CARBONATED BEVERAGES

1. Introduction

The carbonated beverage has its origin in the study of mineral waters in Europe in the sixteenth century. In the late eighteenth century, artificial mineral waters were investigated for their medicinal properties both in Europe and America. The first commercial artificial mineral water was manufactured in Europe during the 1780s and in America in the early 1800s.

Flavored carbonated beverages, or soft drinks, were developed by apothecaries and chemists in the early nineteenth century by the addition of flavored syrups to fountain-dispensed carbonated water. The introduction of proprietary flavors began in the late 1880s. Charles H. Hires introduced his root beer extract in 1876, Vernors's Ginger Ale was marketed by James Vernor in 1880, R. S. Lazenby perfected the formula for Dr. Pepper in 1885, and John S. Pemberton developed the formula for Coca-Cola in 1886. Brad's Drink was introduced in 1896 and was later renamed Pepsi-Cola in 1898.

Early bottling of flavored carbonated beverages was limited by spoilage, poor flavor, and color stability. Improvements and innovations in bottling equipment, glass manufacturing, stable flavors and ingredients, crown closures, and transportation resulted in the rapid expansion of the bottled soft drink industry. Soft drinks consist of carbonated water, nutritive or nonnutritive sweeteners, acidulants, preservatives, flavors, juices, and color.

Over the past few years beverage product variety has exploded. In the not-too-distant past, It was easy enough to segment beverages and beverage companies. A soft drink company made soft drinks. A juice company produced juice beverages. A water company bottled water. But what if you do it all? That is the position America's leading nonalcoholic refreshment beverage companies find themselves in today.

After an intensive decade or more of innovation, consolidation and responding to consumer demand, the best-known marketers of liquid refreshment have become, quite simply, beverage companies.

Companies such as The Coca-Cola Company, PepsiCo and Cadbury Schweppes' Americas Beverages are synonymous with carbonated soft drinks, and understandably so. Their flagship brands, Coke, Pepsi and Dr Pepper, were first poured in the 19th century and became some of America's most beloved refreshments in the 20th century. They remain today.

Today, beverage companies of all shapes and sizes recognize consumers' desire to diversify their palates. Whereas 50 years ago the soft drink business produced cola and maybe a few flavors, today there are no-calorie, low-calorie and mid-calorie sodas. There are caffeinated and caffeine-free versions. Tropical flavors have joined lemon-lime and root beer. In short, there is a carbonated variety for every taste and palate (1).

2. Ingredients

2.1. Water.

Water [7732-18-5] is the largest single ingredient used in carbonated beverages and must be of high purity. Drinking water supplied by local municipalities fails to meet the required purity levels for use in carbonated beverages. It must be treated to remove four types of contaminants that may affect the taste, odor, or appearance of the final beverage. The four contaminants are inorganic material, organic compounds, microbiological contamination, and particulate matter. The water treatment process employed in the soft drink industry varies but may include chemical treatment, reverse osmosis, ultrafiltration, and/or ion exchange.

Chemical Treatment. Chemical treatment is used by most carbonated beverage facilities. Treatment includes chlorination for disinfection purposes and oxidation of some impurities in the water. The water is then softened through the addition of lime to reduce alkalinity by removing magnesium and calcium bicarbonates. The reaction products formed as a result of the softening process are removed by coagulation. The coagulants, ferrous sulfate or potassium aluminum sulfate, react with the calcium or magnesium hydroxides to form precipitates. The precipitates settle out and are removed from the bottom of the reaction tank. Any residual precipitates are removed by passing the water through a sand filter. Activated carbon adsorption is used to remove chlorine and any other organic compounds, thus reducing the chance of undesirable odors or tastes. The water may then go through a final polishing stage of filtration to remove any carbon fines.

Reverse Osmosis. This process can be used to remove most water contaminants. Water is pumped at high pressure through a semipermeable membrane. Particulate and microbiological contaminants are retained on the membrane because of pore size. Dissolved ions and organic material are affected by the charge on the membrane and are retained. The water that passes through the membrane can then be used for product water. Reverse osmosis is generally used as a polishing step for other water treating methods.

Ultrafiltration. This process removes macromolecules, microorganisms, particulate matter, and pyrogens using a thin, selectively permeable membrane. Ultrafiltration cannot remove ions from water and is generally employed as a polishing process.

Ion Exchange. Ion exchange, or demineralization, is used to remove inorganic materials from water. The process employs either a mixed bed of ion-exchange resins or separate beds of cation- and anion-exchange resins. A cation-exchange resin replaces cations, such as calcium, sodium, magnesium, or potassium, with hydrogen ions. The anion-exchange resin replaces anions, such as carbonates, bicarbonates, sulfates, and chlorides, with hydroxide ions. These resins can be regenerated and reused.

2.2. Sweeteners. The sweeteners used in carbonated beverages may be either nutritive or nonnutritive. The quality of the sweetener is one of the most important parameters affecting the overall quality of the beverage. Organoleptic profile (taste and odor), solubility, microbial stability, and temperature stability are important quality parameters.

