



Original Article

Erosive Potential of Industrialized Teas: An in vitro study

Andressa Feitosa Bezerra de Oliveira¹, Fabio Correia Sampaio², Ingrid Andrade Meira³, Marcella Guedes Pereira Gouvêa Bezerra⁴, Nayanna Lana Soares Fernandes⁴, Valeska Maria Souto Paiva⁴

¹Professor, Department of Morphology, Federal University of Paraíba, João Pessoa, PB, Brazil.

²Professor, Department of Clinical and Social Dentistry, Federal University of Paraíba, João Pessoa, PB, Brazil.

³MSc Student, Piracicaba Dental School, State University of Campinas, Piracicaba, SP, Brazil.

⁴Undergraduate Student, School of Dentistry, Federal University of Paraíba, João Pessoa, PB, Brazil.

Author to whom correspondence should be addressed: Ingrid Andrade Meira, Rua Capitão Emídio, 455, Piracicaba, SP, Brasil. 13416040. Phone: 55 98 399909-8804. E-mail: ingrid_meiraa@hotmail.com.

Academic Editors: Alessandro Leite Cavalcanti and Wilton Wilney Nascimento Padilha

Received: 28 June 2016 / Accepted: 21 July 2017 / Published: 03 August 2017

Abstract

Objective: To evaluate the erosive potential of manufactured teas according to pH, titratable acidity and buffering capacity. **Material and Methods:** Eight types of manufactured teas of different brands and flavors acquired in supermarkets of João Pessoa, Brazil, were investigated. Indaiá® mineral water and Coca-Cola® were controls. The pH measurement and titratable acidity for pH 5.5 and 7.0 were performed in triplicate in 50 ml of each beverage. The buffering capacity was calculated based on pH and titratable acidity for pH 7.0. ANOVA, Tukey, and Pearson correlation, with $p < 0.05$, were used for data analysis. **Results:** Data showed normal distribution by Kolmogorov-Smirnov test for all variables. There was a statistically significant relationship between groups analyzed in all variables (ANOVA, $p < 0.001$). The pH of teas ranged from 2.70 (Black Tea with lemon-Leão Fuze®) to 4.03 (Natural Mate Tea - Matte Leão®). The following significant correlations ($p < 0.01$) were observed: pH and titratable acidity; buffering capacity and pH; buffering capacity and titratable acidity. **Conclusion:** All teas analyzed were potentially erosive; however, Black Tea with lemon (Leão Fuze®) had the lowest pH, the highest titratable acidity and buffering capacity, demonstrating that the saliva will have greater difficulty in buffering this tea in the oral environment.

Keywords: Tooth Erosion; Beverages; Dental Enamel.

Introduction

Dental erosion is the physical result of pathological, chronic, localized and painless loss of mineralized dental tissue chemically submitted to acid attack without bacterial involvement [1]. This type of loss of dental tissue can be caused by extrinsic and intrinsic factors. Intrinsic causes have been linked to anorexia nervosa and bulimia as well as to any persistent gastroesophageal disorder that puts the gastric acid in direct contact with the hard dental tissues, resulting in the loss of minerals. Extrinsic causes involve acidic drugs such as vitamin C, in addition to the consumption of acidic foods and beverages [2]. Dental erosion is a multifactorial condition² whose chemical, biological and behavioral interactions help explain why some individuals have more manifestations of this pathology than others [3]. However, the most relevant acids that can cause dental erosion are from the diet [4] and from the stomach [5].

Currently, the population has consumed a large number of beverages and processed foods, due to their easy access, low cost and convenience [6]. In addition, the constant care of the body and the physical beauty has led to a constant search for practical and healthy drinks and foods, which includes industrialized teas as an alternative to coffee [7]. Tea is prepared by the infusion of plant leaves, flowers or roots, usually with hot water, varying the taste depending on the processing adopted, which can be with or without fermentation, toasted or not, add of aroma or spices [8]. Many people believe that because it is tea, the frequent use of this beverage would be beneficial. In the past, teas were considered therapeutic beverages, mainly due to their high amount of flavonoids [8]. However, INMETRO [8] questions the real benefits of this component in the composition of the teas.

