


Investigation of the Erosive Potential of Different Types of Alcoholic Beverages

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Abstract

Objective: To evaluate the erosive potential of different alcoholic beverages according to pH, titratable acidity and buffering capacity. **Material and Methods:** Thirteen industrialized alcoholic beverages of different brands were selected and divided into five groups according to their type and composition. 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 Shapiro-Wilk test. The pH of alcoholic beverages ranged from 2.49 (Miks Ice Tea - Green Fruits) to 7.64 (Smirnoff). The highest values of acid titration (4.68) and buffer capacity (19.97) were observed in Smirnoff Ice. The following correlations ($p < 0.01$) were noted between: pH and titratable acidity; buffering capacity and pH; buffering capacity and titratable acidity. **Conclusion:** Some beers and alcopops presented erosive potential due to their lower pH associated with high acid titration values. The whisky and sugarcane liquor examined were not potentially erosive.

Keywords: Alcoholic Beverages; Alcoholism; Adolescent; Tooth Erosion; Dental Enamel.

Introduction

Dental erosion is defined as a loss of dental hard tissue without bacterial involvement [1,2]. It has a multifactorial etiology and is caused by frequent teeth exposure to an acidic environment [1,2]. Acids associated with dental erosion may be from the stomach, diet [2], or from some working environment atmospheres [3]. The acids present in diets, like drinks and foods, have been the focus of current students. Nowadays, a change is being noted in habits with a high consumption of acidic foods and drinks and their relation to the increase in dental erosion worldwide [4].

Alcoholic beverages are defined as drinks that have more than 2.8% ethanol in their composition [5], with some variations according to countries' regulations [6]. In Brazil, only beverages with more than 0.5% alcohol by volume are considered alcoholic [6]. The per capita consumption of alcohol in Brazil is approximately 8.7 liters, considerably higher than the 6.2-liter average for the rest of the world [6].

The main alcoholic beverage researched is wine [5,7-9] since its professional tasting is associated with a high risk of dental erosion, and its severity tends to increase with years of occupational exposure [7]. Beer is the second most-consumed alcoholic beverage in the world [6], and it is the most consumed in Brazil with an annual consumption rate of about 57 liters per person [10] followed by sugarcane liquor [6]. However, among young adults and teenagers, mainly females, there is a preference for alcopop due to its more pleasant flavor [11-13].

Although some studies evaluated the erosive potential of alcoholic beverages, they have been restricted to wines [5,8] and some flavors and brands of beers [14,15] and alcopops [16,17]. Therefore, it is necessary to analyze other alcoholic beverages, such as whiskey and sugarcane liquor, as well as beers and alcopops of other brands and flavors since different compositions can alter their erosive potential [14,15]. Thus, this study aims to analyze the erosive potential of five types of alcoholic beverages frequently consumed by Brazilian people using their initial pH value, titratable acidity (TA) and buffering capacity (BC). The null hypothesis states that there are no differences between the erosive potential of the analyzed alcoholic beverages.

Material and Methods

Selection of Beverages

Thirteen industrialized alcoholic beverages of different brands were selected from local markets, and divided into five groups, according to their type and composition as described in Table 1. Beverages were stored according to manufacturers' instructions. Mineral water and a cola-based soft drink were used as negative and positive controls, respectively.

Table 1. Type and brand of the alcoholic beverages analyzed in this study.

Type of Beverage (Flavor)	Composition	Brand / Manufacturer	Lot
Beer (Pilsen)	Water, malt, unmalted sorghum, carbohydrates, hops, antioxidants: INS 316 and INS 221 and stabilizer INS 405. Alcohol by volume: 4,7%	Skol / Ambev S.A.	Not Informed
Beer (Pilsen)	Water, malt, unmalted sorghum, carbohydrates, hops, antioxidants: INS 316 and INS 221 and stabilizer INS 405. Alcohol by volume: 5%	Brahma / Ambev S.A.	Not Informed
Beer (Pilsen)	Water, malt, unmalted sorghum, carbohydrates, hops, antioxidants: INS 316 and INS 221 and stabilizer INS 405. Alcohol by volume: 4,9%	Antarctica / Ambev S.A.	Not Informed

