Chapter 4

PLASTICS BASED PACKAGE FORMS & SPECIALITY PACKAGING FOR FOOD PRODUCTS

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Plastic materials are synthetics made from oil, coal or natural gas and are now one of the principal packaging materials being used in the form of wraps, pouches, bags, sacks, bottles, jars, tubes, trays, and boxes. Plastics have applications in transport packaging too, where they have replaced steel, wood and glass. They are also used in the form of stretch wrapping and shrink wrapping and shrink film, and as strapping for securing palletized loads. There will be many other packaging openings in the future for this group of materials. The properties of plastics like pliability, flexibility, formability and ease of handling will enable plastics to expand their position in the market against competition from other materials such as natural fibers, glass and metal.

Fig. 4.1. Flexible films and laminates

Speciality packages which possess certain functional properties to enable processing and/or preservation of food products include retort pouches/trays, aseptic packages, modified atmosphere packages, frozen and oven proof packages and active and smart packaging.

New plastics, along with new combinations of natural and synthetic materials, will undoubtedly continue to be developed in the form of co-polymerized, laminated and co-extruded packaging products to meet a wide range of needs.

FLEXIBLES

Flexible films are basically produced through extrusion, extrusion blowing and to some extent through moulding. Flexible films are used to make wraps, pouches, bags, and their variations.

WRAPS

Probably the simplest type of flexible package ever devised is the intimate wrap, where a sheet material is used to enclose a quantity of product. The wraps are most widely used in bakery and confectionery industry. Metalised films and composite materials in the form of twist wraps, Pleated bunch wraps and folded wraps are commonly used methods of wrapping.

Fig. 4.2. Bread wrapping

POUCHES

Pouches are totally enclosed packages which are intended to hold the product with or without assistance.

Flexible pouches can be made either from monolayers or multilayered by laminates or co-extruded structures. Metalization on plastic films to improve the barrier properties and opacity is also common. Also composite flexibles are widely used in food industries particularly for bulk packaging applications.

Flexible pouches are used to pack foods such as: processed, frozen and fresh meats, poultry and seafood; dairy foods, frozen vegetables, dry bakery goods, coffee, tea, candy and snack foods; dry powders; prepared entrees and processed fruit and vegetables; condiments and liquids; and cereals and pet foods. Flexible pouches being light weight and adaptable are competing favorably with other containers, such as glass and plastic bottles, metal and composite cans and paperboard boxes. Following are the commonly used pouch styles.

Fin Pouch

Fin pouch is made by simply folding the web material in half and sealing both sides. The bottom sometimes also has a seal depending on web material and product. Fin pouches with an applied re-closeable zipper are also popular. Liquids and powders are generally packed in this package style.

Gusset Pouch

Gusset pouch is formed by folding the web material into a "W" shape at the bottom of the pouch. By adapting the fin pouch style to have a gusset at its base, the fill volume of the pouch is increased.

Stand Up Pouch

Stand Up Pouch has proved to be one of the most successful means of packaging a wide variety of products. The method of producing the Stand Up pouch is very similar to making a gusset pouch with the addition of sealing the edges and bottom of the gusset in order that the pouch will stand upright on the store shelf. The style is ideal for snack foods, pet treats, delicate products, dried soup mixes, condensed soups and other liquids.

Membrane Pouch

The membrane pouch concept was designed for separating a fin, gusset or stand up pouch into two separate compartments by means of a center web. Membrane pouches are used for separating any two ingredients from each other prior to dispensing from the pouch.

Tandem Pouches

Tandem pouch configuration is ideal for increasing output of a single product fill, increasing output of a multi-product fill or the presentation of a two part product in separate packages. Pouches may remain attached with a perforation or serration. They can also be cut into individual pouches after discharge from the pouching machine.

Frangible Pouch

The frangible pouch is used for keeping two components separate from one another prior to being mixed them within the pouch itself. The two components are kept separate until one of the compartments is squeezed and the resulting pressure ruptures the seal between the compartments and allows the components to mix. After mixing, the pouch is opened and the product is dispensed.

Bags

A plastic bag is defined here as a bag manufactured from extensible film by heat sealing one or more edges. They are produced in different sizes for use in different packaging applications. The plastic bags are identified by the type of heat seals

Fin pouch *Gusset pouch* *Stand up pouch*

Frangible pouch *Membrane pouch* *Tandem pouch*

Fig. 4.3. Different pouch styles.

employed. There are basically three types of seal methods in use and they are: side weld, bottom-seal, and twin seal. Plastic bags, available in virtually all shapes, sizes and colours and configurations have replaced paper in most light duty packaging applications. Polyethylene such as LDPE, HDPE, HMHDPE and polypropylene are the most commonly used materials for bags. Bags are generally classified as commercial bags and consumer bags. Commercial bags are used as a packaging medium for another product, whereas consumer bags are used to contain the purchased materials from the market.

Fig. 4.4. Plastic bags

Bag-in-Box

Bag–in-box is a two package system used for commercial packaging of food and non-food products. It is used in bulk packaging of liquid and semi liquid products consisting of three main components. (1) a flexible, collapsible, fully sealed bag made from one or more plies of plastic films; (2) a closure and a tubular spout through which contents are filled and dispensed; and (3) a rigid outer corrugated or solid fibreboard box or container, usually holding one but sometimes more than one bag.

Edible oils packed in bag-in-box are very popular in the market. Other products being packed in this system are fruit juices and non-carbonated beverages. Both hot fill and aseptic filling techniques can be used. Other liquid products that are being used in bag-in-box include water, milk, wine, cider, vinegar, soya sauce, tomato ketchup, salad dressings, etc. Bag-in-box is not just confined to small packs and packs up to 1,000 liter capacity are also in the market. The bag-in-box technique was originally used for liquids but has successfully diversified into packaging of dry powdered or granular products. The typical materials used for the construction of bag are Kraft/PE/Foil/PE, Bleached Kraft/PE/Foil/PE and PET/PE/Foil/PE.

