pH and titratable acidity levels of alcoholic and non-alcoholic beverages contrast with the threshold pH level for tooth enamel demineralization

Rozina Akter
PhD Fellow, Department of Conservative Dentistry and Endodontics, Faculty of Dentistry.
rizdinahossain11@gmail.com
Bangabandhu Sheikh Mujib Medical University

Md. Ali Asgor Moral
Dean and Chairman, Department of Conservative Dentistry and Endodontics, Faculty of Dentistry.
aliasgormoral@gmail.com
Bangabandhu Sheikh Mujib Medical University,

AKM Bashar
Professor, Department of Conservative Dentistry and Endodontics, Faculty of Dentistry.
drbasharakm@gmail.com
Bangabandhu Sheikh Mujib Medical University

Md. Khalequzzaman
Associate Professor, Department of Public Health and Informatics, Faculty of Community Medicine.
romenraihan@yahoo.com
Bangabandhu Sheikh Mujib Medical University

Suvasish Das
Associate Professor Department of Prosthodontics Faculty of Dentistry.
suvasish@bsmmu.edu.bd
Bangabandhu Sheikh Mujib Medical University

ABSTRACT

Acidic drinks/ beverages can be so harmful to teeth if it is consumed regularly. A beverage's acidity level is determined by how much acid it contains from citrus or other additives. The pH scale measures this trait, but any pH level below 7.0 is considered acidic, and the lower the number, the more harmful to the tooth. To compare the pH and titratable acidity level of beverages with the threshold pH level for tooth enamel demineralization/ erosion, an in-vitro quasi-experimental study was conducted for 12 months. Total 6 samples of beverages (3 alcoholic and 3 non-alcoholic) were considered as study samples. Beer, wine, and distilled spirit as an alcoholic group, and carbonated drink, commercial fruit juice, and apple cider vinegar as a non-alcoholic group were included. the pH level of beverages was evaluated using pH Meter and titratable acidity level of beverages was evaluated by titration with .13 N NaOH strong base. Both tests were conducted at the Chemical Engineering Department, Bangladesh University of Engineering and Technology. The pH level of all included alcoholic and non-alcoholic beverages is lower than the threshold pH level (5.5). The pH level of carbonated is the lowest (2.96) and pH level of beer (4.33) is the highest. In contrast, the greatest titratable acidity level belonged to apple cider vinegar (7.50 g/L) and the lowest titratable acidity level belonged to distilled spirit (1.25 g/L). Despite the popularity of all included alcoholic and non-alcoholic beverages have extreme demineralization/ erosive effects on tooth enamel. Based on the pH level, carbonated beverage is the highest acidic and most prone to demineralize or erode enamel structure. In contrast, the highest titratable acidity level belonged to apple cider vinegar. The acidity level measurement of the beverage using pH meter differed from the acidity (g/L) level measurement by titration method.

Keywords: *pH of beverage, Titratable acidity of beverage, Threshold pH for demineralization*

1.1 Introduction

The three most common acids in non-alcoholic beverages are citric, carbonic, and acidic acid.[1,2] Alcoholic beverage or any fermented liquor such as beer, wine, or distilled spirits that contains ethyl alcohol or ethanol (CH_3CH_2OH) is considered an acidic beverage.[2,3] Although the pH level and the titratable acidity (TA) level are measures of acidity for most cases, pH is a more useful measurement. But several scientists claim that the TA is a more reliable indicator because pH measurement is more sensitive to small changes in the acidity of the products.[4] Titratable acidity is a measure of the total acidity as an approximate value (g/L). It means that the titratable acidity gives the

sum of free protons and un-dissociated acids in a solution.[5] Usually, 0.13 N NaOH (act as TA titrant) strong base is used in the measurement of TA.[5,6] To make 0.13 N NaOH, the number of equivalents of OH (1) and the sum of the atomic masses of the Na, O, and H; 22.99 + 16.00 + 1.01 = 40.00 g/mole is required. The gram equivalent weight of NaOH Eq = 40.00 / 1 = 40.00 g/eq. To make a 1N solution of NaOH, 40 grams of NaOH are dissolved in 1 liter of water. So, to make a 0.1 N solution of NaOH, it is divided by a factor of 10, and 4 grams of NaOH per liter is needed.[6] As Most of the published articles were conducted regarding the pH of carbonated drinks and acidity effect on tooth enamel structure.[7] So, it's needed to assess the pH and titratable acidity level of alcoholic and non-alcoholic beverages. The basic cause of enamel demineralization is the existence of a threshold/ critical pH value, less than 5.5.[7,8] The critical or threshold pH value is the value when the solution/ beverage is saturated with mineral particles that enamel is composed of.[8] If the pH value of the solution/ beverage is below 5.5, the solution is not saturated and it causes tooth enamel demineralization.[8,9] So, the study aimed to compare the pH of different beverages with threshold pH levels for tooth enamel demineralization.

