown in Tables 44, 45, 46 and 47 respectively.

The moisture pickup in the monsoon season were quite pronounced as seen from Table 44. In control sample without packaging and without calcium propionate treatment, the moisture increased from 34.02 to 42.02 percent. With calcium propionate treatment, the moisture increased from 34.02 to 41.83 percent. Both control samples were discarded after 4 days due to heavy fungal growth and putrid odour. Moisture content did not vary much in packed samples. The WVTR of the packaging materials and moisture absorption by the dried products showed good correlation. The percentage absorption of moisture was less in laminates and cellophane coated with PVDC.

Figure. 16



Sorption isotherm characteristic of cured, Dried and treated mackerel.

Table 41

Details of sample

1. Control sample without treatment with calcium propionate without any packaging.

1a. Control sample treated with 0.1% calcium propionate without packaging.

2. A control sample treated with 0.1% calcium propionate without packaging.

3. Samples treated with 0.1% calcium propionate packed in 200 gauge LDPE.

4. Samples without treatment packed in 100 gauge HM-HDPE.

5. Samples treated with 0.1% calcium propionate packed in 100 gauge HM-HDPE.

6. Samples without treatment packed in 200 gauge polypropylene.

7. Samples treated with 0.1% calcium propionate packed in 200 gauge polypropylene.

8. Samples without treatment packed in 250 gauge LD-HD co-extruded film.

9. Samples treated with 0.1% calcium propionate packed in 250 gauge LD-HD co-extruded film.

10. Samples without treatment packed in 100 gauge LLDPE film.

11. Samples treated with 0.1% calcium propionate packed in 100 gauge LLDPE film.

12. Samples without treatment packed in 300 MXXT/LDPE film.

13. Samples treated with 0.1% calcium propionate packed in 300 MXXT/LDPE film.

14. Samples without treatment packed in 12 micron metallised polyester/150 gauge LDPE.

15. Samples treated with 0.1% calcium propionate packed in 12 micron metallised PEST/150 gauge LDPE.

16. Samples without treatment packed in 12 micron plain polyester/150 gauge LDPE.

17. Samples treated with 0.1% calcium propionate packed in 12 micron plain polyester/150 gauge LDPE.

Table 42

Initial analysis of the cured, dried and treated Mackerel

Moisture	%	34.02
Fat	%	6.46
Crude protein	%	40.12
Salt	%	18.40
Ash	%	19.52
FFA	mg %	1.44
TVN	mg %	32.94

Table 43

Physical properties of packaging films used

	WVTR (g/sq m/24 hr/ 37°C/90% RH)	OTR (cc/sq m/24 h/ atmosphere)
200 gauge LDPE	8.2	4100
100 gauge HM HDPE	5	2500
200 gauge polypropylene	5	1500
250 gauge LD-HD coextruded film	5.84	6448
100 gauge LLDPE	8	3800
300 MXXT/LDPE	6.4	6
12 μ metalised PEST/150 gauge LDPE	0.5	3
12 μ plain PEST/150 gauge LDPE	6.94	102

Table 44

Changes in the moisture content of the cured, dried, treated (with or without) packed mackeral stored at ambient temperature
(Initial value 34.02%)

Samples	4 days	30 days	60 days	90 days	120 days	150 days	180 days
1.	42.02						
1a.	41.83						
2.	34.58	35.03					
3.	34.47	35.53	35.68	35.81	35.78		
4.	34.63	35.13					
5.	34.50	34.65	35.01	34.92	35.08		
6.	34.43	34.98					
7.	34.38	34.49	35.10	35.03	35.18		
8.	34.13	34.83					
9.	34.28	34.39	34.37	34.52	35.02		
10.	34.22	34.31					
11.	34.28	34.38	34.29	34.72	35.08		
12.	34.15	34.13					
13.	34.23	34.42	34.53	34.48	34.52	34.53	34.49
14.	34.09	34.18					
15.	34.13	34.16	34.08	34.18	34.23	34.51	34.39
16.	34.09	34.17					
17.	34.27	34.14	34.19	34.58	34.38	34.32	34.53

