Trop J Phytochem Pharm Sci, January 2025; 4(1): 1 - 8 **ISSN 2955-1226 (Print)** **ISSN 2955-123(Electronic)**

Tropical Journal of Phytochemistry & Pharmaceutical Sciences

Available online at https://www.tjpps.org

Original Research Article

The pH of Commercially Available Non-Alcoholic Beverages In Nigeria and the Dental Health Implications

Nneka N. Ibekwe[1*], Mahmood Abdulkarim[1], Jamiu A. Bello[1], Obi P. Adigwe[2]

[1]*Department of Medicinal Chemistry and Quality Control, National Institute for Pharmaceutical Research and Development, Idu, Abuja, Nigeria.*
[2]*Office of the Director General, National Institute for Pharmaceutical Research and Development, Idu, Abuja, Nigeria.*

ABSTRACT

The objective of this study was to determine the pH values of commercially available non-alcoholic beverages in Nigeria and utilize the information to evaluate their potential erosive effects on dental health. One hundred and eighty commercial brands of non-alcoholic beverages comprising soda drinks (23%), energy drinks (17%), fruit drinks (25%), malt drinks (5%), teas (13%), and bottled waters (17%) were randomly purchased from different sales outlets in Federal Capital Territory, Nigeria. The pH of the beverages was measured in triplicates using a standardised pH meter and reported as mean and standard deviation. The potentials for dental erosion were calculated based on the relative erosivity zones of the samples using a threshold of pH 4.0. The pH of the soda drinks ranged from 2.35-3.93, energy drinks 2.57-3.71, fruit drinks 2.49-4.27, malt drinks 4.00-4.61, teas 3.28-6.38, and bottled waters 3.03-7.73. The erosive potentials of the beverages were categorised as extremely erosive (pH <3.0), erosive (pH 3.0-3.99), and minimally erosive (pH ≥4.0) at 33 %, 33 %, and 34 %, respectively of the total number of samples. The high acidity of non-alcoholic beverages can have a significant impact on dental health.

Keywords: Non-alcoholic beverages, pH, Acidity, Dental enamel, Dental erosion

Received 20 August 2024
Revised 05 January 2025
Accepted 05 January 2025
Published online 01 February 2025

Introduction

The consumption of non-alcoholic beverages is a global lifestyle that is enjoyed by all levels of society, particularly carbonated soft drinks, which are becoming more popular among young people.[1] The non-alcoholic beverage industry is one of the largest industries in the world and it accounts for billions of dollars in gross earnings annually. The revenue that accrued from the non-alcoholic beverage market worldwide amounted to over a trillion dollars in 2023.[2] The figures reported by the National Bureau of Statistics (NBS) indicated that the Nigerian market is attractive and flourishing, as evidenced by the expenditure of ₦551.2bn ($1.3bn) by Nigerian households on non-alcoholic beverages.[3]

The non-alcoholic beverages industry includes all beverages without alcohol. It encompasses liquid refreshment beverages (LRB) such as bottled water, carbonated soft drinks, energy drinks, fruit beverages, ready-to-drink coffee and tea, sports beverages, and value-added water.[4] Non-alcoholic beverages are interchangeably and popularly referred to as 'soft drinks', a term also generally considered for any non-alcoholic, carbonated or non-carbonated beverage that contains water, sweeteners, acidulants, flavourings, colourings, emulsifiers and preservatives. Bottled water is the leading consumed non-alcoholic beverage, followed by carbonated soft drinks which are produced by absorbing carbon dioxide in potable water with or without added substances.[2, 5]

*Corresponding author. E mail: nnekaibekwe@yahoo.com
Tel: +2348058939488

Citation: Ibekwe NN, Abdulkarim M, Bello JA, Adigwe OP. The pH of Commercially Available Non-Alcoholic Beverages in Nigeria and the Dental Health Implications. Trop J Phytochem Pharm. Sci. 2025; 4(1): 1 - 8 http://www.doi.org/10.26538/tjpps/v4i1.1

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria.

The high consumption rate of non-alcoholic beverages can be attributed to the taste, dehydration due to hot weather conditions, lack of potable water, urbanisation, dietary habits, lifestyle changes, and as a source of energy. Consumption of carbonated soft drinks commonly known as soda, has become a highly controversial public health and public policy issue with countries such as Britain, France, and many states in the United States limiting or banning sales.[6] For similar reasons, the Nigerian government recently imposed an excise tax of ten Naira on carbonated and sugar-sweetened beverages increasing the costs. However, despite that, the market continues to flourish.[7]

The prevalence of dental erosion in the twenty-first century has been associated with an increased consumption of acid-containing beverages.[8] Acids are added to the drinks to impart tartness, reduce the growth of bacteria and fungi, improve shelf-life, impart a tangy flavour, or function as a preservative.[9] Phosphoric and citric acids are commonly added to carbonated soft drinks, while malic, ascorbic, and tartaric acids are also used but less frequently.[4, 10]

