Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 6: Glass as Packaging Material

6.1 Introduction

Glass is defined as 'an inorganic product of fusion which has cooled to a rigid state without crystallizing'. Glass is made by cooling a heated, fused mixture of silicates, lime and soda to the point of fusion. After cooling, it attains a condition which is continuous with, and similar to, the liquid state of that substance, but which, as a result of a reversible change in viscosity, has attained so high a degree of viscosity as to be for all practical purposes solid.

6.1.1 Glass packaging

The two main types of glass container used in food packaging are

1. Bottles, which have narrow necks,
2. Jars and pots, which have wide openings.

6.1.2 Glass containers market sectors for foods and drinks

A wide range of foods is packed in glass containers. Examples are as follows: instant coffee, dry mixes, spices, processed baby foods, dairy products, sugar preserves (jams and marmalades), spreads, syrups, processed fruit, vegetables, fish and meat products, mustards and condiments etc. Glass bottles are widely used for beers, wines, spirits, liqueurs, soft drinks and mineral waters. Within these categories of food and drinks, the products range from dry powders and granules to liquids, some of which are carbonated and packed under pressure, and products which are heat sterilized.

6.2 Glass composition

6.2.1 White flint (clear glass)
Colourless glass, known as white flint, is derived from soda, lime and silica. This composition also forms the basis for all other glass colours. A typical composition would be: silica (SiO_2) 72%, from high purity sand; lime (CaO) 12%, from limestone (calcium carbonate); soda (Na_2O) 12%, from soda ash; alumina (Al_2O_3), present in some of the other raw materials or in feldspar-type aluminous material; magnesia (MgO) and potash (K_2O), ingredients not normally added but present in the other materials.

6.2.2 Pale green (half white)
Where slightly less pure materials are used, the iron content (Fe_2O_3) rises and a pale green glass is produced. Chromium oxide (Cr_2O_3) can be added to produce a slightly denser blue green colour.

6.2.3 Dark green
This colour is also obtained by the addition of chromium oxide and iron oxide.

6.2.4 Amber (brown in various colour densities)

Amber is usually obtained by melting a composition containing iron oxide under strongly reduced conditions. Carbon is also added. Amber glass has UV protection properties and could well be suited for use with light-sensitive products.

6.2.5 Blue

Blue glass is usually obtained by the addition of cobalt to a low-iron glass. Almost any coloured glass can be produced either by furnace operation or by glass colouring in the conditioning forehearth. The latter operation is an expensive way of producing glass and commands a premium product price. Forehearth colours would generally be outside the target price of most carbonated soft drinks.

6.3 Attributes of food packaged in glass containers

The glass package has a modern profile with distinct advantages, including:

6.3.1 Quality image

Consumer research by brand owners has consistently indicated that consumers attach a high quality perception to glass packaged products and they are prepared to pay a premium for them, for specific products such as spirits and liqueurs.

6.3.2 Transparency

It is a distinct advantage for the purchaser to be able to see the product in many cases, e.g. processed fruit and vegetables.

6.3.3 Surface texture

Whilst most glass is produced with a smooth surface, other possibilities also exist, for example, for an overall roughened ice-like effect or specific surface designs on the surface, such as text or coats of arms. These effects emanate from the moulding but subsequent acid etch treatment is another option.

6.3.4 Colour

A range of colours are possible based on choice of raw materials. Facilities exist for producing smaller quantities of nonmainstream colours, e.g. Stolzle's feeder colour system.

6.3.5 Decorative possibilities

Including ceramic printing, powder coating, coloured and plain printed plastic sleeving and a range of labelling options.

6.3.6 Impermeability

For all practical purposes in connection with the packaging of food, glass is impermeable.

6.3.7 Chemical integrity

Glass is chemically resistant to all food products, both liquid and solid. It is odourless.

6.3.8 Design potential

Distinctive shapes are often used to enhance product and brand recognition.

6.3.9 Heat processable

Glass is thermally stable, which makes it suitable for the hot-filling and the in-container heat sterilization and pasteurization of food products.

6.3.10 Microwaveable

Glass is open to microwave penetration and food can be reheated in the container. Removal of the closures is recommended, as a safety measure, before heating commences, although the closure can be left loosely applied to prevent splashing in the microwave oven. Developments are in hand to ensure that the closure releases even when not initially slackened.

6.3.11 Tamper evident

Glass is resistant to penetration by syringes. Container closures can be readily tamper-evidenced by the application of shrinkable plastic sleeves or in-built tamper evident bands. Glass can quite readily accept preformed metal and roll-on metal closures, which also provide enhanced tamper evidence.

6.3.12 Ease of opening

The rigidity of the container offers improved ease of opening and reduces the risk of closure misalignment compared with plastic containers, although it is recognized that vacuum packed food products can be difficult to open. Technology in the development of lubricants in closure seals, improved application of glass surface treatments together with improved control of filling and retorting all combine to reduce the difficulty of closure removal. However, it is essential in order to maintain shelf life that sufficient closure torque is retained, to ensure vacuum retention with no closure back-off during processing and distribution.

6.3.13 UV protection

Amber glass offers UV protection to the product and, in some cases, green glass can offer partial UV protection.

6.3.14 Strength

Although glass is a brittle material glass containers have high top load strength making them easy to handle during filling and distribution. Whilst the weight factor of glass is unfavourable compared with plastics, considerable savings are to be made in warehousing and distribution costs. Glass containers can withstand high top loading with minimal secondary packaging. Glass is an elastic material and will absorb energy, up to a point, on impact. Impact resistance is improved by an even distribution of glass during container manufacture and subsequent treatment.

6.3.15 Hygiene

Glass surfaces are easily wetted and dried during washing and cleaning prior to filling.

6.3.16 Environmental benefits

Glass containers are returnable, reusable and recyclable. Significant savings in container weight have been achieved by technical advances in design, manufacture and handling.

6.4 Glass and glass container manufacture

6.4.1 Melting

Glass is melted in a furnace at temperatures of around 1350°C and is homogenized in the melting process, producing a bubble-free liquid. The molten glass is then allowed to flow through a temperature controlled channel (forehearth) to the forming machine, where it arrives via the feeder at the correct temperature to suit the container to be produced. For general containers, suitable for foods and carbonated beverages, this would be in the region of 1100°C.

6.4.2 Container forming

In the feeder, the molten glass is extruded through an orifice of known diameter at a predetermined rate and is cropped into a solid cylindrical shape. The cylinder of glass is known in the trade as a *gob* and is equivalent in weight to the container to be produced. The gob is allowed to free-fall through a series of deflectors into the forming machine, also known as the IS or individual section machine, where it enters the parison. The parison comprises a neck finish mould and a parison mould, mounted in an inverted position. The parison is formed by either pressing or blowing the gob to the shape of the parison mould. The parison is then reinverted, placed into the final mould and blown out to the shape of the final mould, from where it emerges at a temperature of approximately 650°C A container is said to have been produced by either the *press and blow* or *blow and blow* process.

In general terms, the press and blow process is used for jars and the blow and blow process for bottles. An alternative, for lightweight bottles, is the *narrow neck press and blow* process. The press and blow process is generally best suited to produce jars with a neck finish size of ≥35mm (≥1.25″); the other two processes are more suited to produce bottles with a neck finish size of ≤35mm (≤1.25″)

The narrow neck press and blow process offers better control of the glass distribution than the blow and blow process, allowing weight savings in the region of 30% to be made.

6.4.3 Design parameters

One of the design parameters to be borne in mind when looking at the functionality of a glass container is that the tilt angle for a wide-mouthed jar should be ≥22° and that for a bottle ≥16°. These parameters are indicative of the least degree of stability that the container can withstand.

6.4.4 Surface treatments

Once formed, surface treatment is applied to the container in two stages: hot end and cold end treatment, respectively.

6.4.5 Hot end treatment

The purpose of hot end surface treatment is to prevent surface damage whilst the bottle is still hot and to help maintain the strength of the container. The most common coating material deposited is tin oxide, although derivatives of titanium are also used. This treatment tends to generate high friction surfaces; to overcome this problem, a lubricant is added.

6.4.6 Cold end treatment

The second surface treatment is applied once the container has been annealed. Annealing is a process which reduces the residual strain in the container that has been introduced in the forming process. The purpose of the cold end treatment is to create a lubricated surface that does not break down under the influence of pressure or water, and aids the flow of containers through a high speed filling line. Application is by aqueous spray or vapour, care being taken to prevent entry of the spray into the container, the most commonly used lubricants being derivatives of polyester waxes or polyethylene. The surface tension resulting from this treatment can be measured by using Dynes indicating pens. Labelling compatibility should be discussed with either the adhesive supplier or the adhesive label supplier depending on the type of label to be used.

6.5 Thermal processing of glass packaged foods

Glass containers lend themselves to in-bottle sterilization and pasteurization for both hot and cold filled products. Subject to the headspace volume conditions being maintained and thermal shock ground rules being observed, no problems will be experienced.

In general terms, hot-fill products filled at 85°C and then cooled will require a minimum headspace of 5%, whilst a cold filled product requiring sterilization at 121°C will require a 6% minimum head space. In all cases the recommendations of the closure supplier should be obtained before preparing the design brief. It should be noted that the thermal shock of glass containers is twice as high when cooling down as when warming up. To avoid thermal shock, cool down differentials should not exceed 40°C and warm up differentials should not exceed 65°C.

Internal pressure resistance. A well-designed glass container can withstand an internal pressure of up to 10 bar (150 pounds per square inch), although the norm required rarely exceeds 5 bar. It is also capable of withstanding internal vacuum conditions and filling of thick concentrates, with steam-flushing of the headspace to produce the initial vacuum requirements for the closure seal.

6.6 Packing – due diligence in the use of glass containers

6.6.1 Receipt of deliveries

Glass containers are usually delivered on bulk palletized shrink-wrapped pallets. A check should be made for holes in the pallet shroud and broken glass on the pallet, and any damaged pallets rejected.

6.6.2 Storage/on-site warehousing

Pallets of glass must not be stored more than six high, they must be handled with care and not shunted. Fork-lift trucks should be guarded to prevent the lift masts contacting the glass. Where air rinser cleaning is used on the filling line, the empty glass containers should not be stored outside. Pallets damaged in on-site warehousing must not be forwarded to the filling area until they have been cleared of broken glass.

6.6.3 Depalletization

Plastic shrouds must be removed with care to prevent damage to the glass; if knives are used, the blade should be shrouded at all times, so as not to damage the glass. It is necessary to ensure that the layer pads between the glass containers are removed in such a way as to prevent any debris present from dropping onto the next layer of glass.

6.6.4 Cleaning operation

- *Air rinse*. The glass must be temperature-conditioned to prevent condensate forming on the inside, which would inhibit the removal of cardboard debris. The air pressure should be monitored to ensure that debris is not suspended and allowed to settle back into the container.
- *On-line water rinse*. Where hot-filling of the product takes place, it is essential to ensure that the temperature of the water is adequate to prevent thermal shock at the filler, i.e. not more than 60°C differential.
- *Returnable wash systems*. The washer feed area must be checked to ensure that the bottles enter the washer cups cleanly. A washer-full of bottles must not be left soaking overnight. In the longer term this would considerably weaken the container and could well create a reaction on the bottle surface between the hot end coating and the caustic in the washer. Where hot-filling is taking place, it is necessary to ensure that the correct temperature is reached to prevent thermal shock at the filler.

6.6.5 Filling operation

Clean-up instructions should be issued and displayed. It is essential to ensure that flood rinsing of the filler head in question is adequate to prevent contamination of further bottles. It is necessary to ensure that filling levels in the container comply with trading standards' requirements for measuring containers.

6.6.6 Capping

Clean-up instructions on the procedure to follow should breakage occur in the capper should be issued and displayed, and all breakages recorded. The application torque of the caps and vacuum levels must be checked at prescribed intervals, as must the cap security of carbonated products.

6.6.7 Pasteurization/sterilization

It is necessary to ensure that cooling water in the pasteurizer or sterilization retort does not exceed a differential of more than 40°C (104°F), to prevent thermal shock situations. The ideal temperature of the container after cooling is 40°C, which allows further drying of the closure and helps prevent rusting of metal closures. Air knives should be used to remove water from closures to further minimize the risk of rusting.

6.6.8 Labelling

Where self-adhesive labels are to be used, all traces of condensate must be eliminated to obtain the optimum conditions for label application. Adhesives must not be changed without informing the glass supplier, since this could affect the specification of adhesives/surface treatments.

6.6.9 Distribution

It is essential to ensure that the arrangement of the glass containers in the tray, usually plastic or corrugated fibreboard, is adequate to prevent undue movement during distribution, that the shrink-wrap is tight and that the batch coding is correct and visible.

6.6.10 Warehousing

The pallets of filled product must be carefully stacked to prevent isolated pockets of high loading that might create cut through in the lining compound of the container closures, as this would result in pack failures.

6.6.11 Quality management

The procedures of good management practice in the development, manufacture, filling, closing, processing (where appropriate), storage and distribution of food products in glass containers discussed in this chapter have been developed to ensure that product quality and hygiene standards are achieved along with consumer and product safety needs. Their application indicates *due diligence* in meeting these needs. It is essential that all procedures are clearly laid down, training is provided in their use and that regular checks are made on their implementation.

6.7 Environmental profile

6.7.1 Reuse

Glass containers can be reused for food use. The daily doorstep delivery of fresh milk in bottles and the collection of the empty bottles in the UK and collection of empty bottles of carbonated beverage are well established examples. There are wide disparities in the number of trips that can be expected depending on the location, with around 12 trips per bottle being the national average.

6.7.2 Recycling

Glass is one of the easiest materials to be recycled because it can be crushed, melted and reformed an infinite number of times with no deterioration of structure. It is the only packaging material that retains all its quality characteristics when it is recycled.

6.7.3 Reduction – lightweighting

In the period 1992–2002, it is claimed that the average weight of glass containers has been reduced by 40–50%.

6.8 Glass as a marketing tool

Glass packaging supports brand differentiation and product identification by the use of:

- Creative and unique shapes and surface textures
- Ceramic printing, acid etching and coating
- Labelling, both conventionally and by plastic shrink sleeving

Current developments include the use of metallic, thermochromic, photochromic finishes, UV activated fluorescent and translucent inks and the ability to incorporate embossed, foiled, velvet textured and holographic materials. These finishes are compatible with laser etching and offer the possibility of permanent traceability coding.

Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 01: Introduction to food packaging

1. INTRODUCTION

In today's world, packaging is universal and important too. It surrounds, enhances and protects the goods we buy, from processing and manufacturing through handling and storage to the final consumer. Without packaging, materials handling would be a difficult, inefficient and costly exercise and modern consumer marketing would be virtually impossible. Most of the containers in the market today are used to protect a specific quantity of product during procurement, storage, distribution and retail sales, although several are also designed for bulk supply. The quality of the individual package depends on the nature, uniqueness and value of the product besides the prevailing social practices and legislation.

The selection of a packaging, storage and distribution system will depend on existing economic ability, production and distribution efficiency, retailing pattern, consumer preferences and ecological aspects.

Despite the importance and key role which packaging plays, it is often regarded as a necessary evil or an unnecessary cost. Furthermore, in the view of many consumers packaging is, at best, somewhat unnecessary and at worst, a serious waste of resources and an environmental threat. Such an opinion arises because the functions which packaging has to do are either unknown or not considered fully. By the time most consumers come into contact with a package, its job in many cases is almost over, so it is understandable that the view that excessive packaging has been used has gained some belief.

The Packaging Institute International defines packaging as the enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other container form to perform one or more of the following functions: containment; protection and/or preservation; communications; and utility or performance. If the device or container performs one or more of these functions it is considered a package.

2. FUNCTIONS OF PACKAGING

The functions of a package are "to preserve the quality and freshness of food, to add appeal to the food to attract consumers, and to facilitate its storage and distribution." The basic functions required of a package can be grouped under five major categories.

2.1 To Contain the Product

The primary function of any package is to contain the food and facilitate handling, storage, and distribution all the way from the manufacturer to the ultimate user or even the time the rest portion is utilized by the consumer. However, there are usually various levels of packaging. A primary package is one that comes into direct contact with the contained product, e.g., metal cans, glass jars, and plastic pouches. By law, a primary package must not yield any substance that may be injurious to the health of the consumer. Further development to facilitate handling is to bundle a series of primary packages together, and this lead to the concept of secondary packages. Examples of secondary package is corrugated box in which tins of apple juice are packed. As methods of handling and transportation have become more sophisticated, these secondary packages are often palletized and secured by strapping with metal or, more commonly, by shrink- or stretch-wrapped film to give yet another level of packaging, i.e tertiary packaging. In turn, these pallet loads may be packed into large metal containers, i.e., quaternary packaging for transportation over long distances by air, land, or sea. The secondary, tertiary and quaternary packaging is also known as packing. The following are basic functions during containing.

a. Adequate size and shape (trays to support biscuits in package)
b. Proper constructional features. No leakage, spillage, diffusion, i.e. loss prevention.
c. Package: Must contain the commodity in natural form (chips packed in Pillow pack, prevent damage)
d. No subsequent damage after packaging during handling transportation and storage.
e. Optimum compatibility (nontoxic, non soluble with product, No physical, chemical or biochemical changes/alteration, i.e. inert to the product.)
f. Containment or agglomeration - Small objects are typically grouped together in one package for reasons of efficiency. For example, a single box of 1000 pencils requires less physical handling than 1000 single pencils. Liquids, powders, and granules need containment.

2.2 To Protect the Product

One of the most important functions of any container is to protect the product contained against any form of loss, damage, deterioration, spoilage, or contamination that might be encountered throughout the distribution chain. Packaging can prevent physical damage, e.g., bruising caused by vibration shocks during transportation or stacking in a warehouse. Proper packaging will also prevent material loss, e.g., potatoes from a weak sack or juice from a leaky can. Packaging can also protect products against moisture loss or gain, dust, and light, which causes deterioration of some light-sensitive products. It can also protect the package contents against temperature fluctuations in the transit of chilled and frozen foods. Packaging can also be used to control the availability of oxygen to fruits and vegetables and to protect against loss of flavor or fragrance and help products retain their nutritional value. Proper packaging may also protect the product against microbial spoilage by bacteria, yeasts, and molds. It can also protect against microbiological spoilage of stored products due to rodents and insects.

Packaging protects the product against damages which may be due to different hazards viz. (a) Mechanical, (b) Environmental (c) Microbial & Biochemical and (d) Social

Table 1: Hazard, damage and protection of packaging materials

Sr. No	Storage	Hazard	Damage	Protection
I	Handling and transportation	Drop, shunting, shocks, vibrations, stack load, compression etc.	Breakage, loss of shape, dusting, seepage	Cushioning, blocking.
II	Storage	Stack load, compression, Attack by rodents and insects	Crushing, distortion sticking, spillage, contamination, spoilage	Adequate compression strength of package. resistance and repulsiveness to insects
III	Environment during storage transportation and distribution	Biological or otherwise	Contamination	Toughness of packaging material (to resist penetration).
		High/low humidity moisture/water.	Physical, chemical and biological deterioration due to loss/gain of moisture	Efficiency of closure providing. Water vapour barrier properties. Package desiccant etc.
		O_2	Oxidative rancidity	O_2 BARRIER VACUUM – O_2 N_2/CO_2 flushing

				packaging in impermeable package
		Light U.V. rays	Vitamin Destruction, Off flavour development, Oxidative rancidity, Bleaching of pigments	Use of opaque or dark coloured packaging material.
	Storage	Temperature	Change of state, Increase of moisture ingress Increased rate of deterioration	Heat insulation Use of poor conductor Use of reflective insulation
		Time	Gradual and slow changes occur and staling and other deteriorative changes occur	Early/immediate marketing (FIFO) Proper schedule of dispatching order providing Heat insulation Use of Barrier material

Barrier protection - A barrier from oxygen, water vapor, dust, etc., is often required. Permeation is a critical factor in design. Some packages contain desiccants or Oxygen absorbers to help extend shelf life. Modified atmospheres or controlled atmospheres are also maintained in some food packages. Keeping the contents clean, fresh, and safe for the intended shelf life is a primary function of the package.

2.3 Medium of information

An important function of any food package is to identify the product and its origin; to inform the consumer how to use the contents; to provide any other information needed or required; and very importantly, to attract the user and encourage purchase of the product. Package design has been an important and constantly evolving phenomenon for many years. Marketing communications and graphic design are applied to the surface of the package and in many cases the point of sale/display. The information a package can convey to the consumer may include the following:

1. Product manufacturing and best before dates
2. Proper storage conditions
3. Instructions for use
4. Size and number of servings or portions per pack
5. Nutritional information per serving
6. Manufacturer's name and address
7. Cost
8. Suggested recipes
9. Country of origin
10. Information transmission - Packages and labels communicate how to use, transport recycle, or dispose of the package or product.

2.4 Means of minimizing costs:

An important factor often overlooked is that packaging actually reduces costs for the consumer. Packaging reduces food costs by reducing the cost of processing. Foods can be processed where they are grown, waste is treated at the processing plant, and shipping weights are reduced, thereby lowering the cost of transportation. The handling of packages in quantity is important for the economics of bulk storage, warehousing, transport, and distribution. Proper packaging facilitates efficient and mechanized handling, distribution, and marketing of products, thus reducing the high labour costs that would have to be absorbed into the price of the product. Thus, packaging not merely contains the product, but it is a process of bringing goods from the production point to the point of use in a most beneficial manner. This involves all aspects of handling, storage, preservation, distribution, advertising, sales promotion, preparation and various other facts of industry.

2.5 Means of selling product:

The packaging and labels can be used by marketers to encourage potential buyers to purchase the product. Packaging is often referred to as the "silent salesman." Robertson (1992) concisely summarized the multifunction of packaging when he stated that "a package must protect what it sells and sell what it protects." Packages can have features which add convenience in distribution, handling, display, sale, opening, reclosing, use, and reuse.

According to Jelen (1985), primary packages should have the following characteristics to facilitate the sale of products:

1. Aesthetic appeal
2. Non toxic
3. Transparent
4. Lightweight
5. Tamper evident
6. Easy to pick up and handle
7. Easy to fit into cupboards, shelves, refrigerators, etc.
8. Easy to open and dispense from
9. Easy to reclose
10. Returnable, recyclable, or reusable
11. Safe and presents no hazards in the way of broken glass or sharp jagged metal edges
12. Display the product
13. Glamorize: Create an illusion of something very precious, by decoration, embossing techniques and exotic closures, but it should not deceive the people.

The desirable polyfunctional properties of packaging materials are summarized in Table 2.

Table 2: Functional Requirements of Packaging Materials

No.	Functional Property	Specific Factors
1	Gas permeability	O_2, CO_2, N_2, H_2O vapor
2	Protection against environmental factors	Light, odor, microorganisms, moisture
3	Mechanical properties	Weight, elasticity, heat-sealability, mechanical sealability, strength (tensile, tear, impact, bursting)
4	Reactivity with food	Grease, acid, water, color
5	Marketing-related properties	Attractiveness, printability, cost
6	Convenience	Disposability, repeated use, resealability, secondary use
7	Aroma	Aroma compound barrier property

Source: Jelen, P. 1985. Food packaging technology. In *Introduction to Food Processing*, Reston Publishing, Reston, VA, pp. 249–266.

3. OTHER FUNCTIONS OF A PACKAGE:

1. **Dispensing:** Product not used all at once, remove a portion, without destroying/damaging the remaining product/container.
2. **Preserve:** Remaining product in container-Protection and preserve it for extended/desired period.
3. **Measuring / Portion control:** Single serving or single dosage package has a precise amount of contents to control usage. Bulk commodities (such as salt) can be divided into packages that are a more suitable size for individual households. It also aids the control of inventory: selling sealed one-liter-bottles of milk, rather than having people bring their own bottles to fill themselves.
4. **Security** - Packaging can play an important role in reducing the security risks of transport. Packages can be made with improved tamper resistance to deter tampering and also can have tamper-evident features to help indicate tampering. Packages can be engineered to help reduce the risks of package pilferage: Some package constructions are more resistant to pilferage and some have pilfer indicating seals. Packages may include authentication seals to help indicate that the package and contents are not counterfeit. Packages also can include anti-theft devices, such as dye-packs, RFID tags, or electronic article surveillance tags, that can be activated or detected by devices at exit points and require specialized tools to deactivate. Using packaging in this way is a means of loss prevention.

4. PACKAGING TYPES:

4.1 Terms used:

- **Package:** It cuts contact between material and outside influences. Package material comes in direct contact with the product (Packaging).
- **Pack:** Secondary container. **Packing material never comes in contact with product**.
- **Packing:** Number of containers/packages put together in big container is called packing.

Packaging may be looked at as several different types. For example a **transport package** or **distribution package** is the package form used to ship, store, and handle the product or inner packages. Some identify a **consumer package** as one which is directed toward a consumer or household. It is sometimes convenient to categorize packages by layer or function: "primary", secondary", etc.

1. **Primary packaging** is the material that first envelops the product and holds it. This usually is the smallest unit of distribution or use and is the package which is in direct contact with the contents (viz. butter in parchment paper).
2. **Secondary packaging** is outside the primary packaging – perhaps used to group primary packages together (viz. paper board pack containing butter wrapped in veg. parchment paper).
3. **Tertiary packaging** is used for bulk handling, warehouse storage and transport shipping. The most common form is a palletized unit load that packs tightly into containers (viz. Boxes containing 20-25 or 50 butter packs are put together).

These broad categories can be somewhat arbitrary. For example, depending on the use, a shrink wrap can be primary packaging when applied directly to the product, secondary packaging when combining smaller packages, and tertiary packaging on some distribution packs.

Table 3: Differences between packaging and packing

No.	Packaging	Packing
1	Comes in direct contact with the product	Never in direct contact
2	Called primary packaging material	Secondary / Tertiary / Quaternary
3	Should be food grade, non-toxic, tasteless, odourless, lowest possible migration	No strict requirements
4	Packaging- a must e.g. Ice cream party pack, Bulk pack, Ghee	May be done/may not be done. Packaging then packing e.g. CFB, cartons, etc. Bulk biscuit packs.
5	Materials used: Plastics / glass / metal / treated paper or their combination	CFB / Plastic board boxes, wood, metal, etc. Shrink/ stretch wrapping
6	Objectives: Mainly to contain, carry, protect. Help in selling, legal aspects, marketing / sale, technical, transportation	Mainly ease in transportation and protection of packages
7	Generally attractive. Not a must: Biscuits & rolls in a pack. E.g Kellogs flakes, toffee. The exposed portion must be attractive.	Generally not attractive. But if retail pack, secondary packing exposed to consumers then attractive: Butter carton
8	Recycled material never used.	Much preferred.

9	Selection of packaging material: Physico-chemical properties of product are considered.	Generally stress / strength properties puncture resistance / burst strength, folding endurance, environmental factors considered.
10	Keeping quality is determined by packaging material.	Generally not so.
11	Single unit packaging.	Generally multi unit packaging. Sometimes single unit also. Butter carton, Bag in box. Here packing materials should be more attractive / effective than packaging material.

Reasons for selecting a particular style/type of packaging are vast and varied, numerous and changing. Product and packaging are becoming so interdependent that one cannot separate/consider one without another. Greatest part of food is spent in some form of package.

5. REQUIREMENTS FOR PRODUCING SUCCESSFUL PACKAGE:

Some sets of facts are necessary to be known for producing a successful package (mainly related to product - package interaction and transportation):

5.1 Facts about the product:

a. The nature of the product, the material from which it is made and the manner in which it can deteriorate.
b. Its size and shape.
c. Its weight and density: eg. Powder – Bulk Density, size of tins
d. Its weakness-which parts will break, move about, become bent or scratch or abrase the box easily.
e. Its strengths: which part will withstand loads or pressures and which might be suitable for loading the product in the pack.
f. The effect of moisture and temperature changes on the product and whether it will absorb moisture or corrode.
g. Compatibility: whether the product is likely to be affected by any of the possible packaging materials, which items can be packed together, with protection if necessary and which items must not be packed together under any circumstances.

h. How far stripping down may be carried out to reduce the package size to a minimum such that the customer can handle them.