Beer (Lager Premium)	Water, Pure Barley Malt, Hops, Yeast and Gluten. Alcohol by volume: 5%	Heineken / CKBR S.A.	5202076B1451
Alcopop	Water and rectified alcohol. Alcohol by volume: 37.5%	Vodka SMIRNOFF No.21 / DIAGEO	Not Informed
Alcopop (Lemon)	Carbonated water, vodka, sugar, acidulants: citric acid and tartaric acid, natural lemon flavorings, acidity regulators: sodium citrate and malic acid and preservative sodium benzoate. Gluten-free. Alcohol by volume: 5%	Smirnoff Ice / DIAGEO	LE 462 L2
Alcopop (Lemon)	Water, sugar, simple alcoholic distillate of cereals, acidulants: INS 330 and INS 334, natural lemon flavor, INS 150C dye and acidity regulators: INS 331III and INS 296. Gluten-free. Alcohol by volume: 8%	Skol Beats Senses / Ambev S.A.	Not Informed
Alcopop (Green fruits with green tea)	Vodka, sugar, preservative sodium benzoate (INS 211), acidulants: citric acid (INS 330), malic acid (INS 296) and tartaric acid (INS 334), pear extract, kiwifruit extract, green tea extract, aroma identical to natural pear, INS 133 and INS 102 dyes, and carbonated water. Alcohol by volume: 5.5%	Miks Ice Tea / Distribuidora de Bebidas F Antônio Chiamulera Ltda	Not Informed
Alcopop (Green apple with mate and tonic water)	Vodka, sugar, preservative sodium benzoate (INS 211), acidulants: citric acid (INS 330), tartaric acid (INS 334), EDTA sequestrant (INS 385), malic acid (INS 296), green mate extract, aroma identical to natural apple green, aroma identical to natural tonic water and carbonated water. Alcohol by volume: 5.5%	Miks Ice Tea / Distribuidora de Bebidas F. Antônio Chiamulera Ltda	Not Informed
Red Wine (Soft Burgundy)	Fermented grapes and sugar. Preservatives INS 202 and INS 220. Alcohol by volume: 10.1%	Quinta do Morgado / Fante Ind. Bebidas Ltda	0815 13:54 L3
Whisky (Scotch)	Malt whisky, grain whisky distilled and aged in the origin, water and caramel dye INS 150 ^a . Alcoholic graduation 40% of the volume.	Teacher's / Pernord Ricard Brasil Ind. e Com. Ltda	15147R345001057
Sugarcane Liquor	Distillation of fermented sugarcane juice and sugar. Alcohol by volume: 40%	Pitú / Pitú Ltda	1820840
Sugarcane Liquor	Distillation of fermented sugarcane juice, sugar and water. Alcohol by volume: 39%	51 Pirassununga / Companhia Müller de Bebidas Nordeste	200914
Mineral Water	Strontium: 0.027. Calcium: 0.614. Potassium: 0.500. Sodium: 94.100. Vanadium: 0.087. Sulfate: 39.26. Carbonate: 79.82. Bicarbonate: 33.77. Fluoride: 0.45. Nitrate: 0.31. Chloride: 2.83. Bromide: 0.02.	Ibira / Ibira Água Mineral Natural Ltda	140612
Cola-based Soft Drink	Carbonated water, sugar, kola nut extract, caramel colorant IV, phosphoric acid as the acidifier, caffeine and natural aroma.	Coca-Cola / The Coca-Cola Company	21608SP

Analysis of pH, Titratable Acidity (TA), and Buffering Capacity (β)

For chemical analyses, 50 mL of each beverage at room temperature (27°C) was used to measure the initial pH and titratable acidity for pH levels 5.5 and 7.0 (total amount of base needed to raise the pH of the substance to 5.5 or 7.0). The beverages pH levels were measured immediately after opening it using a calibrated electrode coupled to a pH meter (Orion, model 420A, Thermo Fischer Science Inc., Waltham, MA). After this, the freshly-opened alcoholic beverage was placed in a beaker with a non-heating magnetic stirrer until a stable reading was obtained.

The TA was estimated with the addition of increments of 0.2 mL of 1M of standard NaOH solution, until pH reached 5.5 and 7.0, at room temperature (27°C). Finally, the buffering capacity (β) was calculated with the values of pH and quantity of NaOH added to the solution, using the formula proposed [18]: $\beta = \Delta C / \Delta pH$, which ΔC is the amount of base used and ΔpH is the change in pH caused by the addition of the base. All measurements for pH, TA and β were carried out in triplicate and an average result was obtained for each beverage.

