Food Packaging Technology

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Module- 1 Factors affecting shelf of food material during storage, spoilage mechanism during storage

Lesson- 1. Factors affecting shelf life of food

1.1 Introduction

Packaging is an essential part of processing and distributing foods. Whereas preservation is the major role of packaging, there are several other functions for packaging, each of which must be understood by the food manufacturer. Packaging must protect against a variety of assaults including microorganisms, insects and rodents. Environmental factors such as oxygen and water vapor will spoil foods if they are allowed to enter packages freely.

Packaging can become a shelf life limiting factor in its own right. For example, this may be as a result of migration of tainting compounds from the packaging into the food or the migration of food components into the packaging. Different groups within the food chain, i.e. consumers, retailers, distributors, manufacturers and growers, proffer subtly different perspectives of shelf life, reflecting the aspect of greatest importance and significance to them. For consumers, it is imperative that products are safe and the quality meets their expectations. Consumers will often actively seek the product on the shelf with the longest remaining shelf life as this is considered to be indicative of freshness.

1.2 Shelf life

The quality of most foods and beverages decreases with storage or holding time. The shelf life of a product is best determined as a part of the product development cycle. The Institute of Food Technologists (IFT) in the United States has defined shelf life as “the period between the manufacture and the retail purchase of a food produ-ct, during which time the product is in a state of satisfactory quality in terms of nutritional value, taste, texture and appearance”. The Institute of Food Science and Technology (IFST) in the United Kingdom has defined shelf life as “the period of time during which the food product will remain safe; be certain to retain desired sensory, chemical, physical, microbiological and functional characteristics; and comply with any label declaration of nutritional data when stored under the recommended conditions” .

The date of minimum durability is defined as the date until which the food retains its specific properties when properly stored. It must be indicated by the words “Best before” followed by the date (or a reference to where the date is given on the labeling). Depending on how long the food can keep, the date can be expressed by the day and the month, the month and the year, or the year alone.

1.3 Factors affecting shelf life

1.3.1 Product characteristics

Product characteristics including formulation and processing parameters i.e. intrinsic factors. Intrinsic factors are the properties resulting from the make-up of the final product and include the following:

- Water activity (a_w)
- PH/total acidity
- Natural micro flora and surviving microbiological counts in final product
- Availability of oxygen
- Reduction potential (E_h)
- Natural biochemistry/chemistry of the product
- Added preservatives (e.g. salt, spices, antioxidants)
- Product formulation

1.3.2 Environmental factors

Environment to which the product is exposed during distribution and storage i.e. extrinsic factors. Extrinsic factors are a result of the environment that the product encounters during life and include the following:

1.3.2.1 Temperature

Temperature is a key factor in determining the rates of deteriorative reactions, and in certain situations the packaging material can affect the temperature of the food. For packages that are stored in refrigerated display cabinets, most of the cooling takes place by conduction and convection. Simultaneously, there is a heat input by radiation from the fluorescent lamps used for lighting. Under these conditions, aluminum foil offers real advantages because of its high reflectivity and high conductivity.

1.3.2.2 Relative humidity

The RH of the ambient environment is important and can influence the water activity (a_w) of the food unless the package provides an excellent barrier to water vapor. Many flexible plastic packaging materials provide good moisture barriers, but none is completely impermeable.

1.3.2.3 Gas atmosphere

The presence and concentration of gases in the environment surrounding the food have a considerable influence on the growth of microorganisms, and the atmosphere inside the package is often modified. The simplest way of modifying the atmosphere is vacuum packaging, that is, removal of air (and thus O_2) from a package prior to sealing; it can have a beneficial effect by preventing the growth of aerobic microorganisms. Flushing the inside of the package with a gas such as CO_2 or N_2 before sealing is the basis of modified atmosphere packaging (MAP). For example, increased concentrations of gases such as CO_2 are used to retard microbial growth and thus extend the shelf life of foods. MAP is increasing in importance, especially with the packaging of fresh fruits and vegetables, fresh foods, and bakery products.

Atmospheric O_2 generally has a detrimental effect on the nutritive quality of foods, and it is therefore desirable to maintain many types of foods at a low O_2 tension, or at least prevent a continuous supply of O_2 into the package. Lipid oxidation results in the formation of hydroperoxides, peroxides, and epoxides, which will, in turn, oxidize or otherwise react with carotenoids, tocopherols, and ascorbic acid to cause loss of vitamin activity.

With the exception of respiring fruits and vegetables and some fresh foods, changes in the gas atmosphere of packaged foods depend largely on the nature of the package. Adequately sealed metal and glass containers effectively prevent the interchange of gases between the food and the atmosphere. With flexible packaging, however, the diffusion of gases depends not only on the effectiveness of the closure but also on the permeability of the packaging material, which depends primarily on the physicochemical structure of the barrier.

1.3.2.4 Light

Many deteriorative changes in the nutritional quality of foods are initiated or accelerated by light. Light is, essentially, an electromagnetic vibration in the wavelength range between 4000 and 7000 A, the wavelength of ultraviolet (UV) light ranges between 2000 and 4000 A. The catalytic effects of light are most pronounced in the lower wavelengths of the visible spectrum and in the UV spectrum. The intensity of light and the length of exposure are significant factors in the production of discoloration and flavor defects in packaged foods.

There have been many studies demonstrating the effect of packaging materials with different light-screening properties on the rates of deteriorative reactions in foods. Among the most commonly studied foods has been fluid milk, the extent of off-flavor development being related to the exposure interval, strength of light, and amount of milk surface exposed.

1.3.3 Enzymic reactions

In food packaging technology, knowledge of enzyme action is essential to a fuller understanding of the implications of different forms of packaging. The importance of enzymes to the food processor is often determined by the conditions prevailing within and outside the food. Control of these conditions is necessary to control enzymic activity during food processing and storage. The major factors useful in controlling enzyme activity are temperature, a_w, pH, chemicals that can inhibit enzyme action, alteration of substrates, alteration of products, and preprocessing control.

Three of these factors are particularly relevant in a packaging context. The first is temperature i.e. the ability of a package to maintain a low product temperature and thus retard enzyme action will often increase product shelf life. The second important factor is a_w, because the rate of enzyme activity is dependent on the amount of water available, low levels of water can severely restrict enzymic activities and even alter the pattern of activity. Finally, alteration of substrate (in particular, the ingress of O_2 into a package) is important in many O_2 dependent reactions that are catalyzed by enzymes, for example, enzymic browning due to oxidation of phenols in fruits and vegetables.

1.3.4 Chemical reactions

Many of the chemical reactions that occur in foods can lead to deterioration in food quality (both nutritional and sensory) or the impairment of food safety. Such reaction classes can involve different reactants or substrates, depending on the specific food and the particular conditions for processing or storage. The rates of these chemical reactions are dependent on a variety of factors amenable to control by packaging, including light, O_2 concentration, temperature, and a_w. Therefore, the package can, in certain circumstances, play a major role in controlling these factors, and thus indirectly the rate of the deteriorative chemical reactions.

The two major chemical changes that occur during the processing and storage of foods and lead to deterioration in sensory quality are lipid oxidation and nonenzymic browning (NEB). Chemical reactions are also responsible for changes in the color and flavor of foods during processing and storage.

1.3.4.1 Lipid oxidation

Autoxidation is the reaction of molecular O_2 by a free radical mechanism with hydrocarbons and other compounds. The reaction of free radicals with O_2 is extremely rapid, and many mechanisms for initiation of free radical reactions have been described. The crucial role that autoxidation plays in the development of undesirable flavors and aromas in foods is well documented, and autoxidation is a major cause of food deterioration.

1.3.4.2 Nonenzymic browning

Nonenzymic browning (NEB) is one of the major deteriorative chemical reactions that occur during storage of dried and concentrated foods. The NEB or Maillard, reaction can be divided into following three stages.

(1) Early maillard reactions involving a simple condensation between an aldehyde (usually a reducing sugar) and an amine (usually a protein or amino acid) without browning.
(2) Advanced maillard reactions that lead to the formation of volatile or soluble substances
(3) Final maillard reactions leading to insoluble brown polymers.

1.3.4.3 Color changes

Acceptability of color in a given food is influenced by many factors, including cultural, geographical and sociological aspects of the population. However, regardless of these many factors, certain food groups are acceptable only if they fall within a certain color range. The color of many foods is due to the presence of natural pigments such as chlorophylls, anthocyanins, carotenoids, flavonoids, and myoglobin.

1.3.4.4 Flavor changes

In fruits and vegetables, enzymically generated compounds derived from long-chain fatty acids play an extremely important role in the formation of characteristic flavors. In addition, these types of reactions can lead to important off-flavors. Enzyme-induced oxidative breakdown of unsaturated fatty acids occurs extensively in plant tissues, and this yields characteristic aromas associated with some ripening fruits and disrupted tissues.

Aldehydes and ketones are the main volatiles from autoxidation, and these compounds can cause painty, fatty, metallic, papery, and candle like flavors in foods when their concentrations are sufficiently high. However, many of the desirable flavors of cooked and processed foods derive from modest concentrations of these compounds. The permeability of packaging materials is of importance in retaining desirable volatile components within packages and in preventing undesirable components entering the package from the ambient atmosphere.

1.3.4.5 Nutritional changes

The four major factors that influence nutrient degradation and can be controlled to varying extents by packaging are light, O_2 concentration, temperature, and a_w. However, because of the diverse nature of the various nutrients as well as the chemical heterogeneity within each class of compounds and the complex interactions of these variables, generalizations about nutrient degradation in foods are unhelpful.

1.3.5 Physical changes

The physical properties of foods can be defined as those properties that lend themselves to description and quantification by physical rather than chemical means and include geometrical, thermal, optical, mechanical, rheological, electrical, and hydrodynamic properties. Geometrical properties encompass the parameters of size, shape, volume, density, and surface area as related to homogeneous food units, as well as geometrical texture characteristics. Although many of these physical properties are important and must be considered in the design and operation of a successful packaging system, in the present context the focus is on undesirable physical changes in packaged foods.

1.3.6 Microbiological changes

Microorganisms can make both desirable and undesirable changes to the quality of foods, depending on whether they are introduced as an essential part of the food preservation process or arise adventitiously and subsequently grow to produce food spoilage. Every microorganism has a limiting a_w value below which it will not grow, form spores, or produce toxic metabolites. Water activity can influence each of the four main growths cycle phases by its effect on the germination time, the length of the lag phase and the growth rate phase, the size of the stationary population, and the subsequent death rate. Whether a microorganism survives or dies in a low a_w environment is influenced by intrinsic factors that are also responsible for its growth at higher a_w. These factors include water-binding properties, nutritive potential, pH, E_h, and the presence of antimicrobial compounds. Microbial growth and survival are not entirely ascribed to reduce a_w but are also attributable to the nature of the solute. Key extrinsic factors relating to a_w that influence microbial deterioration in foods include temperature, O_2, and chemical treatments. These factors can combine in a complex way to encourage or discourage microbial growth.

Lesson- 2. Spoilage mechanism during storage

2. Introduction

The nature of the deteriorative reactions in foods and the factors that control the rates of these reactions will be briefly outlined. Deteriorative reactions can be enzymic, chemical, physical, and biological. Biochemical, chemical, physical, and biological changes occur in foods during processing and storage, and these combine to affect food quality. The most important quality-related changes are as follows:

- Chemical reactions, mainly due to either oxidation or nonenzymic browning reactions.
- Microbial reactions, microorganisms can grow in foods. In the case of fermentation this is desired; otherwise, microbial growth will lead to spoilage and, in the case of pathogens, to unsafe food.
- Biochemical reactions, many foods contain endogenous enzymes that can potentially catalyze reactions leading to quality loss (enzymic browning, lipolysis, proteolysis, and more). In the case of fermentation, enzymes can be exploited to improve quality.
- Physical reactions, many foods are heterogeneous and contain particles. These particles are unstable, and phenomena such as coalescence, aggregation, and sedimentation usually lead to quality loss.

The interactions of intrinsic and extrinsic factors affect the likelihood of the occurrence of reactions or processes that affect shelf life. These shelf life limiting reactions or processes can be classified as: chemical/biochemical, microbiological and physical. The effects of these factors are not always detrimental and in some instances they are essential for the development of the desired characteristics of a product.

Table: 2.1

Example	**Type**	**Consequences**
Nonenzymic browning	Chemical reaction (Maillard reaction)	Color, taste and aroma, nutritive value, formation of toxicologically suspect compounds (acrylamide)
Fat oxidation	Chemical reaction	Loss of essential fatty acids, rancid flavor, formation of toxicologically suspect compounds

Fat oxidation	Biochemical reaction (lipoxygenase)	Off-flavors, mainly due to formation of aldehydes and ketones
Hydrolysis	Chemical reaction	Changes in flavor, vitamin content
Lipolysis	Biochemical reaction (lipase)	Formation of free fatty acids and peptides, bitter taste
Proteolysis	Biochemical reaction (proteases)	Formation of amino acids and peptides, bitter taste, flavor compounds, changes in texture
Enzymic browning	Biochemical reaction of polyphenols	Browning
Separation	Physical reaction	Sedimentation, creaming
Gelation	Combination of chemical and physical reaction	Gel formation, texture changes

2.2. Chemical/biochemical processes

Many important deteriorative changes can occur as a result of reactions between components within the food, or between components of the food and the environment. Chemical reactions will proceed if reactants are available and if the activation energy threshold of the reaction is exceeded. The rate of reaction is dependent on the concentration of reactants and on the temperature and/or other energy, e.g. light induced reactions. A general assumption is that for every 10°C rise in temperature, the rate of reaction doubles. Specialized proteins called enzymes catalyse biochemical reactions.

2.3. Oxidation

A number of chemical components of food react with oxygen affecting the colour, flavor, nutritional status and occasionally the physical characteristics of foods. In some cases, the effects are deleterious and limit shelf life, in others they are essential to achieve the desired product characteristics. Packaging is used to exclude, control or contain oxygen at the level most suited for a particular product. Foods differ in their avidity for oxygen, i.e. the amount that they take up, and their sensitivity to oxygen, i.e. the amount that results in quality changes. Estimates of the maximum oxygen tolerance of foods are useful to determine the oxygen permeability of packaging materials required to meet a desired shelf life.

Foods containing a high percentage of fats, particularly unsaturated fats, are susceptible to oxidative rancidity and changes in flavor. Saturated fatty acids oxidize slowly compared with unsaturated fatty acids. Antioxidants that occur naturally or are added, either slow the rate of, or increase the lag time to, the onset of rancidity. Three different chemical routes can initiate the oxidation of fatty acids: the formation of free radicals in the presence of metal ion catalysts such as iron, or heat, or light – termed the classical free radical route; photooxidation in which photo-sensitisers such as chlorophyll or myoglobin affect the energetic state of oxygen; or an enzymic route catalyzed by lipoxygenase.

In milk chocolate, the presence of tocopherol (vitamin E), a natural antioxidant in cocoa liquor provides a high degree of protection against rancidity. However, white chocolate does not have the antioxidant protection of cocoa liquor and so is prone to oxidative rancidity, particularly light induced. In snack products and particularly nuts the onset of rancidity is the shelf life limiting factor. Such sensitive products are often packed gas flushed to remove oxygen and packed with 100% nitrogen to protect against oxidation and provide a cushion to protect against physical damage.

Oxidation of lycopene, a red/orange carotenoid pigment in tomatoes, causes an adverse colour change from red to brown and affects flavor. In canned tomato products this can be minimized by using plain unlacquered cans. The purpose of the tin coating is to provide protection of the underlying steel, but it also provides a chemically reducing environment within the can.

Tomato ketchup used to suffer from *black neck* – the top of the ketchup in contact with oxygen in the headspace turned black. To disguise this, a label was placed around the neck of the bottle, hiding the discoloration. It has since been shown that oxidation depends on the level of iron in the ketchup and blackening has now been prevented.

2.4. Enzyme activity

Fruits and vegetables are living commodities and their rate of respiration affects shelf life – generally the greater the rate of respiration, the shorter the shelf life. Immature products such as peas and beans have much higher respiration rates and shorter shelf life than products that are mature storage organs such as potatoes and onions. Respiration is the metabolic process whereby sugars and oxygen are converted to more usable sources of energy for living cells. Highly organized and controlled biochemical pathways promote this metabolic process. In non-storage tissues where there are few reserves, such as lettuce and spinach, or immature flower crops such as broccoli, this effect is even greater. Use of temperature control reduces the respiration rate, extending the life of the product. Temperature control combined with MAP further suppresses the growth of yeasts, moulds and bacteria, extending shelf life further.

All plants produce ethylene to differing degrees and some parts of plants produce more than others. The effect of ethylene is commodity dependent but also dependent on temperature, exposure time and concentration.

2.5. Microbiological processes

Under suitable conditions, most microorganisms will grow or multiply. During growth in foods, microorganisms will consume nutrients from the food and produce metabolic by-products such as gases or acids. They may release extra-cellular enzymes (e.g. amylases, lipases, proteases) that affect the texture, flavor, odor and appearance of the product. Some of these enzymes will continue to exist after the death of the microorganisms that produced them, continuing to cause product spoilage. In canning, low acid foods are filled into containers that are hermetically sealed and sterilized, typically at 115.5–121^{0}C or above, to ensure all pathogens, especially *Clostridium botulinum*, are destroyed. Low temperatures might inhibit the growth of an organism and affects its rate of growth. Some microorganisms are adapted to grow at chill temperatures, hence the composition of organisms in the natural microflora will change.

2.6. Physical and physico-chemical processes

Many packaging functions such as protection of the product from environmental factors and contamination such as dust and dirt, dehydration and rehydration, insect and rodent infestation, containment of the product to avoid leakage and spillage, and physical protection action against hazards during storage and distribution are taken for granted by the consumer. Packaging is very often the key factor to limiting the effects of physical damage on product shelf life. Different forms of this process is

Physical damage

- Insect damage
- Moisture changes
- Barrier to odor pick-up

2.7. Migration from packaging to foods

The direct contact between food and packaging materials provides the potential for migration. Additive migration describes the physico-chemical migration of molecular species and ions from the packaging into food. Such interactions can be used to the advantage of the manufacturer and consumer in active and intelligent packaging, but they also have the potential to reduce the safety and quality of the product, thereby limiting product shelf life.

Module- 2 Definition, requirement, importance and scope of packaging of foods, types and classification of packaging system, advantage of modern packaging system

Lesson- 3 Functions of food packaging

3.1. Introduction

Packaging is an industrial and marketing technique for containing, protecting, identifying and facilitating the sale and distribution of agricultural, industrial and consumer products.

Or

The packaging institute international defines packaging as a 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 as 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 as a package.

The UK Institute of packaging provides three definitions of packaging.

(a) A coordinated system of preparing goods for transport, distribution, storage, retailing and end-use.

(b) A means of ensuring safe delivery to the ultimate consume in sound condition at minimum cost.

(c) A techno-economic function aimed at minimizing cost of delivery while maximizing sales.

3.2. Basic functions of packaging

Efficient packaging is a necessity for every kind of food, whether it is fresh or processed .It is an essential link between the food producer and the consumer, and unless performed correctly the standing of the product suffers and customer goodwill is lost. The basic functions of packaging are more specifically stated.

3.2.1. Containment

The containment function involves the ability of the packaging to maintain its integrity during the handling involved in filling, sealing, processing (in some cases, such as retorted, irradiated, and high-pressure-processed foods), transportation, marketing, and dispensing of the food.

3.2.2 Protection

The need for protection depends on the food product but generally includes prevention of biological contamination (from microorganisms, insects, rodents), oxidation (of lipids, flavors, colors, vitamins, etc.), moisture change (which affects microbial growth, oxidation rates, and food texture), aroma loss or gain, and physical damage (abrasion, fracture, and/or crushing). Protection can also include providing tamper evident features on the package. In providing protection, packaging maintains food safety and quality achieved by refrigeration, freezing, drying, heat processing, and other preservation of foods.

3.2.3 Communication

The information that a package provides involves meeting both legal requirements and marketing objectives. Food labels are required to provide information on the food processor, ingredients (including possible allergens in simple language), net content, nutrient contents, and country of origin. Package graphics are intended to communicate product quality and, thus, sell the product. Bar codes allow rapid check-out and tracking of inventory. Other package codes allow determination of food production location and date. Various open dating systems inform the consumer about the shelf life of the food product. Plastic containers incorporate a recycling code for identification of the plastic material.

3.2.4 Preservation

Product protection is the most important function of packaging. Protection means the establishment of a barrier between the contained product and the environment that competes with man for the product.

3.2.5 Convenience

Providing convenience (sometimes referred to as utility of use or functionality) to consumers has become a more important function of packaging. Range of sizes, easy handling, easy opening and dispensing, resealability, and food preparation in the package are examples of packaging providing convenience to the consumer.

3.2.6 Unitization

Unitization is assembly or grouping of a number of individual items of products or packages into a single entity that can be more easily distributed, marketed, or purchased as a single unit. For example: a paperboard folding carton containing three flexible material pouches of seasoning or soup mix delivers more product to a consumer than does a single pouch. A paperboard carton wrapped around 12 beer bottles provides more desired liquid refreshment for home entertainment than does an attempt to carry individual bottles in one's hands.

Unitization reduces the number of handlings required in physical distribution and, thus, reduces the potential for damage. Because losses in physical distribution are significantly reduced with unitization, significant reductions in distribution costs are affected.

3.2.7Information about the product

Packaging is one of the major communications media. Usually overlooked in the measured media criteria, packaging is the main communications link between the consumer or user and the manufacturer, at both the point of purchase and the point of use. Packaging educates consumers about requirements, product ingredients and uses etc.

3.2.8 Presentation

Material type, shape, size, colour and merchandising display units etc. of packaging improve display of food.

3.2.9Brand communication

Packaging provides brand communication to the consumers by the use of typography, symbols, illustrations, advertising and colour, thereby creating visual impact.

3.2.10 Promotion

Packaging helps to promote the food as it informs to consumers about many offers i.e. free extra product, new product, money off etc.

3.2.11 Economy

The package is also an important part of the manufacturing process and must be efficiently filled, closed, and processed at high speeds in order to reduce costs. It must be made of materials which are rugged enough to provide protection during distribution but be of low enough cost for use with foods. Packaging costs, which include the materials as well as the packaging machinery, are a significant part of the cost of manufacturing foods, and in many cases, these costs can be greater than the cost of the raw ingredients used to make the food. Therefore, packaging materials must be economical, given the value of the food product.

3.3 Other functions of packaging

Other functions of packaging include apportionment of the product into standard units of weight, measure, or quantity prior to purchase. Yet another objective is to facilitate product use by the consumer with devices such as spouts, squeeze bottles, and spray cans. Aerosols not only serve as dispensers, but also prepare the product for use, such as aerating the contained whip toppings. Still other forms of packaging are used in further preparation of the product by the consumer, for example tea bags that are plastic-coated, porous paper pouches, or frozen dinner trays, which were originally aluminum and now are fabricated from other materials such as crystallized polyester and polyester-coated paperboard.

3.4 Requirements for effective food packaging

Some of the important general requirements of food packages are given below

- Be nontoxic
- Protect against contamination from microorganisms
- act as a barrier to moisture loss or gain and oxygen ingress
- protect against ingress of odors or environmental toxicants
- Filter out harmful UV light
- Provide resistance to physical damage
- Be transparent (8) be tamper – resistant or tamper – evident
- Be easy to open
- Have dispensing and resealing features
- Be disposed of easily,
- Meet size, shape and weight requirements
- Have appearance, printability features
- Be low cost
- Be compatible with food
- Have special features such as utilizing groups of product together.

Lesson- 4 Packaging systems

4.1 Aseptic packaging

Aseptic packaging is a method in which food is sterilized or commercially sterilized outside of the can, usually in a continuous process, and then aseptically placed in previously sterilized containers which are subsequently sealed in an aseptic environment. After cooling, the sterile food product is pumped to an aseptic packaging system where the food is filled and hermetically sealed into previously sterilized containers. Aseptically processed foods can be packaged in the same types of containers used for retorted foods. However, another advantage of aseptically processed foods is that they can be packaged in containers that do not have to survive the conditions of a retort. These include LDPE/Pb/LDPE/AL/LDPE laminate cartons and multilayer plastic flexible packaging that has cost and convenience advantages.

The disadvantage of these packages is that they are not as easily recycled as metal and glass containers. Aseptic filling systems have also been developed for HDPE and PET bottles. Aseptic filling of PET containers may have a cost advantage over hot filling of heat-set PET containers. Another advantage of aseptically processed foods is that they can be filled into drums, railroad tank cars, tank trucks and silos that have been previously sterilized with steam. The food can be later reprocessed and packaged to meet market demands. The sterilization agents available for aseptic packaging include heat, chemical treatment with hydrogen peroxide and high energy irradiation (UV light or ionizing (gamma) irradiation). A combination of hydrogen peroxide and mild heat is most commonly used with plastic and paperboard-based laminate packaging.

The most commercially successful form of aseptic packaging utilizes paper and plastic materials which are sterilizes, formed, filled and sealed in continuous operation. The package may be sterilized with heat or combination of heat and chemicals. In some cases, the disinfectant property of hydrogen peroxide (H_2O_2) is combined with heated air or ultra violet light to make lower temperatures effective in sterilizing these less heat resistant packaging materials.

Aseptic packaging is also used with the metal cans as well as large plastic and metal drums or large flexible pouches. Great quantities of food materials are used as intermediates in the production of further processed foods. This frequently requires packaging of such items as tomato paste or apricot puree in large containers. The food manufacturer then may use the tomato paste in the production of ketchup or the apricot puree in bakery products. If such large volumes were to be sterilized in drums, by the time the cold point reached sterilization temperature the product nearer the drum walls would be excessively burned. Such items can be quickly sterilized in efficient heat exchangers and aseptically packaged.

4.2 Modified Atmosphere Packaging

Modified atmosphere packaging (MAP) is a procedure which involves replacing air inside a package with a predetermined mixture of gases prior to sealing it. Once the package is sealed, no further control is exercised over the composition of the in-package atmosphere.

However, this composition may change during storage as a result of respiration of the contents and/or solution of some of the gas in the product. Vacuum packaging is a procedure in which air is drawn out of the package prior to sealing but no other gases are introduced. This technique has been used for many years for products such as cured meats and cheese. It is not usually regarded as a form of MAP.

The gases involved in modified atmosphere packaging, as applied commercially are carbon dioxide, nitrogen and oxygen. Carbon dioxide reacts with water in the product to form carbonic acid which lowers the pH of the food. It also inhibits the growth of certain microorganisms, mainly moulds and some aerobic bacteria. Lactic acid bacteria are resistant to the gas and may replace aerobic spoilage bacteria in modified atmosphere packaged meat. Most yeasts are also resistant to carbon dioxide. Anaerobic bacteria, including food poisoning organisms, are little affected by carbon dioxide. Consequently, there is a potential health hazard in MAP products from these microorganisms. Moulds and some gram negative, aerobic bacteria, such as Pseudomonas spp, are inhibited by carbon dioxide concentrations in the range 5–50%. In general, the higher the concentration of the gas, the greater is its inhibitory power. The inhibition of bacteria by carbon dioxide increases as the temperature decreases.

Nitrogen has no direct effect on microorganisms or foods, other than to replace oxygen, which can inhibit the oxidation of fats. As its solubility in water is low, it is used as a bulking material to prevent the collapse of MAP packages when the carbon dioxide dissolves in the food. This is also useful in packages of sliced or ground food materials, such as cheese, which may consolidate under vacuum. Oxygen is included in MAP packages of red meat to maintain the red colour, which is due to the oxidation of the myoglobin pigments. It is also included in MAP packages of white fish, to reduce the risk of botulism. Other gases have antimicrobial effects. Carbon monoxide will inhibit the growth of many bacteria, yeasts and moulds, in concentrations as low as 1%.

However, due to its toxicity and explosive nature, it is not used commercially. Sulphur dioxide has been used to inhibit the growth of moulds and bacteria in some soft fruits and fruit juices.

Argon, helium, xenon and neon, have also been used in MAP of some foods. MAP packages are either thermoformed trays with heat-sealed lids or pouches. With the exception of packages for fresh produce, these trays and pouches need to be made of materials with low permeability to gases (CO_2, N_2, and O_2). Laminates are used, made of various combinations of polyester (PET), polyvinylidene chloride (PVdC), polyethylene (PE) and polyamide.

4.3 Active packaging

Active packaging refers to the incorporation of certain additives into packaging film or within packaging containers with the aim of maintaining and extending product shelf life. Packaging may be termed active when it performs some desired role in food preservation other than providing an inert barrier to external conditions. Active packaging includes additives or 'freshness enhancers' that are capable of scavenging oxygen, adsorbing carbon dioxide, moisture, ethylene and/or flavor/odor taints, releasing ethanol, sorbates, antioxidants and/or other preservatives and/or maintaining temperature control. Table

2.1 lists examples of active packaging systems, some of which may offer extended shelf life opportunities for new categories of food products.

