# Recent Trends in Sugar Content and pH in Contemporary Soft Drinks

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## ABSTRACT

**Purpose**: The purpose of this study was to determine the content of sucrose, glucose, total sugar, and pH in a range of popular contemporary Japanese soft drinks and compare their changes in different periods.
**Methods:** The pH value and content of sucrose and glucose of popular Japanese soft drinks were determined, and this study's results were compared with the previous data of beverages in 1978, 1981, 1985, and 1997.
**Results:** Coffee drinks showed the highest content of sucrose, while carbonated diet drinks showed the lowest. Energy drinks showed the highest content of glucose and total sugar, while carbonated diet drinks showed the lowest. Coffee and energy drinks showed the highest and lowest pH levels, respectively. The total sugar content of a soft drink has remained unchanged over the years, but the sucrose content of soft drinks has decreased over the years.
**Conclusions:** All drinks showed pH values below 7, with a very wide variety of sugar content; sugar content of soft drinks has generally decreased since the 1980s in Japan.
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In recent years, the relationship between soft drinks and tooth erosion as well as dental caries has been a focus of attention in western countries.[1] It has been reported that sugared drink consumption was associated with increased dental caries risk[2,3] and prevalences of overweight and obesity.[4] Conversely, pH value, calcium, phosphate, and fluoride content in soft drinks are important factors affecting tooth erosion.[5] Some of the factors strongly associated with dental caries incidence in 1.5- to 3-year-olds were "frequency of drinking sports drinks" and "frequency of drinking juice" in Japan.[6]

The total amount and frequency of consuming acidic soft drinks has continued to increase. Approximately 5,000 kinds of soft drinks have been produced since 2001, and these drinks have been easily available from vending machines, convenience stores, and supermarkets in Japan.[7] Recently, there has been a large and increasing demand for reduced sucrose intake from a nutritional and marketing point of view.[8] The Japan Soft Drink Association[7] reported a considerable increase in the sale and consumption of a variety of soft drinks; however, little information exists regarding their range of sugar content. It is well known that in popular drinks, initial pH, titration amount of alkali for neutralization, acid productivity, and adhesive insoluble glucan synthesis caused by *Streptococcus sobrinus* are important risk factors for dental caries.[9]

Moreover, the pH value of beverages influences the degree of saturation of hydroxyapatite, which is the driving force behind dissolution and tooth erosion.[5] It has been suggested that dental erosion is an area of research and clinical practice that will undoubtedly expand in the next decade.[10]

The purpose of the study was to determine the content of sucrose, glucose, and total sugar and the pH in a range of popular contemporary Japanese soft drinks and to

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compare these values with previous data of beverages in 1978, 1981, 1985, and 1997 for changes over time.

## METHODS

The 45 different soft drinks used in this study were chosen from 9 popular drink brands and included: 9 carbonated drinks; 3 carbonated diet drinks; 11 sports drinks; 4 juice drinks (20-30% juice); 4 100%-concentrated juice drinks; 3 energy drinks (nutritious supplementary drinks); 3 different brands of tea; 5 coffee drinks; and 3 lactic acid drinks. The number of different drinks was determined by the percentage of the soft drink market share in 2005.[7] Carbonated diet drinks include low-calorie, sugarless, or sugar-free drinks.

Immediately after removing a soft drink tab or cap, the pH was measured 3 times using a pH meter (HM-60G, TOA, Kobe, Japan). To minimize its influence, carbonate was removed by stirring a carbonated drink for 1 hour prior to analysis.[11] Next, the sucrose and glucose content of each drink was determined 3 times using a biochemistry analyzer (2700 Select, YSI, Yellow Springs, Ohio) after the drinks were diluted 10 times with distilled water. Total sugar content of samples was measured 3 times by density[12] using a hand refractometer (N-20E, Atago, Tokyo, Japan).

Prior to the study, duplicate types of 5 different drinks were purchased in three different cities. The content of sucrose, glucose, and total sugar and the pH were measured to make sure they were the same regardless of where they were purchased. The difference between the results of these groups was statistically analyzed via 1-way analysis of variance and Scheffé test by using SPSS 11.0 for Windows (SPSS Inc, Chicago, Ill). The results of this study were compared with the data of beverages determined in 1978, 1981, 1985, and 1997.[13,14]

## RESULTS

Table 1 shows the content of sucrose, glucose, and total sugar and the pH of all kinds of soft drinks used in this study. Differences in the contents between and within the categories were exhibited.

