BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 21, Issue 8

DOI: 10.58240/1829006X-2025.21.8-144

CASE REPORT

DEMINERALIZATION OF TOOTH ENAMEL: A CLINICAL AND LABORATORY ASSESSMENT OF ENERGY DRINK CONSUMPTION AMONG YOUTH IN KYRGYZSTAN

Eshiev Abdyrakman Moldalievich[1], Abdirasulova Tattybubu Abdirasulovna[2], Eshieva Asel Abdyrakmanovna[3], Murzaibraimov Azamat Kochkonbaevich[4]

[1].Osh State University : Osh State University , Medical Faculty, Department : Surgical dentistry with a course of pediatric surgical dentistry City : Osh . e-mail: eshiev.abdyrakman@rambler.ruInstitution / ORCID : https://orcid.org/0009-0009-9330-7522.
[2] Institution: Osh State University, Department of Prosthetic Dentistry with a Course in Orthodontics, City: Osh, Country: Kyrgyzstan. E-Mail : daniel.emiliya.daniyarovy@gmail.com / ORCID : https://orcid.org/0000-0001-8623-4470
[3] Osh State University, Department of Pathology, basic and clinical pharmacology, Osh, Kyrgyzstan. E-mail: eshieva020928@gmail.com / ORCID: 0000-0003-3152-8038
[4] Institution: Osh State University, Medical Faculty, City : Osh, Country : Kyrgyzstan. e-mail : azamat.1992stom@gmail.com / ORCID : https://orcid.org/0009-0007-6329-6442

ABSTRACT

Background: The worldwide consumption of energy drinks shows a substantial rise among young consumers. The high sugar levels and low pH in these beverages lead to dental health problems which include enamel demineralization and erosion. The research aimed to study how energy drinks affect tooth enamel structure and the chemical composition of oral fluids.

Materials and Methods: In an in vitro experiment, 30 extracted teeth were divided into two groups. One group was submerged in "Nitro" energy drink for two weeks, while the control group was placed in a physiological saline solution. Changes in tooth mass and morphology were observed using a "CJ OPTIK Flexion Advanced" microscope. This vivo study collected mixed saliva samples from two student groups (n=25 each) consisting of regular energy drink consumers and non-consumers. The researchers measured saliva pH at five different time points which included before consumption and at 15, 30, 45 and 60 minutes after consumption. The Pearson's chi-squared ($\chi 2$) test served as the statistical tool for analysis.

Results: The in vitro study showed that teeth exposed to the energy drink experienced a significant loss of mass (7.15% of initial mass) and morphological defects, while the control group showed no change. The in vivo study found that 15 minutes after a single consumption of an energy drink, the average salivary pH in the experimental group dropped significantly from a baseline of 6.68 ± 0.12 to 5.82 ± 0.14 ($p < 0.05$). Although the pH partially recovered to 6.20 ± 0.13 after 60 minutes, it remained significantly lower than both the baseline and the control group's stable pH (6.70–6.77). This prolonged "acid phase" below the critical pH of 5.5, the "point of zero mineralization," creates a persistent risk of enamel demineralization.

Conclusion: The initial consumption of an energy drink leads to long-term acidification of oral fluids which reduces buffer capacity and creates conditions that lead to enamel demineralization. The prolonged period of salivary pH recovery indicates that early caries development remains at risk. The prevention of these risks requires public awareness campaigns together with preventive measures that include consumption limits and buffer rinse use and fluoride prophylaxis enhancement. Future research needs to investigate the long-term consequences of energy drinks especially among adolescent populations.

