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ORIGINAL ARTICLE

Evaluation of Titratable Acidity and pH Level of Different Coffee Drinks- An In-vitro Study

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ABSTRACT

Aim: This in-vitro study aims to assess the acidity of coffee drinks with different combinations and evaluate their pH level in relation to the critical pH of dental enamel (5.5) and dentin (6.7).

Methodology: All beverages (black coffee, black coffee with milk, Arabic coffee, and Turkish coffee) were mixed according to the manufacturer's instructions with deionized water and cooled down to room temperature (25ºC). The pH of the solutions was compared with that of the control groups, i.e., 0.3% citric acid and distilled water as positive and negative controls, respectively, at 10mins, 30mins, 1hr, and 2hrs. (0.1N) NaOH solution was introduced to the tested solutions to reach a pH of 8 to evaluate the titratable acidity.

Results: Instant black coffee was found to be the most acidic with a pH value of (5.13 ± 0.02), whereas instant black coffee with milk was the least acidic with a pH of (6.20 ± 0.01). Instant black coffee with milk was found to have the highest concentration of titratability with a value of (16.2 ± 0.1) mL of (0.1 N) NaOH, to reach a pH of 8.

Conclusion: This in-vitro study showed that the tested solutions can reach the critical pH that can cause enamel and dentin erosion. Also, the data showed little correlation between the pH and titratable acidity titrated to a pH value of 8.

MeSH Keywords: Dental erosion, pH level, titratable acidity, enamel, dentin, teeth, coffee.

INTRODUCTION

Coffee is a worldwide popular beverage consumed in approximately 1.6 billion cups daily.[1] Coffee is dark in color, bitter in taste, sometimes acidic, and has a boosting effect in humans, due to its caffeine element.[2] While coffee is among the most popular and highly consumed beverage in many countries, its negative effects on oral health cannot be overlooked. The effects of coffee on hard tooth surfaces have been demonstrated in studies, ranging from macroscopic to microscopic changes including intrinsic staining, thinning of enamel layers, loss of continuity in the enamel-dentin junction, and wide spaces in dentin tubules at the histological level.[3] In addition, decalcification of teeth exposed to coffee has been reported, which corresponds to dental erosion.[3] Dental erosion is a multifactorial condition that causes irreversible loss of dental hard tissues without bacterial involvement.[4] Its prevalence has increased significantly due to frequent exposure of teeth to acids, mostly through acidic beverages consumption.[5,6] Many studies have been conducted to test the erosive effect of different beverages, where most of them concentrated on the erosive potential of soft drinks and some on hot tea and coffee.[7,8] According to Al-Majed et al, several permanent maxillary incisors with dental erosion in Saudi Arabian children were associated with frequency of night beverage intakes and prolonged duration of beverage time in the oral cavity.[9] For the dental enamel and dentin to be dissolved, the pH has to reach what is called the critical pH. It is noteworthy that critical pH is not a fixed value, instead, it is inversely proportional to the calcium and phosphate concentration in the solution.[10] Approximately the critical pH for enamel is 5.5 and 6.7 for dentin.[11]

Dental erosion is considered an oral health concern in Middle Eastern countries. Erosion prevalence rates in Saudi Arabia have been reported as 34% for 5 to 6 years old and 26% for 12- to 14-year-old boys.[12] Erosive potential depends on two factors: the low pH and the buffering capacity.[9] The buffering capacity which is defined as the amount of strong base needed to titrate the pH for a specific solution to a certain pH is measured by titratable acidity (TA).[13]

Although there is high consumption of coffee worldwide, the studies focusing on the erosive potential of coffee are limited and have not mentioned, tested, or compared the pH level nor the titratable acidity of different types of coffee drinks. Moreover, there has been no study done to the best of our knowledge focusing on the erosive potential of coffee with the presence of different additives such as milk. Therefore, this study focuses to measure the acidity and titratable acidity of four types of instant coffee with different additives (black coffee, black coffee with milk, Arabic coffee, and Turkish coffee). This was followed by assessing the correlation between the pH, the TA with the enamel and dentin critical pH.

METHODOLOGY

Experimental design: In this study four types of instant coffee solutions were prepared then their acidity was measured. The study investigated two outcomes: the pH and TA were measured at four-time points; at baseline, after

10mins, 30mins, 1hr, and 2hrs. The pH and the TA measurements were performed by a calibrated examiner.

