# Chapter 22
# Functions of Common Beverage Ingredients

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**Keywords** Additive • Food processing • Acidity regulator • Antioxidant • Synergist • Preservative • Sequestrant • Emulsifier • Stabilizer • Thickener

**Key Points**

1. Beverages contain added ingredients that work to enhance flavor, color, nutritional value, texture, and/or shelf stability.
2. Beverages commercially sold must comply with FDA guidelines that require food safety barriers such as thermal processing.
3. Beverage requirements may be met by techniques such as thermal processing or by use of preservative systems such as added ingredients to prevent microbial growth or to prevent quality loss from heating or time prior to sale.
4. Organic acids impart tart taste and have antioxidant and preservative qualities.
5. Fatty acids serve as emulsifiers and hydrocolloids provide thickness.
6. Salts provide electrolytes, fluid stability, and/or microbiological control (preservative).
7. Sweeteners affect taste characteristics and caloric content.

## Introduction

The numerous beverage brands, flavors, and products that include regular and diet carbonated soft drinks, juices, sports drinks, energy drinks, teas, coffees, beers, wines, and other alcoholic beverages represent a vast industry in the USA. Each beverage represents a unique profile of ingredients (chemicals) that are critical to

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defining the taste, function, and shelf-life of these products. By itself, the nonalcoholic beverage industry commands an impressive $141 billion direct economic impact and provides 233,000 jobs [1].

In order for these products to resist spoilage and maintain their original flavor and consistency during transportation and shelf-life prior to sale, a wide range of ingredients with a numerous functions are used to formulate nonalcoholic beverages. All of the ingredients used by US manufacturers are deemed safe for use in foods by the FDA. Ingredients have to be deemed GRAS (generally recognized as safe) in order to be legally used in foods. Flavors have either been assessed by FDA as GRAS or are deemed GRAS by FEMA (The Flavor and Extract Manufacturers Association of the United States (https://www.femaflavor.org/gras). However, while the safety of ingredients has been well characterized, other ingredient characteristics are not well determined. For example, FDA has no specific guidance to define the term "natural" for most ingredients. They do, however, have definitions for natural flavors and natural colors.

Some of the functions of ingredients found in nonalcoholic beverages are to impart taste characteristics, reduce caloric intake, add color, add flavor, act as a preservative, and regulate the appearance and consistency of the beverage. Manufacturers may choose to add fortificants, or other functional ingredients including vitamins, minerals, botanicals, and electrolytes. Ingredients that are often added to nonalcoholic beverages include organic acids, fatty acids, starches, gums, salts, sweeteners, flavors, and colors. This chapter identifies some of the more common additives used in nonalcoholic beverages and provides an explanation of their functions.

## Organic Acids

Organic acids, including citric, fumaric, and malic acids, are naturally found in fruits and vegetables, such as grapes, peaches, lemons, tomatoes, and red peppers [2]. In nonalcoholic beverages, organic acids are added to impart sour or tart taste, provide or stabilize pH dependent colors, and provide antioxidant properties that also stabilize colors and flavor systems and for preservative or antimicrobial qualities. While organic acids can be directly added to beverages, some are produced as by-products of fermentation, although this is mostly true for alcoholic drinks and some nonalcoholic beverages such as kombucha tea, and probiotic-cultured beverages are also fermented. While some suggest that organic acids can harm tooth enamel, this effect requires prolonged contact of the acid with the tooth. Thus, bathing teeth over a long period of time with soda and certain juices, including lime, lemon, and orange, can theoretically lead to this effect, but when normally consumed the saliva neutralizes this acidity rapidly [3].

Organic acids are often termed *acidity regulators* or *buffers* in industry because they allow manufacturers to control the pH of their products. This is an important consideration with thermal processing, where pH will change with temperature and severe changes in pH can deteriorate the beverage quality or taste. For example, the stabilization of pH can be critical in protein-containing beverages. Many organic acids can function as *antioxidants*, prolonging shelf-life by preventing the oxidation of lipids, including some pigments and natural flavor oils. In addition, certain organic acids function as *synergists*, enhancing the ability of antioxidants to control free radicals. When consumed by humans, drinks containing these antioxidants and synergists may also aid in the control of free radicals in the human system. As a result, the marketability of some beverages can be improved by including the word "antioxidant" on the product label to attract consumer interest for perceived health benefits. However, most organic acids are in beverages for their function properties and not to confer any specific health benefit.