The pH of soft drinks ranged from 2.8 to 5.5. Coffee drinks showed the highest pH (5.53±0.35 SE), following by tea (5.32±0.86), 100% juice drinks (3.86±0.14), lactic acid drinks (3.71±0.19), sports drinks (3.61±0.04), juice drinks (3.47±0.10), carbonated diet drinks (3.06±0.15), carbonated drinks (2.96±0.16), and energy drinks (2.84±0.07) (Figure 1). There were significant differences between tea and carbonated drinks, coffee drinks and carbonated drinks, coffee drinks and carbonated diet drinks, tea and sports drinks, coffee drinks and sports drinks, coffee drinks and juice drinks, tea and energy drinks, and coffee drinks and energy drinks ($P<.001$). There were also significant differences between tea and juice drinks ($P<.02$), coffee drinks and lactic acid drinks ($P<.02$), coffee drinks and 100% juice drinks ($P<.02$), and tea and carbonated diet drinks ($P=.004$).

***Table 1. Content of Sucrose, Glucose, Total Sugar, and pH of All Kinds of Soft Drinks Used in This Study***

| | g/dl | | | |
|---|---|---|---|---|
| | Total Sugar | Glucose | Sucrose | pH |
| (Carbonated drink) | | | | |
| A | 10.72 | 4.09 | 0.73 | 2.41 |
| B | 10.78 | 4.21 | 0.27 | 2.53 |
| C | 11.94 | 4.52 | 0.59 | 2.43 |
| D | 11.84 | 4.13 | 0.37 | 3.16 |
| E | 9.87 | 3.31 | 1.56 | 3.76 |
| F | 9.82 | 3.49 | 0.94 | 3.45 |
| G | 9.78 | 3.09 | 2.04 | 2.89 |
| H | 11.57 | 4.27 | 0.71 | 2.72 |
| I | 9.70 | 2.49 | 2.99 | 3.32 |
| (Carbonated diet drink) | | | | |
| A | 0.52 | 0.01 | 0.00 | 2.77 |
| B | 0.29 | 0.00 | 0.00 | 3.10 |
| C | 1.00 | 0.01 | 0.00 | 3.29 |
| (Energy drink) | | | | |
| A | 15.60 | 5.25 | 4.53 | 2.76 |
| B | 12.08 | 4.11 | 2.75 | 2.80 |
| C | 17.66 | 3.29 | 2.51 | 2.97 |
| (Sports drink) | | | | |
| A | 4.83 | 0.08 | 0.00 | 3.57 |
| B | 6.86 | 1.53 | 3.23 | 3.51 |
| C | 2.90 | 0.05 | 0.50 | 3.74 |
| D | 4.34 | 1.20 | 0.30 | 3.65 |
| E | 4.85 | 0.21 | 1.57 | 3.65 |
| F | 6.70 | 0.90 | 0.94 | 3.80 |
| G | 4.90 | 0.63 | 0.00 | 3.67 |
| H | 1.44 | 0.00 | 0.00 | 3.30 |
| I | 2.21 | 0.04 | 0.00 | 3.57 |
| J | 3.80 | 0.00 | 0.00 | 3.53 |
| K | 5.92 | 0.02 | 0.00 | 3.73 |
| (Tea) | | | | |
| A | 9.86 | 0.08 | 4.91 | 6.82 |
| B | 4.62 | 0.04 | 3.91 | 5.29 |
| C | 6.07 | 0.88 | 3.92 | 3.86 |
| (Juice drink) | | | | |
| A | 9.60 | 1.37 | 3.40 | 4.23 |
| B | 8.58 | 1.24 | 2.52 | 3.84 |
| C | 11.85 | 2.41 | 3.66 | 3.80 |
| D | 11.41 | 2.58 | 1.49 | 3.56 |
| (100% juice) | | | | |
| A | 10.67 | 3.23 | 1.49 | 3.27 |
| B | 10.26 | 3.37 | 0.70 | 3.56 |
| C | 10.18 | 3.49 | 0.92 | 3.34 |
| D | 9.16 | 0.72 | 0.69 | 3.68 |
| (Coffee drink) | | | | |
| A | 9.30 | 0.07 | 6.35 | 6.25 |
| B | 5.79 | 0.16 | 3.93 | 5.07 |
| C | 7.07 | 0.05 | 5.28 | 4.91 |
| D | 7.42 | 0.04 | 5.83 | 4.90 |
| E | 14.18 | 1.39 | 0.39 | 6.53 |
| (Lactic acid drink) | | | | |
| A | 10.08 | 0.88 | 7.41 | 3.42 |
| B | 18.52 | 4.96 | 3.90 | 3.63 |
| C | 16.17 | 2.49 | 1.71 | 4.07 |