Nutritive Sweeteners. These include granulated sucrose, sucrose in solution, invert sugar, dextrose, and high fructose corn syrup.

Sucrose [57-50-1], $C_{12}H_{22}O_{11}$, obtained from cane or sugar beets, was historically used as the primary sweetener for carbonated beverages. In the presence of acids, sucrose is hydrolyzed to fructose [57-48-7], $C_6H_{12}O_6$, and dextrose

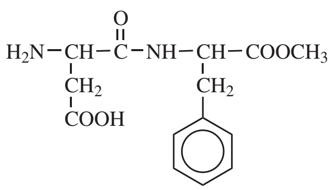
(D-glucose) [50-99-7], $C_6H_{12}O_6$; the mixture is called invert sugar. The change in carbohydrate profile changes the perception of sweetness in the beverage. Some beverage manufacturers start with liquid invert sugar rather than allowing the beverage to invert over time.

High fructose corn syrup (HFCS)was first introduced to the beverage industry in the early 1970s. Improvements in quality encouraged parent soft drink companies to allow HFCS to replace sucrose as the primary nutritive sweetener for the beverage industry by 1984. HFCS is derived from corn starch through a process that includes breakdown of the starch to glucose, enzymatic conversion of glucose to fructose, separation of the sugars, and blending of the sugars to produce various concentrations of fructose and glucose. HFCS-42, HFCS-55, and HFCS-90 are available and contain varying concentrations of fructose and percent solids (Table 1). The choice of sweetener depends on the final sweetness desired and the particular beverage formulation.

Manufacturers may choose to use blends of nutritive sweeteners; the most common blends consist of various concentrations of liquid invert sugar and HFCS-42 or HFCS-55. The amount of sweetener in a soft drink ranges from 7 to 14% (1).

Nonnutritive Sweeteners. Diet or low calorie beverages represent a significant portion (31%) of the total soft drink market. Currently, aspartame [22839-47-0], $C_{14}H_{18}N_2O_5$, saccharin [81-07-2] sucrose [56038-13-2], and acesulfame [55589-62-3] are the only nonnutritive sweeteners approved for use in beverages by the U.S. Food and Drug Administration (FDA). Saccharin, $C_7H_5NO_3S$, was first available for commercial use in 1900. It was used in soft drinks as a blend with sucrose during World War I because of the shortage of nutritive sweeteners. Saccharin is 300–400 times sweeter than sucrose. The FDA formally approved its use in foods and beverages in 1938. The FDA proposed a ban on saccharin as a bulk additive in foods in 1977. Congress has enforced and frequently renewed a moratorium on the proposed ban of saccharin in beverages.

Aspartame (1) is the primary nonnutritive sweetener used in carbonated soft drinks. It is approximately 200 times sweeter than sucrose. Aspartame is the methyl ester of a dipeptide of L-phenylalanine and L-aspartic acid.



(1)

Some sources consider aspartame a nutritive sweetener. It is sensitive to low pH and high temperatures and degrades over time. Aspartame can be used alone or in a blend with other sweeteners.

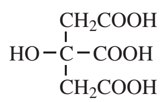
Sucralose (Splenda) has the taste quality and time intensity profile close to sucrose than any other sweetener. Acesulfame K resembles saccharin in structure and taste profile. It also has a long shelf life.

To meet consumer demands, manufacturers are developing new nonnutritive sweeteners that more closely match the taste and mouthfeel of sucrose. There are several nonnutritive sweeteners currently pending FDA approval for use in soft drinks. They include alitame [80863-62-3], encapsulated aspartame, and cyclamates.

2.3. Acidulants. Acidulants give the beverage a tart or sour flavor, adjust pH to facilitate the function of benzoate as a preservative, reduce microbiological susceptibility, and act as a catalyst for the hydrolytic inversion process in sucrose sweetened beverages. The primary carbonated beverage acidulants are phosphoric acid [7664-38-2] and citric acid [77-92-9]. Other acidulants include ascorbic, tartaric, malic, and adipic acid (Table 2).

Phosphoric Acid. This acid is the primary acidulant in cola beverages. Phosphoric acid is stronger than most organic acids and weaker than other mineral acids. The dibasic properties of phosphoric acid provide minor buffering capacity in the beverage. Food-grade phosphoric acid is commercially available in concentrations of 75%, 80%, and 85% and is one of the most economical acidulants.

Citric Acid. This acid is used in a variety of flavored carbonated beverages, including lemon–lime, orange, other fruit flavors, some root beers, and colas. Citric acid (**2**) is also a sequestering agent for heavy metals and can be used to some extent as an antioxidant. Citric acid is naturally found in most fruits and was originally obtained from lemons. It is commercially derived from the fermentation of dextrose and a strain of mold, *Aspergillus niger*. Citric acid can be added during the syrup manufacturing process as a powder or as a 50% solution.