The TVN values were only 33-35 mg percent in control samples at the time of rejection after 4 days of storage, while those of packed samples continued to increase. This may be due to the loss of volatile nitogenous bases in the control samples as they were exposed. In treated samples packed in different flexible packaging materials, the amount of TVN production was comparatively less compared to non treated samples. The general trend was an increasing one with storage time. The FFA values were only 1.75 to 1.85 mg percent in control samples at the time of rejection after 4 days of storage while those of packed samples continued to increase. In treated samples packed in different flexible packaging materials, the amount of FFA production was comparatively less compared to treated samples. Organoleptically, both the treated and the untreated samples without packaging had a shelf life of only three days. The dried untreated samples could be kept for a period of 60 days in all the packages made of LDPE, PP, HM-HDPE, LD-HD, MXXT/LDPE, PEST/LDPE and Metallised PEST/LDPE. In treated samples, it can be kept for a period of 7 months in 300 MXXT/150 guage LDPE, 12 micron metallised PEST / LDPE and 12 micron polyester LDPE pouches and 5 months in LDFE, PP, HM-HDPE and LD-HD co extruded films.

Rao and Sen (1966) showed that potassium sorbate, sodium benzoate and sodium acid phosphate in the curing salt enhanced the shelf life of the cured fish. However, this had the disadvantage of the chemical being absorbed into the muscle and consequent change in the flavour. Valsan (1968)

Table 45

Changes in TVN values as mg % of the cured, dried, treated and packed material stored at ambient temperature (Initial value 24.94 mg %)

Samples	4 days	30 days	60 days	90 days	120 days	150 days	180 days
1. Control sample treated without Calcium Propionate without packaging	34.98	******	d i s c o n t i n u e d			******	
1a. Control sample treated with Calcium Propionate without packaging	33.12	******	d i s c o n t i n u e d			******	
2.		27.95	66.80				
3.		26.82	38.20	47.75	80.50	96.02	
4.		28.25	58.20				
5.		27.92	31.85	43.92	48.53	88.82	
6.		27.89	60.52				
7.		26.98	33.90	44.85	49.92	81.00	
8.		28.75	52.50				
9.		29.25	44.85	55.83	63.85	72.05	
10.		29.25	54.85				
11.		27.82	36.45	41.85	49.92	75.50	
12.		28.94	45.30				
13.		29.05	35.38	36.95	34.80	44.50	49.85
14.		25.80	49.50				
15.		28.85	32.35	34.85	38.45	35.52	40.85
16.		28.92	43.82				
17.		26.65	29.00	27.85	35.85	34.98	43.78

Table 46

Changes in the FFA values of the cured, dried, treated (with or without) packed mackerel stored at ambient temperature, mg % oleic acid
(Initial value 1.44 mg%)

Samples	4 days	30 days	60 days	90 days	120 days	150 days	180 days	210 days	240 days
1.	1.85	Discontd.							
1a.	1.75	Discontd.							
2.		3.85	24.54	Discontd.					
3.		2.95	18.23	20.82	22.50	26.27	Discontd.		
4.		3.73	22.85	Discontd.					
5.		2.85	17.28	22.73	22.95	25.85	Discontd.		
6.		2.95	20.95	Discontd.					
7.		3.01	15.95	21.92	22.50	25.95	Discontd.		
8.		3.02	21.85	Discontd.					
9.		2.75	17.38	19.95	21.85	26.55			
10.		2.85	16.95	Discontd.					
11.		2.75	15.85	18.85	26.27	27.82			
12.		1.85	20.47	Discontd.					
13.		1.95	12.25	14.85	15.92	16.98	23.55	28.55	Discontd.
14.		1.70	18.55	Discontd.					
15.		1.65	10.85	12.95	14.85	15.02	19.85	21.83	Discontd.
16.		1.82	17.85	Discontd.					
17.		1.70	11.92	12.35	15.95	18.85	24.95	Discontd.	

Table 47

Changes in pbysical and organoleptic qualities of cured, dried, treated and untreated packed mackerel stored at ambient conditions
Initial quality : very good, whitish flesh

Samples	4 days	30 days	60 days	90 days	120 days	150 days	180 days	210 days	240 days
1	Poor, heavy fugus growth								
1a	-do-								
2		Good almost whitish	Fair to poor slightly brownish	poor bitter brown Not acceptable	*** **** *Discontinued* **** ***				
3		--do--	Good almost whitish	Fair slightly brown	Fair to slightly brown	poor brown Acceptable	Poor bitter brown Not Acceptable		
4		--do--	Fair to poor slightly brownish	poor bitter brown Not acceptable	*** **** *Discontinued* **** ***				
5		--do--	Good almost whitish	Fair slightly brown	Fair to slightly brown	poor brown Acceptable	Poor bitter brown Not Acceptable		
6		--do--	Fair to poor slightly brownish	poor bitter brown Not acceptable	*** **** *Discontinued* **** ***				
7		--do--	Good almost whitish	Fair slightly brown	Fair to slightly brown	poor brown Acceptable	Poor bitter brown Not Acceptable		
8		--do--	Fair to poor slightly brownish	poor bitter brown Not acceptable	*** **** *Discontinued* **** ***				