Fig. 4.5. Aseptic bag in a box.

Skin Packs

Skin packaging is another form of blister packaging. In skin packaging, the product itself is the mould over which the heated plastic film or a "skin" is drawn by vacuum and heat sealed to paperboard card. There are three principal components associated with skin packaging: the plastic film, the heat seal coating and the paperboard card.

There are three types of films used in skin packaging: LDPE, PVC and Surlyn Ionomer. Normally, skin packaging films are heated, draped and formed, and bonded to the paperboard card in one operation.

Fig. 4.6. Skin packaging of chicken sausages.

Stretch Films

Stretch films are basically used to unitise smaller individual items into a larger unit loads. The advantages of unitization are:

- Reduced handling costs
- Less manpower requirement
- Transportation savings
- Protection to the commodities.

In addition to the above advantages, stretch films offer further advantages:

- Low supply cost
- Protection from moisture, dirt and abrasion
- Reliable performance
- Automation
- Scan through optics
- Ease of removal
- Recycling

Stretch packaging operation consists of stretching the film around the objects to be wrapped and then heat sealed. The residual tension in the film provides the tight contour wrap. Again, like shrink wrapping, it finds its use in collating, pallet overwrapping and retail wrapping.

The main films used in stretch wrapping are LDPE, EVA and PVC. The choice of stretch film depends on factors such as appearance, protection required and the susceptibility to damage by compression of the articles to be wrapped.

Stretch wrapping of pallet load is done by spiral winding so that a standard width of film can be used, irrespective of the pallet load dimensions. Pallet stretch wrap equipments are also available for this purpose.

Shrink Films

Shrink films are basically used to wrap awkwardly shaped articles, which otherwise are difficult to pack. The availability of tougher, cheaper films with higher softening points such as LDPE, PVC along with hot air shrink tunnels made shrink packaging a reality. The applications include collation of cans, jars, bottles or cartons. For cans, bottles and cartons, it is necessary to use fibreboard trays or plastic trays such as PVC or EPS. Cost-wise, shrink wrapping is cheaper compared to fibreboard boxes.

The use of shrink film at retail store level has a positive impact from the environmental point of view. The amount of packaging to be disposed off at retail level is smaller compared to paperboard packaging, and this is an important positive point from the environmental point of view.

Overwrapping of complete pallet loads displacing the use of paper or board coverings held in place by metal or plastic strappings by shrink wrapping ensures more stability than strapped loads and this provides extra protection against ambient conditions.

Fig. 4.7. Shrink wrapping of aseptic fruit juice packages and HDPE container.

Plastic Woven Sacks

Woven sacks are manufactured by weaving of monoaxially oriented tapes of HDPE, PP and LDPE for packaging of foodgrains, sugar, rice, salt, milk powder, onion, potato, etc.

For high moisture sensitive foods, where higher barrier properties are required, loose liners of LDPE, LLDPE or HMHDPE are used or LDPE lamination of the woven fabric is done before stitching into sacks.

Advantages of Circular Woven Sacks

- Coverage is very much better because the tapes do not get twisted as in flat weaving.
- Savings up to 25% because of superior coverage.
- Much higher output compared to the conventional flat looms.
- Improved strength of the weaving fabric.
- Savings in floor space, number of operations and labour.
- Higher output of sacks.

Advantages of Woven Sacks over Conventional Sacks of Jute, Paper, etc.

- Weighs only 20% of the jute sacks.
- Resistant to even most corrosive products.
- Safe for direct contact with food products and do not cause contamination as likely with jute fibres.
- Are water repellent and can be made water and moisture-proof by using a loose liner or lamination.
- Do not contain Jute Batching Oil (JBO).
- No corrosion even in presence of water or in corrosive atmosphere.
- Superior drop impact properties; as such bursting losses are very low or almost nil.
- Resist fungal attack.
- Can be manufactured in any desired colours for easy identification as well as for the brand image.
- Attractive printing.
- Clean appearance.
- Easy disposability and reusability.

Possible Variations

- Leno bags for the packaging of potatoes, onions, apples, fruits, etc — fabric is open mesh with average weight of less than 30 g/m^2. For example, a 40 kg potato bag weighs only 28 g each.

- Fabric can be laminated to paper for Plastic film.
- Medium size bulk containers up to 2 ton capacity are manufactured using a fabric weighing 200-250 g/m^2 from UV stabilized PP Tapes.

Fig. 4.8. Plastic woven sacks.

Nettings

Plastic nettings are produced either by knitting or by extrusion. Netting is produced in the form of tube and sheet in a wide variety of mesh sizes, diameters, width and colours.

Extruded netting is produced through counter rotating dies. As the inner and outer dies rotate, small strands of molten plastic overlap each other, bonding themselves together where they overlap. The material is heated and stretched to the point just before breakage to get the orientation. Knitting machines offer simple and sophisticated stitch patterns. HDPE and PP are the most commonly used plastic materials for nettings.

Plastic netting is a valuable packaging means. It is resilient, strong, and flexible. Netting can be frozen and then heated or vice versa, keeping its strength and flexibility. Plastic netting is very cost effective compared to other forms of packaging and is recyclable. Plastic netting is used in many packaging applications. As a flexible material it conforms to irregular products. Netting provides an excellent packaging media as a decorative and protective overwrap. Netting has wide applications in the packaging of fresh fruits and vegetables especially root vegetables and in the poultry industry.

Fig. 4.9. Potatoes and onions in plastic netting

RIGID AND SEMI-RIGID CONTAINERS

Bottles and Jars

When used to make jars or bottles, plastics have some distinct advantages over glass or metal including the following:

- *Non breakability:* At least most plastics in many applications are less likely to break on impact than glass. With most commercial plastics, unbreakability is a major advantage.