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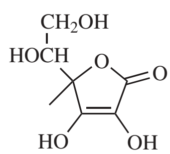

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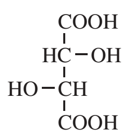

(4)

Other Acids. Ascorbic acid (**3**) is used primarily as an antioxidant and to a lesser extent as an added nutrient in beverages. It oxidizes readily, preventing the oxidation of certain flavoring compounds. Tartaric **(4)** and adipic acids are used to a lesser extent in grape flavored beverages. Malic acid can be used as an alternative to citric acid in some fruit flavored beverages.

2.4. Preservatives. The carbonation and acid content in cola and lemon–lime beverages usually act as adequate preservation against microbial growth. Benzoate or sorbate salts are often added to other beverages for protection (Table 2).

Sodium or potassium benzoate at a concentration of 0.05% is a universally used preservative agent active against yeast and mold. At higher concentrations benzoate is also effective against bacteria. It is most effective at a pH between 2.0 and 4.0. Sodium or potassium sorbate inhibits the growth of yeast and mold and is most effective below pH 6.5.

2.5. Carbon Dioxide. Carbon dioxide [124-38-9] provides soft drinks with a pungent taste, acidic bite, and sparkling fizz. Carbon dioxide (qv) also acts as a preservative against yeast, mold, and bacteria. The carbon dioxide used in soft drinks must be food-grade and free of impurities that may affect the taste or odor of the final product.

Carbonation can be measured in terms of volumes of carbon dioxide dissolved in one liter of beverage at a standard temperature and pressure (0°C, 101.3 kPa = 1 atm). One liter of carbon dioxide dissolved in one liter of beverage has a carbonation volume of one.

Carbon dioxide gas is added to either the water used to prepare beverages or the syrup and water mixture, depending on the type of manufacturing equipment. In both manufacturing processes, the carbon dioxide gas is introduced under pressure to the system. The carbonation of the beverage is dependent on the carbon dioxide pressure and the temperature of the mixture.

Carbon dioxide concentrations vary depending on the beverage formulation. Cola and lemon–lime beverages normally contain more carbonation than berry flavored or other citrus beverages.

2.6. Flavors. Flavor is the most important attribute of a carbonated beverage. Most carbonated beverages contain complex mixtures of different flavors produced in several commercial forms as alcoholic solutions, emulsions, and concentrates. The majority of flavors used in carbonated beverages are derived from natural sources.

Caffeine. Caffeine [58-08-2], $C_8H_{10}N_4O_2$, is usually added to cola beverages for its pleasantly bitter taste. Cola beverages not containing caffeine are designated as caffeine-free.

Juice-Based Flavors. Fruit juices are concentrated for use in carbonated beverage flavors. The final juice is concentrated between four to six times its initial strength by removing the water under vacuum; it is then pasteurized. Orange, grapefruit, lemon, grape, and apple are the most common fruit juices used in carbonated beverages.

Essential Oils. Volatile oils from plants are referred to as essential oils. The oils can be obtained through steam distillation, solvent extraction, or separation of the oils from pressed fruit. They consist of oxygenated compounds, terpenes, and sesquiterpenes. The primary flavor components of essential oils are oxygenated compounds. Terpenes contain some flavors but are often removed from the essential oil because they are easily oxidized (causing off-flavors or odors) and are insoluble. Essential oils are prepared from fruits, herbs, roots, and spices.

Oleo Resins. These oily residues, obtained from the solvent extraction of herbs, contain more of the characteristic flavors than do the essential oils. The solvent extraction removes nearly all of the flavor bodies from the herb. The extract solvent is distilled, reducing the solution to an oily residue. Oleo resins of interest to the carbonated beverage industry are ginger, celery, and black pepper.

Alcoholic Solutions or Extracts. Alcoholic extracts are prepared by dissolving the flavor-bearing body in a solution of alcohol and water. They may require filtration using filter aids to remove any insoluble precipitates or oils that may form. Alcoholic extracts are clear solutions and are used in beverages that do not require a haze or cloudiness.

Emulsions. An emulsion is the mixture of essential oils with an emulsifying agent, such as gum acacia or tragacanth, that is then homogenized. The homogenization process reduces the size of the emulsion particle, increasing its stability. The specific gravity of the emulsion is altered using brominated vegetable oil or glyceryl abietate [1337-89-9] (ester gum) as weighting agents. The adjustment is necessary to keep the emulsion in proper suspension in the beverage. If the specific gravity of the emulsion is less than the finished beverage, it will float to the top, forming a neck ring. Emulsions always produce an initially cloudy beverage.

Concentrates. These are mixtures of alcoholic solutions or emulsions with other fruit juice mixtures to produce a water-soluble solution. The concentrate can be easily used in the manufacture of syrup, providing carbonated beverage of consistent quality.