Table 4.1 Selected active packaging systems

S.N.	Systems	Mechanisms	Food application
1.	Oxygen scavengers	1. Iron-based 2. Metal/acid 3. Metal (e.g. platinum) catalyst 4. Ascorbate/metallic salts 5. Enzyme-based	Bread, cakes, cooked rice, biscuits, pizza, pasta, cheese, cured meats, cured fish, coffee, snack foods, dried foods and beverages
2.	Carbon dioxide scavengers/ emitters	1. Iron oxide/calcium hydroxide 2. Ferrous carbonate/metal halide 3. Calcium oxide/activated charcoal 4. Ascorbate/sodium bicarbonate	Coffee, fresh meats, fresh fish, nuts, other snack food products and sponge cakes
3.	Ethylene scavengers	1. Potassium permanganate 2. Activated carbon 3. Activated clays/zeolites	Fruit, vegetables and other horticultural products
4.	Preservative releasers	1. Organic acids 2. Silver zeolite 3. Spice and herb extracts 4. BHA/BHT antioxidants	Cereals, meats, fish, bread, cheese, snack foods, fruit and vegetables

		5. Vitamin E antioxidant 6. Volatile chlorine dioxide/ sulphur dioxide	
5.	Ethanol emitters	1. Alcohol spray 2. Encapsulated ethanol	Pizza crusts, cakes, bread, biscuits, fish and bakery products
6.	Moisture absorbers	1. PVA blanket 2. Activated clays and minerals 3. Silica gel	Fish, meats, poultry, snack foods, cereals, dried foods, sandwiches, fruit and vegetables
7.	Flavour/odour adsorbers	1. Cellulose triacetate 2. Acetylated paper 3. Citric acid 4. Ferrous salt/ascorbate 5. Activated carbon/clays/ zeolites	Fruit juices, fried snack foods, fish, cereals, poultry, dairy products and fruit
8.	Temperature control packaging	1. Non-woven plastics 2. Double-walled containers 3. Hydro fluorocarbon gas 4. Lime/water 5. Ammonium nitrate/water	Ready meals, meats, fish, poultry and beverages

The shelf life of packaged food is dependent on numerous factors, such as the intrinsic nature of the food (e.g. pH, water activity, nutrient content, occurrence of antimicrobial compounds, redox potential, respiration rate, biological structure) and extrinsic factors (e.g. storage temperature, relative humidity, surrounding gaseous composition). These factors directly influence the chemical, biochemical, physical and microbiological spoilage mechanisms of individual food products and their achievable shelf life. By carefully considering all of these factors, it is possible to evaluate existing and developing active packaging technologies and apply them for maintaining the quality and extending the shelf life of different food products.

Lesson- 5 Modern Packaging System

5.1 Introduction

Various terms for new packaging methods can be found in the literature, such as active, smart, interactive, clever or intelligent packaging.

The definitions of active and intelligent packaging are

- Active packaging changes the condition of the packed food to extend shelflife or to improve safety or sensory properties, while maintaining the quality of the packaged food.
- Intelligent packaging systems monitor the condition of packaged foods to give information about the quality of the packaged food during transport and storage.

5.2 Active packaging

Active packaging refers to the incorporation of certain additives into packaging film or within packaging containers with the aim of maintaining and extending product shelf life. Packaging may be termed active when it performs some desired role in food preservation other than providing an inert barrier to external conditions. Active packaging includes additives or 'freshness enhancers' that are capable of scavenging oxygen, adsorbing carbon dioxide, moisture, ethylene and/or flavor/odor taints, releasing ethanol, sorbates, antioxidants and/or other preservatives and/or maintaining temperature control.

Active packaging techniques for preservation and improving quality and safety of foods can be divided into three categories; absorbers (i.e. scavengers, releasing systems and other systems. Absorbing (scavenging) systems remove undesired compounds such as oxygen, carbon dioxide, ethylene, excessive water, taints and other specific compounds. Releasing systems actively add or emit compounds to the packaged food or into the head-space of the package such as carbon dioxide, antioxidants and preservatives. Other systems may have miscellaneous tasks, such as self-heating, self-cooling and preservation. The main active packaging systems are:

5.2.1 Oxygen scavenger:

The most common oxygen scavengers take the form of small sachets containing various iron-based powders containing an assortment of catalysts. These chemical systems often react with water supplied by the food to produce a reactive hydrated metallic reducing agent that scavenges oxygen within the food package and irreversibly converts it to a stable oxide. The iron powder is separated from the food by keeping it in a small, highly oxygen permeable sachet.

5.2.2 Carbon Dioxide Scavengers/Emitters

There are many commercial sachet and label devices that can be used to either scavenge or emit carbon dioxide. The use of carbon dioxide scavengers is particularly applicable for fresh roasted or ground coffees that produce significant volumes of carbon dioxide. Fresh roasted or ground coffees cannot be left unpackaged since they absorb moisture and oxygen and lose desirable volatile aromas and flavors.

5.2.3 Ethylene Scavengers

Ethylene (C_2H_4) is a plant hormone that accelerates the respiration rate and subsequent senescence of horticultural products such as fruit, vegetables and flowers. Many of the effects of ethylene are necessary, e.g. induction of flowering in pineapples and colour development in citrus fruits, bananas and tomatoes, but in most horticultural situations it is desirable to remove ethylene or to suppress its effects. Effective systems utilize potassium permanganate ($KMnO_4$) immobilized on an inert mineral substrate such as alumina or silica gel. $KMnO_4$ oxidizes

ethylene to acetate and ethanol and in the process a change colour from purple to brown and hence indicates its remaining ethylene-scavenging capacity. $KMnO_4$-based ethylene scavengers are available in sachets to be placed inside produce packages or inside blankets or tubes that can be placed in produce storage warehouses.

5.2.4 Ethanol Emitters

The use of ethanol as an antimicrobial agent is well documented. It is particularly effective against mould but can also inhibit the growth of yeasts and bacteria. Ethanol can be sprayed directly onto food products just prior to packaging. The size and capacity of the ethanol-emitting sachet used depends on the weight of food, a_w of the food and the shelf life required. When food is packed with an ethanol-emitting sachet, moisture is absorbed by the food and ethanol vapor is released and diffuses into the package headspace.

5.2.5 Preservative Releasers

One most commonly used preservative releaser is a synthetic silver zeolite that has been directly incorporated into food contact packaging film. The purpose of the zeolite is apparently to allow slow release of antimicrobial silver ions into the surface of food products. Many other synthetic and naturally occurring preservatives have been proposed and/or tested for antimicrobial activity in plastic and edible films. These include organic acids, e.g. propionate, benzoate and

sorbate, bacteriocins, e.g. nisin,, spice and herb extracts, e.g. from rosemary, cloves, horseradish, mustard, cinnamon and thyme, enzymes, e.g. peroxidase, lysozyme and glucose oxidase, chelating agents, e.g. EDTA, inorganic acids, e.g. sulphur dioxide and chlorine dioxide, and anti-fungal agents, e.g. imazalil and benomyl. The major potential food applications for antimicrobial films include meats, fish, bread, cheese, fruit and vegetables.

5.2.6 Moisture Absorbers

Excess moisture is a major cause of food spoilage. Soaking up moisture by using various absorbers or desiccants is very effective at maintaining food quality and extending shelf life by inhibiting microbial growth and moisture-related degradation of texture and flavor. Moisture absorber sachets for humidity control in packaged dried foods, several companies manufacture moisture drip absorbent pads, sheets and blankets for liquid water control in high a_w foods such as meats, fish, poultry, fruit and vegetables are available.

5.2.7 Flavour/Odor Adsorbers

The interaction of packaging with food flavors and aromas has long been recognized, especially through the undesirable flavor scalping of desirable food components. Two types of taints amenable to removal by active packaging are amines, which are formed from the breakdown of fish muscle proteins, and Aldehydes that are formed from the autoxidation of fats and oils. Volatile amines with an unpleasant smell, such as trimethylamine, associated with fish protein breakdown are alkaline and can be neutralized by various acidic compounds [89]. The bags that are made from film containing a ferrous salt and an organic acid such as citrate or ascorbate are claimed to oxidize amines when they are absorbed by the polymer film. Odor and Taste Control (OTC) technology removes or neutralizes aldehydes.

5.3 Intelligent packaging

Intelligent packaging includes indicators to be used for quality control of packed food. They can be so-called external indicators, i.e., indicators which are attached outside the package (time temperature indicators), and so-called internal indicators which are placed inside the package, either to the head-space of the package or attached into the lid.

5.3.1 Time temperature indicator (TTI)

A time temperature indicator (TTI) can be defined as a simple device that can give the idea about easily measurable, time-temperature dependent change which affects full or partial temperature history of a food product to which it is connected. The principles of TTI operation are based on mechanical, chemical, electrochemical, enzymatic or microbiological irreversible change.

5.3.2 Freshness indicators

Two types of the changes can take place in the fresh food product i.e.

(i) Microbiological growth and metabolism resulting in pH changes, formation of toxic compounds, off-odors, gas and slime formation,

(ii) Oxidation of lipids and pigments resulting in undesirable flavors, formation of compounds with adverse biological reactions or discoloration.

A freshness indicator indicates directly the quality of the product. The indication of microbiological quality is based on a reaction between the indicator and the metabolites produced during growth of microorganisms in the product. An indicator that would show specifically the spoilage or the lack of freshness of the product, in addition to temperature abuse or package leaks, would be ideal for the quality control of packed products.

5.3.3 Pathogen indicators

Commercially available Toxin Guard™ is a system to build polyethylene-based packaging material, which is able to detect the presence of pathogenic bacteria with the aid of immobilized antibodies. As the analyte (toxin, microorganism) is in contact with the material it will be bound first to a specific, labelled antibody and then to a capturing antibody printed as a certain pattern. The method could also be applied for the detection of pesticide residues or proteins resulting from genetic modifications.

Module- 3 Different types of packaging materials used

Lesson- 6 Paper/Paperboard

6.1. Introduction

Pulp is the raw material for the production of paper, paperboard, corrugated board and similar manufactured products. It is obtained from plant fiber and is therefore a renewable resource. Today about 97 percent of the world's paper and board is made from wood pulp, and about 85 percent of the wood pulp used in from spruces, firs and pines – coniferous trees that predominate in the forests of the North Temperate Zone. There are three main constituents of wood cell wall:

- **Cellulose**

This is a long chain, linear polymer built-up of a large numbers of glucose molecules and is the most abundant, naturally occurring organic compound. Cellulose is moderately resistant to the action of chlorine and dilute sodium hydroxide under mild conditions, but is modified or dissolved under more severe conditions. It is relatively resistant to oxidation and therefore bleaching operations can be used to remove small amounts of impurities such as lignin without appreciable damage to the strength of the pulp.

- **Hemicelluloses**

These are lower molecular weight mixed sugar polysaccharides consisting of one or more of the following molecules: Xylose, mannose, arabivose, and glactose. Hemicelluloses are usually soluble in dilute alkalis.

- **Lignin**

This is highly branched, thermoplastic polymer of uncertain size, built up largely from substituted phenyl-propane units. It has no fiber forming properties and is attacked by chlorine and sodium hydroxide with formation of soluble, dark brown derivatives. It softens at about 160^{o}C.

The principal differences between paper, paperboard and fiberboard are thickness and use. Paper are thin, flexible and used for bags and wraps, paperboard is thicker, more rigid and used to construct single layer cartons, fiberboard is made by combining layers of strong papers and is used to construct secondary shipping cartons. Paper from wood pulp is bleached and coated or impregnated with waxes, resins, lacquers, plastics and laminations of aluminum to improve its strength, especially in high humidity environments such as are often found around foods. Acid treatment of paper pulp modifies the cellulose and gives rise to water and oil resistant parchments of considerable wet strength. These papers are called greaseproof or glassine papers and are characterized by long wood pulp fibers which imparts increased physical strength.

Kraft paper is the strongest of papers and in its unbleached form is commonly used for grocery bags. If bleached and coated, it is commonly used as butcher warp. The word Kraft comes from the German word for strong. Acid treatment of paper pulp modifies the cellulose and gives rise to water and oil resistant parchments of considerable wet strength.

These papers are called greaseproof or glassine papers and are characterized by long wood pulp fibers which impart increased physical strength.

Papers and paperboards used for packaging range from thin tissues to thick boards. The main examples of paper and paperboard based packaging are:

1. paper bags, wrapping, packaging papers and infusible tissues, e.g. tea and coffee bags, sachets, pouches, overwrapping paper, sugar and flour bags, carrier bags
2. multiwall paper sacks
3. folding cartons and rigid boxes
4. corrugated and solid fiberboard boxes (shipping cases)
5. paper based tubes, tubs and composite containers
6. fire drums
7. liquid packaging
8. moulded pulp containers
9. labels
10. sealing tapes
11. cushioning materials
12. cap liners (sealing wads) and diaphragms (membranes).

Paper and paperboard packaging is used over a wide temperature range, from frozen food storage to the high temperatures of boiling water and heating in microwave and conventional radiant heat ovens.

Whilst it is approved for direct contact with many food products, packaging made solely from paper and paperboard is permeable to water, water vapor, aqueous solutions and emulsions, organic solvents, fatty substances (except grease resistant paper grades), gases, such as oxygen, carbon dioxide and nitrogen, aggressive chemicals and to volatile flavors and aromas. Whilst it can be sealed with several types of adhesive, it is not, itself, heat sealable.

Paper and paperboard, however, can acquire barrier properties and extended functional performance, such as heat sealability for leak-proof liquid packaging, through coating and lamination with plastics, such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET or PETE) and ethylene vinyl

alcohol (EVOH), and with aluminum foil, wax, and other treatments. Packaging made solely from paperboard can provide a wide range of barrier properties by being overwrapped with a heat sealable plastic film such as polyvinylidene chloride (PVdC) coated oriented polypropylene (OPP or BOPP).

6.2. Properties of paper and paperboard

The features of paper and paperboard which make these materials suitable for packaging relate to appearance and performance. These features are determined by the type of paper and paperboard – the raw materials used and the way they have been processed. Appearance and performance can be related to measurable properties which are controlled in the selection of raw materials and the manufacturing process.

6.2.1. Appearance

Appearance relates to the visual impact of the pack and can be expressed in terms of colour, smoothness and whether the surface has a high or low gloss (matte) finish. Colour depends on the choice of fibre for the outer surface, and also, where appropriates, the reverse side. As described above, the choice is either white, brown or grey. In addition some liners for corrugated board comprise a mix of bleached and brown fibers. Other colors are technically possible either by using fibers dyed to a specific colour or coated with a mineral pigment colored coating.

6.2.2. Performance

Performance properties are related to the level of efficiency achieved during the manufacture of the pack, in printing, cutting and creasing, gluing and the packing operation. Performance properties are also related to pack compression strength in storage, distribution, at the point of sale and in consumer use. Specific measurable properties include stiffness, short span compression (rigidity) strength, tensile strength, wet strength, % stretch, tear strength, fold endurance, puncture resistance and ply bond strength. Other performance properties relate to moisture content, air permeability, water absorbency, surface friction, surface tension, ink absorbency etc. Chemical properties include pH, whilst chloride and sulphate residues are relevant for aluminum foil lamination. Flatness is easily evaluated but is a complicated issue as lack of flatness can arise from several potential causes, from the hygrosensitivity characteristics of the fibre, manufacturing variables and handling at any stage including printing and use. Neutrality with respect to odor and taint, and product safety are performance needs which are important in the context of paper and board packaging which is in direct or close proximity to food.

6.3. Types of paper

Paper is divided into two broad categories: Fine papers, generally made of bleached pulp, and typically used for writing paper, bond, book and cover papers, and coarse papers, generally made of unbleached Kraft softwood pulps and used for packaging. Main types of packaging papers are:

6.3.1. 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.

6.3.2. Bleached paper

These are manufactured from pulps which are relatively while, 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 augmented by day coating on one or both sides.

6.3.3. 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 break the cellulose fibers which absorb so much water that they become superficially gelatinized and sticky.

6.3.4. Glassine paper

Glassine paper derives its name from its glassy, smooth surface, high density and transparency. It is produced by further treating grease proof paper in a super calendar.

6.3.5. Vegetable parchment

Vegetable parchment takes its name from its physical similarity to animal parchment, which is made from animal skins. Because of its grease resistance and wet strength, it strips away easily from food material without defibering, thus finding use as an interleaver between slices of food such as meat or pastry. It was first used for wrapping fatty foods such as butter.

6.3.6. Tissue paper

Tissue papers range from semitransparent to totally opaque, and can be waxed. They are generally either machine – Finished (MF) or machine – Glazed (MG). MG papers may also be machine finished to improve the smoothness on both sides.

6.3.7. Waxed paper

Waxed papers provide a barrier against penetration of liquids and vapors. 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. 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 laminate.

6.4. Types of paper boards

Paperboards are made from the same raw materials as papers. They normally are made on the cylinder machine and consist of two or more layers of different quality pulps. The types of paperboard used in food packaging include:

6.4.1. Chipboard

Chipboard is made from a mixture of repulped waste with chemical and mechanical pulp. It is dull grey in colour and relatively weak. It is available lined on one side with unbleached, semi or fully bleached chemical pulp. A range of such paperboards are available, with different quality liners. Chipboards are seldom used in direct contact with foods, but are used as outer cartons when the food is already contained in a film pouch or bag e.g. breakfast cereals.

6.4.2. Duplex board

Duplex board is made from a mixture of chemical and mechanical pulp, usually lined on both sides with chemical pulp. It is used for some frozen foods, biscuits and similar products.

6.4.3. Solid white board

In Solid white board, all plies are made from fully, bleached chemical pulp. It is used for some frozen foods, food liquids and other products requiring special protection.

Lesson- 7 Glass

7.1. Definition of glass

The American Society for Testing Materials defined glass as 'an inorganic product of fusion which has cooled to a rigid state without crystallizing' (ASTM, 1965). The atoms and molecules in glass have an amorphous random distribution. Scientifically this means that it has failed to crystallize from the molten state, and maintains a liquid-type structure at all temperatures. In appearance it is usually transparent but, by varying the components, this can be changed-as also can important properties such as thermal expansion, colour and the pH of aqueous extracts. Glass is hard and brittle, with a chonchoidal (shell-like) fracture.

7.2. Glass Composition

Glass is primarily formed from oxides of metals, with the most common being dioxide which is common sand. Glass is made by mixing several naturally-occurring inorganic compounds at a temperature above their melting points. The molten mixture is then cooled to produce a noncrystalline, amorphous solid. The main ingredient is silica (sand) (SiO_2) that serves as the network-forming backbone of the glass. However, silica has a very high melting temperature, and molten silica has high viscosity that makes it difficult to form into shapes. Adding soda (Na_2O) modifies the silica network by disrupting some of the Si-O bonds, with resulting lower melting temperature and viscosity but reduced resistance to dissolving in water. Thus, lime (CaO) is added as a network stabilizer, with the result that durability is increased but tendency to crystallize is also increased. Finally, alumina (Al_2O_3) is added as an intermediate to resist crystallization. Minor amounts of colorants are added to produce colored glass, including chromium oxide for green, cobalt oxide for blue, nickel oxide for violet, selenium for red, and iron plus sulfur and carbon for amber. Amber provides the best protection for light-sensitive foods and beverages, transmitting very little light with wavelength shorter than 450 nm.

7.3 Types of glass

7.3.1 White flint (clear glass)

Colorless glass, known as white flint, is derived from soda, lime and silica. This composition also forms the basis for all other glass colors. 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. Cullet, recycled broken glass, when added to the batch reduces the use of these materials.

7.3.2 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.

7.3.3 Dark green

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

7.3.4 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.

7.3.5 Blue

Blue glass is usually obtained by the addition of cobalt to a low-iron glass. Almost any colored 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 colors would generally be outside the target price of most carbonated soft drinks.

7.4 Attributes of food packaged in glass containers

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

7.4.1 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.

7.4.2 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.

7.4.3 Surface texture

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.

7.4.4 Colour

A range of colors are possible based on choice of raw materials. Facilities exist for producing smaller quantities of nonmainstream colors.

7.4.5 Decorative possibilities

Decorative possibilities including ceramic printing, powder coating, colored and plain printed plastic sleeving and a range of labeling options.

7.4.6 Impermeability

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

7.4.7 Chemical integrity

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

7.4.8 Design potential

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

7.4.9 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.

7.4.10 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.

7.4.11 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.

7.4.12 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.

7.4.13 UV protection

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

7.4.14 Strength

Although glass is a brittle material glass containers have high top load strength making them easy to handle during filling and distribution. While the weight factor of glass is unfavorable 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.

Lesson- 8 Plastic

8. 0 Introduction

Plastic is an 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.

Plastics are used in the packaging of food because they offer a wide range of appearance and performance properties which are derived from the inherent features of the individual plastic material and how it is processed and used. Plastics are resistant to many types of compound – they are not very reactive with inorganic chemicals, including acids, alkalis and organic solvents, thus making them suitable, i.e. inert, for food packaging. Plastics do not support the growth of microorganisms. Some plastics may absorb some food constituents, such as oils and fats, and hence it is important that a thorough testing is conducted to check all food applications for absorption and migration. Gases such as oxygen, carbon dioxide and nitrogen together with water vapor and organic solvents permeate through plastics. The rate of permeation depends on:

- type of plastic
- thickness and surface area
- method of processing
- concentration or partial pressure of the permeant molecule
- storage temperature

Plastics have properties of strength and toughness. Polyethylene terephthalate (PET) film has a mechanical strength similar to that of iron, but under load the PET film will stretch considerably more than iron before breaking.

8.1. Application of Plastic in food processing

- Plastics are used as containers, container components and flexible packaging. In usage, by weight, they are the second most widely used type of packaging and first in terms of value. Applications of plastic are
- rigid plastic containers such as bottles, jars, pots, tubs and trays
- 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 withstand compression is required
- plastic lids and caps and the wadding used in such closures

- diaphragms on plastic and glass jars to provide product protection and tamper evidence 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 heat shrinkable sleeves
  - components of coatings, adhesives and inks.

8.2. Types of plastic used in packaging

8.2.1 Polyethylene

PE is structurally the simplest plastic and is made by addition polymerization of ethylene gas in a high temperature and pressure reactor. A range of low, medium and high density resins are produced, depending on the conditions (temperature, pressure and catalyst) of polymerization. Polyethylenes are readily heat sealable. They can be made into strong, tough films, with a good barrier to moisture and water vapor. They are not a particularly 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, which increases as the density increases.

LDPE and LLDPE can be used in blends with EVA to improve strength and heat sealing. There is a degree of overlap in application between LDPE and LLDPE, due to the fact that there are differences in both, as a result of the conditions of polymer manufacture and on-going product development. The thickness used for specific applications can vary, and this can also have commercial implications.

MDPE or medium-density PE 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.

HDPE or high-density PE 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.

8.2.2 Polypropylene (PP)

PP is an addition polymer of propylene formed under heat and pressure using Zieger-Natta type catalysts to produce a linear polymer with protruding methyl (CH2) groups. The resultant polymer is a harder and denser resin than PE and more transparent in its natural form.

The high melting point of PP (160°C) makes it suitable for applications where thermal resistance is needed. The surfaces of PP films are smooth and have good melting characteristics. PP films are relatively stiff. When cast, the film is glass clear and heat sealable. It is used for presentation applications to enhance the appearance of the packed product. PP is chemically inert and resistant to most commonly found chemicals, both organic and inorganic. It is a barrier to water vapor and has oil and fat resistance. Aromatic and aliphatic hydrocarbons are, however, able to be dissolved in films and cause swelling and distortion. Many of the PP films are used in the form of laminations with other PP and PE films. This allows for the reverse-side printing of one surface, which is then *buried* inside the subsequent laminate.

8.2.3 Polyethylene terephthalate (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. PET melts at a much higher temperature than PP, typically 260°C, and due to the manufacturing conditions does not shrink below 180°C. This means that PET is ideal for high-temperature applications using steam sterilization, boiling-the-bag and for cooking or reheating in microwave or conventional radiant heat ovens. The film is also flexible in extremes of cold, down to −100°C. PET is a medium oxygen barrier on its own but becomes a high barrier to oxygen and water vapor when metalized with aluminum. 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 high fat content requiring barriers to oxygen and ultra violet (UV) light.

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. 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.

8.2.4 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. 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.

Modified EVAs are available for use as peelable coatings on lidding materials such as aluminum 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.

8.2.5 Polyamide (PA)

Polyamides (PA) are commonly known as nylon. However, nylon is not a generic name; it is the brand name for a range of nylon products made by Dupont. 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 characterized by a number which relates to the number of carbon atoms in the originating monomer.

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

8.2.6 Polyvinyl chloride (PVC)

PVC has excellent resistance to fat and oil. It is used in the form of blowmoulded 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 vapor 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. 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 plasticized, 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.

Unplasticised PVC (UPVC) has useful properties but is a hard, brittle material, and modification is necessary for it to be used successfully. Flexibility can be achieved by the inclusion of plasticizers, reduced surface friction with slip agents, various colors by the addition of pigments and improved thermal processing by the addition of stabilizing agents.

8.2.7 Polystyrene (PS)

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 dead fold property. It has a low barrier to moisture vapor 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.

Lesson- 9 Metal

9.0. Introduction

Two basic types of alloyed metals are used in food packaging i.e. steel and aluminum. Steel is used primarily to make rigid cans, whereas aluminum is used to make cans as well as thin aluminum foils and coatings. Nearly all steel used for cans was coated with a thin layer of tin to inhibit corrosion, and called as "tin can". The reason for using tin was to protect the metal can from corrosion by the food. Tin is not completely resistant to corrosion, but its rate of reaction with many food materials is considerably slower than that of steel.

The strength of the steel plate is another important consideration especially in larger cans that must withstand the pressure stresses of retorting, vacuum canning and other processes. Can strength is determined by the temper given the steel, the thickness of the plate, the size and the geometry of the can, and certain construction features such as horizontal ribbing to increase rigidity. This ribbing is known as beading. The user of cans will find it necessary to consult frequently with the manufacturer on specific applications, since metal containers like all other materials of packaging are undergoing constant change.

Aluminum is light weight, resistant to atmospheric corrosion, and can be shaped or formed easily. However, aluminum has considerably less structural strength than steel at the same gauge thickness. This means that aluminum has limited use in cans such as those used with retorted foods. Aluminum works well in very thin beverages cans that contain internal pressure such as soda or beer. This internal pressure from CO2 gives rigidity to the can. Aluminum in contact with air forms an aluminum oxide film which is which is resistant to atmospheric corrosion. However, if the oxygen concentration is low, as it is within most foods containing cans, this aluminum oxide film gradually becomes depleted and the underlying aluminum metal is then no longer highly resistant to corrosion. (potter)

9.1 Metals used in packaging

The metal materials used in food packaging are aluminum, tinplate and electrolytic chromium-coated steel (ECCS). Aluminum is used in the form of foil or rigid metal.

9.1.1. Aluminum Foil

Aluminum foil is produced from aluminum ingots by a series of rolling operations down to a thickness in the range 0.15–0.008 mm. Most foil used in packaging contains not less than 99.0% aluminum, with traces of silicon, iron, copper and in some cases, chromium and zinc. Foil used in semi rigid containers also contains up to 1.5% manganese. After rolling, foil is annealed in an oven to control its ductility. This enables foils of different tempers to be produced from fully annealed (dead folding) to hard, rigid material. Foil is a bright, attractive material, tasteless, odorless and inert with respect to most food materials. For contact with acid or salty products, it is coated with nitrocellulose or some polymer material. It is mechanically weak, easily punctured, torn or abraded. Foil is used as a component in laminates, together with polymer materials and, in some cases, paper. These laminates are formed into sachets or pillow packs on FFS equipment (see Section 9.3.6). Examples of foods packaged in this way include dried soups, sauce mixes, salad dressings and jams. Foil is included in laminates used for retortable pouches and rigid plastic containers for ready meals. It is also a component in cartons for UHT milk and fruit juices.

9.1.2. Tin

9.1.2.1. Tinplate

Tinplate is the most common metal material used for food cans. It consists of a low-carbon, mild steel sheet or strip, 0.50–0.15 mm thick, coated on both sides with a layer of tin. This coating seldom exceeds 1% of the total thickness of the tinplate. The mechanical strength and fabrication characteristics of tinplate depend

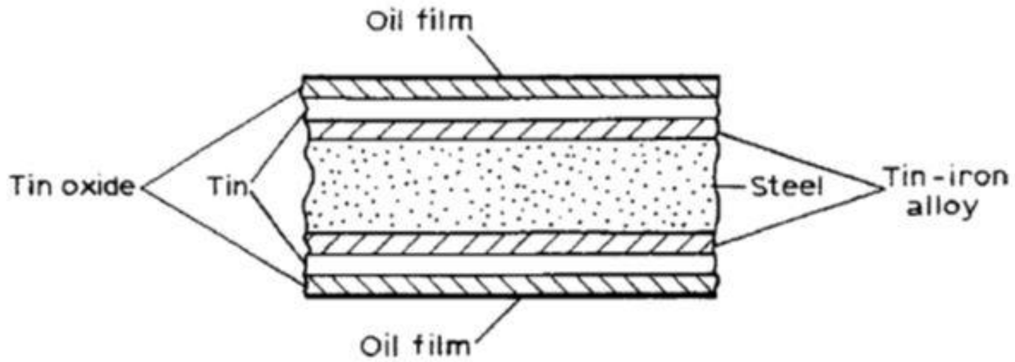


Figure 9.1: Structure of tin plate

on the type of steel and its thickness. The minor constituents of steel are carbon, manganese, phosphorous, silicon, sulphur and copper. At least four types of steel, with different levels of these constituents, are used for food cans. The corrosion resistance and appearance of tinplate depend on the tin coating.

9.1.2.2. Tin coating

The role of tin coating is an essential component of the can construction and plays an active role in determining shelf life. The most significant aspect of the role of the tin coating is that it protects the steel base-plate which is the structural component of the can. Without a coating of tin, the exposed iron would be attacked by the product and this would cause serious discoloration and off-flavors in the product and swelling of the cans; in extreme cases the iron could be perforated and the cans would lose their integrity. The second role of tin is that it provides a chemically reducing environment, any oxygen in the can at the time of sealing being rapidly consumed by the dissolution of tin. This minimizes product oxidation and prevents colour loss and flavor loss in certain products.