Statistical Analysis

Results were evaluated throughout descriptive and inferential analyses. The Shapiro-Wilk test was used to identify if the data had normal distribution. ANOVA, followed by Tukey test was used to compare the pH, TA and β between the tested groups. Pearson correlations were used to assess bivariate associations between the different chemical properties. The statistical calculations were performed using the SPSS 19 software. The significance level was set at 0.05.

Results

The data had a normal distribution by the Shapiro-Wilk ($p > 0.05$) test, allowing the use of parametric tests. A statistically significant relationship was observed between the groups analyzed (ANOVA, $p < 0.05$): initial pH ($F = 1463.991$; $df = 14$; $p < 0.001$), titratable acidity for pH 5.5 ($F = 201.109$; $df = 12$; $p < 0.001$), titratable acidity for pH 7.0 ($F = 201.218$; $df = 12$; $p < 0.001$) and buffering capacity ($F = 153.780$; $df = 12$; $p < 0.001$).

Among the alcoholic beverages evaluated, it was noted that the lowest 2.49 pH was from Miks Ice Tea (Green Fruits), while the highest 7.64 was from the Smirnoff Red Triple. Furthermore, it was observed that the highest value of titratable acidity and buffering capacity were found on alcopop (Smirnoff Ice) and for both variables, the lowest values were obtained from Pitú (Table 2).

Table 2. The mean (\pm DP) of initial pH, titratable acidity (mmol/l NaOH to reach pH 5.5 and 7.0) and buffering capacity (β) of each tested beverage.

Group	Beverages	pH	TA		β
			pH 5.5	pH 7.0	
Beer	Skol	4.05 \pm 0.05	0.57 \pm 0.29	1.87 \pm 0.15	12.20 \pm 0.81
	Skol Beats	2.51 \pm 0.05	2.87 \pm 0.15	4.55 \pm 0.05	18.59 \pm 0.36
	Brahma	4.11 \pm 0.01	0.57 \pm 0.03	2.05 \pm 0.13	13.64 \pm 0.88
	Antarctica	3.85 \pm 0.05	0.63 \pm 0.03	2.08 \pm 0.16	12.7 \pm 0.88
	Heineken	4.26 \pm 0.03	0.60 \pm 0.05	2.10 \pm 0.22	14.69 \pm 1.58
Sugarcane Liquor	Pitú	4.29 \pm 0.02	0.02 \pm 0.00	0.03 \pm 0.00	0.22 \pm 0.00
	51	4.01 \pm 0.08	0.04 \pm 0.00	0.06 \pm 0.01	0.38 \pm 0.05
Alcopop	Smirnoff Red Triple	7.64 \pm 0.35	0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
	Smirnoff Ice	2.70 \pm 0.10	3.22 \pm 0.13	4.68 \pm 0.13	19.97 \pm 0.17
	Miks Ice Tea (Green Fruits)	2.49 \pm 0.03	2.67 \pm 0.16	4.10 \pm 0.13	16.79 \pm 0.59
	Miks Ice Tea (Green Apple)	2.71 \pm 0.01	2.15 \pm 0.05	3.33 \pm 0.21	14.57 \pm 0.83
Red Wine	Quinta do Morgado	3.12 \pm 0.01	3.3 \pm 0.48	3.87 \pm 0.55	18.47 \pm 2.49
Whisky	Teacher's	3.80 \pm 0.03	0.04 \pm 0.01	0.06 \pm 0.01	0.40 \pm 0.04
Controls	Ibira	10.11 \pm 0.02	0	0	0
	Coca-Cola	2.47 \pm 0.01	0.63 \pm 0.15	1.97 \pm 0.21	8.36 \pm 0.86

Analyzing all the beverages, including the control groups, it was observed that the positive control had the lowest pH (2.47). However, this control did not have the highest titratable acidity and buffering capacity. Besides that, it was noted that all alcoholic beverages had a statistically different initial pH from negative and positive control, except for the Skol Beats and the Miks Ice Teas with green fruits or green apple (Table 3).

A significant correlation was observed between buffering capacity and initial pH ($r = -0.531$, $p < 0.01$); and titratable acidity (pH 7.0) with buffering capacity ($r = +0.947$, $p < 0.01$) and initial pH ($r = -0.743$, $p < 0.001$).

