Original Articles

Erosive tooth wear potential of some traditional plant drinks and cola based drinks on human extracted teeth

Sanhouri. N. M[1], Ziada. H[2], Yahia. N. A[1*], Kamis. A. H[3]

[1] *Faculty of Dentistry; University of Khartoum*

[2] *Faculty of Dentistry; Kuwait University, Department of Surgical Sciences*

[3]*Hamdan Bin Mohammed College of Dental Medicine,UAE*

Abstract

Background: This study aimed at investigating the pH, titratable acid and erosive tooth wear potential of some local beverages in Sudan, *Adansonia digitata* (baobab), *Tamarindus indica* (tamarind), *Hibiscus sabdariffa* (hibiscus)) and cola-based drinks.

Methods: Twenty extracted premolar teeth were sectioned and treated with tested drinks for 10, 20 and 30 minutes representing three consumption frequencies. The pH and titratable acid of drinks were measured using a pH meter. Calcium and phosphorus release were recorded as measures for teeth demineralization. Calcium release was determined photometrically, using atomic absorption spectrophotometry, and phosphorus release using the phosphomolybdate-malachite green procedure.

Results: Cola- based drinks recorded the lowest pH (1.87) while *Hibiscus sabdariffa*, the second lowest pH (1.93) and the highest titratable acid (60.12 mmolOH^-/L). The local beverages (*Adansonia digitata, Tamarindus indica,* and *hibiscus sabdariffa)* showed high levels of calcium as compared to the cola-based drinks. There was a correlation between the calcium and phosphorus contents of the drinks and calcium and phosphorus release over different times. The pH of drinks and calcium release correlated significantly. There was no significant association between pH of drinks and phosphorus release and with TA and calcium and phosphorus release.

Conclusion: Despite their high nutritive values, local drinks tended to alter the ionic concentration of teeth when contacting them indicating an erosive potential. Work needs to be supplemented by in-vivo trials investigating factors such as salivary parameters and modes of drinking influencing their erosive potential.

***Corresponding author:** *Sanhouri N. M. E-mail Address: nadasanhouri@gmail.com,*

Introduction:

Erosive tooth wear seems to be one of the most concerning problems in current dentistry. One of the predisposing factors to erosive tooth wear is dietary acids [1-3]. Organic acids, in particular maleic, tartaric and citric acid are strongly erosive to dental tissues, due to their ability to form chelate complexes with calcium released from teeth [4]. The erosive potential of food and beverages is not only dependent on their pH, but also influenced by their titratable acidity and mineral contents, mainly calcium and phosphorus [4, 5].

In hot tropical countries there is increased consumption of locally produced drinks, containing one or more organic acids as well as consumption of cola-based drinks. In Sudan the most commonly consumed local drinks are: baobab (*Adansonia digitata),* locally known as gongolaise or tabaldi which is rich in ascorbic, tartaric, maleic and citric acids [6, 7].

Another local drink is tamarind (*Tamarindus indica)*, known locally as aradieb. In Sudan and other African countries, it is either consumed as a drink or the pulp is sucked and then eaten. The pulp contains tartaric acid, citric, succinic and maleic acids as well as sugars, proteins and also rich in polyphenols [8, 9] also known for their antibacterial properties [10] .

The third commonly consumed refreshing beverage is karkade (*Hibiscus sabdariffa).* It contains citric, maleic, tartaric, and ascorbic acids [11, 12]. The tooth surface erosive potential of these frequently consumed drinks has been reported in school children in Khartoum [13].

The aim of this study was to evaluate the pH and titratable acid of local drinks as well as cola- based drink and the diet version of the cola- based drink, and to investigate the erosive potential of these drinks on human extracted teeth.

Materials and Methods

Tested drinks:

The test drinks included a cola- based drink, Pepsi and the same version named Diet Pepsi (Arrak Company for Food Industry; Pepsi Co Ink, Borchas, New York) together with samples of the local drinks (baobab, tamarind and hibiscus).

