EVOLUTION OF PACKAGING: TREND AND GROWTH OF THE PLASTIC INDUSTRY

Ever since ancient man felt the need for storing food for the next day's consumption, technology of food packaging in its primitive form emerged. In earlier times, ancient man was using plant leaves to cover the food, which he could not consume, and perhaps that was the beginning of food packaging. As he gathered experience with vulnerability of such protection, the concept was innovated with the formation of a container made from plant leaves using tiny needles of a tree stem. With the progress of civilisation, the concept of protecting food products was developed more and more in response to increasing needs.

Traditional Packages (Bamboo Baskets, Wooden Containers and Jute Sacks) for Packaging of Fruits and Vegetables

The concept of traditional packaging itself is changing with times. Dictionary meaning of traditional is conventional, time honoured, routine or historic. If we ask a senior citizen about traditional packaging, he would cite examples of packages made from plant leaves, bamboo baskets, ceramic jar or earthen pots and other similar forms made from natural materials. For modern packaging, the senior citizen would give examples of metal containers, glass bottles, etc. However, if we ask the same question to a youngster, perhaps he may give examples of metal cans and glass bottles for traditional packaging and for modern packaging he would cite packages such as laminated cartons, blister packs, flexible bottles, PET bottles, various forms of pouches and other similar packages. With the passage of time the concept of traditional and modern packaging will further change.

In today's context, packaging is both a symbol of society's consumption habits and reflection of its progress. The user expects the packaging to have better strength, be easier handled, be lighter, more aesthetic and safer from the point of view of hygiene. In addition to its standard attributes, today's packaging is also expected to contribute to protecting the environment, besides being friendly to human health.

Emergence of Plastic Packages

For food packaging, metal container has been the choice of the food product manufacturers and for some products even glass bottle has been traditionally used for packaging.

Modern Plastic Based Packages for Confectionery

Till recently, the quantum of steel production was considered to be an index of industrialisation of a country. Even today, the quantity of steel, cement and similar products produced in a country is taken as an indicator of its industrialisation. With development of science and technology, alternative materials like plastics have emerged either to replace natural and traditional materials with a benefit of cost reduction purpose, to cater to certain applications which were not possible with the traditional materials, as well as for enhancing utility of traditional materials.

In the new millenium, use of plastics both in terms of quantity and variety is perhaps the correct index of industrialisation of a country, the status of its economy and the standard of living of its citizens.

Development of plastics received an impetus in last 30 years as natural materials such as wood was not available in adequate quantities; man-made materials such as steel, glass were found to be very expensive or could not provide economically viable solutions for packaging of products of mass consumption.

Traditional Glass Bottles for Packaging of Sauces

A few decades back, scientific tools and technology was not available to measure and predict performance of a traditional or conventional packaging. As a result, tendency of package designer/purchaser was to play safe by using over-designed packages. Stronger packages such as metal containers, glass bottles, etc. were used for quite sometime more due to the anxiety of the product marketer for preserving the product as long as possible. With the development of technology, modern gadgets became available to measure and predict protection and preservation offered by a given packaging form.

In the modern times, product marketer knows precisely the time period (shelf-life) over which the package is required to preserve the product. With the use of plastics, the marketer is in a position to select the right structure, which can give him the desired protection and preservation capabilities required for the product and market

Traditional Tinplate Containers for Packaging of Ghee

Traditional Tinplate Containers and HDPE Containers for Edible Oils needs. Added to this, consumer became more demanding and was not willing to accept inconveniences of traditional and conventional packaging forms. A typical consumer would expect an easy opening package with the features such as easy opening flip top cap or metering or similar devices for retrieving the product in the required quantity and would not like to use instruments such as scissors, knife, etc. to open the packages. Plastic packages have the versatility to provide such convenient features, which boosted development of plastic packaging.

Plastic Packages – Options

In plastics, there are a variety of materials, which are used for packaging applications. The important plastics, which find large packaging applications are HDPE, PP, PVC, Polyester, Polystyrene, etc. These are used for building the body structure of the packages, while other polymers are often used, in less thickness, as coating to improve the functional properties of basic packaging.

Examples of such speciality polymer coatings are Polyvinylidene Chloride (PVDC), Ionomer, Ethylene Vinyl Alcohol (EVOH) and others. These speciality coatings provide specific properties such as high barrier to oxygen, moisture aroma/flavour or it may impart sealability to a package even when its surface is contaminated with product. Sometimes, a speciality polymer coating may also provide a good hot tack resistance over a wider temperature range. In other situations, when rigors of handling and distribution demand higher mechanical strength, plastics can be used to enhance such properties.

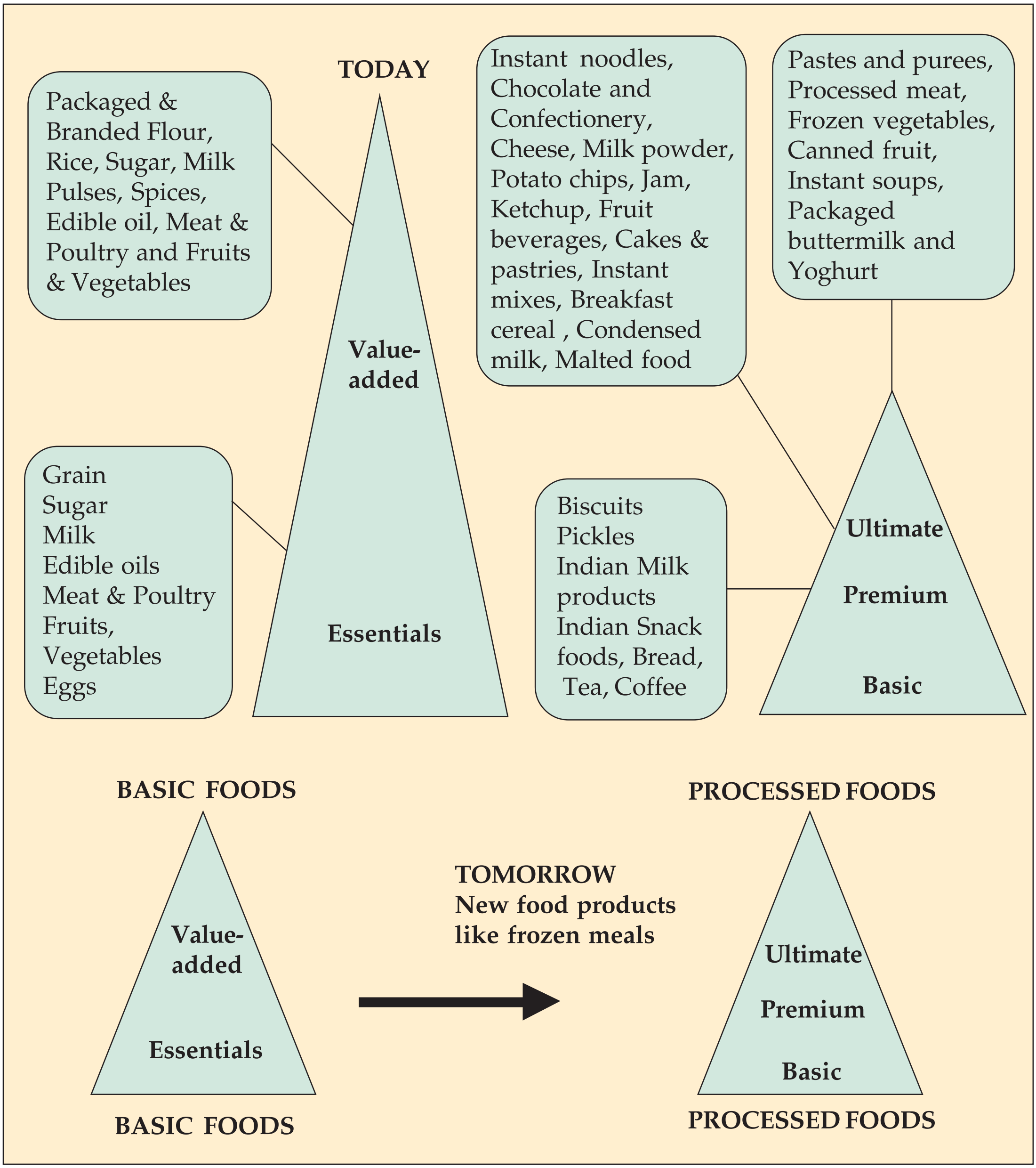
Thus, the advantage of plastics is in the range of mechanical barrier and other properties it offers and also the feasibility of tailoring a structure required to meet precisely the product protection, preservation and distribution needs.

