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Module-21: Packaging of Beverages

21.1 Introduction

Beverages are an important part of the diet of humans and have been since ancient times. Although the origins of many beverages are unknown, there is no doubt that the range and sophistication of beverages has increased dramatically in this century. Much of this growth can be attributed to the developments in packaging which have made it possible for a large national and international trade in beverages to flourish. Today a wide variety of quite different beverages are consumed in the home, at work, and at a myriad of sporting, leisure and entertainment activities, and the full range of packaging media are used to bring these beverages to the consumers. In this module, we will discuss the packaging aspects of major categories of beverages.

21.2 Water

Bottled water is available for sale almost everywhere. The growth in bottled water is influenced by three public concerns: poor quality from municipal water supplies; toxic contamination of ground water; and an increased interest in personal health.

Bottled water can be divided into either natural or processed categories, natural water being bottled directly from underground sources, while processed water is tap or well water that is highly filtered or distilled.

The major deteriorative reaction in bottled water is microbial growth. To avoid this, the water is usually treated prior to bottling with chlorine or ozone.

21.2.1 Packaging

Glass bottles are still the container of choice for the sparkling waters. The majority of still waters are packaged in plastic containers, with five principal resin alternatives: HDPE; PP; PVC; PC and PET. Antioxidant additives are used as processing aids in the plastic resins and it is important that they not migrate into the water and cause undesirable odors and taste.

PVC has been a very common in Europe, with special low taste and odor compounds being used. PVC is less popular in the USA due to adverse publicity in 1974 about vinyl chloride monomer (VCM) residues in PVC. Problems with VCM residues have long since been addressed and PVC is generally regarded as the most suitable polymer. A PVC bottle is crystal clear with a high gloss surface finish. As well, it provides relatively high oxygen barrier that assists the retention of dissolved oxygen found in many bottled waters, thus allowing for a more consistent taste and longer shelf life. However, recent public concerns in Europe over the use of PVC as a packaging material are leading to the use of alternative resins, particularly PET.

21.3 Coffee

The fruit from trees of the genus *Coffee* (the two most important species are *C. arabica* and *C. robusta)* is a small pod that contains two coffee beans. The major deteriorative reaction in coffee is staling, due to loss of flavor volatiles or to chemical changes in the volatile components caused by moisture and oxygen absorption. The aroma degeneration during staling has been described as changing from flat to old to sharply rancid, with a cocoa odor appearing in the advanced stage.

21.3.1 Packaging

21.3.1.1. Roasted Whole Beans

Depending on the shelf life required, the choice of packaging material has to be considered in regard to moisture vapor permeability, O_2 permeability, CO_2 and volatile component permeability and grease resistance if oily, dark-roasted beans are being packaged. The major problem with the packaging of roast whole beans (RWB) is the evolution of CO_2. The quantity of CO_2 entrapped in RWB is around 25 ml per gram of roasted coffee. Thus, when RWB are placed within a closed package, the CO_2 released will have to be contained within the available headspace within the package or, depending on the nature of the packaging material, permeate through the package.

Permeability constant for CO_2 was greater than that for O_2. Hence, if plastic laminates are used to package RWB, a satisfactory O_2 barrier can be obtained which will still permit CO_2. However, it is still necessary to reduce the initial O_2 content inside the package immediately prior to sealing by flushing of the package and contents with an inert gas: either CO_2 or N_2.

21.3.1.2. Roast and Ground Coffee

Oxygen is a prime determinant of shelf life and there are three main ways of lowering its concentration inside a package. The first method is to apply a high vacuum immediately after filling into the package and then sealing. The second is to flush the roast and ground coffee and package with an inert gas immediately prior to sealing. The third is to place a sachet containing compounds which will absorb O_2 inside the package.

21.3.1.2.1 Metal Cans

The oldest type of commercial package for roast and ground coffee is the vacuum-packed tinplate can. It provides impermeability to moisture vapor, gases and volatiles and can be made with a scored, removal aluminum end over which a threaded screw cap is placed. After filling, a high vacuum (700 mm Hg) is pulled on the can; to give an oxygen content of less than 1%. After sealing, CO_2 gas evolution will reduce the vacuum until atmospheric pressure is restored. It is important that pressure does not build up inside the container during storage; to prevent this occurring, the roast and ground coffee must be degassed in bulk to reduce its CO_2 content to an acceptable level.