The local drinks were prepared according to conventional local steps by immersing 50g of the plants in 50 mls of water for half an hour then sieving the solution to separate the contents. Fifty mls of each of the local drinks were used. After drinks preparation, 10 mls of each drink were utilized for the experiment.

The pH and titratable acidity measurements of tested drinks:

The pH of each drink was measured at room 35-38°C using a standard pH meter with two decimals accuracy (Metrohm Biotrode, 6.0224.100, Switzerland). The titratable acidity (TA) was measured as the volume (in ml) of 1 M NaOH (Titrisol) required to raise the pH of 50 ml of the drink to neutral pH. For the TA, a standard titrator and auto-burette were used [14]. Both pH and TA were recorded three times and the mean values were taken. The initial pH as well as after 10 min, 20 min, and 30 min intervals was measured in each drink.

Erosive tooth wear potential of tested drinks:

Twenty premolar teeth extracted as part of orthodontic management used for testing erosive tooth wear potential, were disinfected and stored in sodium hypochlorite immediately after extraction. They were examined under the stereo microscope to exclude teeth defects. The teeth crowns were then sectioned into two halves, rinsed with distilled water and dried. A random selection was conducted for the sections to be immersed in the tested drinks. Each section was immersed in 10 ml of the respective drink, and the drinks were tested for calcium and phosphorus presence before and after 10, 20, and 30 minutes of immersion.

The ability of the solutions to demineralize the teeth sections leading to changes in the calcium and phosphorus contents of the tested solutions was taken as a measure of the degree of erosive wear. The erosive potential was measured using the chemical analysis test, where the differences in calcium and phosphorus concentrations of the drinks were recorded before and after immersion of teeth sections [15].

Calcium and phosphorus content of tested drinks:

The calcium was measured using the spectrophotometry procedure (Atomic Absorption Spectrophotometer, AA-6800, Shimadzu). The phosphorus was measured by the phosphomolybdate-malachite green procedure (6505uv/vis, Spectrophotometer, Jenway). The calcium and phosphorus contents of the tested drinks were measured prior to teeth sections' immersion. After immersion of the teeth sections for the different times, the calcium and phosphorus contents of each tested drink were measured. The measurements were made in duplicates and a mean value was calculated for each tested drink according to the standardization of the device. The mean concentration of calcium and phosphorus contents of the tested drinks was taken as a measure of ionic movements between drinks and teeth sections per solution.

Statistical analysis

The student's t-test, ANOVA and Pearson's correlation coefficient tests were used to analyze the data with the p-value set at 0.05.

Results

The pH and titratable acidity (TA):

The initial pH values of drinks and their corresponding TA are shown in Figure 1. The initial pH of drinks tested were; 2.52, 2.13, 1.93, 1.87 and 2.39 for baobab, tamarind, hibiscus, cola- based and its diet version respectively. The titratable acidity showed that hibiscus had the highest (TA) of 60.12 mmolOH^-/L and pepsi-diet drink had the lowest (TA) of 41 mmolOH^-/L. The changes in drinks' pH during the first 10 minutes of exposure were seen mostly with the baobab showing an increase of 0.14 in pH value whereas the other drinks had minimal changes. However, none or minimal changes in pH were noted after 20 and 30 minutes intervals as shown in Figure 2.

Chemical analysis of the drinks:

Local drinks have high levels of calcium compared to the cola-based drinks. Hibiscus had the highest level of calcium with a mean concentration of 291.5ppm, followed by baobab (89.82 ppm) and tamarind (48.97 ppm). The cola- based and its diet version had a mean calcium concentrations of 3.42 ppm and 3.06 ppm respectively. There was a gradual increase in the mean level of calcium of baobab drink detected over the three immersion times.

The mean calcium level of tamarind drink dropped in the first 10 minutes of immersion and increased after the 20 minutes, and dropped again after 30 minutes immersion.

