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ORIGINAL ARTICLE

Dental Caries and Erosion Potential of Beverages on Sale in Indonesia

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ABSTRACT

Introduction: The aim of this research was to test the potential capacity for beverages sold in Indonesia to cause caries and dental erosion by measuring sugar content, pH level and titratable acidity (TA). **Methods:** A total of 124 beverages, classified as teas, energy drinks, sports drinks, fruit juices, milk drinks, carbonated drinks and coffees, were tested. Sugar content (g·100 mL^{-1}) was gathered from the nutrition information on the product packaging. The pH was determined using a pH meter. Titratable acidity was measured by adding 0.5 mL increments of NaOH 0.1 N into 10 mL of each tested beverage to bring the pH to neutral. Data were analysed using one-way ANOVA and Dunnett's T3 post hoc multiple comparisons at a significance level of $p < 0.05$. **Results:** Energy drinks contained the highest amounts of sugar (11.9 ± 3.4 g·100 mL^{-1}), and sports drinks the lowest (5.3 ± 2.1 g·100 mL^{-1}). Milk drinks had the highest pH (6.4 ± 0.2), whereas carbonated drinks had the lowest (2.2 ± 0.6). The results of acid titration indicated that the highest acid concentration was present in energy drinks (4.1 ± 1.5 mL) and the lowest was in teas (0.5 ± 0.4 mL). The results of ANOVA testing showed significant differences between variants in terms of sugar content, pH and titratable acidity ($p<0.001$). **Conclusion:** Energy drinks and carbonated drinks had the highest cariogenicity and erosive potential for dental health. However, all the beverages tested had cariogenic or erosive potential or both.

Keywords: Dental caries, Tooth erosion, Beverages

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INTRODUCTION

Beverages are one of the consumer commodities that are growing very rapidly every year in almost all countries in the world, including Indonesia. The growth of the Indonesian economy and population has had the effect of expanding consumption. This condition has led to the development of a modern retail industry in which sales of food and beverages has increased by more than 8% per year (1). In turn, the relationship between the level of beverage consumption and non-communicable diseases has been extensively investigated. The increased beverage consumption raises two significant concerns with implications for dental health: cariogenicity and acidity. Dental plaque bacteria metabolise the sugar content in beverages and the resulting acid production may cause tooth demineralisation, while the acidity of the beverages themselves may cause enamel erosion (2).

The results of a systematic review indicated that caries rates are lower in subjects with a low sugar intake of less than 10% of the total energy. When sugar intake is limited to less than 5%, another possible additional benefit is a reduced risk of caries in consumers of all ages (3, 4). One of the causes of high sugar consumption is a penchant for beverages due to strong marketing campaigns. This propensity is triggered by the tendency towards unlimited sugar consumption when consumers are oblivious to the free sugar quantity (consisting of monosaccharides and disaccharides) in purchased products (5).

Each beverage type has different characteristics and chemical composition that define its distinctive taste. Manipulation of acid content is one of the strategies used to attract consumers. Unfortunately, the acid concentration in beverages is regarded as a cause of dental erosion. The dental erosion potential of a food or beverage can be characterised based on its pH and titratable acidity (TA). Beverages with pH values below 5.5 can adversely affect root dentin and enamel and cause erosive wear (6). However, the TA level is now considered a more useful measure of food and beverage acidity than simple pH evaluations. The pH value represents the hydrogen ion (H^+) concentrations; however, it does not account for all free H^+ in the beverages (7), whereas TA indicates all available H^+ that can cause tooth erosion (8). The pH value identifies the erosive potential at the initial time, whereas the TA tends to reflect that potential for longer exposure times (9).

The concern for potential dental harm due to beverage consumption in Indonesia has arisen from several recent studies. For example, one study in Jakarta revealed that 88% of 12-year-old children had experienced tooth erosion and found a significant relationship of this erosion to the frequency of citrus beverage consumption (10). Caries was also prevalent among school children and significantly associated with sugar consumption (11). Thus, identifying the parameters that determine the cariogenic (sugar) which cause caries and acidogenic (pH and TA) potential which cause dental erosion of locally available beverages has become a significant public health need. The aim of this study was to measure sugar content, pH level and TA of beverages sold in Indonesia as potential cause of caries and dental erosion.