Fig. 4.10. Plastic bottles and jars in various shapes and sizes.

- *Lighter weight:* As low as 1/3 the weight of metal and 1/8 the weight of glass in comparable applications.
- Lower noise level in packaging and in use, again compared to glass and metal no corrosive as opposed to metal cans.
- *Transparent:* Some plastics–when compared to metal.
- *Smaller size:* When compared to glass, wall thickness for equivalent strengths and volumes are less, and so equivalent contents can be contained in packages of smaller exterior size.
- *Flexibility of forming:* Capital investment required to produce rigid plastic containers is only a small fraction of that required for glass or metal.

The major plastic materials used for bottles and jars are HDPE, LDPE, PP, PVC, PS, PC, PET, Multilayers of desired combinations.

Co-extruded Blow Moulded Multilayer Bottles

Co-extruded blow moulded multilayer bottles offer new packaging possibilities for improved barrier requirements with a potential to replace traditional glass and metal containers. A wide range of different polymers can be combined in different ways, and also the wall thickness of the individual layer can be optimized to achieve the necessary functionality and offer the best economics. Manufacture of these bottles involves use of flexible co-extrusion machines suitable to rheological behaviour of the different polymers as well as quality control.

Co-extruded bottles are already in the market for a wide range of foods such as ketchup, sauces and jellies. These bottles have replaced glass bottles and they are unbreakable, squeezable and light weight.

Fig. 4.11. Co-extruded multilayer plastic bottles.

The most popular material combination in use today is the six layer combination – PP or HDPE/regrind/adhesive/EVOH/adhesive/PP or HDPE. Another three layer combination is PC/PET/PC. Here, no adhesive material is required , since both polymers belong to the polyester family and have excellent adhesion.

Stretch Blow Moulded Bottles

The hollow type of extrusion blow moulded bottles made of various thermoplastics like LDPE, HDPE, PVC, PS, PC, etc. have been in commercial use for over three decades. However, the biggest breakthrough in bottle making was the invention of stretch blow moulding technique since it provides material savings, improved clarity and good mechanical strength. Following are the advantages of stretch blown moulding:

- Raw material savings up to 25% since thinner walls are possible because of superior mechanical strength due to biaxial orientation.
- Improved clarity particularly in case of PET bottles.
- Improved barrier properties.
- Improved mechanical properties.

The major materials that are processed by this process are PET and PVC followed by PP. Thermoforming is another technique used for making jars.

Cans

Cans are also made by plastics, by injection moulding, blow moulding and thermoforming. Since plastics are not as rigid as metals, thicker walls are needed for equivalent performance, and container weight and cost can become excessive. Heat resistance is another important property required by the can to undergo pasteurization and sterilization for most of the acid and low acid food products. A precise flange is needed to guarantee a perfect seal, which is absolutely critical for sterilized cans, and certainly desired for contained liquids, especially under pressure. Plastic ends or metal ends are used in these type of cans. Another design concern is the necked-in end now customary for beverage cans, which allows tighter six packer and cheaper ends. This can be done with plastics, but mould design is more complicated to permit the undercut needed.

These cans have huge applications in softdrink and beer markets. Thermoformed and blow moulded PET bottles coated with PVDC are in the market in USA, Britain and Italy. For heat resistance PP is the most suitable material. However, PC can also be used but it is expensive. For better barrier properties, a multilayered co-extruded PP/EVOH/PP can also be used. Injection moulded HDPE and PS cans are also in use for some food products.

Fig. 4.12. Plastic can with metal lid.

Collapsible Tubes

Many plastics can be used to make plastic tubes, but LDPE/HDPE is the primary material used today. It has high moisture barrier properties, low cost and good appearance. Its lack of oxygen and flavor barrier have been improved with barrier coatings. HDPE and PP are also used, but they are much stiffer than LDPE for tube side walls, and hence not as popular as LDPE. EVOH based co-extruded tubes offer excellent barrier to oxygen and flavour.

These tubes are produced by Strahm and Downs method, basically an extrusion process. The collapsible tubes are corona treated during extrusion for better ink adhesion during printing. HDPE and PP screw caps are used as closure for collapsible tubes. At present, the all plastic barrier tube is not economically viable with a laminated structure. Plastic collapsible tubes will find a major share in the market, in the event of reduction of EVOH prices in the future.

Fig. 4.13. Collapsible plastic tubes

Pails

Plastic pails are open head containers with removable lids and containers produced as a single unit called tight head containers. The container top or lid can be manufactured with one or more openings for filling and dispensing. The openings are designed to be used with a variety of closures.

In the open-head design configuration, the containers are usually supplied with a removable lid designed to be used with either liquids or solids. The lids are available with spouts of various types. The most commonly used pour fittings for liquids is the flexible polyethylene spout. This fitting snaps into position in a preformed hole or is a spout that incorporates metal collar that is crimped onto a formed, ridged opening in the lid. The open head pails are generally non-vertical and are nested into each other for efficient storage and transportation, prior to being filled and sealed. In the closed-head configuration, no nesting advantage exists. The size of pails varies from 3 L to 25 L capacity. Both open-head and closed-head pails are made from HDPE. These pails are universally injection moulded.

Fig. 4.14. Plastic pails for vanaspati

Blister Packs

Blister packs are the fastest packing method world over. It consists of combination of plastic materials with paperboard to produce visual, self vending packages. The rapid growth of self service retailing created a demand for innovative packaging that protects the product and also provides sales appeal in terms of product visibility and instruction for use. The size and shape are numerous because of the flexibility it offers. The blister packs consists of a preformed plastic blister, paperboard and a heat sealing coat on the paperboard. The selection of packaging material for blister in terms of type, thickness and grade depends on many factors like height and weight of the product, sharp and pointed edges of the product, heat sealing properties, compatibility with the product and machinability. The most commonly used plastic materials for blister packs are PVC, PVDC coated PVC, OPS and recently PET is also being used.

