Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 25: Active and Intelligent Packaging

1. Introduction:

For a long time packaging also had an active role in processing and preservation of quality of foods. Variations in the way food products are produced, circulated, stored and sold, reflecting the continuing increase in consumer demand for improved safety, quality and shelf-life for packaged foods are assigning greater demands on the performance of food packaging. Consumers want to be assured that the packaging is fulfilling its function of protecting the quality, freshness and safety of foods. Thus, advances in food packaging are both anticipated and expected. Society is becoming increasingly complex and innovative packaging is the outcome of consumers' demand for packaging that is more advanced and creative than what is currently offered. “Active packaging” and “intelligent packaging” are the result of innovating thinking in packaging.

Active packaging can be defined as “Packaging in which supplementary constituents have been deliberately added in or on either the packaging material of the package headspace to improve the performance of the package system”. In simple terms, Active packaging is an extension of the protection purpose of a package and is commonly used to protect against oxygen and moisture. It permits packages to interact with food and environment. Thus, play a dynamic role in food preservation. Developments in active packaging have led to advances in many areas, like delayed oxidation and controlled respiration rate, microbial growth and moisture migration. Other active packaging technologies include carbon dioxide absorbers/emitters, odour absorbers, ethylene removers, and aroma emitters.

On the other hand, intelligent packing can be defined as “Packaging that has an external or internal indicator to provide information about characteristics of the history of the package and/or the quality of the food packed”. Intelligent packaging is an extension of the communication purpose of conventional packaging and provides information to the consumer based on its ability to sense, detect, or record external or internal changes in the product's environment. Eg: time-temperature indicators, ripeness indicators, biosensors, and radio frequency identification.

According to the definitions of the Actipak project, co-ordinated by Mr Nico deKruijf, TNO, the Netherlands, active and intelligent packaging are:

• Active packaging changes the condition of the packed food to extend shelf-life 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.

2. Active Food Packaging Techniques

Active packaging technologies have started to receive a great deal of attention since the last decade. The market for active packaging films was about $50 million worldwide in 2004, and this market is growing rapidly.

Active packaging techniques for preservation and improving quality and safety of foods can be divided into three categories; absorbers or scavengers, releasing systems and other systems. Absorbing (scavenging) systems remove undesired compounds such as oxygen, carbon dioxide, ethylene, excessive water, and other specific compounds. Releasing systems actively add or release 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.

Depending on the physical form of active packaging systems, absorbers and releasers can be a sachet, label or film type. Sachets are placed freely in the head-space of the package. Labels are attached into the lid of the package. Direct contact with food should be avoided because it impairs the function of the system and, on the other hand, may cause migration problems.

2.1 Oxygen Scavengers

High levels of oxygen present in food packages may facilitate microbial growth, off-flavours and off-odours development, colour change, and nutritional losses, thus causing significant reductions in the shelf-life of foods. Thus, the control of oxygen levels in packages is important to limit the rate of such deteriorative and spoilage reactions in foods. Oxygen absorbing systems provide an alternative to vacuum and gas flushing and improve product quality and shelf-life. Also, they are economically viable in reducing packaging costs and increasing profitability.

Typical oxygen absorbing systems are based on the oxidation of iron powder by chemical means or scavenging of oxygen by the use of enzymes. In the former, iron kept in a sachet is oxidized to iron oxide. The sachet material is highly permeable to oxygen and in some cases, to water vapour, for the sachet to be effective. This well-known oxygen scavenging system was first developed and introduced to the food packaging market by the Mitsubishi Gas Chemical Company, known as Ageless. The type and amount of absorbent that needs to be used in a sachet is determined by the initial oxygen level in the package, the amount of dissolved oxygen present in food, permeability of the packaging material, nature (size, shape, weight, etc.) of food and the water activity of the food. These iron-based oxygen absorbing systems have the ability to scavenge oxygen in many foods, including high, intermediate, or low moisture foods, and foods containing lipids. They can also work at refrigerated and frozen storage conditions, and can be used as effective oxygen scavengers with microwaveable food products.