MATERIALS AND METHODS

This study was approved by the Faculty of Dentistry Ethics Committee, Universitas Gadjah Mada, Yogyakarta (No.001129/KKEP/FKG-UGM/EC/2017). In total, 124 beverages registered with the National Agency of Drug and Food Control of the Republic of Indonesia were selected from three different well-known supermarket chains in Yogyakarta, Indonesia. The beverages were grouped according to predefined categories and included tea (n = 22), energy drinks (n = 12), sports drinks (n = 18), fruit juices (n = 28), milk drinks (n = 16), carbonated drinks (n = 14) and coffee (n = 14). The samples were selected as representatives of each category across supermarkets. If a brand was sold in various serving sizes but with the same formulation, one sample only was included. The company and name of the product, along with serving size information, were recorded.

Data on sugar content were gathered from the nutrition information on the product packaging. Beverages containing sugar substitutes (artificial sweeteners) were not included in the study. Calculation of sugar content was adjusted based on 100 mL. A double-check procedure was applied to avoid errors in recording the data, and 5% of the data entries were randomly re-checked against the original source. The sugar contents were then categorised as high (>11.25g·100 mL^{-1}), moderate (11.25 to 2.5 g·100 mL^{-1}) or low (<2.5 g·100 mL^{-1}) (12).

The pH and TA were measured immediately after opening the packages. The pH measurements were made using an ION meter IM-55G (TOA DKK, Japan) and electronic pH meters. The electrodes were rinsed with distilled water and dried with clean tissue papers before each measurement. The electrodes were calibrated with a universal pH 7 buffer solution, followed by a universal pH 4 buffer solution. The TA was evaluated by adding in 0.5 mL increments of 0.1 N NaOH into 10 mL of test beverage to neutralise the beverage acidity. The volume of 0.1 N NaOH added was recorded as the TA content. The indicator used in this titration stage was phenolphthalein to a pale rose colour. The pH range during the titration was monitored with a pH meter. All the samples were analysed in triplicate.

Descriptive statistics were determined and presented as mean, frequency, standard deviation (SD) and range, as indicated. Statistical analyses included one-way ANOVA and Dunnett's T3 tests to compare the sugar content, pH and acid content of the different beverage categories. The significance level was 5%. The research was conducted at the Integrated Research Laboratory, Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta.

RESULTS

The average sugar content in the different tested beverages was 8.5 ± 2.7g·100 mL^{-1}, placing them in the moderate category. However, 9.5% of the beverages were in the high category. The measurement results for pH, sugar and acid content for each beverage category are shown in Table I. The sugar content among the different beverages types ranged from 1.6 g·100 mL^{-1} to 16.7g·100 mL^{-1}. On average, energy drinks and carbonated drinks contained the highest amounts of sugar, while sports drinks had the least. The pH of all the tested beverages ranged from pH 1.2 to pH 7.0, with an average pH of all the beverages of pH 4.3 ± 1.6. Milk drinks had the highest pH (6.4 ± 0.2), close to neutral, whereas carbonated drinks (pH 2.2 ± 0.6) had the lowest pH (acidic). The acid titration results indicated that energy drinks had the highest acid concentration (4.1 ± 1.5 mL) and teas had the lowest (0.5 ± 0.4 mL). The average acidity of all the beverages was 1.2 ± 1.3 mL and ranged from 0.1 to 6.1 mL.

The seven groups of data were processed by one-way ANOVA to find the differences among each of the parameters. Significant differences (all $p < 0.001$) were detected among the beverage types in terms of sugar content, pH and TA (F = 21.59, 58.07, and 51.75, respectively). Multiple comparison post hoc tests using Dunnett's T3 calculation method were implemented to identify the difference in sugar content, as depicted in Figure 1. Energy drinks had the highest sugar content, followed by carbonated drinks, coffees, fruit juice, milk drinks, teas and sports drinks, in that order.