Because organic acids create an acidic environment, they have antibiological qualities that are bacteriostatic to many microorganisms and thereby function as *preservatives*. Additionally, organic acids also function as *sequestrants*, or *chelating agents*, due to their ability to form several bonds to a single metal ion. Free metal ions are undesirable as they have the ability to react with other compounds, producing insoluble and/or colored compounds. Organic acids form water-soluble chelates with these metal ions, preventing them from negatively affecting the quality and aftertaste of the product in which they are contained [4].

## *Citric Acid, Fumaric Acid, and Malic Acid*

Citric acid contributes to the sour taste of some fruits, including lemons. Citric acid is a chelating agent and a synergist to antioxidants. At an alkaline pH, the citrate ion increases the solubility of calcium by forming a soluble, negatively charged calcium-citrate complex [5]. Fumaric acid and malic acid are derivatives of citric acid with a similar function, although the degree to which each contributes to the sourness of a product is different (Fig. 22.1).

## *Ascorbic Acid and Erythorbic Acid*

Ascorbic acid (vitamin C) is a water-soluble vitamin that aids in the repair and growth of tissues; repair and maintenance of bones, teeth, and cartilage; facilitates collagen creation; and acts as an antioxidant [4, 6]. The nutritional importance of

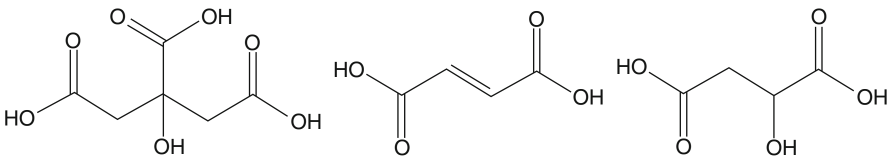


**Fig. 22.1** Chemical structures of common organic acids

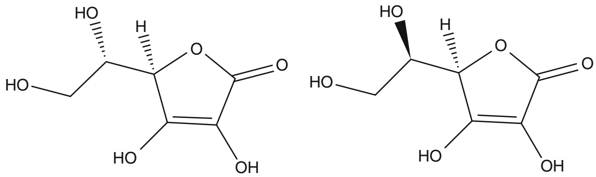


**Fig. 22.2** Organic acid stereoisomers

this vitamin prompts beverage manufacturers to add it to their products. Additionally, most beverage processing may lead to the degradation of the ascorbate content of the original fresh fruit. As a result, ascorbate is commonly added back to make up for degradation of the original ascorbate. Erythorbic acid is a stereoisomer of ascorbic acid and also functions as an antioxidant. It is used in beverages due to its comparatively low price (Fig. 22.2).

## *Calcium Disodium EDTA and Tartaric Acid*

Calcium disodium EDTA (the salt complex formed from ethylenediaminetetraacetic acid/edetic acid) is a good chelating agent that is used to sequester metal ions in aqueous solutions [4] and consequently has the ability to preserve color and retain flavor. Beverages that contain both benzoate salts and ascorbic (or erythorbic) acids can potentially form carcinogenic benzene; however, EDTA salts can prevent benzene formation [7]. Tartaric acid acts as an antioxidant and metal chelating agent [4].

## *Carbonated Water*

Carbon dioxide gas dissolved in water creates carbonic acid (see equation). The carbonated water that is present in beverages can be found naturally in spring water or artificially created by the addition of carbon dioxide gas. The process of fermentation that is so critical to kombucha tea, kefir, and champagne is another way that a beverage can become carbonated.

$$H_2O + CO_2 \leftrightarrow H_2CO_3$$

Carbon dioxide experiences increased solubility at lower temperatures. Carbonated beverages are packed at very low temperatures, thereby increasing the solubility of both $CO_2$ and $H_2CO_3$ in the container. When the container is opened, pressure is released, freeing trapped carbonic acid as bubbles of $CO_2$.

### *Phosphoric Acid (Inorganic)*

Phosphoric acid is an inorganic acid that has antimicrobial properties, the ability to buffer pH, and is also able to stabilize flavor. Colas contain phosphoric acid and typically have a pH of 2.8 to 3.2 [8], imparting a tart taste at the cost of potential negative effects on tooth enamel. Diets containing high amounts of phosphate and low amounts of calcium can theoretically lead to decalcification of bones [9]. However, there is no evidence that the casual consumption of colas leads to decreased bone density in humans [10, 11]. Further, it has been suggested that the amount of phosphoric acid present in cola is not sufficient for decalcification of bones to occur [9]. The association between phosphoric acid and bone loss remains controversial [10].

