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RESEARCH ARTICLE

Carbonated Beverages and their Erosive potential–An In Vitro Study

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Abstract

Objective: To determine the erosive potential of carbonated beverages by measuring their initial pH and titratable acidity. **Methods:** Twenty four commercially available carbonated beverages were included in the study. They were divided into two groups, multinational and regional beverages, based on their marketing reach. Each group comprised of twelve beverages. The initial pH was measured using a pH meter whereas titratable acidity was obtained by measuring the volume of 1M sodium hydroxide (NaOH) required to raise the pH to 5.5 and 7 when added in increments of 0.2-0.3 ml into 100 ml of each sample. The data obtained was analyzed using Repeated measures of ANOVA (RANOVA) and Independent sample 't' test. **Results:** When the initial pH was analyzed, we found that the mean initial pH of the regional and that of the multinational carbonated beverage was 2.89 was 2.82 respectively. Although the mean volume of 1 M sodium hydroxide required to bring the pH to 5.5 (critical pH) was not statistically significant between the two groups, the mean volume of 1 M sodium hydroxide required to increase the pH to 7 (neutral pH) was 4.54 ml for regional and 5.43 ml for multinational beverages and this was found to be statistically significant ($p<0.05$). **Conclusion:** This study can decisively conclude that multinational beverages have a higher buffering capacity and a higher erosive potential as compared to their regional counterparts.

Introduction

Consumption of carbonated soft drinks has shown a colossal increase in the world in recent times[1]. Although soft drink consumption is considered as a harmless habit, there are a number of serious health issues associated with its regular consumption. High consumption of carbonated beverages have been associated not only with dental erosion, but also with general health disorders like gastro-intestinal diseases, osteoporosis, obesity, diabetes, hypertension, and kidney stones [2-4]

Dental erosion is the superficial loss of dental hard tissue by a chemical process that does not involve bacteria. Erosion may not only cause a reduction in the size of teeth but, might also result in the total destruction of the dentition[2]. Carbonated beverages not only make available acid directly into the oral cavity but also promote acid production by the action of biofilm bacteria on the fermentable sugars present in the beverages. The critical pH at which hydroxyapatite dissolves is 5.5, and therefore teeth are vulnerable to decalcification in acid media.[5]

Repeated exposure to acid beverages changes the intraoral pH to below the critical pH (pH5.5), and this sustained low pH of less than 5.5, allows the development of frangibles ((attrition, erosion, abrasion, and decay)[6].

Studies have shown that saturation degrees and the titratable acidity measured from the total acid content are useful for determining the erosive potential of beverages.[7-9] Drinks with lower pH and higher titratable acidity, have been shown to have high erosive potential [10]

Various carbonated beverages are available all over the world. Some are multinational with their produce being marketed in different countries of the world whereas some are regional, confined to certain regions of particular countries. Most of these drinks neither specify their contents nor do they have strict food regulations. Because of their easy availability and low cost, they are consumed frequently especially by children. Inspite of the safety issues of these beverages, no data is available on their erosive potential. This inspired the conception of this in vitro study with the aim of determining the erosive potential of carbonated beverages.

Materials and Methods:

An in- vitro study was carried out to find out the erosive potential of the most widely and commonly used regional and multinational carbonated beverages in Mangalore, India. Among the 24 samples selected, 12 were regional and 12 were multinational.

Ethical clearance to conduct the study was obtained from the Institutional Ethics Committee. A single calibrated examiner performed the analysis and the recordings were done on study specific charts by the Principal investigator.

pH measurement:

All the selected beverages belonged to the same batch and were kept at room temperature. The initial pH of each sample was measured using a digital pH meter (Cyber Scan pH 620 by Eutech, India)[11] The electrode was calibrated using standard buffers of pH 4.0 and 7.0. Five minutes after opening the bottle, 100ml of each sample was placed in a beaker and homogenized by stirring with a glass rod. The bulb of the pH meter electrode was then fully immersed in the sample and the pH recorded (Figure 1). Measurements were repeated in triplicates for each sample and the mean pH of the sample was estimated. Between readings, the electrode was rinsed in distilled water, to prevent cross contamination.[11]

Buffering capacity and Erosive potential:

Hundred milliliters of each sample was titrated with 1M sodium hydroxide, in increments of 0.2ml-0.3ml and the volume of 1 M sodium hydroxide required to bring the pH to 5.5(critical pH) was noted. The sample was further titrated with 1M sodium hydroxide, again in increments of 0.2ml-0.3 ml, and the amount of 1 N sodium hydroxide required to increase the pH to 7 (neutral pH) was noted. The total titratable acidity was expressed as the volume of 1M sodium hydroxide required to neutralize the sample. Titrations were repeated in triplicates for all samples to check for reproducibility and to give a mean value for that sample. Larger the amount of 1M sodium hydroxide required to raise the initial pH to 5.5 and 7, the greater will be the erosive potential of that particular sample.[11]

Data management and statistical analysis:

The data was coded and analyzed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, version 11.5). Statistical evaluation was performed using Repeated measures of ANOVA (RANOVA) and Independent ‘t’ test. Statistical significance was assessed at the conventional level of 5% significance and 80% power.