9.1.2.3 *Tin toxicity*

High concentrations of tin in food irritate the gastrointestinal tract and may cause stomach upsets in some individuals, with symptoms which include nausea, vomiting, diarrhoea, abdominal cramps, abdominal bloating, fever and headache. Tin corrosion occurs throughout the shelf life of the product. It is therefore imperative to take steps to reduce the rate of corrosion. Accelerating factors include heat, oxygen, nitrate, some chemical preservatives and dyes, and certain particularly aggressive food types (e.g. celery, rhubarb). A high vacuum level is one effective method of reducing the rate of tin pick-up in cans with un-lacquered components.

9.2. Electrolytic Chromium-Coated Steel (ECCS)

Electrolytic chromium-coated steel (ECCS), sometimes described as tin free steel, is finding increasing use for food cans. It consists of low-carbon, mild CR or DR steel coated on both sides with a layer of metallic chromium and chromium sesqueoxide, applied electrolytically. ECCS is less resistant to corrosion than tinplate and is normally lacquered on both sides. It is more resistant to weak acids and sulphur staining than tinplate.

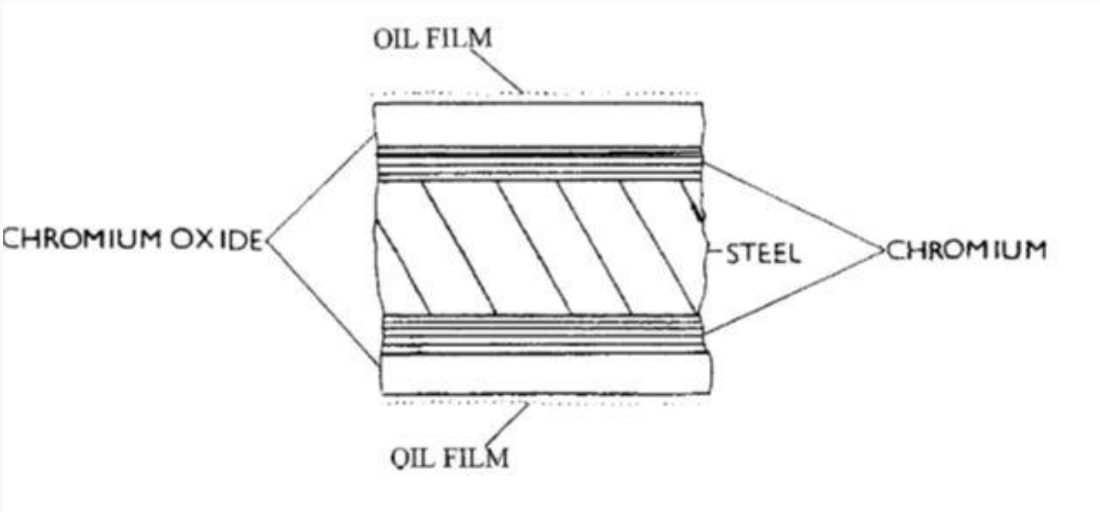


Figure1: Structure of ECCS plate

9.3. Aluminum Alloy

Hard-temper aluminum alloy, containing 1.5–5.0% magnesium, is used in food can manufacture. It is lighter but mechanically weaker than tinplate. It is manufactured in a similar manner to aluminum foil. It is less resistant to corrosion than tinplate and needs to be lacquered for most applications. A range of lacquers suitable for aluminum alloy is available, but the surface of the metal needs to be treated to improve lacquer adhesion.

9.4. Lead

Lead was a problem with older, soldered cans but levels are now very low. However, some tinplate is contaminated with minimal amounts of lead. The manufacture of lead soldered cans may still be found in the developing world.

9.5. Lacquers

The presence of lacquer or enamel very effectively limits dissolution of tin into the product, and so the use of lacquers is becoming increasingly common, even with those products which were previously packed in plain tinplate cans. There are several different types of lacquer in common use today. By far the most common type is the Epoxy Phenolic group, which are suitable for packing meat, fish, vegetable and fruit products.

These have largely replaced the oleoresinous group, which had a similar wide range of application. Some canners use cans lacquered with vinyl resins, which have the important quality of being free from any taste and odor, and are therefore particularly suitable for dry packs such as biscuits and powders, but also some drinks. White vinyl lacquers have been used where staining of the underlying metal caused by reaction with the product is a problem. Also, white vinyl lacquers have been used for marketing reasons in order to present a hygienic/clinical appearance and not the aesthetically undesirable corrosion patterns on tinplate.

Lesson- 10 Other packaging materials

10.1. Edible films

Edible films and coatings formed from polysaccharides, proteins, lipids, resins, and/or waxes fall within the active packaging definition, since they can enhance the protective function, provide convenience, and minimize package environmental impact. Edible films placed or formed between components of a packaged food control transfer of moisture, oils, etc. over which the package has no control. Edible coatings or edible film pouches (as a primary package) work to complement the protective function of the nonedible (secondary) package. Such coatings and films can act as barriers to the external environment and maintain food integrity, thus reducing the amount of packaging required. Edible film pouches carrying premeasured amounts of ingredients can provide the convenience of placing pouch with ingredients into the food formulation. Edible coatings can also carry antimicrobials that can inhibit microbial growth at both the food-coating interface and the coating outer surface.

A number of food applications of edible films and coatings have been. Several polysaccharide-, sucrose-ester-,lipid- and resin-based edible coating formulations are available commercially to control moisture loss and respiration in fresh fruits and vegetables. Starch, hydroxypropyl methylcellulose (HPMC), zein, gelatin, and shellac coatings are available for confectionery and other food products. Edible collagen casings and wraps for meat and HPMC pouches for dry foods are available commercially. A large number of foods would benefit from development of suitable edible films or coatings.

Food materials can be protected from loss of volatiles or reaction with other food ingredients by being encapsulated in protective edible materials. This can be done by spray drying various flavoring materials emulsified with gelatin, gum Arabic, or other edible materials to form a thin protective coating around each food particle. The coatings of raisins with starches to prevent them from moistening a packaged breakfast cereal and the coating f nuts with monoglyceride derivatives to protect them from oxidative rancidity are additional examples of edible coatings.

Food materials such as amylase starch and the proteins zein and casein when solubilized can be cast to give sheets of edible films on drying. These films may then be used to fabricate small packets to hold other food ingredients. One application of such films has been to package baking ingredients which can then be added directly to the mixing bowl as an intact packet, on addition of water, the edible film dissolves and releases the packed ingredients.

Edible films are also used to coat fresh fruits and vegetables to reduce moisture loss and to provide increased resistance to growth of surface molds. The most common and oldest edible film is wax .A wide range of products such as apples are waxed for appearance and improved keeping quality. Newer edible films are being developed which can keep produce longer.

10.2. Laminates

Packages made of polymer films are not absolute barriers against the transfer of water and O_2 through the package, although they may be excellent barriers against microorganisms and dirt. Various flexible materials (papers, plastic films, thin metal foils) differ with respect to water vapor transmission, oxygen permeability, light transmission, burst strength, pinhole and crease hole sensitivity and so on. Multilayers or laminates of these materials that combine the best features of each can be used to produce packaging materials with combined properties such as the strength of paper, heat seal ability of plastics, and barrier properties of aluminum foils. Another new technique for combining different plastics is co extrusion simultaneously forces two or more molten plastics through adjacent flat dies in a manner that ensures laminar flow and produces a multilayer film on cooling. Such structured plastic films may be complete in themselves or be further bonded to papers or metal foils to produce more complex laminates.

10.3. Retortable pouches and Trays

Flexible pouches, semi-rigid/rigid plastic trays and cans, and paperboard-based cartons have been developed as alternatives to heat processing (retorting) in rigid metal cans or glass containers. The pouches, trays, and tubs are always multilayer laminate structures that contain different polymers which provide heat resistance, strength, and toughness (PET), pierce and pinhole resistance (nylon), oxygen barrier (EVOH, nylon or PVDC) and (for the pouches and trays) heat sealability (PP). An aluminum foil layer often serves as the moisture and oxygen barrier in pouches. The retortable paperboard cartons have external and internal PP layers that are impermeable to liquid and allow heat sealing, along with an internal aluminum layer that provides a gas and light barrier.

Retortable pouches can be either preformed or in-line formed using form/fill/seal equipment. Common pouch structures are PET/nylon/foil/PP and PET/nylon/EVOH or PVDC/PP. Retortable trays have a semi-rigid or rigid body and a sealable flexible lid. The trays are generally made from coextruded laminate such as PET/EVOH/PP by thermoforming. Retortable tubs are made from similar multi-layer laminates. An easy-open scored metal lid with pull ring is double seamed onto the tub body.

The advantage of retortable pouches and trays is that they have thinner profile than conventional metal or glass containers. The results are shortened process times, reduced energy consumption, and improved food quality due to more rapid and even heat transfer. In addition, retort pouches, trays, and tubs are convenient because of easy transport (due to shape and light weight) and easy opening. Plastic (with no foil layer) pouches, trays, and tubs are microwaveable. The main disadvantage of retortable pouches, trays, tubs, and cartons is more difficult recycling.

Flexible materials can be combined to withstand even the adverse conditions of retorting encountered with low-acid foods. Such "flexible cans" have becomes standard containers for some applications such as providing foods to soldiers in the fields. The advantages of pouches and trays over cans and jars of equivalent volume include shorter retort times, which can produce higher quality products and save on energy, lighter weight, increased compactness, easier opening and easier disposability. Retortable pouches are constructed of a three-ply laminate consisting of 1) an outer layer of polyester films for high – temperature resistance, strength and printability. 2) A middle layer of aluminum foil for barrier properties, and 3) an inner layer of polypropylene film that provides heat- seal integrity. Retortable trays are constructed from multilayers of polymers, one of which is ethylene- vinyl alcohol to provide an oxygen barrier. These trays are often sealed with a polymer-foil laminate film.

10.4. Cloth materials

Jute and cotton are woven materials which have been used for packaging foods. Sacks made of jute are used, to a limited extent, for fresh fruit and vegetables, grains and dried legumes. However, multiwall paper sacks and plastic sacks have largely replaced them for such products. Cotton bags have been used in the past for flour, sugar, salt and similar products. Again, paper and plastic bags are now mainly used for these foods. Cotton scrims are used to pack fresh meat. However, synthetic materials are increasingly used for this purpose.

10.5. Wooden Containers

Outer wooden containers are used when a high degree of mechanical protection is required during storage and transport. They take the form of crates and cases. Wooden drums and barrels are used for liquid products. The role of crates has largely been replaced by shipping containers. Open cases find limited use for fish, fruits and vegetables, although plastic cases are now widely used. Casks, kegs and barrels are used for storage of wines and spirits. Oak casks are used for high quality wines and spirits. Lower quality wines and spirits are stored in chestnut casks.

10.6. Composite Containers

So called composite containers usually consist of cylindrical bodies made of paperboard or fiberboard with metal or plastic ends. Where good barrier properties are required, coated or laminated board may be used for the body or aluminum foil may be incorporated into it. Small containers, less than 200 mm in diameter, are referred to as tubes or cans and are used for foods such as salt, pepper, spices, custard powders, chocolate beverages and frozen fruit juices. Larger containers, known as fiberboard drums, are used as alternatives to paper or plastic sacks or metal drums for products such as milk powder, emulsifying agents and cooking fats.

10.7. Regenerated Cellulose

Regenerated cellulose (cellophane) differs from the polymer films in that it is made from wood pulp. Good quality, bleached sulphite pulp is treated with sodium hydroxide and carbon disulphide to produce sodium cellulose xanthate. This is dispersed in sodium hydroxide to produce viscose. The viscose is passed through an acid-salt bath which salts out the viscose and neutralizes the alkali. It provides general protect against dust and dirt, some mechanical protection and is greaseproof. When dry it is a good barrier to gases, but becomes highly permeable when wet. Plain cellulose is little used in food packaging. Plain regenerated cellulose is mainly used coated with various materials which improve its functional properties. The most common coating material is referred to as 'nitrocellulose' but is actually a mixture of nitrocellulose, waxes, resins, plasticizers and some other agents.

10.8. Cellulose Acetate

Cellulose acetate is made from waste cotton fibers which are acetylated and partially hydrolyzed. The film is made by casting from a solvent or extrusion. It is clear, transparent and has a sparkling appearance. It is highly permeable to water vapor, gases and volatiles. It is not much used in food packaging except as window material in cartons. It can be thermoformed into semirigid containers or as blister packaging

Module- 4 Different forms of packaging, metal container, glass container,plastic container,flexible films,shrink packaging,vacuum & gas packaging

Lesson- 11 Metal Containers

11.0 Introduction

The total world market for metal containers is estimated at 410 billion units per annum. Of this, drink cans account for 320 billion and processed food cans account for 75 billion. The remainder is 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 pasteurization process.

11.1. Raw materials for can-making

Steel and aluminum are used for metal container and closure construction for food and drink products. Both are relatively low-cost materials that are nontoxic, having adequate strength and are capable of being work hardened.

11.1.1. Steel

Steel is used in the form of low-carbon steel which is initially produced as black plate. This is then converted into tinplate or tin-free steel (TFS) for container and closure manufacture. Tinplate is created by electrolytically coating black plate with a thin layer of tin. The tin is coated on both sides of the plate in thickness to suit the internally packed product and the external environment. Different thicknesses of tin may be applied to each side of the plate. Tin, plated in sufficient thickness, provides good corrosion-resisting properties to steel, and is suitable for direct contact with many products including specific foodstuffs such as white fruits (e.g. peaches, apricots, pineapple and pears) and certain tomato-based products (e.g. tomatoes in brine and beans in tomato sauce). However, for most foods and drinks it is necessary to apply an organic coating to the inside surfaces of the tinplate container to provide an inert barrier between the metal and the product packed. This barrier acts to prevent chemical action between the product and container and to prevent taint or staining of the product by direct contact with the metal (see later). The tin surface assists in providing good electrical current flow during welding processes. Being a very soft metal, it also acts as a solid lubricant during the wall ironing process of forming two piece thin wall cans.

11.1.2. Aluminum

Aluminum for light metal packaging is used in a relatively pure form, with manganese and magnesium added to improve the strength properties. This material cannot be welded by can-making systems and can only be used for seamless (two-piece) containers. The internal surfaces of aluminum containers are always coated with an organic lacquer because of the products normally packed.

11.2 Recycling of packaging metal

Both aluminum- and steel-based packaging materials are readily re-melted by the metal manufacturers. Waste materials arising during the can-making processes may be returned for recycling through third party merchants. Postconsumer metal packaging waste is collected and, after automatic separation from other waste materials, is ultimately returned to the metal manufacturers for re-melting. Aluminum and steel suffer no loss of quality during the re-melting process so may be reused an unlimited number of times for the production of first-quality packaging material. Certain recycling processes permit the tin to be separated from the steel base prior to re-melting.

11.3. Can-making

Metal cans are the most common metal containers used for food packaging. The traditional three-piece can (open or sanitary) is still very widely used for heat-processed foods. The cylindrical can body and two ends are made separately. One end is applied to the can body by the can maker, the other (the canners end) by the food processor after the can has been filled with product. The ends are stamped out of sheet metal, the edges curled in and a sealing compound injected into the curl. The body blank is cut from the metal sheet, formed into a cylinder and the lapped, side seam sealed by welding or by polyamide adhesive. Both ends of the cylindrical body are flanged in preparation for the application of the can end. Food and drink cans may be constructed either as three-piece or two-piece containers.

Three-piece cans consist of a cylindrical body rolled from a piece of flat metal with a longitudinal seam (usually formed by welding) together with two can ends, which are seamed onto each end of the body. The three-piece can-making process is very flexible, as it is possible to produce almost any practical combination of height and diameter. This process is particularly suitable for making cans of mixed specifications, as it is relatively simple to change the equipment to make cans of different dimension. Three-piece welded food cans are only constructed from steel, as aluminum is not suitable for welding by this particular process. Coils of steel, after delivery from the steel maker, are cut into sheets approximately $1m^2$. The cut sheets are then coated, and printed if necessary, to protect and decorate the surfaces. Areas where the weld will be made on the can body are left without coating or print to ensure the weld is always sound. The coatings and inks are normally dried by passing the sheets through a thermally heated oven where the temperature is in the range 150–205°C. Alternatively, for some non-food contact uses, ultraviolet (UV)-sensitive materials may be applied. These are cured instantaneously by passing the wet coating/ink under a UV lamp.

The drawn can (DR can) is a type of two-piece container. The can body and base are made in one operation from a blank metal sheet by being pressed out with a suitable die. The open end of the body is flanged. The can end, manufactured as described above, is applied to the body by double-seaming after the can is filled with product. Because of the strain on the metal, DR cans are shallow with a maximum height: diameter ratio of 1: 2. The drawn and re-drawn can (DRD) is another type of two-piece can. It is made by drawing a cup to a smaller diameter in a series of stages to produce a deeper container than the DR can. The can end is applied to the filled can by double-seaming. DRD cans are usually relatively small, cylindrical and have a height: diameter ratio of up to 1.2: 1.0.The drawn and wall-ironed can (DWI) is made from a disc of metal 0.30–0.42 mm thick. This is drawn into a shallow cup which is forced through a series of ironing rings of reducing internal diameter so that the wall of the cup gets thinner and higher. The top of the body is trimmed, flanged and the end applied by double-seaming after filling the can. Because of the very thin body wall, typically 0.10 mm thick, DWI cans are mainly used for packaging carbonated beverages. The internal pressure supports the thin wall.

The dimensions of cylindrical cans are usually specified in diameter and height, in that order. In many countries the units of diameter and height are millimeters. In the UK and USA inches and 16ths of an inch are used. Thus a can specified as 401/411 has a diameter of 41/16 inches and a height of 411/16 inches. In the case of rectangular or oval cans, two horizontal dimensions must be given.

Other metal containers used for packaging foods include:

- cylindrical cans with a friction plug closure at the canners end, used for dry powders such as coffee and custard powders or for liquids such as syrups and jams;
- rectangular or cylindrical containers with push-on lids, often sealed with adhesive tape, used for biscuits and sweets;
- rectangular or cylindrical containers, incorporating apertures sealed with screw caps, used for liquids such as cooking oils and syrups;
- metal drums used for beer and other carbonated drinks

11.4. End-making processes

11.4.1 Plain food can end and shells for food/drink easy-open ends

The initial processes for making plain food can ends and easy-open ends for food and drink cans are the same. The body of an end that will be ultimately converted into an easy-open end is referred to as a shell. Plain ends/shells may be stamped directly from wide coils of metal or from sheets cut from coils. Whether from coil or sheet, the metal is fed through a press that produces multiple stampings for every stroke.

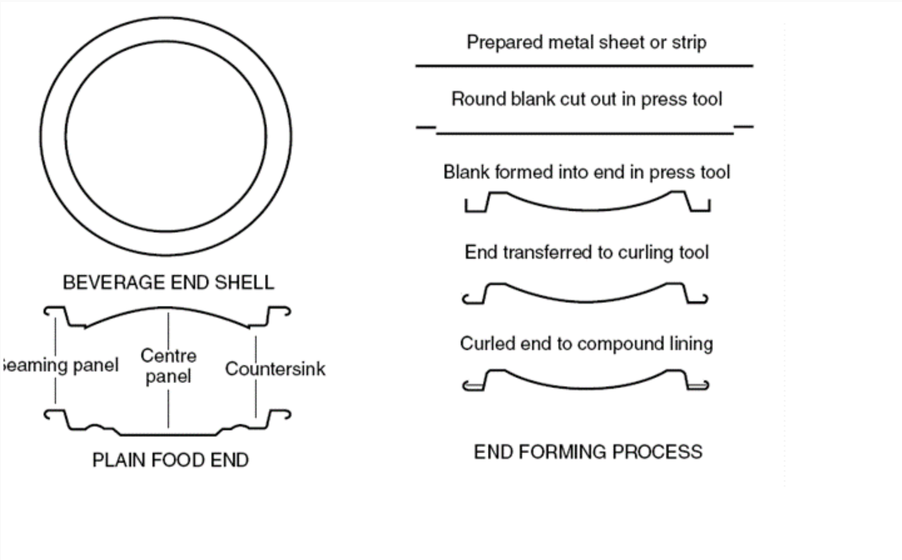


Figure 11.1: Forming of Plain ends

After removal from the forming tool, the edges of the end shells are then curled over slightly to aid in the final operation of mechanical seaming the end onto the flange of the filled can. After curling, the end shells are passed through a lining machine that applies a bead of liquid-lining compound around the inside of the curl.

11.4.2 Conversion of end shells into easy-open ends

The principles used in the conversion of end shells are the same for both full aperture food easy-open ends and small aperture drink easy-open ends. The conversion operations comprise scoring (partially cutting through) the perimeter of the opening panel and attaching a metal tab with which to tear-open the panel. Scoring is necessary to reduce the force required to open the end to an acceptable level.

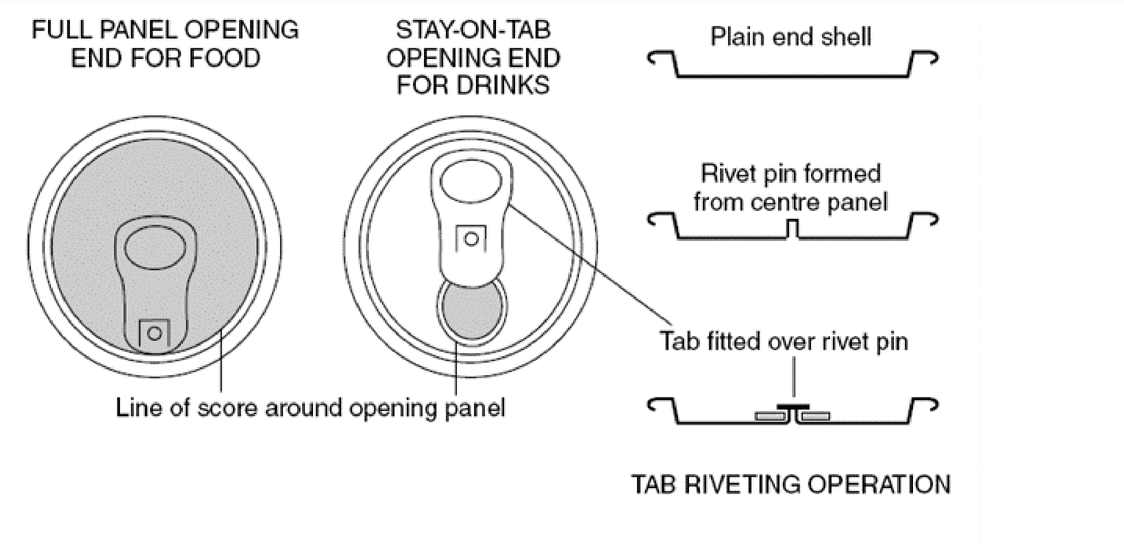


Figure 11.2.: Easy-open end conversion

The pull-tab is made from a narrow strip of pre-coated aluminum or steel, which is in coil form. The strip is first pierced and cut, and then the tab is formed in two further stages before it is ready to be joined to the end shell.

Lesson- 12 Glass Containers

12.0 Introduction

Glass is inert with respect to foods, transparent and impermeable to vapours, gases and oils. Because of the smooth internal surface of glass containers, they can be washed and sterilized and used as multitrip containers, e.g. milk and beer bottles. However, glass containers are relatively heavy compared to their metal or plastic counterparts, susceptible to mechanical damage and cannot tolerate rapid changes in temperature (low thermal shock resistance).Broken glass in a food area is an obvious hazard. The two main types of glass container used in food packaging are bottles, which have narrow necks, and jars and pots, which have wide openings. Glass closures are not common today, but were once popular as screw action stoppers with rubber washers and sprung metal fittings for pressurized bottles, e.g. for carbonated beverages, and vacuumised jars, e.g. for heat preserved fruits and vegetables. Ground glass friction fitting stoppers were used for storage jars, e.g. for confectionery. 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.

12.1. Glass container manufacture

12.1.1. Melting

Glass is melted in a furnace at temperatures of around 1350°C (2462°F) 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 (2012°F).

12.1.2. 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 (1200°F).

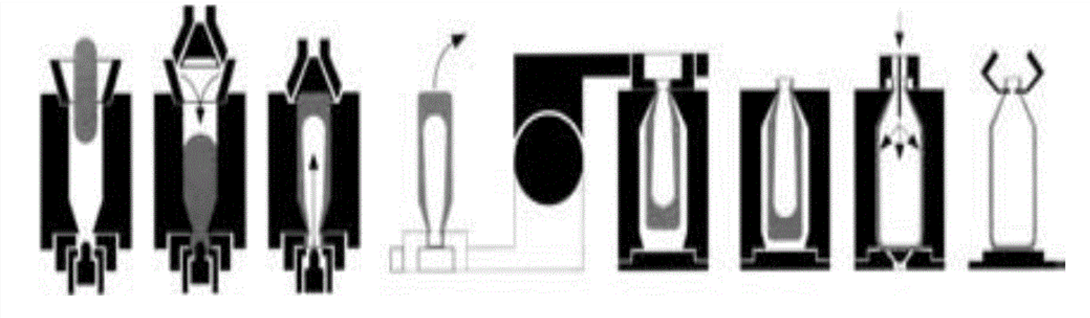


Figure 12.1: The blow and blow forming process (courtesy of Rock ware Glass)

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”).

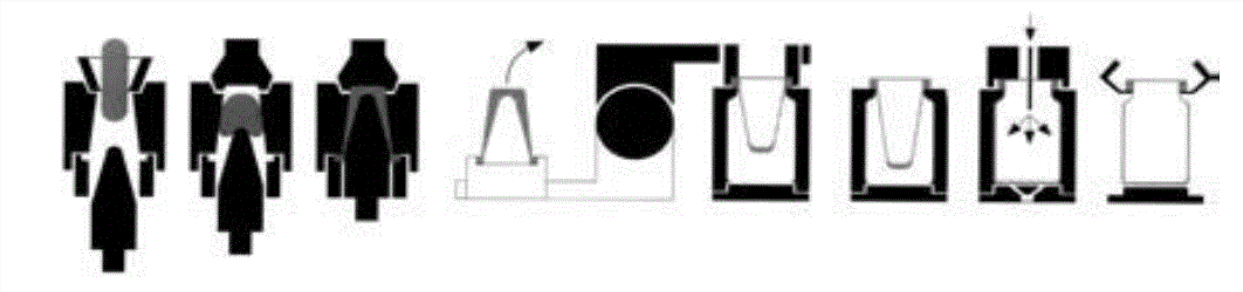


Figure 12.2: The wide mouth press and blow forming process (courtesy of Rockware Glass)

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.

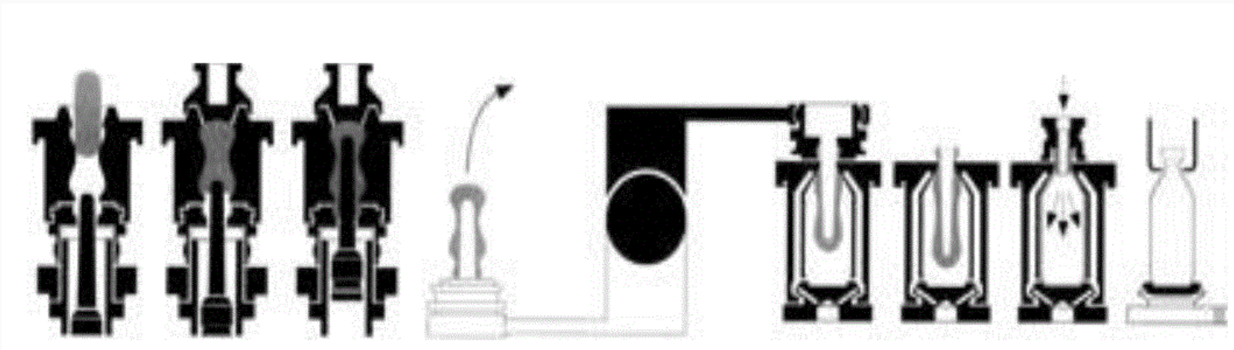


Figure 12.3: The narrow neck press and blow forming process (courtesy of Rockware Glass)

Glass containers become weaker with use, due to abrasion of the outer surface as a result of container to container contact or contact with other surfaces. Treating the surface with compounds of titanium or tin and replacement of the sodium ions at the surface with potassium ions can reduce this problem. The resistance of glass containers to sudden changes in temperature is reduced as the thickness of the glass increases. Thus, when designing glass containers which are to be subjected to heating or cooling, e.g. when the product is to be sterilized or pasteurized in its bottle or jar, or if the container is to be hot-filled with product, a compromise has to be achieved between their mechanical strength and thermal shock resistance. Heating and cooling should be carried out relatively slowly to avoid thermal damage to glass containers.

Glass containers are sealed by compressing a resilient disc, ring or plug against the sealing surface of the container and maintaining it in the compressed condition by means of a retaining cap. The resilient material may be cork, rubber or plastic. The cap is made of metal or plastic. The cap may be screwed on, crimped on or pushed in or onto the finish of the container. Roll-on caps are used as tamper-evident closures. Different closures are effective when: (a) the pressure inside the container is close to atmospheric pressure (normal seal), (b) the pressure inside the container is less than that outside (vacuum seal), (c) the pressure inside the container is higher than that outside (pressure seal). Pressure seals are necessary when packaging carbonated drinks. Single trip glass containers are used for liquids such as some beers, soft drinks, wines, sauces, salad dressings and vinegars and for dry foods such as coffee and milk powders. Multitrip containers are used for pasteurized milk, some beers and soft drinks. Products heated in glass containers include sterilized milk, beer, fruit juices and pickled vegetables.

12.2. Surface treatments

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

12.2.1. 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

12.2.2. 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 vapor, 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.

12.3 Inspection and quality

Quality assurance needs are defined and incorporated into the specification of the glass container at the design stage and by, consistency in manufacture, thereby meeting the needs of packing, distribution and use. Quality control, on the other hand, comprises the procedures, including on-line inspection, sampling and test methods used to control the process and assess conformity with the specification. The techniques used can broadly be defined as chemical, physical and visual.