Human saliva, a biofluid consisting of more than 99 % water, is responsible for maintaining the acid-base balance in the mouth and preserving oral health. The pH (concentration of hydrogen ions) of a balanced oral environment ranges from 6.2-7.6 and has an average value of 6.9.[11] The neutrality of the oral milieu, however is usually challenged because of the acidic foods and drinks we consume. The pH of 5.5 is widely accepted as the critical pH below which demineralization of the dental enamel occurs [10, 12-17]. The enamel is the outer part of the teeth consisting of mineral calcium hydroxyapatite (HAP) with the stoichiometric formula $Ca_{10}(PO_4)_6(OH)_2$).[17] Acidic beverages when consumed, lower the pH of the oral environment below the critical threshold and this causes solubility of the enamel. This leads to demineralisation of the tooth surface and the progression of tooth damage into the dentin will lead to intense pain caused by inflammation of the dental pulp, and eventually tooth loss.[18] Enamel erosion is usually irreversible because enamel damaged by acid cannot be recalcified as there is no suitable matrix for crystal growth.[19]

Several studies have reported pH as a principal determinant of dental erosion.[20-24] Extant literature on the pH of commercially available non-

ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

alcoholic beverages in Nigeria is few, and the paucity of data necessitated the research to bridge the gap.[25-28] Our objective in this study was to provide data on the pH of commercially available non-alcoholic beverages in the Federal Capital Territory, Nigeria, rank their erosive potentials, and use the information to create awareness and advisory on dental health.

Materials and Methods

Location of the Survey

The survey was carried out in the Federal Capital Territory, a city geographically situated in the central region of Nigeria and comprises six area councils (Figure 1). The city lies between latitudes 8.25 and 9.20 north of the equator and longitudes 6.45 and 7.39 east of Greenwich Meridian.[29] The Federal Capital Territory encompasses a landmass of approximately 7,315 km^2, and as a cosmopolitan city, it serves as a commercial hub that houses a diverse range of consumption commodities, including non-alcoholic beverages that are sold in both wholesale and retail outlets.

Sample Collection

The non-alcoholic beverages were purchased from retail stores and supermarkets in different areas of the Federal Capital Territory, Nigeria (Figure 1). A total of 180 samples were collected between June and September 2022 and categorised into six groups; soda drinks, energy drinks, fruit drinks, malt drinks, teas, and bottled waters. The samples were checked for relevant label information such as brand name, batch number, manufacturer's name and address, dates of manufacture and expiry, and NAFDAC registration number. The code or name of the acidulant/s in the beverages if present, was also stated on the cans/bottles. All the samples were analysed before their expiration dates.

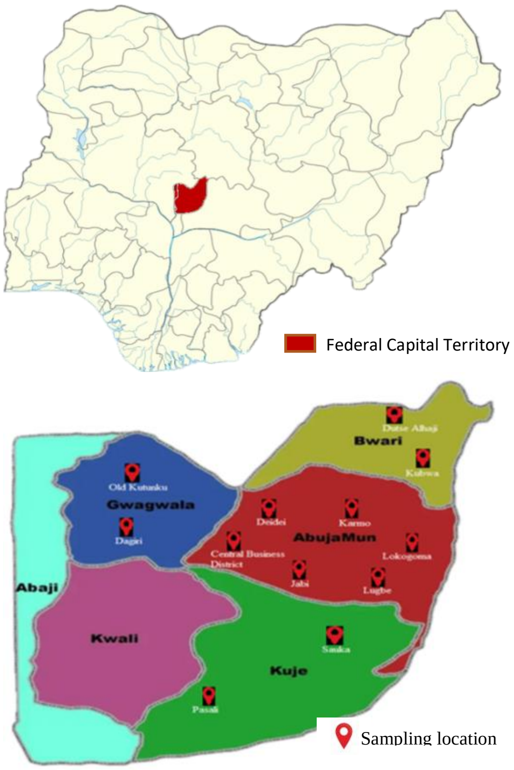

Figure 1: From left to right (a) Map of Nigeria showing the Federal Capital Territory (b) Map of Federal Capital Territory showing the sampling locations

Experimental

The pH analysis of each sample was carried out on a pH meter and probe (Metler-Toledo, SevenCompact™ pH/Ion S220, Switzerland). The samples were investigated for their pH values immediately after the cans or bottles were opened. Before each daily test, Centipur® fresh buffer solutions (pH 2.0, 4.0, 7.0, and 9.0; Merck, Germany) were used to calibrate the pH meter, and buffer solution 7.0 was used for verification. The measurements were taken at a temperature of 23 °C. For the tea samples, the home tea preparation method was adopted. One tea bag sample was infused in 100 mL of hot table water and allowed to cool to room temperature before taking the pH readings, as previously described. The pH values obtained were used to determine the relative erosivity zones of the samples based on the threshold of pH 4.0 derived from apatite solubility studies of Larsen and Nyvad.[20]

Statistical Analysis

The pH measurements of each sample were taken in triplicates and the result was recorded as mean ± standard deviation (SD). Descriptive statistical analyses of the sample data were done using Microsoft Excel and represented graphically on pie and bar charts.