Changing Trends in Food Processing and Packaging Technology

Yoghurt Packed in Traditional Earthern Pot and Injection Moulded Plastic Containers

The changing food consumer in India will be one of the most powerful forces for change in the food industry. Increasing incomes, increasing literacy rates, smaller family sizes, women entering the work force, urbanisation and increasing concern about health and hygiene will be motivating consumer changes in attitudes. Figure 1 depicts the markets for basic food

Figure 1: Today and Tomorrow



and processed food today and in the future, taking into account changing consumer attitudes.

In response to the changing trends, the traditional processing and packaging technologies have either been improved or a few new technologies have progressed to match new requirements.

Table 2 gives the evolution that has taken place in processing and packaging of food.

TABLE 1

Evolution of Processing and Packaging of Food

Past	Present	Future
Canning Pasteurization Freezing Dehydration	Map/Cap system Aseptic system Anti microbial Biosensors/Chemical markers Robotics, computers Infusion technologies, Irradiation, Microwave	Biotechnology High pressure processing Pulsed electric field Pulsed light field

Aseptic Packaging

These new processes either extend the shelf-life of food product or allow more sophisticated product or different packaging concepts. They also improve the nutritional and sensory properties of the food product during its entire shelf-life.

Minimal Processing Technologies for Food Preservation

Consumers increasingly demand food, which retains the natural flavour, colour and texture and contains fewer additives such as preservatives. In response to these needs, one of the most important recent developments in the food industry has been the development of minimal processing technologies designed to limit the impact of processing on nutritional and sensory quality and to preserve food without the use of synthetic additives.

Traditional thermal processing techniques can be both beneficial to food in such areas as preservation and flavour formation but detrimental in damaging other sensory and nutritional properties. Minimisation of undesirable changes can be achieved in a number of ways, whether through more effective process control, the use of High Temperature Short Time (HTST) techniques such as aseptic processing, or newer thermal technologies such as volume heating methods, infrared heating, dielectric methods such as the use of microwaves, and ohmic heating etc. The other alternates to thermal processing, range from irradiation to high pressure processing and the use of pulsed electric fields.

The safety and effectiveness of minimal processing depends on the use of the novel preservation technologies and most notably in packaging.

Numerous electromagnetic energy sources-initially developed for other purposes can now be used for food and other material processing. They are derived from generations of research aimed at much larger targets than the micro-organisms that present threat to the stability and safety of food materials. Currently, a considerable range of thermal and non-thermal processes are being assessed to improve quality and variety.

Minimal food processing technology under thermal and non-thermal methods are given in Figure 2.

Figure 2: Minimal Food Processing Technology

Minimal Processing Technology

Minimal processing of foods with thermal methods

- Thermal conduction, convection and radiation
- Heat processing in the package
- Aseptic and semi-aseptic processing
- Sous-vide processing
- Infrared heating
- Ultraviolet light
- Electric volume heating methods for foods
- Electric resistance/ohmic heating
- High frequency (HF) or radio frequency (RF) heating
- Microwave heating
- Inductive electrical heating
- Improvements in conventional thermal processing

Minimal processing of foods with non-thermal methods

- Ionising radiation
- High pressure (HP) processing
- Methods based on pulsed discharge of a high capacitor
- Pulsed white light
- Laser light
- Pulsed electric field (PEF) or High Electric Field Pulses (HEFP)
- Oscillating magnetic fields (OMF)
- Other non-thermal anti-microbial treatments
- Ultrasound
- Pulse power system
- Air ion bombardment
- Plasma sterilisation at atmospheric pressure

Current Trends in Processing and Packaging Technologies

Details of some of the trends currently prevailing in the food processing are described below:

Aseptic Filling / Processing

In this method, the food material is heated rapidly in a heat exchanger, held for sufficient time to achieve commercial sterility and then cooled before filling into a de-contaminated container within an aseptic zone. It is critical that all food contact surfaces are sterilized before production starts and that any other surfaces in proximity to the food should be sterilized too, in order to avoid re-infection. This is now a well known technology, and in the last few years, there have been interesting developments in the following areas:

- Particulate filling which allows the aseptic filling of large pieces of meat and vegetables allowing new product formulations and market opportunities. The overall quality of the product will be related to the average time and temperature treatment of the particles.
- Bulk aseptic filling which allows new markets such as foodervice applications (sauces, milk based products) and temporary storage (seasonal products). With this concept, most of the bag-in-box systems use gamma irradiated pouches.
- New methods of sterilising machine and package to replace hydrogen peroxide. Another concept would be to use superheated steam.

Aseptic processing has replaced in many applications the traditional heat processed method, as it gave to the product much better sensorial and nutritional benefits.

Within the dairy industry, the UHT treatment has gained a lot of importance to obtain shelf-stable products durable for few months. Various package forms are used from brick packs to pouches and plastic bottles.

As a consequence of application of this technology, more and more clean or ultra clean filling equipment are in use. This concept provides extra days for a refrigerated product and will not be as expensive to run as a fully aseptic process.

For flexible aseptic packages, paperboards coated or laminated with PE, BOPP, PET, EVA blends or aluminium foil or any other suitable combinations are used depending upon the product characteristics and the shelf-life required.

Ohmic / Induction Heating

As a support to aseptic filling, a system has been developed whereby liquid products containing particulate up to 25 mm can be uniformly heated through electric current. This process will prevent destruction of flavours, nutrients and keep particulate integrity.

In ohmic heating processes, food is made part of an electric circuit through which alternating current flows, causing heat to be generated within the food due to the electrical resistance of the food, thus offering a way of processing food at the rate of HTST processes, but without the limitation of conventional HTST on heat transfer to particulate.

This interesting, new continuous heating technology has a potential for commercial applications in the future.

"Sous vide" Cooking

This process is quite new and its main benefit is to retain flavours and juices in processed food. The packed food is cooked under vacuum at low temperature (close to pasteurisation) and then rapidly chilled to 2-3°C and maintained at this low temperature.

Using this method, products can be stored chilled up to 3 weeks depending on the products and the thermal process. Solid products such as roasts, ham and fish can be processed this way. Specific packaging materials have been developed for this application (barrier shrink bag). This simple process allows a centralized production of a high quality product, an optimum cooking yield and requires no skilled labour at the other end (only re-heating).

Another processing/packaging system also proposed is "DARFRESH FTF" (flex-tray-flex) for ready meals which is an extension of the "sous vide" cooking. A rigid tray (aluminium, CPET, PP) containing the food product is "sandwiched" between two flexible film webs. Both films are multi-layer films with a barrier layer. The top film moulds around the foodstuff during the vacuum skin process without crushing the food and sealing is applied between the two films with an easy-open feature built-in the bottom web. The skin package is then cooked under vacuum and then rapidly chilled. Products are sold chilled or frozen. These packages can be reheated in a microwave oven, a conventional oven or in boiling water. A very high degree of hygiene is required for these above-mentioned processing methods.

Microwave Processing

This kind of pasteurisation offers an extension of shelf-life and the short time process inherent to microwave heating will minimise product degradation but has the obvious drawback of microwave cooking, i.e. temperature is not uniform due to the different dielectric properties of food.

This method could be combined with other methods, such as hot air, in order to overcome the issue of non-uniformity of microwave cooking. The microwave processing has been made use of for drying of fruit juices, pulps, apple segments and finished drying of potato chips.

The most commonly used material today is crystallized polyester (CPET) in the form of trays. The advantages of using these trays are with respect to flexibility in the shape and design and resistance to oils and greases. These trays have another distinct advantage of dual ovenability. PP co-extruded with barrier resins such as EVOH is used when a longer shelf-life is required.

"Single-flow FSTP"

This system is designed for thermal processing of liquid food containing particulate of recognisable size. The basic principle is to have particulate being held for any desirable period of time in order to be given any required processing value. Selective holding sections can be used for different particle sizes requiring different holding times. The liquid fraction is sterilised through a conventional tubular heat exchanger.

The main advantage of this system is to reach optional cook values for the various particle sizes, without much thermal degradation of smaller particulate and liquid.

Steam / Vacuum Cooking

This concept consists of steam cooking at 130°C in an open can containing the product. In a very short time, water in the can is replaced by steam thus ensuring product sterilisation. The can is then steamed. The steam cools down, condenses on the product, keeping them moist.

A few benefits are:

- lighter can (no water)
- mineral salts and vitamins retained by the vegetables
- improved texture and flavour

However, a few drawbacks are:

- cost (additional cost of 40%)
- perception of an empty can by the consumer

Food Irradiation

This is not a new technology, gamma-rays are already used in some food applications. This technique involves exposure of food to short-wave energy and is mainly used today to reduce contamination by micro-organisms and pests, delay ripening and for sprout inhibition in vegetables, thus increasing the shelf-life of products and also reducing potential health hazards caused by micro-organisms.

This technique can be used on most fruits and vegetables, meat, poultry, seafood, spices, potatoes, grains etc. This process could be used in combination with others to develop novel food and to enhance overall product quality.

