Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 9: Plastics as Packaging Material and Flexible Films

9.1 Introduction

Plastics are defined as organic macromolecular compounds obtained by polymerisation, polycondensation, polyaddition or any similar process from molecules with a lower molecular weight or by chemical alteration of natural macromolecular compounds.

Molecules with a lower molecular weight are known as monomers and the *macromolecular compounds* are known as polymers – a word derived from Greek, meaning *many parts.*

The first plastics were derivativeof natural raw materials (coal, oil and natural gas) in the first half of the 20th century. The most widely used plastic today, polyethylene, was invented in 1933 – it was used in packaging from the late 1940s onwards in the form of squeeze bottles, crates for fish replacing wooden boxes and film and extrusion coatings on paperboard for milk cartons.

Plastics can meet the needs of a wide temperature range, from frozen food processing (−40°C) and storage (−20°C) to the retort sterilization (121°C), and reheating of packaged food products by microwave(100°C) and radiant heat (200°C). Most packaging plastics are thermoplastic,which means that they can be softened and melted repeatedly when heated.This feature has several important implications for the use and performance ofplastics, as in the forming of containers, film manufacture and heat sealing property.

9.1.1 Advantages of plastics

Plastics are widely used for packaging materials because of following advantages:

- Flowability and mouldability under certain conditions
- Almost inert
- Cost effectiveness
- Lightweight
- Transparent
- Ease of giving colour
- Ease of heat sealing
- Heat resistance and barrier.

9.1.2 Use of plastics in food packaging

Plastics are used as containers, container components and flexible packaging.In usage, by weight, they are the second most widely used type of packagingand first in terms of value. Examples are as follows:

- Rigid plastic containers such as bottles, jars, pots, tubs and trays etc.
- Flexible plastic films in the form of bags, sachets, pouches and heat-sealable flexible lidding materials
- Plastics combined with paperboard in liquid packaging cartons
- Expanded or foamed plastic for uses where some form of insulation, rigidity and the ability to survive compression is required

- Plastic lids and caps and the lining used in such closures
- Diaphragms on plastic and glass jars to provide product protection and tamper indication
- Plastic bands to provide external tamper evidence
- Pouring and dispensing devices
- To collate and group individual packs in multipacks, e.g. Hi-cone rings for cans of beer, trays for jars of sugar preserves etc.
- Plastic films used in cling, stretch and shrink wrapping
- Films used as labels for bottles and jars, as flat glued labels or heatshrinkable sleeves
- Components of coatings, adhesives and inks.

9.1.3 Types of plastics used in food packaging

The following are the types of plastics used in food-packaging

- Polyethylene (PE)
- Polypropylene (PP)
- Polyesters (PET, PEN, PC) (PET is also referred to as PETE)
- Ionomers
- Ethylene vinyl acetate (EVA)
- Polyamides (PA)
- Polyvinyl chloride (PVC)
- Polyvinylidene chloride (pvdc)
- Polystyrene (PS)
- Styrene butadiene (SB)
- Acrylonitrile butadiene styrene (ABS)
- Ethylene vinyl alcohol (EVOH)
- Polymethyl pentene (TPX)
- High nitrile polymers (HNP)
- Fluoropolymers (PCTFE/PTFE)
- Cellulose-based materials
- Polyvinyl acetate (PVA)

PE constitutes the highest proportion of consumption as packaging material followed by PP, PET, PS (including expanded polystyrene or EPS) and PVC.

9.2 Manufacture of packaging film

The plastic raw material (resin) is in the form of pellets. Plastics in powder form are used in some processes. While some plastics are used to make coatings, adhesives or additives in other packaging related processes, the first major step in the conversion of plastic resin into films, sheets, containers etc., is to change the pellets from solid to liquid or molten phase in an extruder.

The plastic is melted by a combination of pressure, friction and heat. This is done by forcing the pellets along the barrel of an extruder using specially designed, polymer-specific, screw under controlled conditions that ensure the production of a homogeneous melt prior to extrusion.

The molten plastic is then forced througha narrow slot or dies to manufacture film and sheet while it is forced into shape using a mold to manufacture rigid packaging, such as bottles and closures.