Dental erosion has become a frequent pathology among many populations [9], with estimated prevalence of 30.4% among children and adolescents aged 9-19 years, according to a systematic review [7]. In addition, during the last decade, a significant increase in the severity of dental erosion lesions has been observed, particularly in children and adolescents [7,9-11]. In Brazil, prevalence of up to 34.1% has been observed in adolescents aged 13-14 years [12]. Currently, increasing data on the prevalence of dental erosion have attracted the attention of the dental community for the development of many studies [13].

However, it is noteworthy that erosion differs from dental caries, as the latter occurs in areas covered by biofilms, while erosion occurs in biofilm-free areas on all exposed surfaces [1]. Initially, the most common feature of erosion is loss of enamel glaze, leaving the surface polished. The lesion is generally broad and shallow, frequently U-shaped with no evident angles. When it invades the dentin, it causes sensitivity to cold, heat, and osmotic pressure, and restorations may become more prominent and projected off the surface [14]. Therefore, late diagnosis or inadequate preventive intervention may lead to advanced tissue loss, compromising vitality, functionality or tooth aesthetics [15]. The aim of this study was to analyze the erosive potential of industrialized teas of different brands and flavors through pH, titratable acidity and buffering capacity.

Material and Methods

Selection of Beverages

Eight types of industrialized teas of different brands and flavors were acquired in the supermarket chains of the city of João Pessoa, Brazil, as described in Chart 1. Beverages were stored according to the manufacturer's instructions. For the negative control, mineral water was used and for positive control, a cola-based soft drink was used.

Chart 1. Basic information of the beverages analyzed in this study according to flavor, composition, and manufacturer.

Beverages	Flavor	Ingredient List	Brand Name/Producer
White tea	Natural	Water, white tea powder (<i>Camellia sinensis</i>), vitamin C, acidulant citric acid and malic, acidity regulator: potassium and sodium citrate, artificial sweetener sodium cyclamate (40 mg/100 ml), sucralose (6 mg/100 ml) and sodium saccharin (4 mg /100 ml).	Feel Good/Wow Nutrition®
Green tea	Natural	Water, green tea powder (<i>Camellia sinensis</i>), vitamin C, acidulant citric acid and malic, acidity regulator: potassium and sodium citrate, aroma identical to lemon natural, sweetener sodium cyclamate (40 mg/100 ml), sucralose (6 mg/100 ml) and sodium saccharin (4 mg /100 ml).	Feel Good/Wow Nutrition®
Green tea	Orange e Ginger	Water, green tea powder (<i>Camellia sinensis</i>), stabilizing sodium citrate, concentrated orange juice and ginger extract, acidulant malic and citric acid, acidity regulator: sodium citrate, sweetener sodium cyclamate (40 mg/100 ml), sucralose (6 mg/100 ml) and sodium saccharin (4 mg/100 ml), antioxidant ascorbic acid and aroma identical to the natural orange and ginger.	Feel Good/Wow Nutrition®
Green tea	Cranberry	Water, green tea powder (<i>Camellia sinensis</i>), concentrated juice, ascorbic acid (vitamin C), identical aroma natural cranberry, acidulants citric acid and malic acid, stabilizing potassium citrate, natural sweeteners, steviol glycosides (20mg/100mL) and artificial sucralose (7mg/100mL) and natural cochineal carmine dye.	Feel Good/Wow Nutrition®
Black tea	Lemon	Water, sugar, lemon juice concentrate, black tea aqueous extract (<i>Camellia sinensis</i>), synthetic aroma identical to natural, acidulants citric acid and phosphoric acid, acidity regulator sodium citrate and antifoaming dimethyl polysiloxane.	Leão Fuze/ Coca Cola® Brasil
Black tea	Peach	Water, peach juice concentrate, black tea aqueous extract (<i>Camellia sinensis</i>), acidulants citric acid and phosphoric acid, synthetic aroma identical to natural, acidity regulator sodium citrate, sucralose sweeteners (12 mg) and acesulfame potassium (5mg) per 100mL antifoaming dimethylpolysiloxane.	Leão Fuze/ Coca Cola® Brasil
Mate tea	Lemon	Water, sugar, mate aqueous extract (<i>Ilex paraguariensis</i> St. Hil.), lemon juice concentrate, synthetic aroma identical to natural, antioxidant ascorbic acid, conservative potassium sorbate and sodium benzoate.	Matte Leão/Coca Cola® Brasil
Mate tea	Natural	Water, sugar, mate aqueous extract (<i>Ilex paraguariensis</i> St. Hil), acidity regulator citric acid and antioxidant ascorbic acid.	Matte Leão/ Coca Cola® Brasil
Cola soft drink	Cola	Carbonated water, sugar, cola nut extract, caffeine, caramel IV, phosphoric acid and flavours.	Coca-Cola®/The Coca-Cola Company®
Mineral water	---	Chloride =23.80; Sodium=14.99; Nitrate=2.9; Bicarbonate=0.80; Sulfate=0.8; Potassium=0.79; Magnesium=0.76; Calcium=0.23; Barium=0.027 e Strontium=0.006.	Mineral Water FONT: Santa Rita I Indaiá®/ Indaiá Brasil Águas Minerais Ltd.