Inert gas packing of roast and ground coffee in metal containers is also practiced. The usual procedure is to first apply a vacuum and then release it with an inert gas, usually nitrogen. In order to prevent excessive pressures developing in the can, it is necessary to degas the coffee to a much lower level than for high-vacuum packing.

21.3.1.2.2 Hard Packs

As an alternative to the metal can, shape-retentive packages of flexible laminated materials shaped into bags have been developed and widely used in recent years. These packs are called hard since on application of a high vacuum after filling and sealing, the material collapses onto the coffee to form a brick which is hard to the touch. However, if significant quantities of CO_2 are evolved and/or air enters from the atmosphere, the bag will become soft. This is an undesirable condition since consumers may erroneously perceive that the coffee has deteriorated although this is not necessarily so.

Many flexible laminates used for this type of package used to contain a central layer of aluminum foil but this has been replaced in recent years by a metalized layer. A typical early construction was 12 mm PET/12 mm Al foil/70 mm LDPE, while recent structures would be metalized PET laminated to LDPE. Most United States coffee roasters employ a more durable four-ply structure which utilizes BOPP in addition to PET, Al foil and LDPE. The sealed, filled bag is usually placed inside a close-fitting paperboard box for retail sale.

21.3.1.3. Instant Coffee

If the moisture content was maintained at less than 45% w/w, the coffee will retain its original quality for at least two years at ambient conditions. With more sophisticated products (i.e. with higher retained levels of volatiles), shelf life of at least 18 months is possible provided that the initial O_2 headspace contents are lowered to less than 4.0%.

Instant coffee for the retail market was for many years packaged in either tinplate cans or glass jars of various shapes. A waxed paper or metal foil diaphragm sealed to the rim of the container provided an effective barrier to moisture vapor and oxygen, over which was placed a tight-fitting metal lid in the case of tinplate containers, and a screw cap of plastic or metal in the case of glass jars.

Recently, refill packs of instant coffee packaged in flexible laminates of PET/Al foil/LDPE or metalized PET/LDPE have reduced the quantity of coffee packaged in metal containers and glass jars.

21.4 Tea

The appealing characteristics of tea as a beverage are its taste, aroma and color. Polyphenols such as catechins, and amino acids such as theanine are the main contributors to the unique taste and color of tea. The components of essential oil in fresh tea leaves and volatile compounds developed during the manufacturing process form the characteristic tea flavor.

21.4.1 Packaging

Loose tea is packaged in a multitude of different shapes, sizes and types of materials, the most common being a paperboard carton with either an aluminum foil liner or an overwrap of PP. Metal containers with snap-on lids are also used for some premium products. Tea bags have now become the most popular form of retail packaging, and considerable development has gone into improving the tissue paper used for this type of package, porous wet-strength paper being required. Once filled, the tea bags must be placed inside a package which provides an adequate barrier to moisture vapor. Paperboard cartons overwrapped with PP are most common.

The storage stability of green tea is the lowest among various teas including black tea, oolong tea and pouchong tea. To most effectively protect the quality of green tea during storage, it is necessary to use nitrogen gas flushing or vacuum packaging.

21.5 Fruit Juices

Fruit juices were originally developed to use up the surplus fresh fruit production. A variety of different types of juice is available. These include clear clarified juices such as grape, apple and blackcurrant; light cloud juices like pineapple; heavy cloud juices containing cellular material in suspension such as orange and grapefruit juices; pulpy juices such as tomato based products; and nectars made by pulping whole fruits like peaches, apricots and comminuted citrus products.

The three key deteriorative reactions in juices are microbiological spoilage, non-enzymic browning and oxidation resulting in loss or degradation of flavor components and nutrients (essentially ascorbic acid).