5.2 Facts about the transport hazards:

a. The type of transport-road, rail, sea or air.

b. The degree of control over the transport. Is it private or public transport?

c. The form of transport- bulk, freight container, unitized load, postal, passenger train, etc.

d. The mechanical conditions and duration of storage (manufacturer → State Distributor → District Distributor … Taluka / City → Retailer. The longer the journey or handling more strength is required in packaging & packing materials leading to higher cost).

e. The nature and intensity of mechanical and climatic hazards in transport, storage, retailing and use. Packaging / packing material has to withstand wide range of temperatures and relative humidity

f. Whether handling aids are available for loading and off-loading at all points between maker and user. (Viz. Lifts, Trolleys, Slip conveyers etc.)

g. The importance of minimum volume in relation to transport costs. Over packaging must be prevented.

5.2.1 Hazards may be:

a. Mechanical: Impact (vertical, horizontal), stationary package impacted by another, vibration, compression, Racking or deformation, piercing, puncturing, tearing etc.

b. Climatic hazard: (High / low temperature / pressure) light, liquid/water (fresh / polluted), dust, and water vapour, R.H.

c. Biological: (Microorganisms, fungi, moulds, bacteria, beetles, moths, flies, ants, termites, mites, rodents (rats and mice), birds.

5.2.2 Contamination by other goods:

- By materials of adjacent packs
- By leaking contents of adjacent packs
- Radioactivity.

6. CONCLUSION

Knowledge of the functions of packaging and the environments where it has to perform will lead to the optimization of package design and the development of real, cost-effective packaging.

Reference:

Anon. 1988. Glossary of Packaging Terms, The Packaging Institute International, Stamford, Connecticut, USA.

Jelen, P. 1985. Food packaging technology. In: *Introduction to Food Processing,* Reston Publishing, Reston, VA, pp. 249–266.

Robertson, G. L. 1992. Food Packaging — Principles and Practice. Marcel Dekker, New York.

Smith, J. P., Zagory, D., Ramaswami, H. S. 2004. Packaging of Fruits and Vegetables. In: *Processing Fruits Science and Technology*, Second Edition. CRC Press. pp. 373 – 413.

Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 07: Metal Packaging Materials

1 INTRODUCTION:

The commercial packaging of foods in metal containers began in the early 19th century, following on from the discovery in the 1790s by the French confectioner Nicolas Appert of a method of conserving all kinds of food substances in containers, a method to which the term canning is now applied indiscriminately, whether the container is made from tinplate, aluminum, glass or plastics. The earliest can makers were tin-smiths who turned out tin plate containers with skill and imagination, in a variety of sizes and shapes. Both ends were soldered to the body, with a hole about 25mm in diameter at the top. After can was filled through this hole a metal disc was soldered into place. Mechanization of the can making process was made possible by the development of a method called double seeming, to attach ends to the soldered can body. Even though many of the fundamental manufacturing processes, such as double seaming and body forming were developed in the late 19th century, the evolution of can making continues. Related technologies such as metallurgy and food engineering are also advancing, creating new applications for the metal packaging materials. Of the total estimated world market of metal cans about 78% is accounted for drink cans and about 18% for processed food cans. The remainder are aerosol and general line cans. Drink cans may be divided into those for non-carbonated drinks (liquid coffee, tea, sports drinks etc.) and carbonated beverages (soft drinks and beer), many of which pass through a pasteurisation process.

2 CONTAINER PERFORMANCE REQUIREMENTS

Metal packages for food products must perform the following basic functions if the contents are to be delivered to the ultimate consumer in a safe and wholesome manner:

1. Preserve and protect the product
2. Resist chemical actions of product
3. Withstand the handling and processing conditions
4. Withstand the external environment conditions

5. Have the correct dimensions and the ability to be practically interchangeable with similar products from other supply sources (when necessary)
6. Have the required shelf display properties at the point of sale
7. Provide easy opening and simple/safe product removal
8. Should be constructed from recyclable raw materials.

In addition, these functions must continue to be performed satisfactorily until well after the end of the stated shelf life period. Most filled food and drink containers for ambient shelf storage are subjected to some form of heat process to increase the shelf life of the product. The heat process cycles used to achieve this are particularly severe and the containers must be designed so as to withstand these conditions of temperature and pressure cycles in a steam or water atmosphere. After heat processing, when the can temperature has returned to ambient, there will normally be a negative pressure in the can, i.e. a vacuum. Under these conditions, the food product itself does not provide any strength to the can to resist external loads.

In the case of carbonated beverage cans, which form the bulk of drink cans filled, once the container is closed, the carbonation pressure continues to provide significant physical support to the container until the moment of opening. In the case of still liquids, such as juices, nitrogen gas may be used to provide the necessary internal pressure for rigidity and compression strength.

3. MERITS AND DEMERITS OF METAL PACKAGING MATERIALS

Metal cans are impermeable to moisture, gases and light. They are produced from readily available and highly recyclable materials. Metal cans are compatible with many products and offer high stacking strength, thermal stability and a good surface for decoration, printing and coating. They have potential for high-speed manufacturing and filling. Many designs today offer easy opening ends that do not require the tools to get the contents. Two-piece design of cans deletes the chances of leaking of its contents as there are no side and bottom seams.

But, the cost of setting up of a production line for cans is high. Food processors also need a variety of sizes for different products harvested in different seasons enhancing the cost further to achieve this diversity.

4. C O N T A I N E R D E S I G N S

Regardless of the particular can-forming process used, the shapes of metal containers are very relevant to their cost, physical performance and compatibility with the filled product. For most metal food and drink containers the cost of the metal itself is 50–70% of the total container cost. The amount of metal in any particular container is the most significant cost item, and this is related to the metal thickness, temper and its surface area. In can design, metal thickness is determined by the need for physical performance in handling, processing and storage of the filled container. Surface area is determined by the volume contents and the shape of the container. For ease of manufacture and handling, most food and drink cans have a circular cross section. But, for different physical performance, cost and product uses, cans may vary from shallow to tall.

4.1 Can Configurations

The three basic types of cans are: three-piece cans, two-piece drawn and ironed cans and two-piece drawn and redrawn cans.

4.1.1 Three-piece Can

As the name suggests, it is made in three pieces: a body and two ends. The manufacture of three-piece cans involves the cutting of metal sheet into can-width strips on a machine called slitter. The slit strips are cut into body blanks and fed into a body maker, the first machine in an automatic can line. In the body maker, the body blanks are rolled, the corners are notched to remove the extra thickness of metal, and the side seam is curled into the ends and passed on to side seamers. Within three-piece category cans, there are three further classifications determined by the method used to join the side seam of the body cylinder. The methods are soldering, welding and cementing.

4.1.1.1 Soldered seams: For soldered cans, the edges of the blanks are bent, brushed with flux, passed over a gas flame and joined in a lap and lock seam while moving over a solder application seam, another burner smoothens the seam and wiper removes excess solder. The soldering seam is then treated with a lacquer. The body blank is flanged to receive the can bottom which is double seamed. The top of the can is usually applied after a filling operation. In the final step a spray coating is applied to the can interior, cured and tested for leaks.

4.1.1.2 Welded seams: The welded side seams are very strong and require a much narrower undecorated strip than that needed for soldering. In welding, the side seam is an overlap of the curled plate, which is subjected to a high-amperage electric current in a resistance welding process. The resulting exposed edge inside the can is coated in a striping operation using powder coating which is cured by infra-red or high-frequency induction heating.

4.1.1.3 Cemented seams: The cemented side seams permit all-round lithography with no base strip required at the solder point. The body former curves the sheet to form a cylinder and overlaps the edges. Cemented seams are produced by passing the body blank edges over an open flame and applying special cement with wheel. Chilling rolls then solidify the cement and trimming knives remove cement between adjacent body blanks. The exposed edges are coated with lacquer. A thorough test is to be followed before the cemented side seams are used for cans under pressure.

4.1.2 Two-piece drawn and ironed cans:

These cans were developed in 1960's. This method of can manufacturing eradicates the side seam and separate bottom. The two-piece can body has an integral side and bottom and is made in a process that thins the sidewall while maintaining the thickness of the bottom. The widest use of these is in the beer and soft drink markets. To make a D&I can, a disc of metal sheet is formed into a shallow cup with a die. The cup is then pushed through several dies, each slightly smaller than the previous one, so that the sidewalls are stretched and thinned. Since the cup is held on the original punch, the inside dimension remains constant during this process. Starting with the plate thickness of 292 µm, the sidewalls are reduced to 97µm, while the bottom thickness remains same. This process of pushing the cup through progressively smaller die rings is termed as the ironing of sidewall. As the walls are ironed, the bottom is domed to provide strength and stability. The maximum ratio of height to diameter is 2:1. The can bodies are then cut to length and cleaned in preparation for coating inside and out. The can is then necked at the top and flanged to receive a top. The necking in produced a can with a narrower top thereby saving material. After leak test the cans are prepared for filling.

4.1.3 Two-piece drawn and redrawn cans:

In D&R method the cup is pushed through each-succeeding die. The gauge of the bottom and the sidewall of container remains essentially the same as the starting gauge but the inner dimensions of the cup becomes smaller. One or more punching operation may be used depending upon the depth of the can to be produced. These subsequent drawings or "redrawing" can be done once or twice. After drawing and redrawing, the can body is necked in at the bottom to permit easy stacking and incrusted in narrow bands to provide extra side wall strength for vacuum packaging.

While coatings will not adhere to D&I cans during production and must be applied to after the can body is formed, they may be applied to the flat can stock in the D&R process prior to drawing. A typical can, eg. Fruits & vegetable would start with steel having 184.6 µm gauge and end up with a side wall of 179.5 µm. The maximum ratio of height to diameter is about 1.5:1.

4.2 Non-round Cross Section Containers

Non-round cross section containers are typically used for fish and meats that are heat processed, as well as for products such as edible oils, which do not need to be processed. Open trays of round or non-round section are used for baked food products or with lids as take away food containers.

5. CLOSURE SYSTEMS

Closure systems for food and drink cans are by necessity very different in their mode of operation. Food cans require an aperture with either total or virtually full internal diameter of the container through which to remove the product, whereas the aperture for drink cans is designed to suit the method of consumption. Historically, food cans have required a can-opening tool to remove the plain lid. In more recent years, full aperture easy-open ends have been developed based on designs originally used for drink products. Whether plain or easy-open ends are used, the end panel for virtually all food and drink cans is mechanically seamed-on to produce a double seam that is capable of withstanding all the heat-processing cycles in use.

5.1 Easy-open Ends:

Easy open ends could be a stay-on tab found on the beverage cans or a ring-pull ends which is found on pet food or heat sealable flexible membrane. The bevcan end is a tab less design with a raised conical profile and a central 19.1 mm pour spout. It is opened by pressing downward a circular panel which pops inward without leaving any hazardous edges. The recent advancement in the easy open membrane lids, which simply peel away and often are teamed with a friction fit plastic lid for protection in the distribution chain.

5.2 Threaded Closures:

Screw-top cans are containers with threaded closures. A wide variety of threaded spouts and applicators have been available. A closure could be specified by the size of the outside of the threads on the container. There are no industry standards for threaded profiles, the caps from one manufacturer may not fit containers from another. Caps and containers must be purchased at the same time from the same source to ensure a good fit.

5.3 Slip Cover Closures:

Shallow cans with slip covers are made by blanking and drawing metal plate to the proper size and curling the edge. This category of closures includes simple reclosure type; firm reclosure type or friction closure type. There are still markets for highly decorated metal boxes, although the uses of these slip cover containers have greatly decreased due to the labour intensive cost of making these cans has soared and other types of mass-produced containers have developed.

6. CAN MATERIALS

Cans are made from either aluminium or steel. The steel can be chrome plated or laminated. The commonly called tin can is a misnomer. The sheet of these cans have only a thin coating of tin either on one side or on both sides.

6.1 Aluminium:

The composition of aluminium alloys for rigid containers varies according to the intended use, with up to 5 % magnesium, 1.5 % manganese and traces of iron, silicon, zinc, copper and titanium. As forming characteristics and resistance to corrosion improve, yield strength usually goes down and heavier gauges are required to have the same strength.

Aluminium alloys or tempers commonly used are: a fully hard material such as 3004 H-19 and a softer one such as 5052 H-34. Where 3004 or 5052 denote the aluminium alloy sheet and H-19, H-34 denotes the tempering. The hard tempered alloy H-19 allows the very thin gauges which make the container bodies economical. Shallow-drawn parts, such as can ends, use alloys with less ductility and medium temper of H-34 for average conditions.

6.2 Steel:

Ferrous metal used in fabricating cans include base steel or "black plate", tin-free steel which has thin coat of electroplated chromium and tin plate which has a thin coat of electroplated Grade-A commercially pure tin. Steel that has completed the tempering process is called 'black-plate'. Traditionally, it is used for spice containers and a number of industrial-packaging applications. It also forms the base of tin plate and electroplated chromium steel. Ferrous materials are used for ends and bodies in both two-piece and three-piece technologies.

An electrochemical passivation treatment, usually with sodium dichromate, stabilizes the surface and adds a thin film of metallic chrome to enhance the corrosion protection. Although the tin coating is only about 0.3 µm thick, it resists the corrosion not only by the protective layer of tin on its surface but also a cathodic reaction that minimizes oxidation at any pin holes or base spots. Tin coating also prevents the iron from being dissolved in certain beverages and food products.

6.3 Can Linings and Lacquers:

Metals used in can packaging often do not provide corrosion resistance, surface abrasion resistance and product-container compatibility. As a result, a variety of lacquers and lining materials have been developed to protect outer and inner surfaces and are also known as enamels. These are usually applied by roller or spray to flat sheet or coil and cured by oven or ultraviolet-light curing process. The enamels protect the surface of can by serving as a barrier to gases, liquid and ions. Enamels generally are specified in terms of mg/in^2.

7. APPLICATIONS

There are three major markets for metal cans; beverages like beer and soft drinks; food and non-food, comprising such products as paints, chemicals, etc.

7.1 Beverage Cans:

The beverage can market has been the fastest growing segment of the industry. Two-piece cans are predominant in the beverages as they are well suited to long production runs with infrequent label changes. Majority of market uses aluminium in manufacture of two-piece beverage cans, though in some European countries steel is still in use.