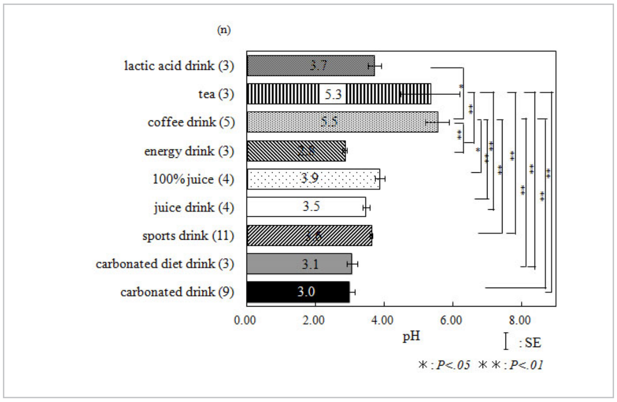


Figure 1. The pH value in 9 kinds of soft drinks.

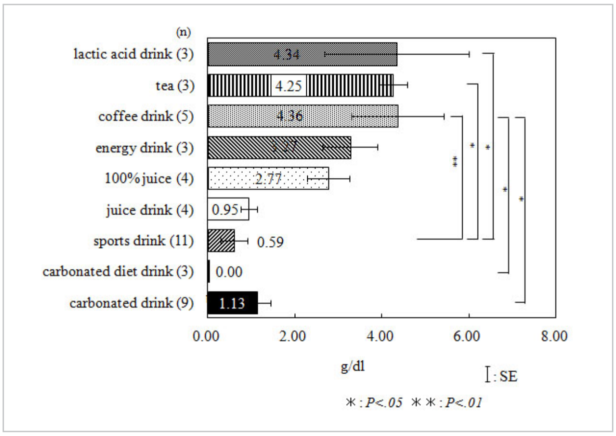


Figure 2. The sucrose content in 9 kinds of soft drinks.

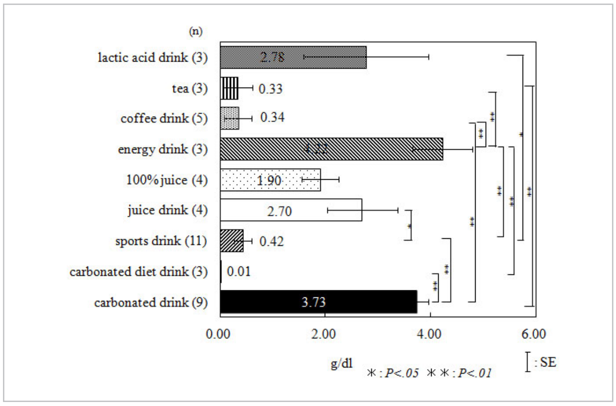


Figure 3. The glucose content in 9 kinds of soft drinks.

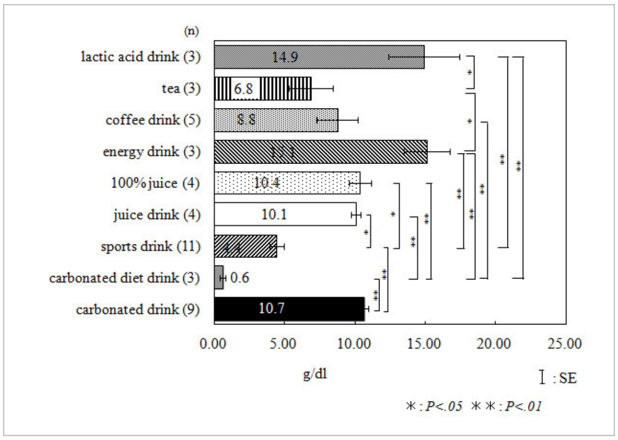


Figure 4. The total sugar content in 9 kinds of soft drinks.