## Salts

Salts are added to beverages to perform multiple functions, including enhancing or providing flavor, acting as a buffering agent to organic acids, and preserving perishable beverage contents.

### *Electrolytes*

Magnesium chloride, calcium chloride, sodium citrate, and potassium citrate are salts that enhance beverage taste. These ions function as electrolytes in the body and stimulate glucose and water absorption in the small intestine. This is discussed further in the chapter by Maughan and Shirreffs on sports drinks. This process helps maintain extracellular fluid volume and stimulates thirst so that a person stays hydrated in order to keep plasma osmolality high [12].

### *Preservatives*

Sodium and potassium benzoate are commonly used as preservatives in the beverage industry, and they can also function as flavor enhancers. Benzoates exert their preservative functions best in acidic environments. The most common benzoates are sodium benzoate and benzoic acid. Sodium benzoate is considered a non-antimicrobial salt that can turn into an antimicrobial, known as benzoic acid, if it is dissolved in water. Because ultra-high temperature (UHT) sterilization can degrade acidic products, lower temperature sterilization must be performed to maintain the preservative function of the benzoates. Benzoates are effective in protecting against yeasts, bacteria, and molds that are not destroyed during this lower temperature process [1]. These preservatives are most commonly associated with diet soft drinks. Sodium and potassium benzoate may be clastogenic, mutagenic, and cytotoxic to human lymphocytes at high concentrations [13]. However, studies must be conducted to determine the minimum threshold at which these complications may occur.

Sodium hexametaphosphate (SMHP) is most commonly used as a preservative and as an *emulsifier*, creating a continuous mixture from immiscible phases. It is used by the beverage industry to maintain consistency and clarity in beverages. SMHP is a chelating agent that prevents the precipitation of metals and minerals such as magnesium, iron, and calcium, whose precipitates can result in an unsightly appearance or altered taste [14].

Potassium sorbate is mainly used as a preservative because of its antimicrobial properties. It works to inhibit the growth of bacteria and molds, allowing it to protect the taste in some non-carbonated and juice-containing drinks. It is most commonly used in wines [15].

## Fatty Acids

Fatty acids are sometimes added to beverages to serve as emulsifiers. In order for a stable emulsion to form, processing that applies force and creates an appropriate chemical environment is required. The integration of lipid-soluble additives that provide flavoring and coloring are made possible by emulsifiers.

An effective emulsifying compound used by industry is brominated vegetable oil (BVO), the product of the reaction between unsaturated vegetables oils and high-density $Br_2$. The use of BVO prevents oil from rising to the surface, maintaining the desirable uniformity qualities of the beverage. Some beverage companies are experiencing consumer pressure to discontinue the use of BVO due to concerns that bromine may accumulate in the fatty tissue of consumers [16]. A successful petition for Gatorade to end the use of BVO gained over 200,000 signatures from the public. Past studies demonstrated that feeding rats a diet containing 1.0 % BVO resulted in severe reproductive interference, high postnatal mortality, and severe behavioral impairment [17]. Even at a level of 0.1 % in the diet, rats exhibited a significant increase in triglyceride content in heart and soleus muscle and an increase in total and esterified cholesterol in the heart muscle [18]. Human clinical trials are difficult to perform due to potential health risks. Therefore, definitive understanding of the risk that BVO poses to humans remains controversial.

Coconut oil/medium-chain triglycerides (MCT) are composed of a mixture of saturated fatty acids with chain lengths of six to ten carbons. MCT may have beneficial effects on weight control and glucose and lipid metabolism when consumed in moderate amounts [19]. Compared to long-chain triglycerides, MCT are easily digested, absorbed, and used for energy by the body. Due to their ability to be quickly metabolized, digestive system stress is minimized [20]. Consequently, MCT are commonly included in sports drinks.