The sugar content was significantly lower in teas (7.4 g·100 mL^{-1}) than in energy drinks (11.9 g·100 mL^{-1}), coffees (9.6 g·100 mL^{-1}) and carbonated drinks (11.2 g·100 mL^{-1}), but higher than in sports drinks (5.3 g·100 mL^{-1}). The sports drink sugar content was statistically

Table I: One way ANOVA of the mean value of sugar, pH and titrable acidity of tested beverages

FLAVOUR	MEAN	SD	MIN	MAX	F	p-value
Sugar ($g \cdot 100\ mL^{-1}$)						
Tea	7.4	1.6	3.6	9.6	21.59	<0.0001
Energy drinks	11.9	3.4	8.0	16.7		
Sports drinks	5.3	2.1	1.6	8.0		
Fruit juice	8.5	1.9	5.6	11.2		
Milk	7.9	1.1	6.0	9.5		
Carbonated drinks	11.2	1.2	10.0	13.3		
Coffee	9.6	1.8	7.2	13.3		
pH						
Tea	5.1	1.5	2.3	6.4	58.07	<0.0001
Energy drinks	3.0	0.3	2.5	3.6		
Sports drinks	3.7	0.9	2.7	5.5		
Fruit juice	3.5	0.5	2.3	4.1		
Milk	6.4	0.2	6.1	6.6		
Carbonated drinks	2.2	0.6	1.2	3.3		
Coffee	6.2	0.3	6.0	7.0		
Titratable Acid (mL)						
Tea	0.5	0.4	0.1	1.4	51.75	<0.0001
Energy drinks	4.1	1.5	2.1	6.1		
Sports drinks	0.9	0.4	0.4	1.6		
Fruit juice	1.3	0.6	0.5	2.6		
Milk	0.7	0.2	0.4	1.1		
Carbonated drinks	1.2	0.3	0.5	1.7		
Coffee	0.8	0.4	0.5	1.6		

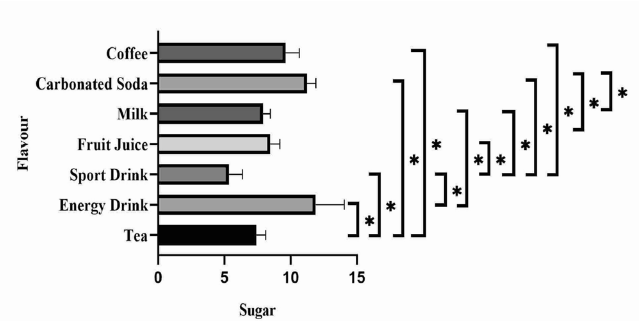

Figure 1: Post hoc comparisons of sugar content ($g \cdot 100\ mL^{-1}$) from beverage variants. *Significantly different, p<0.05, Dunnett's T3 procedure

the lowest of all the beverages. The sugar contents of fruit juices ($8.5\ g \cdot 100\ mL^{-1}$) and milk drinks ($7.9\ g \cdot 100\ mL^{-1}$) did not differ significantly and were lower than in carbonated drinks. The sugar content of fruit juices did not differ significantly the sugar content of coffees and teas.

The drink pH values are summarised in Figure 2. The beverage with the highest pH was milk (pH 6.4), followed by coffee (pH 6.2). Statistical analysis showed no significant difference. The pH values of the beverage groups, from highest to lowest, were: milk, coffee, tea, sports drinks, fruit juices, energy drinks, and carbonated drinks, with the highest acidity levels found in carbonated drinks.

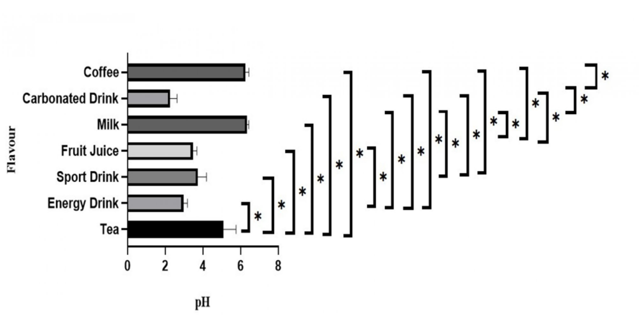

Figure 2: Post hoc comparisons of pH from beverage variants
*Significantly different, p<0.05, Dunnett's T3 procedure

The pH measurements revealed that all beverage groups had pH values below 7. The results of the study are summarised in Figure 3. The volume of NaOH used for acid titration was lowest for teas, followed by milk drinks, coffees, sports drinks, carbonated drinks, fruit juice and energy drinks, in increasing order. No significant difference was observed between coffees and teas, in accordance with the pH measurements. Significant differences were identified between teas and energy drinks, fruit juices, and carbonated drinks. Energy drinks required the largest addition of 0.1 N NaOH (4.1 mL) of for neutralisation, confirming that energy drinks were the most acidic beverage type among the tested drinks.