Received: *Jul 12; 2025* ***Accepted:*** ***Aug.***2025 ***Published:*** *Aug 31.2025*

INTRODUCTION

The worldwide consumption of energy drinks has experienced rapid growth since the last few years mainly among young adults together with adolescents [1]. The products serve as energy boosters while they help users perform better physically and stay focused [2]. The rising popularity of energy drinks creates a mounting public health concern regarding dental health. The oral environment suffers from two major threats because energy drinks contain high free sugar concentrations and low pH levels [3]. The combination of these factors can lead to a range of dental issues, from enamel erosion to an increased risk of dental caries [4]. The trend exists worldwide yet it is particularly noticeable in Kyrgyzstan because many residents now drink energy drinks as part of their regular daily routine. The high occurrence of tooth enamel, dentin and cementum diseases among people who regularly consume these drinks demonstrates the necessity to study their distinct impact on oral health [5]. The research investigates this essential public health matter through a comprehensive evaluation of energy drink effects on dental health.

The research holds importance because previous studies have proven that energy drink consumption causes dental structure deterioration. The high sugar levels in these beverages create an environment where acidogenic bacteria thrive and the low pH directly causes tooth enamel demineralization which results in acid erosion [6]. The erosion process results in permanent tooth structure damage and heightened tooth sensitivity. The research by Abdirasulov T.A. (2023) demonstrates how energy drinks have become popular while showing their possible adverse health effects [7]. The current research requires additional data-based studies to determine the exact mechanisms of this damage. The research problem focuses on the insufficient scientific evidence which particularly lacks information about the short-term and cumulative effects of these drinks on oral health. The study investigates both temporary and long-term modifications of salivary pH levels and tooth structural changes to address a fundamental knowledge deficit in existing research.

The research introduces fresh data through its combination of laboratory and animal studies which show the destructive effects of a widely consumed energy drink. The in vitro experiment showed the destructive power of these beverages through its detailed measurement of tooth mass reduction and structural changes. The in vivo study introduced new findings through its precise measurement of salivary pH changes after a single energy drink consumption. The data shows that oral fluid acidification persists for an extended period which has not been well-documented in previous studies. The study reveals that the salivary buffer system needs more than 60 minutes to recover to a remineralizing pH which demonstrates an ongoing risk of demineralization. The research creates opportunities for future investigations about long-term cumulative effects and adolescent risk assessment and public health intervention development. The study creates opportunities to study preventive measures such as oral rinses and chewing gums to reduce energy drink damage.

MATERIALS AND METHODS

Study Design

The research consisted of two separate parts which included laboratory experiments with extracted human teeth and clinical observations of young adults. The in vitro study evaluated the erosive effects of a well-known energy drink on human teeth extracted from the mouth while the in vivo study measured how energy drink consumption affects oral fluid acid-base levels in young adults.

Ethical Considerations

The research followed the ethical guidelines established by the Declaration of Helsinki [8]. The Institutional Review Board of Osh State University approved the study. The IRB waived the need for individual informed consent because the study used non-invasive anonymous data from an observational retrospective design. The extracted teeth used in the in vitro study came from a biobank through an institutional ethics protocol that allowed their use in dental research. The researchers protected participant privacy through de-identification and anonymous data analysis.

Sample Collection

The researchers obtained thirty human teeth which were free from caries and fractures and any signs of pre-existing erosive wear from the biobank. The teeth were cleaned of any soft tissue and calculus, disinfected with a 0.5% chloramine-T solution, and stored in a physiological saline solution (0.9% NaCl) at 4°C until the start of the experiment to prevent dehydration.

Experimental Groups

The researchers distributed the teeth into two separate groups consisting of 15 teeth in each group.

2.4.1 Experimental Group: The teeth underwent immersion in 100 mL of "Nitro" energy drink inside a sealed glass container. The researchers chose this energy drink because it is well-known and easily accessible throughout Kyrgyzstan.

2.4.2 Control Group: The teeth were placed in 100 mL of 0.9% NaCl physiological saline solution.

Protocol

The containers operated at a fixed temperature of 37°C to replicate oral conditions. The solutions received weekly refreshments to simulate repeated exposure. The experiment ran for two weeks in total.

