FOOD PACKAGING

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Keywords: Packaging, manufacturing, tinplate, electrolytic chromium-coated steel, aluminum, glass, paper, board, corrugated board, plastics, corrosion, mass transport, permeation, migration, sorption, cans, rigid containers, flexible containers.

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Summary

Packaging technology is essential to present life styles in developed societies. With the general use of packaging and the development of modern techniques for food safety and commercialization, the universalized consumption of all food has become possible without distance or seasonal limitations, and at an adequate cost. Efficient packaging is necessary for the commercialization of every food type, from fresh produce to ready-to-eat meals. Nowadays, a wide and diversified supply of packaging materials and designs are available to suit the specific requirements of industry and consumers. Packaging materials can be grouped as metallic materials (tinplate, electrolytic chromium-coated steel, and aluminum), glass, paper and paperboard, plastics, wood, and other materials (ceramics, natural fibers, etc.), and complex materials (combining the materials mentioned).

In this article, the basic characteristics of different packages used in food preservation and commercialization are briefly reviewed. Compositions and properties of each packaging material are reported. The most common manufacturing technologies are discussed, and applications for the diverse containers used in food packaging are briefly mentioned.

1. Introduction

A package is a manufactured product consisting of any material or material combination, used to present, contain, protect, handle, and distribute goods, from raw materials to finished products, in every phase of the distribution chain. Thus, the basic packaging functions follow:

- To contain the product.
- To present and identify the product.
- To protect the products physical integrity.
- To preserve the products properties and quality characteristics.
- To prepare the product for handling during transportation and commercial distribution.
- To inform the consumer.

Packages have changed with time in response to the following social factors: population growth, urbanization, necessity to avoid food deterioration and loss, women's incorporation into the job market, internationalization of commerce, greater awareness about hygiene, consumption of more natural foods, and environmental deterioration. As a result, primitive packages like pumpkin shells, skins, or ceramic containers have been replaced, in a progressive technological evolution, by new industrial materials such as paper, glass, tinplate, and plastics. Today, a wide and diversified supply of packaging materials and designs is available to suit the specific requirements of industry and consumers. Packaging materials can be grouped as follows:

- Metallic materials (tinplate, electrolytic chromium-coated steel, and aluminum)
- Glass

- Paper and paperboard
- Plastics
- Wood
- Other materials (ceramics, natural fibers, etc.)
- Combinations of the above

Many types of containers have been developed with these materials in order to meet the specific requirements of diverse products commercialized in urban societies in large amounts. Nevertheless, these packages can be grouped into a few well-established container types: rigid containers (e.g., classic cans), metal and plastic drums, glass or plastic bottles and jars, cartons or wood baskets, and flexible packages manufactured with paper, carton, plastics or complex structures (e.g., pouches, bags, coatings, etc.).

With such variety, it is obvious that a single package type will not suit the requirements of all foodstuffs. The most adequate package must be selected for each specific use, taking into account diverse parameters. Among all the aspects to consider, the following can be cited:

- Product characteristics (nature, composition, sensitivity to atmospheric factors)
- Possible product/container interactions
- Transportation and commercial distribution
- Type of consumer
- Shelf life
- Costs
- Possible reuse of materials or recycling, and environmental impact

In this article, the basic characteristics of different containers used in food preservation and commercialization are briefly reviewed. Further information can be found in the references given in the Bibliography.

2. Metal Containers

Tinplate as a food packaging material was first used at the beginning of the 19th century. Metallic materials have played a relevant role ever since. The widespread use of metallic containers in packaging all product types is a consequence of their great versatility and excellent properties, namely mechanical strength and formability, light weight, hermeticity, gas impermeability, opacity, thermal conductivity, relative chemical inertness, easy printing, and recycling. These properties, together with constant innovation and technological evolution, have extended the application of metallic materials to all food products, although they are best suited for the packaging of preserves, juices, and carbonated beverages.

2.1. Tinplate

Conventional tinplate is a heterogeneous material with a stratified structure, formed by a low carbon steel sheet coated with tin on both sides. Plate thickness ranges from 0.15 to

0.40 mm, and the tin coating mass varies from 0.5 to 34 g/m^2, representing less than 1 percent of the steel weight.