Aluminium cans manufactured by D&I process are extensively used for pasteurized beverages such as beer and soft drinks. Beer contains carbonic gas and when it is pasteurized after sealing the internal pressure may rise to ten times the pressure in food cans. The beer can therefore has to be designed to contain pressures up to 7 kg/cm^2. Due to their lighter weight per cm^2, aluminium cans reduce transportation cost. Remelting of aluminium cans to make aluminium slabs requires only five percent of the energy used to make virgin metal from bauxite ore. Thus the economics of recycling of aluminium cans have become quite favourable. It helps control the costs of materials and clearly favours the aluminium beverage package.

7.2 Food cans:

Food cans are manufactured in a greater variety of sizes and shapes than beverage cans and are generally produced in shorter production runs with frequent change over between sizes and labels. Both three piece welded cans and two piece steel cans are commonly used. The welding process produces a high-integrity three-piece can that is lead free. Welding technology provides the flexibility to run various specifications. Two-piece cans, which eliminate the side seam, are well suited to short sizes but tend to use more metal in taller sizes.

Shallow drawn aluminium cans are used extensively for processed foods such as vegetables, certain meat products, fillets of fish and various sauces. Deeper cans drawn and ironed are used for vegetables in brine or sauces, soups. Crabs and lobsters packed in aluminium cans do not require parchment lining to avoid discoloration of the product. Tomato sauce and mustard sauce are corrosive products, so the foods prepared in them, if to be packed in aluminium can should not exceed total 3% acidity, expressed as acetic acid. Other fresh foods packed in D&R cans include meat, boned chicken, etc.

A few products like roasted coffee, milk powder are canned in dry state. Heat processing and canning in such cases prevents loss of volatile, and moisture pick-up by hygroscopic powders, etc. Dry packed foods may be hermetically packed under vacuum or packed in an inert gas like nitrogen. Aluminium cans have also been developed for packaging of high sugar products. The shelf life of various food products packed in lacquered cans have been reported to vary from about one year for beer to more than seven years for carrots and peas.

8. Conclusion

Competition among metal, glass and plastic packaging products will continue to be a major force in overall container industry. Metal cans have been able to maintain a large share of the market owing to technological advances permitting efficient high speed operation and conservation of materials and energy.

Recent innovations in the design and manufacture of metal packaging for food products include: large opening stay-on-tab ends for drink cans, widgets to provide a foam head to beer and chilled coffee, self-heating and self-chilling drink cans, full aperture food can ends which are easier to open, square section processed food cans for more efficient shelf storage, peelable membrane ends for processed food cans, two-piece draw and wall iron as well as two-piece draw redraw cans made from steel with plastic extrusion coatings.

The prime purpose of packaging in a metal container is the physical and chemical protection of the product to be marketed. A perfect lacquered can is an ideal container for food with respect to all these. This will ensure that metals will continue to have an extremely important part to play in the cost efficient packaging of foods for short or long term ambient storage conditions. The inherent strength of metal containers and the fact that they are impervious to light contribute to a high level of protection for the contained product over long shelf life periods.

Reference:

Hanlon JF, Kelsey RJ, Forcino HE. 1998. *Handbook of Package Engineering.* Technomic Publishing Co. INe. Lancaster, Basal

Page B, Edwards M, May N. 2003. Metal Cans. *In*: *Food Packaging Technology (Eds: Coles R, Mcdowell D and Kirwan MJ),* Blackwell Publishing, Oxford, UK

Robertson GL. 1993. *Food Packaging Principles and Practice*. Marcel Dekker INe. New York

Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 05: Paper and Paper based Packaging Materials

1. INTRODUCTION:

Paper and paper based materials are the oldest and most versatile packaging materials available on the market today. They are ironic material: they can be permanent or temporary, gentle or strong, cheap or expensive, in plenty or limited. They can be preserved in a museum or thrown away. They are made and used by the millions of tonnes or may be so rare that only a few tonnes of hand-made paper are produced in a year. Paper and board, alone or associated with other materials, has been used in food packaging or food contact for many years. A particular effort for alteration to the environmental concerns and the users' needs was made at the same time as the use of paper and board was increasing. Paper and board is indeed an essential part of our lives and satisfies many human needs. We use it to store and communicate information (newspapers, books, documents and writing paper), for cultural and artistic purposes, to transport and protect goods (packaging, sacks, liquid packaging board), and for personal hygiene (tissues, napkins, nappies, etc.).

2. WHAT IS PAPER?

Paper is made from cellulose fibres, which are obtained from trees, recovered papers and annual plant fibres like cereal straws. Today about 97 per cent of the world's paper and board is made from wood-pulp, and about 85 per cent of the wood-pulp used is from spruces, firs and pines. Nowadays, hardwoods such as birch, aspen and other hardwoods occurring in temperate climates are used as an ideal raw material for processing into fluting for corrugated cases as well as printing and writing papers, while eucalyptus, originally occurring in Australia and New Zealand, has been successfully cultivated in other warm climates as raw material for high-quality pulp suitable for a wide range of papers. Nonetheless, softwoods offer longer fibres (average 3 mm compared with 1 mm for hardwoods) and continue to be used for papers requiring the highest strength characteristics.

Chemically pure cellulose consists of long, ribbon-like molecules made up of smaller glucose units. The glucose units are formed from atoms of carbon, hydrogen and oxygen. These molecules are held together side-by-side by hydrogen bonds to form “sheets”, which in turn are piled together in tightly packed layers to form “microfibrils”. The microfibrils group themselves in bundles, and groups of these bundles form the paper fibre. Paper is called board when it is heavier than 224 g/m^2. The demands placed on the form of paper and board vary widely with the intended use but some are common to all grades, i.e., the paper must be strong enough to fulfil its technical function and also be able to be printed upon in a way that makes it striking to the customer. Paper and board can be used in contact with food in many different ways, either directly or indirectly, and either singly or laminated with other materials such as plastic or metal foil. In the latter case, so-called "functional barriers" are aimed at suppressing any substance transfer between food and the base paper material.

3. MANUFACTURE OF PAPER AND BOARD

Paper and board has a long history, beginning with the ancient Chinese and continuing to the present day. While hand-made methods dominated for thousands of years, paper production became industrialised during the 19th century. The first machine to manufacture paper continuously was invented by the Frenchman Louis-Nicolas Robert in 1799. Originally intended purely for writing and printing purposes, a wide variety of paper grades and uses are now available to the consumer. Each paper or board grade is produced on equipment tailored for this particular grade and mill. Production processes are optimised for each grade. There are many variables: raw material composition (mixture of chemical softwood and hardwood pulp, mechanical pulp, recovered paper, fillers, pigments, additives, etc.), machine size (width, speed), type of production equipment, and automation level.

Paper and board production involves two steps. First, the fibres need to be produced. This is done in a pulp mill where pulp is produced using chemical or/and mechanical processes. Pulp production can be integrated with paper production, or the pulp can be produced in a separate pulp mill. The paper itself is then produced on a paper machine from a mixture of fibres, chemicals and additives.

All paper and board machines are based on a similar basic process. There are seven distinct sections: head box, wire section (wet end), press section, drier section, size press, calender and reel-up.

3.1 The preparation and the cleansing of the pulp:

This untwists the fibers. Beating is a mechanical treatment intended for swelling, fibrillating and shortening the fibres. The result is a better sheet formation and the development of paper's mechanical properties.

3.2 Before sending to the paper machine:

The pulp is initially purified, diluted and air bubbles are eliminated. Sometimes pulp is also bleached if made from recycled paper.

3.3 The wet-end part:

Raw material fibres and chemicals (and 99% of the water) are pumped to the head box, which feeds the stock evenly onto the wire section. This is a woven plastic mesh conveyor belt that can be 35 metres long and up to 10 metres wide. As the paper stock flows from the head box onto the wire, the water drains away through the mesh leaving small fibres as a mat on top of the mesh. The paper machine can travel at speeds of up to 2000 m/minute and by the time the paper stock has travelled half way down the wire, a high percentage of water has drained away. By the time the thin mat of fibres has reached the end of the wire section, it has become a sheet of paper, although very moist and of little strength.

3.4 The press section:

This section consists of a number of sets of felts and heavy cylinders through which the moist paper web passes. More water is pressed out to felts and drawn away by suction. Pressure binds the fibres together and consolidates the web.

3.5 Dryer:

This section consists of a large number of steam-heated drying cylinders which have a temperature of slightly over 100°C. Synthetic drier fabrics carry the paper web round the cylinders until the paper is dry.

3.6 Coating/Calendering:

In many applications, the surface of the sheet needs improvement in order that any characters imposed on the sheet be legible. This is achieved by calendering, a process which reorients the surface fibres in the base sheet of paper (or the coating applied to the surface) by the use of pressure. This serves to smooth the surface, control surface texture and develop a glossy finish. Such papers are known as machine finished.

3.7 Finishing:

At the end of the drying process, the sheet is smoothed using an "ironing" method, which consists of hot polished iron rollers mounted in pairs with synthetic material rollers, one above the other. This also helps to consolidate, polish and glaze the surface of the paper: the characteristics of the surface of the sheet are improved.

3.8 Shipping:

Still travelling at very high speeds, the paper comes off the machine ready for reeling up into large reels (called parent reels), which can be cut or slit into smaller ones, according to customer requirements. These large reels are produced and changed without any interruption of the production process.

3.9 Quality control:

Sensors and computers verify parameters such as the production speed, the pressure, and the resistance at every step of the process to ensure that the paper or board is of a consistently high quality. Moreover, for food contact applications, microbiological, chemical and organoleptic controls have to be carried out.

A board machine often has several formation devices in the wet end producing a multiply sheet, combined on the forming table and press. Basis weight of the boards can be as high as 500 g/m^2, whereas the printing and writing papers are usually 40-120 g/m^2.

Paper and board machines are each different – the size of the production capacity and technology varies. Each one is tailored to the specification of the paper mill.

4. RECOVERED PAPER AND BOARD

Recovered or recycled paper is an important raw material in terms of volume and utilisation for the paper industry in many countries. The recycling of paper is an example of sustainable use of resources. Although recycling is both economically and ecologically sound, recovered paper cannot be used in all paper grades. The final production process for recycled paper is the same as the process for paper made from primary fibres. The main difference is that recovered paper fibres have already been used, so that non-fibre material, will have to be removed.

The major steps in the recycling process are:

1. **Collection and Transportation:** Recovered paper is sorted, graded, formed into bales and delivered to a paper mill.
2. **Repulping and Screening:** After reaching the paper mill, recovered paper is mixed with water and chemicals, which separates the paper into individual fibres.
3. **Cleaning:** The pulp mix is diluted with water and passes through a system of centrifugal cleaning equipment and screens. The pulp is filtered and screened through a number of cycles to make it more appropriate for papermaking. This is done to remove large contaminants like wood, plastic, stones, glass and paper clips, along with small contaminants like string, glue and other sticky materials. Pulp is cleaned in a large spinning cylinder and the heavy contaminants move to the outside of the cylinder and are removed.
4. **De-inking:** For certain uses (e.g. for the production of graphic, sanitary and domestic papers but rarely for manufacture of packaging materials) and for certain types of recovered papers (e.g. newspapers and magazines), the fibres have to be de-inked. The deinking process can be carried out by flotation, with or without washing, with or without kneading, with or without bleaching.

The finished recycled pulp is now ready to be made into paper and is either sent on a mile-long conveyor to the mill for papermaking, or is formed into sheets of pulp for shipment and sale. Depending on the grade of paper being produced, quantities of virgin pulp from sustainable sources may be added. Some papers, such as newsprint and corrugated materials, can be made from almost 100% recycled paper. Once the paper is used, it can be recycled and the process starts again. Individual fibres will gradually be degraded in the process so a continuous addition of new fibres is necessary to sustain the recycling cycle.

There are different grades of recovered paper and board to satisfy the needs of different producers according to specifications. More than 50 grades of recovered paper and board are defined in the European List of Standard Grades of Recovered Paper and Boards.

They can be described as follows:

1. **Low grades** (mixed papers, old corrugated containers, board, etc.): These constitute the main part of the recovered paper consumed. These are used to produce secondary packaging papers and boards, and are not intended to be in direct contact with food
2. **De-inking grades** (newspapers and magazines, graphic papers, etc.): They are usually also considered as low grades because they need extensive recycling treatments. These are for graphic and sanitary papers.
3. **High grades** (scraps, sheets, print offcuts, etc.): They require little or no cleaning. They can be used for the production of any paper product as pulp substitute. They may therefore be suitable for food contact packaging.

5.0 TYPES OF PAPER

Paper is divided into two broad categories: fine papers, generally made of bleached pulp, and typically used for writing paper, bond, ledger, book and cover papers, and coarse papers, generally made of unbleached kraft softwood pulps and used for packaging.

5.1 Kraft Paper

This is typically a coarse paper with exceptional strength, often made on a fourdrinier machine and then either machine-glazed on a Yankee dryer or machine-finished on a calender. It is sometimes made with no calendering so that when it is converted into bags, the rough surface will prevent them from sliding over one another when stacked on pallets.

5.2 Bleached Paper

These are manufactured from pulps which are relatively white, bright and soft and receptive to the special chemicals necessary to develop many functional properties. They are generally more expensive and weaker than unbleached papers. Their aesthetic appeal is frequently improved by clay coating on one or both sides.

5.3 Greaseproof Paper

This is a translucent, machine-finished paper which has been hydrated to give oil and grease resistance. Prolonged beating or mechanical refining is used to fibrillate and break the cellulose fibres which absorb so much water that they become superficially gelatinized and sticky. This physical phenomenon is called hydration and results in consolidation of the web in the paper machine with many of the interstitial spaces filled in. The satisfactory performance of greaseproof papers depends on the extent to which the pores have been closed. Provided that there are few interconnecting pores between the fibres, the passage of liquids is difficult. However, they are not strictly greaseproof since oils and fats will penetrate them after a sufficient interval of time. Despite this, they are often used for packaging butter and similar fatty foods since they resist the penetration of fat for a reasonable period.

5.4 Glassine Paper

Glassine paper derives its name from its glassy, smooth surface, high density and transparency. It is produced by further treating greaseproof paper in a supercalender where is it carefully dampened with water and run through a set of steam-heated rollers. This results in such intimate inter-fibre hydrogen bonding that the refractive index of the glassine paper approaches the 1.02 value of amorphous cellulose, indicating that very few pores or other fibre/air interfaces exist for scattering light or allowing liquid penetration. The transparency can vary widely depending on the degree of hydration of the pulp and the basis weight of the paper. It is frequently plasticized to increase its toughness.