In enzymatic oxygen scavenging systems, an enzyme reacts with a substrate to scavenge oxygen. These systems are more expensive than iron-based systems, due to the cost of enzymes used for the oxygen scavenging purpose. Enzymatic oxidation systems are also usually very sensitive to temperature, pH, water activity and solvent/substrate present in the sachet, thus limiting the widespread use of these enzyme-based systems.

Oxygen scavenging sachets are not appropriate for liquid foods, because the direct contact of the liquid with the sachet usually causes the leakage of sachet contents. Also, sachets may cause accidental consumption with the food or may be ingested by children. Oxygen scavenging sachets sold in the US are required to be labelled "Do not eat," for safety reasons and regulatory purposes mandated by the Food and Drug Administration. Although sachets can be concealed using secondary packages, but this practice increases packaging costs.

The incorporation of scavengers in packaging films is a good way of resolving sachet-related problems. Scavengers may either be inserted into a solid, dispersed in the plastic, or inserted into various layers of the package, including adhesive, lacquer, or enamel layers. Multi-layer oxygen scavengers more effectively absorb oxygen than single layer scavenging systems.

In the structure of a typical multi-layer oxygen scavenging system, an oxygen absorbing substance imbedded in a layer very permeable to oxygen is used to absorb oxygen present in the package head space. Oxygen entry from the outside environment to the oxygen absorbing layer is limited by a barrier layer, which is highly impermeable to oxygen. An inner layer, or a control layer, next to the oxygen absorbing layer is used to minimize any migration of the oxygen absorbing substance into the food.

Scavengers in the form of films allow the absorption of oxygen from all surfaces of the food that are in contact with the film. The rate of oxygen absorption by films changes, depending on the area and thickness of the film.

The Cryovac Corporation has developed a polymer based film that can overcome the negative effects of iron-based oxygen scavenging films. This film uses innovative technology that is invisible to consumers because the scavenging component is co-extruded as a layer of the package. Since oxygen absorbing material is virtually invisible in the films, these films do not alter the look of the package. They also offer shoppers a clear view of the product packed. It is equally effective with wet and dry products, because its scavenging action is initiated "on demand" on the processor's packaging line by an ultraviolet-light triggering process.

2.2 Carbon Dioxide Scavengers and Emitters

High levels of carbon dioxide usually play a beneficial role in retarding microbial growth on meat and poultry surfaces and in delaying the respiration rate of fruits and vegetables. For instances where the package has a high permeability to carbon dioxide, a carbon dioxide emitting system may be necessary to reduce the rate of respiration and suppress microbial growth. The use of a dual function system consisting of an oxygen scavenger and a carbon dioxide emitter is the usual practice for increasing the shelf life of highly perishable foods.

On the contrary, dissolved carbon dioxide formed after the roasting of coffee may cause the package to burst, if the roasted coffee is packed in a can or aluminium foil pouch. This released carbon dioxide from freshly roasted coffee can be scavenged through the use of a carbon dioxide scavenger. A carbon dioxide absorbing sachet is developed, which is composed of a porous envelope containing calcium oxide and a hydrating agent, such as silica gel, on which water is adsorbed. In this system, water reacts with calcium oxide and produces calcium hydroxide, which then reacts with carbon dioxide to form calcium carbonate.

2.3 Moisture Scavengers

If the package has a low permeability to water vapour, water accumulation inside the package is more pronounced. The excess water development inside a food package usually occurs due to the respiration of fresh produce, temperature fluctuations in high equilibrium relative humidity food packages or the drip of tissue fluid from cut meats, poultry, and produce.

An effective way of controlling excess water accumulation in a food package that has a high barrier to water vapour is to use a moisture or water vapour scavenger, like silica gel, molecular sieves, natural clays, calcium oxide, calcium chloride and modified starch, or other moisture absorbing substances. Silica gel is the most widely used desiccant because it is non-toxic and non-corrosive.