Concentrated Flavor or Beverage Bases. Parent soft drink companies may provide franchise bottlers with concentrated flavor or beverage bases that contain all of the necessary ingredients with some exceptions. In certain cases, nutritive sweeteners, preservatives, and some nonnutritive sweeteners may be purchased by the franchise bottler or packaged separately.

2.7. Colorants. Colorants are used in beverages to provide additional sensory appeal. Carbonated beverage may contain some natural color from the use of natural flavors or juices but generally require additional colorants such as caramel or other artificial colors.

Caramel color is used in most cola and root beer flavored carbonated beverages. It is manufactured through the carefully controlled heat treatment of a good-grade carbohydrate source, usually dextrose, and a chemical catalyst, such as food-grade acids, bases, or salts. All caramels are colloidal in nature and carry a small ionic charge. Manufacturers of soft drinks may use caramels with different properties but most require a negatively charged caramel. Caramel is generally supplied in single- or double-strength formulations whose primary difference is the color intensity. The double-strength formulation is used in most diet or low calorie colas because it has a lower caloric contribution than single-strength formulations. A foaming caramel may be used in root beer formulations.

Five FDA approved artificial colors commonly used in soft drinks are listed in Table 3.

The color is often added as a powder during the syrup manufacturing process either by itself or in a mixture with other dry ingredients. The color can also be mixed with the liquid flavor concentrate. All colors must be tested and released by the FDA.

2.8. Potassium. Potassium is another essential nutrient found in many natural and synthetic food ingredients. Like sodium, potassium exists naturally in drinking water and, therefore, soft drinks. Small amounts of potassium are also found in some of the flavoring agents and other ingredients used in soft drinks.

2.9. Sodium. Sodium, in the form of various salts, is present in many natural and synthetic compounds. It is an essential mineral nutrient resonsible for regulating and transferring body fluids, as well as other important body functions. Although an adequate daily intake of sodium is necessary for good helth, excessive consumption has been linked to high blood pressure in some people.

Soft drinks are not significant sources of sodium in the diet. In fact, the local drinking water supply used in making soft drinks contributes most or all of the sodium. Small amounts of sodium in some soft drinks can also come from certain ingredients.

Soft drinks are classified by the Food and Drug Administration (FDA) as "low" or "very low" sodium foods. Sodium-free soft drinks are also available.

3. Manufacturing

Carbonated beverages are manufactured by combining the concentrated flavorings (beverage bases) with a nutritive or nonnutritive sweetener and water to form a syrup; mixing the syrup with a proportioned quantity of carbonated water; filling and sealing the beverage in a container; and then packaging the container into a multipack secondary package (Fig. 1). This simplified process has remained relatively unchanged except for modernization and increased efficiency since the industry began.

3.1. Syrup Mixing and Handling. Most parent companies sell concentrated flavor bases to franchise bottlers and allow the bottlers to mix this with their own sweetener and water. This defrays shipping costs and reduces the labor demand on parent company manufacturing. In return, franchise bottlers are able to purchase sweeteners from local suppliers at a substantial discount and reduce their overall costs.

Concentrated flavor bases include all necessary flavors and ingredients with the exception of sweeteners and, in some cases, preservatives and acidulants. All of these components are mixed according to strict instructions to produce a quantity of syrup. A unit of syrup is defined by the parent company dependent on the brand but is often 189–3400 L (50 to 900 gallons).

A separate room is usually dedicated to syrup mixing. This room must be large enough to handle the various syrup batching requirements for efficient daily production and be of sanitary design to facilitate cleaning. Room design requires the floor to be made of an acid-resistant material such as quarry tile or have an epoxy coating. The walls may also be tiled or painted with an epoxy or latex paint to withstand the frequent cleaning demands.

Various sized tanks are required for the actual mixing. Additional tanks may be required for storage if large batches are made and held for any length of time. Tanks must be made of a corrosion-resistant stainless steel, such as 304 or 316, to prevent acidic syrups from picking up a metallic off-taste. Tanks also must have secured covers to prevent the entrance of airborne or other contaminants. Mixing tanks require agitators of sufficient size and speed to mix the viscous syrup within a reasonable time without harming the flavor by shearing or destroying the delicate flavor blends. Similarly, all pumps, valves, and lines must be of stainless steel or, in the case of lines, of an inert plastic material that does not impart an off-taste.

Once mixed, the syrup must be processed into the beverage as quickly as possible. Many soft drink brands contain delicate and sensitive flavors that may lose some of their taste characteristics because of acid hydrolysis or oxidation if kept in storage too long. Syrups made with aspartame must be processed quickly because this nonnutritive sweetener loses some of its sweetness over time in a low pH environment. Shelf lives of finished syrups depend greatly on their particular ingredients, their general flavor category (cola versus citrus), and whether their storage tanks are refrigerated. A refrigerated syrup retains its flavor longer.