Samples	4 days	30 days	60 days	90 days	120 days	150 days	180 days	210 days	240 days
9		--do--	Good almost whitish	Fair slightly brown	Fair to slightly brown	poor brown Acceptable	Poor bitter brown Not Acceptable		
10		--do--	Fair to poor slightly brownish	poor bitter brown Not acceptable	*** **** *Discontinued* **** ***				
11		--do--	Good almost brownish	Fair slightly brown	Fair to slightly brown	poor brown Acceptable	Poor bitter brown Not Acceptable		
12		--do--	slight brown	poor,bitter,brown not acceptable	-	-	-		
13		--do--	Good almost whitish	Good almost whitish	Good almost whitish	Fair Almost whitish	Fair Almost whitish	Fair to slightly brown	Poor bitter brown Not Acceptable
14		--do--	slight brown	poor,bitter,brown Not acceptable	-	-	-		
15		--do--	Good almost whitish	Good almost whitish	Good almost whitish	Fair Almost whitish	Fair Almost whitish	Fair to slightly brown	Poor bitter brown Not Acceptable
16		--do--	slight brown	poor,bitter,brown Not acceptable	-	-	-		
17		--do--	Good almost whitish	Good almost whitish	Good almost whitish	Fair Almost whitish	Fair to slight brown	Poor bitter brown Not Acceptable	Discontinued

advocated the use of superficial treatment of the product with a preservative mixture containing sodium propionate 3 percent, sodium sulphite 0.5 percent and BHA 1 percent in refined salt. Salted and dried mackerel treated superficially with preservative mixture containing sodium benzoate/ sodium propionate and antioxidants and packed in 200 gauge LDPE pouches remained in good conditions for 270 days at ambient temperature (Antony, *et al.* 1984).

Table 48 shows the proximate composition of *P. indicus* used for the frozen storage studies. It had a moisture content of 78.82 percent and protein 18.26 percent. The fat content was very low i.e. 0.91 percent only. The NPN content was 498 mg percent, more than what is observed in other fishes. It had a higher alpha amino nitrogen and salt soluble nitrogen than that in fishes. The salt extractable nitrogen was 75.2 percent of total nitrogen. Table 49 shows the changes in moisture and protein of *P. indicus* packed in different packaging materials and stored at - 20°C. for six months. The moisture gradually decreased in all the samples during storage but the decrease was more prominent in the samples packed in polypropylene. The protein content was about 18 percent in all the samples and no significant changes were noticed during storage.

Table 48

Proximate composition of P. indicus (grade 90-110 /lb) used for studies

Moisture	78.82 %
Protein	18.26 %
Fat	0.91 %
Ash	1.23 %
NPN	498 mg %
Alpha amino N	137 mg %
WSN	907 mg %
SEN	2.196 mg %
TVBN	5.62 mg %
TMAN	Nil

Table 50 shows the changes in NPN, SSN and TVBN during frozen storage of *P. indicus*. The NPN content reduced in all the samples and poly propylene packed *P. indicus* showed more reduction in NPN than other samples. Similar was the case with SSN too. From the results of the TVBN, no conclusion can be derived and showed somewhat erratic results. The sensory score decreased slowly in all the samples except polypropylene packed one (Table 51). The sensory score showed rapid decrease after 8 weeks in PP packed samples. By 8 weeks, the PP became brittle and broken in many places. These samples showed desiccation which increased on further storage. The texture of PP packed samples became tough.