A blanket or a pad of desiccant is usually wrapped around the food to be preserved (meat, poultry or fish) to absorb water. Another approach to absorb moisture from these foods is to use a superabsorbent polymeric laminate film that has a moisture absorbent layer that is formed from a polyester graft copolymer and a resin, consisting of a polyurethane resin, an acrylic resin and vinyl resin. Moisture absorbing systems in sachet are usually used to maintain low levels of moisture in dried food packages, like chips, nuts, spices, biscuits, crackers, milk powders and instant coffee. The sachets like Desi Pak, Desi View, Sorb-It and 2-in-1 from United Desiccants, USA, MiniPax, StripPax, Natrasorb, and the moisture absorbing label Desimax from Multisorb Technologies, USA are the most common moisture absorbing systems used to absorb and/or control moisture for water sensitive packaged foods in USA.

2.4 Ethylene Absorbers

Ethylene is a hormone that accelerates ripening and senescence by increasing the respiration rate of climacteric fruits and vegetables, thereby decreasing shelf-life. Hence, the removal of ethylene gas from the package headspace slows senescence and improves shelf-life.

The most well-known, inexpensive, and extensively used ethylene absorbing system consists of potassium permanganate inserted in silica. The silica absorbs ethylene, and potassium permanganate oxidizes it to ethylene glycol. Silica is kept in a sachet permeable to ethylene, or it can be incorporated into a packaging film. Potassium permanganate, is not integrated into food contact surfaces of packaging films due to its toxicity. The substrate surface area and the amount of potassium permanganate affect the performance of these systems.

Another system is based on infusing zeolite with potassium permanganate, and then coating the infused zeolite with a quaternary ammonium cation. This system is not only capable of absorbing ethylene from the medium, but also other organic compounds, such as benzene, toluene, and xylene.

Ethylene scavengers have been proven to be effective in the storage of packaged fruits, including kiwifruit, bananas, avocados, and persimmons. Ethylene scavengers are commercially available as Evert-Fresh (Evert-Fresh Co, USA), Ethylene Control (Ethylene Control Incorporated, USA) and Peakfresh (Peak Fresh Products, Australia).

2.5 Flavour Absorbing/Releasing Systems

Food packaging materials like some plastics, may interact with food flavours, resulting in loss of flavours, known as flavour scalping. Flavours are usually lost or degraded after processing foods at high temperatures or after packaging. Therefore, there is a need to replace these lost flavour constituents when scalping occurs. In addition, consumers always like to smell good flavours when they first open a food package. For example, most of the dry instant coffee manufacturers often fill the headspace with distilled volatiles to have fresh coffee fragrance when the package is first opened.

In contrast to flavour releasing systems, flavour absorbers scavenge undesirable flavours, aromas, and odours present in the package headspace. Some orange varieties, such as Navel may develop a bitter flavour when limonin concentration exceeds 12 mg/kg after pasteurization. Internally cellulose acetatebutyrate coated plastic bottles, which act as limonin absorbers, have been shown to considerably reduce bitterness in orange juice thereby increasing shelf-life.

The formation of off-flavours and off-odours in food products are due to (1) the oxidation of fats and oils, leading to the formation of aldehydes; (2) the breakdown of proteins of fish muscle into amines. Although aldehydes and amines can be removed from package headspaces by flavour scavengers, these systems may mask or absorb off-flavours and off-odours that are indicative of spoilage.

3. Intelligent packaging techniques:

The definition of intelligent packaging in the Actipak project 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 like 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 like oxygen indicators for indication of oxygen or package leak, carbon dioxide indicators, microbial growth indicators and pathogen indicators. Various examples of internal and external indicators are shown in the table below.

Indicator	Principle/reagents	Gives information about	Application
Time-temperature indicators (external)	Mechanical, Chemical, Enzymatic	Storage conditions	Foods stored under chilled and frozen conditions
Oxygen indicators (internal)	Redox dyes, pH dyes Enzymes	Storage conditions Package leak	Foods stored in packages with reduced oxygen concentration
Carbon dioxide indicator (internal)	Chemical	Storage conditions, Package leak	Modified or controlled atmosphere food packaging
Microbial growth indicators (internal /external) i.e. freshness indicators	pH dyes, All dyes reacting, with certain metabolites (volatiles or non-volatiles)	Microbial quality of food (i.e. spoilage)	Perishable foods such as meat, fish and poultry
Pathogen indicators (internal)	Various chemical and immunochemical methods reacting with toxins	Specific pathogenic bacteria such as *Escherichia coli* O157	Perishable foods such as meat, fish and poultry

3.1 Time-Temperature Indicators

Temperature abuse is common during storage, transportation, and distribution, these indicators are designed to monitor temperature abuses in a food product’s shelf life.