Table 3. The average of the initial pH values of the alcoholic beverages evaluated in comparison to negative and positive controls.

Groups	Beverages	pH Initial				
		Mean (DP)	Mineral Water Mean (DP)	p-value	Coke Mean (DP)	p-value
Beer	Skol	4.05 ± 0.05	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
	Skol Beats	2.51 ± 0.04	10.11 ± 0.02	0.000	2.47 ± 0.01	1.000
	Brahma	4.11 ± 0.01	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
	Antarctica	3.85 ± 0.04	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
	Heineken	4.26 ± 0.02	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
Sugar Cane Liquor	Pitú	4.29 ± 0.03	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
	51	4.01 ± 0.07	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
Alcopop	Smirnoff Red Triple	7.64 ± 0.35	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
	Smirnoff Ice	2.70 ± 0.11	10.11 ± 0.02	0.000	2.47 ± 0.01	0.039
	Miks (Green Fruits)	2.49 ± 0.02	10.11 ± 0.02	0.000	2.47 ± 0.01	1.000
	Miks (Green Apple)	2.71 ± 0.01	10.11 ± 0.02	0.000	2.47 ± 0.01	0.146
Red Wine	Quinta do Morgado	3.12 ± 0.01	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001
Whisky	Teacher's	3.80 ± 0.02	10.11 ± 0.02	0.000	2.47 ± 0.01	<0.001

Discussion

Alcoholism has become a worrisome world problem [6]. In the Western Pacific and South-East Asia regions, the consumption of alcoholic beverages has increased considerably. In Brazil, since the 1960s, the annual consumption of alcohol for individuals aged 15 years or older has almost tripled [19]. According to the age range, Brazilians aged between 18–29 years represent the age range with the greatest proportion of consumption of alcoholic beverages [20]. Although some studies have evaluated the erosive potential of alcoholic beverages, these have been restricted to wines [5,8] and some flavors and brands of beers [14,15] and alcopops [16,17].

Dental erosion is the acid dissolution of dental hard tissues caused by multiple extrinsic or intrinsic factors [1,2]. Acids from gastro-esophageal reflux disease and vomiting represent the intrinsic factors and those from occupational exposure and diet correspond to the extrinsic factors [1]. In this thought, the excessive use and frequency of some types of alcoholic beverages can be associated with both factors of dental erosion due to its chemical properties and predisposition to cause vomiting. Therefore, the exaggerated and frequent consumption of alcohol is one of the factors related to dental erosion [14].

In the present study, all alcoholic beverages analyzed had an initial pH higher and statistically different from the positive control, except for the Skol Beats and the beverages of Miks brand. It can be observed that only whisky (Teacher's), the sugarcane liquors (Pitú and 51) and the beers (Skol, Brahma and Heineken) had titratable acidity for pH 5.5 lower than Coke. The same view is noted for the titratable acidity reached to pH 7.0, except for Brahma and Heineken beers. Moreover, all the alcohol drinks had buffering capacity higher than the positive control, except Pitú, 51, Smirnoff Red Triple and Teacher's. It is important to emphasize that Smirnoff Red Triple had a pH higher than 7.0 and because of that there was no need to measure its titratable acidity and buffering capacity. Interestingly, the vast majority of the analyzed beverages had low pH values (varying from 2.49 to 7.64), which may lead to enamel tooth demineralization. In general, it can be concluded that all beverages evaluated were able to cause enamel tooth demineralization, only considering that pH values lower than 5.5 can erode tooth enamel. However, some studies have reported that only drinks with a pH lower than 4.0 can actually cause dental erosion [15]. Consequently, Skol, Brahma, Heineken, Pitú, 51 and

Smirnoff Red Triple should not cause enamel erosion. Analyzing according to the type of alcoholic beverages, alcopop was the group that showed the lowest pH values, probably related with its composition.