Eshiev Abdyrakman Moldalievich, Abdirasulova Tattybubu Abdirasulovna, Eshieva Asel Abdyrakmanovna, Murzaibraimov Azamat Kochkonbaevich. DEMINERALIZATION OF TOOTH ENAMEL: A CLINICAL AND LABORATORY ASSESSMENT OF ENERGY DRINK CONSUMPTION AMONG YOUTH IN KYRGYZSTAN.Bulletin of Stomatology and Maxillofacial Surgery.2025;21(8)144-153 doi:10.58240/1829006X-2025.21.8-144

Data Collection and Analysis

The precision analytical balance measured tooth mass with 0.001 g accuracy for initial and final assessments. The experimental group teeth underwent percentage mass loss calculations for each specimen. The "CJ OPTIK Flexion Advanced" microscope from Germany captured high-resolution images to document morphological changes and enamel defects with precision.

Study Population

The research involved 50 Osh State University students between 18 and 25 years old who met particular selection criteria which included no systemic diseases and no medications that could alter salivary composition. The participants were separated into two groups: an experimental group (n=25) made up of students who admitted to drinking energy drinks 3-4 times weekly and a control group (n=25) composed of students who had not consumed energy drinks during the previous month.

Saliva Collection

The participants received instructions to avoid food consumption and drinking all beverages except water for at least two hours before starting the experiment. The researchers obtained unstimulated mixed saliva through non-invasive aspiration techniques. The researchers collected sterile labeled containers of samples from each participant at five distinct time points which included the baseline measurement at T_0 followed by measurements at T_{15}, T_{30}, T_{45} and T_{60} minutes. The experimental group received a single 250 mL can of "Nitro" energy drink while the control group performed a water rinse.

pH Measurement

The pH of oral fluid was measured immediately after collection using a calibrated "pH-121" pH-millivoltmeter with special vacuum electrodes. Each measurement was performed in triplicate, and the average value was recorded to ensure accuracy.

Statistical Analysis

The statistical software (e.g., SPSS, version 25.0) was used to analyze the collected data. The pH values at each time point were summarized using descriptive statistics (mean ± standard error of the mean, SEM). A two-way ANOVA with repeated measures was used to assess the differences between the experimental and control groups. A Student's t-test was used to compare specific time points, with a significance level set at $p < 0.05$. The Pearson's chi-squared ($\chi 2$) test was used to analyze the correlation between energy drink consumption and the observed changes in oral health status.

RESULTS

It is well known that acidic drinks can damage teeth, mostly because they cause demineralisation. When energy drinks and other highly acidic solutions get into the mouth, their low pH makes it easier for the calcified enamel matrix to break down. The process starts with acids moving through the acquired pellicle, which causes hydroxyapatite crystals to dissolve and minerals to be lost from the inter-prismatic enamel areas. To quantitatively examine this effect, our study utilised an in vitro model to compare a widely consumed energy drink, "Nitro," with a physiological saline solution (NaCl). Weighing 30 extracted human teeth at first gave us baseline mass data. The teeth assigned to the experimental group (n=15) exhibited a total initial mass of 31.72 g, whereas the control group (n=15) displayed a total initial mass of 34.8 g. This controlled experimental design enabled a direct evaluation of the erosive potential of the energy drink by quantifying alterations in tooth mass over time, thereby offering an objective measure of mineral loss due to exposure to the test substance.

Figure 1. Determination of the mass of the front and chewing teeth.

After one week of storage in a sealed glass container with the energy drink, a slight loss of mass was recorded. The average mass of all teeth decreased to 30.68 g, which is 1.04 g less than the initial mass. In contrast, the teeth in the physiological solution showed no change in mass, maintaining a value of 34.8 g. As the storage time was extended to two weeks, the changes continued. The average mass of the teeth in the energy drink solution was 29.45 g, which is 1.23 g less than after the first week. The teeth from the physiological solution remained at 34.7 g. These data clearly demonstrate that the acids contained in energy drinks have a destructive effect on tooth enamel, which is evident in the tooth structure and a reduction in their mass. The main signs of erosion also include a loss of luster and a change in tooth morphology, which can be seen as cup-shaped defects, especially on the molars. These processes directly contribute to further loss of enamel tissue and increase the physical wear of the teeth. The "CJ OPTIK Flexion Advanced" microscope from Germany served as our objective tool for diagnosing and measuring tooth enamel erosion [9]. The instrument provides high-quality magnification of images which proves necessary for detecting enamel structure changes at a microscopic level. The experiments required the examination of teeth samples that were submerged in various drink solutions with different acidity levels and chemical compositions.