1.2 Materials and Methods

An in-vitro experimental study was conducted from February, 2022-January, 2023 at the Department of Conservative Dentistry and Endodontics, Bangabandhu Sheikh Mujib Medical University. The total samples of 6 beverages (3 alcoholic and 3 non-alcoholic) were considered as study samples. Date-expired alcoholic and non-alcoholic beverages were excluded from the selection as the study sample. Beer, wine, and distilled spirits were included as alcoholic beverage groups. Carbonated drinks, commercial fruit juice (mango juice), and apple cider vinegar were included as a non-alcoholic group. Most consumed non-alcoholic beverages were selected by surveying authorized groceries in Dhaka city. For surveying, a face-to-face interview was done to collect the data with the help of a pretested semi-structured questionnaire and checklist. A convenient sampling technique was done for the selection of alcoholic beverages. Carbonated beverages, fruit juice, and beer were not diluted but wine (1:1), distilled spirit (1:1), and apple cider vinegar (3:25) were diluted with water. pH level of beverages was evaluated using pH Meter. Measurement of the pH level of the buffer solution was done to check the validity of pH meter. The titratable Acidity level of beverages was evaluated by titration with 0.13 N NaOH strong base at Chemical Engineering Department, BUET. To measure the TA level of the beverage, the formula was used: TA = (t * n* 75) /v in where n = normality of NaOH (0.13 N), t = titre of NaOH required (mL), and v = volume of sample used (10 mL). To check the validity of titratable acidity level measurement, titration of strong base 0.13 N NaOH (20 ml) with a weak oxalic acid solution (10 ml) was done. Phenolphthalein (3 drops) was used as an indicator. Titration of the base with beverage was performed until the pink color appears. Repetition of the titration till three concordant readings were done.

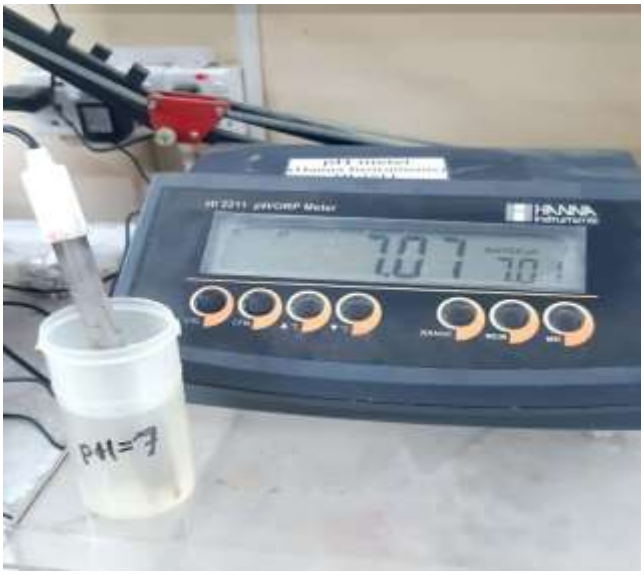


Figure-1: Measurement of pH level of Buffer Solution to check the validity of pH Meter