Chemical testing by spectrophotometry, flame photometry and X-ray fluorescence is used to check raw materials and the finished glass. Small changes in the proportions and purity of raw materials can have a significant effect on processing and physical properties.

Physical tests include checking dimensional tolerances, tests for colour, impact strength, thermal shock resistance and internal pressure strength. Visual tests check for defects that can be seen. Visual inspection on manufacturing and packing lines is assisted today by automatic monitoring systems; Infrared cameras can be used in a system to examine containers directly after formation.

Lesson- 13 Plastic Containers

13.0 Introduction

The first plastics were derived from natural raw materials and, subsequently, in the first half of the 20th century, from coal, oil and natural gas. 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 are widely used for packaging materials and in the construction of food processing plant and equipment, because:

- they are flowable and mouldable under certain conditions, to make sheets, shapes and structures
- they are generally chemically inert, though not necessarily impermeable
- they are cost effective in meeting market needs
- they are lightweight
- they provide choices in respect of transparency, colour, heat sealing, heat resistance and barrier.

Gases such as oxygen, carbon dioxide and nitrogen together with water vapor and organic solvents permeate through plastics. The rate of permeation depends on:

type of plastic

- thickness and surface area
- method of processing
- concentration or partial pressure of the permeant molecule
- storage temperature.

Plastics are chosen for specific technical applications taking the specific needs, in packing, distribution and storage, and use of the product into consideration, as well as for marketing reasons, which can include considerations of environmental perception.

13.1. Plastics packaging

13.1.1 Manufacturing of plastics for packaging

The plastic raw material, also known as resin, is usually supplied by the polymer manufacturer in the form of pellets. Plastics in powder form are used in some processes. Whilst 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.

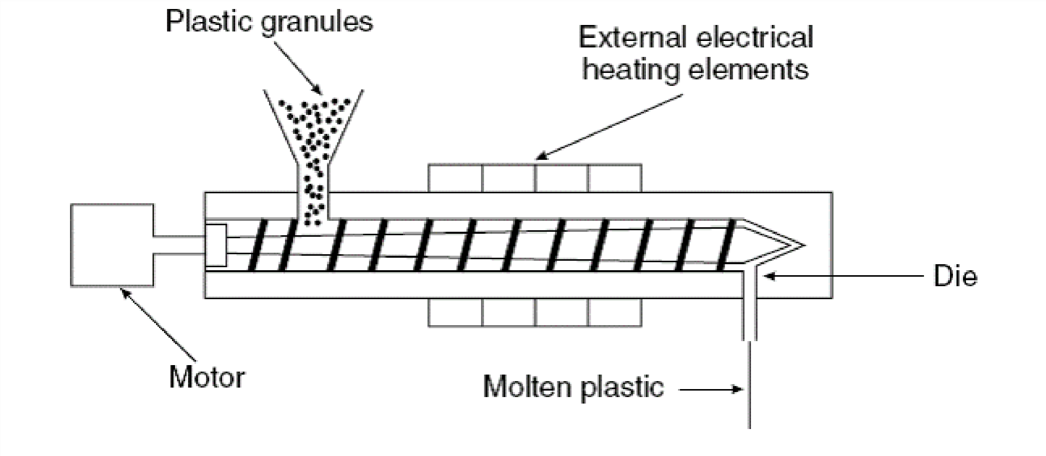


Figure 13.1 :Extruder

The plastic is melted by a combination of high pressure, friction and externally applied 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 (Fig).In the manufacture of rigid packaging, such as bottles and closures, the molten plastic is forced into shape using a precisely machined mould.

13.1.2 Manufacturing of plastic film and sheet for packaging

The most commonly used materials for flexible packaging films are LDPE, LLDPE, HDPE, PP, and PVC. Single-layer films are generally made by extrusion, in which plastic pellets are heat-softened sufficiently to melt and flow, and then the molten plastic is forced through either a slit (slot) die or a circular (tubular) die. The semi-molten film exiting from a slit dies is cooled with a quenching water bath or chilled casting rolls. The film can then be reheated and stretched in the machine direction and/or transverse to the machine direction to orient the polymer chains in the film to improve strength, barrier, and shrink properties. One-direction orientation is called uni-axial orientation, while two-direction is called bi-axial orientation. From a circular die, the film can be blown up like a bubble to give transverse orientation while the film is being pulled to also give orientation in the machine direction. The resulting films can be used as food wraps or heat-sealed into bags and pouches.

A polymer film can be solution-coated or extrusion-coated with another polymer to produce a bilayer film with improved strength, barrier, heat-sealability, appearance, and/or printability properties. Solution coating involves coating with a solution or dispersion of another polymer and then evaporating the solvent. In extrusion coating, a semi-molten film emerging from an extruder is deposited

directly on the previously formed film. Plastic films, most often PP or PET, can also be coated with a thin layer of aluminum or glass. The aluminum is vaporized in a vacuum and then condenses onto the film surface (vacuum metallization). Coatings of SiOx can be formed onto plastic films by sputtering, evaporation, or plasma-enhanced chemical vapor deposition.

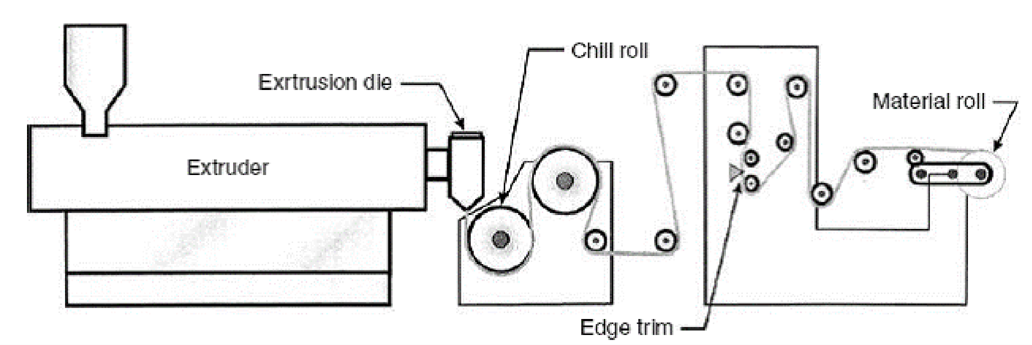


Figure 13.2: Extrusion of cast plastic film using a slit die

Two or more previously formed single-layer films can be laminated to give a multi-layer film with improved properties. The layers can be bonded by applying an adhesive between the films and then passing the laminate structure between pressure rollers (adhesive laminating). The layers can also be bonded by extrusion coating one of the films and then immediately pressing the second film against the still-molten layer (extrusion laminating). Polymer films can also be laminated with paper and/or aluminum foil to combine the properties of each material into a package structure.

In the blown 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 chilled 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. With the blown film process, orienting is achieved by increasing the pressure inside the tube to create a tube with a much larger diameter.

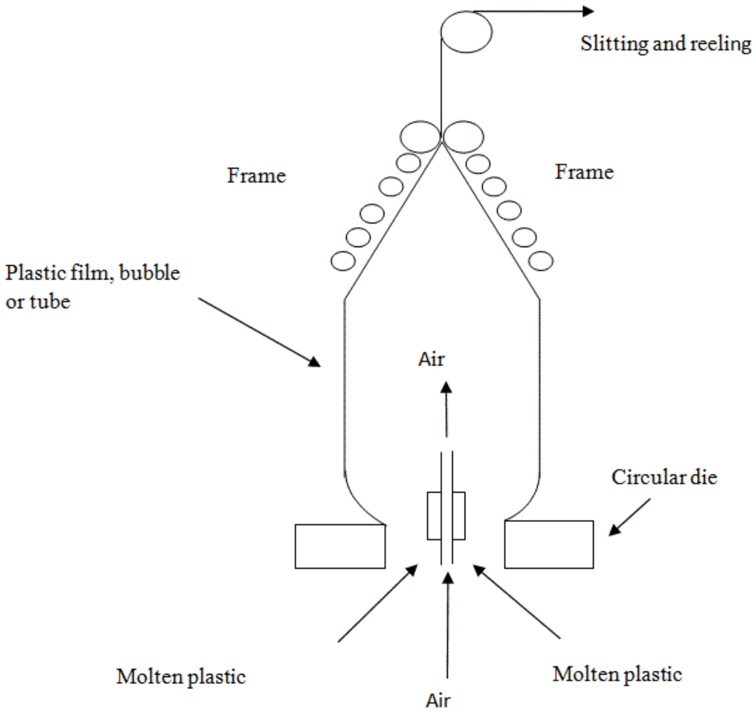


Figure 13.3: Blown film

13.1.3. Pack types based on use of plastic films, laminates etc.

Single films, coextruded films and coated and laminated films in reel form are used to make plastic bags, sachets, pouches and overwraps. Plastic bags are made by folding, cutting and sealing with welded seams which are also cut in the same operation. Pouches are usually made from laminates. They may be formed on the packing machine either from one reel by folding, or from two reels and sealing, inside face to inside face on three sides

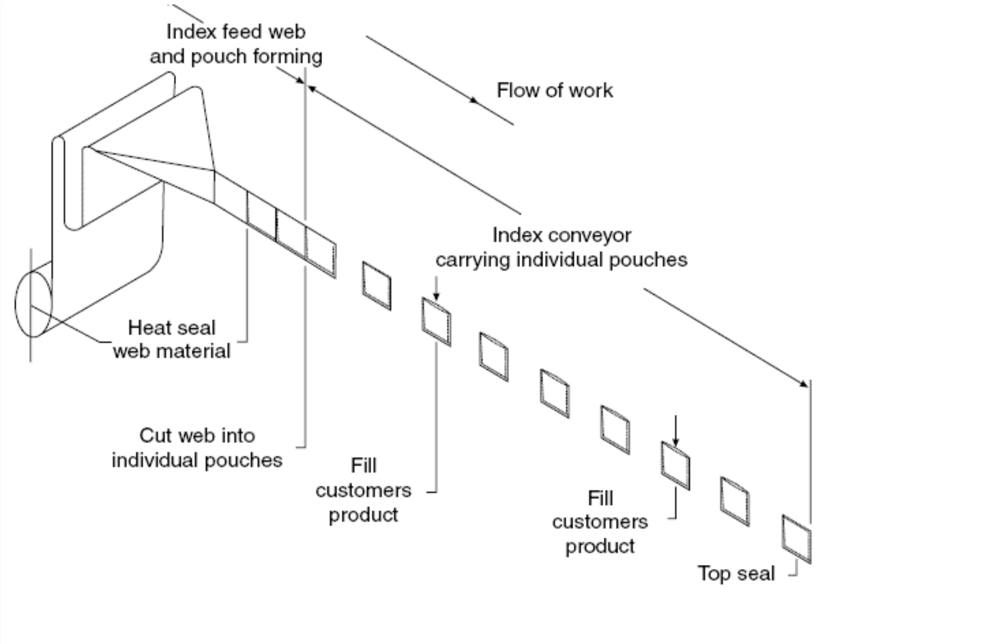


Figure 13.4: Form/fill/seal sachet/pouch machine

prior to filling and closing. The pouches travel horizontally on these machines with the product filled vertically.

Pouches can have a base gusset or a similar feature, which enables them to stand when filled and sealed. Pouches can be made separately, and they can be filled manually or fed from magazines on automatic filling machines. 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. (Fig)

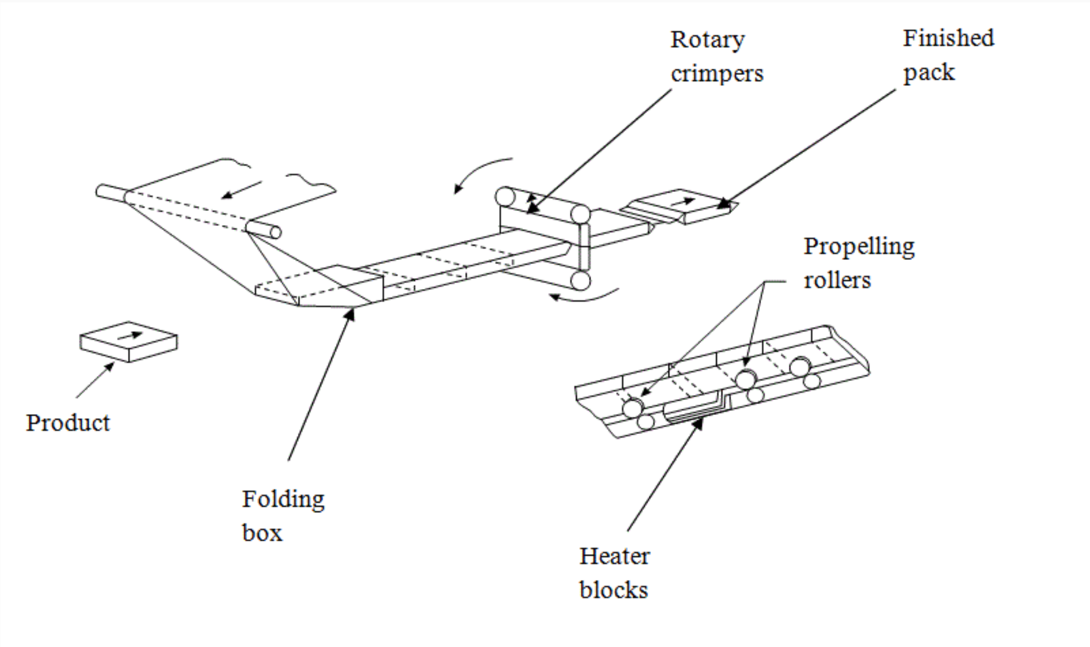


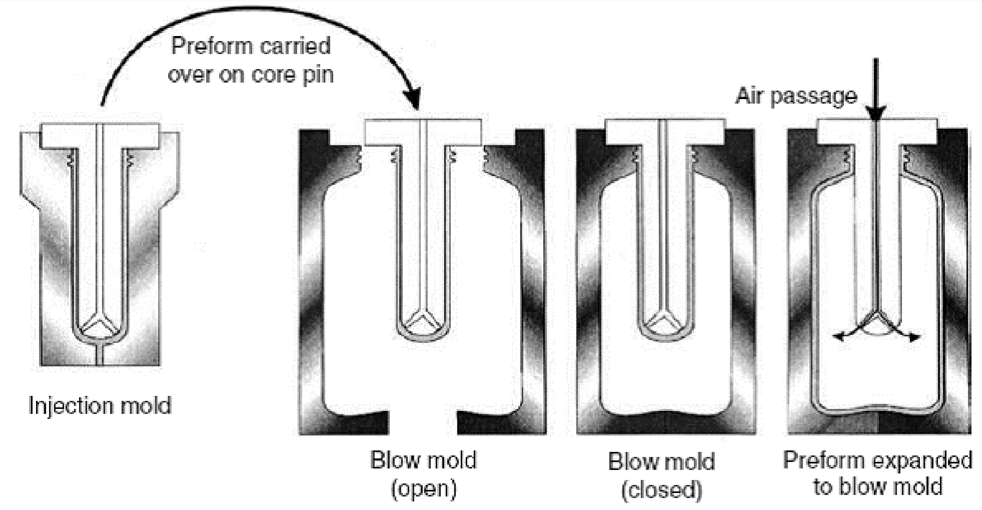
Figure 13.5: Form, fill, seal (f/f/s), flow pack type machine

These packs are formed around a tube, through which the previously apportioned product passes. A longitudinal heat seal is made either as a fin seal, with inside surface sealing to inside surface, or as an overlap seal, depending on the sealing

compatibility of the surfaces. The cross seal is combined with cutting to separate the individual packs.

13.1.4. Semi-Rigid and Rigid Plastic Packaging

Bottles are made by extrusion blow moulding. A thick tube of plastic is extruded into a bottle mould which closes around the tube, resulting in the characteristic jointed seal at the base of the container. Air pressure is then used to force the plastic into the shape of the mould. After cooling, the mould is opened and the item removed. Blow moulding is used for milk bottles (HDPE) and wide mouth jars.



Injection molding involves heat-softening plastic pellets in an extruder and then injection of the molten plastic under pressure into a cool mold. The two halves of the mold then open to eject the solid container. PE, PP, and PS are the most commonly used materials to manufacture plastic tubs, cups, and lids by injection

molding. Retortable and microwaveable PP trays are also made by the injection molding process.

Injection stretch blow molding is similar to injection blow molding. A preform is also made in an injection mold. However, in the blowing step, a rod is used to stretch the preform longitudinally at the same time as it is being blown transversally. The resulting biaxial orientation improves strength, barrier, and optical properties.

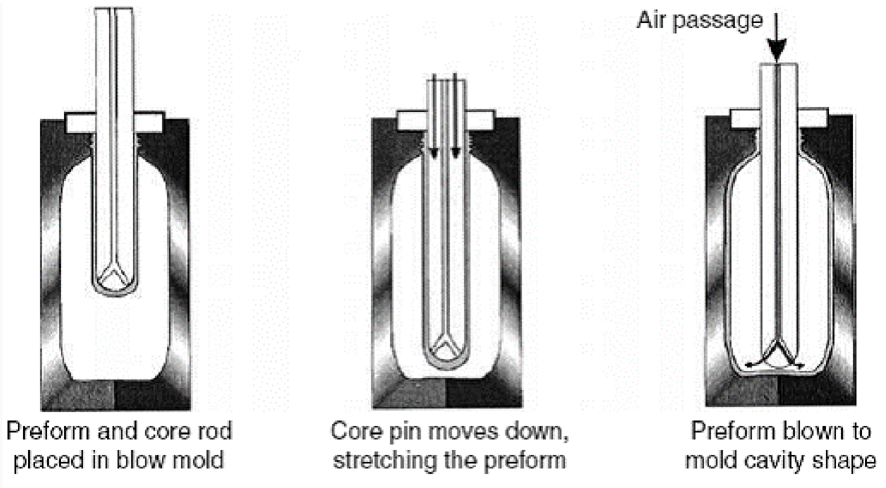


Figure 13.7: Stretch blow molding of a plastic bottle

The polymer that is most commonly injection stretch blow molded is PET for production of bottles intended for both carbonated and noncarbonated beverages. Other polymers that are sometimes molded in this manner include PVC and PP.

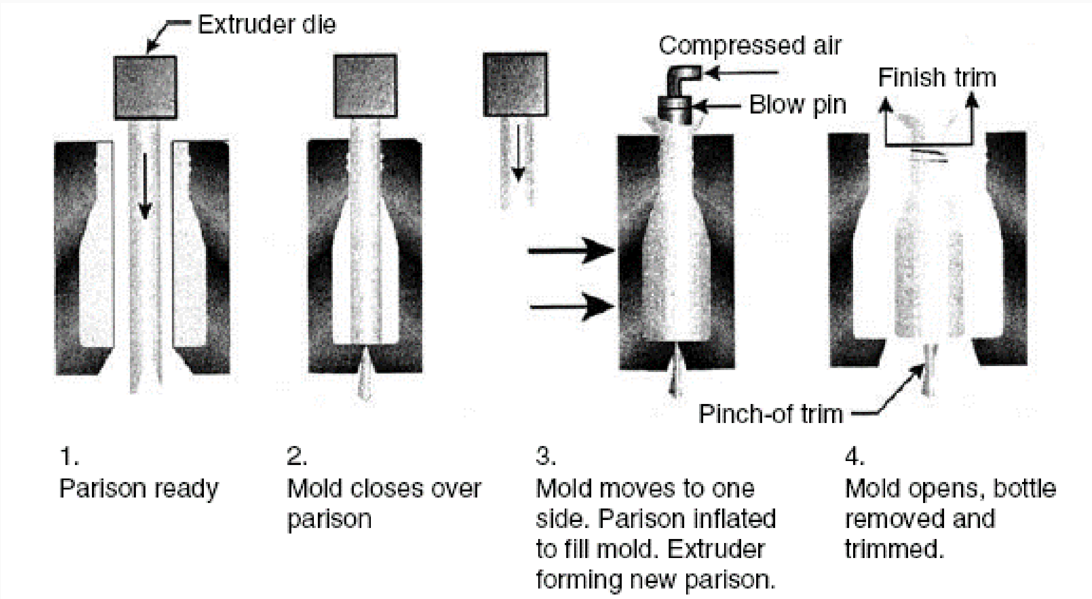


Figure 13.8: Extrusion blow molding of a plastic bottle

Extrusion blow molding involves extruding a heat-softened hollow tube (parison), quickly closing the two halves of a mold around the tube, and blowing the still-soft parison against the sides of the mold. The newly formed bottle or jug is held in the mold until cool. The mold then opens, and the bottle or jug is removed and trimmed above the finish and at the bottom where the mold pinches the parison tube.

Lesson- 14 Retort Pouch

14.0 Introduction

The retort pouch is a rectangular, flexible, laminated plastic, four-side hermetically sealed pouch in which food is thermally processed. It is a lightweight, high-quality, durable, convenient and shelf stable packs. Foods packed and processed in retort pouches are in successful commercial use for a wide variety of foodstuffs in several countries, particularly Japan. The materials from which retort pouches are made are either aluminum foil bearing/plastic laminates or foil-free plastic laminate films. Retortable pouches can be either preformed or in-line formed using form/fill/seal equipment. Common pouch structures are PET/nylon/foil/PP and PET/nylon/EVOH or PVDC/PP. Retortable pouches are used by hotels, restaurants, and other institutions.

Retortable pouches must be inert, heat sealable, dimensionally stable and heat resistant to at least 121°C for typical process times. They should have low oxygen and water vapor permeability, be physically strong and have good ageing properties. Retail consumer products such as tuna, salmon, chicken patties, chipped beef, chili, and ground beef in retortable pouches have become available. Pouches are reverse printed in a wide range of graphics on the PET film before lamination, so that the print cannot come into contact with the food. All laminates are required to meet very stringent requirements to ensure no undesirable substances can be extracted into the packaged food.

14.1. Manufacturing of pouches

Pouches can either be formed from reels of laminated material either on in-line form/fill/seal machines in the packer's plant or they may be obtained as preformed individual pouches sealed on three sides, cut and notched. Forming consists of folding the laminate material in the middle, polyester (or PA) side out, heat sealing the bottom and side seals and cutting to present a completed pouch. Alternatively two webs can be joined, heat seal surfaces face to face, sealed, cut and separated. Hot bar sealing is the most common practice. Notches are made in the side seal at the top or bottom to facilitate opening by the consumer. Modern pouches have cut rounded corners which reduce the possibility of perforation caused by pouch to pouch contact. Rounded corner seals can also be incorporated.

The four-seal flat shape and thin cross section of the pouch is designed to take advantage of rapid heat penetration during sterilization and on reheating, prior to consumption, saving energy and providing convenience. The flat shape also enables ease of heat sealing and promotes high seal integrity. Fin seal design and certain gusset features permit the design of upright standing pouches although they create multiple seal junctions with increased possibility of seal defects. Several of these upstanding pouches are, however, available commercially. A wide range is possible in the size and capacity of pouches.

14.2. Filling and sealing

The premade pouches are filled vertically in-line. Vertical form/fill/seal machines can be used for liquid products. Another method employs a web of pouch material which is formed on a horizontal bed into several adjacent cavities. The cavities are filled whilst the seal areas are shielded. This method is especially useful for filling placeable products. Thereafter the filled cavities are simultaneously sealed from the top using a second web fed from the reel. The essential requirements for filling are:

- Pouch should be cleaned, fully opened to the filling station, solids are filled first followed by the liquid food at a second station
- Matching fill-nozzle design and filler proportioning to the product
- Non-drip nozzles are used for filling
- Shielding of the sealing surfaces
- Bottom to top filling
- Specification and control of weight consistent with the maximum pouch thickness requirement
- Product consistency in formulation, temperature and viscosity
- Deaeration prior to filling.

Sealing machines like fillers are constantly being refined and speed has improved from 30 to 60 pouches per minute to the current production rate of 120–150 pouches per minute. Sealers incorporate either one of two common satisfactory sealing methods namely hot bar and impulse sealing. Both methods create a fused seal whilst the pouch material is clamped between opposing jaws, thereby welding the opposing seal surfaces by applying heat and pressure. Exact pouch-sealing conditions depend on the materials and machinery used.

14.3. Quality assurance

A successful pouch packaging quality system requires:

- Selection and continued monitoring of the most suitable laminate materials.
- Regular testing of formed pouches for seal strength, product resistance and freedom from taint.
- Careful selection, maintenance and control of filling, sealing, processing and handling machinery.
- Specifications for the control of product formulation, preparation (viscosity, aeration, fill temperature etc.) and filling (ingoing mass and absence of seal contamination).
- Post sealing inspection and testing of closure seals to confirm fusion, absence of defects and contamination.
- Control of critical parameters influencing processing lethality such as maximum pouch thickness and residual air content.
- Standardized retorting procedures applying only recommended process times and temperatures confirmed to achieve adequate lethality.
- Regular inspection and testing of retort equipment and controls to ensure uniform heat distribution.
- Visual inspection of all pouches to check sealing after processing.
- Handling only of dry pouches and packing into collective or individual outer packaging specially tested to provide adequate, subsequent, abuse resistance.

- It should be routine that all stocks are held 10–14 days prior to distribution and these should be free of blown spoilage on dispatch.
- Careful staff selection and training at all levels.

14.4. Shelf life

Whilst shelf life is determined by many factors such as storage temperature and the barrier properties of the particular film used, in general, satisfactory shelf stability in excess of two years is easily obtained for a wide range of products in foil bearing pouches. US military rations tested over two years at 20°C showed no significant change in product quality ratings. Some products have been successfully stored for as long as seven years and found to be safe and edible.

Foil-free laminates will demonstrate shelf stability commensurate with oxygen permeability of the particular laminate used and the sensitivity of the product. Commercial experience confirms, however, that product stability from four weeks to six months is obtainable. Nitrogen flushing of the outer container has been successful in extending the shelf life of product in foil-free pouches.

Lesson- 15 Vacuum, Gas and Shrink packaging

15.1. Vacuum Packaging:

Vacuum packaging is the simplest and common means of modifying the internal gaseous atmosphere in a pack. Vacuum packaging is a form of modified atmosphere packaging in which food is placed in a gas-impermeable package, most of the oxygen around the food is removed, and the package is hermetically sealed.

Vacuum packaging inhibits the growth of aerobic microorganism including food spoilage bacteria and molds that would normally deteriorate the quality of products. The removal of oxygen can also prevent degradation or oxidative processes that limit product shelf-life, for example, oxidative rancidity in fats and oils, or color deterioration in raw meats. An added advantage for frozen foods is that the sealing of the food within a skin-tight package prevents dehydration and evaporative water loss from the surface of the food, and can minimize the effects of "freezer burn" (excessive dehydration loss from the product surface) and post-thaw exudate (drip loss) that often limit the quality shelf-life of frozen foods. Reduced oxygen packaging (ROP), which provides an environment that contains little or no oxygen, offers particular advantages but also raises many microbiological concerns. environment that contains little or no oxygen favor the growth of anaerobic microorganism such as facultative pathogenic bacteria (e.g., Listeria, Salmonella, Escherichia coli, Yersinia, and Staphylococcus) and anaerobic bacteria such as nonproteolytic (psychrotropic) Clostridium botulinum type E that can grow at chill temperature (>3.3°C) [11]. Freezing is an excellent.

Table 15.1: Self life of different food commodities in different storage conditions

S.N.	Food	Storage condition	Normal shelf life	Vacuum shelf life
1.	Large cuts of meat: beef, poultry, lamb and pork	Freezer	6 months	2-3 years
2.	Fish	Freezer	6 months	2 years
3.	Coffee beans	Room temperature	4 weeks	16 months
4.	Coffee beans	Freezer	6-9 months	2-3 years
5.	Berries: strawberries, raspberries, blackberries	Refrigerator	1-3 days	1 week

6.	Berries: cranberries, huckleberries, blueberries	Refrigerator	3-6 days	2 weeks
7.	Cheese	Refrigerator	1-2 weeks	4-8 months
8.	Cookies, crackers	Room temperature (periodically opening)	1-2 weeks	3-6 weeks
9.	Flour, sugar, rice	Room temperature	6 months	1-2 years
10.	Lettuce	Refrigerator	3-6 days	2 weeks
11.	Nuts	Room temperature	6 months	2 years
12.	Oils with no preservatives, like safflower, canola, corn oil	Room temperature	5-6 months	1-1.5 years
13.	Wine	Refrigerator	1-3 weeks	2-4 months

Ref: Table adapted by Tilia Inc. from Dr. G.K.York, Dept. of Food Science & Tech, U of California, Davis.

means of long-term food preservation, but it is also an excellent means of preserving microorganisms already present in the food at the outset.

As we can see from table 5.1 vacuum packaging technology is well suited for frozen food products, owing to which it can enhance the shelf life and overall quality of food for a longer period of time. It is now widely used in many kinds of foods, particularly in ready meals. A successful vacuum packaging combined with freezing technology is influenced by the nature of food, the nature of package, and the freezing process. The vacuum packaging requires a high-barrier material to keep almost no oxygen for food products inside package. Vacuum packaging consists of multilayer films with a heat-seal layer and a high-barrier layer. The future materials with high-barrier properties can be developed by using nanotechnology. The nanocomposites film with small amount of organoclay (2%–5%) and nanocoating by plasma technology can enhance the barrier properties and still maintain the transparency of material, and is cost effective.