Figure 2. CJ-Optik Flexion Advanced Dental Microscope

During the study, the teeth in the energy drink solution showed significant enamel defects. Not only were there changes in colour, but a significant loss of lustre was also observed. These observations confirm the negative effect of energy drinks on tooth enamel. The teeth which were placed in physiological saline solution maintained their original colour and shine. The observed results indicate that physiological solutions produce minimal effects on tooth enamel thus enabling researchers to study beverage effects on tooth enamel condition [10]. The research established that energy drinks harm tooth enamel through changes in tooth structure and decreased tooth weight. The observed enamel defects together with the minimal 2.27 g mass reduction which represents 7.15% of the original mass confirm the harmful effects of energy drinks. The teeth submerged in physiological solution maintained their structure and shine which showed that this solution had a minimal impact on enamel. The research findings demonstrate the need to understand how energy drinks damage dental health while creating possibilities to study the effects of different beverages on tooth enamel.

Dynamics of the Acid-Base State of Oral Fluid

To evaluate the short-term impact of energy drinks on the acid-base equilibrium of oral fluid, two equivalent samples were established (n = 25 each): an experimental group (regular energy drink consumers) and a control group (non-consumers). The pH of mixed saliva was measured five times: before drinking (T_0), and 15 minutes (T_{15}), 30 minutes (T_{30}), 45 minutes (T_{45}), and 60 minutes (T_{60}) after drinking.

Table 1. Mean pH values ± SEM (n=25 in each group)

Group	T_0	T_{15}	T_{30}	T_{45}	T_{60}
Energy drink consumers	6.68 ± 0.12	5.82 ± 0.14*	5.96 ± 0.12*	6.19 ± 0.01*	6.20 ± 0.13*
Control	6.70 ± 0.31	6.71 ± 0.14	6.70 ± 0.31	6.75 ± 0.01	6.77 ± 0.12

* Differences are significant compared to the control ($p < 0.05$).

The experimental group showed a rapid acid-base balance change in oral fluid after consuming one energy drink which resulted in a pH value decrease from 6.68±0.12 to 5.82±0.14 just 15 minutes later. The pH value decreased significantly from its baseline measurement and the control group's simultaneous reading (Student's t-test; $p < 0.05$). The measured pH value of 5.82 approaches the critical threshold for enamel demineralization (≈ 5.5) which indicates rapid surface hydroxyapatite dissolution and cariogenic process initiation. The salivary buffer system showed signs of recovery after the initial drop because the average pH reached 6.20±0.13 at the 60th minute. The recorded pH value at 6.20±0.13 remained lower than both the baseline measurement and the control sample range (6.70–6.77) according to a two-way ANOVA with repeated measures (group effect: $F = 44.7$; $p < 0.001$). A single energy drink consumption leads to extended oral fluid acidification but individuals who avoid these drinks maintain stable acid-base levels that support enamel remineralization [11].

Clinical and biological interpretation of the results.

The recorded decrease in salivary pH to 5.82±0.14 just 15 minutes after a single consumption of an energy drink indicates a rapid depletion of the main bicarbonate-phosphate buffer of the oral fluid. The normal concentration of HCO_3^- in mixed saliva is maintained by the secretory activity of the ductal part of the salivary glands. However, under the influence of the highly acidic and sugar-saturated environment of an energy drink, the reserve of alkaline ions is consumed, and the rate of their entry does not have time to compensate for the sudden increase in titratable acidity.

