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RESEARCH ARTICLE

Are Vitamin Beverages Good for Dental Health?

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Background: Although the consumption of vitamin beverages has increased because of the recent interest in health and beauty, guidelines addressing appropriate consumption habits are lacking. Thus, the aim of this study was to investigate the erosive potential of several vitamin beverages and to propose guidelines for the appropriate intake of these drinks.

Methods: Five vitamin beverages were selected after a pre-investigation of the current beverage market. Coca-Cola and mineral water were selected as the control beverages. The pH of the beverages was measured with a calibrated pH meter, and the titratable acidity (TA) was determined by using 1 M sodium hydroxide to reach pH 5.5 (TA5.5) and 7.0 (TA7.0). The screening method suggested by the International Organization for Standardization was used to measure pH variation (ΔpH) by using an under-saturated hydroxyapatite solution to determine the difference between the initial and final pH of the screening solution. All measurements were performed in triplicate.

Results: All vitamin beverages tested in this study exhibited a low pH (2.53~2.99), similar to Coca-Cola, which is known to be a highly acidic beverage. The highest TA5.5 and TA7.0 values of the vitamin beverages were 7.03 ml and 8.81 ml, respectively. The largest change in pH determined by using the screening solution was found in Bacchus D (ΔpH 1.44±0.05). The mean ΔpH of the vitamin beverages was 1.12±0.29, which was higher than that of Coca-Cola (positive control, ΔpH 0.58±0.05).

Conclusion: Vitamin beverages exhibited an erosive potential capable of damaging enamel surfaces. Therefore, the frequency of vitamin beverage intake should be limited, and individuals consuming these drinks should try to restore normal oral pH as quickly as possible.

Key Words: Dental health, Erosive potential, Tooth erosion, Vitamin beverages

Introduction

Vitamin beverages are among several health-enhancing drinks, and the term usually refers to products containing antioxidants such as vitamins, minerals, and/or polyphenols[1]. With the recently increasing interest in beauty and health, there has been a shift in the domestic beverage market, with the relative market share of vitamin beverages expanding[2,3]. A domestic survey team found that one vitamin drink, Vita 500 (Kwang Dong Pharmaceutical Co., Seoul, Korea), had a high "drinking experience" (94.3%). Furthermore, the intake frequency of vitamin beverages has been reported to be relatively high (2～3 times per week [19.9%] for 2～3 weeks per month [25.5%])[4]. Although the vitamin beverage market and consumer demand continue to increase, there is a lack of consumer awareness and consideration about the effects of these beverages on health[5]. A survey reported that a high proportion (approximately 32.9%) of the food ingredient labels of vitamin beverages are not being read by consumers[4]. Many studies have shown that there are numerous side effects of excessive vitamin intake. However, very few studies have examined consumer perceptions of the various ingredients in vitamin beverages. A study of

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energy drinks similar to vitamin beverages found that 42.3% of energy drink consumers did not worry about the ingredients[6].

One health problem to consider when consuming vitamin beverages is dental erosion. Tooth erosion refers to damage to the hard tissue of teeth that is caused by exposure to acids, such as those from the diet and gastric fluid. Several studies have reported that dental caries or erosion can occur when teeth are continually exposed to highly acidic environments ($pH < 5.5$)[7]. Vitamin beverages contain a variety of vitamins including ascorbic acid (vitamin C), which is confirmed to have high acidity with low pH (approximately pH 2.5～3.0). The intake of vitamin beverages may therefore reduce tooth surface hardness and cause tooth erosion[5]. Thus, before consuming vitamin beverages, it is necessary to understand these ingredients and consider their effects on teeth.

Although this need has often been mentioned, there have been few studies addressing the effects of vitamin beverages on dental hard tissues and methods to overcome these problems. Therefore, this study aims to evaluate the potential for dental erosion from some vitamin beverages in Korea and to propose clinical guidelines for appropriate vitamin beverage intake.

Materials and Methods

1. Selection of experimental beverages

Among the 30 types of vitamin beverages marketed in 11 pharmacies, marts, and convenience stores around Y University in Wonju, Korea, three best-selling (Vita 500; Kwang Dong Pharmaceutical Co., Seoul, Korea; Bacchus-D; Dong-A Pharmaceutical, Seoul, Korea; Oronamin C; Dong-A Otsuka, Seoul, Korea) and two high-market vitamin beverages (Daily Lemon 1000 C+; Lotte Chilsung Beverage Co., Seoul, Korea; Glaceau Vitamin Water—Dragon Fruits; Coca-Cola Korea, Seoul, Korea) were selected as the experimental group. Mineral water (Jeju Samdasu; Jeju Special Self-Governing Province Tourism Co., Jeju, Korea) was selected as the negative control, and Coca-Cola (Coca-Cola Korea), which is known to be highly acidic, was used as the positive control (Table 1). The selected beverages were evaluated by using various methods.