Freeze Concentration

Current efforts are focused on cost-effective dehydration processes, such as osmotic dehydration and the development of ready-to-eat, partially dehydrated intermediate moisture items. This is a means of removing water using freezing phenomenon, rather than evaporation phenomenon. Basically, ice crystals are created and filtered out, leaving behind concentrated products.

Membrane Process Technology

Membrane separation processes are basically based on the ability of semi-permeable membranes of appropriate physical and chemical nature to discriminate between molecules primarily on the basis of size, and to a lesser extent, on shape and chemical composition. Depending on the chemical/physical properties of the membrane, concentration or de-watering (reverse osmosis-RO), fractionation of components in solution (ultra filtration-UF) and classification of slurries or removal of suspended matter (micro filtration–MF) are accomplished. Membranes are commercially available. Cellulose acetate and derivatives are most widely used. A composite membrane containing polyamide and polysulfone or polyethylene is also used. Dairy industry is probably the largest user of membrane technology in food processing.

Hurdle Technology

The most important preservation technique for food is refrigeration. However, because of the difficulty in maintaining sufficiently low temperature throughout the production, distribution and storage chain, additional barriers (or HURDLES) are required to control the growth of spoilage or pathogenic micro-organisms. The concept of combining several factors to preserve food has been developed into the HURDLE effect – each factor is a hurdle that micro-organisms must overcome.

In hurdle technology the complex interactions of temperature, water activity, pH and other factors are understood and these factors are used to design a series of hurdles that will ensure microbiological safety of the food products.

Preservation of Chicken Curry by Hurdle Technology

[Studies carried out at DFRL (Defence Food Research Laboratory, Mysore)]

Intermediate moisture chicken curry was prepared from boneless chicken chunks and spices and was preserved by hurdle technology as per the flow diagram:

Flow Diagram for Hurdle Processing of Chicken Curry

Preparation of Spice Paste

Cooking of raw ground onion, ginger and garlic for 35min, followed by addition of vegetable fat

↓

Addition of salt and groundnut Oil after 10 min

↓

Addition of dry powder of chilli, coriander, turmeric and cumin, after another 10 min.

↓

Addition of dry powder of cinnamon, pepper, clove, big & small cardamoms and antioxidant after 20 min

↓

Spice paste (28.13 ± 0.61%) Moisture and 40.57 ± 0.80% fat → (to Mixing of dehydrated chicken and spice paste)

Processing of Chicken

Portioning, deboning and chunking of pre-rigor dressed broiler

↓

Marinating the chunks with salt and antioxidant at 5°C (2°C, 24 hr)

↓

Equilibrating the marinated chunks to Ambient temperature, 27°C (2°C, 2 hr)

↓

Heating for 6-7 min along with the liquid exuded due to marination

↓

Steam cooking for 12 min at 15psi in an autoclave

↓

Dehydration for 4 ½ hr at 45°C to 23.63 ± 0.81% moisture level

↓

Mixing of dehydrated chicken and spice paste (1:2:6) in hot condition, 8 min

↓

Cooling to ambient temperature

↓

Packing in PP and PFP pouches and Storing at AT and CT

[Source: DFRL]

The stability of the product on storage at ambient temperature of 27°C ± 4°C (AT) and chill temperature of 5°C ± 2°C (CT), in pouches of 50 micron Polypropylene (PP) film and laminate of 45 gsm paper / 37.5μ Al foil / 20μ Poly (PFP) was studied by monitoring chemical, microbiological and sensory quality parameters.

Tables 2, 3 and 4 give the effect of storage temperature and packaging on physical, physico-chemical and chemical qualities, microbiological quality and sensory quality respectively, of hurdle processed chicken curry.

TABLE 2

Effect of Storage Temperature and Packaging on Physical, Chemical & Physico-chemical Qualities of the Hurdle Processed Chicken Curry

Parameters	Initial (Freshly Processed)	After 4 Months of Storage			
		AT		CT	
		PP	PFP	PP	PFP
% Moisture content (dry basis), n=6	36.13 ± 0. 54[a]	35.73 ± 0.47[a]	35.94 ± 0.22[a]	35.96 ± 0.29[a]	36.09 ± 0.35[a]
% Fat content (dry basis), n=6	31.06 ± 0.73[a]	30.44 ± 0.57[a]	30.61 ± 0.33[a]	30.98 ± 0.47[a]	30.96 ± 0.31[a]
% FFA (as oleic acid), n=6	1.31 ± 0.20[a]	9.58 ± 0.33[b]	6.86 ± 0.31[c]	5.11 ± 0.31[d]	3.72 ± 0.19[e]
PV (meq peroxide O_2/kg), n=6	7.67 ± 2.07[a]	58.25 ± 4.06[b]	32.77 ± 3.42[c]	19.69 ± 1.67[d]	11.94 ± 0.93[e]
TBA (mg malonaldehyde/ kg), n=6	0.13 ± 0.06[a]	0.58 ± 0.14[b]	0.36 ± 0.05[c]	0.34 ± 0.07[c]	0.24 ± 0.03[d]
pH (25° C), n=6	5.64 ± 0.06[a]	5.74 ± 0.06[b]	5.69 ± 0.04[a]	5.67 ± 0.04[a]	5.64 ± 0.03[a]
W-B Shear (Kg/cm) Lengthwise (n = 10) Across	0.059 ± 0.002[a] 0.122 ± 0.008[a]	0.053 ± 0.003[b] 0.107 ± 0.01 [b]	0.055 ± 0.005[ab] 0.114 ± 0.011[ab]	0.057 ± 0.01[ab] 0.119 ± 0.003[a]	0.058 ± 0.007[ab] 0.12 ± 0.006[a]
Reconstitution Time (min), n=3	10[a]	10[a]	10[a]	10[a]	10[a]
Shelf-life (Day), n=24	–	116 ± 4[a]	170 ± 6[a]	188 ± 5[c]	285 ± 7[d]

FFA = Free fatty value
PV = Peroxide value
TBA = Thiobarbituric acid value
W-B shear = Warner – Brazier Shear value
AT = Ambient temperature
CT = Chill temperature
PP = Polypropylene film
PFP = Paper-Aluminium Foil-Polyethylene Laminate

Each value is Mean ± Standard Deviation, Mean values with different superscripts a,b,c etc., in a row differ significantly (P<0.01).

TABLE 3

Effect of Storage Temperature and Packaging on Microbiological Quality of Hurdle Processed Chicken Curry

Parameters	Initial (Freshly Processed)	After 4 Months of Storage			
		AT		CT	
		PP	PFP	PP	PFP
TPC (log cfu/g), n=6	3.76 ± 2.48[a]	3.32 ± 2.60[b]	3.44 ± 2.41[c]	3.67 ± 2.29[d]	3.59 ± 2.16[e]
YM (log cfu/g), n=6	2.68 ± 1.46[a]	2.46 ± 1.34[b]	2.41 ± 1.25[b]	2.17 ± 1.31[c]	2.11 ± 1.17[c]
SC (log cfu/g), n=6	2.26 ± 1.20[a]	ND[b]	ND[b]	2.11 ± 1.25[c]	1.98 ± 1.17[c]
CC (log cfu/g), n=6	ND	ND	ND	ND	ND
SA (log cfu/g), n=6	1.87 ± 1.04[a]	ND[b]	ND[b]	ND[b]	ND[b]

TPC = Total Plate Count
YM = Yeast and Mould
SC = Spores Count
CC = Coliform Count
SA = Staphylococcus Aureus
ND = Not Detected
log cfu/g = logarithum of colony forming unit per gram sample
AT = Ambient Temperature
CT = Chill Temperature
PP = Polypropylene film
PFP = Paper-Aluminium Foil-Polyethylene Laminate.

Each value is Mean ± Standard Deviation, Mean values with different superscripts a,b,c etc., in a row differ significantly ($P<0.01$).

TABLE 4

Effect of Storage Temperature and Packaging on Sensory Quality of Hurdle Processed Chicken Curry

Parameters	Initial (Freshly Processed)	After 4 Months of Storage			
		AT		CT	
		PP	PFP	PP	PFP
Colour & Appearance	7.69 ± 0.37^{a}	7.19 ± 0.22^{b}	7.33 ± 0.15^{ab}	7.56 ± 0.28^{ab}	7.60 ± 0.34^{ab}
Texture	7.60 ± 0.63^{a}	7.69 ± 0.41^{a}	7.60 ± 0.52^{a}	7.60 ± 0.37^{a}	7.60 ± 0.38^{a}
Flavour	7.57 ± 0.51^{a}	6.47 ± 0.23^{b}	6.59 ± 0.27^{b}	6.83 ± 0.44^{ab}	7.00 ± 0.59^{ab}
Rancidity	7.53 ± 0.41^{a}	6.15 ± 0.31^{b}	6.53 ± 0.46^{bc}	6.69 ± 0.29^{c}	7.04 ± 0.53^{ac}
Overall Acceptability	7.63 ± 0.23^{a}	6.36 ± 0.29^{b}	6.74 ± 0.35^{bc}	6.95 ± 0.33^{c}	7.24 ± 0.48^{ac}

Nine-Point Hedonic Scale: 9 - Like extremely, 8 - Like very much, 7 - Like moderately, 6 - Like slightly, 5 - Neither like nor dislike, 4 - Dislike slightly, 3 - Dislike moderately, 2 - Dislike very much, 1 - Dislike extremely

AT = Ambient temperature

CT = Chill temperature

PP = Polypropylene film

PFP = Paper-aluminium foil-polyethylene laminate.