Alcopops are constituted by a maximum of 5% alcohol by volume, sugars, citric and malic acid [20] with a pH around 3 [16,18], corroborating the values found in most of the alcopops analyzed. In contrast, the Smirnoff Red Triple had the highest value of initial pH (7.64) between all tested alcoholic beverages. The great pH difference between Smirnoff Ice and Smirnoff Red Triple is probably the composition. Smirnoff Ice is composed of citric and tartaric acids, sugar, flavoring and acid regulators, while Red Triple is only composed of water and alcohol. In a previous study, was noted that erosive potential is determined by the total acid content and/or the type of acid that mostly composes beverages [17]. In addition, an *in vitro* study demonstrated that alcopops had a significant erosive effect on bovine enamel similar to the orange juice [16]. Finally, it is possible to note that the titratable acidity value for Smirnoff Ice was almost the double of the Coke, demonstrating the great difficulty that the saliva will have to buffer this beverage.

Regarding beers, the majority of them have a pH higher than 4.0, corroborating previous study [15]. Although, as the same trend alcopops, Skol Beats had a pH lower than 3.0, reflecting its composition with the addition of lemon juice. Furthermore, it can be observed that Heineken showed similar titratable acidity value for pH 5.5 compared with other beers, even with the highest initial pH compared to the others. Thus, it demonstrates the difficulty of the Heineken group to buffer, agreeing with the data presented by other authors [14] in which the Heineken was the only beer that caused enamel surface loss by microhardness after 5 minutes exposure. It is speculated that pure barley malt is one of the reasons for Heineken's behavior [14]. The malted barley is fermented by yeasts and various organic acids (such as lactate, succinate and pyruvate) are excreted, including citrate [10]. This may explain its erosive power due to its ability to chelate the calcium present in dental enamel hydroxyapatite [22]. Therefore, it can be assumed that in the Heineken fermentation process, more citrate should be produced and, if this acid is not completely consumed during this process, the finished beer can present erosive properties [14]. The other beer analyzed had replacements (i.e., supplements) including part of the malted barley in its composition, reducing the citrate production. Therefore, according to beers types and brands [14,15], there are clear differences between their erosive potential, demonstrating the importance of erosive potential studies to analyze diverse beers.

The wine analyzed had a pH value lower than 4.0 with a high titratable acidity due probably to natural and organic acids present in its composition. The relation between wine-tasting professional and their higher risk of suffering erosion related to the great acid-tooth contact is already known [5,7]. On the other hand, sugarcane liquors (Pitú and 51) did not demonstrate erosive potential, having even a pH around 4.0, because of its very low acid titrations, presumably reflecting its composition based on alcohol, sugar and water. Finally, the whisky tested also showed an initial pH lower than 4.0, but both its acid titrations and buffering capacity were lower than Coke, demonstrating that the saliva will have no difficulty in buffering it.

Although the beverage's chemical characteristics such as pH, titratable acidity and buffering capacity are important for the analysis of their erosive potential, the presence of acid components [1,3,5,22] and the concentration of calcium and phosphate [1,14,15,18] can also perform a relevant role in their potential. Therefore, discussions about the beverage composition are one of the most relevant subjects in the dental erosion context [14]. In addition, some habits like smoking and the use of drugs are associated with alcohol consumption and may also cause dry mouth [23]. Associated with this, gastric problems, reflux episodes, and vomiting become frequent when there is high and frequent consumption of alcoholic beverages [24]. And all






that can either contribute to enamel loss effect potentializing tooth-structure loss [21] and increasing the risk of dental erosion [23].

It is worth emphasizing that the present research has some limitations. It was analyzed only a few chemical properties of alcoholic beverages. Also, it was not used pH cycling and the presence of saliva and acquired film were not considered. They are important biological factors that influence and modulate the process of dental erosion [14,15,9]. However, this study is important to alert dentists, especially those attending teenagers, on the risks of dental erosion associated with alcohol consumption. Further, preventive advice can be given to teenagers and their parents, as avoiding brushing their teeth shortly after the consumption of acidic beverages and the importance of regular visits to the dentist [21]. Therefore, further studies should be carried out to evaluate other types and brands of alcoholic beverages, even as *in vitro* studies with pH cycling simulating erosive challenges and analysis of the enamel and dentin surface using profilometry.

Conclusion

The findings of this study indicate that some beers and alcopops may present dental erosive potential due to their lower pH associated with high acid titration and buffering capacity values. The whisky and sugarcane liquors examined were not potentially erosive.

Authors' Contributions

IAM	 0000-0002-3631-0030	Conceptualization, Methodology, Investigation, Formal Analysis and Writing – Original Draft Preparation.
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All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

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