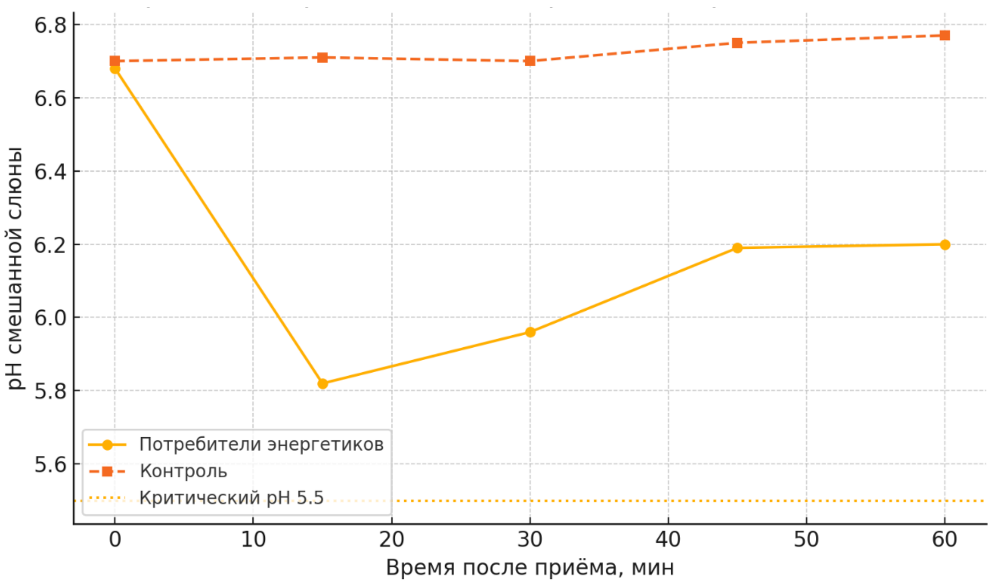

Figure 3. Stefan curve in pH dynamics after taking energy drinks

The "point of zero mineralization" at <5.5 pH defines the critical pH interval where Ca^{2+} and PO_4^{3-} ions in saliva become less active than hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$ solubility constant [12]. The initial demineralization process starts when the threshold of <5.5 is reached because calcium and phosphate ions move from enamel surface into the liquid phase. The Stephan curve model describes acid stress episodes through the relationship between salivary pH duration below critical levels and the resulting total enamel mineral loss which increases with longer exposure time [13]. The pH level returned to 6.20±0.13 after 60 minutes because salivary buffers became active again while organic acids diluted through reflexive salivation. The measured value remains below (i) the normal physiological range of 6.7–6.8 for energy drink consumers and (ii) the "remineralizing range" (pH ≥ 6.8) for the control group because saliva becomes supersaturated with Ca^{2+} and PO_4^{3-} while hydroxyapatite solubility decreases.

6. The graph illustrates the change in oral fluid pH over 60 minutes after the consumption of an energy drink by the experimental group compared to a stable control group.

The oral fluid pH of energy drink consumers decreases right after consumption (peak acid formation) before returning to a level below the critical remineralization threshold of 6.8 throughout the 60-minute period. The control curve demonstrates that students who did not drink the beverage maintained a stable physiological range. The prolonged "acid phase" occurs below a critical pH of 5.5 which demonstrates the strong demineralizing effects of energy drinks.

The environment shows no signs of saturation with fluorapatite and hydroxyapatite after one hour of observation which restricts mineral flow back into the enamel crystalline structure. The clinical cariology perspective shows that the "under-recovered" pH status maintains a continuous risk zone because daily acidic drink consumption extends the time spent below the critical pH ($\sum t < 5.5$) until mineral loss surpasses natural remineralization potential even with proper hygiene practices.

Additional factors that enhance the demineralizing effect of energy drinks include:

1. The high concentration of simple sugars (~11–13 g/100 mL) fuels Streptococcus mutans and Lactobacillus spp., increasing intra-pellicle acidogenesis [14] [15].
2. The drink's low viscosity enables it to spread easily across tooth surfaces while entering the small spaces within dental plaque [16].
3. Caffeine produces a dual effect on salivation by first stimulating then reducing the rate of salivation which extends the time of low buffer capacity [17] [18].