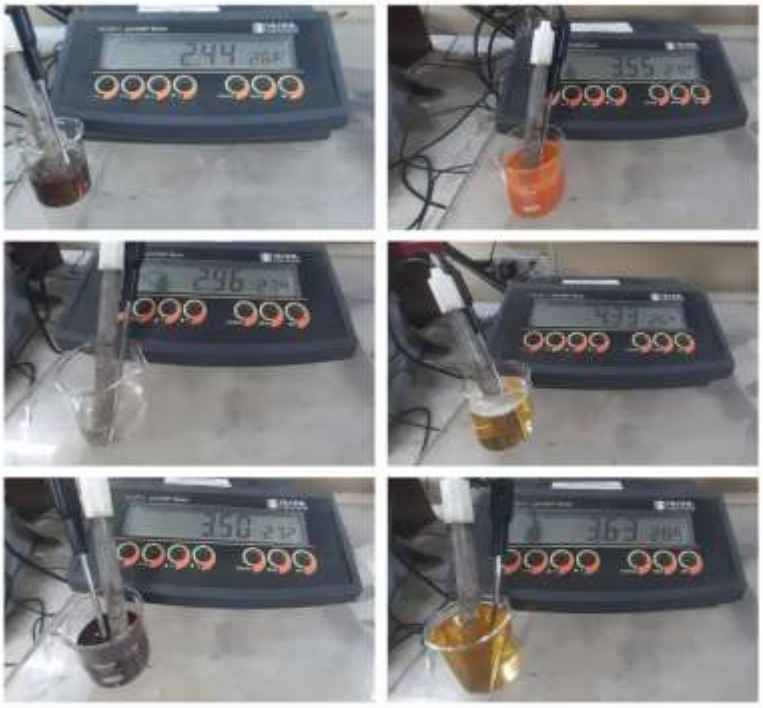


Figure-2: pH level of carbonated beverage, commercial fruit juice (mango juice), apple cider vinegar, beer, wine and distilled spirit (concentrated wine) respectively

Figure-3: Validity checking of titration with oxalic acid

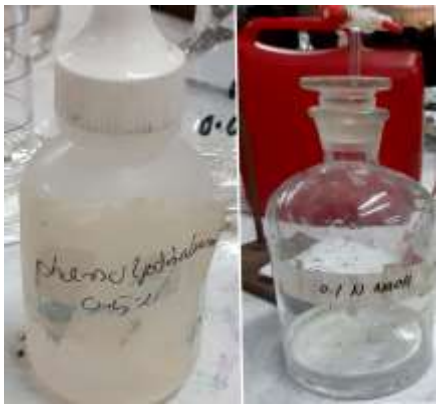


Figure-4: Phenolphthalein indicator and 0.1 N NaoH

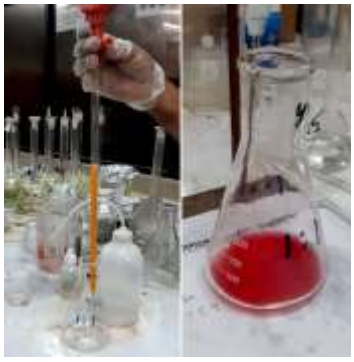


Figure-5: Commercial Fruit Juice (Mango Juice) (before and after titration)

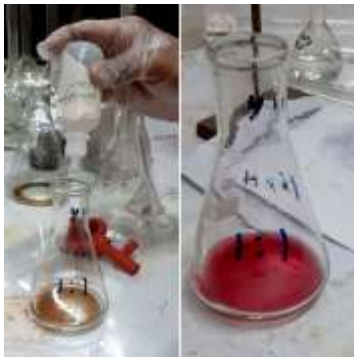


Figure-6: Carbonated Beverages (before and after titration)

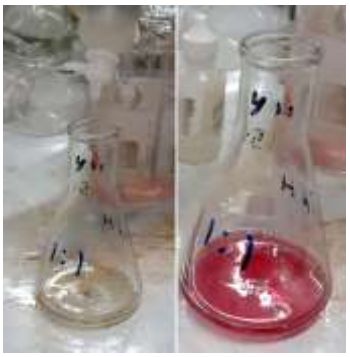


Figure-7: Distilled Spirit (before and after titration)

Figure-8: Beer (before and after titration)