5.5 Vegetable Parchment

Vegetable parchment takes its name from its physical similarity to animal parchment which is made from animal skins. The process for producing parchment paper was developed in the 1850s, and involves passing a web of high-quality, unsized chemical pulp through a bath of concentrated sulphuric acid. The cellulosic fibres swell and partially dissolve, filling the spaces between the fibres and resulting in extensive hydrogen bonding. Thorough washing in water, followed by drying on conventional papermaking dryers, causes reprecipitation and consolidation of the network, resulting in a paper that is stronger wet than dry (it has excellent wet strength, even in boiling water), free of lint, odour and taste, and resistant to grease and oils. Unless specially coated or of a heavy weight, it is not a good barrier for gases.

Because of its grease resistance and wet strength, it strips away easily from food material without defibering, thus finding use as an inter-leaver between slices of food such as meat or pastry. Labels and inserts in products with high oil or grease content are frequently made from parchment. It can be treated with mold inhibitors and used to wrap foods such as cheese.

5.6 Waxed Paper

Waxed papers provide a barrier against penetration of liquids and vapours. Many base papers are suitable for waxing, including greaseproof and glassine papers. The major types are wet-waxed, dry-waxed and wax-laminated. Wax-sized papers, in which the wax is added at the beater during the papermaking process, have the least amount of wax and therefore give the least amount of protection.

Wet-waxed papers have a continuous surface film on one or both sides, achieved by shock-chilling the waxed web immediately after application of the wax. This also imparts a high degree of gloss on the coated surface. Dry-waxed papers are produced using heated rolls and do not have a continuous film on the surfaces. Consequently, exposed fibres act as wicks and transport moisture into the paper. Wax-laminated papers are bonded with a continuous film of wax which acts as an adhesive. The primary purpose of the wax is to provide a moisture barrier and a heat sealable laminant. Often special resins or plastic polymers are added to the wax to improve adhesion and low temperature performance, and to prevent cracking as a result of folding and bending of the paper.

6. FOOD PACKAGING APPLICATIONS OF PAPER & BOARDS

Paper and board comes in a variety of forms for applications:

1. **Paper packaging:** Natural or bleached, rubbed, coated or associated with other materials, paper can be found in the shape of bags e.g. for fruits and vegetables, vegetable parchment paper.

2. **Folding box board:** It is often referred to as carton board, it may be single or multi-ply, wood coloured or grey, coated or non-coated, and it can present various properties like barrier to grease, humidity, gas and it can be found in the shape of pastry boxes or container. It is mainly used in cartons for consumer products such as frozen food and for liquid containers.
3. **Corrugated board:** It is brown and white, of low grammage or high density, resistant to bursting, to humidity or to compression, it can be found in different shapes such as showcases for use in stores, or small boxes for mass-market products. Corrugated cases constitute the highest volume of paper and board for food contact applications.

For food contact applications, the package has to be strong enough to protect the food. It is generally printed to ensure its attractiveness to the customer because it is part of the food delivery structure. To a limited extent, some barrier properties are expected, to protect the food against degradation by the external environment. Specific barrier properties may be obtained with dedicated chemical treatments or through lamination with other materials such as metal or plastic.

There has been a significant increase in the use of paper and paper based packaging in the past 50 years for many reasons.

1. It is robust and flexible – corrugated board can be used to protect delicate porcelain or large electrical items, but also delicate fruits and vegetables.
2. It is practical – cartons can be delivered flat to the packager, reducing space and transport costs.
3. It can be easily recycled.
4. It is made from renewable materials, recovered paper and wood pulp.

7. Conclusion

Paper is a very versatile material. It is produced from cellulosic, naturally renewable fibres. It is therefore considered as an environmentally friendly material, being easily recycled, composted or incinerated after use. It may be used in food packaging applications within a wide range of grammages, being designed as wrapping paper, folding box board or corrugated board, for direct or indirect contact, i.e. as primary, secondary or tertiary packaging. Other paper grades, such as tissue paper, may be used in occasional contact with foodstuffs.

When paper and paper based products are intended, or likely, to come into contact with food, manufacturers follow relevant and acknowledged regulations and guidelines to design manufacturing processes and recipes, and ensure consumer safety.

Reference:

Paine, F.A. and Paine, H.Y. 1992. *A Hand Book of Food Packaging*. Blackie Academic & Professional.

Robertson GL. 1993. *Food Packaging Principles and Practice*. Marcel Dekker INC. New York

Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY

Module – 12: Permeability of multilayer materials and means to measure permeability

1. INTRODUCTION:

The transport behaviour of substances in polymeric materials has become progressively more important in recent years with the widespread use of plastic films and rigid plastics for food packaging. The selection of plastic materials for food packaging applications with strict design specifications relating to their transport behaviour requires knowledge and appreciation of the many features which affect those phenomena.

There are many examples of foods packaged with an obvious lack of proper consideration of the effects of the environment on properties, or of limitations forced on performance due to unfavourable transport characteristics. The plasticization of polymers by sorption of ambient vapours or liquids causing subsequent decrease in mechanical properties and the loss of beverage components are few of many examples which may be cited. An objective of research in this field is to establish mechanisms and expressions relating solubility and transport with the molecular properties and characteristics of the components.

2. PERMEATION

Permeation through a film is a three-part process:

1. Solution/absorption of penetrant into the polymer surface
2. Migration/diffusion of penetrant through polymer(s)
3. Emergence/desorption of penetrant from opposite surface of polymer.

Absorption and desorption depend on the solubility of the permeant, and solubility is greatest when penetrant and material have similar properties.

Other relevant theory comprises:

Graham's Law (1833) states that the velocity of diffusion of a gas is inversely proportional to the square root of the density of material.

Fick (1855) stated that the quantity of diffusing gas is proportional to concentration and time and inversely proportional to the thickness of the material through which it is diffusing.

Henry's Law (1803) states that amount of gas absorbed by a particular volume of a liquid at a specified temperature is directly proportionate to the partial pressure of the gas.

In practice, the film of packaging material may comprise more than a single polymer, and there may be discontinuities in coatings, pinholes in films, variations in molecular structure and degree of crystallinity. The penetrant molecular size, shape and degree of polarity and ambient conditions are relevant. These are all factors which affect diffusion and solubility, which in turn have a direct impact on permeability.

The permeability of plastic films to water vapour and common gases like oxygen, carbon dioxide and nitrogen has been measured by standardised test methods. Oxygen, can cause oxidative rancidity in oil or fat containing food products. Water vapour permeation into a product may cause a loss of texture, and the outflow of water vapour, from a product through the packaging may cause dehydration, textural changes and loss of weight. An example of the latter would be a plastic film-wrapped cakes or bread which would lose moisture in storage prior to sale, where a negotiation has to be made in balancing weight loss in storage with initial weight and the water vapour barrier protection provided by the plastic film. In this example, in addition to flavour retention and texture, the actual weight at the point of sale would also have to meet appropriate regulations.

The results of permeability tests give direction with respect to the choice of material(s) for the packaging of specific food products. Some other possible penetrants and the effect of the presence of polymer additives can lead to unexpected results. It is still necessary to carry out shelf life tests to establish performance of packaging material in practice with the food under consideration.

Under steady state conditions, a gas or vapour will diffuse through a polymer at a constant rate if a constant pressure difference is maintained across the film. The diffusive flux, J, of a permeant in a polymer can be defined as the amount passing through a plane surface of unit area normal to the direction of flow during unit time, i.e:

$$J = Q / A \times t$$

Where, Q is the total amount of permeant which has passed through area A during time t.

2.1 Desired Properties of a Good Barrier Material

To be a good all-round barrier material, the polymer must possess the following properties:

1. Some degree of polarity as found in nitrile, chloride, fluoride, acrylic or ester groups;
2. High chain stiffness;
3. Inertness to the permeant. Polymers containing polar groups, can absorb moisture from the atmosphere. This has the effect of swelling or plasticizing the polymer and reducing the barrier properties.
4. Close chain-to-chain packing ability got by molecular regularity, crystallinity or orientation. Linear polymers with a simple molecular structure lead to good chain packing and lower permeability than polymers in which the backbone has a bulky side groups leading to poor packing ability. The higher the degree of crystallinity, the lower the permeability, because crystalline regions are less permeable compared with the amorphous regions. Orientation of amorphous regions decreases permeation by about 10 to 15%, while in crystalline polymers reductions of over 50% can be observed.
5. Some bonding between chains. Cross-linking of polymers restricts their mobility and thus decreases permeability, due to the decrease in the diffusion coefficient. For example, in the case of polyethylene, one cross-link about every thirty monomer units leads to a one half the reduction of the diffusion coefficient. The effect of cross-linking is more prominent for large molecular sized permeants.

3. PERMEABILITY OF MULTI-LAYER MATERIALS

Multi-layer materials can be considered as a number of membranes in series. Consider the case of three layers in series. The total thickness XT = X1 + X2 + X3. Assuming steady state flux, the rate of permeation through each layer must be constant, i.e.

$$QT = Q1 = Q2 = Q3$$

Likewise, the areas will also be constant so that

$$AT = A1 = A2 = A3$$

Therefore, by substituting in equation:

$$\frac{Q}{t} = \frac{P}{X} A \ (\Delta p)$$

then

$$\frac{Q_T}{t} = \frac{P_1}{X_1} A_1 (p_1 - p_2) = \frac{P_2}{X_2} A_2 (p_2 - p_3) = \frac{P_3}{X_3} A_3 (p_3 - p_4)$$

By rearranging above equation and writing it for the case of permeation through the multi-layer material:

$$\frac{Q_T \ X_T}{t \ A_T \ P_T} = (p_1 - p_4) = \Delta p_i$$

Now since,

(p1 - p4) = (p1 - p2) + (p2 - p3) + (p3 - p4)

Therefore

$$\frac{Q_T \ X_T}{t \ A_T \ P_T} = \frac{Q_T}{t \ A_T} \left[\frac{X_1}{P_1} + \frac{X_2}{P_2} + \frac{X_3}{P_3} \right]$$

and

$$\frac{X_T}{P_T} = \frac{X_1}{P_1} + \frac{X_2}{P_2} + \frac{X_3}{P_3}$$

or

$$P_T = \frac{X_T}{(X_1/P_1) + (X_2/P_2) + (X_3/P_3)}$$

Thus if the thicknesses and permeability coefficients are known for each layer, and provided that the permeability coefficients are independent of pressure, then above can be used to calculate the permeability coefficient for any multi-layer material. If they are not, then differing permeability coefficients will be obtained depending on the positioning of the layers.

The standard methods for gas permeability measurements through plastic materials specify dry gas. But, in practice the films are almost used in humid conditions, and for materials such as ethylene-vinyl alcohol copolymers, the oxygen permeability is dependent on the humidity. In such a case the above equation cannot be used directly since P2 (the permeability coefficient of the centre layer) will depend on the average partial pressure at the centre.

An equation for forecasting the average partial pressure at the centre of a multi-layer material containing a water sensitive centre layer can be derived as follows. Consider again the case of three layers in series, but this time assume that the oxygen permeability of the centre layer is moisture dependent and that the direction of water vapour flux is from the outside to inside.

Since the partial pressure of water vapour will not be constant across the multi-layer, the equation must be modified to include a term for the partial pressure difference and the thickness:

$$WVTR = \frac{Q}{A \times t} \Delta p$$

Now since the area A and time t will be the same for all three layers, the equilibrium WVTR between the outside and centre layers can be calculated as:

$$\frac{Q_1}{X_1}(p_1 - p_2) = \frac{Q_2}{X_2}(p_2 - p_3)$$

Similarly, the equilibrium WVTR between the centre and the inside layer is

$$\frac{Q_2}{X_2}(p_2 - p_3) = \frac{Q_3}{X_3}(p_3 - p_4)$$

The average partial pressure of the centre layer (p_c) will be:

$$p_c = \frac{p_2 + p_3}{2}$$

Simultaneous linear solution of equations for p_2 and p_3 and substitution in above equation:

$$p_c = \frac{p_1\left[\frac{X_2}{Q_2} + 2\frac{X_3}{Q_3}\right] + p_4\left[\frac{X_2}{Q_2} + 2\frac{X_1}{Q_1}\right]}{2\left[\frac{X_3}{Q_3} + \frac{X_2}{Q_2} + \frac{X_1}{Q_1}\right]}$$

= average partial pressure of the center layer.

By the data of pc, the permeability coefficient Pc of the centre layer can be determined at this partial pressure and equation for P_T can be used to calculate the overall permeability of the multi-layer material.

4 MEASUREMENT OF PERMEABILITY

4.1 Gas Permeability

There are many methods for measuring permeability; the some important methods will be considered here. For a complete understanding of the principles behind permeability measurements it is important that the meaning of two terms which are constantly used - total and partial pressure of gases in a mixture is clearly appreciated.

In constant volume, total pressure exerted by gases present is the sum of the partial pressures of each of the gases, a discovery made by John Dalton and known as Dalton's law. The partial pressure of any one of the constituent gases is the pressure which would result if that particular gas occupied the same volume by itself. That is, each gas in a gas mixture behaves independently of the other gases.

The permeation rate of a gas through a polymeric material is function of the partial pressure difference of that gas across the material and not of the total pressure difference between the two sides.

4.1.1. Pressure Increase Method

The ASTM standard method for measuring gas transmission rates and permeability of flat films is labelled as D 1434. It includes the manometric method which utilizes the Dow gas transmission cell. The film is backed with a filter paper and sealed with an O-ring. The pressure in the receiving compartment is measured with an open-ended mercury manometer. Detailed descriptions of the calibration and testing procedures are given in the ASTM method. The corresponding British Standard is BS 2782 Part 8 Method 821A.

On condition that the pressure on the high-pressure side remains much larger than on low-pressure side, the pressure difference remains constant and the permeability coefficient can be calculated as follows. The slope of the straight line portion of the plot of the pressure (in mm Hg) on the low-pressure side versus time (ΔpL / Δt) is determined and substituted into the following equation:

$$P = \frac{\Delta p_L}{\Delta t} \times \frac{V_L}{760} \times \frac{273}{T} \times \frac{X}{A}$$

Where V_L is the volume of the low-pressure side, X the thickness of the film, T the absolute temperature and A the film area.