Thus, the recorded acid shift and its incomplete recovery objectively confirm the high cariesogenic danger of regular consumption of energy drinks. In clinical practice, the results emphasize the need to limit the frequency of contact of enamel with an acidic substrate, recommend rinsing with neutral or slightly alkaline solutions ($nahco_3$ 1 %**),** strengthen fluoroprophylaxis to reduce the solubility of dental mineral, and inform young people about the pathogenetic mechanisms and risks associated with these drinks.

Clinical and biological interpretation of pH decrease in oral fluid

The acid-base index of mixed saliva dropped to pH = 5.80 ± 0.14 during the first 15 minutes after consuming an energy drink because the main bicarbonate-phosphate buffer which forms primarily through parotid gland ductal secretion became depleted quickly. The normal Hco_3^- concentration in mixed saliva (15-20 mmol/l) would neutralize external acids within 2-3 minutes but the energy drink's titrated acidity (pH ≈ 2.6–3.2) and sugar content (≈ 11-13 g / 100 ml) deplete the buffer capacity in seconds. The pH decrease happens because the drink contains high titratable acidity between pH 2.5-3.5 and substantial sugar content of 11-13 g per 100 ml which simultaneously: 1. The formation of poorly soluble calcium salts of organic acids decreases saliva's calcium and phosphate ion saturation levels. 2. The acid-causing microflora including Streptococcus mutans and Lactobacillus spp. becomes activated within 5-10 minutes after substrate contact which further decreases biofilm pH. 3. The caffeine and taurine activate alpha-and beta-adrenergic receptors to competitively block saliva secretion thus restricting bicarbonate intake [19].

Critical demineralization threshold

The pH <5.5 zone represents the " zero mineralization point "(dissolution threshold) for hydroxyapatite $Ca_{10}(po_4)_6(OH)_2$. The ionic activity of $Ca2^+$ and $PO3^-$ in the liquid phase becomes less than the product of the solubility of Ksp when the level falls below this point which makes the enamel surface thermodynamically unstable and starts the release of calcium and phosphate into the salivary film [20]. The Stefan curve clinical model shows that the time duration when the pH of the curve stays below the critical line (area under the critical pH curve, AUC-crit) determines the extent of mineral loss: the bigger the AUC-crit area the more severe the demineralization [21].

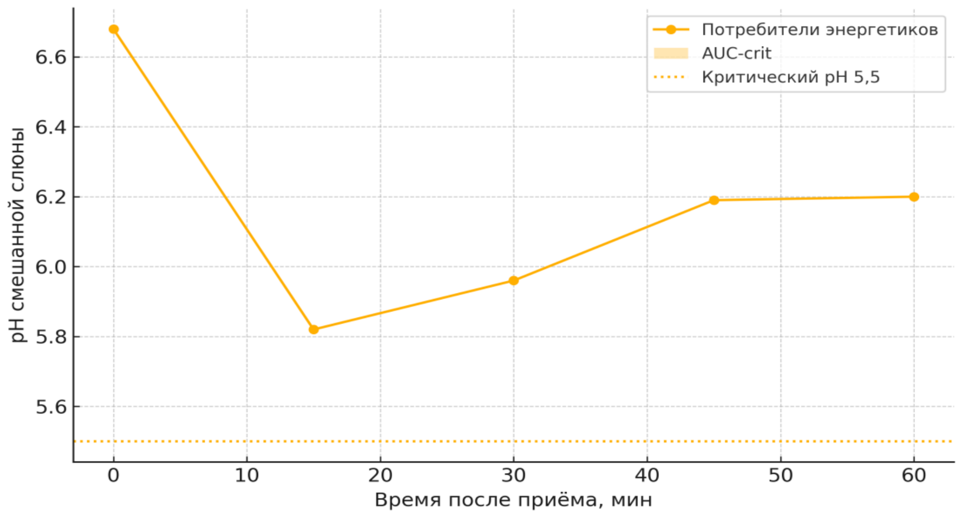

Figure 4. Stefan curve with the selection of the critical zone AUC-crit

The diagram shows the dynamics of oral fluid pH in energy drink consumers and visualizes the area under the critical pH value = 5.5, corresponding to the period of demineralization risk. The shaded area (AUC-crit) correlates with the total mineral loss of enamel.