The mean level of calcium in hibiscus dropped after 10 minutes of immersion and increased considerably after 20 minutes and dropped again after 30 minutes, to a level still higher than the initial calcium concentration.

The cola-based drink showed a drop in the mean calcium level after 10 minutes but increased considerably after the 20 and 30 minutes immersion solutions. Its Diet version showed considerable reduction in the mean calcium level during the 10 and 20 minute immersion times but increased dramatically after the 30 minutes immersion time as shown in Figure 3.

The highest phosphorus level was detected in hibiscus with a concentration of 0.163 ppm followed by tamarind, cola-based drink and its diet version with concentrations of 0.074, 0.095 and 0.044 ppm respectively. No phosphorus was detected in baobab.

The phosphorus contents of the tested solutions increased between 4 to 6 times for tamarind, cola-based and diet cola-based drinks and almost 2 times for hibiscus, with very minimal increase for baobab after 10 minutes of immersion. After the 20 minutes immersion time, there was a considerable drop in phosphorus concentrations in all solutions. After the 30 minutes immersion times phosphorus presence was not detected except for the diet version of the cola based drink, Figure 4.

There was a significant correlation between the calcium and phosphorus contents for the different drink and calcium and phosphorus release over the different times (r_2=0.697; $p<0.001$ and r_2=0.950; $p<0.001$) respectively. There was also a significant association between the pH of the drinks and calcium release ($p=0.03$), whereas there was no significant association between the pH of drinks and phosphorus release or between TA of drinks and calcium and phosphorus release.

Discussion

Drinks and beverages prepared from plants in many African and Asian countries are widely consumed due to their low cost as compared to cola-based and similarly manufactured drinks. Their nutritive values have been well documented [7, 8, 16]

The chemical process that leads to erosive wear is a complex process. The erosive solution has to contact the tooth surface to interact with the mineralized portion of the tooth which is a carbonated and calcium deficient hydroxyapatite [17, 18]. The acid in the solution with its hydrogen ions or chelating properties will dissolve the apatite crystals releasing its minerals which are the calcium and phosphorus. The outflow of ions will continue until no further chelating agents or acids are provided. The pH, titratable acid, calcium and phosphorus concentrations are the primary determinants of the erosive potential of a drink, since they determine the degree of saturation with respect to tooth minerals [18]. In this study, an efflux and influx of calcium and phosphorus ions was recorded in the solutions over the different time intervals.

This study recorded a significant association between pH of tested drinks and calcium release. This result is in harmony with an in-vitro study by Jensdottir et al [19]. However, there was no significant association between calcium and phosphorus release and the titratable acid of the drinks, as reported by Hannig et al [20].

The calcium and phosphate loss from human teeth sections, utilized as an indicator of erosive potential, is considered a sensitive and reliable method [20, 21]

The progression of erosion differs according to the type of enamel. This study took this into consideration and hence human teeth were used to give a true representation of the process, unlike other studies that utilized bovine teeth [22, 23].

The use of 10ml solutions almost mimic the amount of fluid left following swallowing and thus simulate the process of drinking in the mouth where such small amounts remain contacting the teeth surfaces. The 10, 20 and 30 minutes time resemble drinking juices once, twice and three times per day.

Baobab recorded low pH and a high titratable acid (2.52, 47 mmolOH$^-$/L respectively) and high level of calcium 89.818ppm. The high levels of calcium do not usually result in a high degree of erosiveness. However, a continuous rise in the drink's ions, indicate a continuous outflow of tooth minerals and hence a high erosive challenge. This could be explained by the fact that Baobab has a low pH, high titratable acid and a number of organic acids such as citric, maleic, tartaric, and ascorbic acids, known for their strong chelating and hence potent erosive characters[20].