9.2.1 Plastic film and sheet for packaging

As per the definition, the thickness of a film should be less than 100 µm (1 µm = 10^{-6} m). Film is used to cover product, to overwrap packaging (single packs, groups of packs, palletised loads), to make sachets, bags and pouches, and is combined with other plastics and other materials in laminates, which in turn are converted into packaging. Plastic sheets in thicknesses up to 200 µm are used to produce semi-rigid packaging such as pots, tubs and trays.

The characteristics of plastic films and sheets are dependent on the plastic(s) used and the method of film manufacture together with any coating or lamination. In film and sheet manufacture, there are two different methods of processing the molten plastic which is extruded from the extruder die. In the *cast* film process,the molten plastic is extruded through a straight slot die onto a cooled cylinder, known as the chill roll.

In the *blown*, or tubular, film process, the molten plastic is continuously extruded through a die in the form of a circular annulus, so that it emerges as a tube. The tube is prevented from collapsing by maintaining air pressure inside the tube or bubble.

In both the processes, the molten polymer is quickly cooled and solidified to produce a film which is reeled and slit to size.

For increased strength and improved barrier properties, film can be stretched to realign, or orient, the molecules in both the machine direction (MD), and across the web in the transverse (TD) or cross direction.

Film stretched in one direction only is described as being *mono-oriented*.When a film is stretched in both the directions, it is said to be *biaxially orientated*. Packing the molecules closer together improves the gas and water vapour barrier properties. Orientation of the molecules increases the mechanical strength of the film.

Oriented films are brought close to their melting point to anneal or release stresses in them and to minimize the amount of shrinkage which may occur when being heated in a post-production process such as printing or heat sealing. Failure to anneal heat set films will ensure that they have very unstable thermal characteristics and allow the films to shrink tightly onto cartons or bottles when heated.

It is difficult to puncture or start a tear in an oriented film, but once punctured, the alignment of the molecules allows easy increase of the rupture and tear. This feature is made use of to assist the opening of film sachets by incorporating a tear-initiating notch mechanically into the sealing area.

The majority of plastic films are transparent and not easily coloured by dyeing or adding pigments. In order to develop opacity, films can be cavitated during film manufacture. Cavitation causes internal light scattering, which provides a white or pearlescent appearance. With some plastics, such as cast PE, a chemical compound can be added to the plastic resin, which gives off a gas such as nitrogen or carbon dioxide, when heated in the film manufacturing process. The small gas bubbles in the plastic cause light scattering, which gives the film a pearlescent appearance.

However, because oriented films are thin, there is the probability of the bubbles being so large that the film may be ruptured. So instead of using gas bubbles, a shearing compound or powder is added to the polymer, causing internal rupturing of the plastic sheet as it is being stressed. This causes voids in the film and light is scattered across the whole spectrum. Incident white light is reflected inside the film as a result of the differing refractive index between the plastic and free air. The process reduces the density of the film and may result in more cost-effective packaging as a result of the increased area yield.

The technique of pigmenting plastics has been developed using white compounds such as calcium carbonate or, more usually, titanium dioxide, to give a white appearance. The addition of such inorganic filler, however, increases the density by up to 50%, lowering the yield and increasing the risk of mechanically weakening the film.

Metalizing with a very thin layer of aluminium is another way to achieve opacity by causing a high proportion of incident light to be reflected offthe surface away from the film. This technique has the additional benefit of improving barrier properties.

Transparency, the opposite of opacity, depends on the concerned polymer and on the way the film has been produced. If the film is allowed to cool down slowly, then large crystals may be formed and this gives the film a hazy appearance due to the diffraction and scattering of incident light by the crystals. Transparency improves as polymer crystallinity decreases and is also influenced by additives in the film. If the size of the additive particle is too large or if, as with slip agents, they migrate to the surface, the film becomes hazy.

The surface of a film needs to be as smooth as possible to enhance the surface for printing. A rough surface will give a dull appearance to the final printed effect, which is generally considered to be less attractive than a shiny, mirror smooth appearance. Furthermore, a rough surface may give packaging machine slippage problems, as it may be difficult to make the film slideover machine parts without creating static electricity in the film. It is overcome by incorporating food grade additives in the film. Films will also tend toblock and become adhered layer to layer in the reel. Waxes, for example carnaubawax, are added to minimize the blocking. The action of a slip additive, such assilica, depends on the particles of silica migrating to the surface of the filmwhere they act like ball bearings holding the surfaces apart.