Data Collection

Immediately after opening, the pH of the selected beverages was measured using an electrode coupled to a pH meter (Orion, model 420A-Thermo Fischer Science Inc., Waltham, MA). Titratable acidity was performed with the addition of 1M NaOH to 50ml of each beverage in 0.2ml increments until reaching pH 5.5 (critical) and pH 7.0 (neutral). Measurements were performed with constant stirring in triplicate to obtain an average value to be used. The buffering capacity (β) was calculated through Eq. (1), according to Lussi et al. [1]:

$$(1) \beta = \Delta C / \Delta pH$$

Statistical Analysis

Results were evaluated through descriptive and inferential analyses. After analyzing data normality, the parametric ANOVA test, followed by the Tukey test, was used to compare pH, titratable acidity and buffering capacity variables. Correlations between variables were made with the Pearson correlation test. The significance level adopted was 95% ($p < 0.05$).

Results

Data presented normal distribution by the Kolmogorov-Smirnov test for all variables (pH, titratable acidity and buffering capacity), allowing the use of parametric tests (Table 1). A statistically significant relationship was observed between groups analyzed in all variables (ANOVA, $p < 0.001$).

Table 1. The mean (\pm DP) of initial pH value, titratable acidity (mmol/l NaOH) to pH 5.5 and 7.0 and buffering capacity ($\Delta C/\Delta pH$) of the analyzed beverages.

Beverages	pH* (initial)	Titratable acidity (mmol/l NaOH) to pH 5.5*	Titratable acidity (mmol/l NaOH) to pH 7.0*	Buffering Capacity*
White tea-Natural	3.53 \pm 0.046	0.9 \pm 0.000	1.25 \pm 0.050	7.03 \pm 0.365
Green tea-Natural	3.34 \pm 0.400	0.65 \pm 0.087	0.95 \pm 0.029	4.97 \pm 0.743
Green tea-Orange e Ginger	3.41 \pm 0.076	1.06 \pm 0.058	1.36 \pm 0.050	6.78 \pm 0.223
Green tea-Cranberry	3.16 \pm 0.015	1.12 \pm 0.126	1.5 \pm 0.100	7.60 \pm 0.515
Black tea-Lemon	2.70 \pm 0.080	1.28 \pm 0.153	1.85 \pm 0.132	8.30 \pm 0.454
Black tea-Peach	2.84 \pm 0.021	1.02 \pm 0.058	1.48 \pm 0.058	6.93 \pm 0.276
Mate tea-Lemon	3.76 \pm 0.000	0.73 \pm 0.029	1.0 \pm 0.029	5.85 \pm 0.173
Mate tea-Natural	4.03 \pm 0.056	0.42 \pm 0.029	0.57 \pm 0.029	3.78 \pm 0.210
Negative control				
Mineral water Indaiá®	4.33 \pm 0.042	0.012 \pm 0.000	0.026 \pm 0.007	0.194 \pm 0.114
Positive control				
Coca-Cola®	2.71 \pm 0.071	0.67 \pm 0.035	2.57 \pm 0.106	11.41 \pm 0.262