Tinplate is produced via the electro-deposition of tin on steel from aqueous solutions of tin salt. The electrolytic plating produces a perfect coating control, allowing a different coating on each surface of the steel plate (differential tinplate). To protect the tin coating, the manufacturing procedure includes an electrolytic passivation treatment and a final oil coating.

For cans, the quality and aptitude of tinplate are both defined by certain properties, which are commonly included in the technical specifications of the material: tin coating weight, steel substrate, temper, passivation, and surface finish. The tin coating weight is of the greatest practical interest. At present, the tin coating weights of commercial tinplates are fully standardized, 2’8, 5’6, 8’4, and 11’2 g/cm^2 being the most common. To identify differential tinplates, it is common to draw two parallel lines on the surface having the greater coating weight. Separation between these lines depends on the coating and is defined in the standards. Nowadays, low tin coating tinplates (LTS) with 1.4, 1.0, and even 0.5 g/m^2 of tin are being commercialized for particular use, since they are more economical than standard tinplate.

Temper is related to the mechanical resistance of the materials and is a property that measures the quality of the steel substrate. Temper values are measured by the elastic module or by using Rockwell hardness (following the HR 30T standard). Among the different passivation treatments developed, the cathodic treatment with dichromate is most commonly used. This procedure produces a passivation film of metal chromium and chromic oxides ranging from 2 to 10 mg/m^2. The composition of this film is a determinant of the lacquers adhesion.

2.2. Electrolytic Chromium-Coated Steel

Besides the reduction of tin coatings, the most interesting alternative to reducing tinplate costs is the electrolytic chromium-coated steel (ECCS). This material was developed in Japan during the 1960s and was originally known as tin free steel (TFS-CT). ECCS consists of a steel plate like the one used for tinplating, coated with a metal chromium film (50 to 90 mg/m^2) and a passivation coating of metal chromium and chromium (III) oxide (10 to 20 mg/m^2).

Compared to tinplate, electrolytic chromium-coated steel is lower priced, has better resistance to atmospheric oxidation, and has excellent lacquer adhesion. Adversely, it shows poorer resistance to corrosion by acid solutions, especially by foods. For this reason, ECCS is always lacquered. The usual welding procedure utilized in the manufacture of three-piece cans cannot be applied to this material.

2.3. Aluminum

As a packaging material, aluminum has very attractive properties: lightness, ductility, high thermal conductivity, gloss, and large impermeability to gases, water vapor, and light.

However, this material is expensive due to the high cost of the electrolytic process used to obtain aluminum metal from raw material.

Packaging applications of aluminum as a single material, or combined with paper and plastics, cover all industrial needs: rigid containers (cans), semi-rigid containers (trays, jars, and compressible tubes), flexible pouches and bags, thin films for wrapping, easy-open closures for aluminum or tinplate cans, capsules and caps for bottles or jars, etc. The use of aluminum as an alternative to tinplate for rigid containers is limited to the packaging of beer and carbonated beverages. For these containers, aluminum alloys with variable concentrations of magnesium (up to 5 percent), manganese (1.5 percent), and traces of other elements like Fe, Si, Cu, Zn, etc., have been developed.

2.4. Protective Coatings: Lacquers and Lithography

The use of organic coatings on metallic cans has become a generalized procedure, as it imparts greater protection against corrosion and improves presentation. Usually one or two layers of protective lacquers (varnishes) are applied to one of the metal sheets surfaces, while a decorative coating is applied to the other side. This coating is formed with primer, printing inks, and a finishing lacquer to protect the print.

Lacquers and inks are polymeric systems containing a polymer base (film-forming polymer that constitutes the coating matrix) and auxiliary compounds to impart specific properties. These coatings are applied as solutions or dispersions in an adequate solvent. Through solvent evaporation and eventual chemical reaction, the solutions become a solid film adhered to the metallic substrate. In general, lacquers and printing are applied to the metal plate before the container is manufactured, although they can also be applied to a finished container (for certain use). The solution is applied to sheets previously cut to container dimensions until the final coating thickness is reached. The sheets are then dried in an oven where the solvent is removed and the varnish polymerizes to form a solid film.