Results and Discussion

The pH (mean ± standard deviation) of the samples under the six categories of non-alcoholic beverages are presented in Tables 1-6, and the percentage distribution of the analysed samples is shown in Figure 2. The median was our choice of measure of the pH as shown in the graphical presentation in Figure 3. The pH of the soda drinks category ranged from 2.35 to 3.93 and the median pH was 2.82 for the 41 products. The cola sub-group of the soda drinks category (A01-A08) presented the lowest pH values ranging from 2.35-2.54. The drinks in this sub-group all contain phosphoric acid, a weak triprotic inorganic acid with a low pK of 2.15, which makes it act like a strong acid.[30] Two of the products added to the soda drinks category, A21 (flavoured water) and A36 (tonic water) are considered misnomers as under bottled water regulations, water constitutes only water and no additives, except carbon dioxide for carbonated bottled waters.[12] The low pH value of A21 at 3.03 may be attributed to extracts that are high in naturally occurring fruit acids, such as citric acid as flavouring agents,[31] and that of A36 at 2.59 may be due to carbonic acid produced by carbon dioxide gas infused into water, and the addition of quinine. The majority of soda drinks contain citric acid, a trihydroxycarboxylic acid that occurs naturally in citrus fruits. Citric acid is a weaker acid compared to phosphoric acid and that may explain the higher pH values obtained with the soft drinks containing the acid. Our results compared well with similar studies on global brands of soda drinks.[4, 9, 20, 32] The category of energy drinks presented a pH range of 2.57 to 3.55 with a median pH of 3.10 for the 30 products. The fruit drink category had the highest number of samples and presented a pH range of 2.49 to 4.39 with a median of 3.04 for the 46 products. The malt drinks had the narrowest pH range at 4.00 to 4.61, with a median of 4.39 for the 9 products. In the tea category, the pH values ranged from 3.28 to 6.38, and a median value of 5.02 for the 24 products. The results of the energy, fruit, tea, and malt beverages were also in agreement with similar studies.[4, 9, 27, 33] Citric acid is a major constituent of most energy and fruit drinks.[34] The 30 bottled water samples gave pH values that ranged from 4.46 to 7.73, with a median of 5.89. From the analysis, 68.97 % of the bottled waters had pH values below the standard range of 6.5-8.5.[35] The acidity of bottled waters can be influenced by various factors, including its source, mineral content, and treatment processes. Some sources may naturally have a lower pH due to minerals or dissolved gases. Water treatment technologies such as reverse osmosis and distillation also allow for the absorption of carbon dioxide, causing the pH to drop.[36]

The consensus regarding pH as the major determinant of the erosive effects of non-alcoholic beverages on dental enamel is well documented.[9, 13, 20-24, 37-40] Larsen and Nyvad, [20] demonstrated that the enamel dissolution increased logarithmically with a drop in pH, and was parallel with the solubility of apatite. The authors explained that

 ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

for each unit decrease in pH, enamel solubility increased by a factor of 10, resulting in a notable escalation of enamel demineralization particularly as the pH approached 2.0 from the initial 4.0. Building on the works of Larsen and Nyvad,[20] Reddy *et al.,*[9] employed the threshold of pH 4.0 as a key determinant in the dental erosion process, and classified the non-alcoholic beverages into 3 groups of relative erosivity zones; extremely erosive (pH < 3.0), erosive (pH 3.0–3.99) and minimally erosive (pH ≥ 4.0). We adopted that approach to our study and our analyses revealed that 66 % of the beverages (118 out of 180) were erosive. This is summarised in Figure 4. All the soda drinks, energy drinks, and fruit drinks presented erosive potentials at pH ≤ 4.0 while all the bottled waters, malt drinks, and teas (except E20, a lemon tea @ pH 3.20) showed minimal erosive potentials at pH ≥ 4.0. The erosive effect of soft drinks may be attributed to the dietary acids present, especially the frequently occurring citric and phosphoric acids.