15.2. Gas packaging:

Gas packaging is a form of packaging involving the removal of air from the pack and its replacement with a single gas or mixture of gasses. Gas packaging can be achieved in two fundamental ways. These are the replacement of air with a gas or mixture mechanically or by generating the atmosphere within the package either passively as in the case of fruits or vegetables or actively by using atmosphere modifiers such as oxygen absorbents. There are two techniques for mechanical air replacement in a package

15.2.1 Gas flushing

This method employs a continuous gas stream that flushes air out from the package prior to sealing. This method is less effective at flushing air out of the pack, and this result in residual oxygen levels of 2–5%. Gas flushing is therefore not suited for oxygen-sensitive food products. Generally, gas flushing machines have a simple and rapid operation and therefore a high packing rate. The gas flush process is usually performed on a form-fill-seal machine. Gas is injected into a package to replace the air. This dilutes the air in the head space surrounding the food product. When most of the air has been replaced the package is sealed. There is a limit to the efficiency of the system since replacement of the air in the package is accomplished by dilution. Typical residual oxygen levels in gas flush technique is not suitable for packaging very oxygen sensitive food. The great advantage of the gas flush process is speed. It is a continuous operation.

15.2.2 Compensated vacuum

This method uses a two-stage process:

15.2.2.1 The evacuation stage

A vacuum is pulled on the pack to remove air. Generally, it is not possible to achieve a full vacuum, since reduced pressures will result in water to boil, at which point the vacuum cannot be improved.

15.2.2.2 Gas flushing stage

The pack is flushed with the modified gas mix. The evacuation of air from the pack results in lower residual oxygen levels than that achieved by gas flushing, and therefore this method is better suited for packing oxygen-sensitive products. The two-stage process employed by the compensated vacuum method results in a lower packaging rate than that possible with gas flushing.

15.3. Shrink Packaging

Shrink film is used as the basic material and heat forms an important part of the operation in shrink packaging or commonly known as shrink wrapping. Shrink wrapping is done in following four stages:

- wrapping (sleeve wrapping or over-wrapping)
- sealing (necessary only for over-wrapping)
- shrinking (with application of hot air), and
- cooling

Shrink wrapping is mainly used for unitization, but some time same is also being used as primary packaging system. This system is also used for bulk packaging as well as retail packaging of foods. Shrink wrapping is now being used for some major applications like sleeving for labelling on various containers or sealing, besides wrapping. But material selection plays an important role, because without the correct material, proper shrink wrapping may not be possible.

15.3.1 Plastics used for Shrink Wrapping

Shrink wrapping can be quite complex in their structure. Most of the packaging films that are used for shrink wrapping are from the polyolefin range. These are materials produced from oil based chemicals by what is called a polymerization process, which basically means getting the right molecules and atoms to club together in a way that is required or desirable for a particular application.

The most commonly used plastic materials for shrink packaging are

15.3.1.1 Polypropylene

Polypropylene is comparatively less used in shrink and stretch wrapping, because it is slightly harder than the other commonly used materials. It has a higher melting temperature and is less stable when shrinking. However, many over-wrapping

machines use polypropylene and some can be put through a shrink tunnel to give a slight tightening effect.

15.3.1.2 Poly vinyl chloride

PVC is a dense material. As most polymers are sold by weight and there has been ecological pressure in Europe and America against its use, sometime use of PVC is restricted. However, it is still considered to be a common material in India, when clarity is an important selection criterion, particularly for consumer packaging.

15.3.1.3 Polyethylene

Polyethylene is the most commonly used material for shrink and stretch wrapping because it is relatively cheap and can be produced in a range of different densities and modified with additives to perform many functions. The vast majority of shrink film is LDPE and some of the more sophisticated films have blends of LLDPE as well. Sometimes a little quantity of HDPE material is also added. For selection of plastic material, besides type of plastics, the yield of the film is also important to be considered from the economy point of view.

Table 15.2: Performance Comparison of Shrink Films

S.N.	Film type	Advantage	Possible problems
1.	Polyethylene (low density)	1) Strong heat seals (2) Low temperature shrinks. 3) Medium shrink force for broad	1) Narrow shrink temperature range. 2) Low stiffness 3) Poor optical property 4) Sealing wire contamination

		application 4) Lowest cost	
2.	Polypropylene	1) Good optical appearance 2) High stiffness 3) High shrink force 4) No heat sealing fumes 5) Good durability	1) High shrink temperature 2) High shrink force, not suitable for delicate or fragile product. 3) Brittle seals 4) High sealing temperature
3.	Co-polymers	1) Strong heat seals 2) Good optical appearance 3) High shrink force 4) No heat sealing vapours	1) High shrink force, not suitable for fragile products 2) Higher shrink temperature 3) Higher heat seal temperature 4) Lower film slip-may give machine problems
4.	Poly Vinyl Chloride	1) Lowest shrink temperature 2) Wide shrink temperature range 3) Excellent optical appearance 4) Controlled stiffness by plasticizer content control 5) Lowest shrink force for wrapping fragile products	1) Weakest heat seals 2) Least durable after plasticizer loss 3) Toxic and corrosive gas emission from heat sealing, therefore good ventilation required 4) Durability problem at low temperature 5) Low shrink force inhibits use as a multiple –unit bundling film 6) Low film slip causes machine wrapping difficulties

5.	Multilayer Co-extrusion	1) Excellent optical appearance 2) Good machineability 3) Low shrink temperature	1) In co-extruded films, one ply co-extrusion compensates for the deficiencies of the other. As a result, they are superior films with no significant performance shortcomings. 2) The wide variability in layer composition and number of layer makes performance analysis difficult.

For shrink film, the next important factors considered are the shrinkage and the slip of the film. Shrinkage means the percentage shrink in the machine direction, i.e. along the reel of the film, and also in the transverse direction i.e. across the reel of the film. The slip can be of different types – high, medium or low depending upon how much slippery property in the film is required from the operational point of view. Usually, low slip is desirable. For shrink wrapping small packs at high speed, particularly for consumer products or display purposes, PVC or specially modified Polyolefin may be used. The “high shrink films” are crystal clear but generally expensive.

Module- 5 Packaging requirement & their selection for the raw & processed foods

Lesson- 16 Role of Ideal packaging materials

16.0 Introduction

Packaging provides quality and quantity assurance besides creating hygienic environment for food product. It offers security through tamper proof designs and contributes to the product image through structural and graphical design. Food safety is permanent importance as package products against biological, chemical and distribution damages. The primary objective or packaging is to protect the contents during storage, transportation and distribution against deterioration. It may be physical, chemical or biological. According to Robertson (1992), packaging as the enclosure of the products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other containers to perform the various functions, i.e. containment, protection, information, promotion, etc.

Packaging of food serves many purposes such as providing effective protection to package foods against external contamination from environment; preserving the quality of food. It is one of the most important parameters that sale the product and also a communication device to provide detailed information about the product like, contents, ingredients, notional values, cooking instruction, packaging and expiry dates, etc. generally packaging material s are lighter in weight, easier to open, reseal and store, ensure safe transport and distribution, protect the product from adverse effects such as heat, cold, moisture, etc.

16.1. Properties of Ideal packaging materials

An ideal packaging material should have following qualities:

- It should contain the content within it
- It should not affect the flavor of the product packaged it
- Stable performance over large range of temperature.
- Adequate compulsive strength and sufficient impact and puncture strength.
- Sufficient thickness of cushioning materials with sufficient ventilation, space for rapid cooling of product.
- Protect the product from O_2, moisture and light.
- Protection of the content form adulterations.
- Closure characteristics such as opening, sealing, resealing and pouring.
- Low cost and availability.
- It should non-toxic in nature.

- Proper labeling, storing, marketing appeal to sale, etc.

16.2. Requirement of food packaging

Protection of the product means that there must be a resistance to both internal and external corrosion, with effective properties that guarantee resistance to gas, oxygen, water and smells. Packaging must be safe, it must be impregnable and have safeguards in place to show that it has not been tampered with much of consumer confidence in the products they buy derives from the knowledge that the product has not been opened or tampered with, as seen through the existence of visible seals on products such as the mango juice carton. Packaging is vital to conserve the product. In industrialized countries only 2% of products are spoilt when they reach the consumer compared with a staggering 30-50% in developing countries, where the packaging chain is less well developed. Packaging must meet consumer requirements that products are not just kept in top condition but that they are kept fresher for longer. Packaging also performs overtly technical functions, displaying what the product actually is and information regarding the product, as well as creating brand awareness. Consumer demands and legislative requirements mean that information contained on packaging has become far more specific, for example, detailing the origin and composition of the product. Packaging is also the spokesperson for the manufacturer of the product. The package is the interface between the maker and consumer and therefore must present a desirable image.

16.3. Purpose of Packaging

In addition to the direct approach to food preservation, such as drying and freezing, other measures such as packaging and quality management tools need to be implemented in the process to avoid contamination or recontamination. Although these measures are not preservation techniques, they can play an important role in producing high-quality safe food. Packaging performs five main functions i.e. Product containment, preservation and quality, presentation and convenience, protection, and provide storage history.

16.3.1. Product Containment

The first function of packaging is its capability of containment. The primary purposes of packaging are containment and protection. It is self-explanatory; liquids, semi-liquids, and powders, as well as bulk solids, cannot be marketed without suitable containers. According to the size of the package, different amounts of the product can be delivered to consumers suiting their choice and convenience [18]. In certain circumstances, quantification is mandatory, as in the case of medical pills or capsules that are marketed individually in a blister-type package. Containment refers to holding goods in a form suitable for transport, whereas protection refers to safekeeping goods in a way that prevents significant quality deterioration.

16.3.2. Preservation by Maintaining Quality

The second function of packaging is to control the local environmental conditions to enhance storage life and safety. The main purpose of food packaging is to protect the product from surroundings and maintain the quality of the food throughout the product's shelf life. One means of spreading the product availability over time is by the proper use of packaging. Product shelf life is controlled by three factors: product characteristics, properties, and storage and distribution conditions of individual package. Reactions causing deterioration in foods include enzymatic, chemical, physical, and microbiological changes. Additional problems include insects, pests, and rodents.

16.3.3. Presentation and Convenience

The third function is the presentation and convenience. In many cases, these are most important factors to the consumers.

16.3.3.1. Presentation

Food labels are intended by law to provide the information that consumers need to be able to make the necessary decisions about those purchases of food. It is important to display the product in an attractive manner to the potential buyer. A cleverly designed and beautifully produced packaging can help sell a product, which is an essential ingredient of an effective marketing campaign. The packaging helps in distinguishing products on the shelf, which is a trait especially important when marketing low-fat or nutritional products. Furthermore, packaging must address communication, legal, and commercial demands. For a package to be effective, it must present the product well and should do its own publicity. The protective packaging may have flaps that can be opened to give a ready-made display for the product, whereas some stores may remove the protective packaging to display the product directly on the shelves, leading to a preference for rectangular containers. The clarity (haze) and gloss optical characteristics are important in packaging presentation.

16.3.3.2. Convenience

In many cases, packaging provides convenience to the consumers, for example, paper carton for milk or juice with an ease-open and easy-pour cap, thus can also increase consumption. Changes in society, such as diminishing population pattern, increasing average age, smaller families, more leisure time, as well as improvements in the quality of life, standard of living, and general level of education, may also demand specific function of packaging. Eating styles, such as ready-to-eat meals, snacks, and microwaveable ready meals, have been changed over the years, which need innovation in packaging. For children, the packaging might represent innovation or fun. Today's consumer wants to buy food that is ready to eat, or needs a minimum of preparation, and is good value for money. With microwave food preparation increasing, there is a need for the packaging industry to confront the particular problems in designing packages that deliver microwave products to the dinner table. Food processors can accelerate the usage of microwave ovens by designing products and packages that use the phenomenon of microwave heating/cooking to provide quality. Two types of materials, transparent to microwave and reflective to microwave, can affect the cooking. The transparent materials are nonmetallic substances, such as ceramics, that are coated or filled with microwave absorbent materials. The reflective category is composed of all devices that are metallic and absorb heat. Packaging should meet the future demand of meeting eating style of the society. Other conveniences could be ease of opening, smaller portions, enclosable, and tamper-proof methods. Consumers want tamper-evident closures to avoid packaging being opened unnoticed. In general, tamper-proof packaging makes products more difficult to open, so there is clearly a need to balance safety with consumer accessibility. The tamper-resistant package is to alert the consumer that tampering has taken place and provide visible evidence of tampering. In many cases, consumers are ready to pay more for tamper-resistant packaging. Value-added packaging allows in-package cooking and facilitates on-the-go consumption. Self-heating containers are also being developed for the convenience of consumers, who do not need to reheat the product during consumption.

16.3.4. Protection during Distribution and Processing

The fourth function is to protect the product during transit to the consumer. Packaging is part of the distribution process necessary to deliver goods to the consumer and facilitate handling and transportation. It also has affected international trade by making shipping of food products possible, allowing seasonal products to be more accessible out of season. Packaging can handle better when there are challenges in food distribution chain, such as heat, humidity, or dew. It is important to be aware of the distribution challenges and designing of package to suit it. In case of prepacked product, it should have the ability to stand the severity or type of process conditions, such as flexible packaging during canning, microwaveable foods, oven able, and reportable foods. Irradiated foods are usually prepacked prior to treatment by ionizing radiation, which prevents recontamination. Packaging materials are also exposed to radiation during treatment, though in this instance it can lead to radiation-induced degradation of the packaging material, followed by interaction between the material and food product.

Protective packaging is a term applied to packaging primarily designed to protect the goods, rather than for appearance or presentation, so it is generally used to apply to the outer containers used for transporting goods from the manufacturer to the point of sale, and filling materials inside the outer containers, e.g., nylon barrier-sealed bubble packaging (computer parts), urethane expanding foam, PE foam package “cushions,” and PS loose-fill packaging. The most widely used protective package is the outer carton. All packaging is protective as one of its primary functions, so it is more accurate to call this transport packaging or tertiary packaging (on the basis of the primary packaging in contact with the product, secondary for grouping units together for single purchase, and tertiary being for grouping secondary packaging for convenience distribution). A pallet is the frame base for carrying the transport packs. The primary packages are put into cartons and the sealed cartons are transported through specialized conveyors, allowing products from different processing lines and sorted onto individual product pallets. Another aspect of protective packaging involves primary packaging designed to prevent anyone from opening the package before purchase. Cases of extortion or sabotage are also reported. In the mid-1970s, child-resistant packaging became an issue, leading to the development of childproof lids for poisonous products. Tamper-resistant refers to the ability of the packaging to resist tampering (or opening), e.g., for child protection, whereas tamper-evident refers to the ability of the packaging to reveal that it has been opened.

16.3.5. Provide storage history

Time-temperature indicator (TTI) is effective for predicting microbial concentrations and other parameters of food quality during shipping and storage. It helps in ensuring proper handling and provides a gauge of product quality for sensitive products in which temperature control is imperative to efficacy and safety. TTIs are tags that can be applied to individual packages or shipping cartons to visually indicate whether a product has been exposed to time and temperature conditions that adversely affect the product quality. TTI could be used in chilled foods to identify the temperature abuse during storage and distribution. According to the response mechanisms, TTIs can be divided into three groups: (i) biological, (ii) chemical, and (iii) physical systems. One of them is the use of enzyme-based TTIs to monitor and predict shelf life of products. The tags are available in a one-dot version and a three-dot version with the three dots changing color at different rates. The change of color of the dot indicates the exposed time and temperature of the product. There is considerable potential for use of TTIs in the food distribution chain, but there are two issues to be considered. One is the economics. When using a TTI for a relatively low-cost product, such as lettuce, the indicator also has to be relatively low in cost. This should be considered or addressed by the manufacturer of the indicator. The other issue is knowledge of the food product. The food processor must know the degradation kinetics of his product—how the quality characteristics of his product are changing with time and temperature exposure—so that he can select the indicator that matches it.

Lesson- 17 Selection criteria of packaging material for raw foods

17.0 Raw Meat

The adoption of preservative packaging for raw meats has led to major changes in the processing and marketing of such products. As a result of the widespread adoption of vacuum packaging for primal cuts of red meats, trade in red meat carcasses has declined to trivial proportions in many developed countries, and the international trade in chilled raw meats has greatly increased, with a consequent decline in trading of frozen meats. The enhanced stability of vacuum-packaged products has facilitated consolidation of meat-packing facilities. Most meat is offered to consumers in a freshly or recently cut form, with little further processing to suppress the normal microbiological flora present from the contamination received during the killing and breaking operations required to reduce carcass meat to edible cuts. Fresh meat is vulnerable to microbiological deterioration from microorganisms. These microorganisms can be as benign as slime formers to stink producers to pathogens such as E. coli O157:H7. The major mechanisms to retard fresh meat spoilage are temperature reduction, often coupled with reduced oxygen during distribution, to retard normal spoilage microbial growth. Reduced oxygen also leads to fresh meat color being the purple of myoglobin, a condition changed upon exposure to air which converts the natural meat pigment to bright cherry red oxymyoglobin characteristic of most fresh meat offered to and accepted by consumers. Reduced oxygen packaging is achieved through mechanical removal of air from the interiors of gas barrier ultilayer flexible material pouches closed by heat scaling the end after filling.

17.1. Fish and Sea foods

Varieties of fish are among the most difficult of all foods to preserve in their fresh state because of their inherent microbiological populations many of which are psychrophilic, i.e., capable of growth at refrigerated temperatures. Further, seafood may harbor a nonproteolytic anaerobic pathogen, Clostridium botulinum type E, capable of toxin production without signaling spoilage.

The high-quality shelf life of most seafood in chill storage is relatively short, being only a few days. This short period does not allow sufficient time from reception through to distribution and display to ensure the restaurateur or consumer can obtain seafood at its best. Packaging for fresh seafood is generally moisture resistant but not necessarily against microbial contamination. Simple polyethylene film is employed often as a liner in corrugated fiberboard cases. The polyethylene serves not only to retain product moisture but also to protect the structural case against internal moisture. Seafood may be frozen in which case the packaging is usually a form of moisture resistant material plus structure such as polyethylene pouches or polyethylene coated paperboard cartons. Canning of seafood is much like that for meats because all sea foods are low acid and so require high pressure cooking or retorting to effect sterility in hermetically sealed metal cans.

17.2. Fruits and vegetables

Increasing demand for a wide range of harvested fruits or vegetables (raw and fresh-cut) has led to dynamic growth in sales and new market opportunities for the fresh produce sector. However, their preservation still constitutes one of the most challenging applications for the food industry. Fresh produce is a living, "breathing" entity fostering the physiological consumption of oxygen and production of carbon dioxide and water vapor. From a spoilage standpoint, fresh produce is more subject to physiological than to microbiological spoilage, and measures to extend the shelf life are designed to retard such reactions and water loss. One major problem is that produce may enter into respiratory anaerobiosis if the oxygen concentration is reduced to near extinction. In respiratory anaerobiosis, the pathways produce undesirable flavor compounds. To minimize the production of these undesirable end products, elaborate packaging systems have been and continue to be developed. Most of these involve mechanisms to permit air into the package to compensate for the oxygen consumed by the respiring produce. High gas permeability plastic films, micro perforated plastic films, plastic films disrupted with mineral fill, and films fabricated from temperature-sensitive polymers have all been proposed or used commercially.

Fresh-cut vegetables, especially lettuce, cabbage, and carrots have been a major product in both the retail and the hotel/restaurant/ institutional market. Cleaning, trimming and size reduction lead to greater surface to volume of the produce and to the expression of fluids from the interior to increase the respiration and microbiological growth rate. On the other hand, commercial fresh-cutting operations generally are far superior to mainstream fresh produce handling in cleanliness, speed through the operations, temperature reduction, and judicious application of microbicides such as chlorine. Uncut produce packaging is really a multitude of materials, structures, and forms that range from the old and traditional, such as wood crates, to inexpensive, such as injection-molded polypropylene baskets, to polyethylene liners within waxed corrugated fiberboard cases. Much of the packaging is designed to help retard moisture loss from the fresh produce or to resist the moisture evaporating or dripping from the produce (or, occasionally, its associated ice) to ensure the maintenance of the structure throughout distribution. Some packaging recognizes the issue of anaerobic respiration and incorporates deliberate openings to ensure passage of air into the package, as, for example, perforated polyethylene pouches for apples or potatoes.

For freezing, vegetables are cleaned, trimmed, cut, and blanched prior to freezing and then packaging, or prior to packaging and then freezing. Blanching and the other processing operations reduce the number of microorganisms. Produce may be individually quick frozen (IQF) using cold air or cryogenic liquids prior to packaging or frozen after packaging as in folding paperboard cartons. Frozen food packages are generally relatively simple monolayer polyethylene pouches or polyethylene-coated paperboard to retard moisture loss. Fresh-cut vegetables coupled with bread sticks and dip constitutes a reasonably flavorful mouthful and nutritious snack for adults and younger persons.

17.3. Milk

Milk is a complex mixture of water, proteins, lipids, carbohydrates, enzymes, vitamins, and minerals. Due to its specific composition and a pH close to neutral, it is a highly perishable product with high spoilage potential that can result in rapid deterioration of quality and safety. Packaging serves a number of different functions, including containment, protection, convenience, and communication, the most important being protection. Packaging protects milk and dairy products against environmental, physical, chemical, as well as mechanical hazards. It also protects the product from loss of desirable flavor compounds or pick-up of undesirable odors, and contamination from spoilage or pathogenic microorganisms, insects, or rodents during storage and distribution. An effective packaging system should fulfill numerous other requirements, including compatibility with the dairy product it contains recyclability or reuse, tamper evidence, nontoxicity, aesthetics, machinability, and functionality in terms of shape, size, and disposability.

Milk and its derivatives are generally excellent microbiological growth substrates and therefore potential sources for pathogens. For this reason, almost all milk is thermally pasteurized or heated short of sterility as an integral element of processing. Refrigerated distribution is generally dictated for all products that are pasteurized, to minimize the probability of spoilage. In recent years, milk packaging has been upgraded to incorporate reclosure, a feature that has been missing from gable top polyethylene-coated paperboard cartons. Further, in recent years, the packaging environmental conditions have been upgraded microbiologically to enhance refrigerated shelf life. Aseptic packaging is employed to deliver ambient temperature shelf stable fluid dairy products. The most common processing technology is ultra high temperature short time thermal treatment to sterilize the product, followed by aseptic transfer into the packaging equipment. Fluid milk is generally pasteurized, cooled, and filled into bag-in-box pouches for refrigerated distribution.

Lesson- 18 Selection criteria of packaging material for processed foods

18.0 Introduction

Foods are materials, raw, processed, or formulated, that are consumed orally by humans or animals for growth, health, satisfaction, pleasure, and satisfying social needs. Generally, there is no limitation on the amount of food that may be consumed (as there is for a drug in the form of dosage). This does not mean that we can eat any food item as much as we want. Excessive amounts could be lethal, for example, salt, fat, and sugar. Chemically, foods are mainly composed of water, lipids, fat, and carbohydrate with small proportions of minerals and organic compounds. Minerals include salts and organic substances include vitamins, emulsifiers, acids, antioxidants, pigments, polyphenols, and flavor-producing compounds. The different classes of foods are perishable, nonperishable, harvested, fresh, minimally processed, preserved, manufactured, formulated, primary, secondary derivatives, synthetic, functional, and medical foods. The preservation method is mainly based on the types of food that need to be prepared or formulated.

Fresh fruit and vegetables have a short shelf life under ambient conditions of temperature and humidity due to their highly perishable nature. They soon lose their freshness and become subjected to mould and bacterial attack, and consequently decay and become useless as articles of human diet. Fruits and vegetables are an important supplement to the human balanced diet as they provide the essential minerals, vitamins and dietary fiber (roughage) for maintaining the tear and wear of the over body. Fresh fruits and vegetables are valued for their quick sources of available energy. Fresh fruits have high water content (70-96%), varying amount of carbohydrate (3-27%) and fiber (0.2-3.1%) and a low content of protein, fat and minerals. Fruits are important source of Pro-vitamin A and vitamin C. The loss of moisture causes vegetables to wilt and become limp. In addition, vegetables also supply fair amount of carbohydrates, protein and energy and add colour, flavor and aroma to human diet. India is one of the largest producers of fruits and vegetables after china. Ideal climatic conditions ensure round the year availability of broad range of fruit and vegetables in large quantities.

Packaging provides quality and quantity assurance besides creating hygienic environment for food product. It offers security through tamper proof designs and contributes to the product image through structural and graphical design. Food safety is permanent importance as package products against biological, chemical and distribution damages. The primary objective or packaging is to protect the contents during storage, transportation and distribution against deterioration. It may be physical, chemical or biological. According to Robertson (1992), packaging as the enclosure of the products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other containers to perform the various functions, i.e. containment, protection, information, promotion, etc.

Packaging of food serves many purposes such as providing effective protection to package foods against external contamination from environment; preserving the quality of food. It is one of the most important parameters that sale the product and also a communication device to provide detailed information about the product like, contents, ingredients, notional values, cooking instruction, packaging and expiry dates, etc. generally packaging material s are lighter in weight, easier to open, reseal and store, ensure safe transport and distribution, protect the product from adverse effects such as heat, cold, moisture, etc.

18.1. Selection criteria of packaging material for the raw and processed foods

18.1.1 Mechanical Damage

Fresh, processed and manufactured foods are susceptible to mechanical damage. The bruising of soft fruits, the break-up of heat processed vegetables and the cracking of biscuits are examples. Such damage may result from sudden impacts or shocks during handling and transport, vibration during transport by road, rail and air and compression loads imposed when packages are stacked in warehouses or large transport vehicles. Appropriate packaging can reduce the incidence and extent of such mechanical damage. Packaging alone is not the whole answer. Good handling and transport procedures and equipment are also necessary. The selection of a packaging material of sufficient strength and rigidity can reduce damage due to compression loads. Metal, glass and rigid plastic materials may be used for primary or consumer packages. Fiberboard and timber materials are used for secondary or outer packages. The incorporation of cushioning materials into the packaging can protect against impacts, shock and vibration. Corrugated papers and boards, pulp board and foamed plastics are examples of such cushioning materials. Restricting movement of the product within the package may also reduce damage. This may be achieved by tight-wrapping or shrink-wrapping. Inserts in boxes or cases or thermoformed trays may be used to provide compartments for individual items such as eggs and fruits.

18.1.2 Permeability Characteristics

The rate of permeation of water vapor, gases (O_2, CO_2, N_2, and ethylene) and volatile odor compounds into or out of the package is an important consideration, in the case of packaging films, laminates and coated papers. Foods with relatively high moisture contents tend to lose water to the atmosphere. This results in a loss of weight and deterioration in appearance and texture. Meat and cheese are typical examples of such foods. Products with relatively low moisture contents will tend to pick up moisture, particularly when exposed to a high humidity atmosphere. Dry powders such as cake mixes and custard powders may cake and lose their free flowing characteristics. Biscuits and snack foods may lose their crispness. If the water activity of a dehydrated product is allowed to rise above a certain critical level, microbiological spoilage may occur. In such cases a packaging material with a low permeability to water vapor, effectively sealed, is required. In contrast, fresh fruit and vegetables continue to respire after harvesting. They use up oxygen and produce water vapor, carbon dioxide and ethylene. As a result, the humidity inside the package increases. If a high humidity develops, condensation may occur within the package when the temperature fluctuates. In such cases, it is necessary to allow for the passage of water vapor out of the package. A packaging material which is semipermeable to water vapor is required in this case.

The shelf life of many foods may be extended by creating an atmosphere in the package which is low in oxygen. This can be achieved by vacuum packaging or by replacing the air in the package with carbon dioxide and/or nitrogen. Cheese, cooked and cured meat products, dried meats, egg and coffee powders are examples of such foods. In such cases, the packaging material should have a low permeability to gases and be effectively sealed. If a respiring food is sealed in a gastight container, the oxygen will be used up and replaced with carbon dioxide. The rate at which this occurs depends on the rate of respiration of the food, the amount in the package and the temperature. Over a period of time, an anaerobic atmosphere will develop inside the container. If the oxygen content falls below 2%, anaerobic respiration will set in and the food will spoil rapidly. The influence of the level of carbon dioxide in the package varies from product to product. Some fruits and vegetables can tolerate, and may even benefit from, high levels of carbon dioxide while others do not. In such cases, it is necessary to select a packaging material which permits the movement of oxygen into and carbon dioxide out of the package, at a rate which is optimum for the contents. Ethylene is produced by respiring fruits. Even when present in low concentrations, this can accelerate the ripening of the fruit. The packaging material must have an adequate permeability to ethylene to avoid this problem.

To retain the pleasant odor associated with many foods, such as coffee, it is necessary to select a packaging material that is a good barrier to the volatile compounds which contribute to that odor. Such materials may also prevent the contents from developing taints due to the absorption of foreign odors. It is worth noting here that films that are good barriers to water vapor may be permeable to volatiles. In those cases where the movement of gases and vapours is to be minimized, metal and glass containers, suitably sealed, may be used. Many flexible film materials, particularly if used in laminates, are also good barriers to vapours and gases. Where some movement of vapours and/or gases is desirable, films that are semi-permeable to them may be used. For products with high respiration rates the packaging material may be perforated. A range of micro-perforated films is available for such applications. In the case of an intact polymer film, the rate at which vapours and gases pass through it is specified by its 'permeability' or 'permeability constant', *P*, defined by the following relationship:

$${\bf{P}} = \frac{{{\bf{q}}{\bf{l}}}}{{{\bf{A}}({{\bf{P}}_1} - {{\bf{P}}_2})}}$$

where q is the quantity of vapor or gas passing through A, an area of the film in unit time, l is the thickness of the film and p_1, p_2 are the partial pressures of the vapor or gas in equilibrium with the film at its two faces. The permeability of a film to water vapor is usually expressed as x g m^{-2} day^{-1} (i.e. per 24 h) and is also known as the water vapor transfer rate (WVTR). Highly permeable films have values of WVTR in the range from 200 g m^{-2} day^{-1} to >800 g m^{-2} day^{-1}, while those with low permeability have values of 10 g m–^{2} day^{-1} or below. The permeability of a film to gases is usually expressed as x cm^{3} m^{-2} day-^{1}. Highly permeable films have P values from 1000 cm^{3} m^{-2} day^{-1} to >25 000 cm^{3} m^{-2} day–1, while those with low permeability have values of 10 cm^{3} m^{-2} day^{-1} or below. When stating the P value of a film, the thickness of the film and the conditions under which it was measured, mainly the temperature and (p_1, p_2), must be given.