Standardizing the variables, assessing each beverage's pH level and titratable acidity: All beverages were mixed according to the manufacturer's instructions with deionized water and cooled down to room temperature (25ºC). The pH level and titratable acidity of the prepared tested solutions were measured using a pH meter (Seven Compact S220-Basic, pH/Ion benchtop meter). Then, the results were compared with the results of the control groups, which are 0.3% citric acid with natural pH (2.4- 2.6) and distilled water as positive and negative controls, respectively. To determine pH changes over time, the pH was measured for each beverage after 10mins, 30mins, 1hr, and 2hrs. ANOVA test compared the variation of pH across the tested solutions (One time reading).

The buffering capacity of each solution was measured by introducing (0.1N) NaOH solution using Pipette controller (Eppendorf Easypet® 3), to reach a pH of 8. The readings were repeated thrice, recorded in the assessment sheet, and analyzed using the ANOVA test.

RESULTS

PH level: The results of the pH level of the tested solutions are shown in Table (1) and Graph (1). Kruskal-Wallis ANOVA displays that there is a statistically significant difference in the mean rank of pH values of the beverages at all time intervals.($p< 0.05$). Instant black coffee was found to be the most acidic pH value of (5.13 ± 0.02), whereas instant black coffee with milk was the least acidic with a pH of (6.20 ± 0.01). A slight difference was noticed between the pH level of the instant Arabic coffee which was (5.64 ± 0.05) and the instant Turkish coffee which was (5.69 ± 0.03). For the control group, the distilled water was (7.2 ± 0.2), and the citric acid was (2.52 ± 0.4).

Titratable acidity: The total titratable acidity of the tested solutions was expressed in mL of (0.1 N) NaOH required to titrate 10g of coffee to a pH of 8 as shown in Table (2). Instant black coffee with milk was found to have the highest concentration of total titratable acidity of (16.2 ± 0.1) mL of (0.1 N) NaOH, to reach a pH of 8. The Instant Arabic coffee was observed to have the lowest concentrations of total titratable acidity about (3.2 ± 0.2) mL of (0.1 N) NaOH. For the Instant black coffee, the titratable acidity was (11.5 ± 0.01) mL of (0.1 N) NaOH and (6.7 ± 0.3) mL of (0.1 N) NaOH for Instant Turkish coffee. The data in this study showed no correlation between the pH and titratable acidity titrated to pH 8.

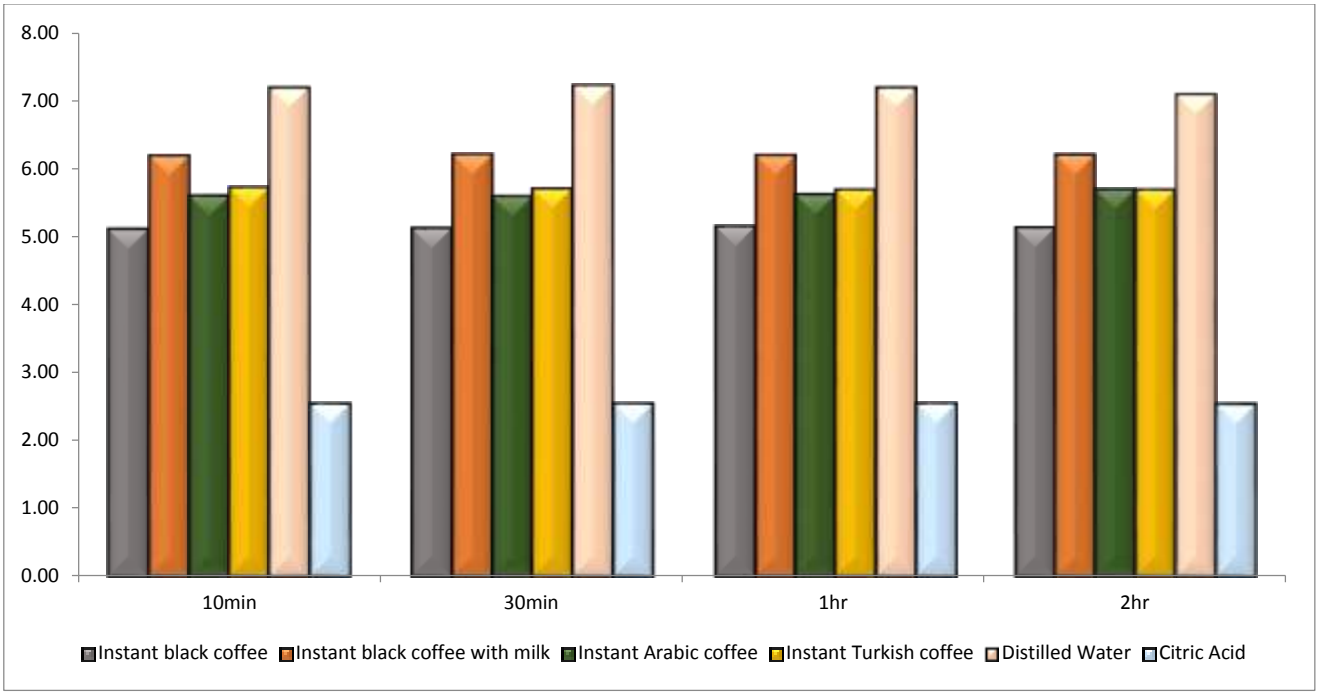
Table 1: Comparison of mean pH of the beverages and controls at 10 min, 30 min, 1hr, and 2 hrs of time intervals.

