

Chemistry of Soft Drinks

Pohanyar Mohammad Kabir Masomy

Department of Chemistry, Faculty of Education, Faryab University, Afghanistan

Abstract

Fruit juices and soft drinks are available in essentially the same form almost anywhere in the world. From polar bases to the tropics, and from the largest developed nations to small and less developed countries, soft drinks and fruit juices are available in bottles, cans, laminated paper packs, pouches, cups and almost every other form of packaging known.

Soft drinks are those drinks which do not contain alcohol. These soft drinks are either carbonated or non-carbonated soft drinks. Carbonated soft drinks are consumed widely across the globe. Today, when people are becoming more health conscious, concerns are being raised regarding the impact of carbonated soft drinks on health. When discussing the effects of carbonated soft drinks on health carbon dioxide, phosphoric acid and sugar are main concern. Most carbonated beverages have acidic pH which results in gastroesophageal reflux disease (GERD) like symptoms. The phosphoric solution in these beverages is powerful enough to cause human teeth to become soft. The caffeine present in colas is known to be a hazardous factor for osteoporosis. When taken after a period of dehydration, the sugar in these beverages is known to cause more renal injury than plain water. The sugar in these beverages may lead to lipids production in the body and result in obesity, hypertension, non-alcoholic fatty liver disease (NAFLD), and pancreatic cancer. Hence, it is necessary to monitor diet and focus on natural and healthy beverages [2:13-14].

Keywords: *Fruit juice, soft drinks, carbonated soft drink, noncarbonated soft drinks*

Introduction

What are soft drinks? There is no single definition available but it is generally accepted that they are sweetened water-based beverages, usually with a balancing acidity. They are flavored, frequently colored and often contain an amount of fruit juice, fruit pulp or other natural ingredients. The predominant ingredient is water – often ignored and frequently maligned – and it should be remembered that the primary function of soft drinks is hydration. The sweetness and other characteristics are in some respects secondary and yet they do have importance in the provision of energy and some of the minor essential nutrients needed to meet daily requirements [4:12].

It is generally accepted that the description of soft drinks excludes tea, coffee, milk beverages and, until recently, alcohol. However, in many countries the production of ‘soft’ drinks containing alcohol is growing. Many see this as an undesirable trend because traditionally the taste of alcoholic beverages has been associated with adulthood. The blurring of the edges between the markets and tastes for alcoholic drinks and soft drinks appears to facilitate an easy transition for children and young people to the consumption of alcohol. There are two basic types of soft drinks: the so-called ready-to-drink (RTD) products that dominate the world market and the concentrated or dilute-to-taste products that are still important in some markets. These include syrups and so called squashes and cordials. RTD or dilute able, soft drinks characteristically contain water, a sweetener (usually a carbohydrate, although artificial sweeteners are increasingly important), an acid (citric or malic are the most common), flavoring, coloring and preservatives. There is a large range of additional ingredients that can be used for various effects [5:9]

We all love to have a sip of our favorite soft drinks (aka cold drinks, carbonated water or just soda water) when we are thirsty, especially in summers. And we also love to have a little fizz in it. This fizz is the bubbly effervescence that is produced by adding pressurized carbon dioxide gas to water. The aim of this article is to highlight the composition of cold drinks, the purpose of uses of its ingredients and their impact on human health and the chemistry behind these effects.

Joseph Priestley was the first person to invent soda water. He suspended a bowl of water over a beer vat in a brewery and patiently waited to see what happened. Soon the bowl of water was fizzing with carbon dioxide released from the fermentation of beer. And that was how soda water was born. However, it was only in the later part of the 19th century that soda water was introduced as a popular soft drink. Today, soda water is made by sending pressurized carbon dioxide through water. The high pressure allows more carbon dioxide to dissolve than it

would normally be possible. The soda is then packed into an airtight bottle. When this pressurized bottle is opened, the gas rises to the top bubbling. And if you shake the bottle before opening, the soda will spill out splashing all over, when opened [1:3-4].