3.2. Mixing Procedures. Each carbonated beverage flavor has its own unique mixing requirements but certain common principles apply. Preservatives such as sodium or potassium benzoate dissolve best in a nonacidic solution. Therefore, preservatives are usually dissolved in a mixing tank prior to the addition of flavors or acidulants. Conversely, aspartame dissolves best in an acidic solution and is usually added to a mixing tank after the flavors and acidulant have been added. A general mixing sequence is as follows:

Add required treated water, withholding a quantity sufficient to rinse all containers to remove all traces of ingredients.

Start agitator. Add preservatives if applicable, and mix until dissolved.

Add nutritive sweetener if applicable.

Add flavor concentrate, rinsing containers with water withheld for that purpose.

Add nonnutritive if applicable.

Add any remaining water to complete batch.

Agitate until completely mixed (usually 30–90 min).

Test syrup for quality control parameters, and release to production if analysis is satisfactory.

3.3. Filling. The filling process begins with mixing the syrup and treated water to beverage proportions and then carbonating this mixture. The water, and sometimes the finished beverage mixture, is often cooled to better facilitate carbonation and increase filling speed. Empty beverage containers are indexed at the filler after they have been washed, rinsed, or air blown, depending on the particular package. Containers are filled and then either crowned, capped, or in the case of cans, seamed to seal the container. From this point the filled container is transferred to packaging to be cased and palletized for distribution.

The filling process is relatively simple in design but can be complicated by the wide array of packages, products, container materials, and multiple secondary packaging options. For example, dozens of brands of soft drinks are manufactured by the same facility. Once canned, these brands can be loose-pack cased, six-pack cased, 12-pack wrapped, 15-pack wrapped, or 24-pack wrapped. The packaging decision is based on many factors including marketing strategy, promotions, and local market preferences.

Table 4 is a summary of the steps in soft drink can production (2).

3.4. Continuous Blend Production. The latest development in beverage manufacturing is the continuous blending of concentrate directly to beverage. This continuous blend system enjoys several advantages over the conventional syrup batch method in that finished syrup holding tanks are not required and the beverage is mixed immediately. Another advantage is that the total time required to produce the beverage is greatly reduced.

A continuous blend system requires predissolved powder components and sufficient liquid beverage base components. These are constantly metered and pumped into a beverage mixture. The components are mixed using positive displacement pumps that meter precise quantities. The continuous blend process requires the use of in-line ingredient monitors to measure the concentrations of ingredients constantly. Recent technological innovations have resulted in in-line monitors that are capable of measuring beverage components with the necessary precision required to produce a quality beverage.

4. Economic Aspects

According to Beverage Marketing Corporation, every person in the United States consumes 192 gallons of liquid per year. This translates to about 3.7 gallons per week or 2 liters per day. About 13% of all beverages consumed are alcoholic. Of the remaining nonalcoholic 87%, the most popular continues to be carbonated soft drinks, which accounted for 28% of the overall total in 2005. However, in the past five years carbonated soft drink's share has slipped slightly, while bottled water's share has risen by almost one half. According to *Beverage Digest*, Americans spent roughly $\$92.9 \times 10^9$ on refreshment beverages in 2004.

Table 5 gives data on U. S. per capita availability of carbonated soft drinks.

5. Packaging

Carbonated beverages were packaged primarily in returnable glass bottles until 1948, representing 98.8% of the total take-home market. A few independent bottlers began using nonreturnable bottles in 1948, representing 0.2% of the market. By 1964 the nonrefillable bottlers represented 13% of the total take-home market.

Cans were introduced to the soft drink industry in the mid-1950s. By 1965, cans made up 6.5% of the soft drink market. Today cans are the largest selling package in the United States, exceeding 50% in many markets.

Another significant development in the growth of soft drinks was the tremendous proliferation of packages starting in the mid-1950s. In 1953, The Coca-Cola Company abandoned its "one product and one package" philosophy relating to its 6.5-oz (0.2 L) bottle to compete with Pepsi-Cola's 12-oz bottle (0.35 L). Since that time, the types of packages have expanded to include dozens of sizes from 0.2 to 3 liters. They are packaged in various quantities (eg, 6-and 12- packs, a case of 24). Added to this wide array of sizes are the different container types including refillable glass, nonrefillable glass, poly(ethylene terephthalate) (PET) or plastic bottles, aluminum cans, steel cans, and even plastic (PET) cans.

The beverage industry is constantly innovating and improving its packaging to be effective, while at the same time reducing its overall environmental footprint. Work on lightweight containers has paid off. For carbonated beverage products, for example, the industry used 40 percent less packaging in 2003 than in 1990, while increasing sales by 45 percent.

6. Quality Control

6.1. Ingredients. Ingredients used in the manufacture of carbonated beverages must meet all *Food Chemical Codex* specifications and be approved for use in soft drinks by the FDA. In addition to the government stated specifications, manufacturers of carbonated beverages may complete additional analyses based on specific needs or concerns.