Hibiscus and Tamarind had similar patterns of calcium and phosphorus ions movement during the first 10 minutes solutions and seemed to lose ions, indicating an inward flow and hence mineralization of tooth surface which is reversed during the 20 minutes immersion time indicating an outflow of ions and hence erosion of the teeth surfaces followed by an inward flow during the 30 minutes immersion time. These inward-outward movements of ions could be explained by the fact that the volume of solutions is comparatively small and when becoming supersaturated compared to teeth hydroxyapatite, an inward movement of ions will occur mineralizing teeth surfaces; but when becoming under-saturated, due to mineral loss, ions will flow outwards eroding teeth surfaces. These differences in behavior compared to Baobab could be due to Baobab phosphorus deficiency indicating higher erosiveness.

The cola-based drink showed an inward movement of calcium ions during the 10 minutes immersion time followed by a recognizable outward flow of ions during the 20 and 30 minutes immersion times indicating great erosive potential. On the other hand, its diet version, showed an inward movement of calcium ions during the 10 and 20 minutes immersion times followed by a dramatic outflow of ions during the 30 minutes immersion time. This behavior indicates that the diet cola-based drink tested in this study was less erosive than the non -diet version, concurring with the findings of Attin et al [24].

The tested local drinks Baobab, Tamarind and Hibiscus, are of high nutritive significance [7, 12]. On contact with the teeth, they tend to alter the ionic concentration of hydroxyapatite indicating a potential erosive challenge to the teeth. Their potential erosiveness need to be further investigated since they contain more than one organic acid with different structures so various behaviors are expected when interacting with the hydroxyapatite of the teeth.

Behavioral factors such as food type, eating and drinking habits, oral hygiene methods; biological factors such as saliva and soft tissues; together with the chemical properties of saliva [14] may all affect the erosive potential of the drinks.

The nutritional values of these local drinks cannot be overlooked .However, public awareness of their erosive effect on teeth and the consequent complicated oral rehabilitation needed for severe cases must be addressed.

Taking the drinks in a chilled form is better than drinking them hot or at room temperature. The use of straws directed to the oral cavity, as oppose to direct contact on teeth surfaces, will minimize the erosive potential of these drinks [25].

In addition, and as a result of the increase in dental awareness, many people tend to brush their teeth immediately after drinking acidic juices. This misbehavior will aggravate the condition. So, it is recommended to postpone the brushing of teeth for an hour and to use fluoridated pastes if available.

The current study supported the findings of other investigators regarding the erosive potential of Cola-based drinks in relation to ordinary and light or diet versions [23, 24]

Further in-situ studies are required to test their actual erosive effect under biological conditions.

Acknowledgement

This work is funded by a grant from the Ministry of Higher Education and Research in Sudan.

*This work is dedicated to the soul of our ex-dean Dr. Nadia Ahmed Yahia . May her soul rest in peace.

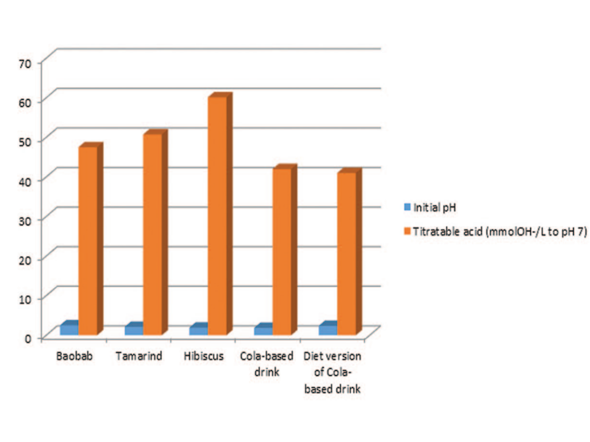

Figure 1: Initial pH and titratable (mmol OH-/L to pH 7) acids of tested drinks before teeth sections' immersion