Table 49

Changes in moisture and protein of P.indicus packed in different packaging materials and strored at -20 ±2°C

Period Weeks	Moisture 1	2	3	4	5	Protein 1	2	3	4	5
Before Freezing	78.82					18.26				
0	78.63	79.10	78.76	78.21	78.18	18.32	18.41	18.12	18.35	18.20
4	78.24	77.98	78.06	78.19	77.89	18.12	18.23	17.96	18.03	17.85
8	77.96	77.82	78.12	77.69	77.65	18.28	17.96	18.12	18.20	18.06
12	77.68	78.21	77.69	77.92	77.28	18.06	17.86	17.92	18.32	17.26
16	77.52	77.82	77.63	77.62	76.32	17.91	18.20	17.86	17.64	17.63
20	77.76	77.26	77.62	77.31	75.81	18.06	18.31	17.94	18.02	18.02
24	77.28	77.54	77.35	77.26	75.29	18.12	18.18	17.83	17.93	17.91

1. Glazed blocks of P. indicus packed in LDPE (100 gauge) frozen and stored at -20 ±2°C
2. Glazed blocks of P.indicus packed in LLDPE (60 gauge)
3. MXXT/LDPE (300 MXXT/150 gauge LDPE)
4. Polyester/LDPE (12μPEST/150 gauge LDPE)
5. Polypropylene (200 gauge)

Table 50

Changes in non protein nitrogen, salt soluble nitrogen and total volatile nitrogen of *P. indicus* packed in different packaging materials and Stored at - 20°C

Period of Storage Weeks	NPN mg %					SSN % to Total Nitrogen					TVBN mg %				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Before freezing	498	498	498	498	498	75.21	75.21	75.21	75.21	75.21	5.62	5.62	5.62	5.62	5.62
0	502	486	492	489	504	71.28	73.46	70.46	74.26	73.18	6.28	5.48	7.28	6.76	5.48
4	488	492	486	481	486	69.34	71.52	70.84	72.81	68.48	5.82	6.86	6.48	5.92	6.82
8	486	475	482	469	474	68.74	69.68	65.41	70.98	65.2	7.31	7.18	6.96	7.49	7.21
12	472	468	476	472	457	66.17	68.24	66.72	68.24	62.73	6.89	7.82	7.42	8.21	6.46
16	438	447	457	437	408	63.28	64.76	63.48	64.49	58.28	7.28	6.46	8.16	7.28	5.42
20	398	402	412	386	362	58.72	62.41	60.81	58.28	54.86	8.36	7.72	8.64	8.16	6.61
24	336	362	356	341	298	57.46	63.15	58.21	60.76	48.42	7.86	6.96	7.92	8.96	5.26

The moisture content in all the samples decreased. For the first 8 weeks, all the samples showed almost same moisture content, but the moisture content of PP packed samples decreased significantly afterwards. The rapid decrease in moisture of PP packed samples can be attributed to the breakage of PP by 8 weeks storage and the resultant dehydration of the products. This caused denaturation of the proteins and development of fibrous texture. The amount of SSN decreased considerably in PP packed samples compared to other samples. As a result of desiccation and dehydration and changes in texture more drip was formed in PP samples and hence caused considerable leaching of NPN in that sample.

The sensory scores corroborated the biochemical results and indicated a low score in PP packed samples compared to other samples at the end of 6 months storage. The difference in the scores were significant. Because of extensive desiccation, the PP samples in the outer layer were not acceptable in appearance after 8 weeks, but taste panel found it acceptable.

This experiment clearly indicated that the packaging material used has a major role in determining the shelf life and quality of the product during frozen storage. The packaging material should not undergo changes during frozen storage and should retain its original characteristics. All the films used maintained its physical characteristics except PP after 6 months storage.

Table 51

Sensory score of *P. indicus* packed in different packaging materials and stored at -20 ±2°C

Period of Storage	Sensory score					Remarks
Weeks	1	2	3	4	5	
0	8.21±0.26	7.93±0.42	8.42±0.18	8.16±0.36	8.26±0.28	All packaging materials flexible
4	7.65±0.39	7.82±0.56	7.93±0.49	8.02±0.43	7.85±0.23	PP became brittle
8	7.3±0.43	7.63±0.42	7.76±0.52	7.62±0.36	6.86±0.63	PP became too brittle and broken material showed signs
12	7.18±0.36	7.26±0.68	7.38±0.62	6.94±0.43	6.13±0.93	of descication
16	6.96±0.46	6.63±0.54	7.25±0.53	6.82±0.56	5.46±1.12	Considerable descication in PP
20	6.32±0.52	6.72±0.46	6.96±0.49	6.36±0.69	4.83±0.86	Significant descication in PP packed samples
24	6.21±0.78	6.38±0.7	6.73±0.58	6.48±0.82	4.16±0.65	Sample (5) texture became tough