Heat seal coatings provide a bond between the plastic blister and the printed paperboard card. These solvent or water based coatings can be applied to rolls or sheets of printed paperboard using roll coaters, gravure or flexographic methods. Paperboard of thickness between 0.45 and 0.60 mm in generally used. The normal sequence of assembly involves loading the blister with product, placing the paperboard card over the blister and heat-sealing the package.

Fig. 4.15. Artificial sweetener in a blister pack

Thermoformed Containers

Tubs, trays and box inserts are the commonest containers formed by this method particularly where very thin walls are required, such that it would be difficult for a polymer to flow between the mould walls in an injection moulding.

PS, Polypropylene, PVC, HDPE, and PET have all been used for thermoformed containers. The latest materials in this field are foamed polystyrene andPP, which can be thermoformed to give trays and containers with built in cushioning properties. The thermoformed articles are produced either by vacuum forming or by pressure forming.

Continuous on-line Thermo-Form-Fill-Seal (TFFS) machines are also available in the market. This type of machine uses a reel fed web of plastics material into which is thermoformed a series of tray like depressions. The depressions are indexed forward as a web and after filling a further web is fed over the open top of the filled tray and sealed on to the flanges of the trays to form a closure. The web of filled and closed trays is then punched to form individual packs, or slit into partially jointed strips containing several units. Lidding materials can be plastic film or film laminations, although metal foil reverse coated for heat sealing to the container is more widely used. Re-closable plastic lids can be provided for some thermoformed containers, either by a separate operation or by on-machine thermoforming at the lidding station.

The products, which are commonly packaged in thermoformed containers, are butter, cream, yogurt, processed cheese, ready-to-eat foods, fruits, vegetables, and jams.

Use of thermoformed cups made of polypropylene are widely used. These have functional advantage of transparency and toughness over HIPS cups. These can be used for packing Dairy products and drinking water.

Fig. 4.16. Thermoformed trays of various shapes and sizes.

Fig. 4.17. Food products in thermoformed containers

Drums

Open top plastic containers up to 25 L capacity are called jars or pails. The term "Drum" applies to containers larger than 25 L capacity, and the container can be either open or closed type. The standard drum sizes commonly used are 30, 60, 120 and 216 L. The development of large plastic drums took many years because they required special resins and processing equipment. These drums are used in food processing industries for the shipment and storage of products that include concentrated fruit juice, vegetable pulps and condiments. They are made by extra high molecular weight high density polyethylene. These have relatively high resistance to permeation, which can be further improved by using higher wall thickness. The service life of HDPE drums cannot be predicted because it largely depends on climatic conditions. Different colorings, especially black, blue, green, white and gray, increase resistance to weathering and protect the product from light. Depending on the climatic conditions additional UV stabilizers must be added.

Drums are manufactured by rotational moulding. In this process, a fine powder or

Fig. 4.18. Plastic drum and milk cans

liquid thermoplastic takes on the shape of a heated mould subjected to tri-axial total rotation. Once the receptacle has been formed, the mould is cooled and opened. The particle size of the powder used also affects the surface appearance, the quality of which improves with the fineness of the powder.

Crates

Plastic crates are being used for many years in the food industries as returnable shipping containers. The more familiar uses have been as milk crates, fresh fruits and vegetable crates, beverage cases, as a storage container in factory warehouses, etc.

Fig.14.9. HDPE crates.

There are five different methods employed to manufacture plastic crates: Injection moulding; Compression moulding; Blow moulding; Rotational moulding; and Thermoforming. Each process is suited to the production of a range of geometries with a variety of materials at different costs. But the most often used method is injection moulding. This method is most suited for reusable shipping container because it allows intricate shapes to be moulded at high rates of production. HDPE is the most commonly used material for plastic crates. There are four different types of crates available:

- Nest only
- Stack only
- Stack and nest
- Collapsible

Corrugated Sheets & Boxes

Plastic corrugated boxes are used in situations where the traditional paper based CFB are inadequate in certain situations. Theoretically, it is possible to use all plastic materials for conversion into corrugated sheets, but the costs can be prohibitive. The most commonly used materials are HDPE and PP. PC is also used as sheets for some special applications. Following are the advantages and disadvantages of plastic corrugated boards, which designer should keep in mind while selecting the material.

Table 4.1. Advantages and disadvantages of plastic corrugated boxes

Advantages	Disadvantages
Long life	Cost
Chemical resistance Insulation	Formability Temperature resistance
Multiple colour choice	UV degradation
Strength:weight ratio Waterproofness	

Forming Methods

Corrugated plastic boards are manufactured using standard box making techniques. Generally, flatbed presses using cam action or single stroke are used to die-cut, score, crease, or fold the material. Three-point or four-point, single-side bevel-edge rule is used for cutting. Six-point creasing is used for creasing parallel with the flutes, three-point of creasing across the flutes, to obtain a 90° bend. The polyolefin board has a "memory" and, unlike paperboard, will generally attempt to return to its previous shape. This characteristic calls for modified bending and creasing techniques.

High-frequency welding is the method used for joining the material. Because of the nature of the polymer, glues are not generally successful. But lap joints have been accomplished using corona-treated board with silicone-type or hot melt adhesives. Metal stitching can be used, but this creates a weak spot immediately surrounding the staple.

Fig. 4. 20. HDPE and PP corrugated sheets.

Pallets

Plastic pallets are primarily used inside the plants or in closed-loop shipping system due to their higher costs. Plastic pallets are almost always found in applications where the user can retrieve most of the pallets after each trip. Following are the advantages of plastic pallets:

- Long pallet life
- Reduced load damage
- Easy cleanup
- Reduced worker injury
- Chemically inert
- Moisture proof
- No harbor for pests
- Nestability
- Interstackability

The commonly used materials are HDPE, PS and FRP. But HDPE is the most favoured material because of low cost, uniform performance, ready availability, wide acceptance, excellent resistance to impact, and good performance under wide range of operating conditions. The only negative point of HDPE is the poor creep resistance. Following are the methods employed for the manufacture of plastic pallets:

- Structural foam moulding
- Injection moulding
- Rotational moulding
- Thermoforming
- Reaction injection moulding

Foams

The mould comprises of two walls between which steam is diffused through a mass of plastic granules (EPS, PE, polyurethane), entering by a large number of apertures or slitted plates uniformly distributed over the inner wall.