Temperature abuse does not only cause quality and nutritional losses, but also may lead to food poisoning and food losses. Many time-temperature indicating systems are based on a colour change or colour development, which is correlated with food quality loss. Nevertheless, time-temperature indicators that have a response in the form of visible mechanical deformation are also available. Time-temperature indicators must satisfy some requirements to be effective as monitoring devices such as

1. They must be easily activated and sensitive.
2. They must provide a high degree of accuracy and precision.
3. They should have tamper evident characteristics.
4. Response should be irreversible, reproducible, and correlated with food quality changes.
5. Physical and chemical characteristics of time-temperature indicators should be determined.
6. Response should be easily readable and, should not be confusing.

Time-temperature indicators for frozen, refrigerated, modified atmosphere packaged and thermally processed foods are commercially available. Although time-temperature indicators are still in their infancy, continued research and consumer appreciation are expected to play positive roles in the development of more reliable and sophisticated systems.

3.2 Freshness indicators

A freshness indicator indicates directly the quality of the product. The indication of microbiological quality is, for example, based on a reaction between the indicator and the metabolites produced during growth of microorganisms in the product.

The freshness indicators are mainly based on compounds like glucose, organic acids and their salts, ethanol, volatile nitrogen compounds, carbon dioxide and sulphuric compounds. For example, Concentration of D-lactate increases with storage of meat. Thus it can be taken as freshness indicator.

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. The number of concepts of package indicators for contamination or freshness detection of food is still very low, however new concepts of freshness indicators are patented and new commercially available products are likely to become available in the near future.

4. Other Active & Intelligent Packaging Systems

Other active packaging applications that are expected to find increased consideration in the future include antioxidant releasing films, colour containing films, light absorbing/regulating systems, anti-fogging and anti-sticking films, susceptors for microwave heating, gas permeable/breathable films, and insect repellent packages. For example, antioxidant incorporated films can be used to prevent the oxidation of fats and oils that lead to rancidity. They can also be used to prevent the formation of off-odours and off-flavours in foods.

5. Conclusion

Oxygen scavengers, carbon dioxide absorbing/releasing systems, and indicators are promising form of active and intelligent food packages. Most of the applications are concentrated on fresh produce. Although passive packaging has been used to minimize microbial growth and the rate of deteriorative reactions in fresh fruits and vegetables, active packaging offers new opportunities in preserving fresh produce and prolonging shelf life, while intelligent packaging gives idea about history of the product and thus, the consumable quality of the product.

In the USA, Japan and Australia, active and intelligent packaging systems are already being successfully applied to extend shelf-life or to monitor food quality and safety. Despite this, regardless of intensive research and development work on active and intelligent packaging, there are only a few commercially significant systems on the market. Oxygen absorbers added separately as small sachets in the package head-space or attached as labels into the lid probably have the most commercial significance in active food packaging nowadays. Sachets suffer from inadequate consumer acceptance due to fears of ingestion by children and accidental consumption with package contents. The development and use of active packaging systems in the form of thin films can be expected to increase in the next decade.

Intelligent packaging can help in intelligent quality control. Thus, an intelligent product quality control system enables more efficient production, higher product quality and a reduced number of complaints from retailers and consumers. Continued innovations in active and intelligent packaging are expected to lead to further improvements in food quality, safety, and stability.

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Paper No.: 12
Paper Title: FOOD PACKAGING TECHNOLOGY
Module – 31: Quality evaluation of Packaging Materials

1. INTRODUCTION:

In order to evaluate the performance of a package in the market place, it is important to test the different packaging materials used for their manufacture. Thus, quality evaluation of the packaging materials is done mainly for the following purposes:

1) Comparison with competitive packaging material, e.g. to compare offers.
2) Comparison of the current supply of material with the quality of that offered for the first time; also regular checking of uniformity in new supplies of packaging materials.
3) Quality checks during the production of packaging materials.
4) Evaluation of the suitability of a packaging material for a certain specific purpose, for instance protection against mechanical or climatic hazards.

