Fundamentals of food packaging technology

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Introduction

Food packaging plays a crucial role in preserving and protecting food products from external factors that can impact their quality, safety, and shelf life. It involves the design, production, and use of various materials and techniques to ensure that food products reach consumers in optimal condition. Packaging is vital to our modern food distribution and marketing systems. Without protective packaging, food spoilage and wastage would increase tremendously. The advent of modern packaging technologies and new methods of packaging materials made possible the era of convenience products. In the past, packaging emphasized the expectations of the producers and distributors but now it has shifted towards the consumer since they are becoming more demanding and aware of different choices to choose from. A food package usually provides a number of functions in addition to protection. Different products have different packaging requirements and it is important to choose suitable packaging material accordingly. The intended storage conditions of the product, i.e., temperature, relative humidity and expected shelf life have to be known. Multilayered plastics are very popular since properties of different films can be effectively used to pack different products. The basic function of food packaging is to protect the product from physical damage and contaminants, to delay microbial spoilage, to allow greater handling and to improve presentation.

Importance of Food Packaging

Proper food packaging serves multiple purposes, including:

- **Protection**: Packaging safeguards food from contamination, spoilage, and damage during transportation and storage.
- **Preservation**: It extends the shelf life of food by preventing moisture loss, exposure to light, and the entry of oxygen.
- **Information**: Packaging provides essential details about the product, such as ingredients, nutritional information, and storage instructions.
- **Branding and Marketing**: Packaging plays a significant role in attracting consumers, conveying brand identity, and promoting product differentiation.

Classification of Packaging Materials

Packaging materials can be classified in various ways based on different criteria. Here are some common classifications of packaging materials.

1. Based on Material Type

Glass: Glass containers have been used for many centuries and still one of the important food packaging material. Glass has its unique place in food packaging since it is strong, rigid and chemically inert. It does not appreciably deteriorate with age and offers excellent barrier to solids, liquids and gases. It also gives excellent protection against odour and flavor and product visibility. Glass can also be moulded to variety of shapes and sizes. But it has disadvantages like fragility, photo oxidation and heavier in weight.

Metal Cans: Most frequently used container for packing food for canning is tin plate can. Tin plate containers made their appearance in 1810. The base steel used for making cans is referred as CMQ or can making quality steel. Corrosion behaviour, strength and durability of the tin plate depend upon the chemical composition of the steel base. The active elements are principally copper and phosphorous. The more of these elements present the greater the corrosiveness of steel. Cans are traditionally used for heat sterilized products and different types are standard tin plates, tin free steel and vacuum deposited aluminium on steel and aluminium cans. For food products packing they are coated inside to get desirable properties like acid resistance and sulphur resistance. But care has to be taken to avoid tainting of the lacquer.

Polymer coated two-piece cans of 6 oz capacity (307 x 109) with a universal polymer coating can be widely used for a variety of products. The can is made of Electrochemically chromium coated steel (ECCS) plate with clear polyethylene terephtahalate (PET) coating on either side The finished plate has a thickness of 0.19mm (0.15 mm of base steel + 20 μ PET coating on either side). The cans are made out of the steel plate by draw and redraw (DRD) process. The chromium coating along with the PET coating provides the can with a smooth, greyish, glistening appearance in addition to act as a barrier between the product and the base steel. The bottom of the can is designed for better stackability so that it can be stacked vertically without risk of toppling on the shelf. This also helps to reduce the storage space requirement for the cans. These cans are found to be suitable for thermal processing of fish and fish products. These cans are having easy open ends. Metal cans are advantageous as packages because of superior strength, high speed manufacturing and easy filling and dosing. Disadvantages of metal cans are weight, difficulty in reclosing and disposal.

Paper: A very considerable portion of packaged foods is stored and distributed in packages made out of paper or paper-based materials. Because of its low cost, easy availability and versatility, paper is likely to retain its predominant position in packaging industries. Paper is highly permeable to gases, vapour and moisture and loses its strength when wet. Ordinary paper is not grease and oil resistant, but can be made resistant by mechanical processes during manufacturing.

Paper board: Thicker paper is called as paper board. There is not a clear-cut dividing line between the heaviest grade of paper and the lightest board. The lightest standard board is 0.19 mm thick and heavy papers are of 0.125 mm thickness. Paper boards are used for making corrugated fibre board cartons.