18.1.3. Grease proofness

In the case of fatty foods, it is necessary to prevent egress of grease or oil to the outside of the package, where it would spoil its appearance and possibly interfere with the printing and decoration. Greaseproof and parchment papers may give adequate protection to dry fatty foods, such as chocolateand milk powder, while hydrophilic films or laminates are used with wet foods, such as meat or fish.

18.1.4. Temperature

A package must be able to withstand the changes in temperature which it is likely to encounter, without any reduction in performance or undesirable change in appearance. This is of particular importance when foods are heated or cooled in the package. For many decades' metal and glass containers were used for foods which were retorted in the package. It is only in relatively recent times that heat resistant laminates were developed for this purpose. Some packaging films become brittle when exposed to low temperatures and are not suitable for packaging frozen foods. The rate of change of temperature may be important. For example, glass containers have to be heated and cooled slowly to avoid breakage. The method of heating may influence the choice of packaging. Many new packaging materials have been developed for foods which are to be processed or heated by microwaves.

18.1.5. Light

Many food components are sensitive to light, particularly at the blue and ultraviolet end of the spectrum. Vitamins may be destroyed, colors may fade and fats may develop rancidity when exposed to such light waves. The use of packaging materials which are opaque to light will prevent these changes. If it is desirable that the contents be visible, for example to check the clarity of a liquid, colored materials which filter out short wavelength light may be used. Amber glass bottles, commonly used for beer in the UK, perform this function. Pigmented plastic bottles are used for some health drinks.

18.2. Chemical Compatibility of the Packaging Material and the Contents of the Package

It is essential in food packaging that no health hazard to the consumer should arise as a result of toxic substances, present in the packaging material, leaching into the contents. In the case of flexible packaging films, such substances may be residual monomers from the polymerization process or additives such as stabilizers, plasticizers, colouring materials etc. To establish the safety of such packaging materials two questions need to be answered: (a) are there any toxic substances present in the packaging material and (b) will they leach into the product? Toxicological testing of just one chemical compound is lengthy, complicated and expensive, usually involving extensive animal feeding trials and requiring expert interpretation of the results.

18.3. Protection against Microbial Contamination

Another role of the package may be to prevent or limit the contamination of the contents by microorganisms from sources outside the package. This is most important in the case of foods that are heat-sterilized in the package, where it is essential that post-process contamination does not occur. The metal can has dominated this field for decades and still does. The reliability of the double seam in preventing contamination is one reason for this dominance. Some closures for glass containers are also effective barriers to contamination. It is only in relatively recent times that plastic containers have been developed, which not only withstand the rigors of heat processing, but also whose heat seals are effective in preventing post process contamination. Effective seals are also necessary on cartons, cups and other containers which are aseptically filled with UHT products. The sealing requirements for containers for pasteurized products and foods preserved by drying, freezing, curing, etc. are not so rigorous. However, they should still provide a high level of protection against microbial contamination.

18.4. In-Package Microflora

The permeability of the packaging material to gases and the packaging procedure employed can influence the type of microorganisms that grow within the package. Packaging foods in materials that are highly permeable to gases is not likely to bring about any significant change in the microflora, compared to unpackaged foods. However, when a fresh or mildly processed food is packaged in a material that has a low permeability to gases and when an anaerobic atmosphere is created within the package, as a result of respiration of the product or because of vacuum or gas packaging, the type of microorganisms that grow inside the package are likely to be different to those that would grow in the unpackaged food. There is a danger that pathogenic microorganisms could flourish under these conditions and result in food poisoning. Such packaging procedures should not be used without a detailed study of the microbiological implications, taking into account the type of food, the treatment it receives before packaging, the hygienic conditions under which it is packaged and the temperature at which the packaged product is to be stored, transported, displayed in the retail outlet and kept in the home of the consumer.

Module- 6 Advantages and disadvantages of these packaging materials, effects of these materials on packed commodities

Lesson- 19 Advantages of different packaging materials

19.1 Retortable pouches

The pouches, trays, and tubs are always multilayer laminate structures that contain different polymers which provide heat resistance, strength, and toughness (PET), pierce and pinhole resistance (nylon), oxygen barrier (EVOH, nylon or PVDC) and (for the pouches and trays) heat sealability (PP). An aluminum foil layer often serves as the moisture and oxygen barrier in pouches. The retortable paperboard cartons have external and internal PP layers that are impermeable to liquid and allow heat sealing, along with an internal aluminum layer that provides a gas and light barrier.

19.1.1 Advantages of retortable pouches

- less energy is required to manufacture pouches compared with cans
- transport of empty containers is cheaper (85% less space required than cans)
- packaging is cheaper than equivalent can and with carton cost is about the same
- filling lines are easily changed to a different size
- rapid heat penetration and faster process results in better nutrition/flavour
- contents are ambient shelf stable – no refrigeration is required
- packed pouch is more compact requiring about 10% less shelf space
- less brine or syrup used, pouches are lower in mass and cheaper to transport
- fast reheating of contents by immersion of pack in hot water. No pots to clean
- opens easily by tearing or cutting
- ideal for single portion packaging and serving size control
- retort pouch materials are non-corrosive
- convenient for outdoor leisure and military rations use.

19.2. Glass

Glass is made by mixing several naturally-occurring inorganic compounds at a temperature above their melting points. The molten mixture is then cooled to produce a noncrystalline, amorphous solid. The main ingredient is silica (sand) (SiO2) that serves as the network-forming backbone of the glass. However, silica has a very high melting temperature, and molten silica has high viscosity that makes it difficult to form into shapes. Adding soda (Na_2O) modifies the silica network by disrupting some of the Si-O bonds, with resulting lower melting temperature and viscosity but reduced resistance to dissolving in water. Thus, lime (CaO) is added as a network stabilizer, with the result that durability is increased but tendency to crystallize is also increased. Finally, alumina (Al_2O_3) is added as an intermediate to resist crystallization. Minor amounts of colorants are added to produce colored glass, including chromium oxide for green, cobalt oxide for blue, nickel oxide for violet, selenium for red, and iron plus sulfur and carbon for amber. Amber provides the best protection for light-sensitive foods and beverages, transmitting very little light with wavelength shorter than 450 nm.

19.2.1. Advantages of Glass

- Inert
- Total barrier to
- Gas
- Water vapor
- Aroma
- Good compression resistance
- Good heat resistance
- Allow viewing of product
- Microwavable
- Customer perception of high quality
- Reclosable
- Recyclable
- Refillable

19.3. Metals

Like glass, steel and aluminum are total barriers to gases, water vapor and aromas. Both also have good heat resistance and can withstand physical and thermal shock. Because of steel's greater strength, it is used more often in the thermal processing of foods. Neither steel nor aluminum is as inert as glass; thus both must be coated to avoid interactions with the foods they contain. Tin or chromium is used to coat steel, usually followed by a coating with a polymeric lacquer (enamel). Aluminum is coated directly with a lacquer. Other advantages of metal containers are exclusion of light from food products that are light-sensitive and their recyclability.

19.3.1 Advantages of Metal Containers

- Total barrier to
- Gas
- Water vapor
- Aroma
- Good compression resistance
- Good heat resistance
- Good thermal and physical shock resistance
- Light protection
- Recyclable

19.4. Plastic

The most commonly used thermoplastic polymers are inexpensive, and their conversion into food packaging is also relatively inexpensive. These plastics can be molded or extruded into a wide range of flexible, semi-rigid and rigid containers

that are lightweight, noncorrodible, shock-resistant, and heat-sealable. Most are transparent and some are microwaveable. Certain plastics have high enough heat resistance that they can be hot-filled, retorted and/or used in a conventional oven. Finally, the most commonly used plastic semi-rigid and rigid containers are recyclable. Similar to glass and metal, plastic properties have improved over the years so that less material is necessary for making containers with acceptable integrity.

19.4.1 Advantages of plastics

- Inexpensive materials
- Inexpensive conversion to packaging
- Versatile
- Flexible
- Rigid
- Semi-rigid
- Moldable
- Light-weight
- Noncorrodible

- Shock-resistant
- Heat-sealable
- Transparent
- Can be pigmented
- Microwavable (some)
- Good heat resistance (some)
- Recyclable (some)

19.5. Paper

Paper is a quite versatile material, utilized in flexible, semi-rigid, and rigid packaging. It is made into a wide variety of single- and multi-wall bags. It can also be made into a thicker stronger structure (>0.012 in. /0.03 cm) called paperboard (Pb), which is made into cartons and boxes that provide mechanical protection for many foods. The paperboard can be converted to an even stronger material called corrugated paperboard that is converted into boxes used for logistics (tertiary and quaternary packaging). Most types of paper provide a partial or complete barrier to light. It can also be manufactured into transparent and clear materials. The starting material of paper, wood, is a renewable resource, and paper is recyclable and biodegradable.

19.5.1 Advantages of Paper Packaging

- Versatile
- Rigid
- Semi-rigid
- Flexible
- Mechanical protection
- Logistics functions
- Barrier to light
- Renewable resource
- Recyclable
- Biodegradable

Lesson- 20 Disadvantages of packaging materials

20.1 Glass

Glass is one of the oldest manufactured materials and one of the first manufacturing businesses in the New World. Nonetheless, glass still serves as an important packaging material for food. The disadvantages of glass include its weight and vulnerability to fracture from thermal shock (rapid temperature change) and physical shock. In recent years, advances in the science and technology of glass have resulted in lighter, stronger glass containers. For those food products vulnerable to light-catalyzed reactions, glass's transparency to light is another disadvantage. Use of light-absorbing colorants in the glass, as well as glass container labels and direct printing on the glass, will affect the transmission of light.

20.1.1 Disadvantages of glass

- glass is a heavy packaging material than others.
- breakage and subsequent loss of product
- hermetic seal that is more easily compromised
- the increased possibility of broken glass contaminating the finished product
- color changes of the product due to exposure of light
- expensive food packaging material

20.2 Metals

The disadvantages of metal containers include their multi-step manufacture, weight (particularly steel), and (for some foods) lack of transparency. In recent years,

advances in the science and technology of these metals have resulted in lighter, stronger metal containers.

20.2.1 Disadvantages of metal

- metal is corrosive material, can affect the quality of food
- metal is moderately heavy packaging material.
- Can't see the food content after packaging
- Due to multi –step can manufacturing process, can making is time taking process
- Metal can react with the food material

20.3 Plastic

Plastics are high molecular weight polymers that can be molded into desired shapes such as films, trays, bottles, and jars using heat and pressure. Plastics do not provide a total barrier to gases, water vapor, and aromas. The permeabilities of a given plastic material to water vapor, oxygen, carbon dioxide, and aromas depend on the particular polymer composition and structure. This must be considered when selecting a plastic for a specific application and desired shelf life. Plastics are often combined in layers, to take advantage of the unique barrier properties of each polymer. Similar to glass, plastic container transparency to light can be detrimental to foods vulnerable to light-catalyzed reactions. Pigmenting, labeling or direct printing of plastic containers can reduce this problem for sensitive food products. Plastic materials do not have the compressive strength of glass or metal, and only a few plastics have high enough heat resistance for heat processing or preparation of foods. Plastic additives and any residual monomers have potential for migrating into foods. Thus, much attention and testing are devoted to minimizing this possibility. On the other hand, food components such as aromas and flavors can sorb into plastic packaging, with resulting loss of food quality. Finally, most plastic materials used in food packaging are not recyclable. Fortunately, these are used in lower quantities than recyclable plastic containers.

20.3.1 Disadvantages of plastic

- Permeable to
- Gas
- Water vapor
- Aroma
- Monomers
- Additives
- Food components can sorb into plastic
- Low compressive strength
- Lack heat resistance (some)
- Not recyclable (some)

20.4. Retortable Pouches

The main disadvantage of retortable pouches, trays, tubs, and cartons is more difficult recycling. Pouch integrity and sealing have also been concerns that are addressed through vigorous package inspection and regulation. National Food Processors Association (NFPA) recommends several tests, including squeeze test, burst test, and seal tensile strength. Seals can also be tested using a dye penetration test or headspace gas composition test. Retorting of pouches and trays must include overpressure and critical control of pressure changes to prevent seal failure. Also, special racks or trays are incorporated in the retort to restrain pouches to a defined thickness for consistent heat transfer.

20.4.1. Disadvantage of retortable pouches

- to achieve equivalent cannery production efficiency, a major investment in new capital equipment for filling and processing is required
- production speed on single filler/sealer is usually less than half that of common can seamers
- new handling techniques have to be adopted and may be difficult to introduce
- heat processing is more critical and more complex
- to retain rapid heat penetration there are limitations on pouch dimensions
- some form of individual outer wrapping is usually required, adding to cost
- being non-rigid products such as some fruits lose their shape
- being a new concept, education of the consumer as to correct storage and use is required during marketing.

Lesson- 21 Effect of packaging materials on food commodities

21.1. Packaging materials for Cereals and Snack foods

21.1.1. Paper, Paperboard, and Printed Fiberboard

Most cereals and snack foods are packaged with paper-based materials made from wood / fibers. Microflute corrugated paperboards have unique characteristics including good strength properties, excellent shock absorbing ability, good aesthetic appearance, environmental advantages, and distinctive print properties. White board is suitable for contact with food and is often coated with low density polyethylene (LDPE), PVC (poly vinyl chloride) or wax. It is used for snack, chocolate, and frozen food cartons.

21.1.2. Plastic Films

Flexible plastic/films have been used for cereals in single packaging or multiserving size packages with other packaging materials. Typically, the majority of snacks are in flexible bags. Biaxially oriented /films are most widely used for snack foods. Biaxially oriented polypropylene (BOPP) has qualities of toughness (against puncture and abrasion) and clarity, and is rendered heat sealable by coextrusion or coating with polyolefin copolymers. Films are also coated with other polymers or aluminum to improve the barrier properties or to impart heat Sealability.

21.1.3. Metals

Metal containers have been rarely used for cereals and snack foods due to their cost, despite their perfect gas barrier properties, convenience, and extreme strength. However, composite containers are used for molded chips and nuts. The body of the container is made of LDPE-coated foil on spirally wound paperboard. The top and bottom ends of the containers may be made of metal or plastic. An aluminum pull-tab top and a reclosable plastic lid on the container form a reclosable canister.

21.2. Packaging materials for beer

21.2.1 Aluminum cans

The total barrier provided by a double-seamed aluminum can prevents ingress of O_2 or egress of CO_2. Any oxidation leading to off-flavors, off-colors, and haze is due to O_2 remaining in the beer after the brewing process and any O_2 added in the filling operation. Thus, the extension of shelf life of beer in cans appears to be dependent on reducing levels of O_2 exposure from these two sources.

21.2.2 Glass bottles

As with aluminum cans, glass bottles prevent O_2 ingress and CO_2 egress. However, unlike aluminum can double-seam closures, bottle closures provide an opportunity for gas transmission through the closure lining. If no O_2 is added to a bottle of beer during filling, the resulting shelf life for the beer would be 4–13 months for a maximum O_2 ingress of 1 ppm. In order to decrease O_2 ingress through the closure lining, with resulting increase in shelf life, various O_2 scavengers have been developed and commercialized for bottle closures. It is recognized that pry-off crown closures provide a tighter seal than do twist-off crowns.

21.3. Packaging materials for carbonated beverages

21.3.1. Metal cans

Metal cans for beverages have an easy-open end consisting of a scored portion in the end panel and levering tab (formed separately) that is riveted into a bubble-like structure fabricated during pressing. The aluminum alloy used to manufacture easy-open ends for beverage cans is specially developed to give the required mechanical properties but is subject to environmental stress cracking (ESC) corrosion due to reaction with moisture. The score area is particularly susceptible because of the tensile stress to which this part of the end is subjected.

21.3.2. Glass bottles

Glass is attractive as it allows the consumer to see the product but offers little protection against the adverse effects of visible light on the product. Some protection of the product can be achieved by using colored glass or wrap-round labels or by the application of a film to all or part of the outside of the bottle.

The principal advantages of glass include its quality image; low-cost production tooling; brand differentiation through shape, design, and texture; product compatibility; impermeability; odor resistance; good transparency; tamper resistance; resaleability; recyclability; reuse opportunity; sleeving and decorative opportunities; protection against UV light; suitability for in-pack pasteurization; and good top-load strength and rigidity.

21.3.3. PET bottles

The O_2 barrier performance of PET is low, but, with high levels of carbonation and the shelf life required for most carbonated beverages, it is regarded as acceptable. PET shows one of the highest CO_2 gas barriers for all plastics used for packaging and is an order of magnitude better than polyolefins or polycarbonates. PET shows less favorable retention of moisture than polyolefins and poorer resistance to heat than polycarbonates but overall has the most favorable balance of performance for carbonated beverages.

21.4. Packaging materials for milk powders

21.4.1. Metal cans

The main reason for using metal cans is their excellent physical strength, durability, absolute barrier properties to moisture, O_2, and light, absence of flavor or odor, and rigidity. Because bare steel is susceptible to corrosion, it is commonly electrolytically coated with a very thin layer of tin; in addition, an organic lacquer is applied to further protect the metal from corrosion and avoid metal–food contact.

Milk powder has a long shelf life when packed in metal cans due to their excellent barrier properties. The exchange of moisture and O_2 and the influx of light are not possible. Powders with a higher fat content are more susceptible to oxidation, and most powders are susceptible to deteriorative effects such as lumping and caking from moisture ingress. With adequately constructed cans, a shelf life in excess of 5 years is realistic, particularly when FMP products have been gas-flushed with N_2 to minimize the amount of available O_2.

21.4.2. Multilayer pouches

Commonly, a laminated multilayer pouch for milk powder must comprise a barrier to water vapor, O2 (at least for WMP products), and light. Aluminum foil is capable of providing such a barrier provided the foil does not have pin holes in it. Aluminum foil built into a flexible material provides a close-to-absolute barrier. Building into a flexible material is essential because the foil does not have any mechanical strength by itself and therefore needs protection from mechanical damage. A sandwich construction with two plastic layers—one on the inside, such as low density polyethylene (LDPE), so that the pouch can be sealed and one on the outside, such as biaxially oriented polypropylene (BOPP) or poly (ethylene terephthalate) (PET), to provide mechanical protection and also carry information is commonly practiced.

21.5. Packaging materials for Vegetables Oils

21.5.1. Metal

Tinplate containers have been used for a long time for oil packaging and are still well appreciated because of their many advantages. They provide total protection against light, O_2, water vapor, and microorganisms, and are resistant to several types of mechanical abuses.

Aluminum is also employed as a packaging material for edible oils as it is light and very resistant to corrosion. In order to increase its mechanical resistance, aluminum alloys with small amounts of Mg, Mn, and Si/Mg are recommended.

21.5.2. Glass Bottles

Glass containers are widely used for bottling olive oils and virgin olive oils in particular. Transparent glass, however, leads to photo-oxidation of olive oil and reduction of its shelf life. The use of colored glass bottles prevents or slows down the oxidation process. Metal and glass are the only packaging materials that provide a virtually total barrier to moisture and gases. The word "virtually" is used because such containers require a closure that incorporates other materials such as polymeric sealing compounds in cans and in closures, through which O_2 can easily permeate and promote oxidation.

21.5.3. Plastic Bottles

PET is one of the most used plastics in food packaging covering a wide range of packaging structures.PET satisfies many important requirements: good aesthetic aspect (brilliance and transparency);suitability for coloring; good mechanical, thermal, and chemical resistance; low production cost; good barrier properties against CO_2; suitability for prolonged storage, easy recyclability, and low weight with respect to glass bottles. HDPE is largely used as a packaging material because of its tensile strength and hardness and good chemical resistance. Blow-molded HDPE containers in the form of bottles, jars, and jerry cans are used for packaging edible oils. PVC is a popular packaging material for edible oils in many countries, mainly due to its transparency, adaptability to all types of closures, total compatibility with existing packaging lines, and potential for personalized design features.

21.5.4. Multilayer pouches

The adoption of multilayer pouches for oil storage has increased due to consumer preference for unit packages. Generally, limited quantities of edible oil are packed in flexible pouches (up to 500 g). Flexible pouches may be manufactured from laminates or multilayered films of different compositions and the pouches may be in the form of a pillow or stand-up pouch. The selection of a laminate or multilayer film is governed primarily by the compatibility of the contact layer, heat Sealability, heat seal strength, and shelf life required, together with machinability and physical strength parameters.

Module- 7 Package testing

Lesson- 22 Determination of parameters of different packaging materials

22.1 Introduction:

The best package for any particular purpose is the one which would protect the contents against the hazards the package would undergo during its journey at the minimum cost. The simplest and the most efficient way of testing package is to carry out field trials with sufficient number of package under the actual conditions of usage. Evaluation of package performance or package testing is a means of shortening this process and of obtaining results in a shorter period with a reasonable degree of accuracy.

22.2 Mechanical Tests

22.2.1 Bursting Strength

The popularity of bursting strength test depends not only on the ease with which the test is made but also on the combination of strength and the toughness, which it measures and which serves as a measure of the serviceability of paper in various applications. It has some disadvantage i.e. it depends in a complicated way on the machine direction, tensile strength, stretch and size of the burst area. Bursting strength is measured by the pressure developed behind a circular rubber diaphragm when it is forced through the paper so as to burst it.

A tester in which testing is done by hydraulic pressure communicated through the medium of glycerin or by compressed air to a pure gum rubber diaphragm in contact with the paper, shall be used. The diaphragm used in the equipment shall be such that it does not materially affect the bursting pressure and shall be between 0.35 mm and 0.45 m thick. The rubber sheet used shall be pure gum vulcanization containing not less than 95 % by volume of first quality smoked sheet rubber, the only ingredient in the mix, apart from rubber, shall be those necessary to effect correct vulcanized and resistance to premature aging at normal temperatures. The pressure required to bulge the diaphragm 5 mm above the top plane of the lower clamping surface of the rest instrument shall be not more than 0.07 kg/cm^2.

For determination of bursting strength, first clamp the piece of packaging material firmly over the diaphragm without slippage during the test between two annular, planes, unpolished surface of 30 mm internal diameter. After clamping the test piece, run the machine so that the pressure increases at a uniform rate (0.75 kg/cm^2 per second) until the test piece burst. Now, with the help of pressure gauge the pressure in kilograms per square centimeter at which the test piece burst. Take two reading with each sample sheet, one with the wire-side upper most and the other with the top- side uppermost. For calculating the burst factor the formula is as follows:

Burst factor =Bursting strength (g/cm^2)/substance (g/m^2)

22.2.2 Tearing resistance

The tearing resistance is usually greater in the cross direction than in the machine direction. Ballistic type of tear-tester such as the 'Elmendorf' is recommended. The machine is provided with two clamps, the one fixed and the other carried on a sector-shaped pendulum suspended from a column by means of a friction less bearing located near the apex of the load of pendulum recorded through a spring load friction pointer on the circumferential scale marked on pendulum.

For determination of tearing resistance, accurately cut the piece with a template in such a way that two parallel slides from a centre tongue giving a double tear. At least one test piece in each direction shall be taken from each specimen. First holds outer tongues of the test piece in a fixed clamp and the centre tongue in the movable clamp. Release the pendulum and note the load necessary to continue to tear. The test may be made such that either the reading is not less than 25% and not more than 75% of the capacity of the instrument. The tearing resistance shall be tested separately for machine and cross direction. Record average, maximum and minimum of the reading in such direction separately and state the number of test piece used for each determination. Tear factor is used for comparing two papers with regards to their tearing strength and is calculated as follows:

Tear Factor = Tearing resistance/ substance

22.2.3 Impact strength of glass bottles

Impact strength in glass can be determined by two methods. First method is drop tester. In this method, the certain height at which glass is break determined. In second method the impact strength is determined by pendulum. In this, keep glass bottle at platform and gives oscillation at which point glass break. Whatever energy required to break the glass is becomes impact strength.

During recycling of bottles; thermal shock resistance decreases, because of pitting of bottle, then application and use of caustic soda, acid, hot water etc. due to these severe processes; thermal shock resistance decreases. During recycling of bottles; thermal shock resistance decreases, because of pitting of bottle, then application and use of caustic soda, acid, hot water etc. due to these severe processes; thermal shock resistance decreases. To avoid this problem; silicates coating is done on bottles. When you treat with caustic soda, this coating is protecting other coating and the properties of glass remains as such for long time. Pressure at which beverages bottles withstand is 15 kg / cm^2. By this experiment, one can determined the thermal shock resistance for glass bottles.

22.2.4 Thermal shock

For determination of thermal shock test requiring a basket for holding the bottles upright. Two water baths are also requiring. One contained hot water and other cold water. It may also have a device to control the desired temperature of the baths within +- 1^o C, otherwise the temperature has to be controlled manually using thermometers. Each water bath may also be provided with a stirrer to keep uniform temperature.

First adjust the cold water bath to a temperature of 30+-1^{o}C and the hot water bath at a temperature of 72+-2^{o}C. Now fill a basket fully or partially with the empty sample bottles. When the bath has attained the prescribed temperature, immerse quickly the basket containing the bottles in the hot water bath in such a manner that the bottles become completely filled with hot water.

Allow the bottles to soak for 15 minutes. After this transfer the basket with the bottle filled with water to the cold water bath so that the bottles are immersed in water up to the neck, taking care that no cold water enter the bottles. Keep the bottles immersed for 2 minutes. Then remove the basket from cold bath. The process of transfer from the hot to the cold bath shall be completed in 15+-2 sec. Take every precaution to protect the apparatus from draughts. At last inspect each bottle for cracks or breaks.

22.3 Climatic Tests

22.3.1 Salt Spray Test

Salt spray test is used to evaluate the resistance of the package to corrosion by salt spray. The package is placed for nearby 50 hours, to a wet, dense fog environment generated by the automation of a 20% water solution of sodium chloride. The solution shall maintain at a PH of 6.5 to 7.2, the temperature of the fog is maintained at 95^{o}F.

22.3.2 Sand and Dust Tests

Sand and dust test is used to evaluate the resistance of a package to the penetration of sand and dust, to determine the erosive effects of blowing sand and dust. A standardize mixture of sand and dust of density 0.1 to 0.5 gm/cu.ft. is used to create an atmosphere for this. The temperature of this atmosphere is maintained at 77^{o} F for a period of 6 hours and then increased to 160^{o} F for another 6 hours.

22.4 Opacity

Opacity of all kinds of paper and paper products is determined by measuring the apparent light reflectance. The apparatus shall be capable of measuring the apparent light reflectance. It may measure the value separately or give directly the ratio of the apparent reflectance. The values of apparent light reflectance are relative to the apparent reflectance from magnesium oxide taken as 100%. The standard white backing shall have an apparent reflectance of 91.5% and the standard black blacking shall have an apparent reflectance of not more than 0.5%.Completely diffused illumination from incandescent lamps at a colour temperature of 2400 to 2800 Kelvin shall be used. The direction of viewing shall be not more than 20o from the normal to the surface of the specimen. Observations shall be made visually or by equivalent means such as a photo- electric with a filter adjusting its sensitivity to that of the human eye.

Place the test piece first over the standard white backing, then over the standard black backing and then measure the apparent reflectance of the light. The ratio of reflectance over black backing to that over white backing expressed as a percentage is the contrast ratio. Calculate the average contrast ratio from determination on both sides of each test piece.

Lesson- 23 Identification of different packaging materials

23.1 Introduction

The basic function of the package is to protect and preserve the contents during transit from the manufacturer to consumer. Protection is required against spillage, dirt, ingress and egress of moisture, insect infestation, contamination by foreign material, tempering, pilferage etc. Identification techniques for different packaging materials are given below.

23.2 Packaging tests are as follows:

23.2.1 Visual Test:

- Fold the film several times to make number of layers.
- Observe the Colour of the film. E.g. Clear, Hazy Watery, White, Yellowish etc. and compare the results with Table 23.1.

23.2.2 Tear Test:

- Fold the film and Tear it on the fold.
- Try tearing the film from a straight edge.
- Nick the film.
- Compare the results with Table 23.1.

23.2.3 Burning Test:

- Burn a film very carefully at the edge with help of a burner flame.
- Observe the edge of the film as it burns of the smoke and compare the results with Table 23.1.

23.2.4 Solubility Test:

- Cut the film into small pieces.
- If necessary, crush the sheet material to increase the rate of solubility.
- Dissolve this film in a glass beaker using appropriate solvents.
- Amount of the solvent should not be less than 10 times the volume of the solid material. If needed, 25 time volume may also be used.
- Compare the Solubility of the given film with the values given in Table 23.2.

23.2.5 Determination of density:

Weight a small amount of the material in a flask.

- If necessary, cut it into pieces.
- Add water up to the mark on the neck.
- Remove air bubble (if any) trapped with the film using vacuum.
- Weigh the flask containing water and film.

Weigh the same flask filled with only water at the same temperature.

- The difference in weights may be used in calculating the density of the given film.
- Compare the density of the given film with the values given in Table 23.3 which would help in identifying the material.

23.2.6 Melt Test:

- Light a match stick and let the stick to burn for few seconds.
- Extinguish it and make contact of the hot stick to the film.
- Use Table 23.4 for film identification

23.2.7 Water Test:

- Place a drop of water on the flat surface of the film and observe.
- Compare the observations with those given in Table 23.4.

23.2.8 Shrink Test:

- Hold the film I" away from the flame of a match or a burner and observe.
- Compare the observations with those given in Table 23.4.

23.2.9 Drip Test:

- Roll the film into a tape like and allow to burn.
- Observe the burning and dripping of the film.
- Compare the observations with those given in Table 23.4.