Test procedures that are applicable for general classes of materials or packages are available and published in standardized form (Paine *et al.*, 1992; Griffin *et al.*, 1972).

ASTM - American Society of Testing and Materials Standards
TAPPI - Technical Association for the Pulp and Paper Industry (USA) Standards
BIS - Bureau of Indian Standards
ISO/R - International Standards Recommendations
BS - British Standards
FEFCO - Federation Europeanne des Fabricants de Carton Ondule Test Methods
PIFA - Packaging and Industrial Films Association Standards
ABA - American Box Board Association
BPBMA - British Paper and Board Manufacturers' Association
NFPA - National Flexible Packaging Association

2. CONDITIONING OF THE SAMPLES

It is very important that the quality evaluation of the packaging material should be carried out in standard atmospheric conditions and the samples should be allowed to reach equilibrium prior to evaluation which normally takes 24 hours. This is so because the properties of many packaging materials depend on the climatic conditions to which these materials are exposed. The physical properties of paper are affected by its moisture content and the moisture content varies in proportion to the relative humidity and temperature of the surrounding atmosphere. In special cases it may be necessary to check the moisture content of the test specimen, in order to ensure that the climate has had its effect on the specimen. Quality evaluation laboratories are constructed to maintain the standard atmospheric conditions and no test is considered official if conducted under any other conditions. In a number of countries a standard atmospheric condition has been established, i.e. 20°C and 65% R.H. in Argentina, Australia, Belgium, France, Germany, Netherlands, New Zealand, UK; 23 ° C and 50% R.H. in USA, Canada, Burma, Mexico, South Africa and 27°C and 65% R.H. in India.

3. IMPORTANT QUALITY EVALUATION METHODS

Most of the tests for evaluation of packaging materials are based mainly on evaluation of one or other type of strength of packaging material to be evaluated.

3.1 Grammage or GSM

Papers, foils and films are purchased on weight basis and any deviation from the prescribed weight will affect purchaser and the vender. Most physical properties such as bursting strength, thickness are specified in accordance with a particular basis weight or bulk.

Method of Test: The samples are cut by selecting the suitable template considering the type of the sample. For heavy paper (weighing above 100 GSM) template of the size 10 cm x 10 cm is taken and hung on one of the arms of the instrument. Reading is taken directly on the scale "A". In case the paper or paper board is light and reading remains below 100 GSM then template of size 10 cm x 20 cm is used to get more accurate results and reading is taken on scale "B". At least 5 readings are taken and results are expressed in range as g/m^2.

Suitable size of paper is cut with a template and then weighed on a balance. The weight is recorded and converted in to g/m^2 and expressed as grammage or GSM.

3.2 Thickness

Many physical and mechanical properties of paper, paperboard and flexible packaging materials are dependent upon the thickness of the material. Properties like tensile strength, sealability, and seal strength, moisture, gas and light barrier properties are directly related to thickness. In case of laminates the thickness of the constituent plies are more important as they influence the barrier properties. This test is useful for routine control.

Method of Test: Cut a piece from sample without any irregularities of size 10 cm x 10 cm. Place the specimen between two points of the micrometer, one of which has to be lifted gently to insert the paper and note the corresponding reading. The thickness can be expressed in any unit such as micron, inches, mil etc. Take at least 10 readings.

0.001" = 25 micron = 100 gauge = 1 mil.

3.3. Bursting Strength: (IS 1009-1966 Part I)

Bursting strength of paper and paperboard is determined in order to assess both strength and toughness of the material. It is essentially the ability of the sample to absorb energy.

Method of Test: The sample is fixed between clamps. The area exposed is 1.2 in^2. The sample is subjected to steadily increasing pressure hydraulically exerted on a rubber diaphragm beneath the sample until it ruptures. The maximum pressure required to rupture the sample is automatically recorded by a pressure gauge. This test is of importance in routine quality check of packaging material during manufacture. Eg. Corrugated Boxes.