## Hydrocolloids

### *Starches*

Two kinds of starch are used as thickeners in the beverage industry: unmodified starch and modified starch. The selection of the kind of starch to use is dependent on the pH of the product. For example, in milk products, unmodified starch is often used as a *thickener*, increasing the viscosity of the product and creating a smooth mouthfeel. In low pH products, such as juices and soft drinks, unmodified starch breaks down and a modified food starch must be used. Starch can be modified by enzymatic, chemical, or physical processes, including bleaching, oxidation, acid and alkali treatment, acetylation, and roasting [21]. Modified food starch can originate from corn, wheat, rice, tapioca, or potato; however, FDA-regulated products must specify the source of the starch (potato starch, wheat starch, etc.), and unspecified "starch" is assumed to be derived from corn. Those who have celiac disease or wish to follow a gluten-free diet should be mindful of modified food starch and remain aware that wheat contamination is possible.

### *Gums and Pectins*

Water-soluble gums are often used to stabilize and thicken beverages, aiding in the suspension of oils in water [21]. A wide range of plant-based gums are used in the beverage industry. Gum acacia (gum arabic) originates from the hardened sap of the acacia tree. Natural gum arabic is comprised of the mixed salts of arabic acid, carbohydrates, and some protein [22]. Glycerol ester of wood rosin (ester gum) is created by the reaction of glycerin with refined wood rosin. It is often used as a weighting agent that stabilizes liquid flavor emulsions with essential oils. Cellulose gum (sodium carboxymethyl cellulose) is derived from the natural polysaccharide cellulose that is found in plants, particularly from the cell walls of woody plants such as trees and cotton. Guar gum is extracted from guar beans. While gums are primarily used as beverage thickeners, they may also have other benefits. For instance, human studies have shown the potential of guar gum to curb diabetes and cardiovascular risk and aid in weight loss [23, 24].

Some gums originate as bacterial fermentation products. Xanthan gum is the polysaccharide product of the fermentation of sugars by strains of the bacterium *Xanthomonas*. These polysaccharides are then precipitated with isopropyl alcohol, dried, and ground to a powder [25]. The same process is used to produce gellan gum from the bacterium *Sphingomonas elodea*. Gellan gum can be found in alternative milk drinks, such as almond milk; in fortified drinks to suspend vitamins, minerals, and proteins; and in coffee drinks.

Pectin is a natural polysaccharide that is present in the cell wall of plants. Citrus fruits are commonly used as a source of pectin for food applications. Pectin acts as an emulsifier and stabilizer, aiding in the suspension of pulp, and also provides viscosity as well as texture to juices. Carrageenan is a natural carbohydrate that is extracted from red seaweed. λ, κ, and ι are the most common carrageenans that combine with milk proteins to improve the solubility and texture of products, thereby functioning as a thickener and stabilizer. Carrageenan is often added to milk, where it combines with milk proteins to suspend cocoa solids in chocolate milk, and in low-calorie products due to its ability to be substituted for fat. Undegraded carrageenan, the form of carrageenan used in food products due to its thickening properties, has been approved for human consumption. The use of carrageenan is complicated by the potential contamination of degraded carrageenan (or poligeenan), which has been shown in animal studies to have potentially negative effects on health such as the promotion of intestinal neoplasms and ulcerations [26].

## Sweeteners

### *Caloric Sweeteners*

There are multiple sources of caloric sweeteners, and many are natural. Caloric sweeteners include sucrose (table sugar), honey, molasses, agave, and high fructose corn syrup (HFCS). Other sweeteners include monosaccharides such as glucose and fructose (fruit sugar) and disaccharides such as lactose (milk sugar). Like most carbohydrates, caloric sweeteners provide 4 calories (17 kilojoules) per gram. The primary purpose of sweeteners is to preserve and/or enhance flavor.

Sucrose is a disaccharide composed of glucose and fructose molecules linked together by a relatively weak glycosidic bond. HFCS is produced by processing cornstarch to produce a nearly 100 % pure glucose product that is enzymatically converted to fructose. The result of this conversion is a syrup containing approximately 42 % fructose, aptly named HFCS 42. HFCS 42 can be further purified into a 90 % fructose syrup (HFCS 90). To make HFCS 55, the HFCS 90 is mixed with HFCS 42. The process of forming HFCS is more thoroughly described in the chapter by White and Nicklas. For many companies, HFCS has become one of the cheapest forms of sweeteners, prompting companies to switch from sucrose to HFCS.