The era of cold drinks/soft drinks began in early 1950s but as this industry was quite luring as well as profitable, many multinational companies launched their products in different flavors with various brand names such as Sprite, 7up, Pepsi, Coca cola, Mountain Dew, Fanta, Miranda, etc. People take these drinks according to their temperaments and moods, e.g. it is generally believed that Miranda, Fanta and especially Sprite give a feeling of lightness whereas Pepsi & Coca Cola activate pulse and brain. Often a distinction is made between a soft drinks and a cold drink. A soft drink is a non-alcoholic drink which may or may not include fizzy drinks. Examples of such drinks include lemonade or fruit juices. Whereas, the cold drinks (Pepsi, Miranda, Fanta, sprite, etc.) are majorly composed of alcohol, carbohydrates, carbon dioxide, phosphate ions, sodium benzoate, acesulfame potassium (Ace-K) and caffeine. These ingredients are responsible for the feeling of warmth, lightness and tangy taste which is liked by everyone. But unfortunately, these soft / cold drinks not only provide taste and a little energy but also cause some severe effect on our health which most probably we forget when we take such drinks. It has becomes a big dilemma of our society that we grew up on such diets which has high consumption of soft drinks and its worse tragedy that we are a nation/ people who are becoming addicted to soft drinks day by day [3:44].



Figure 1. Image for different kinds of soft drinks produced by different companies

History of soft drink consumption

The category of soft drinks falls under consumer goods. Soft drinks tend to be non-durable and do not last for over 3 years. As non-durables it has relative price stability in comparison to durable goods [5:12].

The history of soft drink has not been traced by scholarly research at present. However preliminary inquiry and investigation of soft drink consumption patterns in human history has revealed that soft drinks (may have) first appeared in seventeenth-century Europe as a mixture of water and lemon juice sweetened with honey. In 1676, the Paris-based *Compagnie de Limonadiers* was founded and granted a monopoly by the French monarchy. Company vendors dispensed cups of lemonade from tank packs on their backs. The first carbonated beverages, which also debuted in Europe, were inspired by the popularity of effervescent water from natural springs, which were widely thought to have medicinal value.

Many believe that Joseph Priestley was the founder of soft drink manufacturing. He was among the first who experimented with carbon dioxide gas from brewery fermenting vats. In 1772, he invented a small carbonating apparatus in London that pumped carbon dioxide into water. Mineral salts and flavors were later added as the appeal of soft drinks spread.

Today the soft drink industry is among the most dominant industries in the world. Valuation of the industry differs according to organizations/firms but it is undoubted that the Mineral Waters, Soft Drinks, Fruit and Vegetable Juices industry has a substantial demand around the world. For example the Soft Drink Concentrates Market was estimated to be \$25,500.00 million in 2013, and is projected to reach \$34,761.36 million by 2019 [4:19-21].

However this does not mean that soft drink consumption has remained uniform or static throughout the world. Soft drink consumption varies widely by region and by 7 culture. As a result, consumption does not necessarily coincide closely with population or economic development.

Chemical and Nutrition points of soft drinks and fruit juice

The nutritional value of soft drinks is sometimes exaggerated by manufacturers who want consumers to perceive their products to be of special benefit. That said, the value of soft drinks must not be understated, because they are an essential vehicle for hydration. Soft drinks are usually absorbed more readily than water (because of their osmolality), can replace lost salts and energy quickly and are rapidly thirst quenching. Their balance of sweetness and acidity, coupled with pleasant flavors, makes them attractive to all ages of consumers. Products are specially formulated to meet the tastes, nutritional needs and physiological constraints of the whole population, from babies to geriatrics.

The claims that are legally permitted for soft drinks vary from country to country but for the most part are limited to nutritional claims concerning energy, proteins, vitamins and/or minerals. Any form of medicinal claim (i.e. curative or symptomatic relief) will almost always be excluded by corresponding medicines legislation. There is, nevertheless, a growing trend to include natural extracts in many soft drinks (e.g. ginseng or ginkgo) and then rely on the general understanding and folklore that surrounds such ingredients to impart the special values that have been attributed to them. There are three main areas of particular nutritional significance for soft drinks. The first is energy. Some soft drinks are formulated to deliver a rapidly assimilated energy boost to the consumer. All carbohydrates are important sources of energy but soft drinks generally contain soluble sugars, which are easy to administer. However, because high levels of sugars are often intensely sweet and even sickly, with a cloying sensation in the mouth, energy drinks are formulated around glucose syrup. For a given solid carbohydrate content, this raw material is much less sweet than sucrose. Selection of the method of hydrolysis used for the corn starch allows glucose syrup to be tailored, to some extent, to include mixed carbohydrates, that is, mono-, di-, tri- and oligosaccharides. Such blends are the basis of some very effective products used by athletes and those recovering from illness. The second area of nutritional significance is that of the so-called isotonic drinks, which are of equivalent osmolality to body fluids. They promote extremely rapid uptake of body salts and water, and are very important products for sportspeople and others requiring almost instant hydration. Third, soft drinks have been widely formulated to low-calorie forms and these are now available for those who wish to enjoy such beverages and yet minimize their calorific intake. Other nutritional benefits that are claimed by some producers include the delivery of essential vitamins and minerals, especially to children.