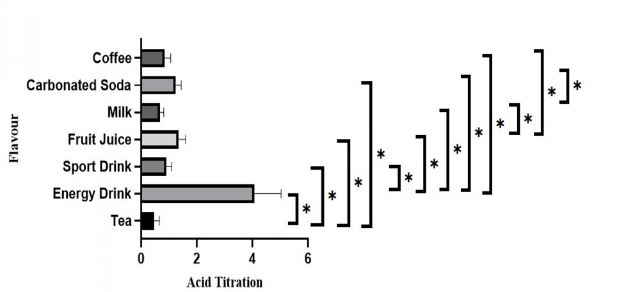

Figure 3: Post hoc comparisons of titratable acidity (mL) from beverage variants. *Significantly different, p<0.05, Dunnett's T3 procedure

DISCUSSION

The aim of this study was to test the potential of beverages sold in Indonesia to induce caries and dental erosion by measuring sugar content, pH level and TA. Analysis of a total of seven beverage types revealed varying levels of three key parameters. The average sugar content was categorised as moderate ($8.5\ g \cdot 100\ mL^{-1}$). Given a standardised serving size of 220 mL, the sugar content of all products, except for the sports drinks, exceeded the daily allowance for children (19 g for children aged 4-6 years) (3). The sugar content printed on labels varied between different brands and even within the same brand. In addition, the kinds of sugar were not clearly stated on the information panel (e.g., either glucose, sucrose, or fructose monosaccharides).
A recent report has indicated an increase in the demand

projections for 2015–2019 for sugar cane (sucrose) from the food and beverage industry in Indonesia (13). Therefore, the sugar used in most soft drinks can be assumed to be sucrose. Unfortunately, sucrose fermentation is considered a leading cause of dental caries because it serves as a substrate that increases plaque attachment. Sucrose increases the colonisation of cariogenic bacteria, which can further reduce the concentration of calcium and phosphate in oral biofilms, thereby limiting the remineralisation of early carious lesions (14).

One interesting finding among the seven types of beverages tested in this study was that the energy drinks had the highest sugar content. This is no different than in other countries (15), where energy drinks are typically glucose-based. However, these drinks also contain stimulants like caffeine, so the health concerns extend beyond the sugar content to include the high levels of caffeine, which are associated with health problems like chronic sleep deprivation and addiction/dependence (16). Based on the sugar content, energy drinks sold in Indonesia are those with the highest potential to cause tooth demineralisation. The serving size of energy drinks also affects the amount of sugar, energy and caffeine that enters the body. This is quite worrying because the sugar content is generally quite high. The present analysis also confirmed that energy drinks have the highest titratable acid content compared to other drinks.

Similar results were found for carbonated beverages, which also had a high sugar content and acidity level. This is alarming, since carbonated drink consumption significantly increases the caries experience score, and the incidence of dental erosion occurs mostly in patients who most often consume carbonated drinks (9, 17). Unfortunately, carbonated drinks are the most preferred beverage, especially in young age groups (18). Therefore, children who often drink corbonated soda can be assumed to have a risk of experiencing erosion and caries in the future.

Sports drinks are often considered the same as energy drinks; however, in fact, they are very different. Sports drinks are intended to provide hydration for the human body and replace fluids and minerals lost through sweat during physical activity. A previous study confirmed the statistical relationship between sports drink consumption and the occurrence of erosive defects (19). However, the erosive potential of isotonic drinks is generally not realised by consumers. In the present study, sports drinks had a moderate sugar content and their pH did not significantly differ from that of energy drinks. Therefore, drinking too many sports drinks is also not recommended.

To date, coffee has been recognised as an acidic beverage. Surprisingly, this study showed a different result, as the acidity of coffee drinks (based both on pH and titratable acid) was lower than that in energy drinks, carbonated drinks, sports drinks and fruit juices. This result may be explained by the types of coffee drinks found in the market and tested in this study, as these were more in the form of mixtures with milk, such as lattes, frappes, cappuccinos and mochaccinos. Dairy drinks are usually made from cow's milk, with pH usually around 6.8—its variations depend on the composition of the milk, including inorganic phosphate, citrate, organic acids and milk protein (20). The results of this study are interesting because the beverages claiming to be coffees actually had an acidity level that was almost equivalent to that of milk drinks. Another possible explanation for the low acidity level of coffee drinks comes from the information panel of one brand, which indicates that the coffee content is only 1% and the beverage is supplemented with artificial coffee taste to enhance the flavour. Therefore, the small amount of actual coffee present would have only a minor effect on the acidity of the coffee drink.