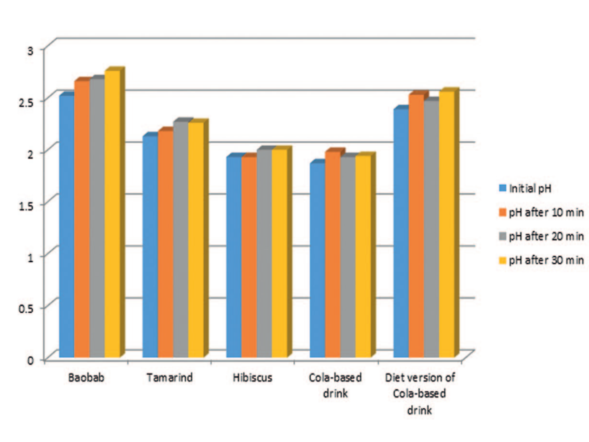

Figure 2: Initial pH of drinks and their pH after teeth sections' immersion for 10, 20 and 30 min

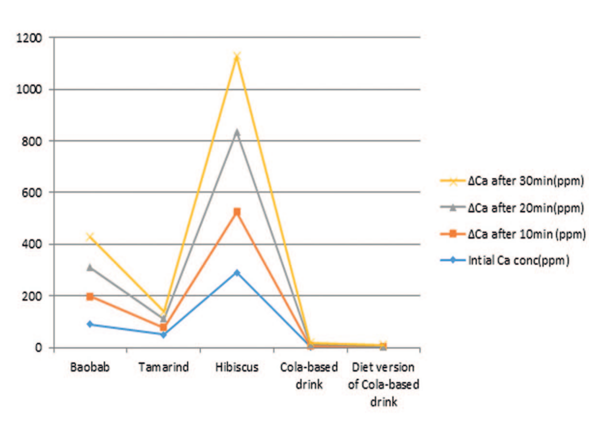

Figure 3: Initial calcium concentration & calcium concentration of tested drinks after 10, 20 & 30 min time

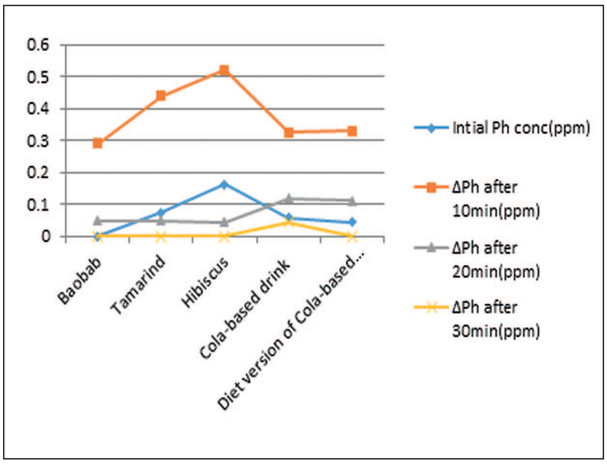

Figure 4: Initial phosphorus concentration & phosphorus concentration of tested drinks after 10, 20 & 30 min time

References

1. Bartlett DW. The role of erosion in tooth wear: aetiology, prevention and management. *Int Dent J*. 2005;55:277-84.

2. Wang YL, Chang CC, Chi CW, Chang HH, Chiang YC, Chuang YC, et al. Erosive potential of soft drinks on human enamel: an in vitro study. *J Formos Med Assoc*. 2014;113:850-6.

3. Lussi A, Jaeggi T. Erosion--diagnosis and risk factors. *Clin Oral Investig*. 2008;12:S5-13.

4. Featherstone JD, Lussi A. Understanding the chemistry of dental erosion. *Monogr Oral Sci.* 2006;20:66-76.

5. Shellis RP, Barbour ME, Jesani A, Lussi A. Effects of buffering properties and undissociated acid concentration on dissolution of dental enamel in relation to pH and acid type. *Caries Res*. 2013;47:601-11.

6. Ghoneim MA, Hassan AI, Mahmoud MG, Asker MS. Protective Effect of Adansonia digitata against Isoproterenol-Induced Myocardial Injury in Rats. *Anim Biotechnol*. 2016;27:84-95.