On the negative side, soft drinks have acquired a reputation for being an agent in the development of dental caries. This has been claimed to arise when sugar residues remain in the mouth or when (especially) young children have an acidic drink almost constantly in their mouths. It is perhaps now accepted that the dental caries problem is related more to the misuse, or even abuse, of soft drinks than to the effects of normal consumption of such products [9:44].

Fruit juice is important in human nutrition far beyond its use as a refreshing source of liquid. Many fruits contain a variety of minor ingredients, particularly vitamins and minerals, as well as carbohydrates, which are the predominant solid component. Although fruit contains small amounts of protein and fat, these are not important ingredients of juices [12:44].

Nutrients frequently consumed in sub-optimal concentrations by humans are proteins, calcium, iron, vitamin A, thiamin (vitamin B1), riboflavin (vitamin B2) and ascorbic acid (vitamin C). Some of these nutrients occur in higher concentrations in fruit juices than in other foods. There is experimental evidence that indicates that ascorbic acid of natural origin is apparently superior to that of synthetic origin. It has been established that the above phenomenon is caused by the presence of certain flavonoid compounds in fruit juice that influence blood circulation, increasing the permeability and elasticity of capillaries. This action is known as vitamin P activity, but the flavonoids showing this property are not classified as vitamins, because there are several substances with this activity and no serious

deficiency diseases occur if they are not consumed. There are indications that these flavonoids have a useful protective action, in particular against some respiratory diseases, but they are readily decomposed in the body and it is impossible to maintain an effective concentration in the blood [9:12].

Apart from the more obvious benefits of fruit juice, such as being a source of potassium, it contains other substances that have or are claimed to have useful pharmacological activity. For example, limonin and other related limonoid substances present in citrus fruit are believed to have a role in inhibiting certain forms of cancer. Sorbitol, which occurs in many fruit juices, has a laxative effect.

Several components with antioxidant activity are found in fruit juices. These include ascorbic acid, tocopherols (vitamin E), beta-carotene and flavonoids. Beta-carotene has antioxidant activity that can quench the singlet oxygen that can induce precancerous cellular changes. Whatever the nutritional interest, it should be noted that changes occur during storage, particularly to the minor components of juices and particularly under adverse conditions (e.g. light, increasing temperature, time) [12:31].

The categories of beverages

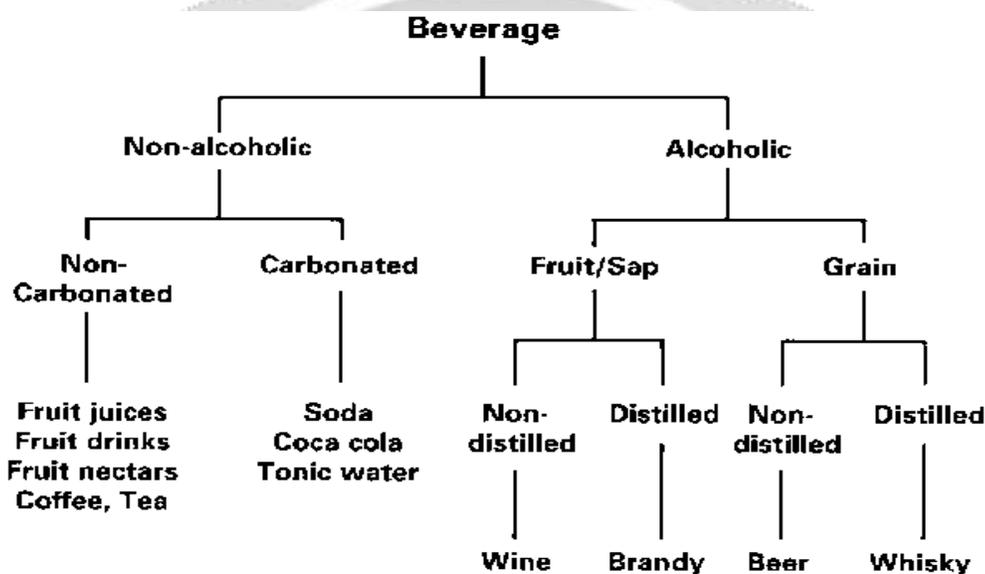


Figure 2. Categories of beverage [1:22]