Table 1. Control and Experiment Groups Used in This Study

Brand name	Manufacturer	Chemical composition	
		Acid	Other
Jeju Samdasu	Jeju Special Self-Governing Province Tourism Co.	-	-
Glaceau Vitamin Water	Coca-Cola Korea	Citric acid	Fructose, white sugar, vitamin C, vitamin A, vitamin B, guarana extract, gum arabic, coloring matter, natural favoring substance
Daily Lemon 1000 C+	Lotte Chilsung Beverage Co.	Citric acid	White sugar, sodium citrate, vitamin C, lemon juice, acacia honey, coloring matter, natural favoring substance
Bacchus D	Dong-A Pharmaceutical	DL-carnitine hydrochloride	Taurine, inositol, nicotinic acid amide, vitamin B_1, vitamin B_2, vitamin B_3, vitamin B_6, caffeine
Vita 500	Kwang Dong Pharmaceutical Co.	Citric acid	Liquid fructose, concentrated apple juice, vitamin C, vitamin B_2, hyaluronic acid, synthetic flavoring, Trisodium citrate, pectin, taurine, DL-apple acid, orange extract
Oronamin C	Dong-A Otsuka	Citric acid	White sugar, liquid fructose, carbonate dioxide, acacia honey, vitamin C, caffeine, vitamin B_2, synthetic flavoring, coloring matter
Coca-Cola	Coca-Cola Korea	Phosphoric acid	Carbonate dioxide, high fructose corn syrup, white sugar, caramel, coloring matter, natural favoring substance, caffeine

2. Measurement of beverage pH

The pH of each experimental beverage (100 ml) was measured while the beverage was being stirred by using a pH meter (Orion 4 star; Thermo Fisher Scientific, Beverly, MA, USA), which was calibrated with a standard buffer solution. Measurements were repeated three times, and the results are expressed as the average of the three values.

3. Titratable acidity of the beverages

The titratable acidity (TA) was measured by adding 1 M sodium hydroxide (NaOH) to evaluate the buffering capacity of the experimental beverages. TA5.5 was defined as the volume of 1 M NaOH added to reach a critical pH of 5.5, at which demineralization could occur on the tooth surface as a result of the acidity of the experimental beverage. TA7.0 was defined as the volume of 1 M NaOH added to reach a neutral pH (7.0). The pH of 100 ml of the experimental beverages was measured while the beverage was being stirred, and 1 M NaOH was added in 0.5 ml aliquots to confirm the change in pH. The total volume of 1 M NaOH added was recorded, after repeated additions to reach pH 5.5 or 7.0. The TA of the experimental beverages was measured three times, and the results are expressed as the average of the three values.

4. Evaluation of erosive potential according to the International Organization for Standardization method

To evaluate the possibility of tooth erosion from vitamin beverages, the method proposed by the International Organization for Standardization (ISO) was used[8,9]. A calcium phosphate solution (pH 5.05±0.05), prepared immediately before use, was used to represent slightly unsaturated hydroxyapatite. This solution was used only on the day of preparation. The pH of the calcium phosphate solution (25 ml) was measured while it was being stirred; the experimental beverages (0.25 ml) were then added, and the pH was measured again. The difference in pH before and after the addition of the experimental beverage was defined as the change in pH (ΔpH). The ΔpH value was calculated from three repeated measurements.

5. Statistical analysis

The relative potential for dental erosion between each beverage sample was evaluated with one-way analysis of variance (ANOVA), followed by Tukey's test to identify statistically significant differences between the samples. Statistical analysis was performed by using IBM SPSS ver. 25.0 software (IBM Corp., Armonk, NY, USA) with a significance level of 5% for the determination of statistical significance.