8. SUMMARY

8. SUMMARY

Packaging is important not only in extending the shel life of fish and fishery products but also improving thei marketability. In the recent years, significant development have taken place in the packaging industry. During the pas decade in India, there is almost a packaging revolution witl the availability of variety packaging materials, thus generating better packaging consciousness in other producer/manufacturing industries. But unfortunately, such realisation is not forthcoming in the fisheries sector and packaging techniques for local and export trade continues to be on traditional lines with their inherent drawbacks and limitations. Better packaging ensures improved quality and presentation of the products and ensures higher returns to the producer. Among several packaging materials used in fishery industry, ISI specifications had been formulated only for corrugated fibre board boxes for export of seafoods and froglegs. This standard was formulated before containersiation came into existance in the export of marine products. Before containerisation, the standards were stringent in view of the rough handling, transportation and storage. Two of the common defects reported in the master cartons exported from India are low mechanical strength and tendency to get wet. They are weakened by the deposits of moisture caused by temperature fluctuations during loading, unloading and other handling stages. It is necessary to rectify the above defects in packaging aquatic products and

hence in the present study extensive investigations were carried out to find out the reasons for the damage of master cartons, to evolve code of practice for the packaging of frozen shrimp for exports, development of alternative style of packaging for the shipping container, development of suitable consumer packaging materials for fish soup powder, cured dried mackeral, fish pickles in oil and frozen shrimp. For the development of suitable packaging materials, it is absolutely essential to know the properties of packaging materials, effect of different packaging materials on their shelf life and their suitability for food contact applications.

Investigations were carried out on the following aspects.

1. Survey on the properties of master cartons, collected from 52 frozen shrimp factories.
2. Physical properties of kraft paper used in the manufacture of corrugated fibre board.
3. Effect of moisture absorption on the properties of kraft paper.
4. Design of alternative package for the corrugated fibre board boxes.
5. Effect of regular fluting and cross fluting on the properties of corrugated fibre board boxes.
6. Survey on the properties of waxed duplex cartons collected from 33 frozen shrimp processing factories.
7. Physical properties of low density polythene films and safety of polythene films for food contact applications.

8. Use of polyester tracing sheet as code slip in frozen shrimp blocks for exports.
9. Survey on the properties of strapping materials collected from 32 different prawn freezing factories.
10. Effect of frozen storage on the physical properties of corrugated fibre board master cartons and waxed duplex cartons kept at -18 to -20°C.
11. Physical properties of various flexible packaging films used in food packaging.
12. Code of practice for the packaging of frozen shrimp in duplex cartons, polythene and corrugated fibre board.

Survey of the packaging materials like corrugated fibre board master cartons collected from more than 52 different frozen shrimp industries shows the following results..

In the case of master cartons only 3.8 percent of the samples studied conformed to the minimum standard of bursting strength (14 Kg/Sq.cm) stipulated by ISI. This is due to poor quality and low grammage of the kraft paper used. About 54 percent of the cartons conformed to the standards for puncture resistance which was fixed at 200 beach units and 36.5 percent of the cartons conformed to the standards of the water proofness. Only 15 percent samples conformed to ISI standards to a minimum of 500g/Sq.m for combined weight of liners, while 32.7 percent samples satisfied the stipulation of a minimum of 150 g/sq.m for the corrugating medium. With the introduction of the container system a few years back the master cartons are not subjected to rough handling in the port and also exposure to adverse environments for longer periods. It was observed that the kraft paper used in the fabrication of corrugated fibre board boxes (CFB box) was of two different grades namely virgin and recycled. As per the specification of IS 1397 (1967), kraft papers are graded 1 and 2 depending on the physical properties. It is seen that only 10 percent of the samples conform to grade 1 as far as burst factor is concerned, 30 percent in case of tear factor and nil in the case of breaking strength and Cobb value. Less than 60 percent of the samples conform to grade 2 specifications. Both virgin grade and recycled paper have shown changes in their physical strength and the changes are pronounced in the case of recycled paper. It is evident from the above that the quality of the kraft paper used in the fishing industry for the manufacture of corrugated fibre board is of grade 2 quality. It is absolutely necessary to revive the standards for the master cartons for export purposes. The following specifications have been suggested for the master cartons for export.