Drinking water supplied to carbonated soft drink manufacturing facilities from private or municipal sources must comply with all regulatory requirements. Treated water must meet all U.S. Environmental Protection Agency primary maximum contaminant levels and may also be subject to additional state requirements. Treated water is routinely analyzed for taste, odor, appearance, chlorine, alkalinity, iron, pH, total dissolved solids, hardness, and microbiological contamination.

Carbon dioxide used in carbonated beverages must be food-grade and must meet the Compressed Gas Association commodity specifications for carbon dioxide. In addition, carbon dioxide is tested for purity, taste, and odor before being used in the production of beverages.

6.2. Syrup. In typical manufacturing processes that produce syrup, several analytical parameters must be checked prior to packaging or beverage preparation. The sucrose or HFCS solids content is verified through the use of density meters or refractometers and reported as degree Brix, % solids, Baumé, or g/mL. The acidulant level is verified using titration or spectrophotometric methods. Preservative concentrations may be confirmed using high pressure liquid chromatography. Syrups are also evaluated for proper color, using spectrophotometric methods or colorimeters, and tested for microbial contamination.

6.3. Beverages. The quality control for carbonated beverages encompasses all aspects of the product from actual chemical components to the physical condition of the container. The beverage is evaluated using laboratory tests as well as in-line monitors.

Laboratory tests on the beverage include degree Brix, syrup to water ratio, taste, and microbiological testing. Beverages must first be decarbonated using blenders, air-stone degassing units, or ultrasonic baths before determining the degree Brix using density meters, hydrometers, or refractometers. The decarbonated beverage is then analyzed for acidulant content or ratio using titration or spectrophotometric methods.

6.4. Packaging. Incoming beverage packages are tested to ensure compliance with parent company specifications. Refillable bottles are visually inspected after washing to ensure that only clean and undamaged bottles are filled with beverage. In some refillable bottler operations, visual inspection is coupled with an electronic bottle inspection machine to further ensure the integrity of the bottles prior to filling. Packaged beverage is further tested for carbonation, closure application, fill height, and net contents. Beverage packages are usually tested at production start up and at various intervals of a production run as specified by the parent company.

Bottles of carbonated beverage are tested for carbonation using a Zahm-Nagel or Ashcroft carbonation tester. The carbonation can be calculated from the measured pressure and temperature values. Canned beverage is tested for carbonation and air content using a Zahm air tester.

Glass or plastic bottles that have plastic or aluminum closures are tested for removal torque. The removal torque represents the force required to remove the closure from the bottle. Closures are also evaluated to ensure that they have been properly applied and that they are tamper evident. Crown closures are also evaluated to ensure proper application.

Packaged carbonated beverage is tested for net contents or fill height to ensure that the package contains the stated weight or volume of beverage. The target value for each package should comply with individual state regulations.

Long-term performances of carbonated plastic beverage bottles depend on many factors. Separation and prediction of the contribution of any one factor to long-time performance is complex. Containers that are evaluated should exhibit a high degree of creep resistance. Visible manifestations of creep are reflected in gross dimensional changes of the bottle and cosequent loss in carbonation. Ref. 4 gives data on the creep deformation of a rubber modified high acrylonitrile resin and its implications of bottle performance.

7. Package Recycling

Because of the sheer volume of carbonated beverages consumed and the highly visible nature of the package, many consumers believe the soft drink containers make up a significant portion of the daily municipal waste. In reality, soft drink containers make up approximately 1.6% by weight of the total solid waste stream in the United States. This perception has led to states enacting forced deposit legislation to reduce litter and encourage recycling.

The states that have enacted such laws were led by Oregon in 1972. Environmental groups and industry leaders continue to encourage other states to look beyond the narrow scope of regulating just beverage containers and to look at the entire solid waste issue.

The beverage industry feels that forced deposit programs, also known as “bottle bills”, is a poor way to address the waste issue. Beverage bottles and cans have always been a valuable and significant component of recycling programs. The beverage industry believes that comprehensive recycling, in which consumers can recycle through curbside pick up or drop off programs, works. Beverage containers account for 40–70% of all revenues earned in community recycling programs (5).

8. Health and Safety Factors

In the United States, consumers are concerned with the rising problem of obesity. The role of soft drinks in this problem is controversial. Some studies show that children who have increased their consumption of drink sugar-sweetened beverages stand the risk of a gain in weight. On the other hand, children in Third World countries who consume large numbers of soft drinks do not share the same obesity rates as children in the United States (6). Other studies show an increased risk of diabetes along with a rise of sweetened beverage consumption (7).

In recent years, debate on whether soft drink vending machines should be allowed in schools is on the rise. Proponents believe children do not understand the consequences of their food choices. Opponents believe that obesity is a complex issue not only related to soft drinks. The American Beverage Association has produced a fact sheet on sales in schools (8).

The beverage industry has responded by providing consumers with low or no calorie beverages. They also believe that obesity is a complex issue and best addressed by consuming foods and beverages in moderation and getting plenty of exercise (9).