Carbonated drinks

A carbonated beverage or an effervescent drink may be a nonalcoholic drink that ordinarily contains water, a sweetener, corrosive and a seasoning ingredient. The term “soft” is owing to the absence of alcohol, not like its presence in exhausting drinks [1:15]. Carbonation may be a term accustomed establish the dissolution of greenhouse emission gas in water utilizing pressure and temperature [2:13]. The effervescent drinks are the third most consumed beverages, across the globe [3:48].

Artificial carbonation was invented by Joseph Priestly, in 1767. First commercial production of carbonated drink was in Switzerland, in 1783. It was mineral water [4:55].

Carbonated drinks are consumed worldwide and the majority of the people drink them daily, making them the easiest source of energy intake. Given the high consumption of these drinks, the scientific community is concerned about their impact on health [6:12]. An association between carbonated drinks and obesity or the metabolic syndrome has been hypothesized, however conjointly, dental, pneumonic or cardiovascular diseases are associated with their consumption [7:55]. This review provides information concerning the consequences of carbonated drinks on health. This information can be used for lifestyle changes, relating to the frequent consumption of carbonated soft drinks.

Chemical ingredients present in soft drinks

Before describing the chemistry of ingredients, it is essential to know about the term called “pH”. The acidity of any substance is measured by means of a pH scale which ranges from 0-14. A lower pH value means high acidity; a higher pH values suggests an alkaline solution whilst a value of 7.0 indicates a neutral solution. The pH has quite a defining effect on the health of any individual. In humans, a normal pH-level of all tissues fluids of the body (except the stomach) is slightly alkaline. Blood is one of the fluid systems that are constantly trying to maintain a pH level of 7.4 (slightly alkaline). Being slightly alkaline means the blood cells and body tissues are highly oxygenated, and in optimal state to neutralize and detoxify the metabolic waste and toxins and you will be in a state of:

1. Vibrant healthy body
2. Enhanced immunity
3. High energy level
4. Sharp mind & brain performance
5. Shining & healthy looking skin
6. Positive emotional state [8:36]

The body makes constant adjustments in tissue fluids’ pH to maintain this very narrow pH range in the blood. All other organs and body fluids will fluctuate in their range in order to keep the blood at a strict pH range (between 7.35 and 7.45 i.e., slightly alkaline). This process is called *homeostasis*.¹ The pH balance is one of the initial and most important measures to avoid disease and to ensure a strong functioning immune system. The pH-balance or Yin-Yang balance (in terms of Traditional Chinese Medicine) of the body is critical to optimal health. It is said that *Taoists*,

Qigong masters and Yogis all live a balanced, harmonized and alkaline life. For example the blood pH of cancer patients is always acidic (without exemption) either due to eating the wrong food and having emotional stress or other stress related issues. In an alkaline cell-environment cancer cells can’t live or grow. The immune system will boost up and is able to fight viruses, infections, bacteria and parasites better and stronger.

The instance of ZamZam is worth mentioning here. The ZamZam well is located at Masjid Al-Haram in Mecca, Saudi Arabia. The ZamZam water (considered to be the miraculously generated water by God) was once believed to the cure of almost all diseases and the same has been proven now. To our surprise, this sacred and health restoring water has a surprisingly alkaline pH (which is 7.9-8.0). It has been observed that high intake of coffee, white bread, Cola, soft drinks, beer, meat, nuts, eggs, vinegar, ascorbic acid, cheese, white sugar and medicines causes a significant decrease in blood pH which has been found to be associated with many diseases including the so far incurable cancer. Also the factors such as overwork, anger, fear, jealousy and physical/emotional stresses causes an acidic blood pH. On the other hand, the food items such as ripe fruits, vegetables, bean sprouts, water, milk, onions, figs, carrots, beets, etc causes an alkaline blood pH and therefore promote better health. There are many chemical ingredients involved in the soft drink composition depending upon their brands however, the ingredients that form the essential part of all cold/soft drinks are discussed here [2:19]

Water

First of the entire basic ingredient, water, is mostly taken from a safe source like municipal supply. Water is usually processed before use in order to remove some organism and plank on by super chlorination and coagulation processes. In this process water is treated with large amount of chlorine. Afterwards, it passes through a sand filter and activated carbon [3:23].