*ANOVA test ($p < 0.01$).

The pH of beverages ranged from 2.70 (Black Tea with Lemon – Leão Fuze®) to 4.33 (Indaiá® Mineral Water). Black Tea with lemon (Leão Fuze®) obtained pH lower than the positive control (Coca-Cola®). Among teas, it was observed that the highest pH was 4.03 for Natural Mate

Tea (Matte Leão®). The highest titratable acidity for pH 5.5 was found for Black Tea with Lemon (Leão Fuze®) and the lowest for Mineral Water (Indaiá®). However, among teas, Natural Mate Tea (Matte Leão®) obtained the lowest titratable acidity value. In titration for pH 7.0, the lowest value was found for Indaiá® mineral water and the highest value for Coca-cola®. Among teas, Natural Mate Tea (Matte Leão®) obtained the lowest value while the highest was found for Black Tea with lemon (Leão Fuze®). Regarding the buffering capacity, the highest value (11.41) was found for the positive control group (Coca-Cola®) and the lowest (0.194) for the negative control (Indaiá® mineral water), as expected. For the group of teas, Black Tea with Lemon (Leão Fuze®) obtained the highest value (8.30), while the lowest (3.78) was found for Natural Mate Tea (Matte Leão®), following the pattern presented by initial pH and titratable acidity.

Significant correlations were observed between initial pH and titratable acidity, both at pH 5.5 ($r = -0.782$, $p < 0.01$) and pH 7.0 ($r = -0.848$, $p < 0.01$). The buffering capacity also showed significant negative correlation with initial pH ($r = -0.651$, $p < 0.01$), and positive correlation with titratable acidity both for pH 5.5 ($r = 0.952$, $p < 0.01$) and pH 7.0 ($r = 0.947$, $p < 0.01$).

Discussion

The present study observed that all beverages analyzed had pH value lower than the critical value for enamel and dentin. In addition, Black Tea with lemon (Leão Fuze®) had pH value lower than that of Coca-Cola®. Mineral water (Indaiá®) also had pH lower than value considered critical for dental tissues; however, its high buffering capacity facilitates its neutralization by the saliva, when present in the oral environment, thus being considered the beverage with less erosive potential. Due to these characteristics, mineral water (Indaiá®) was used as a negative control in this research, since it does not present any erosive substance in its composition [3].

Black tea with lemon (Leão Fuze®) and Green tea with cranberry (Feel Good®) analyzed in this study presented the highest buffering capacity values, being only lower than positive control. It was observed that Coca-Cola®, used as positive control, had high buffering capacity value, showing to be a beverage difficult to be buffered by saliva, and therefore very harmful to dental tissues, demonstrating a faster reactive potential on hydroxyapatite than the other beverages analyzed, corroborating previous study [16], who reported the same for Pepsi®. Coca-Cola® and Pepsi® contain phosphoric acid in their compositions, which has been shown to be highly erosive compared to other organic acids such as citric, malic and lactic acids [17].

The buffering capacity depends on the total amount of the conjugable acid and available base and indicates the amount of acid or base that may be added before the buffer loses its ability to resist pH change [18]. In the oral environment, saliva has buffering action, with remineralizing effects, neutralizing the acids present in beverages. The pH of the mouth is around 6.8, and when we drink some acidic beverage, the pH decreases dramatically, taking about 25 minutes for the saliva to take action in the environment and perform its function [4].