Number of panelists (n) = 8. Each value is Mean ± Standard Deviation, Mean values with different superscripts a,b,c etc in a row differ significantly ($P<0.01$)

The results indicate that the chicken curry has a shelf-life of 116 ± 4 and 170 ± 6 days at ambient temperature and 188 ± 5 and 285 ± 7 days at chill temperature in polypropylene and paper/Al foil/poly pouches respectively. The product was found to have satisfactory microbiological quality, satisfactory sensory attributes, acceptable shear value and rapid reconstitution in boiling water in ten minutes. **This indicates that plastics can be used successfully for preserving hurdle processed chicken curry for a fairly long shelf-life.**

Osmotic Dehydration

Dehydrated products are wholesome, nutritious and palatable but they have not found popular acceptance because the products do not retain the flavour, colour and texture of the original fruit and vegetables after re-hydration. Recently, osmotic dehydration, which is the process of water removal by immersion of water containing cellular solids in a concentrated aqueous solution of fruits and vegetables, is gaining attention due to its important role in food processing industry. This is because the product by osmotic process is more stable during storage due to low water activity by solute gain and water loss, as at low water activity, all the chemical reactions to deteriorate the food, the growth and toxins production by micro-organisms are low. Besides that, it improves the quality of the product in terms of colour, flavour and texture and it is less energy intensive process than air or vacuum drying process (Shafiur Rahman 1992).

Studies on Osmotic Dehydration

[Studies conducted at IARI, (Indian Agricultural Research Institute) New Delhi]

The division of Fruits and Horticultural Technology, New Delhi had conducted studies on preparation of onion powder by Osmostic Dehydration.

The osmotic dehydration process as compared to the conventional air or vacuum drying process, offers better quality product in terms of colour, flavour and texture and it is a less energy intensive process, as indicated above.

A large quantity of onion is used fresh, however, some quantity is also processed into dehydrated powder mainly for exports and for armed forces personnel. The product (like any other dehydrated powder) has a tendency to absorb moisture from atmosphere resulting in lumping and loss of free flow characteristics. Physical/chemical changes can also occur during storage if the product is not suitably packed. The study was aimed at identifying suitable packaging and storage conditions.

The studies indicated that onion powder prepared from 5 mm thick osmotically dehydrated onion slices after drying in a cabinet dryer at 60°C for 10 hours, ground and sieved **can be stored up to 6 months in 400 gauge LDPE or 200 gauge HDPE pouches at 7°C with better pungency, compared to 4 months at ambient condition. Retention of colour and pungency was found to be better in the samples packed in 200 gauge LDPE pouches stored at 7°C.** The IMC (Initial Moisture Content) of the product was 3.85% and the corresponding ERH (Equilibrium Relative Humidity) was found to be 47.5% and the CMC (Critical Moisture Content) was 9.14%. The product was more stable at low temperature (7°C) as compared to high temperature (ambient conditions) in respect of colour and flavour.

Table 5 below gives the ERH of onion powder at room temperature.

TABLE 5

Relative Humidity of Onion Powder at Room Temperature (33-35°C)

Equilibrium Moisture Content, %	Equilibrium Humidity, %	Days Required to Reach Equilibrium	Remarks
1.18	10	30	Free flowing, colour normal, onion flavour
1.24	20	28	Free flowing, colour normal, onion flavour
2.18	30	26	Free flowing, colour normal, onion flavour
3.68	40	24	Free flowing, colour normal, onion flavour
5.22	50	23	Granulation, free flowing, normal colour
9.14	60	20	Colour faded, caking observed
14.47	70	18	Pasty consistency and slight darkening
21.94	80	14	Caky and mould affected after 17 days
31.23	90	9	Wet caky and mould growth appeared after 11 days
42.65	100	6	Mould growth appeared after 9 days

Tables 6 and 7 indicate the changes in chemical constitutents of onion powder stored at room temperature and at 7°C, as recorded by IARI.

TABLE 6

Changes in Chemical Constituents of Onion Powder Stored at Room Temperature (d.w.b.)

Salt Concen-tration, %	Storage Period, Months	Packing System	Moisture, %	Acidity as Pyruvic Acid, %	Reducing Sugars, %	Total Sugars, %	NEB O.D. at 420 nm
0	0	–	4.30	3.32	17.05	43.62	0.361
	6	200 g LDPE	6.58	3.18	18.70	44.05	1.82
		400 g LDPE	5.90	3.22	18.80	44.60	1.71
		200 g HDPE	5.75	3.28	19.22	43.62	1.58
5	0	–	2.15	3.30	18.61	42.11	0.093
	6	200 g LDPE	6.29	3.17	18.91	44.56	1.70
		400 g LDPE	5.89	3.28	18.52	43.64	1.59
		200 g HDPE	5.69	3.28	18.07	42.92	1.48
10	0	–	2.20	3.28	17.33	41.58	0.092
	6	200 g LDPE	3.58	3.23	18.61	46.57	1.76
		400 g LDPE	3.43	3.28	18.27	46.42	1.44
		200 g HDPE	3.33	3.26	18.25	46.28	1.03
15	0	–	2.23	3.24	17.10	41.47	0.09
	6	200 g LDPE	4.73	3.21	18.72	47.58	1.88
		400 g LDPE	3.54	3.22	18.58	47.28	1.34
		200 g HDPE	3.45	3.23	18.28	47.22	1.24
20	0	–	2.25	3.25	16.73	41.42	0.091
	6	200 g LDPE	3.53	3.21	16.91	46.28	1.55
		400 g LDPE	3.51	3.23	16.82	45.37	1.37
		200 g HDPE	3.41	3.23	16.81	45.28	1.20

g = Gauge, LDPE = Low density polyethylene, HDPE = High density polyethylene, NEB = Non enzymatic browning

TABLE 7

Changes in Chemical Constituents of Onion Powder Stored at Low Temperature (7°C) (d.w.b.)

Salt Concen-tration, %	Storage Period, Months	Packing System	Moisture, %	Acidity as Pyruvic Acid, %	Reducing Sugars, %	Total Sugars, %	NEB O.D. at 420 nm
0	0	–	4.30	3.32	17.05	43.62	0.362
	6	200 g LDPE	5.21	3.10	18.60	44.92	1.80
		400 g LDPE	4.68	3.12	18.22	44.91	1.69
		200 g HDPE	4.52	3.18	18.12	44.81	1.55
5	0	–	2.15	3.30	18.61	42.11	0.093
	6	200 g LDPE	4.65	3.21	18.59	44.93	1.78
		400 g LDPE	4.51	3.24	18.22	44.84	1.67
		200 g HDPE	4.42	3.25	18.13	44.82	1.46
10	0	–	2.20	3.28	17.33	41.58	0.092
	6	200 g LDPE	3.29	3.23	18.60	46.87	1.75
		400 g LDPE	3.17	3.25	18.52	46.07	1.44
		200 g HDPE	3.14	3.25	18.50	46.01	1.03
15	0	–	2.23	3.24	17.10	41.47	0.09
	6	200 g LDPE	3.77	3.17	18.92	47.38	1.78
		400 g LDPE	3.75	3.18	18.28	47.27	1.35
		200 g HDPE	3.08	3.18	18.23	47.25	1.03
20	0	–	2.25	3.25	16.73	41.42	0.091
	6	200 g LDPE	3.50	3.22	17.58	46.19	1.75
		400 g LDPE	3.25	3.22	17.57	46.12	1.311
		200 g HDPE	3.10	3.24	17.36	46.10	1.03

g = Gauge, LDPE = Low density polyethylene, HDPE = High density polyethylene, NEB = Non enzymatic browning

Some of the trends in packaging systems are modified atmosphere packaging / controlled atmosphere packaging/ gas flushed/ vacuum packaging and retortable pouch system.