Expanded Polystyrene Foaming

Conversion is carried out by raising the temperature in two stages. In the first stage, pre-expansion or free expansion of polystyrene beads yields expanded polystyrene flakes. These flakes are then used to fill the mould, and they expand to take the form of the mould under heat and pressure. Two processes exit: heating by hot air followed by compression, and steam heating of the mould. Blocks and moulded shapes may be produced.

Polyurethane Foaming

Conversion starts with dosing machines that feed the basic liquid ingredients to a mixing head which deposits them on the belt (free foaming) or into a closed mould (forced foaming) where expansion begins. There are two kinds of machines: the low pressure "pre-polymer" machine (in which mixing is by agitator of compressed air and feeding by gear pump) and high pressure "one-shot" machine.

Polyethylene Foaming

Conversion starts with a mixture of polymer and blowing agent to which crosslinking agents (peroxides of di-cumulated butyl and tributyl) are added. Shaping is effected by calendaring. Chemical or radiation crosslinking is accomplished at temperatures below the breakdown temperatures of the blowing agent.

CLOSURES

Screw Caps

Screw caps are generally injection moulded from wide variety of plastics such as polyethylene, polystyrene or polypropylene or compression moulded from phenol-formaldehyde and urea-formaldehyde. They are commonly used on plastic bottles or jars.

Polypropylene caps are particularly valuable as closures for cosmetic preparations because of their design possibilities. Polypropylene has good resilience so that mouldings having slight undercuts can be "jumped-off" the mould core without damage to the moulding. Decorative inserts can be pressed into these moulded-in undercuts to give caps with highly effective sales appeal. The resilience of polypropylene also makes possible the design of linerless closures.

Plug Fitting

This type of closure is normally injection moulded from low-density polyethylene since its softness and flexibility enables it to give a good seal, even against hard, smooth surfaces such as walls of polystyrene tube. The plug itself is often ribbed to give even better sealing.

An interesting example of the design possibilities inherent in the use of plastic is the plug closure which incorporates flexible prongs on the underside of the plug. The use of this closure for tablet tubes eliminates the necessity for a wad of cotton wool on top of the tablet to prevent their movement with consequent risk of breakage during transport. Again no special equipment is necessary for closing.

Push-on Covers

This type of closure is the normal one for injection-moulded plastic pots or jars and for some types of vacuum-formed containers. In addition to plastic push-on covers, paperboard ones are still used in some instances. Before applying the push-on cover, a foil diaphragm is often crimped over the top of the pot or jar. This gives extra protection or a tamper-proof seal. In thickness gauges, aluminium foil is sometimes used as the only closure, as in the case of yoghurt containers. Flexible push-on covers (in low density polyethylene) can also be used for bottles.

Heat-sealed Covers

These are often used for closing vacuum-formed containers of the tray type, or the deep drawn pyramid type used for fruit drinks. The cover may be flat or recessed to give a shallow plug-type fitting to the container with a consequent increase in rigidity and strength. Sealing is carried out with a heated jig. With certain types of equipment it is possible to vacuum form plastics sheet continuously from the reel, fill the depressions so formed, then covers them with another plastic sheet fed from a separate reel. After heat sealing, the cover on the containers are cut out and trimmed.

Miscellaneous Closures

The possibilities for design inherent in moulding of plastics have led to many special types of closures, such as combined plug and snap-on covers and plug or screw-caps which incorporate means of dispensing the contents in droplet form or as a jet or spray. Such closures are usually fitted to "squeeze" bottle designs. Another interesting design feature which is often incorporated in plastic closures is the integral moulding of a nozzle and cap to give a captive closure. The assembly is fitted as a plug in the bottle neck. The same result has also been achieved by the use of a snap-on action retaining ring.

Fig. 4.21. Closures.

SPECIALITY PACKAGING

Vacuum and Gas Packaging

Where foods are susceptible to oxygen, as frequently occurs in the presence of light, it is helpful to exclude air from the package. Vacuum packaging is more a means of keeping a food at better level of quality during

Table 4.2. Some examples of gas-flushed packaging at refrigerated temperatures

Food	Gases	Shelf-life (days)
Red meats	70% Oxygen 30% Carbon dioxide	7
Organ meats	40% Carbon dioxide 50-60% Oxygen	6-10
Processed meats	20-50% Carbon dioxide 50-80% Nitrogen	21
Fish	80% Carbon dioxide 20% Oxygen	4-8
Pizzas	50% Carbon dioxide 505 Nitrogen	21

Table 4.3. Gases used in packaging and their applications

Gases	Applications
Nitrogen	As a pressure-relief agent to prevent external atmosphere from crushing the product. Nitrogen is inert gas. It does not react with foodstuffs. Common packaging applications: bulk-pack bacon and sauces, shredded and sliced cheese and beef jerky, snack foods.
Carbon dioxide	Depending upon applications, 20-100% carbon dioxide may be used. Carbon dioxide lowers the pH of the food and can exert a powerful slowing effect on the growth of microorganisms. Primary application is for baked foods, cookies, cakes, breads, dough and pasta products. Carbon dioxide tends to be absorbed into the actual body of the food product itself. Carbon dioxide is frequently mixed with nitrogen to prevent the package from clinging too tightly to the product. On the other hand, some products which are not sensitive to strong pressure or tight cling, but which are susceptible to spoilage by mould growth, are packaged in an atmosphere of 100% carbon dioxide.
Oxygen	The applications using oxygen are primarily for red meat. The concept is widely used in Europe for centrally packaged retail cuts. Oxygen is used as an oxygenating agent at levels in the range of 40-80% to form the bright red meat colour. When oxygen is used, it is usually mixed with carbon dioxide and nitrogen—carbon dioxide for its preservation effect, nitrogen to provide a bulking agent. Oxygen tends to disappear inside the package. It can be metabolized by the meat to carbon dioxide which is absorbed in the water phase of the meat as carbonic acid.

its natural life than a means of increasing its shelf life. Under good vacuum conditions, the oxygen level is reduced to less than 1%. In the case of vacuum packed meats, respiration of the meat quickly consumes the residual oxygen replacing it with carbon dioxide which eventually increases to 10-25% within the package.