21.5.1 Packaging

The traditional packaging procedure for fruit juices involved heating the deaerated juice to around 90-95°C in a tubular or plate heat exchanger, filling the hot juice directly into metal cans, sealing and inverting the cans, holding them for 10-20 min and then cooling. This hot-fill/hold/cool process ensured that the juice was commercially sterile, and provided that the seams were of good quality, the cans had an acid-resistant lacquer, and the juice had been properly deaerated, a shelf life of at least 12 months was attainable. However, because of the acidic nature of fruit juices, any imperfections or scratches in the can coating or tin layer resulted in rapid corrosion, dissolution of metal into the juice, production of hydrogen gas and container failure due to swelling. The use of glass containers obviated these problems provided that the container closure (typically metal) was resistant to attack by the juice.

The use of glass bottles for the packaging of fruit juices was also widespread although the hot-fill/hold/cool process had to be applied with care to avoid breakage of the glass containers. Glass is still the preferred packaging medium for high quality fruit juices. However, over recent years an increasing proportion of fruit juices and concentrates have been packaged aseptically, generally into laminates of plastic film/aluminum foil/paperboard. These products are then held at room temperature and the shelf life and nutrient composition are greatly influenced by the barrier properties of the carton, the interactions of the juice with the carton, and the storage environment.

21.6 Carbonated Soft Drinks

Traditionally, soft drinks were prepared by dissolving sugar in water. A variety of ingredients including flavoring and coloring agents, acidulants (either citric or phosphoric acid) and preservatives were added. Other constituents such as fruit juice or comminuted fruit, bodying agents, artificial sweeteners, clouding agents, antioxidants and foaming agents were added, depending on the particular product being made.

The two major deteriorative reactions in carbonated beverages are loss of carbonation, and oxidation and/or acid hydrolysis of the essential flavor oils. The first is largely a function of the effectiveness of the package in providing a barrier to gas permeation, while the later can be prevented to a large extent by the use of high quality flavorings and antioxidants, and deaerating the mix prior to carbonation.

21.6.1 Packaging

21.6.1.1 Glass

For many years virtually all carbonated soft drinks were packaged in refillable glass bottles which were sealed with crown closures. The crown provides a friction-fit sufficient to seal pressurized beverages. The flared cap skirt in conjunction with the smoothness of the bottle neck provides easy access through the prying motion of the bottle opener.

In recent years, non-returnable glass bottles have replaced refillable glass bottles in many markets. These frequently have a foam plastic protective label or a paper/polyolefin or all-plastic shrink sleeve, in part as a safety measure to prevent flying glass fragments should the bottle break. On these non-returnable bottles, the crown closure has been replaced with a roll-on aluminum screw cap on threaded necks with a tamper-evident ring, or a plastic closure which fits and unscrews over the same threads as the roll-on and has some visible indication of tampering.

21.6.1.2 Metal

Three-piece tinplate containers have been used for many years for the packaging of carbonated beverages. The highly corrosive nature of carbonated soft drinks demands complete protection of the metal container from the product by the use of one or more coatings of an impermeable enamel system. For three-piece cans this involves spraying an additional coating of enamel (a process known as sidestriping) over the inside of the container down the side seam area after soldering or welding of the side seam.

Today, most carbonated beverages are packaged in two-piece containers usually made from aluminum, although steel cans are still used. The two-piece container has made it much easier to retain the integrity of the enamel layer inside the can and thus minimize corrosion during storage. The cans must be able to withstand continual internal pressure of up to 5 atmospheres.

21.6.1.3 Plastics

In 1960s, the Coca-Cola and Pepsi-Cola companies were seriously considering the use of plastic bottles for soft drinks. It has been observed that only the polyester and nitrile families of plastics had the necessary physical and chemical characteristics required. PET was the preferred polyester, while acrylonitrile/methylmethacrylate copolymer, methacrylonitrile/styrene copolymer and rubber-modified acrylonitrile/styrene copolymer were suitable.