3.4 Tear Strength or Tearing Resistance: (ASTM, D 689-79 Part 20)

This test is performed on papers and it gives an indication towards the strength of the paper. It is helpful in making selection of papers based on material for packaging purposes. The tear strength requirements may be high or low according to end use of the packaging material. This test measures the energy absorbed by the test sample in propagating a tear that has already been initiated by cutting a small nick in the test piece.

Method of Test: The Elmendorf tearing tester has two grips set side by side with only a small separation. One grip is stationary and is mounted on an upright on the instrument base. The second grip is movable and is mounted on a pendulum. The pendulum is mounted on a frictionless bearing and swings on a shaft. The sample of 50 x 62 mm size is clamped in the two grips and a cut is made using a sharp knife fixed on the tester. When the pendulum is released, it swings down on pre-cut sample. This indicates the residual energy lost in tearing and expressed in mN (milli Newton).

3.4 Water Penetration-Cobb Test: (IS: 4006-1966 Part I):

This test measures the amount of water absorbed by the sample during penetration from one side to another. It is useful in assessing the suitability of paper and paperboards to be used for shipping containers, which may be exposed to water spray.

Method of Test: A weighed sample is clamped under a metal base plate and exposed to water for one minute (paper/paper board). The area exposed is 100 cm^2. After the specific time, the sample is removed, blotted and reweighed. The difference in weight indicates the amount of water absorbed by the sample. The results are expressed as gm / m^2.

3.5 Grease Resistance: (ASTM D-722; TAPPI T - 454)

This test is important for the packaging materials used for fat rich food products like butter, ghee, oil etc.

Method of Test: This test is performed by putting 5 g sand on the specimen through a hollow cylinder metallic piece and then topping the sand with 1.1 ml of coloured turpentine dye. This is placed on a white paper sheet and at specified intervals, the indicator sheet is examined for the first spot and after it the experiment is discontinued. The time between the application of turpentine dye and appearance of first stain is recorded as transudation time in seconds.

3.6 Water Vapour Permeability: (IS: 1060- 1960 Part II)

One of the prime functions of the packaging materials is to act as barrier to gases and vapours. Many hygroscopic foods have to be protected from oxygenated water vapour pick up. The measurement of permeability is therefore very important.

Method of Test: The water vapour permeability may be measured by means of high-vacuum techniques, although there are simple gravimetric methods available which determine Water Vapour Transmission Rate (WVTR) much easily. In this method the value of water vapour permeability is determined by the increase in weight of a dish filled with desiccant (Eg. anhydrous calcium chloride), covered with the test specimen and sealed with molten wax or vacuum grease. The sealed dish is placed in a humidity cabinet maintained at 38 ± 1°C and R.H. 90 ± 2 %.

The WVTR is computed by the following formula:

$$\text{WVTR} = \frac{G \times 24 \ \ g/m^2/24\ hrs}{A \times T}$$

Where;

G = weight gained in gm

T = time during which gain in weight is observed

A = area of the sample exposed in m^2

4. IDENTIFICATION OF PACKAGING MATERIALS:

Over the past decades packages have become more complex and we are presently using number of plastic films in packaging. Film users and converters may use a variety of instruments from high-powered microscopes to spectrophotometers. However, for easy and rapid identification of films, film users and converters usually go for simple non-instrumental techniques.

Method of Test: The first step in analyzing a flexible film is to measure some of its physical properties by density, hardness, stiffness etc. The laminates are to be delaminated into its separate plies so that they can be separately identified. There are several methods available to separate and isolate laminated components. They can be separated by heating on a flame or by immersing in boiling water up to 5 hours.

Tetrahydrofuran vapours are used for rapid separation of different laminates. The plastics can be identified by solubility or by the observation of burning characteristics where the colour of the flame, the way of dripping and the odour of the fumes assist to identify the type of plastic. The characteristics are shown in Table 1. Solubility of films in a particular solvent is an excellent and more dependable test for identification. In this test one-square inch of sample is put into 15 ml of the appropriate solvent and heated to boiling point with proper care to prevent solvent loss.