Carbon dioxide

Carbon dioxide, added to the cold drinks for the fizziness /formation of froth upon shaking the bottle. The process of adding CO₂ into water is called *carbonation* [10:13]. When carbon dioxide combines with water, it forms a new chemical called the carbonic acid. This carbonic acid is actually responsible for the tangy taste of soda water drinks and it is also one of the chemicals responsible for the acidic pH of these drinks [6:14].

Phosphoric acid

The phosphate ions are present in the cold/soft drinks in the form of phosphoric acid (H₃PO₄) which is quite a strong acid (pH = 2.8). This is used because H₃PO₄ creates an acid medium that enhances the absorption of carbon dioxide (which is also forms carbonic acid in water), thus reducing the pressure required and allowing the mixture to be bottled with a metal cap. The carbon dioxide bubbles are released more slowly, particularly if the mixture is chilled. The sour taste of the phosphoric acid is complemented by adding lots of sugar [8:56]

Biological effects of H₃PO₄

H₃PO₄ has the ability to dissolve a nail in just about 4 days. Furthermore, it can damage our teeth enamel and causes cavities and other dental problems. The phosphoric acid in soda water hits your lower intestine and binds with magnesium, zinc and calcium. Instead of those minerals reaching your bones, you pass them out of your system when you urinate, leaving your body depleted with these metal.² Regular soda contain high levels of H₃PO₄, so switching to the “healthier” variety of soda isn't healthier after all [11:43]

Acesulfame Potassium (Ace-K)

Acesulfame Potassium (Ace-K) is a derivative of acetoacetic acid and was approved for use by the FDA as a safe artificial sweetener in July, 1988 [12:99]

Biological effects of Ace-K

Unfortunately, several potential problems associated with the use of Ace-K have been raised. They are based largely on animal studies since testing on humans remains limited. The findings showed the following:

1. Ace-K stimulates insulin secretion in a dose dependent fashion thereby possibly aggravating reactive hypoglycemia ("low blood sugar attacks").
2. Apparently produced lung tumors, breast tumors, rare types of tumors of other organs (such as the thymus gland), several forms of leukemia and chronic respiratory disease in several rodent studies, even when less than maximum doses were given.

Sodium benzoate

Sodium benzoate is added in cold drinks because of its ability to keep soft drinks fresh and prevent harmful bacteria from growing. It's suspected that sodium benzoate, in addition to artificial food color, may increase hyperactivity in some children. Sodium benzoate in soft drinks may also react with added vitamin C to make benzene, a cancer causing substance [5:77].

Caffeine

Caffeine is an addictive stimulant found in coffee, tea, colas, cocoa and chocolate. It is also in some prescribed and over-the-counter drugs. Caffeine drives the adrenal glands to produce stress hormones like cortisol and adrenaline. While some people feel comfortably alert and awake as a result, others are sensitive to this adrenaline rush and experience the flight-or-fight response: fast pulse, rapid heartbeat, quick breathing and muscle tension. These physiological responses typify anxiety states. The affected person feels shaky, nervous, irritable, anxious, restless and can experience insomnia. After consumption of caffeinated foods, a few people may experience sneezing, an itchy mouth, hoarseness, difficulty breathing, hives, swollen throat/tongue/lips/face, difficulty swallowing, eczema, fainting, heart palpitations, pain in the chest or hyperventilation. Caffeine destabilizes our nervous system in other ways. As diuretic caffeine speeds elimination of many minerals and vitamins, such as potassium, zinc, magnesium, calcium, vitamin C and the B vitamins (especially the anti-stress vitamin B1). This can lead to deficiencies, which increase anxiety, panic, mood swings and fatigue. The problem is compounded as caffeine causes blood sugar to rise in the first hour after consumption, creating an initial buzz, and then drops to subnormal levels, causing an energy crash. The overtake of caffeine is associated with many psychological dysfunctions such as psychosis [6:99-102].