4.1.2 Concentration Increase Method / Isostatic method

In this method a partial pressure difference through the film with respect to the test gas is created without change in total pressure, thus avoiding the need for rigid support of the film. A partial pressure difference is maintained by sweeping one side continuously with the test gas and keeping an inert gas on the other side into which the test gas diffuses. The concentration of the diffusing gas can be measured by chemical analysis, gas chromatography, thermal conductivity or special electrodes. As the method of measuring the concentration of the test gas can be specific to that gas, equipment can be developed in which the relative humidity of both the test and inert gases can be controlled. This is of main importance when measurements are carried out on films whose gas barrier properties are related to humidity or moisture.

Instrument in extensive commercial use for the estimation of oxygen permeability by the isostatic method is MoCon Ox-Tran (Modern Controls, Inc., Minneapolis, Minn., U.S.A.). An advantage of this instrument over the permeability cells is that the permeability of not only flat film but also containers, bottles, pouches, tubes, etc. can be measured, thus allowing the analysis of possible adverse effects of machine processing, printing and distribution. The use of this instrument is included in ASTM D 3985.

The Ox-Tran has a two-chamber measuring cell between which the test film is placed. Gas stream of known oxygen partial pressure is passed through one of the chambers; oxygen-free carrier gas is passed through the other chamber to a coulometric detector. A separate part of the instrument is fitted with two openings for the carrier gas over which containers can be fixed and sealed. A glass dome is located over this arrangement into which oxygen flows by means of a filling tube.

Modern Controls, Inc. has designed an instrument for the measurement of carbon dioxide permeability, it is known as the Permatran C, it is similar in construction to the Ox-Tran, but it uses a pressure-modulated infrared detector.

4.1.3. Volume Increase Method

In this method, the change in volume at constant pressure, because of permeation of gas through the film is measured. Variable volume permeation cells are often used for rapid estimation of relatively high steady-state permeation rates. Though, the volume increase method is simpler to implement but less sensitive than the pressure increase method, it is rarely used for high-pressure time lag measurements. Volumetric methods are used relatively infrequently compared with the use of the pressure increase or concentration increase methods.

4.1.4. Detector Film Method

A method for measuring permeability of films which requires little equipment and is both rapid and accurate, has been devised. The principle of the method is a plastic detector film saturated with a reagent which is sensitive to the measured gas. The film, having an absorption spectrum that changes with the gas or vapour when absorbed, is thus suitable for spectrophotometric measurements. The detector film is sealed between two pieces of test film in a simple cell so that the permeation rate of the penetrant gas or vapour can be readily measured. The detector film can measure much less than the minimum detectable quantity of oxygen determined by most other methods, and therefore allows the use of either smaller film samples or more rapid permeability determinations.

The oxygen detector consist a cast film of ethyl cellulose containing dimethylanthracene (DMA) and erythrosine. On absorbing blue light, the erythrosine can trigger oxygen dissolved in the ethyl cellulose to form singlet oxygen, a reactive form of oxygen. Singlet oxygen diffuses to a neighbouring DMA molecule and reacts with it. Thus, the disappearance of DMA is monitored in the UV, which is a measure of the oxygen consumed. As the ethyl cellulose detector is highly permeable to oxygen, it is capable of measuring very low rates of oxygen permeation.

4.2 Water Vapour Permeability

The standard method to determine water vapour transmission rates is to place a quantity of desiccant in an aluminium dish which is covered with a sheet of the material being tested and sealed in the same position with wax. The dish is then placed in a closely controlled atmosphere (Either 25±0.5°C & 75±2% RH for temperate conditions, or 38±0.5°C & 90±2% RH for tropical conditions) and the increase in weight noted as a function of time. If the points are plotted out they should fall more or less on a straight line since Dp is constant throughout the test. To convert WVTR into permeance (P/X), it should be divided by the driving force D_p.

This method has several disadvantages, including the length of time needed to make a determination of 2 and 14 days and the lower limit of the useful range of about 1g / m^2 /day for a typical packaging film. Another disadvantage is that, depending on the desiccant, D_p may not remain constant during the test period. When using anhydrous calcium chloride, the partial pressure of water vapour in the dish remains below 2% of the vapour pressure of water at the test temperature, while in case of silica gel the partial pressure of water adsorbed on it increases with coverage.

Newer type of film detector to measure rate of transmission of water vapour has also been developed. It comprises of transparent cellulose film which becomes bright blue when soaked in cobalt chloride solution and dried over calcium chloride but rapidly turns pink on exposure to high humidity. A humidity cabinet is used to provide the partial pressure gradient through the test film, which is sealed in the same way and in a cell of similar design to that used to measure oxygen permeability. The change in absorbance of the detector film is measured at 690 nm, and from this the quantity of water absorbed by the detector film, and hence WVTR of the test film, can be calculated. Good results have been obtained using this method.

4.3 Odour Permeability

The permeability of packaging materials to organic vapours is of substantial interest, predominantly where the contents of the package has to be protected against foreign odours or where there is a prerequisite that volatile flavouring materials are not lost from the package. The major off-flavours found in some food products may result from the packaging material itself, or may permeate via the packaging material from the outside environment. In other situation, foods may contain highly desirable but volatile flavour compounds whose loss from the packaged food will reduce its quality. In both situations, suitable tests must be undertaken to select materials which have the desired odour barrier properties.

There are no standard methods for the measurement of odour permeability. A number of methods have been described for vapour permeability measurements, although many of them are only suitable for use with saturated vapours only. A sophisticated instrument for studying the transport of aromas in polymer films has been described, which utilizes a mass spectrophotometer to detect the permeant. Temperatures up to 150°C and relative humidity from 0 to 100% can be used, making it possible to obtain data on the likely aroma, flavour and odour permeation of polymeric materials used in retortable pouches. A method for the quantitative evaluation of the aroma barrier of packaging materials has been developed which uses a permeation cell similar to that described for the concentration increase method. Nitrogen gas is bubbled through the liquid permeant and then passed with the permeant vapours through the cell. The concentrations of the permeating vapours and related humidity are monitored by gas chromatography.

A common, odour penetration test involves packaging various odoriferous substances in pouches made from the test materials. The pouches are then placed in clean glass bottles and sealed by crimping with aluminium foil. After storage for a fixed time, the bottles are sampled, either by gas chromatography and mass spectroscopy, or by sniffing using a sensory evaluation panel. By these results it is possible to rank a range of packaging materials according to their odour barrier properties.

5. Conclusion

There are various methods for determination of permeability of multilayer packaging materials. But, particular methods have often been lost and then rediscovered, their origins are forgotten. For example, the isostatic method has been reinvented many number of times, most recently in 1973, since Mitchell used it in 1831. Although the permeability of the permanent gases and of water vapour through many packaging materials are well known, there is a lack of data for the permeation of organic vapours. Much of the published work has involved the use of saturated solvent vapours, and although this data is useful in estimating how well a packaging material will withstand accidental high-level contamination, it is not generally valid to use such data to estimate permeation rates at the very much lower levels of vapour encountered in typical retailing situations. So there is a need of work to be done on measurement of permeability of organic vapours or odorous compounds in the actual retail situations.

Reference:

Ashley, R.J. 1985. Permeability and plastics packaging. In *Polymer Permeability*, J. Comyn (Ed.), Elsevier Applied Science Publishers Ltd., Essex, England

Brown, R.P. (Ed.). 1981. Permeability. In *Handbook of Plastics Test Methods*, 2nd Edn., George Godwin Ltd., Essex, England

Hernandez, R.J., Giacin, J.R. and Baner, A.L. 1989. The evaluation of the aroma barrier properties of polymer films. In *Plastic Film Technology*, K.M. Finlayson (Ed.), Technomic Publishing Co., Inc., Lancaster, Pennsylvania, USA

Paine, F.A. and Paine, H.Y. 1992. *A Hand Book of Food Packaging*. Blackie Academic & Professional, London, England

Pauly, S. 1989. Permeability and Diffusion Data. In *Polymer Handbook*, 3rd Edn., J. Brandrup and E.H. Immergut (Eds.), Wiley-Interscience, New York, USA

Robertson, G.L. 1993. *Food Packaging Principles and Practice*. Marcel Dekker INC. New York, USA

Paper No.: 12

Paper Title: Food packaging technology

Module – 10: Structure and properties of plastic polymers

10.1 Introduction

Different types of plastics are used for different purposes based on the characteristics of plastics and type of product. Some of the plastics are discussed hereunder that can be used in food packaging.

10.2 Polyethylene (PE)

PE is structurally the simplest plastic and is made by addition polymerization of ethylene gas in a high temperature and pressure reactor. Low, medium and high density resins are produced, depending on the conditions (temperature, pressure and catalyst) of polymerization. The processing conditions control the degree of branching in the polymer chain and therefore the density and other properties of films and other types of packaging. Polyethylenes are readily heat sealable. They can be made into strong, tough films, with good moisture and water vapour barrier properties. They are not high barrier to oils and fats or gases such as carbon dioxide and oxygen compared with other plastics, although barrier properties increase with density. The heat resistance is lower than that of other plastics used in packaging, with a melting point of around 120°C. The melting point increases as the density increases.

PE was first used as an insulator in the 1940s. PE films are highly susceptible of generating a static charge and need to have antistatic, slip agents and anti-blocking compounds added to the resin to assist film manufacturing, conversion and use. It is the most widely used and is cost effective.

10.2.1 Low density polyethylene (LDPE)

LDPE is easily extruded as a tube and blown to stretch it by a factor of three times the original area. It is commonly manufactured around 30 µm (20 or 25 µm is also possible) within a density range 0.910–0.925 g cm^{-3}.

The films can be coloured by blending pigment with the polymer prior to extrusion where extruders have more than one die. Two or more layers of the same material or coextruded films comprised of layers of different plastic materials can also be produced. With three extruders, it is possible to produce a film where, for example, a moisture-sensitive polymer, EVOH, is sandwiched between protective layers of PE. EVOH provides a gas and odour barrier, and the PE offers good heat-sealing properties and a substrate for printing.

PE film melts at relatively low temperatures and welds to itself when cut with a hot wire, or blade, to form effective seals. For packaging, it is possible to use either premade bags or form/fill/seal machines using flat film in reel form. A major use of white pigmented LDPE film is for making bags for holding frozen vegetables.

By laminating to other substrates with adhesives, or extruding the PE polymer onto another material, or web, it is possible to make strong sachets, pouches and bags with good seal integrity, as the PE flows to fill holes in the sealing area or around contaminants in the seal.

10.2.2 Linear low-density polyethylene (LLDPE)

LLDPE film has a density range similar to that of LDPE. It has short side chain branching and is superior to LDPE in most properties such as tensile and impact strength and also in puncture resistance. A major use has been the pillow pack for liquid milk and other liquid foods.

10.2.3 Medium-density polyethylene (MDPE)

MDPE film is mechanically stronger than LDPE and therefore used in more demanding situations. LDPE is coextruded with MDPE to combine the good sealability of LDPE with the toughness and puncture resistance of MDPE, e.g. for the inner extrusion coating of sachets for dehydrated soup mixes.

10.2.4 High-density polyethylene (HDPE)

HDPE is the toughest grade and is extruded in the thinnest gauges. This film is used for boil-in-the-bag applications. To improve heat sealability, HDPE can be coextruded with LDPE to achieve peelable seals where the polymer layers can be made to separate easily at the interface of the co-extrusion. HDPE film is available with either TD monoaxial orientation or biaxial orientation.

HDPE is injection moulded for closures, crates, pallets and drums, and rotationally moulded for intermediate bulk containers (IBCs). A major application of HDPE is for blow moulded milk containers with a capacity 0.5–3 l.

10.3 Polypropylene (PP)

PP is an addition polymer of propylene formed under heat and pressure using Zieger-Natta type catalysts to produce a linear polymer. PP is a harder and denser resin than PE and more transparent in its natural form. The usage of PP developed from the 1950s onwards. PP has the lowest density and highest melting point of all the high volume usage thermoplastics and has a relatively low cost. It can be processed in many ways and has many food packaging applications in both flexible film and rigid form.

The high melting point of PP (160°C) makes it suitable for applications where thermal resistance is needed, for example in hot filling and microwave packaging. PP may be extrusion laminated to PET or other high-temperature resistant films to produce heat-sealable webs which can withstand temperatures of up to 115–130°C, for sterilizing and use in retort pouches.

PP is chemically inert and resistant to most commonly found chemicals, both organic and inorganic. It is a barrier to water vapour and has oil and fat resistance.

Orientation increases the versatility of PP film. Oriented PP (OPP) or biaxially oriented PP (BOPP) film was the first plastic film to successfully replace regenerated cellulose film (RCF) in major packaging applications such as biscuit packing. Acrylic-coated OPP has good runnability, including heat sealing, on packing machines, designed for RCF, though improved temperature control of the heat-sealing equipment is required.

OPP film is produced in widths of up to 10 m or more to achieve cost-effective production. The limiting factors in production are either extrusion capacity for the thicker films or winding speed for the very thin films.

The range of food products packed in PP films include biscuits, crisps (chips) and snack foods, chocolate and sugar confectionery, ice cream and frozen food, tea and coffee. Metalized PP film can be used for snacks and crisps (chips) where either a higher barrier or longer shelf life is required.

Paperboard can be extrusion coated with PP for use as frozen or chilled food trays which can be heated in microwave and steam-heated ovens. Major food applications of PP are for injection-moulded pots and tubs for yoghurt, ice cream, butter and margarine. It is also blow-moulded for bottles and wide mouth jars. PP is widely used for the injection moulding of closures for bottles and jars.

It is used in thermoforming from PP sheet, as a monolayer, for many food products such as snacks, biscuits, cheese and sauces. In co-extrusions with PS, EVOH and PE it is used for the packaging of several types of food product including those packed aseptically, by hot filling, and in microwaveable and retortable packs.

10.4 Polyethylene terephthalate (PET or PETE)

When terephthalic acid reacts with ethylene glycol and polymerises, the result is PET.

PET can be made into film by blowing or casting. It can be blow moulded, injection moulded, foamed, extrusion coated on paperboard and extruded as sheet for thermoforming. PET can be made into a biaxially oriented range of clear polyester films produced on essentially the same type of extrusion and Stenter-orienting equipment as OPP. Film thicknesses range from thinner than 12 µm for most polyester films to around 200 µm for laminated composites.