Table 1: Characteristics of different plastics

Film	Density range (gm/cc)	Flammability (self extinguishing)	Colour	Behaviour	Odour
Polyethylene	0.910 - 0.965	No	Top yellow bottom blue	Melts and drips	Burnt wax

			white smoke		
Polypropylene	0.900 - 0.915	No	Top yellow bottom blue white smoke	Melts and drips	Burnt wax and acrid
PVC	1.28-1.38	Yes	Yellow orange with green edge	Darkens, softens & decomposes	Chlorine
PVDC	1.68	Yes	As above with green spurts	Black, hard residue	Chlorine
PVA	1.21-1.33	Yes but slowly	Yellow with gray smoke	Swells, softens and turns brown	Pungent
Poly carbonate	1.2	Yes	Yellow orange with black smoke	No drips, decomposes	Pleasant
Polyester	1.38	No	Yellow-black smoke	No drips, softens, burns steadily	Pleasant
Polystyrene	1.04-1.09	No	Yellow orange black shoots	No drips, softens	Floral (sweet)
Nylon	1.06-1.14	Yes	Blue, yellow top	Melts, drips and froths, Rigid drips	Burnt Hair
Cellophane	1.48	No	Yellow, orange, Grey and smoke	Burns fast and complete, burnt area brittle	Burnt Paper
Cellulose acetate	1.28-1.32	No	Yellow with blue base	Melts, burns quickly and leaves beads	Burnt Vinegar
Cellulose Nitrate	1.35-1.40	No	Yellow	Burns at once and fully	Acrid

5.0 QUALITY EVALUATION OF FABRICATED PACKAGES

Once packaging materials have been fabricated into package, it is important to measure properties of these packages to ensure that they conform to the desired specifications. These tests involve measurement of critical dimensions and one or two critical properties.

5.1 Evaluation of Glass Bottles (IS: 1392 -1967)

5.1.1. Dimensional Measurements:

Height, body diameter, wall thickness and finish are measured to detect possible variations that may exceed the tolerance limits, which have been established by glass manufacturers. Adherence to these tolerance limits is an important factor in operation of high speed filling lines. For checking body dimensions, gauges are used which have been specially designed for each specific bottle. The capacity of glass container is measured by selecting a sample of 12 bottles at random and checking them for volume.

5.1.2 Pressure Test:

Bottles used for liquor, carbonated beverages and soda water etc. have to withstand certain amount of internal pressure. Devices are available which subject the bottles to internal pressure using a gas or liquid. The bottles are subjected to an internal pressure of 150 kg /cm^2 for 1 minute. The temperature at which the test is carried out is very important since, a bottle withstanding 150 kg/cm^2/at 30°C may fail to withstand the same pressure at 60°C. Bottles, which have to withstand pressure, should be carefully designed.

5.1.3 Thermal Shock Test:

This test is performed when the bottles are subjected to sudden temperature difference during actual filling and use. In food industry sterilized product/beverage is packed in bottles and in pharmaceutical industry, the bottles are sterilized by hot steam before use. In this test few bottles are immersed in a hot water bath at a temperature of 72 ±2°C for 300 ± 10 seconds and when the bottles have reached the temperature, they are taken out along with hot water inside and suddenly dipped in a cold water bath at 30 ± 2° C for 30 seconds. The difference between the hot water bath temperature and cold water bath temperature gives the thermal shock to the bottles. The time for transfer of bottles from the hot water bath should not be more than 60 seconds or less than 15 seconds.

5.1.4 Impact Test:

Bottles that are used again and again, often meets certain amount of impact in their daily use. In order to ensure that such bottles do not fail, this test is performed. In this test a steel ball of 400 gm is dropped from a height of 10 cm on the bottle held rigidly. In case of milk bottles the ball is dropped thrice on the same spot on the bottle and the bottle should not freak or crack. In the pendulum test the steel ball swings and strikes at the bottle held rigidly.

6. Conclusion

Packaging materials need specific properties in order to protect the contents. The quality evaluation of different packaging materials is important for manufacturers, raw material suppliers and as well as the users. The manufacturer is always interested in testing the basic quality and to find out what new applications can be developed based on the properties of the packaging material and also to check the quality of the material. The converter has interest in the conformity to specifications and suitability for application. The user wants to ensure that the material he is purchasing is of required quality and adequate to protect the product from spoilage. Thus, quality evaluation of packaging material is an important operation in the food packaging industry.

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