### *Low and No Calorie Sweeteners*

Low- and no-calorie sweeteners (nonnutritive sweeteners (NNS)) provide a sweet taste with less or without calories. Sweeteners that fall under this category include sucralose, acesulfame potassium, aspartame, and various plant-derived sweeteners such as stevia and monk fruit that are rapidly gaining popularity [27, 28]. These NNS are hundreds of times sweeter than their caloric brethren, which means that a smaller amount of NNS can be used to replace a large amount of sucrose or HFCS.

The Academy of Nutrition and Dietetics has provided an excellent review of the relative properties of NNS [27]. Aspartame is considered approximately 200 times sweeter than sucrose. It is composed of two naturally occurring amino acids, phenylalanine and aspartic acid. Aspartame is not considered stable when heated, so it is not suggested for use in thermally processed beverages. Sucralose (sold under the brand name Splenda©) is about 600 times sweeter than sucrose. Acesulfame potassium (Ace-K) is a heat-stable sweetener that is 200 times sweeter than sucrose. However, Ace-K is usually combined with other sweeteners, particularly sucralose, because alone it does not possess an adequate sweetness profile for many beverages.

Plant-derived NNS are also becoming popular for beverage applications. Steviol glycosides (Stevia) are extracted from the leaves of *Stevia rebaudiana*, a plant that is native to South America. Stevia is 200 to 400 times sweeter than sucrose. Stevia appeals to consumers due to its natural plant-based origin. *Monk Fruit* (*Siraitia grosvenorii*) is a gourd that is native to southern China and northern Thailand. The monk fruit contains varying levels of mogrosides I–V, of which mogroside V is incredibly sweet and is consequently used as a standard to measure the relative quality of the monk fruit sweetener product. Sweeteners derived from monk fruit are between 150 and 500 times sweeter than sucrose. Monk fruit has gained attention due to its use in chocolate milk that is sold as part of some school lunches in an initiative to reduce the amount of added sugar to flavored milks.

The ability of the average consumer to identify NNS from food labels based on either chemical (e.g., Sucralose) or trade name (e.g., Splenda®) is arguably weak. A survey was administered to 1,630 university freshman and sophomore students who were taking courses in biology, chemistry, or health sciences. The survey evaluated the ability of the 720 respondents to name NNS from memory [28]. Approximately two-thirds of respondents were unable to name two NNS by chemical or trade name, and only 12 % could name three or more NNS (Fig. 22.3). The poor ability of participants to know which chemicals are NNS may be partly responsible for consumer fears about NNS.

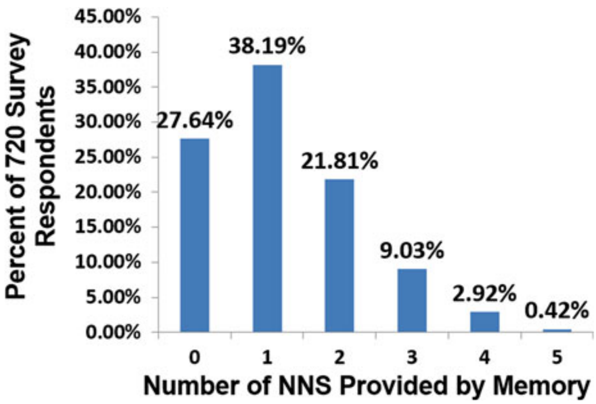


**Fig. 22.3** College freshman and sophomore science students were asked to name NNS (trade or chemical name) from memory. Of the 720 respondents, 38 % could name just one NNS and less than 3 % of respondents could name four examples of NNS [30]

A recent concern associated with no- and low-calorie sweeteners is their potential association with negative health outcomes. Metabolic syndrome, weight gain, hypertension, and cardiovascular disease, as well as the possibility that the sweeteners are not associated with weight loss or even maintenance have been examined [29–31]. However, further investigation to explore the long-term effects of the overconsumption of soft drinks that use NNS on consumer health must take place to draw more definitive conclusions on their health effects.

## Dyes and Coloring

Color is associated with our perception of taste. Most dyes are water-soluble and exist in many forms including liquid, powder, or granule. Dyes and coloring are used to provide color to beverages in order to influence the consumer to perceive the product in a particular way. This topic is more thoroughly described in the chapter by Spence.