Fig. 4.22. Nitrogen filled snack food packages.

Packaging material required for vacuum packaging must possess high resistance to gas permeability and water vapour transmission with perfect seals and also should have good mechanical strength. Typical materials used are: 1. K-Nylon/LLDPE, MXXT/LLDPE, K-PET/LLDPE 2. Laminates of plastic films with aluminium foil. Food products like bacon slices, ham, fish, cheese, coffee, tea, meat, etc. are vacuum packed.

In gas flush packaging the gases used and their applications are given in Table 4.2 and 4.3.

Retort Packaging

Pouches

The materials used in making retort pouches should possess toughness and puncture resistance normally required of flexible packaging, good barrier properties for long shelf-life, and heat sealability over a wide temperature range along with the ability to survive retort temperatures. To get all these desired properties in the pouch material, laminate structures or coextruded films are used.

The outer film of the composite structure is needed for strength and flex resistance. It should be resistant to heat-seal temperatures, printable, and be able to withstand retort temperatures without bursting, shrinking and delamination. The present material of choice is polyethylene terephthalate (PET). It has the added advantage of being reverse printed so that ink is embedded between the outer layer and the next inner layer.

In order to achieve a shelf-life of one year or more, aluminium foil layer as one of the inner layers for barrier properties is essential. The thickness range of aluminium foil varies from 9 to 25μm though 9 μm thickness currently predominates. Thicker foils tend to result in more flexure failures and form more permanent creases or peaks that act as loci for abrasion failures. In Japan, non-foil pouches are quite common since a much shorter shelf life of 3-6 months is acceptable. Nylon is another material used as a barrier film in place of aluminium foil because of its low gas transmission rate and toughness. Being transparent, nylon based laminates cannot provide protection from light unless covered with a overcarton or wrap. The other transparent materials used in place of aluminium foil are EVOH, PVDC, aluminium oxide and silicon oxide coatings on PET.

The current material of choice for inner sealant layer is cast polypropylene, though high density polyethylene modified with isobutylene rubber is also used.

Since thermoprocessing imposes higher performance criteria on pouch materials, developmental efforts centred around the formulation of adhesives and primers capable of laminating the dissimilar plies together with adequate strength to withstand all the rigours of heat sealing, retorting and distribution handling, while being acceptable to regulatory agencies from the standpoint of not contributing harmful components to the foods. Quality assurance procedures are strictly adhered to in view of the several critical factors involved in pouch performance.

Semi-rigid Containers

Retortable semi-rigid containers are of tray or tub type with a structural supporting body and a sealable flexible lid. The tray package is a thin-profile package that offers all the advantages of the retortable pouch with the added convenience of a serving dish. Improved techniques of thermo-forming or cold impact forming and coextrusion have recently advanced the state-of-art of this package. Thermoforming is relatively low-cost technique, wherein the sheet is heated to an optimum temperature and it is then forced into a female cavity mould by compressed air, vacuum, or a male die.

Advantages of semi-rigid packages include ease of filling or top-loading of products with or without in-line forming of the container, and potential increases in line speeds due to multiple pocket forming on a wide web-style operation.

Original semi-rigid packages were made of aluminium foil laminates with cast polypropylene as sealant layer. Oriented polypropylene was used as exterior layer. The 80's have seen high barrier plastics coming into use to serve as an effective replacement for aluminium in order to make the containers microovenable. Two resins that are being used in these are polyvinlyledene chloride (PVDC or saran) and ethylene vinyl alcohol copolymer (EVOH or EVAL).

Though these resins are prohibitively expensive, multi co-extrusion permits the burying of a thin layer of the barrier layer between two or more thicker layers of less expensive polymer. While PVDC provides an excellent barrier to oxygen, its resistance to re-melting and hence the inability of using its regrind may prove to be a disadvantage. In case of EVOH, the barrier to oxygen transmission is adversely affected in presence of high humidity. The use of a desiccant in the tie layers to capture any errant moisture is believed to solve this problem.

In the rotary thermoforming process, a multi-layer sheeting is directly coextruded on to a rotary drum, where it is thermoformed into multicavities while it is still above the melt temperature of the polyethylene. The higher temperature is expected to result in stress-free containers, thereby minimizing warping during retorting.

Following are the typical laminate structures used for retort pouches and trays:

Pouches

- CPP
- PET/CPP
- CPP/Nylon/CPP
- PET/Al.foil/CPP
- PET/Al.foil/Nylon/CPP
- PET/SiO_2 on PET/CPP
- PET/Al_2O_3 on PET/CPP
- PET/PVDC on PET/CPP
- PET/EVOH/CPP

Trays

- CPP
- PET/CPP
- PET/Regrind/PVDC on PET/CPP
- PET/Regrind/EVOH/CPP
- CPP/Regrind/EVOH/Regrind/CPP

Fig. 4.23. Retortable pouches and trays.