9. Recent and Future Developments

The soft drink industry is changing rapidly. In 1995, the first bottle of Aquafina was sold and this guaranteed that soft drink frachisers whold then be known as beverage marketers. In 2001, old brands were packaged in new ways when Mountain Dew Code Red became a hit. Popular sodas were packaged in unexpected ways. The industry also heeded consumers’ wishes when the low-carb movement got under way. Several flagship brands reduced carbohydrates, calories and sugars. The appearance of sodas fortified with calcium, vitamin C, and fruit juice appeared in 2004.

Sales of carbonated soft drinks have slipped so the big names in the industry are trying to address the consumer’s health concerns with new formulas. Name brands will fortify their beverages with vitamins and minerals. One will contain ginseng and extra caffeine.

New packaging and packaging materials seem imminent. The search for nonnutritive sweeteners continues with the hope for longer shelf lives and improved taste for calorie conscious consumers. Lower calorie beverages are clearly the growth area. More efficient methods and equipment are being developed. U.S. soft drink manufacturers will continue to expand overseas markets.

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R. Steve Morrow
Christine M. Quinn
Coca-Cola USA

Updated by Staff

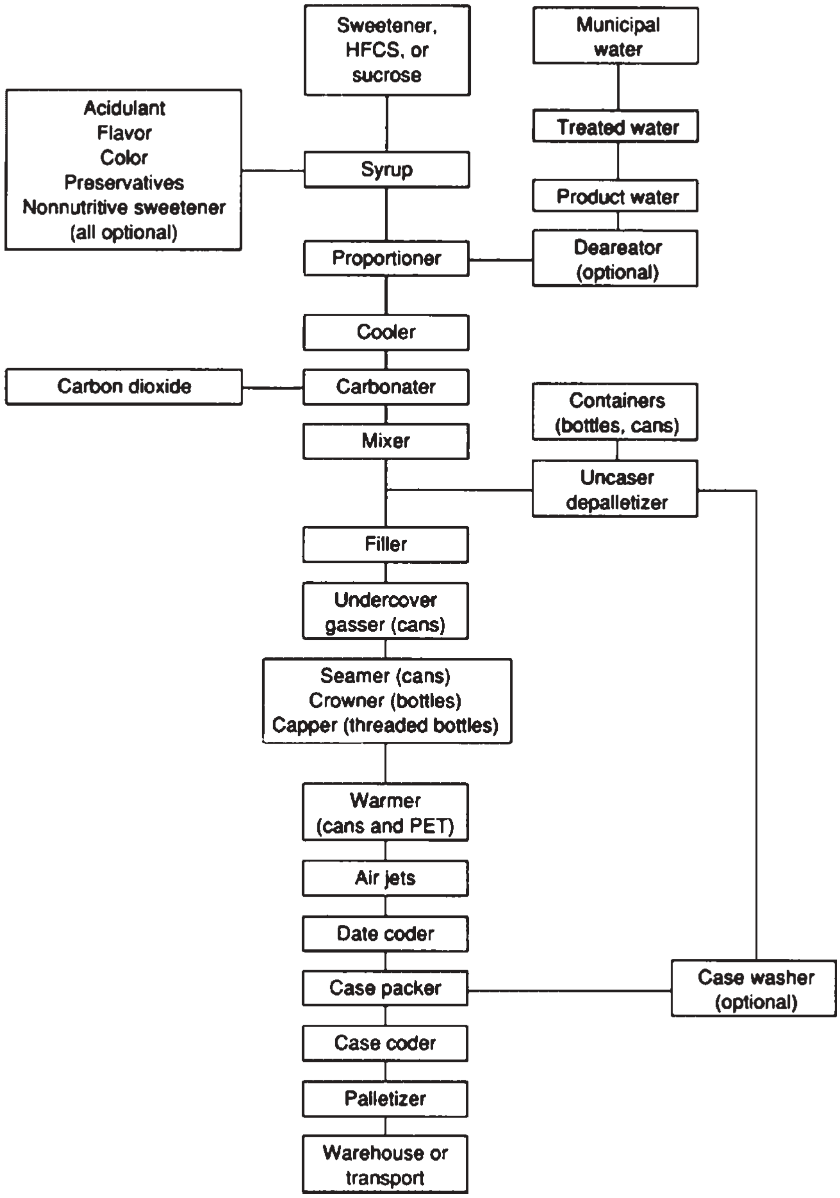


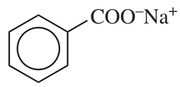
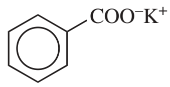
Fig. 1. Manufacturing process flow diagram.

Table 1. **Nutritive Sweeteners Used in the Preparation of Carbonated Beverages**

Type of sweetener	Sucrose, %	Polysaccharides, %	Dextrose, %	Fructose, %	Solids, %
liquid[a] sucrose	98–100	0	0	0	67
liquid[a] invert sugar	40–60	0	20–30	20–30	76
HFCS-42	0	2–9	49–53	40–44	71
HFCS-55	0	2–5	38–42	54–57	77
HFCS-90	0	1–2	7–8	89–91	77

[a]That is, aqueous solutions.