Polymer Packaging: Plastics offer several advantages over other packaging materials since they are light in weight, flexible and offers resistant to cracking. Plastics have the advantage that most of them possess excellent physical properties such as strength and toughness. The requirements with a particular food may not be met with in a single packaging material, as it may not possess all the desired properties. In such cases copolymers or laminates consisting of two or more layers of different polymers having different properties can also be used.

- **Low Density Polyethylene** (LDPE): Most commonly used as it possesses qualities such as transparency, water vapour impermeability, heat sealability, chemical inertness and low cost of production. Organic vapours, oxygen and carbon dioxide permeabilities are high and has poor grease barrier property. Resists temperature between – 40°C to 85°C. Polyethylene (polythene, PE) is the material consumed in the largest quantity by the packaging industry.

- **High Density Polyethylene** (HDPE): HDPE resins are produced by low-pressure process. HDPE possess a much more linear structure than LDPE and has up to 90% crystallinity, compared with LDPE which exhibits crystallinities as low as 50%. The material is stronger, thicker, less flexible and more brittle than LDPE and has lower permeability to gases and moisture. It has a higher softening temperature (121°C) and can therefore be heat sterilized. High molecular weight high density polythene (HM-HDPE) has very good mechanical strength, less creep and better environmental stress crack resistance property.
- **Linear Low-Density Polythene** (LLDPE): Linear low-density polythene is low density polythene produced by a low-pressure process. Normal low-density polythene has many $-C_5H_{11}$ side chains. These are absent in LLDPE, allowing the molecules to pack closer together to give a very tough resin. It is virtually free of long chain branches but does contain numerous short side chains. Generally, the advantages of LLDPE over LDPE are improved chemical resistance, improved performance at both low and high temperatures, higher surface gloss, higher strength at a given density and a greater resistance to environmental stress cracking. LLDPE shows improved puncture resistance and tear strength. The superior properties of LLDPE have led to its use in new applications for polyethylene as well as the replacement of LDPE and HDPE in some areas.
- **Polypropylene** (PP): Polypropylene is produced by the polymerisation of propylene. All PP films have permeability about ¼ to ½ that of polyethylene. It is stronger, rigid and lighter than polyethylene.
- **Cast polypropylene** (CPP): It is an extruded, non-oriented film and is characterized by good stiffness, grease and heat resistance and also has good moisture barrier. However, it is not a good gas barrier.
- **Oriented, Heat set Polypropylene** (OPP): Orientation can be in one direction (unbalanced) or in two directions equally (balanced). The resulting film is characterized by good low temperature durability, high stiffness and excellent moisture vapour transmission rate. One drawback of OPP is its low tensile strength.
- **Polystyrene**: The material is manufactured from ethylene and benzene, which are cheap. The polymer is normally atactic and it is thus completely amorphous because of the bulky nature of the benzene rings prevents a close approach of the chains. The material offers reasonably good barrier to gases but is a poor barrier to water vapour. New applications of polystyrene involve coextrusion with barrier resins such as EVOH and poly vinylidene chloride copolymer to produce thermoformed, wide mouthed containers for shelf stable food products and multi-layer blow moulded bottles. To overcome the brittleness of polystyrene, synthetic rubbers can be incorporated at levels generally not exceeding 14% w/w. High impact polystyrene is an excellent material for thermoforming. Co-polymerisation with other polymers like acrylonitrile butadiene improves the flexibility. Since it is crystal clear and sparkling, it is used in blister packs

and as a breathing film for packaging fresh produce. These materials have low heat sealability and often tend to stick to the jaws of heat sealer.