Results

1. Measurement of beverage pH

The results of this experiment were calculated as the average value after a total of three evaluations for all beverages. The Coca-Cola selected as the positive control in this experiment had a pH of 2.39, and the pH of the mineral water (the negative control) was 7.69. The

Table 2. Potential for Dental Erosion from Vitamin Beverages

Brand name	pH (pH)	TA 5.5 (ml)	TA 7.0 (ml)	ISO (ΔpH)
Jeju Samdasu	7.69 ± 0.08^{a}	-	-	-0.02 ± 0.04^{a}
Glaceau Vitamin Water	2.99 ± 0.04^{b}	0.97 ± 0.13^{a}	1.19 ± 0.15^{a}	0.77 ± 0.09^{b}
Daily Lemon 1000 C+	$2.86\pm0.08^{b,c}$	$7.03\pm0.10^{b,c}$	$7.96\pm0.17^{b,c}$	1.30 ± 0.06^{c}
Bacchus D	2.53 ± 0.05^{d}	6.74 ± 0.13^{b}	8.81 ± 0.13^{b}	1.44 ± 0.05^{c}
Vita 500	2.80 ± 0.04^{c}	6.47 ± 0.31^{c}	7.53 ± 0.34^{c}	1.29 ± 0.11^{c}
Oronamin C	2.71 ± 0.07^{c}	2.37 ± 0.24^{d}	3.34 ± 0.90^{d}	0.81 ± 0.18^{b}
Coca-Cola	2.39 ± 0.03^{d}	0.81 ± 0.02^{a}	2.05 ± 0.19^{a}	0.58 ± 0.05^{b}

Values are presented as mean±standard deviation.
TA: titratable acidity.
[a-d]Different letters within the same column indicate significant differences between groups according to Tukey post hoc analysis at alpha=0.05.

beverage with the highest pH was the Glaceau Vitamin Water (pH 2.99) and the one with the lowest was Bacchus D (pH 2.53) (Table 2). All of the experimental samples, except for the mineral water, exhibited acidic properties within a pH range of 2.00 to 3.00.

2. TA of the beverages

The TA values of the beverages, according to the volume of 1 M NaOH added to evaluate buffer capacity, are summarized in Table 2. The volumes of 1 M NaOH solution (TA5.5, TA7.0) added to restore the low pH of the vitamin beverages to 5.5 and 7.0 were 0.97 to 7.03 ml and 1.19 to 8.81 ml, respectively. The TA5.5 measurements indicated that a large volume of NaOH was required to reach pH 5.5, in the order of Daily Lemon 1000 C+, Bacchus D, Vita 500, Oronamin C, Glaceau Vitamin Water, and Coca-Cola. Large volumes of NaOH were also required to achieve pH 7.0, in the order of Bacchus-D, Daily Lemon 1000 C+, Vita 500, Oronamin C, Coca-Cola, and Glaceau Vitamin Water. Significant differences were found between the samples in both TA5.5 and TA7.0 ($p<0.05$). For Bacchus-D, Daily Lemon 1000 C+, and Vita 500, more than 6.5 ml of additional NaOH were required for pH recovery to 5.5 and 7.0, compared with the other samples. The TA value for the mineral water, with pH > 7.0 could not be measured.

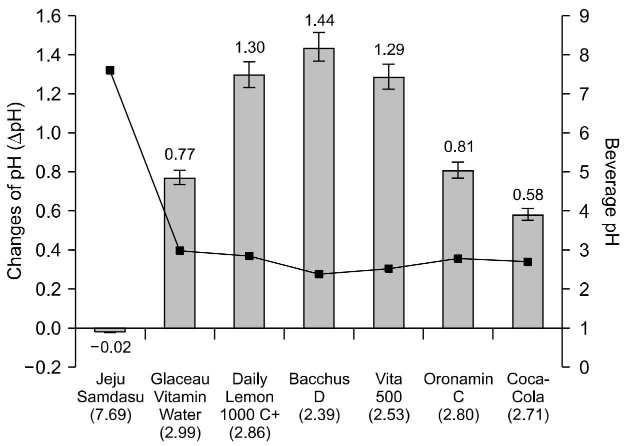

Fig. 1. The test results for erosive potential of vitamin beverages with Ca-PO_4 solution. The bar graph means that changes of Ca-PO_4 solution after addition of experiment beverages. A line is pH of experiment beverages.

3. Evaluation of erosive potential according to the International Organization for Standardization method

The difference between the initial pH and final pH of the calcium phosphate solution was measured and converted into a ΔpH value. As a result, the ΔpH values of the vitamin beverages were −0.02 to 1.44 (Table 2, Fig. 1). Bacchus D, Daily Lemon 1000 C+, and Vita 500 caused a greater change in the pH of the calcium phosphate solution than the other samples ($p<0.05$) (Table 2). In the cases of Glaceau Vitamin Water and Oronamin C, the pH change was slightly higher than that of the positive control group (Coca-Cola); however, there was no significant difference between the samples ($p=0.486$).