Tea is one of the commercially available industrial drinks in the Indonesian market. Consumption of tea is believed to provide significant health benefits due to the antioxidant properties of this beverage. All brewed tea has a pH value close to neutral, but several of the packaged tea products tested in the present study had high acidity (21). In the present study, the pH of tea drinks ranged from 2.3 to 6.4. Ready-to-drink teas with a low pH may have added components, including acidulants (e.g. fruit teas) that would decrease the pH significantly. In the present study, teas had an average sugar content of 7.4 $g \cdot 100\ mL^{-1}$. When standardised to 200 mL per bottle, the sugar content in packaged tea was categorised as high. Tea is one drink that is considered to have an anticariogenic effect because it contains fluoride (22). However, a 2010 study by Singh and Jindal found that any beneficial effects of tea consumption were outweighed by the impact of the sugar content (23). In the present study, the tea drinks not mixed with fruit gave TA values similar to those reported by Singh and Jindal (24). The pH of these teas was considered minimally erosive (pH $\geq$ 4.0), and the TA results also showed that the acidity levels were not high, as relatively small volumes of NaOH were required to neutralise the acidity. Thus, teas can be viewed as having more caries potential than erosion potential.

Most of fruit juice beverages drinks was added by flavourings, sweeteners and even acidulants (25). In this study, all juice drinks tested were sweetened with sugar. All had a pH that was almost the same as a sports drink and a TA similar to carbonated drinks. The present study identified some types of juice drinks with low pH, below the threshold value that can cause tooth demineralisation. The sugar content range of the juice drinks in this study was 5.6 to 11.2, which is sufficiently high to contribute to the initiation of carious lesions. Hence, consuming juice drinks continuously is likely to have an effect on dental health because the juices have the potential to cause caries and erosion.

Results of a previous study demonstrated that the parameters of pH and TA could both display erosive potential (26). In the present study, the energy drinks, fruit juices and sports drinks had similar pH values. However, the highest titratable acidity was found in energy drinks, giving these drinks the highest erosive potential. When the pH of liquids in the mouth becomes acidic, minerals from enamel will dissolve until a saturation point is reached. Therefore, not only the pH but also the presence of minerals, such as calcium, phosphate and fluoride, in these drinks will determine the degree of erosion of tooth minerals. Since milk is rich in these kinds of minerals, regular milk consumption can increase tooth surface hardness and protect against tooth erosion. The findings presented here indicate that milk is one type of beverage that is the least likely to cause erosion of the tooth surface, whereas energy drinks and carbonated drinks are likely to be the most harmful to dental health. However, the addition of sugar to milk drinks is a crucial problem that must be seriously considered since high sugar content will promote caries and tooth demineralisation. From all of the measured indicators, sugar content was the most likely to cause caries while TA likely to cause dental erosion (27,28).

This study had at least three limitations. One was that the samples were taken from well-known supermarkets; there may be other types of beverages sold in smaller grocery stores. A second limitation was that the sugar content written on the packaging served as the primary source of data, but the accuracy of that information would depend on the beverage factory. The third limitation was that the erosive potential of beverages was only estimated from the pH and TA values, without considering the enamel solubility in real clinical situations. Therefore, the present study raises several questions in need of further investigation. One is the need for assessment of the cariogenic and erosive potential based on the portion size of beverages. An interesting experiment might be to conduct a laboratory analysis of enamel solubility to establish a greater degree of accuracy of the potential harmful effects of beverages sold in Indonesia.

One issue that emerges from these findings is that all the beverages tested have either cariogenic or erosive potential or even both. Taken together, the findings suggest that children, adolescents and parents need to recognise the potentially adverse effects of excessive beverage consumption on oral health. Oral health education messages especially targeted at children and/or their parents should encourage limited consumption of commercially available beverages.

CONCLUSION

The results of this investigation showed that energy drinks and carbonated drinks had the highest potential for cariogenicity and tooth erosion. The question posed at the beginning of this study can now be answered by stating that all the beverages tested had either cariogenic or erosive potential or both.

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