- **Polyester**: Polyester can be produced by reacting ethylene glycol with terephthalic acid. Polyester film's outstanding properties as a food packaging material are its great tensile strength, low gas permeability, excellent chemical resistance, lightweight, elasticity and stability over a wide range of temperature (-60° to 220°C). The later property has led to the use of PET for boil in the bag products which are frozen before use and as over bags where they are able to withstand cooking temperatures without decomposing. Although many films can be metallized, polyester is the most commonly used one. Metallization results in considerable improvement in barrier properties. A fast-growing application for polyester is ovenable trays for frozen food and prepared meals. They are preferable to foil trays for these applications because of their ability to be micro wave processed without an outer board carton.
- **Polyamides** (Nylon): Polyamides are condensation products of diacids and diamine. The first polyamide produced was Nylon-6,6 made from adipic acid and hexamethylene diamine. Various grades of nylons are available. Nylon-6 is easy to handle and is abrasion-resistant. Nylon-11 and nylon-12 have superior barrier properties against oxygen and water and have lower heat seal temperatures. However, nylon-6,6 has a high melting point and hence, it is difficult to heat seal. Nylons are strong, tough, highly crystalline materials with high melting and softening points. High abrasion resistance and low gas permeability are other characteristic properties.
- **Polyvinyl Chloride** (PVC): The monomer is made by the addition of reaction between acetylene and hydrochloric acid. It must be plasticised to obtain the required flexibility and durability. Films with excellent gloss and transparency can be obtained provided that the correct stabilizer and plasticizer are used. Thin plasticized PVC film is widely used in supermarkets for the stretch wrapping of trays containing fresh red meat and produce. The relatively high-water vapour transmission rate of PVC prevents condensation on the inside of the film. Oriented films are used for shrink-wrapping of produce and fresh meat. Unplasticized PVC as a rigid sheet material is thermoformed to produce a wide range of inserts from chocolate boxes to biscuit trays. Unplasticized PVC bottles have better clarity, oil resistance and barrier properties than those made from polyethylene. They have made extensive penetration into the market for a wide range of foods including fruit juices and edible oils.
- **Copolymers**: When polythene resins are being manufactured it is possible to mix other monomers with ethylene so that these are incorporated in the polymer molecules. These inclusions alter the characteristics of the polythene. Vinyl acetate is commonly used and the resulting ethylene vinyl acetate (EVA) copolymers display better sealing than modified polythene. Butyl acetate is incorporated with similar effects.

Aluminium foil: Aluminium foil is defined as a solid sheet section rolled to a thickness less than 0.006 inches. Aluminium has excellent properties like thermal conductivity, light weight, corrosion resistance, grease and oil resistance, tastelessness, odourlessness, heat and flame resistance, opacity and non-toxicity. Aluminium foil free from defects is a perfect moisture and oxygen barrier. In all flexible packaging applications using aluminum foil where good moisture and oxygen barrier properties are important, the foil is almost always combined with heat sealing media such as polythene or polypropylene. It is the cheapest material to use for the properties obtained. Foils of thickness 8 to 40 microns are generally used in food packaging. Foil as such is soft and susceptible for creasing. Hence, foil is generally used as an inner layer.

Wood: Used for packaging heavy or fragile items.

2. Flexibility

From skins, leaves, and bark, tremendous progress has been made in the development of diversified packaging materials and in the packaging equipment. In general, packaging materials may be grouped into rigid and flexible structures.

- **Flexible materials**: Plastic film, foil, paper and textiles are flexible materials.
- **Rigid materials**: Wood, glass, metals and hard plastics are examples of rigid materials.

3. Function

- Primary Packaging: Primary packaging refers to the immediate contact packaging of the food product. It is in direct contact with the food and is responsible for preserving its quality and integrity. Primary packaging materials must be safe, non-toxic, and compatible with the food they contain. Examples include bottles, cans, blister packs, etc.
- Secondary Packaging: Secondary packaging is the outer packaging that holds the primary packages together. It provides additional protection during transportation and storage, ensuring the integrity of the primary packages. Examples include cardboard boxes, shrink wrap, etc.
- Tertiary Packaging: Tertiary packaging involves packaging multiple secondary packages into larger units for efficient handling and distribution. It is commonly used in bulk shipments. Examples include pallets, stretch wrap, shipping containers, etc.

4. Environmental Impact

- Sustainable Packaging: Materials designed to minimize environmental impact, such as biodegradable or compostable materials, recyclable materials, etc.
- Non-sustainable Packaging: Materials that have a higher environmental impact, such as non-recyclable plastics, mixed materials, etc.

5. Barrier Properties

- Oxygen Barrier: Materials that protect against oxygen permeation, such as certain plastics or metalized films.
- Moisture Barrier: Materials that provide resistance to moisture, such as coated papers or films.
- Light Barrier: Materials that block light transmission, often used to protect light-sensitive products.
- Aroma Barrier: Materials that prevent the transmission of odours or flavours.

6. **Packaging Format**

- Bottles and Jars: Commonly used for liquids, powders, or small solid items.
- Cans: Used for beverages, food, or aerosol products.