Because the nitrile plastics could be made into bottles using existing blow-molding equipment while PET could not due to its inclination to crystallize and go hazy at higher temperatures, early market development work in the 1970s was carried out with nitrile bottles. Coca-Cola successfully launched a 950 ml nitrile bottle in 1975, but the release in 1977 of toxicological data showing that acrylonitrile monomer could be carcinogenic at high dosage (residual monomer levels in the bottles were less than 0.025 ppm) lead to the removal of the nitrile bottle from the market.

Meanwhile attempts to successfully manufacture PET bottles using a stretch-blow molding process were continuing. In the spring of 1977, the plastic PET bottle for soft drinks was launched by Pepsi-Cola followed soon after by Coca-Cola and other beverage producers. It has been described as probably the biggest single development in the soft drinks industry since the introduction of the ring-pull can a decade earlier. Today the greatest volume of soft drinks is packaged in PET bottles which have achieved their market share mainly at the expense of glass.

The trend for larger and larger containers of soft drink has helped penetration of the PET bottle. The 1 liter glass bottle is considered to be near the limit of size and weight above which it becomes difficult to handle easily. In contrast, PET bottles up to 5 liter in size are now available, resulting in considerable savings in container cost per unit volume, the larger the bottle, the more carbon dioxide is retained per unit of time because of a smaller surface area to volume ratio (i.e. a reduced area for permeation).

21.7 Beer

Beer is an alcoholic beverage made by brewing and fermentation from cereals (usually malted barley) and flavored with hops to give a bitter flavor. Owing to its low pH (about 4.0), microbial degradation is not usually a problem with beer, and the use of pasteurization and aseptic cold filtration excludes wild (i.e. non-cultured) yeasts which could thrive. However, during storage beer can undergo irreversible changes leading to the appearance of haze, the development of off-flavors and increased color.

21.7.1 Packaging

21.7.1.1 Glass

The traditional packaging media for beer is the glass bottle sealed with a crown closure. Pasteurization of the beer in the bottle after sealing is the most common means of securing microbiological stability. The aim is to heat the beer to a high enough temperature and hold it there long enough to destroy any beer spoilage organisms.

The crown closure is made of tinplate and contains a compressible lining material, the composition of which has changed over the years from solid cork to composition cork, plastic and aluminum foil in various combinations. Today, the use of cork-based linings is relatively rare, and most crown closures are lined with PVC (often foamed) or sometimes HDPE. Where cork is still used, it is common to laminate it to aluminum foil to improve its barrier properties.

The material properties as well as the shape of the lining had a great effect on the rate of permeation. Linings with aluminum foil provided a perfect barrier. Although the three types of PVC linings had been foamed to different degrees, they all appeared almost solid after closing and the permeation rates were almost identical.

21.7.1.2 Metal

The first successful canning of beer took place in 1933 in Newark, New Jersey when 2000 cans were produced for a test market. In January, 1935 the first beer cans went on sale. The greatest problem with using cans for beer packaging was preventing the pick-up of metal ions from the tinplated steel and lead solder of the early three-piece cans. The metal ions resulted in undesirable metallic flavors and the rapid onset of haze or metal turbidity. Although several reasonably successful enamel coatings were developed and used, it was not until the development of epoxy-phenolic resin linings around 1960 that a truly effective lining capable of eliminating metal pick-up over a long term.

Until the late 1950s, tinplate was used almost exclusively, but in 1958, launched three-piece aluminum cans, in 1963, by some test markets of two-piece D&I aluminum cans. This latter type of can began to be mass produced in 1966.

Aluminum was used for beer can ends by Schlitz in 1960 when they introduced the soft top can to facilitate opening with a special tool known as a church key. A pull-tab aluminum top was developed in 1962 by Ermal Fraze. It was test marketed and emerged in 1965 as the now familiar ring-pull tab.

21.7.1.3 Plastics

The use of PVC/PVdC copolymer-coated PET bottles for the packaging of beer commenced in the early 1980s in the United Kingdom. The PVC/PVdC copolymer coating is necessary to provide an acceptable barrier to oxidation and to prevent flavor degradation in the beer. It also lowers the carbon dioxide permeability of the bottle. From a consideration of surface area to volume relationships and the oxygen permeability of the bottle material, most brewers have tended to use the larger sized bottles (typically 2 litre) so as to obtain a satisfactory shelf life. A clean filling technique is used to handle the sterile filtered beer, since at present in-container pasteurization cannot be used. However, pasteurizable plastic bottles are available now and being used since 1990.