Table 2. **Acids and Salts in Carbonated Beverages**

Name	CAS Registry Number	Molecular formula	Structure	Use
phosphoric acid	[7764-38-2]	H_3PO_4	$(HO)_3P{=}O$	acidulant
citric acid	[77-92-9]	$C_6H_8O_7$	**(2)**	acidulant antioxidant
ascorbic acid[a]	[50-81-7]	$C_6H_8O_6$	**(3)**	antioxidant nutrient
2-tartaric acid	[87-69-4]	$C_4H_6O_6$	**(4)**	antioxidant
adipic acid	[124-04-9]	$C_6H_{10}O_4$	$HOOC(CH_2)_4COOH$	antioxidant
malic acid	[617-48-1]	$C_4H_6O_5$	OH $HOOCCH_2CHCOOH$	acidulant
sodium benzoate	[532-32-1]	$C_7H_5O_2Na$		preservatives
potassium benzoate	[582-25-2]	$C_7H_5O_2K$		
sodium sorbate	[7757-81-5]	$C_6H_7O_2Na$	$CH_3CH{=}CH{-}CH{=}CHCOO^-Na^+$ or	preservatives
potassium sorbate	[590-00-1]	$C_6H_7O_2K$	$CH_3CH{=}CH{-}CH{=}CHCOO^-K^+$	

[a]Vitamin C.

Table 3. **Commonly Used Artificial Food Colors**

FD & C designation	Common name	CAS Registry Number	CI name	CI number
Yellow #5	Tartrazine	[1934-21-0]	Food Yellow #4	19140
Yellow #6	Sunset Yellow FCF	[2783-94-0]	Food Yellow #3	15985
Red #40	Allura Red AC	[25956-17-6]	Food Red #17	16035
Green #3	Fast Green FCF	[2353-45-9]	Food Green #3	42053
Blue #1	Brilliant Blue FCF	[3844-45-9]	Food Blue #2	42090

Table 4. **Steps in Soft Drink Can Production**[a]

Step	Description
water treatment	coagulation, sand filtration, carbon filtration, and polishing
ingredients	flavors, acidulent, colors, and preservative measured
liquid sweetener	filtered and metered into syrup tank
syrup blending	syrup compounded from ingredients, sweetener, and water
water	chilled and carbonated
beverage proportioning	beverage = 1 part syrup + 5 parts carbonated water
can receiving	empty cans depalletized, inspected, and cleaned
can filling	cans gravity filled through open end on revolving filler
can seaming	filled cans have lid applied and sealed with double seam.
date coding	each can has a date code printed on the side or bottom.
fill check	net contents measured, low fill cans rejected to scrap
can warmer	cans warmed above dew point to prevent condensation in cases
multipacker	cans grouped and wrapped in 6, 12, 18, or 24 packs
case packer	six or 12 packs combined into cases of 24
palletizer	one hundred cases oriented into alternating stack patterns on wood pallets
stretch wrap	pallets wrapped in clear plastic film for protection and stability
warehousing	product stored in warehouse until needed to fill orders
bulk delivery	semitrailer loads transported to customer warehouses
local delivery	smaller trucks deliver to stores, restaurants, vending machines, etc.

[a]Ref. 2

Table 5. **Carbonated Soft Drinks: U.S. Per capita Availability**[a]

Year	Resident population, July 1, 10^6	Carbonated soft drinks					
		Regular, $\times 10^6$ gal	Per capita, gal	Diet $\times 10^6$ gal	Per capita, gal	Total, $\times 10^6$ gal	Per capita gal
1996	*269.394*	10,183.7	37.80	3,717.5	13.8	13,901.2	51.6
1997	*272.647*	10,658.3	39.09	3,698.8	13.6	14,357.2	52.7
1998	*275.854*	10,995.3	39.86	3,845.7	13.9	14,841.0	53.8
1999	*279.040*	11,069.0	39.67	3,861.0	13.8	14,930.0	53.5
2000	*282.193*	11,107.5	39.36	3,897.5	13.8	15,005.0	53.2
2001	*285.108*	11,110.0	38.97	3,970.0	13.9	15,080.0	52.9
2002	*287.985*	11,069.3	38.44	4,132.8	14.4	15,202.1	52.8
2003	*290.850*	10,890.1	37.44	4,368.4	15.0	15,258.5	52.5
2004	*293.657*	10,719.8	36.50	4,647.4	15.8	15,367.2	52.3
2005	*296.410*	10,521.9	35.50	4,749.7	16.0	15,271.6	51.5

[a]Ref. 3 (http://www.ers.usda.gov/data/foodconsumption/FoodAvailDoc.htm#beverages) for more informaton.