MAP/CAP System (Modified Atmosphere Packaging / Controlled Atmosphere Packaging)

The change of the normal composition of air surrounding the product (within the pack) is one of the most effective methods of extending the shelf-life. MAP is a system where there is no control of the final atmosphere inside the package. The air inside the package is replaced partially or completely either with a single gas or mixture of gases or with vacuum, while, in CAP system, the atmosphere within the package is adjusted or controlled to specific requirement. Packaging materials with suitable barrier properties are used.

Generally, the three gases most commonly used are:

- Carbon dioxide to retard the growth of micro-organisms, taking enough care to prevent CO_2 absorption and collapsing of the pack.
- Nitrogen is largely used to displace oxygen and delay oxidation, it is also used as a filler gas to prevent vacuum to occur.
- Oxygen is reduced to as low as possible, except in some specific applications e.g. in meat where colour retention is desired.

Right gas mixture has to be established for each product taking into account the product nature and its requirements, potential gas absorption and proper use of barrier packaging material, With this technology, fresh products can have a shelf-life extended by a few days to a few weeks.

For MAP system, film with anti fog property viz. PS, PVC films are used where as for gas/

Pre-packaged Fresh Vegetables

Fresh Strawberries Packed in Plastic Punnets

vacuum packaging very low permeability structures with good oxygen barriers such as EVOH, PVDC, Polyesters and Nylons are used.

For MAP of perishables, such as fresh fruits and vegetables, which respire and meat products which need to retain the red colour, polymeric films are most suitable for use due to their permeability. Conventional materials like glass and metal are non-permeable to moisture vapour and gases and, therefore, would not be suitable for this application.

Conventional materials like glass and metal containers can be used for MAP of processed and shelf-stable food products, however, these are not cost effective, heavy in weight and fragile (in case of glass).

Retort Pack System

A retort pouch is a flexible, laminated pack having sufficient strength and heat resistance to allow it to be used in place of a metal can for the heat processing and storage of food products. The retort pouch, a flexible laminated food package, can withstand thermal processing and combines the advantages of metal can and the boil in bag and **can be used as an alternative to metal can as plastics are lighter in weight and more cost effective.** Retort pack systems are stable at ambient conditions for a long period.

It is perhaps the most significant advancement in food packaging since the development of the can. The growth of retort pouch system is rapid and dominant form of packaging for heat processed foods. The aim of retorting operation are three-folds:

- To cook the food so that it is in a form for consumption by the consumer with only a minimum further preparation.
- To destroy chemical enzymes naturally present within the food, which could lead to chemical deterioration of the food during storage.
- To destroy micro-organisms within the food to give a condition of commercial sterility, which implies the destruction of all pathogenic i.e. food poisoning, organism, together with all spoilage organisms capable of metabolism under storage conditions.

Retortable flexible plastic pouches are generally constructed from the following combinations :

- PET/Adhesive/Al foil/Primer/Adhesive/PP
- PET/PVDC/PP
- Nylon/PVDC/Nylon/Tie/Sealant/Extrudate/Sealant
- PP/Regrind/Tie/EVOH/Tie/Regrind/PP

Future Trends in Food Processing Technology

Other packing technologies envisioned for the 21st century are non-thermal processes, Pulsed Electric Field (PEF), High Pressure (HP) Preservation, Pulse Light Processing and Oscillating Magnetic Field Technology.

Pulsed Electric Field (PEF)

PEF processing is applied to liquids or pumpable products using a flow-through treatment chamber. In PEF, the flow of current is switched in very high intensity electric fields. It is a very high intensity varying electric field, through which the food passes. The temperature increase is minimal. The micro-organisms are deactivated via electro-permealization of the membrane.

Pulse Light Processing

Pulse Light Processing is an irradiation system rather than a penetration system. It is primarily for surface kill (i.e. inactivation of micro-organisms on surface, killing micro-organisms in a liquid through a very thin film).

Oscillating Magnetic Field Technology

Oscillating Magnetic Field Technology is similar to PEF but instead of using an electric field, a high intensity magnetic field is used, which inactivates micro-organisms and reduces their growth.

High Pressure (HP) Preservation

HP Preservation can be applied to either liquid or solid foods in flexible containers. The improved food preservation technologies are being used to:

- Minimize processed-induced loss of colour, flavour, texture and nutrition
- Retain the highest possible quality in stressful storage environments
- Reduce the logistics burden and cost vs. conventionally processed foods

Because non-thermal processing is relatively new compared to conventional processing, two key issues are particularly critical for PEF and HP technologies. The first major issue is safety and process assurance; the second is sensory quality and consumer acceptance over the intended shelf-life.

Industrial adoption of advanced food processing technologies will contribute to a more flexible and responsive logistics system.

Trends in Packaging Materials

High Barrier Packaging Materials

High barrier is the term, which has been associated with those plastics whose permeabilities are low enough to significantly prolong the shelf-life of food. Barrier packaging is one of the industry's most exciting developments, which has witnessed internal and external coatings, oxygen absorption and other barrier systems competing for a wide range of food and beverage applications.

Barrier packaging is designed to keep oxygen, moisture and carbon dioxide out of the packaging to preserve the flavour, colour, odour and freshness of its contents. With gas-fill techniques, barrier packaging retains CO_2 or N_2 to protect the product and extend its useful shelf-life.

Barrier resins include plastics viz. ethylene-vinyl alcohol (EVOH) copolymer, polyvinylidene chloride (PVDC), polyamide or nylon (PA), cyclic olefin (COC) copolymer, cyclodextrin (CD), MXD6 and others.

Modern Plastic Based Packages for Food Products

- **Ethylene Vinyl Alcohol (EVOH) Copolymer:** EVOH resins are non-toxic and can be used in direct contact with food products and also for high temperature lamination used in meat and cheese packaging. EVOH can be used in multi-layered films with other polymers. In co-extrusion technology it is used as a tie layer.

  EVOH has excellent gas barrier properties and flavour retention properties. It is effective in retaining the modified atmosphere inside the MA package. EVOH is an excellent choice for packaging of oily foods and edible oils.

- **Polyvinylidene Chloride (PVDC):** PVDC film is a clear film with good strength characteristics specially burst stretch. It is heat sealable at low temperatures (120°C to 150°C). It has low permeability to water vapour and gases and even a thin film can provide good barrier properties. Foods for vending and microwave re-heating can be wrapped in PVDC films because of its resistance to hot fats and oils and because it does not melt or fuse while it is in microwave cooking. These films known as Saran are used for cheese, meat, sausages and dried fruits wrapping.
- **Polyamide (PA) / Nylon:** Nylon 6 is widely used in food packaging for its dry barrier properties, toughness and heat and grease resistance. Semi-crystalline PA resins when dry, limit the transfer of gases and food components such as flavours and aromas, and are therefore used in multi-layer barrier constructions with other plastics for packaging of products such as meat, cheese, and edible oils.
- **Metaxylylene Diamine (MXDA):** MXDA is offered as a bi-axially oriented film. This crystalline polyamide differs in properties from Nylon 6, in presenting a significantly high barrier to gas and moisture transmission and greater strength and stiffness when extruded and bi-axially oriented film. The relative insensitivity of MXD6 to moisture is its most noteworthy property when compared to other polymers in use.
- **Liquid Crystals of PET (LCP):** LCP are also high gas barriers. A new option is being examined in terms of its potential for use in packaging films. LCPs are expected to be used in LCP/thermoplastic co-extruded structure for high barrier packaging.
- **Metal Oxide Coated (MOC) and Silicon Coated Films:** MOC films are environmentally friendly transparent barrier films. These coated films are available as:
  - Standard Grade: High barrier transparent film, where aluminium oxide is deposited on PET film.
  - High Barrier Grade: "Ultra" barrier transparent film, where aluminium oxide is deposited on PET film.
  - Retort Grade: Retortable high barrier transparent film, where aluminium oxide is deposited on PET film.
  - Anti-sticking Grade: Anti-sticking high barrier transparent film, where aluminium oxide is deposited on an OPA film.
  - SiOx Grade: High barrier transparent film, where silicon oxide is deposited on a PET film.

These films have wide applications in dried/dehydrated food packaging and in retortable packages.

- **Semi-rigid Thermoforming Films:** Expanded polyester is combined with EVOH to result in PE/EVOH/PE/PET matrix. Clear trays with straight or tapered walls and depths of 35-60mm can be prepared. The trays are best suited for packing fresh meat, fish, poultry and deep frozen foods.
- **Combitherm Films:** This new development is a PA/PE based film that has oxygen barrier as well as an oxygen scavenging layer, which absorbs any oxygen molecules still inside the package, even after evacuation. The scavenging layer is embedded in the film and does not come into contact with the packed product. The film remains

unimpaired during high temperature sterilisation that is used to prolong the shelf-life of a food product.

- **Multi-layer Barrier PET Bottles:** Compared to the conventional monolayer PET bottles, the barrier coinject – higher barrier bottles with PET + EVOH would have 100% improvement in the barrier properties.