Aseptic Packaging

Aseptic processing and packaging basically consists of filling of the commercially sterilized product into presterilized package under aseptic conditions and sealing with a presterilized closure in an atmosphere free of microorganisms. Aseptic packaging consists of the following steps:

- Heating the product to sterilization temperature and holding it at that temperature to achieve commercial sterility,
- Cooling of the product,
- Filling into sterile containers in sterile atmosphere and sealing aseptically.

The versatility of aseptic technology has given rise to the use of a variety of plastic and polyolefin materials for packaging. Since aseptic applications require both product preservation, and utility from the packages, there are several basic requirements that these relatively new packaging materials must meet for successful application in the marketplace, and the most of them are product-or usage-dependent.

1. The packaging materials must be acceptable for use in contact with the intended product, and must comply with material migration requirements applicable.
2. Physical integrity of the package is necessary to assure containment of the product and maintenance of sterility. The term integrity applies to the structural integrity of the container itself as well as that of the closures and seals to assure package soundness and hermeticity during handling and distribution.
3. The package material must be able to be sterilized and be compatible with the method of sterilization used (heat, chemical or radiation).
4. The package must provide the barrier protection necessary to maintain product quality until it is used. Barrier protection means control over the transmission of oxygen, moisture, light, and aroma through the package as required by the product.

The package forms that are used in aseptic packaging are: Rectangular and tetrahedron shaped cartons, Cups, Bags, bottles and bag in box/drums. The packaging materials are sterilized by using either H_2O_2 in combination with heat or gamma irradiation.

The typical packaging structures used are:

LDPE/Paperboard/PE/Al.foil/PE/LDPE/ LLDPE.

LLDPE/EVOH/LLDPE

PET/Al.foil/Paperboard/PP or PE

Fig. 4.24. Aseptic consumer packs and bulk bags.

Frozen Food and Oven-Proof Trays

The continuing growth of microwave oven sales and increasing consumer use of microwave ovens for cooking processes as well as other conventional ovens has made development of dual-oven-proof trays an important proposition in packaging. One of the largest markets for microwave oven-proof trays is restaurants equipped with microwave ovens for quick service. Most plastic trays and paperboard trays with grease-proof coatings are available for microwave oven use only, since temperatures to which trays are exposed are lower than 100°C(boiling point of water).

Social trends and changing life styles, that have made dual-oven-proof paperboard trays dominant in the market, include:

1. Growing popularity of convenience foods,
2. Increasing institutional catering,
3. Development of the microwave oven,
4. Development of dual-oven-proof PET-coated paperboard,
5. The higher production cost of metal and plastic containers,
6. Energy factors,
7. Environmental factors.

Requirements for Dual-Oven-Proof Trays

The Primary requirements of dual-oven-proof tray for food packaging are as follows:

1. Protect the food contained,
2. Aesthetic appeal to the user,
3. Ease of heating or cooking the food for serving,
4. Operating efficiency in manufacturing, and
5. Cost efficiency.

Each requirement must be satisfied by the physicochemical functionalities or properties of materials used in the tray manufacture.

Requirements for Dual-Oven-Proof Paperboard

Dual–oven-proof paperboard has been developed primarily in conformity with the requirements for dual-oven-proof trays already described. Detailed requirements or advantages of dual-oven-proof paperboard for oven-proof trays are as follows :

1. **Dual-oven-proof quality :** Paper itself has a high heat resistance, which is reinforced by the PET coatings. An oven temperature in cooking could be as high as 240°C, and heat resistance against 200-220°C for 30 min is sufficient for most applications.
2. **High temperature resistance :** Oven-proof trays used for frozen food packaging must have a high heat resistance, going from deep freezing at –40°C to reheating at 200-220°C for 30 min.
3. **Browning and odor development resistance :** Browning of paperboard is a major problem to be overcome with PET coating on paperboard as a material of dual-oven-proof trays. Heat is accumulated along the tray flange, while the walls are protected from rising temperature by the heat-sink effect from the foods contained. Coatings should not be degraded to generate odor at oven temperatures.
4. **Good performance under deep freeze conditions :** Frozen foods are handled and distributed under deep-frozen conditions at lower than –15°C, typically –40°C. Oven-proof trays must have sufficient properties as packaging for frozen foods at that temperature.
5. **Grease and water resistance :** These are other important roles of coating, and also are primary requirements for a packaging of frozen foods that will be used to heat and serve.
6. **High in productivity :** This refers to not only productivity of tray itself but also productivity at the packaging operation,

Table 4.4. Dual-oven-proof trays

Basic Material	Coating	Forming
Paperboard (pulp)	PET Acrylic Silicone Polybutylene terephthalate (PBT)	Pressed forming Folded forming Molded forming
Plastic (PET)	-	Vacuum forming Molding (thermoset)
Aluminium	Plastics	Pressed forming Drawn forming

which are very important in the cost performance.

7. **Printability :** Ease of printing and aesthetic qualities are distinctive properties of paperboard.

8. **Heat sealability and gluability :** These are primary requirements for food packaging to protect the contents. Coating affects these requirements strongly, especially heat sealability, which is not original property of paperboard.

9. **Heat tolerance in physical properties :** A tray with food, reheated for serving, must have sufficient physical properties for holding food and serving on the table without any troubles. Rigidity and grease and water resistance are important properties.

10. **Safety as food packaging materials :** All the materials used should be in conformity with regulatory requirements and be approved.

11. **Microwave safe :** Molecules often generate heat from electric oscillation of microwaves which may result in their degradation and hazardous substances.

PET Tray

Dual-oven-proof PET trays have been developed for more than 10 years, and a few products have been introduced. PET has appropriate properties as a material for dual oven-proof trays, including cost of resin, heat resistance, mechanical properties, ease of processability, and compatibility with food products as well as availability of an amorphous and a crystalline state. PET can be extruded to sheeting and can be thermoformed at its amorphous state, and high heat resistance can be achieved in the crystalline state, which is the primary property of the tray for conventional oven use.