Discussion

Recently, the Food Information Statistics System reported that concerns about health and sugar intake have resulted in reduced production of fruit-based drinks, and alternative consumption patterns have emerged, including an increase in the consumption of low-calorie carbonated drinks, ionic and/or vitamin beverages[3,10]. Nevertheless, there is a lack of research investigating the effects of vitamin beverages on teeth to reflect this recent increase in consumption. Therefore, it is necessary to investigate the effects of vitamin beverages on oral health and to produce—or at least, propose—guidelines for healthy beverage consumption.

Approximately 48.2% of beverage sales in the Korean market occur in convenience stores, with approximately 30 types of vitamin beverages circulating in the country[10]. After preliminary research, five types of beverage, which had the highest sales rates and market shares, were selected as the experimental group (Table 1) for an evaluation of the possibility of tooth erosion from vitamin beverages by using various methods.

Changes in oral pH can be caused by a variety of factors, including saliva and bacteria[11]. This can directly affect hard tissue changes, such as dental caries and dental erosion. In particular, the pH level is considered to be the chemical factor in beverages that significantly affects the degree of enamel erosion[12,13]. Therefore, this study attempted to evaluate the potential for dental erosion from vitamin beverages by measuring the pH of the beverages. This pH measurement experiment revealed that the average pH of the five vitamin beverages was 2.78, which was not significantly different from that of Coca-Cola (pH 2.39) (Table 2). A previous study reported that Coca-Cola deposited for 2 minutes reduced surface hardness by approximately 6% and tooth hardness was reduced by approximately 10% after repeated exposure. In particular, approximately 7.5 to 16% of the surface hardness was reduced in dentin[14]. Energy drinks, which are similar to vitamin beverages, also had high tooth erosive potential with low pH and buffering capacity[15,16]. This is presumed to be a result of several ingredients in these beverages and the vitamin beverages, including phosphoric acid and citric acid. Vitamin beverages also contain added sugars to reduce the sourness and bitterness of the vitamins (Table 1). According to the Stephen curve, a representative theory of tooth demineralization, the pH is lower in sugar-containing foods or beverages. Moreover, continual exposure to an environment below pH 5.0 to 5.5 for 20 to 30 minutes can cause tooth demineralization[17]. Therefore, given the average pH of the beverages investigated in this study (2.78), it is necessary to remove remnant components after these beverages are consumed to restore and maintain neutral pH in the oral cavity.

In general, it is believed that tooth erosion is significantly influenced by the acidity of beverages; however, previous studies have reported that acidity and tooth erosion are not directly proportional. This is because the acidity of the beverage is changed to TA in the oral cavity[18]. Highly buffered acidic beverages are more difficult to change to proper acidity that does not cause dental erosion in the oral cavity and cause more demineralization[19]. In other words, TA means that the acidic beverage is resistant to a change in pH value. Accordingly, this study attempted to confirm the potential for tooth erosion from vitamin beverages by evaluating buffering capacity as well as pH value. As a result, TA7.0 was evaluated, and the titratable acidity of four of the vitamin drinks was higher than that of Coca-Cola. That is, more NaOH solution was needed in four of the vitamin beverages (Bacchus D, Oronamin C, Daily Lemon 1000 C+, Vita 500) to reach the neutral pH of 7.0 (TA7.0 3.34 ~8.81 ml) than was required for Coca-Cola. In the case of Daily Lemon 1000 C+, Bacchus D, and Vita 500, 7.5 to 8.8 ml of NaOH solution were required to reach a pH of 7.0, which demonstrates that an individual's buffering capacity needs to be substantial for acidic environments after beverage intake. In the TA5.5 experiment, all beverages required more NaOH than Coca- Cola. As mentioned, it is necessary to be careful when consuming these types of beverages because they may damage the hard tissues at pH < 5.5. The reason why strong buffering capacity is required in vitamin beverage intake is presumably because of the properties of the acid contained in the beverage. Food acids can be classified into organic and inorganic. Coca-Cola contains phosphoric acid, which is an inorganic acid, and citric acid, which is an organic acid, both of which are also included in most vitamin beverages. In the case of organic acids, the initial concentration of hydrogen ions is relatively low, but the degree of dissociation is low. Therefore, the acid dissociates slowly in the oral cavity, and the oral pH recovery rate is slow[20,21]. To overcome this, efforts to restore and maintain a neutral oral environment in the individual or to lower the buffering capacity of the vitamin beverage should be attempted. In other words, by considering the chelating of organic acids, a buffering effect can be achieved by supplementing the surrounding environment with calcium and phosphorus[22]. When these factors are considered, vitamin beverages should contain calcium or phosphorus to improve oral buffering, or the retention of vitamin beverages should be minimized by active management of oral hygiene.