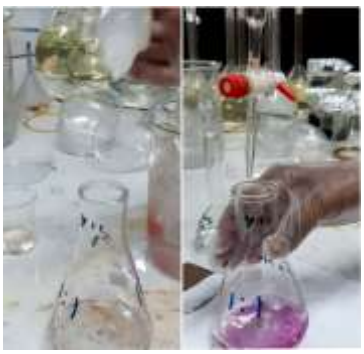
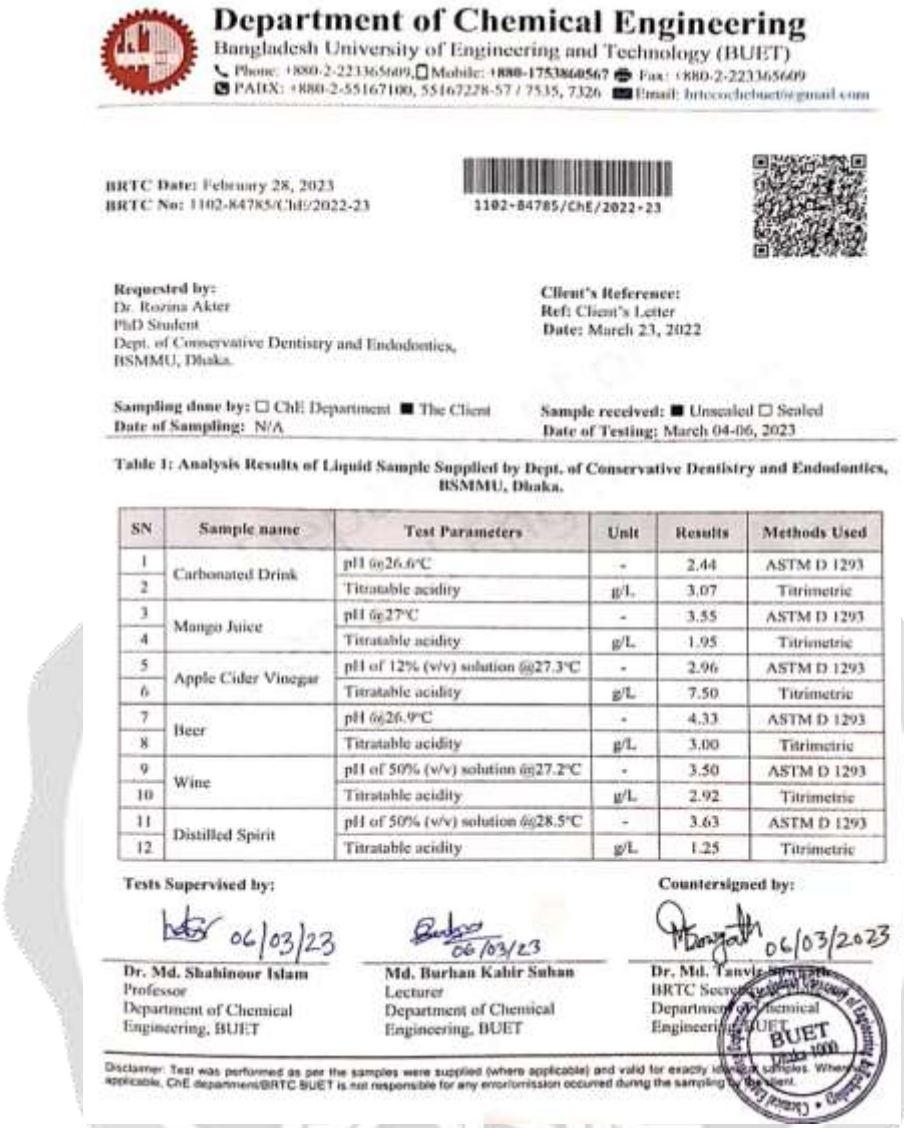


Figure-9: Apple Cider Vinegar (before and after titration)

Figure-10: Wine (before and after titration)



Department of Chemical Engineering
Bangladesh University of Engineering and Technology (BUET)
Phone: +880-2-223365609, Mobile: +880-1753860567 Fax: +880-2-223365609
PABX: +880-2-55167100, 55167228-57 / 7535, 7326 Email: hrtccchebuet@gmail.com

BRTC Date: February 28, 2023
BRTC No: 1102-84785/ChE/2022-23

1102-84785/ChE/2022-23

Requested by:
Dr. Rozina Akter
PhD Student
Dept. of Conservative Dentistry and Endodontics,
BSMMU, Dhaka.

Client's Reference:
Ref: Client's Letter
Date: March 23, 2022

Sampling done by: ☐ ChE Department ■ The Client
Date of Sampling: N/A

Sample received: ■ Unsealed ☐ Sealed
Date of Testing: March 04-06, 2023

Table 1: Analysis Results of Liquid Sample Supplied by Dept. of Conservative Dentistry and Endodontics, BSMMU, Dhaka.

SN	Sample name	Test Parameters	Unit	Results	Methods Used
1	Carbonated Drink	pH @26.6°C	-	2.44	ASTM D 1293
2		Titratable acidity	g/L	3.07	Titrimetric
3	Mango Juice	pH @27°C	-	3.55	ASTM D 1293
4		Titratable acidity	g/L	1.95	Titrimetric
5	Apple Cider Vinegar	pH of 12% (v/v) solution @27.3°C	-	2.96	ASTM D 1293
6		Titratable acidity	g/L	7.50	Titrimetric
7	Beer	pH @26.9°C	-	4.33	ASTM D 1293
8		Titratable acidity	g/L	3.00	Titrimetric
9	Wine	pH of 50% (v/v) solution @27.2°C	-	3.50	ASTM D 1293
10		Titratable acidity	g/L	2.92	Titrimetric
11	Distilled Spirit	pH of 50% (v/v) solution @28.5°C	-	3.63	ASTM D 1293
12		Titratable acidity	g/L	1.25	Titrimetric