It was observed that Black Tea with lemon (Leão Fuze®) presented the lowest pH value and the highest titratable acidity values for pH 5.5 and 7.0 and buffering capacity, showing high erosive potential. This can be explained by its composition [19], since this tea has citric and phosphoric acids in its composition [3], and also due to the addition of concentrated lemon juice, fruit with high citric acid content [19]. Acid is added to accentuate the taste of lemon, but has high capacity for chelating minerals and is responsible for tooth erosion [20].

This finding is consistent with some authors [3], who performed an erosive challenge using Black Tea (Leão®) and observed a significant change in the surface hardness of the dental enamel exposed to this tea, before and after the erosive test, despite presenting fluoride in its composition. It was observed that the amount of fluoride present was unable to promote enamel protection when there is a previous erosive challenge with HCl or in the presence of acids from carbonated beverages [3].

Natural Mate Tea (Matte Leão®) presented the highest pH value and the lowest titratable acidity values and buffering capacity, demonstrating that saliva will not find it difficult to buffer this beverage. These findings indicate its low erosive potential, which is in agreement with previous report [11]. However, the multifactorial character of dental erosion should also be considered [21].

In the present study, it was found that, in general, fruity teas had higher erosive potential than natural ones, which is in agreement with the literature [22]. In a systematic review that included a number of epidemiological, cutoff, laboratory, and case-control studies published between 2000 and 2012 with human and animal specimens, it was found that fruity green and black teas, with added herbs and sugar, had high erosive potential [23], corroborating the results of this study. Therefore, the erosive potential should not be attributed solely to pH, but also the differences among the components of each type of tea, since, in their composition, fruity teas present fruit juices that generally have high citric acid content [24]. In addition, the present study observed significant correlation between pH, titratable acidity and buffering capacity; therefore, these chemical characteristics are important to explain the erosive potential of beverages.

Within the limitations of the present study, the composition of teas and / or their flavor may have influenced the results obtained, demonstrating the importance of these characteristics to evaluate their erosive potential. These findings are relevant as they alert the population about the dangers of these beverages to dental erosion, since they are generally considered healthy and frequently consumed.

Conclusion

All teas analyzed are potentially erosive, since they present initial pH lower than value considered critical for enamel (5.5) and dentine (6.5). Black Tea with lemon (Leão Fuze®) had the lowest pH and the highest titratable acidity values and higher buffering capacity, demonstrating that saliva will have greater difficulty in buffering this product in the oral environment.