Finally, an evaluation was performed with calcium phosphate solution as suggested by the ISO to evaluate the erosive potential of vitamin beverages[8]. In this method, the dental hard tissue is represented by calcium phosphate solution. The difference between the initial pH of the calcium phosphate solution before injection and the lowest pH value after injection was converted into a ΔpH value. The results show that the pH change of all experimental beverages (Glaceau Vitamin Water, Daily Lemon 1000 C+, Vita 500, Oronamin C, Bacchus D) was higher than that of the control (Table 2, Fig. 1). In particular, Bacchus

D and Vita 500, which have the highest sales share of the beverage market, exhibited higher erosion potential than the other drinks, with ΔpH values of 1.29 to 1.44. According to the ISO suggestions, the use of these products should be limited because the risk for tooth erosion is increased when the change in pH is >1.0[8]. Therefore, efforts to minimize oral damage caused by low pH are necessary.

Although not reflected by the data presented in Table 2, the ISO values demonstrated high correlation, with 0.91 and 0.92 at TA5.5 and TA7.0, respectively. This is also presumed to be caused by calcium phosphate. As mentioned earlier, the calcium phosphate concentration can affect the pH value[23,24]. Significant changes in the calcium phosphate solution mean that vitamin beverages have a strong inherent property to maintain acidity[25]. The TA and ISO test results may be similar because of these effects. In addition, it was confirmed that the pH changes depend on the initial pH (Fig. 1). On the basis of these results, beverage manufacturers and consumer organizations should make efforts to regularly screen drinks and report the results for healthier beverage intake across the nation. Furthermore, the ISO method will help screen for the possibility of tooth erosion from drinks including vitamin beverages.

In this in vitro study, certain vitamin beverages were evaluated by using various methods to assess their effects on dental health. However, there are limitations as a result of the various factors (saliva flow, beverage intake frequency, etc.) that may occur in the oral cavity. Nevertheless, it is an advantage of this study that useful information could be provided to the public by using comparatively simple and accurate methods.

The results of this study revealed that vitamin beverages may have an adverse effect on dental health, although this may vary among individuals. However, if the time spent in the oral cavity when a drink is ingested is considered, if the natural balance is not recovered after such a rapid change in pH, the effect will definitely be significant. Therefore, based on these findings, it is necessary to raise awareness in the public and manufacturers about the fact that vitamin beverages have a significant effect on dental erosion. Furthermore, when individuals who regularly enjoy vitamin beverages visit the dental clinic, proper oral hygiene management should be recommended immediately after consumption to increase the pH of the oral cavity as quickly as possible.

Notes

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical approval

This in vitro study does not require an IRB review.

Author contributions

Conceptualization: Eun-Ha Jung. Experiment and Data collection: Su-Hee Park, Jung-Woong Woo, Da-Jung Hong, Kyu-Ri Kim, Chi-Yeong Sung, Ji-Yeon Woo. Formal analysis: Su-Hee Park, Jung-Woong Woo, Da-Jung Hong, Kyu-Ri Kim, Chi-Yeong Sung, Ji-Yeon Woo, Ju-Hui Jeong. Writing - original draft: A-Reum Kang, Eun-Ha Jung.

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References

1. Heckman MA, Sherry K, Gonzalez De Mejia E: Energy drinks: an assessment of their market size, consumer demo-

graphics, ingredient profile, functionality, and regulations in the United States. Compr Rev Food Sci Food Saf 9: 303-317, 2010. https://doi.org/10.1111/j.1541-4337.2010.00111.x