Table 1: pH of soda drinks

Cola drinks	**pH ± SD**	**Acidulant**
A01	2.49 ± 0.03	Phosphoric acid
A02	2.49 ± 0.03	Phosphoric acid
A03	2.35 ± 0.00	Phosphoric acid
A04	2.86 ± 0.06	Phosphoric acid
A05	2.58 ± 0.03	Phosphoric acid
A06	2.54 ± 0.02	Phosphoric acid
A07	2.53 ± 0.03	Phosphoric acid
A08	2.57 ± 0.10	Phosphoric acid
	pH ± SD	Acidulant
A09	3.25 ± 0.01	Citric acid, malic acid
A10	2.66 ± 0.03	Citric acid
A11	2.93 ± 0.01	Citric acid
A12	2.67 ± 0.02	Citric acid
A13	3.67 ± 0.01	Citric acid
A14	2.68 ± 0.02	Citric acid
A15	2.37 ± 0.00	Citric acid
A16	2.87 ± 0.01	Citric acid
A17	2.82 ± 0.02	Citric acid
A18	2.86 ± 0.01	Citric acid, malic acid
A19	2.67 ± 0.01	Citric acid
A20	2.84 ± 0.03	Citric acid
A21	3.03 ± 0.07	Citric acid
A22	2.76 ± 0.02	Citric acid, malic acid
A23	2.94 ± 0.01	Ascorbic acid, malic acid
A24	2.88 ± 0.05	Citric acid
A25	3.12 ± 0.02	Citric acid, tartaric acid
A26	2.71 ± 0.04	Citric acid
A27	2.91 ± 0.01	Citric acid
A28	2.88 ± 0.04	Citric acid
A29	3.04 ± 0.04	Citric acid
A30	2.61 ± 0.01	Citric acid
A31	3.11 ± 0.01	Citric acid
A32	3.00 ± 0.02	Citric acid
A33	3.13 ± 0.01	Citric acid, malic acid
A34	2.71 ± 0.08	Citric acid
A35	3.04 ± 0.00	Citric acid
A36	2.59 ± 0.04	Citric acid
A37	2.66 ± 0.00	Citric acid
A38	3.23 ± 0.06	Citric acid
A39	2.57 ± 0.06	Citric acid
A40	3.93 ± 0.04	Citric acid
A41	2.80 ± 0.10	Citric acid

Table 2: pH of energy drinks

Sample	**pH ± SD**	**ACIDULANT**
B01	3.32 ± 0.01	Citric acid
B02	2.85 ± 0.02	Citric acid
B03	2.83 ± 0.02	Citric acid
B04	3.11 ± 0.02	Citric acid
B05	2.68 ± 0.05	Citric acid
B06	3.35 ± 0.02	Citric acid
B07	3.55 ± 0.01	Citric acid

ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

B08	3.14 ± 0.02	Citric acid
B09	2.76 ± 0.01	Citric acid
B10	2.87 ± 0.03	Citric acid
B11	3.49 ± 0.01	Citric acid
B12	2.57 ± 0.03	Citric acid
B13	2.70 ± 0.04	Citric acid
B14	3.04 ± 0.05	Citric acid
B15	3.12 ± 0.02	Citric acid
B16	3.06 ± 0.06	Citric acid
B17	2.70 ± 0.02	Citric acid
B18	3.71 ± 0.03	Citric acid
B19	3.51 ± 0.04	Citric acid
B20	3.29 ± 0.03	Citric acid
B21	3.30 ± 0.01	Citric acid, malic acid
B22	2.94 ± 0.05	Citric acid
B23	3.17 ± 0.02	Citric acid, tartaric acid
B24	3.09 ± 0.00	Citric acid
B25	3.36 ± 0.07	Citric acid
B26	3.47 ± 0.10	Citric acid
B27	3.07 ± 0.02	Citric acid
B28	2.94 ± 0.01	Citric acid
B29	3.43 ± 0.03	Citric acid
B30	2.79 ± 0.03	Citric acid

Table 3: pH of fruit drinks

Sample	pH ± SD	Acidulant
C01	3.04 ± 0.03	Citric acid
C02	3.02 ± 0.01	Citric acid
C03	3.59 ± 0.00	Citric acid
C04	3.38 ± 0.01	Citric acid
C05	3.52 ± 0.01	Ascorbic acid
C06	2.87 ± 0.01	Citric acid, ascorbic acid
C07	3.02 ± 0.04	Citric acid, ascorbic acid
C08	2.93 ± 0.02	Citric acid
C09	2.72 ± 0.01	Citric acid
C10	3.42 ± 0.03	Citric acid
C11	3.03 ± 0.02	Citric acid
C12	3.08 ± 0.04	Citric acid
C13	2.94 ± 0.03	Citric acid
C14	2.96 ± 0.01	Citric acid
C15	4.27 ± 0.01	No acidulant
C16	3.01 ± 0.01	Citric acid
C17	3.55 ± 0.01	Citric acid
C18	3.46 ± 0.09	Citric acid
C19	3.54 ± 0.03	Citric acid
C20	3.11 ± 0.02	Citric acid, ascorbic acid
C21	3.05 ± 0.03	Citric acid
C22	2.89 ± 0.05	Citric acid, tartaric acid
C23	2.80 ± 0.06	Citric acid
C24	2.88 ± 0.01	Citric acid
C25	2.84 ± 0.01	Citric acid, malic acid
C26	3.00 ± 0.01	Citric acid

ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

C27	3.36 ± 0.01	Citric acid, ascorbic acid
C28	2.83 ± 0.10	Citric acid
C29	2.49 ± 0.02	Citric acid
C30	2.90 ± 0.02	Citric acid
C31	3.84 ± 0.01	Citric acid
C32	3.34 ± 0.03	Citric acid
C33	3.58 ± 0.01	Citric acid
C34	2.62 ± 0.02	Citric acid
C35	3.65 ± 0.01	Citric acid
C36	3.81 ± 0.02	Citric acid
C37	2.84 ± 0.01	Not stated
C38	2.85 ± 0.02	Not stated
C39	2.89 ± 0.02	Citric acid
C40	3.05 ± 0.01	Citric acid
C41	3.10 ± 0.01	Citric acid
C42	3.29 ± 0.02	Citric acid
C43	3.17 ± 0.01	Citric acid
C44	3.06 ± 0.02	Citric acid
C45	2.95 ± 0.00	Citric acid
C46	3.27 ± 0.01	Citric acid

Table 4: pH values of malt drinks

Sample	**pH ± SD**
D01	4.36 ± 0.04
D02	4.42 ± 0.05
D03	4.39 ± 0.04
D04	4.39 ± 0.01
D05	4.61 ± 0.05
D06	4.50 ± 0.10
D07	4.25 ± 0.08
D08	4.00 ± 0.04
D09	4.10 ± 0.03

Table 5: pH values of teas

Sample	**pH ± SD**
E01	4.69 ± 0.02
E02	5.40 ± 0.00
E03	5.41 ± 0.02
E04	4.90 ± 0.01
E05	4.99 ± 0.03
E06	4.93 ± 0.01
E07	5.40 ± 0.01
E08	5.34 ± 0.05
E09	4.81 ± 0.01
E10	5.46 ± 0.03
E11	5.28 ± 0.02
E12	6.38 ± 0.01
E13	5.28 ± 0.01
E14	6.11 ± 0.02
E15	5.01 ± 0.02
E16	5.54 ± 0.01
E17	4.90 ± 0.01
E18	3.95 ± 0.01

 ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

E19	5.03 ± 0.02
E20	3.28 ± 0.01
E21	4.85 ± 0.03
E22	4.94 ± 0.03
E23	4.91 ± 0.01
E24	5.57 ± 0.05

Table 6: pH of bottled waters

Sample	pH ± SD
F01	6.00 ± 0.01
F02	7.28 ± 0.02
F03	6.65 ± 0.10
F04	6.88 ± 0.12
F05	5.40 ± 0.03
F06	5.88 ± 0.19
F07	6.01 ± 0.08
F08	5.70 ± 0.18
F09	6.50 ± 0.06
F10	6.55 ± 0.02
F11	5.66 ± 0.02
F12	6.08 ± 0.16
F13	5.01 ± 0.04
F14	5.91 ± 0.10
F15	5.35 ± 0.16
F16	5.14 ± 0.15
F17	6.01 ± 0.06
F18	5.59 ± 0.02
F19	7.73 ± 0.02
F20	5.44 ± 0.03
F21	4.66 ± 0.22
F22	6.68 ± 0.08
F23	5.57 ± 0.09
F24	6.37 ± 0.13
F25	6.52 ± 0.09
F26	5.60 ± 0.11
F27	5.27 ± 0.09
F28	6.82 ± 0.15
F29	5.41 ± 0.20
F30	5.57 ± 0.09