The content of sucrose ranged from 0.00 to 4.36 g/dl. Coffee drinks showed the highest content of sucrose (4.36±1.07 g/dl), followed by lactic acid drinks (4.34±1.19 g/dl), tea (4.25±0.27 g/dl), energy drinks (3.27±0.57 g/dl), 100% juice drinks (2.77±0.35 g/dl), carbonated drinks (1.13l±0.22 g/dl), juice drinks (0.95±0.66 g/dl), sports drinks (0.59l±0.17 g/dl), and, lastly, carbonated diet drinks (0.00±0.00 g/dl) (Figure 2). There were significant differences between coffee drinks and carbonated drinks (*P*<.04), coffee drinks and carbonated diet drinks (*P*<.03), sports drinks and tea (*P*<.05), sports drinks and lactic acid drinks (*P*<.04), and sports drinks and coffee drinks (*P*=.004).

The content of glucose ranged from 0.01 to 4.22 g/dl. Energy drinks showed the highest content of glucose (4.22±0.57 g/dl) and carbonated diet drinks showed the lowest (0.01±0.00 g/dl) (Figure 3). There were significant difference between carbonated drinks and carbonated diet drinks, carbonated drinks and sports drinks, carbonated drinks and tea, carbonated drinks and coffee drinks, carbonated diet drinks and energy drinks, and sports drinks and energy drinks (*P*<.001). There were also significant differences between energy drinks and tea (*P*=.002), sports drinks and juice drinks (*P*<.03), and sports drinks and lactic acid drinks (*P*<.05).

The content of total sugar ranged from 0.60 to 15.11 g/dl. Energy drinks also showed the highest content of total sugar (15.11±1.63 g/dl) and carbonated diet drinks the lowest (0.60±0.21 g/dl) (Figure 4). There were significant differences between carbonated drinks and carbonated diet drinks, carbonated drinks and sports drinks, carbonated diet drinks and juice drinks, carbonated diet drinks and 100% juice drinks, carbonated diet drinks and energy drinks, carbonated diet drinks and lactic acid drinks, sports drinks and energy drinks, and sports drinks and lactic acid drinks (*P*<.001). There were also significant differences between carbonated diet drinks and coffee drinks (*P*=.004), sports drinks and juice drinks (*P*<.03), sports drinks and 100% juice drinks (*P*<.02), energy drinks and tea (*P*<.02), and tea and lactic acid drinks (*P*<.02).

The glucose and total sugar content of a soft drink have almost remained at the same value over the years. Sucrose contents of soft drinks have varied since the 1980s (Figure 5). At first there was an overall decrease, followed more recently by a slight increase. Especially, the sucrose content of carbonated drinks decreased and was less than sports drinks and lactic acid drinks from 1980's.