Grammage of the paper (g/sq.m)	-	140[5]
Bursting strength (kg/sq.cm)	-	12
Puncture resistance (Beach units)	-	200
Wax coating (g/sq.m)	-	Waxing on both sides preferred. 20 gsm (minimum) on each side.
Compression strength (kg)	-	350 (minimum)
Type of flute	-	B/B (Narrow/narrow)
Type of glue	-	Preferably starch based or any neutral adhesives.

Two alternate package designs for the corrugated box have been worked out. The present corrugated box is a regular slotted container (RSC) which can hold 10 unit cartons in the fashion (2 x 5), 2 per layer and in 5 layers. The boxes by the new design can hold 12 unit cartons in the fashion 3 x 4 to effect savings in the board area used and thus economising the packaging costs. The new boxes are cuboid in shape thus facilitating easier handling and better stacking. Taking the case of 94 million kg of frozen shrimp exported to countries like Japan, USA and Europe during the year 1991-92 the effective cost savings in master cases works out roughly at Rs.2 million and Rs.3.8 million respectively for the new designs.

Regular fluting board alone should be used as shipping container and not to use cross fluting in the manufacture of corrugated fibre board for export of frozen shrimp. Corrugated fibreboard made out of regular fluting is having more compression strength compared to cross fluted boards.

Survey of the waxed duplex cartons collected from 33 frozen shrimp processing factories show that the majority of the waxed duplex cartons collected from various factories had a moisture content varying from 6.5 to 8.8 percent. Sixty one percent of the cartons had the bursting strength above 5 kg/sq.cm. 67 percent of the cartons had puncture resistance above 25 beach units and 88 percent of the cartons had cobb value below 45. The wax content varied from 8 to 43 GSM. The tearing strength varied from 128 to 368 g in machine direction and 140 to 384 g in cross direction. The tensile strength varied from 5.85 to 20 kg in the direction parallel to the specimen of the sample. The common defects associated with the waxed duplex cartons are:

1. Distortion of the waxed carton when filled with water.
2. Interlocked cartons tend to tear at the tags. Distortion of the duplex cartons affected their fit in the corrugated fibreboard box which in turn get distorted and thereby stackability is affected.

It is desirable that certain minimum standards of quality are to be laid down for the waxed duplex carton. The following specifications have been suggested based on the transport worthiness tests like drop test, rolling test and vibration test.

Grammage	-	300 gsm
Caliper	-	0.4 $\pm$0.02 mm
Wax content	-	10 gsm on each side
Polythene coatings	-	20 gsm on each side
Ring stiffness	-	270 N
Bursting strength	-	400 kpa or 4 kg/sq.cm

The ink used for printing the cartons should be free from toxic metals like lead and chromium. The carton should have the following details printed on its exterior.

1. Name and address of the exporter
2. Brand Name
3. Type of product
4. Net content
5. Size grade

For the purpose of inspection, the lable indicating the code number and size grade has to be placed inside the carton. Paper code slip should not be used inside the frozen block as it disintegrates and in the importing country it is taken as filth. The 150 gauge polyester tracing sheet is found to be an ideal material to use as a code slip. It is non porous and it retains the original property after wetting.

The inner wrap low density polythene (100 gauge) should be of food grade conforming to IS : 2508 (1984). The following specification are suggested for the packaging of frozen shrimp which is in accordance with IS specifications for food contact aplications.

Tensile strength in machine direction	-	120 kg/sq.cm
Tensile strength in cross direction	-	85 kg/sq.cm
Elongation at break in machine direction (Min)	-	100%
Elongation at break in cross direction (Min)	-	350%
Impact strength	-	80 g
Overall migration residue	-	Less than 10 mg/ sq.dm. for food contact applications.
Water vapour transmission rate	-	18 gms/sq.m/ 90% RH/24h/37°C

Physical properties of the strapping materials collected from 35 different prawn freezing factories showed that 63 percent of the strapping materials used were recycled high density polythene, the tensile strength of which varied from 930 to 2520 kg/sq.cm. About 20 percent of the samples used straps of polypropylene the tensile strength of which varied from 940 to 3100 kg/sq.cm. About 6 percent of the samples used straps of rayon, the tensile strength of which varied from 1650 to 1800 kg/sq.cm. It is found from the physical properties and frozen storage studies that polypropylene is the most suitable material for strapping frozen fishery products.