Results

When we analyzed the initial pH of the two beverages, we found that the mean initial pH of the regional carbonated beverage was 2.89 and that of the multinational carbonated beverage was 2.82.This difference in the mean initial pH was however not statistically significantly different (Table 1).

When the titratable acidity of these beverages was assessed, the mean volume of 1 M sodium hydroxide required to bring the pH to 5.5 (critical pH) was 1.54 ml for regional and 1.93 ml for multinational beverages. However this difference was not statistically significant (Table 2)

When the sample was further titrated with 1 M sodium hydroxide, the mean volume of1 M sodium hydroxide required to increase the pH to 7 (neutral pH) was 4.54 ml for regional and 5.43 ml for multinational beverages. Therefore the amount of sodium hydroxide required to neutralize the pH was more in case of multinational beverages as compared to regional ones and this was found to be statistically significant. (Table 2)

Repeated measures of ANOVA showed a significant difference between initial pH, critical pH and neutral pH in all the test beverages (Table 3).

The findings were corroborated by the Independent sample ‘t’ test which also showed that although there was no significant difference in initial pH between the regional and multinational beverages, there was a significant difference between both the groups with respect to reaching the neutral pH ($p<0.05$). (Table 4) (Figure 1)

Table 1: Initial pH of regional and multinational carbonated beverages

Test drinks	N	Mean pH	SD
Regional beverages	12	2.89	0.46
Multinational beverages	12	2.82	0.36

SD-Standard Deviation; p > 0.05

Table 2: Titratable acidity of regional and multinational carbonated beverages

Test drinks	N	Initial pH	Titratable acidity	
			Amount of NaOH required to raise the pHto 5.5	**Amount of NaOH required to raise the pH to 7**
Regional beverages	12	2.89	1.54	4.54*
Multinational beverages	12	2.82	1.93	5.43*

*Statistically significant p > 0.05

Table 3:Repeated measures of ANOVA to compare initial, critical and neutral pH values.

Dependent variable	Mauchly's W	Sig	Greenhouse Geisser					Huynh - Feldt				
	0.531	.001	Sum of squares	df	Mean square	F	P value	Type III sum of squares	df	Mean square	F	P value
			131.11	1.36	96.27	283.08	.000	131.11	1.41	92.46	283.08	.000*

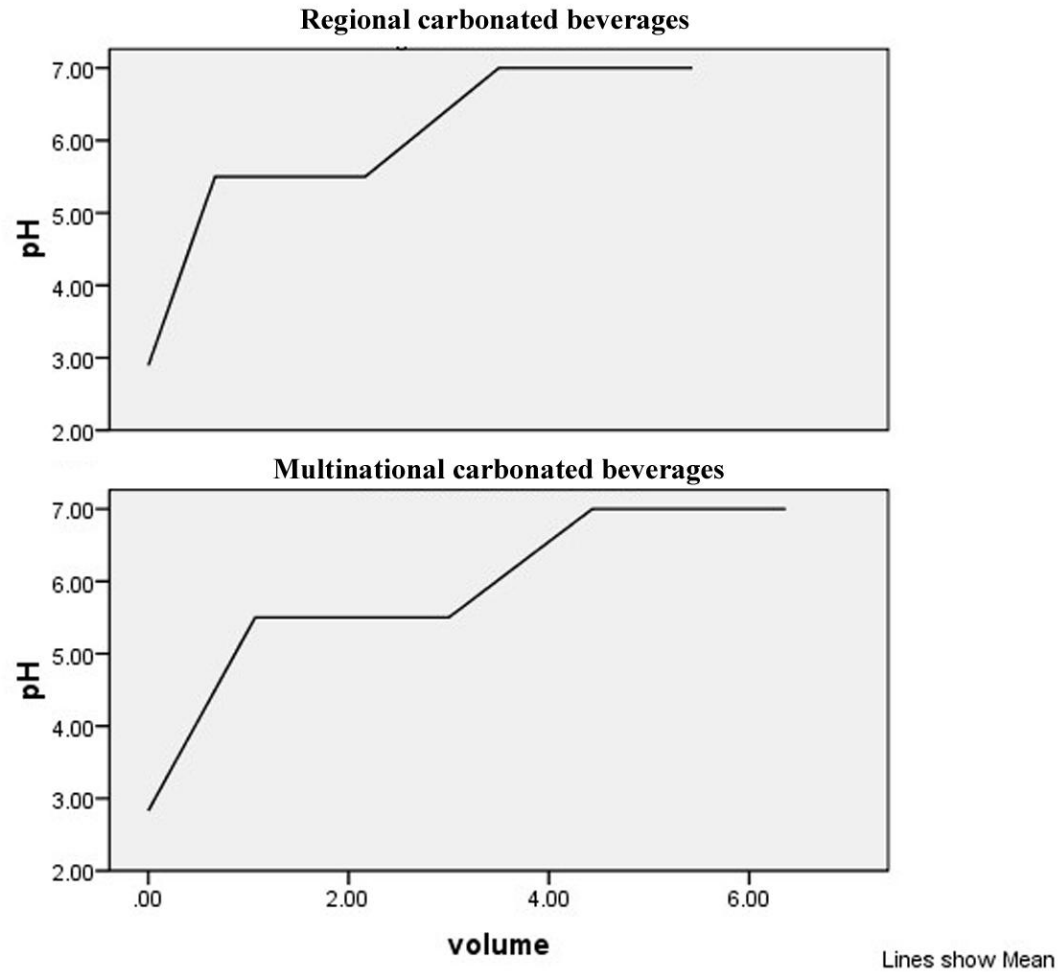
* Statistically significant

Table 4: **Independent sample 't' test to compare initial pH and buffering capacity at critical and neutral pH**