23.2.10 Flame hot wire Test:

- Heat a copper wire on flame and allow it to touch to the film.
- Put the wire again into the flame and observe.
- Compare the observations with those given in Table 23.4.

Table 23.1: Identification Tests for Plastic Films

No.	**Types of Film**	**Visual Test**			**Tear Test**	**Burning Test**														
												Burns slowly with a bead at the edge				**Burns poorly**				
		Crystal Clear	Yellowish Clear	Hazy	Easy to Tear (Notched)	Stretches before tearing	Resists Tearing	Burns Explosively	Burns like paper	Burns like wax, Waxy odour	Burns like wax without dripping, white smoke	Vinegar Odour	Rancid Butter Odour	Marigold Odour, Black smoke	Sweet Odour	Pungent odour	Pungent soapy odour, Black smoke	Rubbery odour	Burning Hair odour	Green flame with copper wire
1	Cellophane	X			X				X											
2	Cellulose Acetate	X			X							X								
3	Cellulose Acetate - Butyrate	X			X								X							

4	Cellulose Nitrate	X			X			X												
5	Nylon	X					X												X	
6	Polyester	X					X			X					X					
7	Polyethylene			X		X					X									
8	Polypropylene			X		X														
9	Polystyrene	X			X									X						
10	Polyvinyl Chloride	X				X	X										X			X
11	Rubber Hydrochloride		X			X	X											X		X
12	Saran	X					X									X				X

Table: 23.2 Solubility of Plastic films for Identification

No.	Film	Acetone	Amyl formate	Carbon tetrachloride	Cresylic acid	Cyclo hexanone	Dimethyl formamide	Ethyl acetate	Ethyl alcohol	Formic acid	Methyl alcohol	Water	Toluene (Boiling)
1	Acrylic			I				S			I		
2	Cellophane	I											
3	Cellulose Acetate	S											
4	Cellulose Butyrate	S						S	I				
5	Cellulose Nitrate	S	S										
6	Cellulose Propionate	S											
7	Nylon			I	S	I		I		S			I

8	Polycarbonate			**S**				**I**					**I**
9	Polyester	**I**											
10	Polyethylene	**I**		**I**				**I**			**I**		**S**
11	Polypropylene	**I**		**I**				**I**			**I**		**S**
12	Polystyrene	**S**		**S**				**S**			**I**		**S**
13	Polyvinyl Alcohol					**S**	**S**					**S**	
14	Polyvinyl Chloride	**S**		**I**				**I**					**I**
15	Rubber Hydrochloride			**S**				**I**			**I**		**S**
16	Saran	**S**		**I**		**S**	**S**	**I**					**I**

I = Insoluble, S = Soluble

Table: 23.3

No.	Film	Density Range (gm/cc)	Flammability (Self Extinguishing)	Colour	Behaviour	Odour
1	Polyethylene	0.91-0.965	No	Top yellow, bottom blue, white smoke	Melts & drips	Burnt Wax
2	Polypropylene	0.90-0.915	No	Top yellow, bottom blue, white smoke	Melts & drips	Burnt Wax & acrid
3	PVC	1.28-1.38	Yes	Yellow orange with green edge	Darkens, softens & decomposes	Chlorine
4	PVDC	1.68	Yes	As above with green spurt	Black, hard residue	Chlorine
5	PVA	1.21-1.33	Yes but slowly	Yellow with gray smoke	Swells, softens & turns brown	Pungent
6	Poly carbonate	1.2	Yes	Yellow orange with black smoke	No drips, decomposes	Pleasant
7	Polyester	1.38	No	Yellow black smoke	No drips, softens, burns steadily	Pleasant
8	Polystyrene	1.04-1.09	No	Yellow orange black shoots	No drips, softens	Floral (Sweet)
9	Nylon	1.06-1.14	Yes	Blue yellow top	Melts, drips & froths,	Burnt

					rigid drips	hair
10	Cellophane	1.48	No	Yellow orange gray and smoke	Burns fast & complete, burnt area brittle	Burnt paper
11	Cellulose Acetate	1.28-1.32	No	Yellow with blue base	Melts, burns quickly & leaves beads	Burnt vinegar
12	Cellulose Nitrate	1.35-1.40	No	Yellow	Burns at once & fully	Acrid

Table23.4: Identification of various films

No.	Observation	Inference
1	**Melt Test:** • Match does not push through readily (film resists melting) • Hot end of the match readily pushes through the film • Film melts readily and does not resist penetration	• Plain Cellophane • NCC cellophane • PVDC coated cellophabe • PE coated cellophane • PVDC (Saran) • Cellulose acetate • Polystyrene • Nylon
2	**Water Test:** • Drop flatters, spreads and softens the film • Drop does not spread. Wetting and softening of the film occurs only when it is dipped in acetone and wiped off as compared to the original	• Plain transparent cellophane • Nitrocellulose coated cellophane

	(undipped) part of the film.	
3	**Shrink Test:** • Film shrinks violently and rapidly to deep wrinkles • Little shrinkage is observed	• PVDC, Cellulose acetate • Polystyrene • Polyester, Nylon
4	**Drip Test:** • Film burns with drip like melting wax leaving molten drops • Some drip • No molten drip but edges tacky when cooled.	• Polyethylene (PE) • Poly Vinyl Chloride (PVC) • Rubber Hydrochloride, Pliofilm
5	**Flame Hot Wire Test:** • Green colour of the flame. • Negative test, film unaffected by accetone	• Vinyl or rubber type of material • Polyethylene coated cellophane

Module- 8 Printing, labelling and lamination

Lesson- 24 Printing

24.1 Introduction:

Printing is a process in which text and images are reproduced, typically with ink on paper using a printing press made from letters, photographs and drawing. It is often carried out as a large-scale industrial process, and is an essential part of publishing and transaction printing. The basic systems of printing are: - 1) the original, (2) the plate, (3) printing ink, (4) a printing medium such as paper and (5) a printing machine. Printing can be classified into two parts:

1) Direct Printing: In this type of printing, printed material comes in direct contact with the plate so that the ink is directly applied to the printing medium.

2) Indirect Printing: In this printing, the ink is first applied to the blanket cylinder from the plate and then printing medium comes in contact with the blanket

24.2 Printing Technologies

Numbers of printing are in trend for printing purposes of packaging materials. Which are?

24.2.1 Lithography

Lithography is a method in which printing is applied on a smooth surface. Lithography is a printing process that uses chemical processes to create an image. Lithography is a form of planographic printing, meaning that the surface is flat, in contrast to relief printing or intaglio printing. For instance, the positive part of an image would be a hydrophobic chemical, while the negative image would be water. Thus, when the plate come in contact with a compatible ink and water mixture, the ink will adhere to the positive image and the water will clean the negative image. This allows for a relatively flat print plate which allows for much longer runs than the older physical methods of imaging (e.g., embossing or engraving). High-volume lithography is used today to produce packaging materials, just about any smooth, mass-produced item with print and graphics on it. Most books, indeed all types of high-volume text, are now printed using offset lithography.

24.2.2 Colour printing

Chromolithography is a method for making multi-colour prints. This type of colour printing stemmed from the process of lithography, and it includes all types of lithography that are printed in colour. Lithographers sought to find a way to print on flat surfaces with the use of chemicals instead of relief or intaglio printing.

Chromolithographs are mainly used today as fine art instead of advertisements, and they are hard to find owing to poor methods of preservation and also because a cheaper form of printing replaced it. Many chromolithographs have deteriorated because of the acidic frames surrounding them. As stated earlier, production costs of chromolithographs were low, but efforts were still being made to find a cheaper way to mass produce colored prints. Although purchasing a chromolithograph may have been cheaper than purchasing a painting, it was still expensive in comparison to other color printing methods which were later developed.

24.2.3 Screen printing

Screen printing has its origins in simple stenciling, most notably of the Japanese form (katazome), used who cut banana leaves and inserted ink through the design holes on textiles, mostly for clothing. This was taken up in France.

24.2.4 Flexography

Flexographic printing is widely used in western countries. Flexography (also called "surface printing"), often abbreviated to "flexo", is a method of printing most commonly used for packaging (labels, tape, bags, boxes, banners, and so on).A flexo print is achieved by creating a mirrored master of the required image as a 3D relief in a rubber or polymer material. A measured amount of ink is deposited upon the surface of the printing plate. The print surface then rotates, contacting the print material which transfers the ink. Ink is picked up by a cavitated anilox roll and transferred to the printing plate. The ink is then transferred to the film. Because the costs of producing the plates are relatively low, flexographic printing is cost effective, especially for short runs. Its printing quality is inferior to that of modern printing techniques such as offset printing and gravure printing. Now a day this printing technology is utilized for printing on polyethylene bags, corrugated boxes and carton after using the photosensitive resins of improved printing quality.

24.2.5 Digital press

Digital printing is the reproduction of digital images on a physical surface, such as common or photographic paper or paperboard-cover stock, film, cloth, plastic, vinyl, magnets, labels etc. it is now possible to create artwork on a computer and transfer the image directly to the packaging film. A design is created on a computer; it may be an individual design or replicated to give several hundreds of impressions. The ink, usually in powder form, is attracted on to the film surface and cured in place. Special coatings are necessary to receive the ink. A standard heat-sealable coating on the reverse side allows the film to be made immediately into packages.

It can be differentiated from litho, flexography, gravure or letterpress printing in many ways, some of which are;

1. Every impression made onto the paper can be different, as opposed to making several hundred or thousand impressions of the same image from one set of printing plates, as in traditional methods
2. The Ink or Toner does not absorb into the substrate, as does conventional ink, but forms a layer on the surface and may be fused to the substrate by using an inline fuser fluid with heat process(toner) or UV curing process(ink).
3. It generally requires less waste in terms of chemicals used and paper wasted in set up or make ready.

4. It is excellent for rapid prototyping, or small print runs which means that it is more accessible to a wider range of designers and more cost effective.

24.2.6 Frescography

Frescography is a method for reproduction/creation of murals using digital printing methods. The frescography is based on digitally cut-out motifs which are stored in a database. CAM software programs then allow entering the measurements of a wall or ceiling to create a mural design with low resolution motifs. Since architectural elements such as beams, windows or doors can be integrated, the design will result in an accurately and tailor-fit wall mural. Once a design is finished, the low resolution motifs are converted into the original high resolution images and are printed on canvas by Wide-format printers. The canvas then can be applied to the wall in a wall-paperhanging like procedure and will then look like on-site created mural.

24.2.7 3D printing

Three-dimensional printing is a method of converting a virtual 3D model into a physical object. 3D printing is a category of rapid prototyping technology. 3D printers typically work by 'printing' successive layers on top of the previous to build up a three dimensional object. 3D printers are generally faster, more affordable and easier to use than other additive fabrication technologies.

24.3 Modern printing technologies

24.3.1 Offset printing

Offset printing is widely used for printing on folding cartons in the packaging field. Offset printing is a widely used printing technique where the inked image is transferred (or "offset") from a plate to a rubber blanket, then to the printing surface. When used in combination with the lithographic process, which is based on the repulsion of oil and water, the offset technique employs a flat image carrier on which the image to be printed obtains ink from ink rollers, while the non-printing area attracts a film of water, keeping the non-printing areas ink-free.

Offset printing has the following advantages:

1) Plate making time is short in this printing technology.

2) Plate making cost is less than that of gravure printing.

3) It is suitable for multicolor printing.

4) In offset printing large sized plates are easily made.

Gravure 24.3.2

Gravure printing gives good quality of printed matter, either in monocolor or in four colors. Gravure printing is an intaglio printing technique, where the image to be printed is made up of small depressions in the surface of the printing plate. The cells are filled with ink and the excess is scraped off the surface with a doctor blade, then a rubber-covered roller presses paper onto the surface of the plate and into contact with the ink in the cells. The printing plates are usually made from copper and may be produced by digital engraving or laser etching. Gravure printing also has a high printing speed and is suitable for high volume printing. In packaging, gravure printing is performed on most flexible packages using cellophane, plastic film or aluminum foil. Gravure printing is used for long, high-quality print runs such as magazines, mail-order catalogues, packaging, and printing onto fabric and wallpaper. It is also used for printing postage stamps and decorative plastic laminates, such as kitchen worktops.

Lesson- 25 Labelling and lamination

25.1 Introduction:

Label is the first point of contact between the consumer and the producer. It allows the consumers to know what exactly they are buying in terms of calories, proteins, fats etc. and thus enables them to make a 'health conscious selection'. It informs the consumers regarding weight of the product, best before date, storage conditions and cooking recipe if any. It allows consumers to compare food products by Value for Money. A label is a piece of paper, polymer, cloth, metal, or other material affixed to a container or article, on which is printed a legend, information concerning the product, addresses, etc. A label may also be printed directly on the container or article. Labels have many uses: product identification, name tags, advertising, warnings, and other communication. Special types of labels called digital labels (printed through a digital printing) can also have special constructions such as RFID tags, security printing, and sandwich process labels.

25.2 Purpose of Labels:

25.2.1 Information about Packaged Foods: It requires that all packaged foods list the name and address of the food's manufacturer, the weight or count of the food and nutrition facts for the food. The NLEA applies to all foods except for meat, poultry, eggs, prepared food or foods that are sold in bulk.

25.2.2 Nutrition value of product: The Nutrition Facts Label is the label with the most information for consumers. The first line of this label lists the serving size. The nutritional information that follows is based on this specific serving size. The next line lists the total calories, and the amount of calories that are from fat. The following lines contain the food's total fat content (including a breakout of saturated and Trans fats), cholesterol and sodium. Carbohydrates, fiber, sugars, vitamins and minerals are listed next. The percent of the daily value for each nutrient, based on a 2,000 calorie diet, is listed on the right side of the label. The footnote on the bottom of the label has the FDA's recommended dietary guidelines. If the food label is very small, this footnote is abbreviated.

25.2.3 Decoration: When food product is choicely labeled in bright and attractive colors, it attracts consumers to buy. It acts as a silent shelf salesman. The color and design should be in symmetry with product color and the level should have some relationship to the size and shape of the package and container.

25.2.4 Warning: Food labels also having warning and instructions about the food product. Labels educate consumers about allergens, preparation methods and storage conditions for products.

25.2.5 Identification: Identification of the product is the main role of the labels as the consumer must be able to identify. Name & address of the manufacturer, packer and / or seller and brand name also identify by the labels.

25.3 Types of Labels:

Paper labels may be classified into four main categories:

1. Plain paper labels
2. Pre-gummed paper labels
3. Thermoplastic labels
4. Pressure sensitive paper labels

25.3.1 Plain paper labels: Plain paper labels are cheaper than other same quality of labels. Any type of the plain paper label can be printed by standard printing machine and by normal printing methods. These labels can be applied by simple hand application, semi automatic to fully automatic procedure.

25.3.2 Pre gummed paper labels: Pre- gummed paper labels are prepared from dextrin and gum Arabic coated papers and then calendared, flattened or non-curled by a special process. The advantage over plain paper is that they require only to be moistened with water for ready use as a postage stamp.

25.3.3 Thermoplastic labels: Thermoplastic labels are prepared from paper coated with a synthetic resin which melts and becomes tacky on the application of heat. There are two varieties a) instant tack and b) delayed action. In thermoplastic labels printing inks are used for the printing purpose. In these types of levels liquid phase or solvent does not activate the adhesive and should be heat resistant.

25.3.4 Pressure sensitive labels: Pressure sensitive labels may be considered as the most advanced form of labelling and is a process where the label is in a stage of permanent activation and does not require heat, moisture or gum in order to make it adhere to a surface. One can use finger pressure for sticking of the label on the surface. Paper sensitive label consists of a label paper coated with permanent tacky adhesive.

25.3.5 Swing labels: A tag may be described as a marking device that is attached to a container or product by some means other than adhesive- strings, ribbons, wire, holes and various types of slots and slits. High class food products, particularly those styled and designed as presentation and gift packages or units.

Some of the common terms for labels

Back label	Used on back of containers.
Band label	Wraps around container or product, does not cover the entire surface.
Can labe	Used on tin cylindrical containers.
Die cut label	Label of irregular shape cut with a die.
Embossed label	Labels which have three dimensional effects

End label	Essentially a spot label applied to end of box or wrapped package
Neck label	Used for neck of bottle
Over-all wrap	Covers the entire surface of a container top, bottom and sides
Spot label	Label which covers only a small portion of the container
Tag	special purpose label, Affixed to product or container by string wire etc.
Wrap around label	Wrap all around the container, does not cover top or bottom

Module- 9 Basics of Economics

Lesson- 26 Basics of Economics

26.1 Introduction

Packaging plays a vital role in product distribution. It is the major factor in ensuring that the quality that is obtained at the end of the production line finishes up in the hands of the ultimate customer. Cost effectiveness is the sole criterion for success in today's competitive business environment. Therefore efficient and cost effective packaging is an essential element in the marketing of a product. Packaging emphasized the delivery of the product in a sound condition at minimum overall cost. Thus the cost factor has a direct impact and the components of overall cost need to be clarified. It is needless to stress that costs associated with the packaging are incurred right through any operation and the basic material or container costs should never be considered in isolation. The factors contributing to the overall cost of packaging a particular product are

1) Package cost

2) Storage and handling cost of packaging materials

3) Quality control cost

4) Packaging line operations costs

5) Storage costs of filled package

6) Cost due to package/product loss/spoilage

It has been proposed that in the selection of packaging materials where cost is often a determining factor, several units of measurement may be considered. Many packaging materials are purchased and paid for on a per kilogram basis. Since the yield factor (square inches per square meter per kilogram) may determine the number of packages that can be prepared from a given weight of packaging material, it too must be considered. The concept of cost per unit area is universally accepted and packaging experts employ this mode of cost operation.

In deciding the package cost, one must consider the effect of the potential loss customer goodwill. If alternative systems are developed for the packaging of the product, one must decide whether to maintain the same packaging cost and reduce the loss rate or to reduce the packaging cost and keep the loss rate constant, also taking into consideration the effect on the customer. Two issues have become apparent when we refer to competitive packaging materials. Firstly, materials must have certain characteristics to perform the functions which are required in their use as a packaging material. Some materials are better placed than others and there is normally a comparison of their properties to decide which will perform best under any given circumstances. No material is perfect and in most cases there is a trade-off of properties to reach a final decision. It is interesting to note that most packaging materials can, through highly scientific means and advanced technological developments, overcome some of their inherent weaknesses to place them in a better competitive position i.e. their toughest opposition.

This invariably costs money, which leads to the second point, namely that of the economics of packaging material. Upgrading the product technologically may be a technically feasible proposition but the strong question remains is it commercially feasible. And in this respect the commercial realities of a product carry more weight than anything else. The crux of the matter is that customers will only convert to an alternative packaging medium if the conversion results in better bottom line performance.

This is a very stable industry, which has grown steadily over many years. It is prone to violent swings in the economic cycle, mainly because the major off-take is pitched at the non-durable segment of the market with a heavy emphasis on beverages – alcoholic and non-alcoholic as well as food.

Packaging, in product distribution is a techno-economic function aimed at maximizing sales, while minimizing the total overall cost of distribution. It can be regarded as a benefit to be optimized rather than merely a cost to be minimized. Packaging must be considered in relation to four major factors in industry today: materials utilization, machinery and line efficiency, movement in distribution and management of people.

26.2 Elements of total cost

These are seven elements of packaging costs:

1. Development costs
2. One-time costs
3. Material costs
4. Packaging Machinery costs
5. Packing Process costs
6. Distribution costs
7. Write-off inventories

In computing economics, the packaging professional should address direct costs such as materials, labour and utilities associated with the packaging. Allocation of indirect costs such as administration, sales, plant over-heads or return on investment are better left to the financial professionals, since each organization has its specific set of rules for accounting.

The development costs are involved in the development of a package and normally carry through issuance of the final specification. Examples would include concept research, design, models, tooling, samples, sample evaluation, testing, test marketing, specifications, preparation, quality control, start-up etc. There will be occasions when the development costs of a package are so expensive that it might require several years to amortize the initial costs, although 1 to 2 years is a normal payback period. While one-time costs are generally regarded as costs that are paid “one-time” and are not repeated during the life of a packaging specification. They include both the above development costs as well as costs for tooling, dies, special moulds, and gravure cylinders. And finally the material costs. We usually think of this when packaging economics is discussed. It is really only part of the costs, and even material costs have their own factors, some of which are frequently ignored, with later embarrassment.

Material costs would include:

- Basic unit price
- Special packing
- Freight
- Packaging materials storage and handling
- Shrinkage of packaging materials
- Sampling and inspection costs

An effective materials pricing policy would include knowledge of:

- how the material is produced
- where it is produced
- alternate methods of price quotation
- production losses
- specification / quality assurance control

A packer need not own all the equipment in his packing lines since lease and rental arrangements are available on many kinds of machines, such as can closers, cluster packers, vacuum cappers, and in general machines which are part of packaging systems. Supplier service and maintenance contracts are available to go with the machinery. The allocation of rental and service charges to total packaging costs is quite easy.

All labour costs (direct and indirect), overhead and incidental materials must be calculated in devising a truly valid process. Plant overhead, floor space, energy and inspection costs must be calculated. In order to save utility charges, some companies elect to install their own energy plants. Fixed overhead should be known and computed into the cost of every package produced. The total monthly costs, divided by units packed, will identify a cost per unit for such materials. With a couple of months’ records on such items the packaging technologist can readily estimate the cost impact on any proposed new package. All expenses concerned with physical moving finished packaged goods from the packaging plant to the customer are distribution costs. These costs include packing materials, palletizing, warehousing, loading and shipment. Certain products need special warehousing conditions.

Lesson- 27 Economics of plastic packaging

27.1 Introduction

A plastic material is one which is a solid at ordinary temperatures and allows appreciable and permanent change of form without losing its coherence on the application of pressure and/or heat. The share of plastics in the packaging market has been growing at remarkable pace, partially replacing paper, glass, and metal. Because of their unique combination of properties, plastics have expanded the packaging industry to sophisticated levels.

- Plastic containers are light weight, breakage resistant, transparent, flexible, squeezable, moldable in complex shapes, easily colored and printed, retortable, sterilizable, reusable, and recyclable.
- Plastics have many positive tradeoffs within their array of versatile properties, including easy processing, good mechanical properties, large range of processing temperatures, lowest density among packaging materials, and (for better or worse) they are permeable materials.

27.2 Economic factors of Plastic packages

The prices of packaging containers depend on the type of material and desired shape of container. Complex conversion processes (e.g. blow molding, coating, and laminations) add to the cost of the finished package. Price of packaging products is affected by the costs of raw materials, technology competition, vertical integration and opportunities in material substitution. Prices are affected by domestic economic conditions, recessions result in oversupply and growth cycles strain production capacity.

27.2.1 Development cost

Main factors determining the cost of a package can be classified as follows.

1. Identification of package characteristics that takes into account the nature of the product, FDA requirements and customer's needs.

2. Concept search; when several types of packaging material can equally serve the same goal, at least two different packages must be considered.

3. Design to provide the best combination of material, shape, size, appearance, color, special features, and product's shelf-life.

4. Preparation of package models to provide a basis for evaluation and even customer research.

5. Fabrication of samples to test the package in real situations.

6. A sample evaluation program may be necessary to assess extreme processes and market conditions, i.e., rough handling or high temperatures.

7. Preparation of cost analysis and specifications taking into account results of the sampling program.

8. Test marketing to evaluate on a small-scale the whole development plan from package production to logistics and consumer satisfaction.

9. Design and specification refinements that may be necessary to improve the original concept.

10. Tooling for production including, but not limited to, molds, litho plates for caps, and containers.

27.2.2 One- time costs

One-time costs are the expenditures that are made only once during the expected time of the package.

1. Machines to make the containers, which may include, e.g. a bag former or blow molder.

2. Supplier molds or dies for the packages, caps, secondary packages.

3. Printing plates, dies or cylinders.

4. Packaging line equipment or replacement parts.

5. Equipment installation.

27.2.3 Package material costs

1. Resins or films to make the container.

2. Packaging for inbound shipment

3. Inbound freight

4. Storage and handling the package material from the supplier to the packer's filling lines

5. Waste factor from damage and loss during container production, filling, or printing

6. Sampling and inspection

27.2.4 Packaging machinery costs other than one-time

1. Rental or lease of equipment and machines

2. Services and maintenance

3. Amortization of purchased machines, auxiliary equipment

4. Energy and utilities

27.2.5 Packaging process costs

1. Direct labor

2. Indirect labor

3. Overhead

4. Incidental materials

27.2.6 Distribution costs

1. Storage handling and warehousing.

2. Outbound freight.

27.3 Main factors for cost analysis of plastic package

27.3.1 Rigid container

Food grade resins are more expensive than the general purpose grade since they require sanitary process conditions, and limitations in the use of scrap and reworked conditions. In the case of polyvinyl chloride (PVC), the addition of heat stabilizer, color, and plasticizer almost double the price of the raw resin.

27.3.2 Injection molding (IM)

IM is used for producing containers and parts, i.e., closures that require high precision in their dimensions. Main cost components of injection molded pieces are

1. Plastic resin(s)

2. Mold and cavities; the mold cost is amortized over a million pieces

3. Molding processes (labor, energy, and overhead)

4. Scrap discarded or grounded for re-use

5. Assembling, finishing, and/or decorating

27.3.3 Blow molding

The most common resins for blow molded containers are: high density polyethylene (HDPE), thermoplastic polyesters, polystyrene and PP. They make up 90% of the market. Rigid blow-molded containers, primarily bottles, are widely used in beverages, food, medicinal products, cleaning products, and many other applications. Compared to glass containers, the cost ratio of polyolefin resins to glass is 1.4 to 1. But plastic containers' lower weight reduces transportation costs, and can more than equalize the raw material cost between polyolefins and glass containers. As a rule of thumb, the price of bulk shipment in large boxes of blow-molded bottles of natural HDPE is about 3.2 times the price of the resin at the molder's plant. Smaller containers, 360 ml have a slightly higher factor while larger containers of 3.75 l are lower. Colored containers cost more depending on the formulation and number of pieces produced.

27.3.4 Thermoforming

Thermoformed packages are made from sheets of thermoplastic materials. Polyethylene, PVC, Ionomers, PETG, polystyrene, and cellulose acetate are common plastics used for thermoformed packages. The cost of thermoformed packages includes:

1. Cost of resin

2. Cost of fabricating the sheet

3. Alternatively, price of purchasing the sheet

4. Thermoforming equipment, mold, and trimming tools (Thermoforming molds are less expensive than blow molding and injection molds.)

5. Thermoforming operations that include heating of sheet, forming the container, and trimming it off

6. In the case of a blister package, heat sealing the blister to a paperboard, normally 0.015 in thick (380 µm)

7. Other costs associated with waste handling, e.g., regrinding and re-extrusion (Laminated structures are eliminated or included as reground layer; scrapless thermoforming substantially reduces the waste.)

8. Post-forming costs including stacking, packing, and shipment

27.3.5 Flexible Packaging

Flexible packaging can be presented with high quality surfaces printed by flexo, gravure, offset, or letterpress processes. Since there are several plastic materials that can be combined with foil, paper, and a variety of surface treatments, the number of flexible structures is very large. Total investment for manufacturing the web of material including the printing is very high. From the standpoint of using a flexible structure, the material cost is related to the flexible structure composition, which in turn is determined by the product characteristics, storage and transportation conditions, and shelf-life requirements. The cost of flexible packaging materials is usually expressed per area of structure, m^2 or 1000 in^2. The costs can be expressed by unit of package or "repeat."

Module- 10 Performance evaluation of different methods of packaging food products, their merits and demerits, scope of improvements

Lesson- 28 Protective functions of food packaging

28.1. Introduction

All packaging aims at preventing contamination of foods by providing a barrier to soils, microorganisms, insects and/or rodents. Depending on the food product, packaging is also designed to control other environmental interactions, including oxygen uptake, moisture loss or gain, aroma loss or gain, food component absorption by the packaging material (scalping), package-component migration into the food, and light transmission.

Packaging works with the preservation approach by preventing microbial contamination, inhibiting microbial growth, and minimizing quality loss. However, after packaging it is possible that foods can deteriorate from one or a combination of biological, chemical, and physical reasons. Destruction and inhibition of microorganisms are the main concerns of food preservation approaches, related to preventing food spoilage and food-borne illness, along with providing the highest food quality (appearance, aroma, taste, texture, etc.) possible.

28.2 Packaged food interaction with surrounding environment

28.2.1 Environment gasses (Oxygen, nitrogen and carbon did oxide)

Exposure to oxygen can cause deterioration of many foods due to oxidation of lipids and other oxygen-sensitive components such as aromas, colors, and vitamins. These foods benefit from packaging that can maintain a vacuum or nitrogen atmosphere and provides a barrier to oxygen.

Foods such as fresh meat, poultry, bakery and pasta products, and chilled prepared foods benefit from packaging that can maintain either a vacuum or a targeted low concentration of oxygen and high concentration of carbon dioxide to prevent oxidation and control microbial growth. High concentration of oxygen combined with high concentration of carbon dioxide maintains color of fresh red meat. Fresh

Table28.1: Interactions possible among food, package and the environment

S.N.	Food	Packaging	Environment	Direction
1.	Color, flavor, nutrient degradation	Light transmission	Light	Environment to Food
2.	Color, flavor, etc. oxidation; respiration	Oxygen permeation	Oxygen	Environment to Food
3.	Carbonation loss; respiration	Carbon dioxide permeation	Carbon dioxide	Food to Environment
4.	Stickiness; texture loss; microbial growth	Water vapor permeation	Water vapor	Environment to Food
5.	Dehydration; texture increase	Water vapor permeation	Water vapor	Food to Environment
6.	Aroma and/or flavor change	Aroma permeation	Aroma	Environment to Food
7.	Aroma and/or flavor change; toxicity	Package component migration		Packaging to Food
8.	Aroma and/or flavor loss	Absorption (scalping)		Food to Packaging

fruits and vegetables are respiring and thus need packaging that allows permeation of oxygen in and carbon dioxide out at appropriate rates. Proper design of fruit and vegetable packaging takes into account the different respiration rates of different fruits and vegetables and controls package-head-space oxygen and carbon dioxide concentrations to targeted levels that reduce product respiration rate and increase shelf life.