21.8 Wine

Wine is a beverage resulting from the fermentation by yeasts of the juice of the grape with appropriate processing and additions. The major deteriorative reaction in white wines is caused primarily by oxidation, the oxygen gradually changing the wine's character, leading to the development of browning and undesirable flavors. With red wines, condensation polymerization reactions between tannins and anthocyanins, resulting in loss of pigmentation and color changes.

21.8.1 Packaging

21.8.1.1 Glass

The most common form of packaging used for wine is the glass bottle sealed with natural cork. Cork is the outer bark of the holm oak, an evergreen species *Quercus suber*, which grows mainly in Spain. It is tough, light and elastic. Since many types of wine are damaged by sunlight, the bottles are usually of colored glass, commonly dark green or brown. Bottled wine is normally stored in the horizontal position so that the cork is kept moist, thereby providing a better barrier to the oxygen permeability.

For approximately 120 years, bottles containing high quality wines have had a protective top capsule of tin-lead applied as a closure around the cork. The tin-lead foil comprises a thin layer of lead sandwiched between much thinner layers of tin roll-bonded to both sides. The purpose of the tin coating is to prevent contact between the lead and the wine, and to provide a good surface for high quality decoration, including printing and embossing. Capsules are also made from aluminum or PVC. As well as providing decoration, the capsule also protects the cork from mold growth, worms, etc., and acts as an additional barrier to oxygen. It also functions as a tamper evident seal.

In recent years, concern has been expressed in various countries about the use of lead in capsules because of its known toxic effects. Contamination of wine by lead is known to occur sometimes as a result of capsule corrosion and the formation of soluble lead salts; this may have various causes, including tin coatings of inadequate thickness that are discontinuous or become disrupted. The disposal of lead-based capsules represents an avoidable burden of a toxic metal into the waste stream, and there are now moves to phase out the use of lead-based capsules. A replacement capsule made solely from tin has been developed which weighs 5 g (half the weight of the tin-lead capsule) but costs considerably more. Research is continuing into capsule materials of tin or tin with some alloying additions in order to reduce the cost of the product and improve efficiency in production and use.

21.8.1.2 Plastics

21.8.1.2.1 Bag-in-box

The most significant change in the packaging of wine (especially white wine) resulted from the development of the bag-in-box package: a flexible, collapsible, fully sealed bag made from one or more plies of synthetic films; a closure and tubular spout through which the contents are filled and dispensed; and a rigid outer box or container.

PVC/PVdC copolymer-coated nylon/LDPE laminate inside a fiberboard box is used as the first bag-in-box. This structure is still used although there have been moves to other materials such as a triplex (three ply) construction of EVA copolymer-PET-LDPE with the PET being metalized, and more recently barrier coextruded materials have been used. These rely on the barrier properties of EVOH copolymer, the strength of nylon and the sealability of LLDPE.

21.8.1.2.2 Bottles

Wine in a 3 L PET container with a PVC/PVdC copolymer layer, or in a 4 L PET, container maintained quality for 10-12 months, when compared to the same wine in 1 gallon glass containers. Changes in SO_2 and color were the most obvious measurable changes due to oxygen permeation into the bottle.

21.8.1.2.3 Metal

Wine has been canned in small quantities since the 1960s in Europe, using beverage cans made from aluminum or occasionally tinplate. When packaging still wines, it is necessary to increase the internal pressure in the cans by nitrogen injection in order to prevent collapse of the can body. This is because the beverage cans are constructed in such a way that they rely on a significant internal pressure to augment the inherently low strength of the can body itself. The keys to the successful packaging of wine in metal containers are the nature and integrity of the enamel lining on the inside walls of the can, and the oxygen content of the wine at the time of filling. The oxygen content should be as close to zero as possible to minimize undesirable degradative reactions; this can be achieved by using nitrogen gas flow closure.