	Regional beverages		**Multinational beverages**			
	Mean	SD	Mean	SD	**t**	**P -value**
Initial pH	2.89	0.46	2.82	0.36	0.38	0.70
Critical pH	1.54	0.40	1.93	0.67	1.70	0.10
Neutral pH	4.54	0.64	5.43	0.64	3.35	0.003*

*Statistically significant

Figure 1: Titratable acidity of regional and multinational carbonated beverages



Discussion

People throughout the world, especially children, enjoy drinking carbonated drinks and commercial fruit juices.[12] Repeated and sequential consumption of fermentable carbohydrates, such as sweetened beverages and acidic beverages, increases the mineral loss of dental tissues[13,14]. Carbonated beverages contain carbonic acid formed by carbon dioxide in solution. Even when the carbon dioxide has been blown off and the drinks have become 'flat' the pH remains low.[15] This indicates that soft drinks have inherent acidity due to other acids like phosphoric and citric acids that are added to stimulate taste and counteract sweetness.[16]

The titratable acidity and pH are related to erosive lesions. The pH or actual acidity is the negative logarithm of the hydrogen ion concentration (actual hydrogen ion concentration) and is measured on a scale of 0 to 14 with a reading below 7 indicating an acid content or environment. In general, beverages with lower pH values have greater erosive effect; however, additional factors can also contribute to enamel dissolution in the oral cavity. The titratable acidity level may be a more realistic and accurate method for measuring the potential acidity in a given beverage.[17]

Maximum pH decrease after intake of different beverages is an important consideration in dental erosion, as apatite dissolution increases in the lower pH range.[18] A pH of 5.5 is traditionally considered to be the 'critical pH' for enamel dissolution, although mineral loss may begin at higher pHs.[19]Hence the test samples are titrated to this critical pH to assess its buffering capacity and then titrated to neutral pH. Intraoral pH decreases to below a pH of 5 within 2 to 3 minutesafter drinking an acidulated drink. The action of oral acidogenic bacterial on fermentable carbohydrates also aggravates the reduction of pH to below the critical pH.[4] Intraoral pH takes about 25 minutes to change the acid environment, as further stimulated saliva neutralizes any residual acid.[5]

The erosive effect of a soft drink depends not only on its intrinsic pH value but also on its buffering effect. The titratable acidity, which is a measurement of the total acid content, is a more important indicator than the actual pH value in determining erosive potential of beverages.[13]Titratable acidity is the total number of acid molecules, both protonated and non-protonated and determines the actual hydrogen ion availability for interaction with the tooth surface. It is a measure of the percent weight of acid present in a solution as calculated from the volume of sodium hydroxide (NaOH) or potassium hydroxide (KOH) required for neutralizing the acidic species. The ability of a beverage to resist pH changes brought about by salivary buffering may inevitably result in prolonged periods of oral acidity and, therefore, may play an important part in the erosion process.[10]

The results of this in vitro study indicate that the multinational carbonated beverages consumed more volume of 1M sodium hydroxide to reach neutral pH than the regional carbonated drinks. The initial pH of the regional beverages varied between 2.39 to 3.48 and that of the multinational beverages varied between 2.36 to 3.41.

It was also interesting to note that in the present study, the initial pH value gave no indication of the underlying buffering capacity and, therefore, the erosive potential of the drink. This was similar to the study done by Singh S et al.[11] Numerous studies have found that pure fruit juices had a higher initial pH than the carbonated drinks but required much more sodium hydroxide to raise the pH.[10, 16, 20] In the present study, the buffering capacity was much higher for multinational beverages when compared to regional beverages. That is multinational drinks consumed more volume of sodium hydroxide and more the volume of sodium hydroxide consumed, greater is the erosive potential.

Limitations and recommendations

The limitations of the present study is that since this was an invitro study, we could not mimic the oral environment with its multiple factors including the ability of a beverage to promote increased salivary flow due to gustatory stimulation. The bacteriological assay and composition of the test drinks were also not assayed.

The water used for manufacturing the local beverages may vary from place to place and this may have an effect on the buffering capacity. Extrinsic agents protective against erosion need to be added in the carbonated beverages. Further in-vivo, multiregional exploratory studies are of great importance in establishing the erosive potential of carbonated beverages.

Conclusion

Within the limitations of this in-vitro study, it can be decisively concluded that multinational beverages have a higher buffering capacity and a higher erosive potential as compared to their regional counterparts.

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