Consequences of a short-term acid attack.

- The peripheral enamel crystals dissolve to create subclinical foci of increased porosity (white spot lesions) in the surface layer at depths of 10–50 µm.
- The sugar substrate of the energy drink promotes Streptococcus mutans and Lactobacillus spp. metabolism while their biofilm becomes activated through additional extracellular polysaccharide deposition which results in plaque pH levels dropping to 4.5–5.0.
- The β-adrenergic phase of caffeine stimulation leads to decreased salivation rates which results in reduced buffer reserves and extended pH recovery times

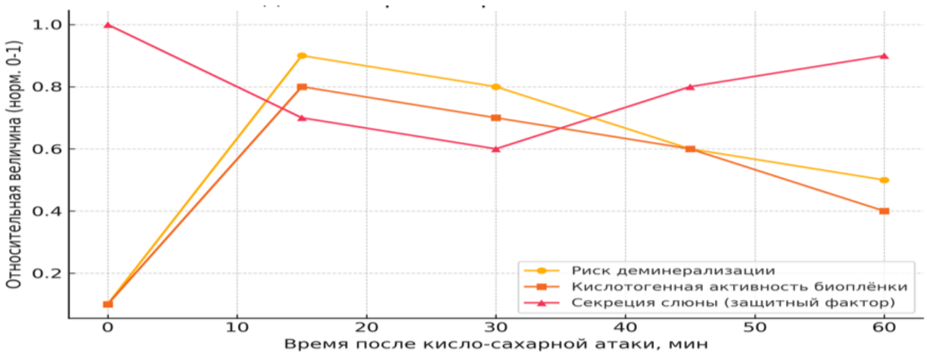

Figure 5. Consequences of a short-term acid attack

The diagram shows how three essential parameters change during the first hour after consuming an acidic drink: the risk of enamel demineralization rises while plaque acidogenic activity increases and salivation decreases as a buffer factor. The values are presented in relative units for visual comparison.

Partial recovery to pH = 6.20 ± 0.13.

The pH level increases after 60 minutes because of two factors: the return of saliva production through parasympathetic stimulation and the combination of organic acid dilution from swallowing movements and bicarbonate intake from blood circulation. The pH value of 6.2 persists because it falls below the optimal remineralizing range of pH 6.8 for saliva saturation with calcium phosphate and it remains below both the initial physiological range of 6.7-6.8 and the control range of 6.70–6.77. The saliva remains unsaturated with hydroxy-and fluorapatite which results in mineral dissolution rates exceeding their reverse deposition rates thus maintaining a high caries risk [22].

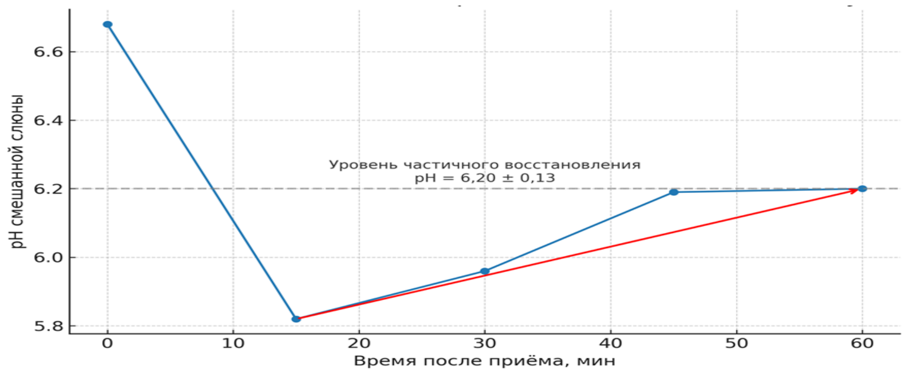

Figure 6. Partial pH reduction to 6.2.