Duration	Tested solutions	N	Mean	SD	Mean Rank	P-Value
10min	Instant black coffee	3	5.11	0.00	5	0.005*
	Instant black coffee with milk	3	6.19	0.01	14	
	Instant Arabic coffee	3	5.59	0.00	8	
	Instant Turkish coffee	3	5.72	0.01	11	
	Distilled Water	3	7.20	0.00	17	
	Citric Acid	3	2.53	0.01	2	
30min	Instant black coffee	3	5.12	0.00	5	0.005*
	Instant black coffee with milk	3	6.21	0.01	14	
	Instant Arabic coffee	3	5.59	0.01	8	
	Instant Turkish coffee	3	5.70	0.01	11	
	Distilled Water	3	7.23	0.06	17	
	Citric Acid	3	2.53	0.01	2	
1hr	Instant black coffee	3	5.15	0.01	5	0.005*
	Instant black coffee with milk	3	6.20	0.00	14	
	Instant Arabic coffee	3	5.61	0.00	8	
	Instant Turkish coffee	3	5.69	0.00	11	
	Distilled Water	3	7.20	0.00	17	
	Citric Acid	3	2.53	0.00	2	
2hr	Instant black coffee	3	5.13	0.00	5	0.005*
	Instant black coffee with milk	3	6.21	0.00	14	
	Instant Arabic coffee	3	5.68	0.01	8.5	
	Instant Turkish coffee	3	5.69	0.00	10.5	
	Distilled Water	3	7.10	0.00	17	
	Citric Acid	3	2.52	0.00	2	

Table 2: The total titratable acidity (TA) of the tested solutions in mL of (0.1N) NaOH required to titrate 10g of coffee to a pH of 8.

Tested solutions	N	Total Acidity pH = 8 (mL of 0.1 N NaOH)	Std. Deviation
Instant black coffee	3	11.5 ± 0.01	0.01
Instant black coffee with milk	3	16.2 ± 0.01	0.01
Instant Arabic coffee	3	3.2 ± 0.02	0.02
Instant Turkish coffee	3	6.7 ± 0.03	0.02
Citric Acid	3		0.03
Total	15	54.52± 0.06	19.23

Graph 1: Distribution of mean pH of the beverages at different time intervals.



DISCUSSION

pH value and titratable acidity: Although instant black coffee with milk had the highest pH value (6.20 ± 0.01) among the rest of the tested solutions (Table 2), the instant black coffee with milk required more concentration of (0.1N) of NaOH to reach a pH of 8. which concludes that the pH and titratable acidity do not correlate. This is concurrent with the findings of Gloss et al.[14] In this study, the pH level and titratable acidity were repeated thrice by the principal investigator. None of the tested solutions were demonstrated below the enamel critical pH value (pH5.5) except for the instant black coffee with a pH of (5.13 ± 0.02). On the other hand, all the four tested solutions were below the dentin critical pH value (6.7). The results revealed no significant difference in pH across time. Instant black coffee with milk was the highest in pH value. This shows that additives may act positively or negatively on the pH value. According to Gedalia et.al. milk can also have a rehardening ability after a tooth has been exposed to acidic beverages.[15] Although the instant black coffee with milk was the highest in the pH value (6.20 ± 0.01), it required more of (0.1N) of NaOH to reach a pH of 8. This could be attributed to the proteins present, bacterial content, and the age of raw milk.[16]

In the oral cavity, salivary flow helps the oral environment to regain the optimum pH level in two ways, mechanically by the brushing effect and rinsing the surfaces, and chemically by its composition of bicarbonate ($HCO3^-$) which is the major buffer system present in saliva.

Limitations: The ability of the oral cavity in remineralization must be considered by using a "Mouth Simulator environment" which was not used in this study. All coffee solutions were set at (25 ^{0}C) to standardize the variables, although that would eliminate the effects of temperature.