Modified Atmosphere Packaging (MAP)

It is a food preservation technique, in which the composition of atmosphere surrounding the food is changed from the normal composition of air. Unlike controlled atmosphere storage, in MAP, there is no way of controlling the atmosphere components at specific concentrations once a package has been hermetically sealed. There are two different methods of MAP: Active modification and Passive modification.

Fig. 4.25. Packaging for frozen foods.

The typical packaging forms used in MAP are pillow pouches, bag-in-boxes and trays with overwrapping. MAP has wide applications in the area of fresh fruits and vegetables and in meat preservation.

The packaging materials used are as follows:

Pouches

PET/PVDC/LDPE/LLDPE

PA/PVDC/LDPE/LLDPE

PC/EVOH/EVA

MPET

MOPP

OPP/PVDC

Trays

UPVC/LDPE

HDPE

EPS/EVOH/LDPE

Bag-In-Box

PA/LDPE

PA/EVOH/LDPE

Active and Smart Packaging

Active packaging can be defined as packaging that performs a role other than an inert barrier to the external environment.

The active functions can be achieved by any one of the methods given below:

1. Scavenging undesirable substances,
2. Release of active substances,
3. Using other new functional package designs/materials.

Oxygen present in the headspace in food package results in oxidation and development of moulds, fungi and bacteria, resulting in spoilage of food. The oxygen can be removed from the package by using the following types of oxygen scavengers:

1. Iron-based,
2. Metal/acid-based,
3. Metal (e.g. platinum) catalyst based,
4. Ascorbate/metallic salts based,
5. Enzyme-based.

Ageless® is a very popular sachet type oxygen scavenging system being used world over. Similarly ethylene scavengers and antimicrobial agents are also incorporated in films to perform specific functions to increase the shelf life of the commodities.

Smart packaging is an advanced active packaging system that contains additional

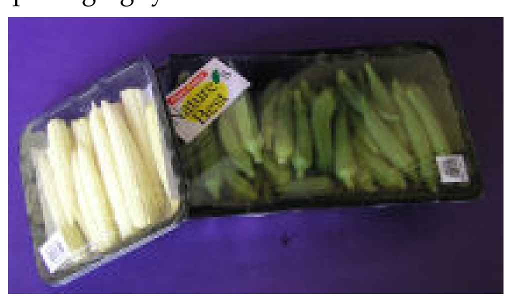

Fig. 4.26. Baby corns and ladies fingers in PS tray wrapped with transparent films.

Table 4.5. Common plastic materials and forms and their applications in food industries.

Types of Plastics	Applications
Low density polyethylene	Foods, milk, frozen foods, agricultural products, shrink wrapping, heavy duty sacks, coating, lamination, multi-layer composites, coextrusion, containers and liners.
Linear low density polyethylene	Trash bags, ice bags, produce bags, shrink, aseptic bags films, heavy duty shipping sacks, liquid milk packs, edible oil packs and lamination film, etc.
High density polyethylene	Woven sacks, films, drums, barrels, milk can bottle crates, fish crates, transport containers, pallets, moulded containers, bags, tapes, strips, blown films, extrusion coating, corrugated sheets, etc.
High molecular high density polyethylene	Films, rolls, bags, pouches, drum liners, garbage bags, lamination for fertilizer packages, milled wheat products, wrapping films, etc.
Polypropylene	Woven sacks, strappings, films and laminates, pouches. Packages for textiles, apparels, bakery products (biscuits, bread, cakes etc.), metallized films, shrink films closures, corrugated sheets, blown moulded bottles, extrusion and stretch blow moulded items, heavy crates, boxes, bucket containers, extruded nets, knitted sacks, corrugated boxes, etc.
Expanded polypropylene	Insulation, packaging medium for electrical and electronics items as a cushioning material, wrapping, liner, etc.
Polyvinyl chloride	Films, sheets, bags, liners, shrink films, shrinkable tubes, skin/blister packs, laminates, adhesive tapes, bottles, etc
Nylon-6	Oxygen and odour sensitive foods, edible oils, spices
Polyester	Spices, instant foods, bakery and confectionery, bottles, laminates etc.
Polyurethane	Coatings, foams, sheets, etc.
Polystyrene	Thermoformed containers for ice cream, condiments, jam, etc.
Expanded polystyrene	Insulating and cushioning material, beverages, frozen foods, fans, motors, typewriters, computers, electricals and electronics, etc.

functions beyond barrier and protecting functions. It also exhibits sensing and interactive and responsive mechanisms. The function of smart packaging are:

- To improve product quality and product value,
- To provide more convenience,
- To change gas permeability,
- To provide protection against theft, counterfeiting and tampering.

There are different techniques used in smart packaging: Time temperature technique; Oxygen indicators; Microbial growth indicators; Moisture indicators, etc.

BIBLIOGRAPHY

Athalye AS (1992). Plastics in Packaging. Tata McGraw Hill, New Delhi.

Brody A (1997). The Encyclopedia of Packaging Technology. John Wiley and Sons, USA

Brown WE (1992). Plastics in Food Packaging. Marcel Dekker Inc, New York.

Jenkins WA and Harrington JP (1991). Packaging Foods with Plastics. Technomic Publication, Lancaster, Pennsylvania.

Paine FA (1962). Fundamentals of Packaging. John Wiley and Sons, London.

Paine FA (1977). Packaging Media. John Wiley & Sons, London.

Paine FA and Paine HY (1983). Handbook of Food Packaging. Leonard Hill, Glasgow, UK.

Parry RT (1993). Principles and Applications of MAP of Foods.

Peleg K (1985). Produce Handling, Packaging and Distribution. AVI Publications, West Port, Connecticut.

Robertson GL (1993). Food Packaging: Principles and Practice. Marcell Decker, New York.

Sacharow S and Griffin RG (1980). Principles of Food Packaging. AVI Publications, West Port, Connecticut.

Sathish HS (1996). Profile on Food Packaging. CFTRI, Mysore.