  The higher temperature resistant PEN-PET bottles have been developed which have temperature resistance up to 90°C and can withstand sterilisation temperatures.

  PET bottles are developed with Amorphous Carbon Treatment for coating a layer of highly hydrogenated amorphous carbon, obtained from food safe gas in the plasma state. Oxygen barrier properties are increased 30 times and CO_2 barrier properties are increased 7 times as compared to the conventional PET bottles.

  The major applications of barrier PET bottles are for packaging of products such as beer, fruits juices, milk and tomato ketchup.

Future Developments in Plastic Material

Bio-degradable Plastics (Films)

Interest has been created to consider the use of packaging materials, particularly films which are bio-degradable to overcome the hottest issue of ecological problem becoming serious because films are light weight and bulky. Some of the bio-degradable plastics are already commercialised with improved performance and reduced costs. Research work is still going on to bring about further improvements and innovate newer materials. Some of the major bio-degradable plastics are briefly listed below:

- One of the earliest bio-degradable plastics was polyhydroxybutyrate valerate (PHBV), a bacterially grown polyester with properties similar to PP. This was discontinued later in 1998.
- Starch based plastics constitute a major volume of biodegradable plastics. By carefully using selected starch feedstock and water as a plasticizer, thermoplastics from nearly 100% starch or from blends of starch with other biodegradable components are produced. Many of these materials are water soluble in addition to being biodegradable.
- Biodegradable plastics based on lactic acid are available for packaging applications.
- The other biodegradable plastics include protein-based plastics, polysaccharides, polyoxyethylene, which is water-soluble, polyvinylalchohol etc.

Speciality Additives in Polymers

Additives such as pigments, master batches, antioxidant, antistatic agent, slip additives, UV stabilisers etc. are some of the commonly used and known additives. Some of the not so common additives with great potential are:

- Antifogging agents in transparent bottles or films for packaging of beverages and perishables.

- Nucleating agents for obtaining clarity in polymers such as PP, Adipic acid, Benzonic acid and some metal salts of these acids are used for PP. For Nylon, collodial silica is commonly used. With these additives, PP sheets can be made highly transparent, and has a large market segment potential for thermoformed disposables for food packaging.
- Other additives include slip additives for smooth operation on FFS machines, anti-microbial additives for preventing bacterial growth.
- Active and Intelligent Packaging: A lot of action in this field is going on, particularly with the growth of moisture controllers, ethylene absorbers, oxygen scavengers and theft deterrents in the ranks. Perhaps, a time has come to control internal relative humidity and oxygen, remove undesirable odours and disperse anti-microbials and desirable aromas into package interiors from a single package surface.

Plastics Industry and its Growth

Packaging is constantly evolving to meet the changing demands of the society. A major change has been our ability to produce and preserve products with packaging. Plastics with their unique combination of properties are the key in meeting these demands in a sustainable manner in both the developed and the developing world. In India, an impressive growth is recorded vis-a-vis other packaging materials as shown in Table 8.

Share of various packaging materials in the Table 10 shows not much of a deviation from the past except that the share of plastics is increasing from 4% in 1983 to 12% in 1997 and to over 32% by 2000.

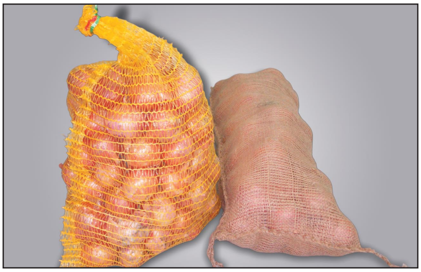
Plastics have made significant inroads at the global level as well as in the life of Indian consumers. The global consumption of plastics went up from 154 million metric tonnes in 2000 to 183.5 million metric tonnes in 2003, and is projected to touch 300 million tonnes in 2010. By 2020 the expected global demand is 540 million tonnes with the overall annual growth rate of 6% to 7% in the next few years. Table 9 gives a comparison of plastic consumption by major world areas.

TABLE 8

Growing use of Plastics in Packaging

Material (by weight)	Consumption Level (%) during Different Years		
	1983	1997	2000
Paper & Paper board	33	30	22
Glass Containers	15	22	15
Tin-Plate & Steel	16	13	9
Plastics	4	12	32
Composites	1	4	10
Aluminum	1	1	2
Jute	30	18	10
Total	100	100	100

{Source: Plastics for Environment and Sustainable Development (ICPE/CIPET, Ministry of Chemicals & Fertilisers}



Traditional Jute Bags and Knitted Plastic Bags for Onions

Modern Plastic Based Packages for Food Products

In India, however the consumption of major plastics is about 4% of the global consumption. According to the latest available data, the polymers consumption in India will touch 12.5 million

TABLE 9

Plastics Consumption by Major World Areas (Year 2000)

Region	Plastics Consumption ('000 metric tonnes)	Population (Million)	Per Capita Consumption (Kg / annum)
Europe W, C, E	40,000	450	90
Eurasia, Russia & Others	4,000	285	14
North America	45,000	310	145
Latin America	11,000	500	22
Middle East, incl. TR	4,000	200	20
Africa, North & South	2,500	190	13
Other Africa	500	610	<1
China	9,000	1,285	14
India	4,000	1,025	4
Japan	11,000	125	90
Other Asia Pacific, rest	13,000	1,120	11
Total World	1,54,000	6,100	25

[Source: Indian Rubber & Plastics Age - 7]

metric tonnes in 2010 from 4.4 million metric tonnes in 2003, registering a compounded annual growth rate (CAGR) of 14%.

This growth rate is likely to sustain and by the year 2010, India is expected to be the third largest consumer in the world at 12.5 million metric tonnes as against the US consumption level of 39.9 million metric tonnes and China's consumption level of 37.5 million metric tonnes.

On the basis of the CAGR of polymers, India is leading the world at 14.1% followed by CIS-9.1%, China-8.1% and the US at 6.6%.

The per capita consumption of plastics in India has improved to 4kg/annum in 2002 from less than 1 kg a decade ago and still lagging behind the world's average of 20 kg/annum.

At the global level, the higher growth sectors or demand drivers for plastic consumption are consumer and bulk package, building construction, electrical and electronics, automotive, consumer goods, medical, telecommunications, furniture and household applications. The output value of commodity engineering and high performance polymers was US $ 115 billion, accounting for about 7% of total chemical output value globally.

The estimated growth of plastics in India in the various end use segments is shown in Table 10.

TABLE 10

Growth of Plastics in Various End Use Segments

Segments	CAGR (%)
Packaged Consumer Goods	19
Other Consumer & Industrial Packaging	14
Automobiles	12
Consumer Durable Goods	11
Fibres & Multi filaments	13
Infrastructure	9
Agriculture	12
Healthcare	15
Miscellaneous Applications	11

[Source: Financial Express, May 26, 2003.]

Table 10 depicts that "The Packaged Consumer Goods" segment is likely to achieve highest growth rate in polymer consumption. One of the major factors for this high growth rate is the increasing awareness of Indian consumers for genuine unadulterated, hygienic and safe, quality products in convenient unit packs.

Factors for Growth

There are a number of factors that are driving growth and new developments in the plastic-based packaging materials for food and other consumer products:

- Enhanced polymer manufacturing capacities in India
- Availability of wide range of materials indigenously
- Growing awareness about plastics
- Changes in lifestyles of urban and rural middle class
- Entry of multinational companies
- Shift from bulk to smaller consumer packs

The consumption of plastics in India in different sectors is given in Table 11.

TABLE 11

Consumption of Plastics in Different Sectors

Sectors	Consumption (%)
Building and construction	25
Telectronics	17
Packaging	15
Agriculture and water management	25
Transport	5
Others	13

[Source: Popular Plastics and Packaging, Feb. 2003]

At the global level plastic consumption sector-wise and resin-wise along with the corresponding growth rate from 2000 - 2010 is given in Table 12.

TABLE 12
Global Plastic Consumption, by Resin

('000 MT)

Plastics	Consumption
Commodity	**1,48,000**
PVC	26,000
LDPE	17,000
LLDPE	14,000
HDPE	23,000
PP	30,000
PS	10,500
EPS	2,600
ABS	3,800
Other styrenics	1,000
PET bottles	6,700
PET film, other	1,500
PUR	8,500
PMMA	1,000
UP	1,000
Thermosets	400
Epoxy	1,000
Engineering	**5,510**
PA	1,800
PC	1,500
POM	600
PPE	310
PBT PET	500
Alloys	800
Speciality	**213**
PTFE	70
Other FP, PVDF	30
PPS	54
PSU	27
PES	5
LCP	18
PEEK, PAEK	6
PEI	6
PI	5
All others	**1**
Total (rounded)	**1,54,000**

[Source: Indian Rubber And Plastics Age, June 2003]

Polymers, is probably the single largest family in terms of varieties and types of packaging media catering to multitude of applications. About 50% of the polymers produced/consumed domestically are estimated to be used by the packaging sector. A lion's share of this goes for food applications. Food packaging creates opportunities for more innovations as this sector is constantly and continuously influenced by the changing consumerism and market trends.