Miscellaneous ingredients

Some other food ingredients like Carbohydrates and sugars /artificial flavors are also added to the add taste or energy to the drink. Carbohydrates are added as an energy source while a regular soda contains up to 11 teaspoons of sugar per can. The sugar causes your blood sugar to spike, which results in a release of insulin. All cold drinks/soft drinks have significant amount of sugar and therefore, are responsible for type-II diabetes. In past mostly drinks contain aspartame (an artificial low-calorie sweetener) as an additive but now it is banned by Food and Drug Administration (FDA) because it causes migraines, dizziness and more over it reduce memory. In addition to this, these drinks cause weight gain as they interfere with body's natural ability to suppress the feeling of hunger. Acidified body, mineral imbalance and physical weakness caused by poor diet and soft drinks, stress and toxic environment are very common among present generations. Quite recently, a research has pointed out that soft/cold drinks especially those with caramel coloration contain a carcinogenic (cancer causative) agent known as 4-methylimidazole, or 4-MEI.⁶ The only reason for adding 4-MEI is to impart brownish color to such drinks and it has no other role.

Almost everyone knows that soda isn't a healthful drink, but you might not realize how much it can damage your health. Evidence backs up the detriments of this fizzy drink, and once you understand what it does to your bones, you might never look at soda the same way again. It is important to point out here the corrosive properties of these drinks which can be easily understood from the fact that for transportation of these drinks, the commercial trucks are bound to bear the label of "hazardous material". These drinks have been found to cause damage to blood cells. In addition to their use as entertainment drugs, these soda drinks can be used as drain openers/cleaners, for removing rust, corrosion from metal surfaces and can be used as detergents to remove grease from clothes. Cola drinks can cause constipation, calcium loss, hypertension, nausea, vomiting, headaches, and kidney damage by interaction with antacids [4:33-36].

Conclusions

Soft drinks and fruit juices are widely consumed in ever-increasing quantities and are very important commodities in the trade of most countries. This volume sets out to introduce the reader with a good general science background to the more detailed aspects of these products, and it is hoped by this means to provide a useful reference work that will be widely used by those wishing to learn more about the products.

Instead of drinking soda, quench your thirst with something that supplies calcium instead of taking it away. For example, a water supply with a small amount of added calcium hydrates your body and is the healthiest thing you can drink. Milk is another excellent option to nourish your body and provide a bit of calcium. Unsweetened tea and black coffee, provided you drink them in moderation, can also stand in as healthier alternatives to soda.

Fruit juices are of great commercial importance in their own right as well as for direct use as ingredients in food and beverage products, and, as we have seen, they form the basis of a worldwide industry. Although production of natural strength juices can be sustained locally for direct consumption, it is the concentrates that offer advantages in transworld trade in view of savings in terms of bulk transportation. Modern methods of processing are aimed at optimizing all quality factors by use of highly efficient, short-time processing followed by pasteurization and aseptic filling. Aseptic filling techniques and sanitization of plant facilities have now reached a very high standard. Improved conditions of storage incorporating refrigeration are used more and more to offset color degradation effects and to maximize product shelf-life. This chapter has touched upon some of the mechanical techniques used to express juice from the fruit source, but it should be noted that there are process variations on those listed that are subject to exclusivity within parts of the industry and the details of which are not publicly available. Good improvements in the concentration of fruit juices have been achieved in recent years. As it is the case that the majority of concentrates are to be reconstituted in application, the quality achievable for the natural strength remake will be an important issue. Commercial fruit juice represents the end of a carefully orchestrated chain of events starting with the selection and cultivation of certain fruit-bearing botanical species. Harvesting yields, seasonal changes and maturation, among other factors, have to be taken into account before the processing and juice production take place, and so it is not surprising that we encounter subtle variations in the taste profile of the final product. We can anticipate that in future more focus and research effort will be directed to the recovery and treatment of the aroma volatiles and other natural flavor ingredients and the manner in which their reintroduction into the diluted concentrate is carried out. It is here, in the area of taste, that the consumer finally puts product quality to the test and a resulting guarantee of satisfaction will be essential to future growth and commercial viability throughout the industry.

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