Tests Supervised by:

06/03/23

Dr. Md. Shahinour Islam
Professor
Department of Chemical Engineering, BUET

06/03/23

Md. Burhan Kabir Suhan
Lecturer
Department of Chemical Engineering, BUET

Countersigned by:

06/03/2023

Dr. Md. Tanvir Shahriar
BRTC Secretary
Department of Chemical Engineering, BUET

BUET

Disclaimer: Test was performed as per the samples were supplied (where applicable) and valid for exactly identical samples. Where applicable, ChE department/BRTC BUET is not responsible for any error/omission occurred during the sampling by the client.

Figure-11: Image of pH level and titratable acidity level of beverages (n=6)

Statistical analysis: Distribution of quantative data regarding pH level with beverage's solution temperature (^{0}C) and titratable acidity level (g/L) of beverages were presented in table.

1.3 Results

Table-1: Distribution of pH and titratable acidity (g/L) level of study samples (n=6)

Chr. no.	Beverage name	pH	Solutions temperature	Titratable Acidity (g/L)	Threshold pH for enamel demineralization
1	Carbonated Drink	2.44	(26.6^{o}C)	3.07	5.5
2	Commercial Juice	3.55	(27^{o}C)	1.95	
3	Apple Cider Vinegar	2.96	(27.3^{o}C)	7.50	
4	Beer	4.33	(26.9^{o}C)	3.00	
5	Wine	3.50	(27.2^{o}C)	2.92	
6	Distilled Spirit	3.63	(28.5^{o}C)	1.25	

Table-1 illustrated that the pH level of all included alcoholic and non-alcoholic beverages are lower than the threshold pH level (5.5) for tooth enamel demineralization. In addition, pH level of carbonated drinks is the lowest

(2.96) and pH level of beer (4.33) is the greatest among all tested beverages. In contrast, the greatest titratable acidity level belonged to apple cider vinegar (7.50 g/L) and the lowest titratable acidity level belonged to distilled spirit (1.25 g/L).

1.4 Discussion

The present study revealed that pH levels of all included alcoholic and non-alcoholic beverages are lower than the threshold pH level (5.5) for tooth enamel demineralization.[1,2] Several previous studies such as Mulic et al found that fruit juices and carbonated beverages are risk indicators for tooth erosion/ demineralization.[4] Similarly, there was confirmed in a meta-analysis by Li et al in where carbonated beverages showed the highest and statistically significant odds ratio (2.41) for the development of dental erosions.[5] In accordance Habib et al found a statistically significant odds ratio of 2.38 for tooth erosion with acidic fruit juice consumption.[6]

A previous descriptive cross-sectional study was conducted in Bangladesh in 2021 by Kibria et al to determine the level of health-compromising ingredients in carbonated beverage/fizzy drinks.[7] In their study, ten carbonated beverage/ soft drinks (SfD) and five energy drinks (EgD) available in the markets of Dhaka city, Bangladesh, were analyzed and they revealed that the pH of SfD and EgD ranged from 2.5-3.4 and 2.9-3.4, respectively which value is less than threshold pH level of enamel demineralization/ erosion (pH=5.5).[7] That study result is similar to the present study.

Fundamentally speaking, all alcoholic and non-alcoholic beverages lie on the acidic side of the pH spectrum, and most range from 2.5 to about 4.5 pH (7 is neutral).[8,9] There are several different types of acids found in alcoholic beverages, which will affect how acidic an alcohol tastes. The most prevalent acids found in alcohol are tartaric acid, malic acid, and citric acid.[10,11] In the present study, the pH level of included alcoholic beverages also should have similar results.

In addition, many people are not aware of the damage beverages can do to the teeth. Acidic drinks/ beverages can be so harmful to the teeth if it is consumed regularly.[12,13] A beverage's acidity level is determined by how much acid it contains from citrus or other additives. The pH scale measures this trait, but any pH level below 7.0 is considered acidic, and the lower the number, the more harmful to the tooth enamel.[13] Though enamel is the strong outer layer that protects the teeth, acidic beverages can wear enamel down, weakening it and causing long-term tooth demineralization/ erosion.[14] Even beverages that offer health benefits like fruit juice can be harmful to the teeth. Any flavor or type of beverage can be acidic, depending on the ingredients, additives, and formulation.[15]

2. Conclusion

Despite the popularity of all included alcoholic and non-alcoholic beverages have extreme demineralization/ erosive effects on tooth enamel. Based on the pH level, carbonated beverage is the highest acidic and most prone to demineralize or erode enamel structure. In contrast, the highest titratable acidity level belonged to apple cider vinegar. The acidity level measurement of the beverage using a pH meter is different from the acidity (g/L) level measurement by titration method.