For marketing purposes, it may be desirable to create a unique impact on theshelf at selling point, and hence films have been developed which are rough on one side and have a gloss surface on the other. This is done by casting thefilm against the rough surface of a sand-blasted chill roll.

It is possible to combine streams of molten plastic from separate extrudersin the die to make co-extrusions. Higher productivity is attained for a giventhickness of film if the same plastic is extruded in two or more layers andcombined in the die to form a single film. Co-extrusion is fast developing area, with extruders capable of combining up to seven layers of differingplastics to achieve specific properties and characteristics.

9.2.2 Pack types based on use of plastic films, laminates

Single films, co-extruded films and coated and laminated films in reel form areused to make plastic bags, sachets, pouches and overwraps.

Plastic bags are made by folding, cutting and sealing with welded seamswhich are also cut in the same operation. Pouches are generally made from laminates. They may be formed on the packing machine either from one reel byfolding, or from two reels and sealing, inside face to inside face on three sidesprior to filling and closing. The pouches travel horizontally on these machineswith the product filled vertically.

Free-flowing products such as granules and powders can also be filled vertically on form, fill, seal machines where the film is fed vertically from the reel. These packs are formed around a tube, through which the previouslyapportioned product passes. A longitudinal heat seal is made either as a finseal, with inside surface sealing to inside surface, or as an overlap seal, dependingon the sealing compatibility of the surfaces. The cross seal is combined withcutting to separate the individual packs.

Solid products such as chocolate bars are packed horizontally on form, fill, sealmachines. Biscuits can be packed in this way, provided they are collatedin a base (plastic) tray, though they are also packed at high speed on roll-wrappingmachines with the ends of the film gathered together and heat sealed.

Products packed in cartons are often overwrapped with plastic film, e.g.chocolate assortments and tea bags. The cartons are pushed into the network offilm, a longitudinal seal is made and the end seals are neatly folded, envelopestyle, prior to sealing with a hot platen which presses against the folded ends.

Shrink wrapping is similar to the overwrapping described above, except thatthe packs pass through the heated tunnel once the cross seal is made – there areno end seals. The film shrinks over the ends of the pack, the extent dependingon the width of the film used.

9.2.3 Rigid plastic packaging

Bottles are prepared by extrusion blow moulding. A thick tube of plastic is extrudedinto a bottle mould which closes around the tube, resulting in the characteristicjointed seal at the bottom of the container. Air pressure is then used toforce the plastic into the shape of the mould. After cooling, the mould isopened and the item removed. (The bottle shows a thin line in the positionwhere the two parts of the mould are joined.) Blow moulding is used for milkbottles (HDPE) and wide mouth jars.

It is possible to apply co-extrusion to extrusion blow moulding so that multi-layered plastic containers can be made with a sandwich of various plastics. Anexample would be where high oxygen barrier, but moisture sensitive, EVOH is sandwiched between layers of PP to protect the oxygen barrier from moisture.This construction will provide for a 12–18 month shelf life for oxygen-sensitiveproducts such as tomato ketchup, mayonnaise and sauces.

A variation of injection and extrusion blow moulding is to stretch the pre-form after softening it at the second stage and then stretching it in the direction of the long axis using a rod. The stretched pre-form is then blow moulded which results in biaxial orientation of the polymer molecules, thereby increasing strength, transparency, gloss and gas barrier. Injection stretch blow moulding is used to make PET bottles for carbonated beverages.

Screw cap and pressure fit closures with precise profiles are made by injection moulding. Wide mouth tubs and boxes are also made by injection moulding.

Not only are injection moulded items very accurate dimensionally but they can also be made with a very precise thickness. It should be noted that co-extrusion is not possible with injection moulding.

There are many food applications for rigid and semi-rigid thermoformed containers. Examples include a wide range of dairy products, yoghurts etc. in single portion pots, fresh sandwich packs, compartmented trays to segregate assortments of chocolate confectionery and trays for biscuits. Thermoforming can be combined with packing on in-line thermoform, fill and seal machines. These machines can incorporate aseptic filling and sealing.