2. Food Information Statistics System: 2017 processed food segment market report-beverage market. Food Information Statistics System, Naju, pp.25-45, 2017.
3. Food Information Statistics System: Summary report on the 2019 processed food segment market - beverage market. Food Information Statistics System, Naju, pp.1-2, 2019.
4. Department E: U&A survey for energy drinks. Macromillembrain, Seoul, pp.211-249, 2012.
5. Kim HN, Yoon TL, Min JH: Evaluation of the potential of commercial vitamin drinks to induce tooth erosion. J Dent Hyg Sci 19: 154-161, 2019. https://doi.org/10.17135/jdhs.2019.19.3.154
6. Park JS, Lee EJ, Lee CY, Jung HS: Consumption status, risk awareness and experience of adverse effects of high-caffeine energy drink among university students. J Korean Public Health Nurs 29: 102-114, 2015. https://doi.org/10.5932/JKPHN.2015.29.1.102
7. Imfeld T: Dental erosion. Definition, classification and links. Eur J Oral Sci 104: 151-155, 1996. https://doi.org/10.1111/j.1600-0722.1996.tb00063.x
8. International Organization for Standardization: Dentistry-screening method for erosion potential of oral rinses on dental hard tissues, ISO28888. ISO, Geneva, Switzerland, pp.7-11, 2013.
9. Kim SK, Park SW, Kang SM, Kwon HK, Kim BI: Assessment of the erosive potential of carbonated waters. J Korean Acad Oral Health 39: 273-279, 2015. https://doi.org/10.11149/jkaoh.2015.39.4.273
10. Food Information Statistics System: 2019 processed food segment market report-beverage market. Food Information Statistics System, Naju, pp.32-58, 2019.
11. Loke C, Lee J, Sander S, Mei L, Farella M: Factors affecting intra-oral pH - a review. J Oral Rehabil 43: 778-785, 2016. https://doi.org/10.1111/joor.12429
12. Dong YM, Pearce EI, Yue L, Larsen MJ, Gao XJ, Wang JD: Plaque pH and associated parameters in relation to caries. Caries Res 33: 428-436, 1999. https://doi.org/10.1159/000016547
13. Honório HM, Rios D, Júnior ES, de Oliveira DS, Fior FA, Buzalaf MA: Effect of acidic challenge preceded by food consumption on enamel erosion. Eur J Dent 4: 412-417, 2010. https://doi.org/10.1055/s-0039-1697861
14. Jeon HS, Kang SM, Kwon HK, Kim BI: Influence of toothbrushing on eroded enamel and dentin by carbonated soft drink. J Korean Acad Dent Health 32: 170-181, 2008.
15. Jeong MJ, Jeong SJ, Son JH, et al.: A study on the enamel erosion caused by energy drinks. J Dent Hyg Sci 14: 597-609, 2014. https://doi.org/10.17135/jdhs.2014.14.4.597
16. Oh HN, Lee HJ: The effect of energy drink on enamel erosion. J Dent Hyg Sci 15: 419-423, 2015. https://doi.org/10.17135/jdhs.2015.15.4.419
17. Miller WD: The agency of acids in the production of caries of the human teeth, with comparative analysis of carious dentine and dentine softened by acids. Dent Cosm 25: 337-344, 1883.
18. Meurman JH, ten Cate JM: Pathogenesis and modifying factors of dental erosion. Eur J Oral Sci 104: 199-206, 1996. https://doi.org/10.1111/j.1600-0722.1996.tb00068.x
19. Larsen M, Nyvad B: Enamel erosion by some soft drinks and orange juices relative to their pH, buffering effect and contents of calcium phosphate. Caries Res 33: 81-87, 1999. https://doi.org/10.1159/000016499
20. Yoshimura N, Okazaki M, Nakagawa N: Simultaneous estimation of the dissociation constant and concentration by a linear least-squares method with non-negative constraint. Anal Sci 16: 1331-1335, 2000. https://doi.org/10.2116/analsci.16.1331
21. Seo DG, Kim HS, Jeong SH, Choi CH, Kwon HS, Kim BI: Measurement of intra-plaque pH and recovery speed of soft drinks by telemetry. J Korean Acad Dent Health 30: 151-162, 2006.
22. Kim EJ, Jin BH: Effects of titratable acidity and organic acids on enamel erosion in vitro. J Dent Hyg Sci 19: 1-8, 2019. https://doi.org/10.17135/jdhs.2019.19.1.1
23. Park SW, Kim SK, Jung EH, Kwon HK, Kim BI: Erosive potential of several fruit-flavored liquors in Korea. J Korean Dent Assoc 54: 521-528, 2016.
24. Kim BR, Min JH, Kwon HK, Kim BI: Analysis of the erosive effects of children’s beverages using a pH-cycling model. J Korean Acad Oral Health 37: 141-146, 2013. https://doi.org/10.11149/jkaoh.2013.37.3.141
25. Dawes C: What is the critical pH and why does a tooth dissolve in acid? J Can Dent Assoc 69: 722-724, 2003.