Coloring substances can be extracted from a variety of sources—animal, vegetable, or mineral. There are a number of naturally derived colors used in the beverage industry. Juice made from elderberry fruit is an example of a natural dye that imparts a dark coloring. Other common natural colorings include annatto, saffron, paprika, grape skins, beetroot, cochineal, and beta-carotene. Sugar can be burned to produce a caramel coloring.

With some color additives, hypersensitivity and allergies can result from ingestion, making proper labeling important. The FDA requires that manufacturers of coloring substances provide sufficient evidence that the substance is safe for human consumption and requires that labels list all dyes that are present. The majority of dyes that are used in beverages are synthetically produced, such as blue dyes 1 and 2, and red dyes 3 and 40. The ingestion of some synthetic dyes has been implicated in the increased hyperactivity of some children [32]; however, there is no conclusive evidence existing that this is a cause of ADHD [33]. Consumers often perceive natural dyes as safer than artificial dyes, but this may be a false assumption as the relative safety of natural and artificial dyes cannot be unequivocally established.

Many different artificial colorants are used in the food and beverage industry. To impart a cherry pink color, red dye #3, also known as erythrosine, is used. It has a maximum accepted daily intake (ADI) of 0.1 mg/kg. Red dye #40 lends an orange-red color, is known as allura red, and has a maximum ADI of 7 mg/kg. To achieve an orange coloring, yellow dye #6, commonly known as sunset yellow, can be added. It has an ADI of 7.5 mg/kg. Yellow dye #5 conveys a lemon-yellow coloring, has a maximum ADI of 7.5 mg/kg, and is known as tartrazine. Blue dye #1 provides a bright blue hue, is aptly called brilliant blue, and has a maximum ADI of 12.5 mg/kg. To achieve a royal blue or indigo color, blue dye #2, or indigotine, can be added and has a maximum ADI of 5 mg/kg [34].

Negative public perceptions about the safety and palatability of dyes and colorings can lead to changes in product formulation. Consumer displeasure can lead to

**Table 22.1** Amounts of caffeine in common beverages

| Beverage type | Serving size (oz) | Caffeine count (mg) |
|---|---|---|
| Brewed coffee | 8 | 95–200 |
| Black tea | 8 | 40–70 |
| Green tea | 8 | 24–45 |
| Diet cola | 12 | 23–47 |
| Regular cola | 12 | 23–39 |

reductions in sales and a consequential need for reformulation. For example, cochineal red (or carmine red) is a pigment obtained from an insect that lives on a cactus. It has been used in foods and beverages for several hundred years but was only recently linked with the promotion of allergic hypersensitivity [35]. Moreover, some consumers would probably not feel comfortable consuming a dye that is derived from an insect. Cochineal red was removed from Starbucks coffee products in 2012 [36], and there is presently pressure on Dannon to remove it from their yogurt.

## Caffeine

Caffeine is a nitrogenous organic compound with stimulant effects that is found naturally in coffee and tea beverages. It is used as an additive in various beverages. Kola nuts are a commonly used source of caffeine. The typical caffeine content of various beverages is summarized in Table 22.1 [37]. Caffeine is considered GRAS (generally recognized as safe) in quantities of up to 400 mg for adults in the USA [38]. The FDA requires beverage labels to state that the product contains caffeine but does not require that manufacturers indicate the actual amount. Public pressure is increasing for the FDA to require specific caffeine content labeling, and some beverage manufacturers are now doing this in their products [39]. Labeling of the actual caffeine content can help improve marketability or for consumer education about potential risk (e.g., of energy drinks).

## Conclusion

Beverages contain a diverse array of compounds that work to enhance flavor, color, composition, and overall quality of a drink. Organic acids impart a tart taste, antioxidant properties, and preservative qualities. Fatty acids serve as emulsifiers and may provide nutritional qualities. Starches, gums, and pectins provide thickness to a beverage. Salts provide electrolytes and act as preservatives. Caloric and noncaloric sweeteners modify beverage sweetness and, by extension, overall palatability. Manufacturers create the signature taste and qualities of the beverages that they market using these ingredients.

Beverage ingredients must follow regulations to ensure that consumers receive a safe and consistent product. Consumers have a growing desire to have more information regarding the function, source, and health outcomes of the ingredients that are listed on the labels of the products that they consume. Unfortunately, we do not as yet have conclusive evidence regarding the health effects, either positive or negative, of some ingredients.

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