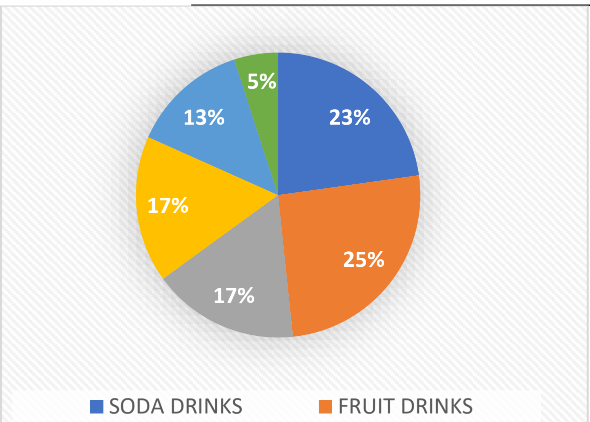

Figure 2: Percentage distribution of non-alcoholic beverages

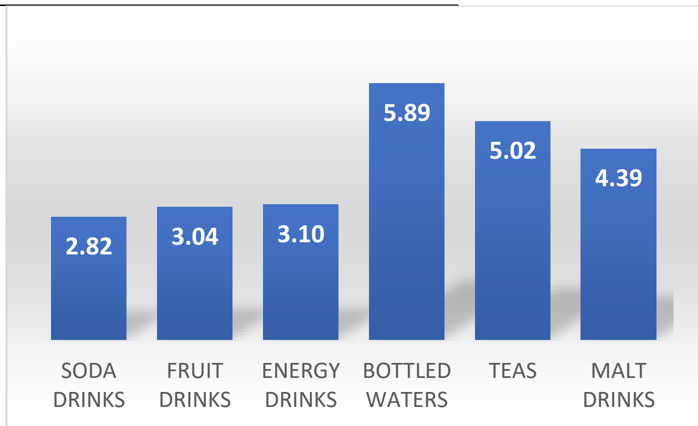

Figure 3: Median pH of categories of non-alcoholic beverages

 ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

Featherstone and Lussi,[41] employed a model that explained the chemistry of enamel erosion. The authors described the enamel as being composed of calcium-deficient carbonated hydroxyapatite with the chemical formula $Ca_{10-x}Na_x(PO4)_{6-y}(CO_3)_z(OH)_{2-u}F_u$, which was more soluble than hydroxyapatite (HAP). The erosive potentials of the acidic beverages were ascribed to the ability of the acid to dissociate, forming hydrogen ions (H^+) which react with the carbonate and/or phosphate releasing the ions from that region of the crystal surface, and leading to direct surface etching. In addition to the effect of the hydrogen ions, the higher erosivity of citric acid was due to the complexation (chelation) of the citrate anion with calcium ions and, removal from the crystal surface and/or from the saliva. The presence of three carboxylic groups and, the molecular shape of citric acid were responsible for the chelating property.[42] Phosphoric acid, on the other hand, is arguably less erosive than citric acid because the phosphate anions slightly reduce hydroxyapatite dissolution, despite the dissociation of this acid molecule which also provides the hydrogen ions that attack the mineral surface.[42] These chemical processes increase the level of undersaturation of the drinks with respect to dental minerals, thereby promoting demineralization.[13, 30] Other studies corroborated the higher erosive potentials of beverages with citric acid compared to other dietary acids.[13, 20, 30] Most studies that demonstrated the demineralizing effects of acidic beverages on tooth enamel were done *in vitro*. The experiments which were done at different time intervals, showed that prolonged contact time between acidic beverages and enamel increased the chances of enamel erosion.[13, 14, 20, 22, 30, 43] Although saliva was not included, the studies provided empirical support to the erosive potentials of acidic beverages, and highlighted their effect on dental health. Apart from the acidic characteristics, biological and behavioural factors that could also affect the erosive potential of beverages include salivary flow rate, pellicle formation and drinking habits.[20, 23, 43] The scope of our study was limited to the study of pH only.

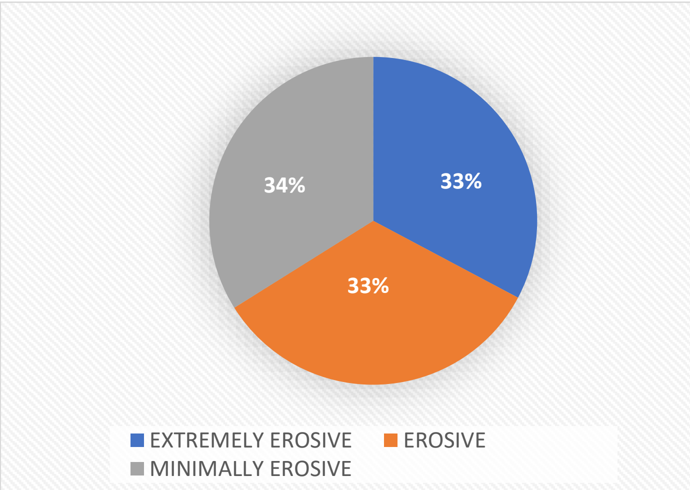

Figure 4: Erosive potential of non-alcoholic beverages

Conclusion

The study provides information on the pH of non-alcoholic beverages consumed in Nigeria and underscores the significance of the beverages on dental health. Thirty-two per cent (32 %) of the analysed beverages had a pH of less than 3. Soda drinks were found to be the most acidic and two-thirds of the beverages (66%) were found to be erosive. Bottled waters remain the best option among beverages for the maintenance of good dental health. The findings of the study would serve as a resource for health policy interventions and also as an advisory to regulatory agencies, health practitioners, nutritionists and the general public to make more informed dietary decisions, especially concerning dental health.