References

1. Lussi A, Megert B, Shellis RP, Wang X. Analysis of the erosive effect of different dietary substances and medications. *Br J Nutr* 2011; 107(2):252-62. doi: 10.1017/S0007114511002820.
2. Lussi A, Hellwing E, Ganss C, Jaeggi T. Buonocore Memorial Lecture. Dental erosion. *Oper Dent* 2009; 34(3):251-62. doi:10.2341/09-BL.
3. Amoras DR, Corona SAM, Rodrigues ALJ, Serra MC. Effect of beverages on bovine dental enamel subjected to erosive challenge with hydrochloric acid. *Braz Dent J* 2012; 23(4):367-72. doi: 10.1590/S0103-64402012000400010.
4. Amaechi BT, Higham SM, Edgar WM. Factors influencing the development of dental erosion in vitro: enamel type, temperature and exposure time. *J Oral Rehabil* 1999; 26(8):624-30.
5. Scheutzel P. Etiology of dental erosion--intrinsic factors. *Eur J Oral Sci* 1996; 104 (2(Pt 2)):178-90.
6. Buzalaf MAR, Bastos JRM, Granjeiro JM, Levy FM, Cardoso VES, Rodrigues MHC. Fluoride content of several brands of teas and juices found in Brazil and risk of dental fluorosis. *Rev Fac Odontol Bauru* 2002; 10(4):263-7.
7. Salas MM, Nascimento GG, Huysmans MC, Demarco FF. Estimated prevalence of erosive tooth wear in permanent teeth of children and adolescents: an epidemiological systematic review and meta-regression analysis. *J Dent* 2015; 4(1):42-50. doi:10.1016/j.jdent.2014.10.012.
8. Brasil. Ministério do desenvolvimento, indústria e comércio exterior. Instituto nacional de metrologia, normalização e qualidade industrial. Inmetro. Programa de análise de produtos: Relatório sobre análise em chás. Rio de Janeiro (RJ); 2009.
9. Corrêa MSNP, Corrêa FNP, Corrêa JP, Murakami C, Mendes FM. Prevalence and associated factors of dental erosion in children and adolescents of a private dental practice. *Int J Paediatr Dent* 2011; 21(6):451-8. doi: 10.1111/j.1365-263X.2011.01150.x.
10. Singh S, Jindal R. Evaluating the buffering capacity of various soft drinks, fruit juices and tea. *J Conserv Dent* 2010; 13(3):129-31. doi:10.4103/0972-0707.71643.
11. Mirkarimi M, Toomarian L. Effect of green tea extract on the treatment of dentin erosion: An in vitro study. *J Dent* 2012; 9(4):224-8.
12. Alves LS, Brusius CD, Damé-Teixeira N, Maltz M, Susin C. Dental erosion among 12-year-old schoolchildren: a population-based cross-sectional study in South Brazil. *Int Dent J* 2015; 65(6):322-30. doi: 10.1111/idj.12189.
13. Gonçalves GKM, Guglielmi CAB, Correa FNP, Raggio DP, Correa MSNP. Erosive potential of different types of grape juices. *Pesqui Odontol Bras* 2012; 26(5):457-63. doi:10.1590/S1806-83242012005000015.
14. Araújo NC, Massoni ACLT, Katz CRT, Rosenblatt A. Dental erosion and consumption of industrialized beverages in a group of children in Recife/Pernambuco, Brazil. *Rev Odontol Ciênc* 2009; 24(2):120-3.
15. Bardsley PF, Taylor S, Milosevic A. Epidemiological studies of tooth wear and dental erosion in 14-year-old children in North West England. Part 1: The relationship with water fluoridation and social deprivation. *Br Dent J* 2004; 197(8):413-6. doi: 10.1038/sj.bdj.4811747.
16. Benjakul P, Chuenarrom C. Association of dental enamel loss with the pH and titratable acidity of beverages. *J Dent Sci* 2011; 6(3):129-33. doi: 10.1016/j.jds.2011.05.001.
17. West NX, Hughes JA, Addy M. Erosion of dentine and enamel in vitro by dietary acids: the effect of temperature, acid character, concentration and exposure time. *J Oral Rehabil* 2000; 27(10):875-80.
18. Cochrane NJ, Cai F, Yuan Y, Reynolds EC. Erosive potential of beverages sold in Australian schools. *Aust Dent J* 2009; 54(3):238-44. doi: 10.1111/j.1834-7819.2009.01126.x.
19. Meurman JH, Frank RM. Progression and surface ultrastructure of in vitro caused erosive lesions in human and bovine enamel. *Caries Res* 1991; 25(2):81-7.
20. Young WG. Tooth wear: diet analysis and advice. *Int Dent J* 2005; 55(2):68-72.
21. Imfeld T. Dental erosion, definition classification and links. *Eur J of Oral Sci* 1996; 104 (2(Pt 2)):151-5.
22. Grenby TH, Phillips A, Desai T, Mistry M. Laboratory studies of the dental properties of soft drinks. *Br J Nutr* 1989; 62(2):451-64.
23. Jaâfoura S, Khemiss F, Kammoun D, Chebbi R, Baccouche C, Ghouli-Mazgar S. Dental erosion and tea: A systematic review. *Int J Sci Res* 2014; 3(11):2436-9.
24. Hughes JA, West NX, Parker DM, van den Braak MH, Addy M. Effects of pH and concentration of citric, malic and lactic acids on enamel, in vitro. *J Dent* 2000; 28(2):147-52.