Plastics used in food packaging can be in the form of wrappers, pouches, bags, bottles, cans, trays and tubs as primary structures; seals, closures and overwraps; labels and tamper-evident devices, shrink bands, tear strips, etc as secondary packages and components; and as tertiary package such as in shrink wrap around pallet loads of boxes and cartons.

Packaging forms are broadly classified as:

- Flexibles – films and laminates, woven fabrics.
- Semi rigids – extruded and laminated tubes.
- Rigids – moulded, blow moulded, sintered and thermoformed products. Material handling products such as crates, pallets etc.

The use of plastics in the above types of packages is given in Table 13.

TABLE 13

Use of Plastics for Packaging in India

(Quantities in million tonnes)

Type of Packaging	Year 2000	Year 2010*	Growth
Rigid packaging	0.4	1.8	16%
Films	0.6	3.0	17%
Woven sacks / multi-filament	0.5	1.4	12%
Total	**1.5**	**6.2**	**16%**

* Estimated

[Source: Presentation "Polymer Industry a new Decade"
Mr. K.P. Nanavaty, RIL, Mumbai]

Flexible packaging products are gaining acceptance in the market due to their characteristics and benefits like variety and reduction in size, convenience of storage resulting in space saving, ease of opening and re-closing, light weight, disposability, cheaper than rigid packaging in most cases and effective in prevention of adulteration.

Flexibles as Economical Media

If one compares the product sale cost v/s the packaging cost for various types of packages, the most economical pack would be a flexible pouch.

It will be useful to compare traditional (conventional) packages made using modern technology such as metal can, glass bottle etc. with packages made from plastic materials.

Plastics Packages	Conventional Packages
Require low energy inputs for manufacturing and conversion	Require high energy inputs for manufacturing and conversion
Can be moulded to different shapes and sizes	Constraints in making odd shapes and sizes
Limitations in decoration with direct printing of multi colour graphics	Can be decorated by directly printing with multi colour graphics
Limitations for filling very hot products	Hot products can be filled
Limitations in treatment/sterilisation with steam or high temperature dry air	Can be treated/sterilised by steam and high temperature dry air
Proven storage trials required for food product compatibility	Normally compatible (with lacquer in some cases)
Mechanical properties - relatively lower	Mechanical properties - relatively better
Recycling by heating/melting is easier	Recycling by heating/melting is not easy/possible
Not perceived by consumer as a premium product packaging	Positively perceived by the consumer as a premium product packaging
Relatively low cost packages	Cost is on the higher side
Low tare weight (of empty packages)	High tare weight (of empty packages)

The materials used for laminates broadly fall into three categories – Paper, Aluminium foil and heat-sealable plastic films like Polyethylene, Polyester, Bi-axially Oriented Polypropylene (BOPP) and Cast Polypropylene.

Most of these laminates are made into pouches, bags, sachets by heat sealing and therefore the innermost ply of the laminates is heat-sealable. The other layers are selected depending upon the properties required from the pouch.

Flexible converting industry could be classified as:

- Adhesive Laminating Industry
- Co-extrusion Industry
- Extrusion Coating Industry

Amongst all the above, the adhesive laminating industry is the most rapidly growing and adhesive laminates are widely used as packaging media in the processed food industry. Some of the processed food sectors, where adhesive laminates are used are given below:

- Chocolate Bars
- Spices
- Baby Foods / Malted Foods
- Milk Powder
- Fruit Juices
- Suparies / Pan Masalas

- Gems like confectionery
- Biscuits
- Tea
- Extruded Foods / Snack Foods
- Coffee

The products that go in packages made by extrusion coating are as follows:

- Confectionery
- Biscuits
- Bread
- Tea

Co-extrusions are not generally referred to as laminates and are usually called films. It involves combining two or more layers of plastics into a multi-layer film. Up to five layers can be co-extruded in a single step. Co-extruded films are widely used in milk, vanaspati and oil pouches.

The demand estimates for adhesive laminates, extrusion coated films and co-extruded films are given in Tables 14, 15 and 16 respectively.

TABLE 14

Flexible Packaging Media in the Food Sector

Adhesive Laminates

(in tonnes)

Product	**Growth %**	**Packaging Material**	**1998-99**	**1999-2000**	**2004-05**
Chocolates Bars	15	Foil POLY/PET POLY	1,587	1,825	3,670
Gems Like Confectionery	15	BOPP/PLY/PET/POLY	396	456	917
Biscuits	15	PET or BOPP/POLY	5,951	6,843	13,765
Tea	20	PET POLY	10,800	12,960	32,248
	2	Foil/Paper	1,040	1,061	1,171
Extruded Foods/ Snack Foods	20	PET or BOPP/POLY	12,960	15,552	38,698
Coffee	10	PET/POLY Glass/POLY	1,815	1,996	3,215
Spices	15	PET/POLY	1,719	1,977	3,976
Baby Foods/Malted Foods	15	Foil/POLY	5,951	6,843	13,765
Milk Powder	15	Foil/POLY	158	182	367
Fruit Juices	10	Foil/POLY	423	465	750
Suparies / Pan Masalas	25	PET/POLY	39,062	48,828	1,49,011
Total			**81,862**	**98,988**	**261,553**

[Source: IIP – Working Group Report, MFPI]

TABLE 15
Flexible Packaging Media in the Food Sector
Extrusion Coatings/ Laminates

(in tonnes)

Product	Growth %	Packaging Material	1998-99	1999-2000	2004-05
Confectionery	5	Wax Paper	275	289	369
Biscuits	5	Wax Paper	2,205	2,315	2,954
	5	Glass/Poly Paper/Poly	1,323 4,000	1,389 4,000	1,772 4,000
Bread	5	Wax Paper	19,293	20,258	25,855
Tea	5	Paper/Poly	330	347	443
Total			**27,426**	**28,598**	**35,393**

[Source: IIP – Working Group Report, MFPI]

TABLE 16
Flexible Packaging Media in the Food Sector
Co-extruded Films

(in tonnes)

Product	Growth %	Packaging Material	1998-99	1999-2000	2004-05
Edible Oil	20	3 & 5 Layered Films	9,504	11,404	23,649
Vanaspati Ghee	2	LD-LLDPE and Nylon Based Films	1,591	1,623	1,757
Milk	5	LD-LDPE or LLDPE	61,354	64,421	78,305
Salt	20	LD-LLDPE	3,024	3,628	7,524
Total			**75,473**	**81,076**	**111,235**

[Source: IIP – Working Group Report, MFPI]

Semi Rigid and Rigid Plastic Containers

Plastics have played a major role in containing and protecting foods. Their contribution to the world's food protection and distribution system is immense and growing. They have been widely adopted in packaging of foods for the advantages they offer and their versatility. Foremost among the features are their formability into unlimited range of shapes and sizes to suit most end use applications.

Typical examples of rigid and semi-rigid forms include drums, bottles, containers, carboys, jars, cups, trays, crates, caps, closures, lids etc. Some common applications in food packaging are given in Table 17.

TABLE 17
Common Applications in Food Packaging

Plastic Type	Package Type	Application
LDPE	Bottles and containers	Fruit juices
HDPE	Bottles, containers, jars Carboys & drums	Edible oils, vanaspati, dairy products
PP	Bottles and jars	Edible oil, milk powder
EPS/HIPS	Cups, trays & Containers	Processed food, dairy products
PVC	Bottles, cups, trays	Mineral water, edible oil, processed foods
PET	Bottles and jars	Edible oils, hot & cold beverages, malted foods, preserves.

The total demand for polymers in rigid and semi-rigid forms is given in Table 18.

TABLE 18
Demand in Rigid & Semi Rigid Forms

(million tonnes)

Year	LDPE + HDPE + LLDPE	PP	PVC	PS	PC	PET	Total
1994-1995	80	40	35	16	0.5	14	185.5
1995-1996	97	50	42	22	1	30	242
1996-1997	108	60	54	28	2	50	302
1997-1998	127	70	77	35	3	70	382
1998-1999	151	80	92	42	4	90	459
1999-2000	171	90	117	50	5	115	548
2000-2005 (estimated)	366	203	395	157	55	1044	2220

[Source : I I P, Working Group Report - MFPI]

As per the Packaging Consortium Report (for IIP), the packaging markets in India for different plastic based packages is given in Table 19.