PET melts at 260°C, and due to the manufacturing conditions does not shrink below 180°C. Therefore, PET is ideal for high-temperature applications using steam sterilisation, boil-in-the-bag and for cooking or reheating in microwave or conventional radiant heat ovens. The film is also flexible in extremes of cold (−100°C). Heat-sealable versions are available, and it can also be laminated to PE to give good heat-sealing properties. Coating with PVdC give a good gas barrier and heat-sealing capability.

PET is a medium oxygen barrier but becomes a high barrier to oxygen and water vapour when metalized with aluminium. This is used for vacuumised coffee and bag-in-box liquids, where it is laminated with EVA on both sides to produce highly effective seals. It is also used in snack food flexible packaging for products with a high fat content requiring barriers to oxygen and ultra violet (UV) light. Metalized PET, either as a strip or as a flexible laminate, is used as a susceptor in microwaveable packaging.

Reverse printed PET film is used as the external ply on FFS pouches where it provides a heat-resistant surface for contact with the heat-sealing bars. The amorphous cast grades can be used as the bottom web in formed applications which are lidded with a heat-sealable grade of PET. These packs can be reheated in microwave and conventional ovens.

PET film is also used as the outer reverse-printed ply in retort pouches, providing strength and puncture resistance, where it is laminated with aluminium foil and either PP or HDPE. PET can be oxide coated with SiO_2 to improve the barrier, whilst remaining transparent, retortable and microwaveable.

Paperboard is extrusion coated with PET for use as ready meal trays which can be reheated in microwave or conventional radiant heat ovens, i.e. dual ovenable. The PET coated side of the paperboard is on the inside of the tray which is erected by corner heat sealing.

PET is the fastest growing plastic for food packaging applications as a result of its use in all sizes of carbonated soft drinks and mineral water bottles which are produced by injection stretch blow moulding. PET bottles are also used for edible oils, as an alternative to PVC.

10.5 Polycarbonate (PC)

PC is a polyester containing carbonate groups in its structure. It is formed by the polymerisation of the sodium salt of bisphenolic acid with phosgene. It is glass clear, heat resistant and very tough and durable. PC is mainly used as a glass replacement in processing equipment and for glazing applications. Its use in packaging is mainly for large, returnable/refillable 3–6 litre water bottles. It is used for sterilisable baby feeding bottles and as a replacement in food service. It has been used for returnable milk bottles, ovenable trays for frozen food and if coextruded with nylon could be used for carbonated drinks.

10.6 Ionomers

Ionomers are polymers formed from metallic salts of acid copolymers and possess interchange ionic cross-links which provide the characteristic properties of the family of plastics. The metallic ions can be zinc or sodium and the copolymer is based on ethylene and methacrylic acid. It is clear, tougher than PE, having high puncture strength, and has excellent oil and fat resistance. Hence, it is used for the packaging of products contain essential oils, in the aseptic liquid packaging of fruit juices in cartons, and fat containing products (e.g. snack foods) in sachets. It has excellent heat-sealing properties, leading to increased packing line speeds. It is used in the packaging of meat, poultry and cheese. It is particularly useful in packing product with sharp protrusions.

In food packaging, ionomer films, including coextruded films, are used in laminations and extrusion coatings in all the main types of flexible packaging.

These include:

- vertical and horizontal FFS
- vacuum and MAP packing
- four-side sealed pouches and twin-web pouches with one web thermoformed
- inner ply of paperboard composite cans, e.g. aluminium foil/ionomer
- diaphragm or membrane seals.

Ionomers are used in laminated and coated form with PET, PA, PP, PE, aluminium foil, paper and paperboard.

10.7 Ethylene vinyl acetate (EVA)

EVA is a copolymer of ethylene with vinyl acetate. It is similar to PE in many respects, and it is used, blended with PE, in several ways. The properties of the blend depend on the proportion of the vinyl acetate component. Generally, as the VA component increases, sealing temperature decreases and impact strength, low temperature flexibility, stress resistance and clarity increase. At a 4% level, it improves heat sealability, at 8% it increases toughness and elasticity, along with improved heat sealability, and at higher levels, the resultant film has good stretch wrapping properties. EVA with PVdC is a tough high-barrier film which is used in vacuum packing large meat cuts and with metalized PET for bag-in-box liners for wine.

Modified EVAs are available for use as peelable coatings on lidding materials such as aluminium foil, OPP, OPET and paper. They enable heat sealing, resulting in controllable heat seal strength for easy, clean peeling. These coatings will seal to both flexible and rigid PE, PP, PET, PS and PVC containers.

Modified EVAs are also used to create strong interlayer tie bonding between dissimilar materials, e.g. between PET and paper, LDPE and EVOH. EVA is also a major component of hot melt adhesives, frequently used in packaging machinery to erect and close packs, e.g. folding cartons and corrugated packaging.

10.8 Polyamide (PA)

PA are commonly known as nylon. They were initially used in textiles, but subsequently other important applications were developed including uses in packaging and engineering. Polyamide plastics are formed by a condensation reaction between a diamine and a diacid or a compound containing each functional group (amine). The different types of polyamide plastics are characterised by a number which relates to the number of carbon atoms in the originating monomer. It has mechanical and thermal properties similar to that of PET and therefore similar applications. PA resins can be used to make blown film, and they can be coextruded.

PA can be blended with PE, PET, EVA and EVOH. It can be blow moulded to make bottles and jars which are glass clear, low in weight and have a good resistance to impact.

Biaxially oriented PA film has high heat resistance and excellent resistance to stress cracking and puncture. It has good clarity and is easily thermoformed, giving a relatively deep draw. It provides a good flavour and odour barrier and is resistant to oil and fat. It has a high permeability to moisture vapour and is difficult to heat seal. These features can be overcome by PVdC coating. They can also be overcome by lamination or co-extrusion with polyethylene, and this structure is used as the bottom thermoformable web, i.e. deep drawn, for packing bacon and cheese in vacuum packs or in gas-flushed packs (MAP or modified atmosphere packaging). The film can also be metalized.

PA film is used in retortable packaging in structures such as PA/aluminium foil/PP. The film is non-whitening in retort processing. PA is relatively expensive compared with PE, but as it has superior properties, it is effective in low thicknesses.

10.9 Polyvinyl chloride (PVC)

If one of the hydrogen atoms in ethylene is replaced with a chlorine atom, the resultant molecule is called vinyl chloride monomer (VCM). Addition polymerization of vinyl chloride produces PVC.

Rigid Unplasticized PVC (UPVC) is used for transparent or coloured compartmented trays for chocolate assortments and biscuits. It is used with MAP for thermoformed trays to pack salads, sandwiches and cooked meats.

Most PVC films are produced by extrusion, using the bubble process. It can be oriented to produce film with a high degree of shrinkability. Up to 50% shrinkage is possible at quite low temperatures. The film releases the lowest energy of the commonly used plastic films when it is heat shrunk around products. It is plasticised, and the high stretch and cling make it suitable for overwrapping fresh produce, e.g. apples and meat in rigid trays using semi-automatic and manual methods.

Printed PVC film is used for heat-shrinkable sleeve labels for plastic and glass containers. It is also used for tamper-evident shrink bands. Thicker grades are thermoformed to make trays which, after filling, are lidded with a heat seal-compatible top web.

PVC has excellent resistance to fat and oil. It is used in the form of blow moulded bottles for vegetable oil and fruit drinks. It has good clarity. As a film, it is tough, with high elongation, though with relatively low tensile and tear strength. The moisture vapour transmission rate is relatively high, though adequate for the packaging of mineral water, fruit juice and fruit drinks in bottles. PVC softens, depending on its composition, at relatively low temperatures (80–95°C). PVC easily seals to itself with heat, but heat sealing with a hot wire has the disadvantage of producing HCl gas.

The permeability to water vapour and gases depends on the amount of plasticizer used in manufacture. UPVC is a good gas and water vapour barrier, but these properties decrease with increasing plasticiser content. There are grades which are used to wrap fresh meat and fresh produce, where a good barrier to moisture vapour retards weight loss, but the permeability to oxygen allows the product to *breathe*. This allows fresh meat to retain its red colour and products such as fruits, vegetables and salads to stay fresh longer by reducing the rate of respiration, especially when packed in a modified atmosphere (MAP).

10.10 Polyvinylidene chloride (PVdC)

PVdC is a copolymer of vinyl chloride and vinylidene chloride – the latter forms when two hydrogen atoms in ethylene are replaced by chlorine atoms.

PVdC is heat sealable and is an excellent barrier to water vapour and gases and to fatty and oily products. As a result of the high gas and odour barrier, it is used to protect flavour and aroma sensitive foods from both loss of flavour and ingress of volatile contaminants. It is used in flexible packaging in several ways:

Monolayer film: A well-known application is the Cryovac range introduced by W.R. Grace and now operated by the Sealed Air Corporation. This includes poultry packing where hot water shrinkable bags are used to achieve a tight wrap around the product. The film can be used in the form of sachets but is less likely to be cost effective compared with other plastic films – some of which may incorporate PVdC as a coating. An interesting use is as sausage and chubb casing.

Coextrusions: PVdC is often used in coextrusion, where, today, extruders incorporate three, five and even seven extrusion layers to meet product protection and packaging machinery needs cost effectively.

Coatings. These may be applied using solutions in either organic solvents or aqueous dispersions to plastic films such as BOPP and PET, to RCF and to paper and paperboard.

Hence, PVdC is a widely used component in the packaging of cured meats, cheese, snack foods, tea, coffee and confectionery. It is used in hot filling, retorting, low-temperature storage and MAP as well as ambient filling and distribution in a wide range of pack shapes.

10.11 Polystyrene (PS)

PS is an addition polymer of styrene, a vinyl compound where a hydrogen atom is replaced with a benzene ring. PS has many packaging uses and can be extruded as a monolayer plastic film, coextruded as a thermoformable plastic sheet, injection moulded and foamed to give a range of pack types. It is also copolymerised to extend its properties.

It is less well known as an oriented plastic film, though the film has interesting properties. It has high transparency (clarity). It is stiff, with a characteristic crinkle, suggesting freshness, and has a deadfold property. The clear film is used for carton windows, and white pigmented film is used for labels. The film is printable. It has a low barrier to moisture vapour and common gases, making it suitable for packaging products, such as fresh produce, which need to breathe.

PS is easily processed by foaming to produce a rigid lightweight material which has good impact protection and thermal insulation properties. It is used in two ways. The blown foam can be extruded as a sheet which can be thermoformed to make trays for meat and fish, egg cartons, a variety of fast food packs such as the clam shell-shaped container, as well as cups and tubs. Thin sheets can be used as a label stock. The foam can also be produced in pellet or bead form which can then be moulded with heat and pressure. This is known as expanded polystyrene or EPS. It can be used as a transit case for fresh fish, with thick walls for insulation.

PS so far described is general purpose polystyrene. The main disadvantage as a rigid or semi-rigid container is the fact that it is brittle. This can be overcome by blending with styrene butadiene copolymer, SB or SBC, an elastomeric polymer. The blend is known as high-impact polystyrene or HIPS.

Blending produces a tougher material. It is translucent and is often used in a white pigmented form. The sheet can be thermoformed for short shelf life dairy products.

HIPS is also used in multilayer sheet extrusion with a variety of other polymers, each of which contributes to the protection and application needs of the product concerned. Other polymers which may be used in this way with HIPS include PE, PP, PET, PVdC and EVOH. The food products packed with these materials include dairy products such as cream and yoghurt-based desserts, UHT milk, cheese, butter, margarine, jam, fruit compote, fresh meat, pasta, salads etc. Many of these products are packed aseptically on thermoform, fill and seal machines.

10.12 Ethylene vinyl alcohol (EVOH)

EVOH is a copolymer of ethylene and vinyl alcohol. It is related to polyvinyl alcohol (PVOH), which is a water-soluble synthetic polymer with excellent film-forming, emulsifying and adhesive properties. It is a high-barrier material with respect to oil, grease, organic solvents and oxygen. It is moisture sensitive and, in film form, is water soluble. PVOH itself has packaging applications in film form but not in food products, and it is used as a coating for BOPP.

EVOH was developed to retain the high-barrier properties of PVOH. It is also an excellent barrier to oxygen and is resistant to the absorption and permeation of many products, especially those containing oil, fat and sensitive aromas and flavours. Though it is moisture sensitive to a much lesser degree than PVOH, it is still necessary to *bury* it in multilayered coextruded structures, such as film for flexible packaging, sheets for thermoforming and in blowmoulded bottles, so that it is not in contact with liquid.

The other polymers used depend on the application, i.e. the food product and type of pack. PS/EVOH/PS and PS/EVOH/PE sheets are used for processed cheese, pâtè, UHT milk and milk-based desserts and drinks. It is also used for MAP of fresh meat and for pasta, salads, coffee and hot filled processed cheese, including portion packed cheese and fruit compote.

A higher-barrier sheet can be constructed with PP/EVOH/PP for pasterizable and retortable products such as fruit, pâté, baby food, sauces like ketchup and ready meals, some of which are reheated by microwave. Coextruded film applications can involve EVOH with nylon, LLDPE and ionomer with food products such as bag-in-box wine, processed and fresh meat.

Extrusion lamination can involve EVOH with PET, LDPE and LLDPE for coffee, condiments and snacks. It is used with PET and PP for tray lidding material. Extrusion lamination of paperboard with EVOH and PE is used for aseptically packed UHT milk and fruit juices where the EVOH layer provides an oxygen barrier as a replacement for aluminium foil. In blow moulding, EVOH is used with PP for sauces, ketchup, mayonnaise and cooking oil and with HDPE for salad dressings and juices. Ketchup and mayonnaise bottles based on EVOH are squeezable.

Small tubes made by profile coextrusion are used for condiments by incorporating EVOH into structures with LDPE and LLDPE. EVOH is an important polymer in many processing applications providing protection for many types of food product.

10.13 Fluoropolymers

Fluoropolymers or fluoroplastics are high-performance polymers related to ethylene where some or all of the hydrogen atoms are replaced by fluorine, and in the packaging polymer a hydrogen is also replaced by a chlorine atom to produce polychlorotrifluoroethylene (PCTFE).