28.2.2 Water Vapor

Food stability and food properties, it is appropriate to use water activity, aw, as a measure of the degree of water association with the food's nonaqueous constituents plays a very important role. Food which is in equilibrium with its environment.

$$a_w = ERH/100$$

Where:

ERH- Equilibrium relative humidity

The water activity affects food stability in a number of different ways. A typical relationship between water activity and moisture content (moisture isotherm) and the relative rates for a number of chemical reactions, enzyme activities, and microorganism growths that lead to food deterioration.

Table 28.2: Approximate Amounts of Oxygen and Moisture with which Foods Can Interact before Unacceptable Change

S.N.	Food or beverage	Maximum O_2 gain(ppm)	Maximum water gain or loss
1.	Canned milk, vegetables, flesh foods, baby foods, soups, and sauces	1–5	3% loss
2.	Beers and wines	1–5	3% loss
3.	Instant coffee	1–5	2% gain
4.	Canned fruits	5–15	3% loss
5.	Dried foods	5–15	1% gain
6.	Dry nuts and snacks	5–15	5% gain
7.	Fruit juices, drinks and carbonated soft drinks	10–40	3% loss
8.	Oils, shortenings, and salad dressings	50–200	10% gain
9.	Jams, jellies, syrups, pickles, olives, and vinegars	50–200	3% loss
10.	Liquors	50–200	3% loss
11.	Condiments	50–200	1% gain
12.	Peanut butter	50–200	10% gain

28.2.3 Aroma

Undesirable interactions of food with the environment include the possibility of loss or gain of aromas. Loss of food aromas to the environment reduces the fresh character of food. Gain of aromas from the environment can include engine fuel and exhaust vapors, as well as the aromas of other products such as cosmetics and cleaning agents. Thus, packaging that retains food aromas and excludes foreign aromas is important for maintaining food quality.

28.3 Packaged food interaction with light

Solid foods are least sensitive to light, because the penetration of light into the food decreases exponentially. However, the situation is different for liquid foods. Diffusion in the liquid exchanges light-sensitive food components between the surface and interior, so that light-degraded compounds are replaced with non-degraded compounds at the surface that are subsequently degraded. The light-degraded compounds can also interact with compounds in the interior to cause further degradation. The quality of food depending on food composition, light can catalyze a number of reactions that lead to chemical deterioration. Light in the high ultraviolet (2900–4000 Å) and low visible (4000–4500 Å) wavelengths catalyzes lipid, color, flavor, and vitamin degradation.

28.4 Packaged food interaction with Physical stresses

Food physical deterioration can result from bruising, deformation, breakage, or abrasion due to subjection of food to compression, shock, or vibration. Bruising of fresh fruits, vegetables, meat, poultry, and seafood can lead to chemical and biological deterioration. Deformed, fragmented, or abraded food is viewed as inferior by consumers. Rigid and semi-rigid packages protect food from compression damage to the extent they maintain their integrity under compression. Flexible packaging provides little or no protection against compression damage. Thus, primary flexible packages of food are often placed in semi-rigid or rigid secondary packages. All packages, including flexible packages, limit shock and vibration damage to the extent they restrict movement of the food. Beyond protecting food from physical deterioration, the packaging must maintain its integrity to provide its other functions. Failure of the packaging material will result in food contamination from soils and microorganisms, as well as increased interactions with the atmosphere.

28.5 Packaged food interaction with packaging materials

In scalping (sorption), a component of a food product is absorbed by the packaging material without transfer to the surrounding atmosphere. To varying degrees, all materials used for food packaging have been found to interact with food in one or both ways. Possible migrating substances include plastic monomers and plasticizers, paper coating and adhesive components, metals and metal coatings and glass component ions. The greatest concern is with migration of low molecular weight substances from polymeric plastic materials in contact with food. The existence of these substances in packaging does not necessarily produce migration. The greatest concern with scalping is also with polymeric plastic materials, with resulting loss in food quality. The migration and scalping phenomena are very important to food safety and quality.

Lesson- 29 Performance evaluation of packaging on meat products and dairy products

29.0 Introduction

It has become increasingly important to integrate packaging into the total product system if the objectives of delivering safe and high quality food are to be achieved.

29.1Meats

29.1.1Fresh Meat

Most meat is offered to consumers in a freshly or recently cut form, with little further processing to suppress the normal microbiological flora present from the contamination received during the killing and breaking operations required to reduce carcass meat to edible cuts. Reduced oxygen also leads to fresh meat color being the purple of myoglobin, a condition changed upon exposure to air which converts the natural meat pigment to bright cherry red oxymyoglobin characteristic of most fresh meat offered to and accepted by consumers. Reduced oxygen packaging is achieved through mechanical removal of air from the interiors of gas barrier multilayer flexible material pouches closed by heat scaling the end after filling.

29.1.2Ground Meat

About 40% of fresh beef is offered in ground form to enable the preparation of hamburger sandwiches and related foods. Ground beef was originally a byproduct, that is, the trimmings from reducing muscle to edible portion size. The demand for ground beef is so great that some muscle cuts are specifically ground to meet the demand. The most common packaging technique is pressure stuffing into chubs which are tubes of flexible gas barrier materials closed at each end by metal clips. At retail level the coarsely ground beef is finely ground to restore the desirable red color and to provide the consumer with the desired product.

The retail cuts and portions are placed in expanded polystyrene (EPS) trays which are overwrapped with plasticized polyvinyl chloride (PVC) film. The tray materials are fat and moisture resistant only to the extent that many trays are internally lined with absorbent pads to absorb the purge from the meat as it ages and/or deteriorates in the retail packages. The PVC materials are not sealed but rather tacked so that the modest water vapor barrier structure does not permit loss of moisture during distribution.

29.1.3 Case-Ready Meat

Case-ready retail packaging involves the cutting and packaging under hygienic conditions to reduce the probability of microbiological contamination. The package is usually in a gas barrier structure, typically gas/moisture barrier expanded polystyrene trays heat seal closed with polyester/gas barrier film. The internal gas is altered to a high oxygen/high carbon dioxide internal atmosphere. The high oxygen concentration fosters the retention of the consumer desired red color while the elevated carbon dioxide suppresses the growth of most spoilage microorganisms. for ease-ready beef and pork include the master bag system used widely for cut poultry in which retail cuts are placed in printed polyolefin film overwrapped EPS trays and the trays are multipacked in gas barrier pouches whose internal atmospheres are carbon dioxide to retard the growth of aerobic spoilage microorganisms.

29.1.4 Processed Meat

Longer-term preservation of meats is achieved by curing using agents such as salt, sodium nitrite, sugar, seasonings, spices, and smoke, and processing methods such as cooking and drying to alter the water activity, add antimicrobials, provide a more stable red color, and generally enhance the flavor and mouth-feel of the cured meats. Frankfurters are generally packaged in twin web vacuum packages in which the base tray is an in-line thermoformed nylon/polyvinylidene chloride (PVDC) web and the closure is a heat-sealed polyester (PET)/PVDC flexible material. Sliced luncheon meats and their analogs are in thermoformed Unplasticised PVC or polyacrylonitrile (PAN) trays heat-seal closed with PET/PVDC film. Sliced bacon packaging employs one of several variations of PVDC skin packaging (in contact with the surface of the product) to achieve the oxygen barrier.

29.1.5 Poultry

Poultry is largely chicken, but turkey has become a much more significant category of protein. The dressed birds are chilled in water close to their freezing points after which they are usually cut into retail parts and packaged in case-ready form: expanded polystyrene trays overwrapped with printed PVC or polyethylene film. All meat products may be preserved by thermal sterilization in metal cans. Product is inserted and the container is hermetically sealed usually by double seam metal end closure. After sealing, the cans are retorted to destroy all microorganisms present and cooled to arrest further cooking. The metal serves as a gas, moisture, microbial, etc., barrier to ensure indefinite microbiological preservation.

29.1.6 Sea Foods

Packaging for fresh seafood is generally moisture resistant but not necessarily against microbial contamination. Simple polyethylene film is employed often as a liner in corrugated fiberboard cases. The polyethylene serves not only to retain product moisture but also to protect the structural case against internal moisture. Seafood may be frozen in which case the packaging is usually a form of moisture resistant material plus structure such as polyethylene pouches or polyethylene coated paperboard cartons. Canning of seafood is much like that for meats because all sea foods are low acid and so require high pressure cooking or retorting to effect sterility in hermetically sealed metal cans.

29.2 Dairy Products

29.2.1Milk

Milk and its derivatives are generally excellent microbiological growth substrates and therefore potential sources for pathogens. For this reason, almost all milk is thermally pasteurized or heated short of sterility as an integral element of processing. Refrigerated distribution is generally dictated for all products that are pasteurized, to minimize the probability of spoilage. Milk is generally pasteurized and packaged in relatively simple polyethylene- coated paperboard gable top cartons or extrusion blow-molded polyethylene bottles for refrigerated short-term (several days to 2 weeks) distribution. Three general types of aseptic packaging equipment are employed commercially: vertical form / fill/seal, in which the paperboard composite material is sterilized by hydrogen peroxide, erected preformed paperboard composite cartons that are sterilized by hydrogen peroxide spray, and bag-in-box in which the plastic pouch is presterilized by ionizing radiation. The former two are generally employed for consumer sizes while the last is applied to hotel/restaurant/institutional sizes, largely for ice cream mixes. Fluid milk is generally pasteurized, cooled, and filled into bag-in-box pouches for refrigerated distribution.

29.2.2 Cheese

Fresh cheeses such as cottage cheese, fabricated from pasteurized milk, are generally packaged in polystyrene or polypropylene tubs or polyethylene pouches for refrigerated distribution. These package forms do not afford significant protection beyond barrier against recontamination, i.e., they are little more than rudimentary moisture loss and dust protectors because the refrigerated distribution time is so short.

29.2.3 Fermented Milks

Fermented milks such as yogurts fall into the category of fresh cheeses from a packaging perspective, i.e., they are packaged in either polystyrene or polypropylene cups or tubs to contain and to protect minimally against moisture loss and microbial recontamination. Aseptic packaging of such desserts is occasionally performed to achieve extended ambient temperature shelf life. Two basic systems are employed, one with preformed cups and the other, thermoform/fill/seal. In cured cheese, microbiological growths may be retarded by packaging under reduced oxygen and/or elevated carbon dioxide. Commercially, gas barrier packaging is used to retain the internal environmental condition. Generally, flexible barrier materials such as nylon plus polyvinylidene chloride or polyester/polyvinylidene chloride are employed.

29.2.4 Ice Cream

Ice cream and related frozen desserts are distributed under frozen conditions. The product must be pasteurized prior to freezing and packaging. The packaging is basically moisture resistant because of the presence of liquid water prior to freezing and sometimes during removal for consumption. Water-resistant paperboard, polyethylene-coated paperboard, and polyethylene structures are usually sufficient for containment of frozen desserts.

Lesson- 30 Performance evaluation of packaging on fruits and vegetables and other products

30. Introduction

Fruits are generally high acid and vegetables are generally low acid. Major exceptions are tomatoes, which commercially are regarded as vegetables, and melons and avocados, which are low acid. The most popular produce form is fresh and increasingly fresh-cut or minimally processed. Fresh produce is a living, "breathing" entity fostering the physiological consumption of oxygen and production of carbon dioxide and water vapor. From a spoilage standpoint, fresh produce is more subject to physiological than to microbiological spoilage, and measures to extend the shelf life are designed to retard such reactions and water loss. A variety of food products that do not fall clearly into the meat, dairy, fruit or vegetable categories may be described as prepared foods, a rapidly increasing segment of the industrialized society food market during the 1990s. Prepared foods are those that combine several different ingredient components into dishes that are ready to eat or nearly ready to eat.

30.1 Fruits and vegetables products

30.1.1 Fruits and vegetables

Alteration of the atmospheric environment in the form of modified or controlled atmosphere preservation and packaging have been used commercially to extend the refrigerated shelf life of fresh produce items such as apples, pears, strawberries, lettuce, and now fresh-cut vegetables. Controlled atmosphere has been largely confined to warehouse and transportation vehicles such as trucks and seaboard containers. In controlled atmosphere preservation, the oxygen, carbon dioxide, ethylene, and water vapor levels are under constant control to optimize refrigerated shelf life.

Fresh-cut vegetables, especially lettuce, cabbage, and carrots have been a major product in the retail and the hotel/restaurant/ institutional market. Cleaning, trimming and size reduction lead to greater surface to volume of the produce and to the expression of fluids from the interior to increase the respiration and microbiological growth rate. Uncut produce packaging is really a multitude of materials, structures, and forms that range from the old and traditional, such as wood crates, to inexpensive, such as injection-molded polypropylene baskets, to polyethylene liners within waxed corrugated fiberboard cases. Much of the packaging is designed to help retard moisture loss from the fresh produce or to resist the moisture evaporating or dripping from the produce to ensure the maintenance of the structure throughout distribution. Some packaging recognizes the issue of anaerobic respiration and incorporates deliberate openings to ensure passage of air into the package, as, for example, perforated polyethylene pouches for apples or potatoes.

For freezing, vegetables are cleaned, trimmed, cut, and blanched prior to freezing and then packaging, or prior to packaging and then freezing. Blanching and the other processing operations reduce the number of microorganisms. Fruit may be treated with sugar to help retard enzymatic browning and other undesirable oxidations. Frozen food packages are generally relatively simple monolayer polyethylene pouches or polyethylene-coated paperboard to retard moisture loss.

Canning of low-acid vegetables to achieve long-time ambient-temperature microbiological stability is conventional for low-acid foods, with blanching prior to placement in steel cans. Canned fruit is generally placed into lined three-piece steel cans using hot filling coupled with post-fill thermal treatment. Increasingly one end is easy-open for consumer convenience.

30.1.2 Tomato Products

The highly popular tomato-based sauces, pizza toppings, etc., must be treated as if they were low acid if they contain meat as so many do. For marketing purposes, tomato-based products for retail sale are more commonly packaged in glass jars with reclosable metal closures. The glass jars are often retorted after filling and hermetic sealing.

30.1.3 Juices and Juice Drinks

Juices and analogous fruit beverages may be hot filled or aseptically packaged. Traditional packaging has been hot filling into steel cans and glass bottles and jars. Much fruit beverage is currently hot filled into heat-set polyester bottles capable of resisting temperatures of up to 80ºC without distortion. Hermetic sealing of the bottles provides microbiological barriers but the polyester is a modest oxygen barrier and so the ambient temperature shelf life from a biochemical perspective is somewhat limited. The hot filling generates an internal vacuum within the pouch after cooling so that the contents are generally ambient temperature shelf stable. The package materials used are generally laminations of polyester and aluminum foil with a linear low density polyethylene (LLDPE) internal sealant to achieve an hermetic heat seal.

30.2 Other Foods

30.2.1 Dry Foods

Removing water from food products markedly reduces water activity and its subsequent biochemical activity, and thus also significantly reduces the potential for microbiological growth. Moisture can change physical and biological properties. Engineered dry products include beverage mixes such as blends of dry sugars, citric acid, color, flavor, etc.; and soup mixes, which include dehydrated meat stock plus noodles, vegetables, meats, etc., that become particulate-containing liquids on rehydration with hot water. Such products must be packaged in moisture-resistant structures to ensure against water vapor entry which can damage the contents.

30.2.2 Fats and Oils

Fats and oils may be classified as those with and those without water. Cooking oils such as corn or canola oil and hydrogenated vegetable shortenings contain no water and so are stable at ambient temperatures if treated to preclude rancidity. Unsaturated lipids are susceptible to oxidative rancidity. Hydrogenated vegetable shortenings generally are packaged under nitrogen in spiral-wound composite paper-board cans to ensure against oxidative rancidity. Edible liquid oils are packaged in injection blow-molded polyester bottles usually under nitrogen. Fat-resistant packaging such as polyethylene-coated paperboard, aluminum foil/paper laminations and parchment paper wraps, and polypropylene tubs are used to package butter, margarine, and similar bread spreads.

30.2.3 Cereal Products

Dry breakfast cereals generally are sufficiently low in water content to be susceptible to water vapor absorption and so require good moisture- as well as fat-barrier packaging. Breakfast cereals are usually packaged in coextruded polyolefin films fabricated into pouches or bags inserted into or contained within printed paperboard carton outer shells. Sweetened cereals may be packaged in aluminum foil, metalized plastic, or gas barrier plastic films or laminations to retard water vapor and flavor transmission.

Soft bakery goods such as breads, cakes, and muffins are highly aerated structures subject to dehydration and staling. To retard water loss, good moisture barriers such as coextruded polyethylene film bags or polyethylene extrusion coated paperboard cartons are used for packaging. Package structures for cookies and crackers include fat- and moisture-resistant coextruded polyolefin film pouches within paperboard carton shells and thermoformed polystyrene trays over-wrapped with polyethylene or oriented polypropylene film. Soft chewy cookies are packaged in high moisture-barrier laminations containing metallized film to improve the barrier.

30.2.4 Salty Snacks

Snacks include dry cereal or potato products such as potato and corn and tortilla chips, and pretzels, and include roasted nuts, all of which except pretzels have low water and high fat contents. Snacks are usually packaged in flexible pouches made from oriented polypropylene or metallized oriented polypropylene to provide low moisture and gas transmission. Snack food producers depend on rapid and controlled product distribution to minimize fat oxidation. Many salty snacks are packaged under nitrogen both in pouches and in rigid containers such as spiral-wound paperboard composite cans to extend shelf life.

30.2.5 Candy

Chocolate, a mixture of fat and nonfat components such as sugar, is subject to slow flavor change. Ingredients such as nuts and caramel are susceptible to water content variation. Chocolates, which are generally shelf stable at ambient temperatures, are packaged in fat-resistant papers and moisture/fat barrier such as pearlized polypropylene film. Hard sugar candies are flavored amorphous sugars which are very hygroscopic because of their extremely low moisture contents. Sugar candies are packaged in low-moisture-transmission packaging such as unmounted aluminum foil, oriented polypropylene film, or metallized oriented polypropylene film.

Module- 11 Disposal and recycle of packaging waste

Lesson- 31 Recycling of packaging

30. Introduction

Materials plays an increasing role in packaging and numerous applications can already be found in the market. Ten or twenty years ago most post-consumer packaging waste was going into landfill sites or to incineration. Traditionally, only glass and paper/board were recycled into new applications. In the case of packaging plastics the situation is quite different. Only uncontaminated in-house production waste was collected, ground and recycled into the feed stream of the packaging production line without further decontamination. With increasing environmental demands, however, post-consumer plastics packaging materials have also been considered more and more for recycling into new packaging.

But recycling of packing plastics is also a question of recycling technology and collection of packaging waste. Today many countries have established collection systems for post-consumer packaging waste, like the green dot systems. Such country-wide collecting systems guarantee increasing recovery rates. Together with new developments of recycling systems and with increasing recycling capacity the way is open for some plastics for a high value recycling of packaging waste. Due to health concerns most of the recycled post-consumer plastics are going into less critical non-food applications, but in recent years there have also been efforts to recycle post-consumer plastics like PET into new food packaging applications.

30.1. Recycling technology

Today a considerable diversity in recycling technologies can be found, although all of them have the same objective which is to clean up post-consumer plastics. Most of them first use a water-based washing step to reduce surface contamination and to wash off dirt, labels and clues from the labels. The material is also ground to flakes during one of the first steps in the recycling process. In most cases these washing steps are combined with separating steps where different materials like polyolefin's of PET are separated due to their density. It is obvious, that the cleaning efficiency of these washing processes is normally very different, depending on time, on hot or cold water-based washing or depending on the detergents added to the washing solution. However, typical washing processes are able to remove only contaminants from the surface of the polymers. They are not able to remove organic substances which have migrated in the polymer. Therefore the purity of washed flakes is usually not suitable for closed-loop recycling. A simple remelting or re-extrusion of the washed fakes has an additional cleaning effect; however the purity is usually not sufficient for reuse in the sensitive area of food packaging. Three types of recycling are possible for packaging: mechanical, chemical, and biological.

30.1.1. Mechanical Recycling

The most common type is mechanical recycling, involving reprocessing of recycled materials through physical steps that can include cleaning, shredding/grinding, separating, and reforming. These steps result in metal and glass containers that are acceptable for use with foods. However, they generally do not ensure removal of all possible contaminants from paper and plastic materials to allow use of the recycled-content package with foods involving long-term contact. The FDA reviews food contact applications of these recycled materials on a case-by-case basis that includes consideration of source control to ensure cleanliness, recycling process ability to remove possible contaminants, and the proposed food-contact application(s). FDA has approved several food-contact applications of mechanically-recycled plastics, including HDPE grocery bags, PS egg cartons, HDPE and PP crates for transporting fresh fruits and vegetables, and PET pint and quart baskets for fresh fruits and vegetables. All these applications involve a limited time and area of food contact at ambient and refrigerated temperatures, along with expectation that the food is normally cleaned before use or that the food is protected by a barrier (e.g., egg shell). FDA has also approved use of recycled plastic when it is co-extruded with a virgin layer of the plastic that is the food-contact surface.

30.1.2. Chemical Recycling

Chemical recycling involves depolymerization of plastic polymers to monomers or oligomers and then repolymerization to the polymer. This process allows removal of all possible contaminants, with the repolymerized polymer identical to virgin polymer. Several processes have been developed for chemical recycling of PET. An ideal plastics recycling process would take mixtures of plastic and convert them at high temperature and pressure to an economical petrochemical process stream.

30.1.3. Biological Recycling

Polymers based on renewable resources can be grouped into three categories.

- Polysaccharides and proteins extracted from plant, marine or animal sources (e.g., starch, chitosan and whey protein)
- Polymers synthesized from renewable, bio-derived monomers (e.g., polylactate)
- Polymers produced by microorganisms (e.g., polyhydroxyalkanoates)

Many of the same polysaccharides and proteins being explored for edible films and coatings are also candidates for biodegradable packaging. Biodegradable polymers are generally more expensive than synthetic polymers. Biodegradable packaging must be stable and function properly at the conditions of use, so as not to compromise the quality and safety of the food, and then biodegrade efficiently upon exposure to the appropriate microorganism(s) and environment. Biological recycling must also compete with mechanical and chemical recycling concepts that allow reusing materials rather than degrading them. Finally, biodegradable polymers must be made easily distinguishable from nonbiodegradable polymers so as not to interfere with the mechanical and chemical recycling processes. Reasons for considering use of a biodegradable polymer for packaging include.

Life of the packaged product is short

Mechanical or chemical recycling is not feasible

Biological recycling is favored by consumers

Biodegradability is legally mandated

The numbers of biodegradable packages have been developed for a number of foods are as follows:

- Pulp containers for fruits
- Wood pulp-starch trays for fresh beef and chicken
- Nitrocellulose-coated cellophane films for cheese, fruits, and confections
- Starch-based foamed shells for hamburgers and sandwiches
- Starch-based grocery bags

Polylactic acid (PLA) bottles for water and tubs for fresh-cut produce and salads

Other possible food applications being explored for biodegradable polymers include fast-food containers, cups, plates, and cutlery.

Lesson- 32 Recycling packaging materials

32.1 Introduction:

Recycling of packaging materials plays an increasing role in packaging, and numerous applications can already be found on the market. Ten or twenty years ago most post-consumer packaging waste was going into landfill sites or to incineration. Traditionally, only glass and paper/board were recycled into new applications. In the case of packaging plastics the situation is quite different. Only uncontaminated in-house production waste was collected, ground and recycled into the feedstream of the packaging production line without further decontamination. With increasing environmental demands, however, post-consumer plastics packaging materials have also been considered more and more for recycling into new packaging.

But recycling of packing plastics is also a question of recycling technology and collection of packaging waste. Today many countries have established collection systems for post-consumer packaging waste, like the green dot systems. Such country-wide collecting systems guarantee increasing recovery rates. Together with new developments of recycling systems and with increasing recycling capacity the way is open for some plastics for a high value recycling of packaging waste.

32.2 Recyclability of packaging plastics

It is generally known that food contact materials are not completely inert and can interact with the filled product. In particular, interactions between packaging plastics and organic chemicals deserve the highest interest in this context. Such interactions start with the time point of filling and continue during the regular usage phase of a package and even longer, in case a consumer 'misuses' the empty packaging by filling it with chemical formulations such as household cleaners, pesticide solutions, mineral oil or others. The inertness of common packaging polymers decreases in the following sequence:

Poly (ethylene naphthalate) (PEN) -------- poly (ethylene terephthalate) (PET) --------- rigid poly (vinyl chloride) (PVC) ----- polystyrene (PS) ------ high density polyethylene (HDPE) ------ polypropylene (PP) ------ low density polyethylene (LDPE)

32.3 Improving the recyclability of plastic packaging

The source control is the first and most important step in closed-loop recycling of packaging plastics. There must be efficient recovery or sorting processes which are able to control the input fraction going into a closed-loop recycling process. The feed stream material should have a minimum polymer type purity of 99%. Some studies were undertaken to determine the impact of PET materials formerly used for non-food applications. Studies came to the same result that due to the low diffusivity of PET packages from non-food applications could also be used as input material for bottle-to-bottle recycling. This underlines the favourite position of PET bottles for a closed loop recycling.

32.4 Using recycled plastics in packaging

Technically, recycled plastics can, in principle, be applied in direct food contact applications or protected from direct food contact by a functional barrier. The use of recycled plastic materials in packaging applications has to comply with the relevant regulations and must not be at the expense of the public health, nor should it alternate the filling's quality. In the following, practical examples of recycled plastics food packaging applications covered by a functional barrier as well as in direct food contact are described.

32.4.1 Indirect contact applications applying functional barriers

In the most general understanding the concept of a functional barrier can be defined as follows: A functional barrier is a layer in the package which protects the food from external influences under the applied fill and storage conditions. In most cases the functional barrier is the food contact layer or, in complex multi-layer structures, one very close to it. This layer acts as a barrier against contamination from the packaging's environment in general and, more specifically, from the recycled core layer or outer compartments of the package.

The functional barrier efficiency must not be confused with an absolute physical barrier such as glass or metal layers. It is related to a 'functional' quantity in terms of mass transfer which is dependent on the technological and application-related parameters of the respective food-package system. These parameters are:

- Manufacture conditions of the package
- Thickness of the functional barrier layer
- Type of functional barrier plastic
- Molecular weight and chemical structure of penetrants (contaminants)
- Concentration and mobility of contaminants in the matrix behind the functional barrier
- Time period between manufacture of package and filling
- Type of foodstuff, i.e. fat content, polarity etc.
- Filling conditions and storage (time, temperature) of the packed foodstuffs

32.4.1.1 three-layer PP cups for dairy products

A study was presented34 where the safety in food contact use of symmetrically coextruded three-layered polypropylene (PP) cups with recycled post-consumer PP in the core layer (mass fraction 50%) and virgin food grade PP in the adjacent layers was investigated. The recycled PP, which contained about 95% PP and 5% PS, was completely under source control in the recollection system and had been used in its prior application for packaging yoghurt. The intended application for the recycled material was again packaging milk products such as yoghurt with storage for short times under refrigerated conditions.

32.4.1.2 Multi-layer PET bottles for soft drink applications

A study was published in which the effectiveness of a virgin PET layer in limiting chemical migration from recycled PET was investigated. For this purpose three-layer bottles were prepared with an inner core (buried layer) of PET which was deliberately contaminated. The model contaminants used were toluene, trichloroethane, chlorobenzene, phenyl decane, benzophenone, phenyl cyclohexane and copper (II) acetylacetonate. As a result no migration was detected through a barrier of virgin PET of 186 ± 39µm thickness into 3% acetic acid using general migration test conditions of 10 days at 40ºC and also after 6 months storage at room temperature. Also migration testing with 50% and 95% ethanol as severe contact media which are relatively aggressive to PET did not lead to measurable migration rates. Consideration of diffusion models using limonene as substance for which diffusion coefficients were available, gave estimates that for a 100µm thick PET layer a breakthrough of a substance with comparable molecular weight would take place after 7.5 years or 0.8 years at room temperature or 40ºC, respectively.

32.4.2 Direct contact applications

Due to higher costs of manufacturing multi-layer bottles, the bottle manufacturing and recycling companies started the development of recycling processes without a functional barrier of virgin PET. The cleaning efficiencies of all the applied deep-cleansing recycling processes were investigated by challenge tests. Applications of direct contact recycled packaging material are in

32.4.2.1 Mono-layer PET bottle for soft drink applications

PET is one of the most favoured candidates for closed loop recycling. Due to higher costs of manufacturing multi-layer bottles, the bottle manufacturing and recycling companies started the development of recycling processes without a functional barrier of virgin PET. One decade later several super-clean recycling processes were established on an industrial scale. The cleaning efficiencies of all the applied deep-cleansing recycling processes were investigated by challenge tests and the cleaning efficiencies are well known.

32.4.2.2 Mono-layer HDPE bottles for fresh milk

Milk bottles were recovered by a deposit system and were subjected to a bottle-to-bottle recycling process. Due to the recovery system the recycled HDPE was completely under source control and had been used in its prior application only for packaging fresh milk. The recovered material was recycled first by a conventional washing based recycling process and then further deep-cleansed using a super-clean process. Subsequently the recycled material was used with a content of 20 to 30% without a functional barrier. The intended application for the recycled material was again bottles for fresh milk with short time storage under refrigerated conditions.

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