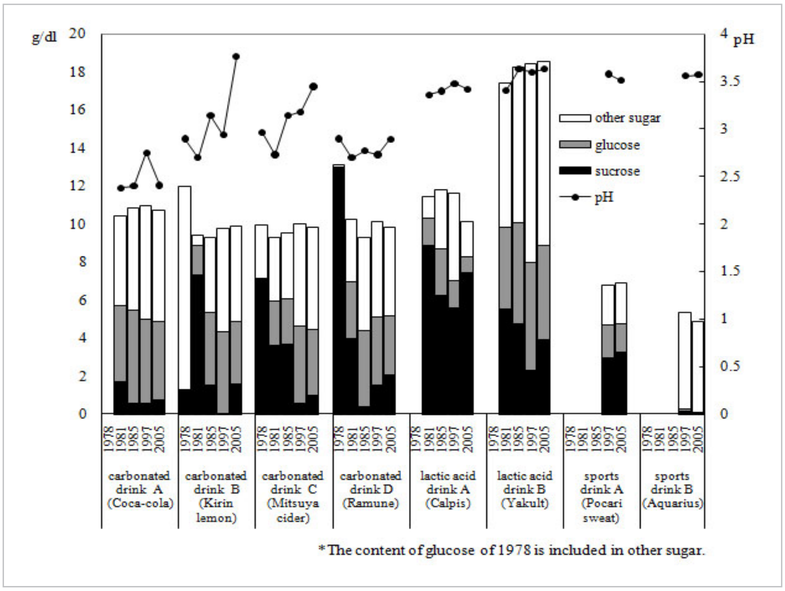


***Figure 5. Recent trends of sucrose, glucose, other sugar content, and pH in common soft drinks.***

## DISCUSSION

The pH values of drinks determine the degree of saturation of hydroxyapataite of dental enamel, which is the driving force behind dissolution.[5] Sohn reported that a high consumption of carbonated soft drinks by young children was significantly associated with an increased risk of dental caries of the primary dentition.[15] Consumption of regular soda pop, regular powdered beverages, and 100% juice drinks in early childhood was associated with an increased caries risk.[1] Jensdottir reported that the initial erosive potential was almost an exponential function of the pH of soft drinks.[16] It was suggested that pH affected the risk of dental erosion and caries more than the sucrose content of soft drinks. In this study, the pH values of coffee drinks and tea were 100 times higher than that of carbonated regular and diet drinks, sports drinks, and energy drinks.

The relationship between dental caries and sugar consumption is well known, but in industrialized countries, the relationship between caries and sugar has been more difficult to demonstrate due to the influence of fluoride exposure.[17] Zero reported that research should be directed at the problem of increased soft drink consumption, especially toward high sugar products targeted at specific populations.[17] Among dietary sugars, sucrose enhances the extracellular polymetric substances of oral biofilm the most, with lesser effects noted for fructose, galactose, glucose, and lactose.[18] In this study, the sucrose content of coffee drinks, tea, and lactic acid drinks was higher than that of carbonated drinks and/or sports drinks. These drinks had higher pH levels than other kinds of drinks, but this study also suggested that these drinks induced a higher risk of dental disease because of their high sucrose contents.

Neff reported that glucose and other saccharide applications reduce the pH of dental plaque just like sucrose applications.[19] In this study, carbonated drinks, energy drinks, lactic acid drinks and juice drinks contained higher glucose levels than other drinks investigated. In particular, carbonated drinks and energy drinks had low pH and high glucose; this suggests that these drinks induced a higher risk of dental disease.

Total sugar content of drinks was determined by the method of density of solutions. The percentages of total sugar contents calculated by this method are consistent with product nutritional label statements of sugar grams per serving.[12] Therefore, additives like sucrose, high fructose corn syrup, glucose, fructose, and oligosaccharide are included in total sugar counts, but sweetening agents are not.[20] This study shows that, except for coffee drinks and tea, almost all kinds of soft drinks replace sucrose with other sugar content like high fructose corn syrup. The latter is frequently substituted for sucrose in Japan.[21] Hashida reported that corn syrup can be utilized as the substitute for acid production but not for insoluble glucan synthesis by *Streptococcus mutans*.[22] To prevent disease, it is acceptable to replace high fructose corn syrup, although it cannot be used in hot drinks[23] and can lead to weight gain and obesity[24] due to overconsumption.

Concurrent advances in refining, isomerization, and separation technologies in the 1960s made possible the production of high fructose syrup from corn starch with sweetness equivalent to sucrose.[23] Ease of handling and a lower price accelerated the acceptance of high fructose corn syrup by beverage producers.[23] In Japan, high fructose corn syrup has been manufactured and sold since the late 1970s and is increasingly utilized as a sucrose substitute in soft drinks.[21]

Therefore, in this study, as shown in Figure 5, the sucrose content of soft drinks has been decreasing since the 1980s as compared with 1978. As the cost of sucrose started to decline in the 1980's, the gap between the cost of sucrose and high fructose corn syrup became smaller.[21] As a result, the consumption of sucrose in soft drinks began rising gradually again in recent years,[21] and explained the rise of sucrose content in 2005 as compared with 1997.

In Japan, however, the canned green tea drinks have been sold since 1983,[20] and the demand for green tea has continued to increase due to its popularity. One of the most important reasons why tooth erosion is not a serious disease in Japan is thought to be because green tea is sugar-free and has a high pH content.

Although sugar content of soft drinks is related to dental disease, individuals usually do not pay attention to it, because the amount of sugar used in soft drinks depends greatly on the market conditions and price fluctuation of sugar. Therefore, there is an urgent need to raise the awareness and knowledge of sugar content and pH when soft drinks are consumed.

## CONCLUSIONS

1. The sucrose content in soft drinks had decreased since the 1980's, but began rising gradually in recent years.
2. The sugar content and pH of soft drinks differes by the kinds of soft drinks with the highest sugar content in energy drinks and the lowest in carbonated diet drinks, and the lowest pH in energy drinks and the highest in coffee drinks.
3. There is need to increase awareness of the sugar content and pH of soft drinks because of the risk of dental caries and dental erosion.

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