It has the highest water vapour barrier of all the commercially available packaging polymers, is a very good gas barrier and offers high resistance to most chemicals at low temperatures. In many applications, it is a suitable replacement for aluminium foil. It is available as a film or sheet. It is transparent, heat sealable and can be laminated, thermoformed, metalized and sterilized.

It is relatively expensive and is best known as a thermoformable blister pack material laminated with PVC for pharmaceutical tablets. Food packaging applications are possible but are not highlighted at the present time. Polytetrafluoroethylene (PTFE), better known as Teflon, is a high melting point, inert and waxy polymer. It is used in the form of tape and coatings on packaging machines to reduce adhesion, where that could be a problem, e.g. heat seal bars, and to reduce friction where packaging materials move over metal surfaces.

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.

Paper no.: 12
Paper Title: Food Packaging Technology
Module-34: Safety aspects of packaging and disposal of used packaging materials

34.1 Introduction

Most of the packaging related regulatory initiatives are concerned to the Product quality, Public Health and Hygiene, Safety, Export Promotion, Transportation and Consumer protection.
Packaging needs to communicate clearly all the mandatory information about the product to the consumer. Wrong information given on the package could mislead the consumer. Moreover, the packaging must communicate the way to handle the package or the product. This helps in protecting the consumers from accidents that could occur while opening the pack or during disposal, as in the case of glass bottles.

The international markets are governed by various packaging rules and regulations that make it mandatory for an exporting country to abide by them. Therefore, packaging for exports should comply with global norms to match with international standards. Government of India has instituted various laws and regulations. All these legislations are classified into two types i.e. Compulsory and Voluntary Standards.

To ensure product quality and provide safety to the consumer, it is important to regulate manufacturing, distribution, marketing and retailing of packaged products. This can be achieved by mandating rules and regulations. The Government of India has formulated a number of laws pertaining to packaging in the past years. Due to the sensitive nature of food, stringent rules and regulations have been mandated to address specific issues that could arise due to faulty packaging.

34.2 Negative Effects of Plastics as Packaging Material

34.2.1 Negative health effects

Following plastics have been associated with negative health effects:

34.2.1.1 Polyvinyl chloride (PVC)

PVC contains numerous toxic chemicals called adipates and Phthalates ("plasticizers"), which are used to soften brittle PVC into a more flexible form.
The World Health Organization's International Agency for Research on Cancer (IARC) has recognized the chemical used to make PVC, vinyl chloride, as a known human carcinogen.

- Plasticizers used to make soft PVC for toys can leach out into the mouths of the children chewing on the toys. In 2006, the EU placed a ban on six types of phthalate softeners, including DEHP (diethylhexyl phthalate), used in toys. An alternative plasticizer, DINP (diisononyl phthalate) is also found to be risky

- PVC plastic has been used safely for more than 70 years in a variety of medical and commercial applications and humans. No reports of adverse human health effects have been reported from intravenous (IV) bags and medical tubing made with PVC

- **Vinyl chloride monomer:** The carcinogenicity of vinyl chloride monomer to humans who were exposed to very high VCM levels, routinely, for many years have been linked. Vinyl chloride is a known human carcinogen that causes a rare cancer of the liver

- **Dioxins:** The dioxin is produced as a byproduct of vinyl chloride manufacture and from incineration of waste PVC in domestic garbage
- Dioxins are a global health threat because they persist in the environment and can travel long distances

At very low levels, dioxins have been linked to immune system suppression, reproductive disorders, a variety of cancers, and endometriosis

34.2.1.2 Polystyrene (PS)
PS is one of the toxins the EPA (Environmental Protection Agency) monitors in America's drinking water. Its production also pollutes the atmosphere, destroying the ozone layer. Some compounds leaching from Styrofoam food containers interfere with hormone functions. It's a possible human carcinogen.

34.2.1.3 Polycarbonates
Other group that consists mainly of polycarbonates, whose primary building block is bisphenol A (BPA), a hormone disrupter that releases into food and liquid and acts like estrogen. Research in Environmental Health Perspectives finds that BPA (leached from the lining of tin cans, dental sealants and polycarbonate bottles) can increase body weight of lab animals' offspring, as well as impact hormone levels. A more recent animal study suggests that even low-level exposure to BPA results in insulin resistance, which can lead to inflammation and heart disease.

34.2.2 Negative effects on environment
- Plastics are durable and degrade very slowly.
- In some cases, burning plastic can release toxic fumes.
- The manufacturing of plastics often creates large quantities of chemical pollutants.
- Thermoplastics can be recycled and reused, and thermoset plastics can be ground up and used as filler, though the purity of the material tends to degrade with each reuse cycle.
- To assist recycling of disposable items, the Plastic Bottle Institute of the Society of the Plastics Industry devised a now-familiar scheme to mark plastic bottles by plastic type. A recyclable plastic container using this scheme is marked with a triangle of three "chasing arrows", which encloses a number giving the plastic type i.e. Resin identification code.
- Unfortunately, recycling plastics has proven difficult. The biggest problem with plastic recycling is that it is difficult to automate the sorting of plastic waste, and so it is labor intensive.

Recycling certain types of plastics can be unprofitable, as well, e.g. polystyrene is rarely recycled because it is usually not cost effective. These unrecyclable wastes can be disposed of in landfills, incinerated or used to produce electricity at waste-to-energy plants.

34.3 Residual Toxic Components Present in Plastics
This is a plastic era and lot many plastics are used for foods. Packaging materials are made up of polymers which are insoluble in beverages as well as pharmaceutical products and foods. Great number of substances are extracted by food such as plasticizers, pigments, catalyst, adhesives and monomers or low molecular weight, polymer/oligomers and these are hazardous and toxic for human health. Even leaching of plasticizers by liquid product from packaging material results into embrittlement of the packaging material itself. The

preservatives in food/pharmaceutical are absorbed into plastic and therefore the resulting unprotected product leads to spoilage.
In case of PE bottles, the milk fat gets into plastic by absorption and it results into rancidity of the product and therefore such bottles can't be reused. Also product and packaging material reacts with each other. Human health is affected by continuous consumption of such product which increases the level of undesirable components in blood. Therefore, for food grade plastics, two types of limits are fixed:

1. **Global migration:** Includes all substances (from plastics) transferred to food i.e. sum of all mobile packaging components transferred to food. They may be toxic/non-toxic, even substances physiologically harmless and even unknown also.

2. **Specific migration:** Includes one or two individual, identifiable components only. For these reasons Toxicological substances and Labeled components are used.

Overall migration units are fixed at 10 mg/cm^2 of the surface of the packaging material or articles in the following cases as per BIS:

- Containers or articles which are similar to containers or which in any case may be filled to a capacity of less than 250 ml provided it is possible to calculate the surface area of contact with the food stuff.
- Sheets, foils and other non-fillable articles for which ratio between the surface areas of the material or article and the quality of food stuffs in contact may not be calculated.
- Rigorous scrutiny and list "Food Grade materials" is to be made. Global migration limits of 60 mg/kg of food stuff or 10 mg/cm^2 is been suggested by EEC. Typical food simulating solvents suggested are water, 3% acetic acid, 50/80% ethanol, Rectified spirit or heptane. Extraction conditions are high temperature, short duration or moderate temperature and long duration.
- India: BIS and CCFS (Central committee on Food Standards) Guide lines prepared.
  - PVC: the VC monomer content limit:1 ppm (max)
  - PS: Styrene monomer limit: 0.2% by mass of polymer.
- Test method specified (IS: 9845 Revised 1986): With a view to help both manufacturer and health authorities, CFTRI and IIP (Indian Institute of packaging, Bombay) have built up infrastructural facilities to assess the compatibility of plastics and also to estimate the migration.

34.3.1 Residual toxic compounds likely to be transferred to food through plastics:

1. **Monomers and oligomers**: Polymers have very high molecular weight and hence not assimilated by the body. Monomers being small may be assimilated by the body and therefore may pose health problems.

2. **Polymerization residues**: There may be presence of catalysts, solvents, emulsifiers and wetting agents having low molecular weight. During film container manufacturing a variety of processing aids are added which are

    a. **Antioxidants:** To prevent fading of colour and prevent cracking, viz. BHA/BHT etc.

b. **Antiblock agents**: To avoid blocking of film i.e. when it is drawn rolled the film surfaces should not adhere to each other.
c. **Antistatic agents**: They are important in packaging industries, when two materials/surfaces are in contact, the electrons on the surface atoms intermingle and may move from one material to another.
   The nature of plastic will determine the degree to which this takes place e.g. PS is most active followed by Acrylic and PE. Friction between the materials increases movement of electrons when they are separated. Absence of antistatic agents may lead to:

   1. Fire/spark hazard
   2. Dust attraction and
   3. Difficulty in Derolling

   Presence of moisture in air causes ionization resulting into neutralized electrons. The antistatic agents absorb moisture from air.

d. **Plasticizers**: At lower processing temperature they avoids decomposition of polymer and modify processing characteristics like flexibility. They do these functions by acting as lubricant. They allow the molecules of plastic to slide over one another freely or by acting as a partial solvent for the resin. Plasticizers tend to ooze out during long contact or high temp and they may migrate from one plastic to another (e.g. from vinyl to PS if they are in contact). They may also leach out by solvents or by liquid product. Even some plastic becomes stiff and brittle when cold. Greatest use of plasticizers is in PVC – PVA. For e.g. Dioctyl phthalate (DOP), therefore PVC has poor resistance to oil. About 33% of DOP migrate into oil products.
   Plasticizers related to cancer by International Agency for Research on Cancer are: DEHA: BIS-2-Ethyl Hexyl Adipate, BBP: Butyl Phenyl Methyl or Butyl Benzyl Phthalate, DEHP: Bis-2- Ethyl Myxyl or Di-Ethyl Hexyl Phthalate

e. **Lubricants**: Internal lubricants such as Fatty acid glycerides reduce friction between plastic molecules, and External lubricants like Montanic acid reduce friction with processing equipments.

f. **Slip agents** like Silicon components helps in easy rolling/derolling of film.

Many additives used, may migrate to food. Therefore limit has to be specified along with list of safe components.

However, in case of recycled materials, it is almost impossible to have migration within the prescribed unit, hence should never be used for food materials.

34.3.2 Methods of reducing migration from packaging material to food:

1. Use of new migration resistant plasticizers.
2. Improvement in formulation to reduce greatly their use.
3. Surface treatment of finished plastic products to reduce plasticizer migration (U.V. light, laser radiation treatments given).

34.3.3 Factors involved in migration:

1. Composition and properties of packaging materials
2. Composition and properties of food stuffs
3. Surface (plastic) to volume (food) ratio
4. Temperature conditions
5. Duration of contact
6. Influence of light

34.4 Disposal Methods of Waste Packages

After product usage, the empty packages have to be discarded, and these constitute a fair proportion of the solid waste produced by the community. In developed countries 4 lb of municipal waste is created by each person in one day. Out of this, packaging accounts for nearly 1/3rd of the volume. The collection and proper disposal of the waste is done by ministerial or public health authorities. Glass, paper, plastics and tin cans are the main packaging materials which get mixed with the city refuse and present problem of their proper disposal. The non - disposable nature of many packaging materials make it much more complicated problem.

34.4.1 The Hierarchy of Waste Disposal

Prevention
↓
Minimization
↓
Reuse
↓
Recycling
↓
Energy Recovery
↓
Disposal

- **Prevention** – Waste prevention is a primary goal. Packaging should be used only where needed. Proper packaging can also help prevent waste.
- **Minimization** – The mass and volume of packaging can be measured and used as one of the criteria to minimize during the package design process. Usually “reduced” packaging also helps minimize costs. Packaging engineers should continue to work toward reduced packaging.
- **Reuse** – The reuse of a package or component for other purposes shall be encouraged. Returnable packaging has long been useful and economically viable.

- **Recycling** – Recycling is the reprocessing of materials (pre- and post-consumer) into new products. Emphasis is focused on recycling the largest primary components of a package. i.e. Steel, aluminium, papers, plastics, etc. Small components can be chosen which are not difficult to separate and do not contaminate recycling operations.
- **Energy recovery** – Waste-to-energy and Refuse-derived fuel in approved facilities are able to make use of the heat available from the packaging components.
- **Disposal** – Incineration and placement in a sanitary landfill are needed for some materials. Material content should be checked for potential hazards to emissions and ash from incineration and leach out from landfill. Packages should not be littered.

34.4.2 Methods of Waste Disposal:

There are various methods of waste disposal

34.4.2.1 Open dumping:

By this method only those packaging materials which would not be expected to contribute to public health hazards can be disposed.

Disadvantage: Discarded food packages may contain residual food products and moisture which can harbour insects and bacteria that may cause public health concern.

34.4.2.2 Sanitary landfill method:

The most popular method of disposing the package waste is the landfill method. Here the trouble free waste packaging material is stored after compressing and piling. The waste is spread layer by layer and each layer is covered by earth. Degradability due to bio-physical agents or chemical oxidation is the common feature in sanitary landfill.

Disadvantage: Leaking of contaminants and then polluting ground water and production of methane gas are the commonly encountered problems in this method.

In general, packaging materials are not easily degradable. Bio degradable material produces methane gas. Plasticizers used in PVC will evolve from waste as emissions. Lead and calcium compounds used in pigments pose a problem of ground water pollution.

34.4.2.3 Composting:

This process is best suited for bio degradable packaging waste material.

Disadvantage: Paper degrades in composting. Glass, metals and plastics do not degrade in composting operation.

34.4.2.4 Incineration:

Incineration means burning of the packaging waste with or without energy recovery. This is the most hygienic method of reducing the volume and weight of solid waste.

Advantages:

a. Incineration of packaging materials like wood, paper and plastics have significant fuel value/ energy source.
b. Packaging is not hazardous contributor to the emissions except PVC.
c. Very little lead and cadmium are found in ash on incineration
d. Most hygienic way of waste disposal.

Disadvantages:

a. Large investment is required to construct plants.
b. High operational cost is involved.

c. Air pollution - Ex: release of hydrogen chloride during burning of PVC.
d. Glass, steel and other metals are not combustible and they should be removed before incineration.

Glass and plastics if not removed, create problems in incinerator due to melting and solidifying inside the equipment.