The film-forming compounds used in lacquers and lithographic coatings are selected to suit a particular product from one of the following chemical families: oleoresins, phenolic, epoxy-phenolic, epoxy-anhydrides, organosol, polyesters, vinyl, and acrylic polymers.
Epoxy-phenolics have dominated the market for the last 30 years. They are used in protective lacquers as well as in decorative coatings. Despite the fact that they are used universally as organic coatings to all product types, they do pose some constraints, particularly in the packaging of sulfur-bearing foods. A successful solution for these specific products is the addition of aluminum, zinc oxide, or titanium dioxide to the resin. Other food requirements may compel the use of any of the commercial alternatives already mentioned.

New organic compounds (epoxy-amines, acrylics, polyesters, organosols, etc.) and coating techniques (electro-deposition, continuous lacquering, etc.) have been developed in response to the requirements of new packaging manufacture technologies and a more exigent market. Today, there is a wide and diversified offering of coatings and application techniques. The main trends in R+D are high solid content lacquers, water-borne lacquers, lacquers of low curing temperature or those cured by radiation, and plastic coatings.

Although these alternatives are interesting, lamination of polymeric films on the metallic substrate is a very promising substitute for traditional organic coatings. These metal/polymer laminations combine metal impermeability and plastic flexibility to yield enhanced protection, as compared to traditional coatings. Polypropylene and polyester films are being applied with thicknesses up to 200 g/m^2, obtaining adequate protection against the most aggressive products. The polymer film is laminated directly onto the preheated metal (supplied in a roll) without adhesives. The metal sheet can be laminated on both sides simultaneously with the same or different plastics.

2.5. Metal Container Manufacturing

Due to the different needs of the final user, diverse package designs have been developed, from the classic open-top cans for preserves to the most complex designs for special products such as aerosols, jerry cans, reclosable cans for chemical products, etc.

Among the different classifications of metallic containers, the most common one takes into consideration the manufacturing technique. Accordingly, three-piece and two-piece cans are differentiated.

2.5.1. Three-piece Cans

Although the conventional open-top metallic can was introduced about 200 years ago, it is still the most widely used in food packaging. Besides the old cylindrical can, three-piece cans are classified according to their transversal sections: circular, rectangular, oval, or trapezoidal. Despite the fact the basic design has hardly been altered, manufacturing technology has significantly changed with electrical weld, robotization, and computer control of the manufacturing lines. Also, the progressive thickness reduction of materials has led to the introduction of beading profiles to maintain the required rigidity during container sterilization and handling, especially in 500 g or larger formats.

Manufacturing is accomplished via a 10-step integrated process. The lateral sides of the body are welded, through actual melting, a consequence of the application of high temperature by means of an electric arch. With adequate control of all process variables, today's equipment produces a perfect joint, maintaining the quality and hardness of the base material, and at a rate faster than 1000 cans per minute. After welding, the joint is protected with a lacquer. The body is completed with a flange on both ends of the cylinder for attachment of the closures, and the wall is ribbed or beaded for radial strength. The can manufacturing process ends with the application of the bottom end, which is cut from a plate in a shell press. The other (top) end is applied after the container is filled.

A double-seam is used to apply the ends to the can body, which is made by inserting the end hook around the body flange. The double seam has five walls, three belonging to the end and two to the body. Strict control of the can closure is required, since the double seam is responsible for package hermeticity, a fundamental requisite in most metallic package uses.

2.5.2. Two-piece Cans

Manufacture of the two-piece can in which the body and the bottom end are formed from a drawing on a flat plate is an old technology used in the production of formats with low height/diameter ratios (<0.6). These cans have been applied to the canning of fish and meat products. New technologies have been developed to obtain deep draw containers: draw-redraw (DRD) and draw and wall ironing (DWI).

DRD cans maintain the original thickness of the flat metal sheet after the drawing process, and therefore provide enough mechanical resistance against deformations during sterilization. DWI cans are lighter (by 40 to 50 percent), since the body wall thickness is significantly reduced to 0.09 mm. Thus, the DWI process implies a greater metal reduction compared to DRD technology. Due to their specific characteristics, DWI cans are appropriate for pressurized liquid products (carbonated beverages, beers, etc.), as the internal pressure compensates for the low mechanical resistance of very thin walls. They can also be used for non-carbonated beverages by introducing liquid nitrogen into the can to generate internal pressure.