7. Chadare FJ, et al. . Baobab food products: a review on their composition and nutritional value. . *Crit Rev Food Sci Nutr.* 2009;49:254-74.

8. Glew RS, Vanderjagt DJ, Chuang LT, Huang YS, Millson M, Glew RH. Nutrient content of four edible wild plants from west Africa. *Plant Foods Hum Nutr*. 2005;60:187-93.

9. Paula FS, Kabeya LM, Kanashiro A, et al. Modulation of human neutrophil oxidative metabolism and degranulation by extract of Tamarindus indica L. fruit pulp. *Food Chem Toxicol.* 2009;47:163-70.

10. Djeussi DE, Noumedem JA, Seukep JA, et al. Antibacterial activities of selected edible plants extracts against multidrug-resistant Gram-negative bacteria. BMC *Complement Altern Med*. 2013;13:164.

11. Zizka A, Thiombiano A, Dressler S, et al. Traditional plant use in Burkina Faso (West Africa): a national-scale analysis with focus on traditional medicine. *J Ethnobiol Ethnomed*. 2015;11:9.

12. Sena LP, Vanderjagt DJ, Rivera C, et al. Analysis of nutritional components of eight famine foods of the Republic of Niger. *Plant Foods Hum Nutr*. 1998;52:17-30.

13. Sanhouri NM ZH, Ahmed GI, Kamis AH. Tooth surface loss, prevalence and associated risk factors among 12-14 years school children in Khartoum State, Sudan. *Community Dent Health*. 2010; 27:206-12.

14. Hooper SM, Hughes J.A, Newcombe R.G, Addy M, West N.X. A methodology for testing the erosive potential of sports drinks. *J Dent*. 2005;33:343-8.

15. Hannig C, Hamkens A, Becker K, Attin R, Attin T. Erosive effects of different acids on bovine enamel: release of calcium and phosphate in vitro. *Arch Oral Biol.* 2005;50:541-52.

16. Ochani PC, D'Mello P. Antioxidant and antihyperlipidemic activity of Hibiscus sabdariffa Linn. leaves and calyces extracts in rats. *Indian J Exp Biol*. 2009;47:276-82.

17. Barac R, Gasic J, Trutic N, et al. Erosive Effect

of Different Soft Drinks on Enamel Surface in vitro: Application of Stylus Profilometry. *Med Princ Pract.* 2015;24:451-7.

18. Karda B, Jindal R, Mahajan S, Sandhu S, Sharma S, Kaur R. Analysis of the Erosive Potential of Commercially Available Drinks on Dental Enamel and Various Tooth Coloured Restorative Materials - An In-vitro Study. *J Clin Diagn Res*. 2016;10: 117-21.

19. Jensdottir T, Bardow A, Holbrook P. Properties and modification of soft drinks in relation to their erosive potential in vitro. *J Dent*. 2005;33:569-75.

20. Hannig C, Hamkens A, Becker K, Attin R, Attin T. Erosive effects of different acids on bovine enamel: release of calcium and phosphate in vitro. *Arch Oral Biol.* 2005;50:541-52.

21. Eisenburger M, Addy M, Rossbach A. Acidic solubility of luting cements. *J Dent.* 2003;31:137-42.

22. Amaechi BT, Higham SM, Edgar WM, Milosevic A. Thickness of acquired salivary pellicle as a determinant of the sites of dental erosion. *J Dent Res*. 1999;78:1821-8.

23. Zimmer S, Kirchner G, Bizhang M, Benedix M. Influence of various acidic beverages on tooth erosion. Evaluation by a new method. *PLoS One*. 2015;10:e0129462.

24. Attin T, Weiss K, Becker K, Buchalla W, Wiegand A. Impact of modified acidic soft drinks on enamel erosion. *Oral Dis*. 2005;11:7-12.

25. Eisenburger M, Addy M. Influence of liquid temperature and flow rate on enamel erosion and surface softening. *J Oral Rehabil*. 2003;30:1076-80.