3. ACKNOWLEDGEMENT

I am sincerely grateful to Md. Rabiul Alam, Lab Chemist, Chemical Engineering Department of BUET for helping me to conduct the lab testing activities for pH and titratable acidity level of beverages measurement.

4. REFERENCES

1. Shahjahan MD, MZ Hossain T, Khatun S, Hossain HA, Rashid KR, Ahmed. Soft Drink Consumption and its Influence on BMI and Academic Performance among Selected School Children in Dhaka City of Bangladesh. Current Research in Nutrition and Food Science Journal 2019. DOI:10.12944/crnfsj.7.3.18
2. He NX, Bayen S. An overview of chemical contaminants and other undesirable chemicals in alcoholic beverages and strategies for analysis**.** Comprehensive Reviews in Food Science and Food Safety 2020. DOI: 10.1111/1541-4337.12649
3. Johnson RK, Frary C. Choose beverages and foods to moderate your intake of sugars: the 2000 dietary guidelines for Americans— what's all the fuss about? The Journal of nutrition 2001. DOI: 10.1093/jn/131.10.2766S

4. Mulic A, Skudutyte RR, Tveit AB, Skaare AB. Risk indicators for dental erosive wear among 18-yr-old subjects in Oslo, Norway. European Journal Oral Science 2012. DOI: 10.1007/s40368-017-0317-5
5. Li H, Zou Y, Ding G. Dietary factors associated with dental erosion: a meta-analysis. PLoS One 2012. DOI: 10.1371/journal.pone.0042626
6. Habib M, Hottel TL, Hong L. Prevalence and risk factors of dental erosion in American children. Journal of Clinical Pediatric Dentistry 2013. DOI: 10.17796/jcpd.38.2.4300111x4321l313
7. Kibria GAHM, Khalequzzaman M, Khan FA, Rayna SE, Khan MMH, Alam MR, Rahman TKM, Saha BK, Motalab M, Islam SS. Health-compromising ingredients in fizzy drinks available in the markets of Dhaka city, Bangladesh. Journal of Food Science and Nutrition Research 2021. DOI:10.26502/jfsnr.2642-11000062
8. Swahn HM, Culbreth R, Salazar LF, Tumwesigye NM, Jernigan DH, Kasirye R, Obot SI. The Prevalence and Context of Alcohol Use, Problem Drinking and Alcohol-Related Harm among Youth Living in the Slums of Kampala, Uganda. International Journal of Environmental Research and Public Health 2020. DOI: 10.3390/ijerph15061061
9. Dewan G, Chowdhury F. Alcohol Use and Alcohol Use Disorders in Bangladesh. Asia Pacific Journal of Medical Toxicology 2015. DOI: 10.22038/apjmt.2015.5091
10. Tyl C, Sadler GD. pH and Titratable Acidity. In: Nielsen, S.S. (eds) Food Analysis. Food Science Text Series. Springer, Cham 2017. DOI: httpa://doi.org/10.1007/978-3-319-45776-5_22
11. Sadler GD, Murphy PA. pH and Titratable Acidity. In: Food Analysis. Springer, Boston, MA 2010. DOI: httpa://doi.org/10.1007/978-1-4419-1478-1_13
12. Reddy A, Norris DF, Momeni SS, Waldo B, Ruby JD. The pH of beverages in the United States. Journal of American Dental Association 2016. DOI: 10.1016/j.adaj.2015.10.019.
13. Nielson SS. Standard solutions and Titratable Acidity. In: Food Analysis Laboratory Manual. Food Science Text Series. Springer, Cham 2017. DOI: httpa://doi.org/10.1007/978-3-319-44127-6_21
14. Somayeh H, Hedieh P, Karim J. Evaluation of the relationship between pH and titrable acidity of five different of iron supplements with the absorption of iron ions in the anterior primary teeth (an in vitro study). Dental research journal 2018. DOI:10.4103/1735-3327.240473
15. Zimmer S, Kirchner G, Bizhang M, Benedix M. Influence of Various Acidic Beverages on Tooth Erosion. Evaluation by a New Method. PLOS ONE 2015. DOI: 10.1371/journal.pone.0129462