In recent years, the can manufacturing industry has been continuously changing. Besides the introduction of new materials and manufacturing processes, there has been a revolution in graphic and structural design. The traditional can, a common shape with few changes over time, has been limited to the application of easy-open closures and diverse shapes and sizes. Due to competition with other packaging materials, today's trend is toward new designs far from the traditional image. Quality and long shelf life are not enough to attract the consumer's attention. Design of cans has become a fundamental aspect due to the increasing pressure of aesthetics and innovation. Great efforts have been made to maintain can functionality while taking into account the new trend toward personalized designs. In line with this, the newest technologies allow for the development of cans with expanded bodies (e.g., square body with circular ends). Also, the image of the traditional can is being replaced by designs in which the ends have a more reduced diameter than the body. In addition to this new look, innovation has resulted in a significant reduction of material and a more stable can piling. New easy-open closure systems also contribute to the new image of tinplate cans.

2.6. Corrosion in Metal Containers

Metal cans are containers impermeable to micro-organisms. Therefore, the shelf life of a microbiologically stabilized canned product should be unlimited. In practice, however, shelf life is limited because of physicochemical changes in foods, such as loss of nutrients (vitamins, proteins, etc.) or sensorial deterioration (aroma, flavor, etc.), although most changes are caused by food/container interactions that slowly but continuously modify product quality. Food/can interactions are due to a mechanism of electrochemical corrosion, which occurs in any metallic material exposed to an electrolytic medium. Corrosion is, in practice, the main cause of canned food spoilage.

The consequences of metal corrosion can be multiple and diverse:

- Perforation of the can by a deep attack on the steel.
- Can swelling from gas accumulation in the headspace.
- Changes in food organoleptic properties (color, aroma, flavor) or nutritional characteristics.

- Deterioration of the internal surface of the can (tinplate detinning or intense attack in lacquered cans) and potential rejection by the consumer due package appearance.
- Migration of metal ions (particularly iron and tin) to the packaged product.

The transfer of metal ions is the most common consequence of a corrosion process, and is always present in canned products. In general, this process does not affect food safety but may result in deterioration of quality.

The extent of corrosion varies depending on product aggressiveness, can characteristics, and packaging technologies, parameters that must be taken into account to select the most adequate material and reduce potential corrosion.

3. Glass Containers

Glass was one of the first synthetic materials used in packaging manufacture. In Babylon, perfumes and oils were preserved in glass containers. Gas and aroma impermeability, transparency, rigidity, shape versatility, and potential reuse and/or recycling are very attractive properties for packaging applications. However, the chemical resistance of glass is the most appreciated property in the packaging of products with high health requirements, such as food or pharmaceuticals. Besides these properties, which are of a high practical interest, glass presents some negative characteristics such as fragility and higher weight when compared to other packaging materials. Nevertheless, glass is used in the packaging of all food types, especially preserves and beverages.

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Bibliography

Brody A.L. and Marsh K.S., eds. (1997). *The Willey Encyclopedia of Packaging Technology*. Second Edition. New York, USA: John Wiley & Sons. [Complete information about materials and technologies of packaging presented as a dictionary.]

Brown W.E. (1992): *Plastics in Food Packaging. Properties, Design and Fabrication*. New York, USA: Marcel Dekker Inc. [Comprehensive review of technical properties and applications of different plastic families. This includes package fabrication methods and practical uses for food packaging.]

Bureau G. and Multon J.L., eds. (1995). *Food Packaging Technology Vol. 1* and *Vol. 2*. New York, USA: VCH Publishers Inc. [This presents relevant aspects of packaging technology for food processing, preservation, distribution and marketing.]

Fellows P.J. (1998). *Food Processing Technology. Principles and Practice*. Lancaster PA, USA: Technomic Publishing Co. Inc. [A comprehensive background on the development of packages and packaging systems for foods.]

Hanlon J.F., Kelsey R.J., and Forcinio H.E. (1998). *Handbook of Package Engineering,* Third Edition. Lancaster PA, USA: Technomic Publishing Co. Inc. [An updated handbook of packaging engineering. This presents the characteristics of packaging materials and equipment for packaging operations.]

Kadoya T. (1990). *Food Packaging*. New York, USA: Academic Press Inc. [Fundamentals of food packaging technology and practical uses for packaging all types of food.]

Katan L.L., ed. (1996). *Migration from Food Contact Materials*. London, UK: Blackie Academic & Professional. [Overview of migration into food from packaging residues.]

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