Deteriorative changes in physical properties of corrugated fibreboard master cartons and waxed duplex cartons during frozen storage under commercial conditions for a period of six months were studied. In case of corrugated fibreboard a sudden spurt was observed in moisture content after one month storage. Thereafter, the increase was not so marked till the end of the fifth month and afterwards a steep increase was observed. Uptake of moisture caused considerable reduction in bursting strength and puncture resistance. In case of duplex cartons, the increase in moisture is maximum after the first month in frozen storage. However, the percentage increase is less than in the former. The fall in puncture resistance is 19 percent in master cartons compared to 9.5 percent in waxed duplex cartons during frozen storage. Tearing and tensile strength were the most affected. The former showed a fall of 20 percent in cross direction and 28.6 percent in the machine direction in six months. Most drastic change was observed in tensile strength, a fall of 34.21 percent of the original.

The physical properties of various packaging films like LDPE, LLDPE, HM-HDPE, PP, Polyester, PVC, Nylon - 6, MXXT Cello, MST Cellophane were studied. Nylon-6 and polyester posses high tensile strength compared to other mentioned films. Water vapour transmission rate is high in case of Nylon-6 film compared to polyester, LDPE, PP and HDPE. High oxygen transmission rate was noticed with LDPE films, low for Cellophane coated with PVDC on both sides, polyester film and Nylon film.

The effect of different packaging materials on the shelf life of fishery products like soup powder, fish pickles in oil, frozen shrimp and dry fish were evaluated. Sorption studies of soup powder revealed that 9.89 percent moisture (dry weight basis) equilibrating to 59 percent relative humidity is critical with respect to loss of free flowing characteristics and appearance of soup. The consumer unit packs made of 100 gauge LDPE,60 gauge HM-HDPE, 12 micron metallised polyester/150 gauge LDPE, 12 plain polyester/ LDPE and 100 gauge PP are suitable for storage of soup powder upto 75 days, while 12 micron plain polyester/LDPE-HDPE coextruded film and 90-100 micron LD/BA/Nylon/BA/Primacore multilayer film can preserve it upto 180 days. Therefore laminates of metallised polyester with polythene and plain polyester with polythene even though give good protective properties against water vapour and oxygen transmission, but they tend to delaminate on prolonged storage.

Salted, cured and dried mackerel treated with 0.1% calcium propionate had a shelf life of 3 to 4 days when stored unpacked at room temperature having an RH 70-95%. The shelf life of above product was improved to 5 months when stored by packing in LDPE, PP, HM-HDPE and LD-HD coextruded film pouches and to 7 months by packing in 300 MXXT/150 gauge LDPE, 12 micron metallised polyester/LDPE and 12 micron plain polyester/LDPE pouches under the same conditions of temperature and humidity. Because of the high humidity prevailing outside, the unpacked dried samples absorbed moisture (42 percent) and developed mould growth in 3-4 days storage while packed materials did not absorb moisture. These dried samples without treatment could be kept for a period of 60 days in all the above packages. Polyester/polythene laminate provides better resistance against penetration of insects than LDPE, PP, HM-HDPE, MXXT/LDPE or LD-HD co extruded film.

Seer fish pickle in oil remained in good condition for a period of more than six months at ambient temperature in 12 micron plain polyester/120 micron LDPE-HDPE coextruded film, 85 micron Nylon - Surylyn film, 12 micron metallised polyester/118 micron LDPE-HDPE and 90-100 micron LD/BA/ Nylon/BA/ Primacore. The average heptane extractive values of nylon/ surylyn, plain polyester/LDPE-HDPE, metallised polyester/LDPE-HDPE,and LD/BA/Nylon/BA/Primacore are below the limit of 50 mg/1 and 60 mg/1 as specified by FDA and IS respectively. These films can withstand transport worthiness tests like drop test and vibration tests. These films can be used safely for the packaging of fish pickles.

Glazed and frozen blocks of peeled and deveined fresh prawns of 90-110 lbs grade packed in different flexible packaging materials and stored at -20 ±2°C, were evaluated for their biochemical and sensory characteristics periodically. Polypropylene film became brittle in 2 months storage and the product developed descication in 4 months and hence found not suitable for packing frozen products. The changes in the biochemical characteristics such as moisture, protein, non protein nitrogen, salt soluble nitrogen and total volatile base nitrogen, showed almost same trend in all other packaging materials. The sensory characteristics also did not differ considerably among the materials packed in LDPE, LLDPE, MXXT/LDPE and PEST/LDPE.

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