CONCLUSION

Despite its popularity, some types of coffee can have an erosive effect on dental enamel and dentin based on the pH level. The effect of coffee drinks and low pH liquids on the teeth sample is not fully captured due to the limitation to simulating the oral environment. Results of this study revealed that instant black coffee was the most acidic whereas instant black coffee with milk was the least acidic among the tested beverages. In conclusion, different types of coffee with different additives can change the pH level of a solution and adding milk to black coffee can increase its pH. More investigational study is required to assess the erosive effect on a natural tooth surface to see its effects at a microscopic level.

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REFERENCES

1. Al Arabiya English. (2020, May 20). Saudi coffee market is valued at $3.9bln. https://english.alarabiya.net/business/markets /2014/12/09/ Saudi-coffee-market-valued-at-SR15b
2. Lee, J. (2021, April 30). Exploring Saudi Arabia's Growing Specialty Coffee Scene. Perfect Daily Grind. https://perfectdailygrind.com/2018/10/exploring -Saudi-Arabia's-growing-specialty-coffee-scene/
3. Manno SHC, Manno FAM, Ahmed I, Ahmed R, Shu L, Li L, Xu S, Xie F, Li VW, Ho J, Cheng SH, Lau C. Spectroscopic examination of enamel staining by coffee indicates dentin erosion by sequestration of elements. Talanta. 2018 Nov 1;189:550-559. DOI: 10.1016/j.talanta.2018.07.032.
4. Imfeld T. Dental erosion. Definition, classification, and links. Eur J Oral Sci. 1996 Apr;104(2 (Pt 2)):151-5. DOI: 10.1111/j.1600-0722.1996.tb00063.x
5. Zero D.T. Etiology of dental erosion–extrinsic factors. Eur. J. Oral Sci. 1996;104(2 (Pt 2)):162–177. DOI: 10.1111/j.1600-0722.1996.tb00065.x.

6. 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 Aug;26(8):624-30. DOI: 10.1046/j.1365-2842.1999.00433.x.
7. Ehlen L, Marshall T, Qian F, Wefel J, and Warren J. Acidic beverages increase the risk of in vitro tooth erosion. Nutr Res. 2008; 28(5): 299–303. DOI: 10.1016/j.nutres.2008.03.001
8. Kitchens M, Owens BM. Effect of carbonated beverages, coffee, sports, high energy drinks, and bottled water on the in vitro erosion characteristics of dental enamel. J Clin Pediatr Dent 2007; 31: 153-9
9. Al-Majed I, Maguire A, Murray JJ. Risk factors for dental erosion in 5-6-year-old and 12-14-year-old boys in Saudi Arabia. Community Dent Oral Epidemiol. 2002 Feb;30(1):38-46. DOI: 10.1034/j.1600-0528.2002.300106.x.
10. Dawes C. What is the critical pH and why does a tooth dissolve in acid? J Can Dent Assoc. 2003 Dec;69(11):722-4. PMID: 14653937.
11. Sung YH, Son HH, Yi K, Chang J. Elemental analysis of caries-affected root dentin and artificially demineralized dentin. Restor Dent Endod. 2016 Nov;41(4):255-261. DOI: 10.5395/rde.2016.41.4.255.
12. Ehlen LA, Marshall TA, Qian F, Wefel JS, Warren JJ. Acidic beverages increase the risk of in vitro tooth erosion. Nutr Res. 2008 May;28(5):299-303. DOI: 10.1016/j.nutres.2008.03.001. PMID: 19083423; PMCID: PMC2516950.
13. Tyl C & Sadler G D. pH and Titratable Acidity. Food Science Text Series,2017; 389–406. https://doi.org/10.1007/978-3-319-45776-5_22.
14. Gloess AN, Schönbächler B, Klopprogge B, et al. Comparison of nine common coffee extraction methods: instrumental and sensory analysis European Food Research and Technology = Zeitschrift fur Lebensmittel-untersuchung und -Forschung. A. 2013 Apr;236(4):607-627. DOI: 10.1007/s00217-013-1917-x.
15. Tooth enamel softening with a cola-type drink and rehardening with hard cheese or stimulated saliva in situ. Journal of Oral Rehabilitation, 18(6), 501–506. https://doi.org/10.1111/j.1365-2842.1991.tb00072.x
16. Schmidt KA, Stupar J, Shirley J E, & Adapa S. Factors affecting titratable acidity in raw milk. Kansas Agricultural Experiment Station Research Reports. 1996;2,60–62. https://doi.org/10.4148/2378-5977.3265