- Bags and Pouches: Flexible packaging formats often used for snacks, confectionery, or powders.
- Cartons and Boxes: Rigid containers, typically made of paperboard, used for various products.
- Blister Packs: Transparent plastic packaging used to display and protect individual items.

Advanced Packaging Techniques

1. **Reduced Oxygen Packaging**

   a. Vacuum packaging: It involves removal of air from a food package before it is sealed, creating a vacuum environment. This process offers numerous benefits, such as preventing oxidation or spoilage and extending the shelf life of perishable food.

   b. Modified Atmosphere Packaging (MAP): Involves altering the composition of the atmosphere inside the package to extend shelf life. Example: Replacing oxygen with a mixture of gases like nitrogen and carbon dioxide.

   c. Controlled Atmosphere Packaging (CAP): It is a technique used in the food industry to extend the shelf life of perishable products by modifying the atmosphere surrounding the food within the packaging. The goal of CAP is to create an optimal gas composition that helps maintain product quality, inhibit microbial growth, and slow down deterioration processes. Unlike in MAP, the gas composition is adjusted and monitored throughout the storage period in CAP to ensure it remains within the desired range for optimal product preservation. The packaging materials used for CAP should have appropriate barrier properties to maintain the desired gas composition and prevent gas exchange with the external environment.

   d. Cook-chill & Sous-vide packaging: Cook-chill is a technique where food is cooked, rapidly chilled, and then packaged in airtight containers. This process helps to extend the shelf life of prepared meals while maintaining their taste and quality. The chilled meals can be reheated later, making it convenient for busy individuals or establishments that require quick service. On the other hand, sous-vide packaging involves vacuum-sealing food in a bag and cooking it in a precisely controlled water bath. This method allows for precise temperature regulation, resulting in even cooking and enhanced flavours. By sealing the food in airtight pouches, the natural juices and aromas are retained, resulting in tender and succulent dishes.
2. **Active Packaging**: Incorporates active substances to interact with the food and extend its shelf life. Examples include oxygen scavengers, moisture absorbers and antimicrobial agents.
3. **Intelligent Packaging**: Uses sensors and indicators to monitor the condition of the product during storage and transportation. Example: Time-temperature indicators to detect temperature abuse.
4. **Aseptic Packaging**: Aseptic packaging involves sterilizing both the food and the packaging separately and then filling the sterile food into the sterile containers. This technique ensures the elimination of harmful microorganisms while maintaining the food's nutritional value.

Quality Evaluation and Testing of Packaging Materials

Physical Tests

- Mechanical Strength Testing: This assesses the physical strength and durability of packaging materials through tests like tensile strength, puncture resistance, and tear resistance.
- Flexibility and Rigidity Testing: It examines the flexibility or rigidity of materials to determine their suitability for specific packaging applications.
- Barrier Performance Testing: This evaluates the ability of packaging materials to resist the transfer of gases, moisture, light, and odour.
- Seal Integrity Testing: It verifies the quality and effectiveness of seals to ensure they are properly formed and capable of maintaining product freshness and preventing leakage.
- Compatibility Testing: It examines the interaction between packaging materials and the packaged product to avoid chemical reactions or alterations in quality.

Chemical Tests

- Migration Testing: This analyses the potential migration of substances from packaging materials into the food, ensuring compliance with safety regulations.
- Chemical Resistance Testing: It determines the resistance of packaging materials to various chemicals, preventing contamination or degradation of the packaged product.
- Volatile Organic Compound (VOC) Testing: This identifies and quantifies the release of volatile organic compounds from packaging materials, ensuring compliance with environmental and health regulations.

Microbiological Tests

- Microbial Growth Testing: It assesses the ability of packaging materials to resist microbial growth, preventing contamination and extending the product's shelf life.
- Sterility Testing: This ensures that packaging materials intended for sterile products are free from microbial contamination.

Regulatory Requirements

Food packaging is subject to various regulations and standards to ensure its safety and compliance. These regulations vary across different regions and cover aspects such as labelling, material composition, and hygiene practices.

Conclusion

Food packaging technology plays a vital role in preserving the quality and safety of food products. It encompasses various techniques and materials that ensure the integrity of the food throughout its journey from production to consumption. From primary to tertiary packaging, each step is carefully designed to protect against physical, chemical, and biological hazards. With the emergence of sustainable solutions and innovative packaging techniques, the future of food packaging looks promising, catering to both consumer needs and environmental concerns.

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