Conflict of Interest

The authors declare no conflict of interest.

Author's Declaration

The authors hereby declare that the work presented in this article is original. Any liability for claims relating to this article will be borne by us.

Acknowledgements

The authors are profoundly grateful to the National Institute for Pharmaceutical Research and Development for the opportunity to conduct the study, and to Mr Fidelis Solomon for the technical support.

References

1. Yang L, Bovet P, Liu Y, Zhao M, Ma C, Liang Y, Xi B. Consumption of carbonated soft drinks among young adolescents aged 12 to 15 years in 53 low-and middle-income countries. Am. J. Public Health 2017; 107(7):1095-1000.
2. Statista Research Department. Revenue of the non-alcoholic drinks market worldwide by country in 2023. Available at: https://www.statista.com/forecasts/758664/revenue-of-the-non-alcoholic-drinks-market-worldwide-by-country. Accessed October 9, 2024.
3. National Bureau of Statistics (NBS). Consumption expenditure pattern in Nigeria-2019. Nigeria: National Bureau of Statistics, 2020.
4. Nik Mohd Rosdy NM, Mohd Amin NA, Roslan N. Erosive Potential and Sugar Content of Popular Beverages: A Double Whammy for Dentition. Int. J. Dent 2023(1):9924186. doi: 10.1155/2023/9924186.
5. National Agency for Food and Drug Administration and Control (NAFDAC). Soft drinks regulations. Federal Republic of Nigeria Official Gazette 2021; 108(158):B3301-3307.
6. Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. Am. J. Public Health 2007; 97(4):667-675.
7. Adedeji OJ, Lucero-Prisno III DE. Taxation on beverages in Nigeria: Impact and burden of the new policy. Popul. Med. 2022; 4:10. doi: 10.18332/popmed/146129.
8. Gambon DL, Brand HS, Veerman EC. Dental erosion in the 21st century: what is happening to nutritional habits and lifestyle in our society? Br. Dent. J. 2012; 213(2):55-57.
9. Reddy A, Norris DF, Momeni SS, Waldo B, Ruby JD. The pH of beverages in the United States. J. Am. Dent. Assoc. 2016; 147(4):255-263.
10. Tahmassebi JF, Banihani AJ. Impact of soft drinks to health and economy: a critical review. Eur. Arch. Paediatr. Dent. 2020; 21:109-117.
11. Patel RM, Varma S, Suragimath G, Zope S. Estimation and comparison of salivary calcium, phosphorous, alkaline phosphatase and pH levels in periodontal health and disease: A cross-sectional biochemical study. J. Clin. Diagn. Res. 2016; 10:58-61.
12. Schmidt J, Huang B. The pH of bottled water commercially available in Australia and its implications for oral health. J. Water Health 2022; 20(5):871-876.
13. Wang YL, Chang CC, Chi CW, Chang HH, Chiang YC, Chuang YC, Chang HH, Huang GF, Liao YS, Lin CP. Erosive potential of soft drinks on human enamel: an in vitro study. J. Formos. Med. Assoc. 2014; 113(11):850-856.
14. Shroff P, Gondivkar SM, Kumbhare SP, Sarode S, Gadbail AR, Patil S. Analyses of the Erosive Potential of Various Soft Drinks and Packaged Fruit Juices on Teeth. J. Contemp. Dent. Pract. 2018; 19(12):1546-1551

ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

15. Harper RA, Shelton RM, James JD, Salvati E, Besnard C, Korsunsky AK, Landini G. Acid-induced demineralisation of human enamel as a function of time and pH observed using X-ray and polarised light imaging. Acta Biomater. 2021; 120:240–248.
16. Quartey-Papafio N, Odoom M, Sackeyfio J, Tormeti D. The acidity of some selected soft drinks on the Ghanaian market. Afr. J. Dent. 2019; 7(6):1-7.
17. Barajas-Torres, GC, Klünder-Klünder M, Garduño-Espinosa J, Parra-Ortega I, Franco-Hernández MI, Miranda-Lora AL. Effects of carbonated beverage consumption on oral pH and bacterial proliferation in adolescents: A randomized crossover clinical trial. Life 2022; 12:1776. doi:10.3390/life12111776
18. Epple M, Enax J, Meyer F. Prevention of caries and dental erosion by fluorides-A critical discussion based on physico-chemical data and principles. Dent. J. 2022; 10:6. doi:10.3390/dj10010006
19. Dawes C. What is the critical pH and why does a tooth dissolve in acid? J. Can. Dent. Assoc. 2003; 69(11):722–724
20. Larsen MJ, Nyvad B. Enamel erosion by some soft drinks and orange juices relative to their pH, buffering effect and contents of calcium phosphate. Caries Res. 1999; 33(1):81-87.
21. Barbour ME, Lussi A, Shellis RP. Screening and prediction of erosive potential. Caries Res. 2011; 45(1):24-32.
22. Barac R, Gasic J, Trutic N, Sunaric S, Popovic J, Djekic P, Radenkovic G, Mitic A. Erosive effect of different soft drinks on enamel surface in vitro: application of stylus profilometry. Med. Princ. Pract. 2015; 24(5):451-457.
23. Cairns AM, Watson M, Creanor SL, Foye RH. The pH and titratable acidity of a range of diluting drinks and their potential effect on dental erosion. J. Dent. 2002; 30(7-8):313-317.
24. Marchan S, Hector T, Bascombe K. The pH and titratable acidity of still and sparkling flavored waters: the effects of temperature and storage time. Open J. Stoma. 2021; 11:148-158.
25. Bamise CT, Ogunbodede EO, Olusile AO, Esan TA. Erosive potential of soft drinks in Nigeria. World J. Med. Sci. 2007; 2(2):115-119.
26. Bamise CT, Ogunbodede EO. Dental erosion: immediate pH changes of commercial soft drinks in Nigeria. Tanz Dent J. 2008; 15(1):1-4.
27. Obuzor GU, Ajaezi NE. Nutritional content of popular malt drinks produced in Nigeria. Afr. J. Food. Sci. 2010; 4(9):585-590.
28. Maduakor CU, Onyemelukwe FN, Okonkwo NI, Azubuike CN, Ogu OC, Chukwu I, Maduakor NS. Evaluation of the Cariogenic and Erosive Potential of Some Beverages Consumed in Enugu Metropolis, South East Nigeria. Annu. Res. Rev. Biol. 2020; 35(2):52-60.
29. Wikipedia. Federal Capital Territory (Nigeria). Available at: en.m.wikepedia.org. Assessed November 2, 2024.
30. West NX, Hughes JA, Addy M. The effect of pH on the erosion of dentine and enamel by dietary acids in vitro. J. Oral Rehabil. 2001; 28(9):860-864.
31. Rees J, Loyn T, Hunter L, Sadaghiani L, Gilmour A. The erosive potential of some flavoured waters. Eur. J. Dent. 2007; 1(1):5-9.
32. Jain P, Nihill P, Sobkowski J, Agustin MZ. Commercial soft drinks: pH and in vitro dissolution of enamel. Gen. Dent. 2007; 55(2):150-154.
33. Ibekwe NN, Mamora AM, Okoye M, Adelakun TA, Adigwe OP. Physicochemical properties of teas sold in Abuja, Nigeria, and evaluation of their caffeine content using HPLC. J. Pharm. Biores. 2022; 19(1):33-42.
34. Ciriminna R, Meneguzzo F, Delisi R, Pagliaro M. Citric acid: emerging applications of key biotechnology industrial product. Chem. Cent. J. 2017; 11:1-9.
35. World Health Organisation (WHO). Guidelines for drinking-water quality (4th ed.). Geneva: World Health Organisation, 2017.
36. Shrivastava BK. Efficient Management of Reverse Osmosis System in Water Treatment Plant. Int. J. Chem. Sci. 2009; 7(3):2047-2055.
37. Shaama FA, Wilson AM, Rafeek RN. The pH and titration values of commonly used beverages in Trinidad: A cross-sectional study. J. Health Res. Rev. 2022; 9(1):39-43.
38. Abdul Wahab NN, Rosman NA, Venkiteswaran A, Abu Bakar N. The effect of temperature and exposure time on the PH of beverages: a pilot study. Proceeding Book of 9th Dental Students' Scientific Symposium, Malaysia 2019; 1:12-13.
39. Taji S, Seow WK. A literature review of dental erosion in children. Aust. Dent. J. 2010; 55(4):358-367.
40. Nayak PP, Singla N, Prasad KV, Rao NS. Are soft drinks soft on teeth? A study on dental erosion caused by soft drinks marketed in India. Indian J. Public Health Res. Dev. 2019; 10(2):245-250.
41. Featherstone JDB, Lussi A. Understanding the Chemistry of Dental Erosion. In: Lussi A (Ed): Dental Erosion. Monogr Oral Sci. Basel: Karger; 2006, (20): 66–76 p.
42. Stefanski T, Postek-Stefanska L. Possible ways of reducing dental erosive potential of acidic beverages. Aust. Dent. J. 2014; 53(3), 280-288.
43. Surarit R, Jiradethprapai K, Lertsatira K, Chanthongthiti J, Teanchai C, Horsophonphong S. Erosive potential of vitamin waters, herbal drinks, carbonated soft drinks, and fruit juices on human teeth: An in vitro investigation. Dent. Res. Dent. Clin. Dent. Prospects 2023; 17(3):129-135.