TABLE 19

Packaging Market – India

Packaged Type	Variants	Market Size
Plastics		
Rigid Containers	Injection Moulded	42,000 MT
	Blow-Moulded (Growth Rate 15% pa)	120,000 MT
	PET bottles (Growth Rate 50% pa)	150,000 MT
Tubes	Total Multi-layer Tube Demand (Growth Rate 10% - 12% pa)	2,000 million nos.
	Seamless Tubes (Premium)	150 million nos.
Speciality Films		
BOPET Films	Total Indian Demand	93,000 MT
	Packaging Usage (Growth rate 3% - 4% pa)	85,000 MT
	World Packaging Usage (Growth rate 4% pa)	1,285 million MT
BOPP Films	Total Indian Demand	70,000 MT
	Packaging Usage (Growth rate 15% pa)	70,000 MT
	World Packaging Usage (Growth rate 6% - 7% pa)	2.9 million MT
Flexible Packaging		
Laminated Films	Speciality Laminates	300,000 MT
	Co-ex/ Mono Layer Films	300,000 MT
	TQPP Films (Growth Rate 15% - 20% pa)	100,000 MT
Woven Sacks	Total Market	400,000 MT/yr.
	Break-up of Market	
	HDPE	150,000 MT/yr.
	PP	250,000 MT/yr.
Short-term growth will be very high due to dilution of JPMA.		

[Source : IIP (I PC Feasibility Study – Stage 1)]

Plastics in Packaging Systems

Aseptic Packaging System

Aseptic processing and packaging system basically comprises of the following:

- Sterilisation of the products before filling
- Sterilisation of packaging materials or containers and closures before filling
- Sterilisation of aseptic installations before operation (UHT unit, lines for products, sterile air and gases, filler and relevant machine zones).
- Maintaining sterility in this total system during operation, sterilisation of all media entering the system, like air, gases, sterile water.
- Production of hermetic packages

Recent efforts of introducing aseptically packaged milk and milk derivatives in flexible pouches has tremendous scope to improve the markets for aseptically packed products for extended shelf-life at affordable prices. Similar development on aseptic flexible pack for fruit juices and fruit drinks can also result in rapid expansion of markets for such products, as there is growing awareness for consuming them for reasons such as better health and fitness.

Retortable Packaging System

Developments in plastic materials and thermal processing technologies have made it possible for the many Indian dishes to be available in ready-to-eat form. The retort pouches used in this case for packaging need to be kept in boiling water prior to serving the food. These "heat and eat" products are preferred for the ultimate convenience they offer to the consumer. They are shelf-stable, which means that they can be stored at room temperature without requiring refrigeration and, in their packed form, remain fresh for over one year. And all this without any added preservatives. The production of shelf-stable products is attained by application of heat that kills organisms, which if not destroyed, will multiply and produce enzymes, which may decompose the food and in some cases produce food poisoning toxins. The main requirement of plastic material is not only to withstand rigors of heating and cooling process, but also to maintain the overpressure correctly so that internal pressure developed during processing is balanced by the pressure of heating system. Retort pouches are flexible packages made from multi-layer plastic films with or without aluminium foil as one of the layers.

Retort trays are semi rigid containers with a high barrier plastic as one of the layers. The material commonly used in retortable container structures include polypropylene, PET, ethylene vinyl alcohol (EVOH) and polyvinyledne chloride (PVDC).

Ethnic food and delicacies like biryani and varieties of non-vegetarian and vegetarian curries can be made available in such retort pouches/trays. The continuing emphasis of Indians for ethnic taste and a growing tendency to minimise time allocation to cooking by Indian women, primarily due to busy schedule and changing lifestyles augur well for introduction of such ready-to-heat and eat products in retort pouches/trays. Popularity of such packaged food will further boost demand for suitable polymers for such applications in coming days.

Micro Ovenable Packaging

Foods packaged for microwave heating and cooking have become among the fastest growing categories of convenience foods. A microwavable package is one, which can be used for cooking or heating the product in a microwave oven. The package alters the heating pattern of the contained food, by releasing or trapping the water vapour inside the package, thereby cooking the product under controlled temperature and pressure.

The different types of materials used to pack micro–ovenable popcorn are:

- Paper / Adhesive / Met PET susceptor with OPP overwrap
- Two PET layers coated with PVDC
- Paper bag overwrapped with OPP / Tie layer / EVOH / Tie layer / Ionomer

All the above packs are shelf-stable.

MAP (Modified Atmosphere Packaging)

The most important methods to extend the shelf-life of food are Controlled Atmosphere Packaging (CAP), Modified Atmosphere Packaging (MAP) and Vacuum Packaging (VP). The principal function of such preservative packaging is to delay microbiological spoilage, but they must also delay non-microbiological deterioration of the product. CAP means that the gaseous environment in immediate contact with the food is controlled with respect to carbon dioxide, oxygen, nitrogen, water vapour and trace gases. MAP is defined as an initial alteration of the gas followed by time-based alteration stemming from product respiration, microbiological action, package gas transmission, etc. In general, all inclusive definition of a food stored in a MAP environment is one in which the product is stored in something other than air.

Vacuum packaging is removal of air from the package, with no gas replacement. Aerobic bacteria and oxidative reactions (leading to rancidity) are the two major spoilage agents of foods. Both these phenomena require oxygen. If oxygen is removed or eliminated, spoilage is inhibited and keeping quality is extended.

The effectiveness of all modified atmosphere packed food depends on the maintenance of the gaseous conditions inside the pack, for which suitable packaging materials must be used. The material should be compatible with the food and have capabilities of transmitting water vapour and gases. For MAP, plastic packaging materials are generally used and all plastics are permeable to gases, in varying degrees.

In practice, suitability of a film's gas transmission is expressed in terms of oxygen transmission rate. Transmission of carbon dioxide is usually between two and eight times that of oxygen.

In general, films with nominal oxygen permeabilities of 100 ml/m^2 /24h/atm can be used for vacuum and modified atmosphere packaging. Laminates or multi-layered structures are widely used for preservative packaging. For example, pouches may have a central gas barrier layer, like PVDC, inner food contact layer with good heat sealing properties, like PE and a damage-resistant outer layer, like nylon. Aluminium foil or metallized films may be used for additional gas barrier properties.

Active Packaging

Packaging is called active packaging when it performs an additional role, other than just exhibiting itself as an inert barrier to external influences.

The concept of active packaging has been developed to correct the deficiencies in passive packaging. For e.g., when a film is a good barrier to moisture, but not to oxygen, the film may still be used safely with the use of an oxygen scavenger to exclude oxygen from the pack. This is active, interactive or functional packaging, where the pack protects what it contains in addition to the classical functions of any packaging.

Other packaging systems, where plastics are successfully used are intelligent packaging, stretch wrapping, shrink wrapping, bag-in-box system etc.

Trends and Future Prospects

Both quantitative and qualitative trends have been identified to establish what the future holds and where the focus needs to be for technological development and upgradation of the industry. These are listed in Tables 20, 21 and 22.

TABLE 20

Indian Packaging Trends

(Growth Indication with base year as 1992)

Material	1992	1995	2000
CFB Boxes	100	123	172
Composite Containers	100	116	148
Multi-Wall Paper Sacks	100	133	214
Carton Wrappers/Bags	100	116	148
Laminates	**100**	**145**	**270**
Glass Containers	100	113	138
Jute (Sacks + Wrap)	100	111	111
Tinplate	100	112	137
Aluminium Foil	100	126	185
Aluminium Tubes	100	119	127
Plastics – Semi –Rigids	**100**	**126**	**185**
Plastics – Films	**100**	**134**	**218**

TABLE 21

World Packaging Trends

Trends

• Fastest growing **segment** is Flexible Packaging.
• Fastest growing **material** is Plastics.
• Specific high growth **areas** are:
  • Stand-up Pouches – highest growth
  • High Barrier Flexibles
  • Plastic Containers-especially High Barrier & PET
  • Labels & Shrink-Sleeves
  • Poly-Lactide Resins – Bio-degradable
  • Extreme concern on Tamper-Proofing & Brand Security
  • Demand for much better graphics

TABLE 22

Indian Packaging Trends

Package Material	**Trend**
Flexible packaging	Dominant
PET bottles	High growth
Paper	Moderate growth
Glass	Low growth
Metal Cans	Low growth

Conclusion

Packaging is more than a just a container with a label stuck on it. It is a vital opportunity to build new brands or reinforce and add value to a positive experience of an existing product or brand.

With development of science and technology, alternative materials like plastics have emerged as an appropriate replacement for natural/traditional materials. Apart from cost reduction, plastics also cater to certain applications, which were not possible with traditional materials. Plastics are the material of the new millennium. Now-a-days, usage of plastics gives the correct index of industrialization of the country, status of its economy and the standard of living of its citizens.

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