The graph shows the dynamics of oral fluid pH in energy drink consumers and shows partial recovery of the saliva buffer system by the 60th minute (pH ≈ 6.20). The AUC-crit value increases with each portion of an energy drink until it reaches a mineral deficit level. The salivary remineralization potential becomes insufficient to compensate for losses when a person consumes two or more servings of these drinks daily. The recommended approach to manage such drinks involves either reducing their contact with enamel or using buffer rinses (1) and drinking water and chewing xylitol gum to speed up pH increase [23]. The preventive application of fluoride- and calcium-phosphate-containing agents (such as Ca/PO_4 bioactive glass and CPP-ACP) remains important because they reduce the critical pH to 4.5–4.8 and boost enamel resistance against acid attacks [24].

Thus, the recorded decrease in pH to 5.8 and its incomplete recovery to 6.2 demonstrate that even a short-term episode of energy drink consumption creates conditions for the demineralization of enamel, and the recovery window for the salivary buffer capacity is insufficient for complete remineralizing repair. This pathophysiological rationale highlights the persistent risk of early caries development and underscores the need for regulated preventive measures.

DISCUSSIONS

Ratthapong Worawongvasu (2015) conducted a study using scanning electron microscopy (SEM) to examine tooth enamel which revealed substantial surface changes including enlarged pores and disrupted enamel prisms structure [24]. The teeth showed a substantial reduction in enamel calcium and phosphorus ion concentrations following exposure to acidic sports and energy drinks. The elevated oxygen levels together with reduced calcium ion concentrations verify that these beverages cause hydroxyapatite breakdown into its basic elements. Silva JG (2021) showed that energy and sports drinks decrease tooth enamel hardness through their erosive action. The evaluation of enamel surface roughness after energy drink exposure revealed higher roughness measurements. Sports drinks resulted in less enamel structural damage compared to other acidic carbonated beverages [25].

The research by von Fraunhofer JA and Rogers MM (2005) involved submerging enamel blocks in different beverages for 14 days which revealed that all tested drinks led to enamel dissolution while flavored beverages and commercial lemonades and energy/sports drinks caused the most severe damage. The research established that sports drinks lead to enamel demineralization and shorter exposure times will minimize the extent of damage [26]. E A Abou Neel (2016) discovered that regular energy drink consumption leads to dental caries development. The researcher found that energy drinks contain two major cariogenic factors which are their acidic nature and high sugar content but he could not prove a definitive link between energy drinks and carious lesion formation. The tested drinks showed pH values between 4.46 and 2.38 which fell below the critical pH threshold of 5.5 for enamel demineralization [27]. Another study highlights how energy drinks could potentially cause enamel erosion. The extent of enamel demineralization depends on the amount of calcium and phosphate ions found in oral fluids according to his research. In vitro experiments show that insufficient hydroxyapatite and fluorapatite saturation in oral fluids speeds up erosive processes which result in permanent tooth surface deterioration [28].

FUTURE RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed for future research and clinical practice to address the dental health risks associated with energy drink consumption:

Conduct Long-Term Epidemiological Studies

It is crucial to move beyond short-term observations and initiate extensive epidemiological studies to investigate the long-term, cumulative effects of regular energy drink consumption on oral health. These studies should track changes in the incidence of dental caries and erosion over several years, particularly in adolescent and young adult populations [29] [30].

Investigate the Impact on Different Demographics

While this study focused on students, future research should explore the effects of energy drinks on other active consumer groups, such as professional athletes and manual laborers. This will provide a more comprehensive understanding of the risks across various lifestyles and age groups [31].

Evaluate Preventive Strategies

Further clinical trials are needed to evaluate the efficacy of specific preventive measures. This includes assessing the effectiveness of different types of oral rinses (e.g., sodium bicarbonate, fluoride), chewing gums (e.g., xylitol), and topical fluoride applications in mitigating the acidogenic and erosive effects of energy drinks [32].

Analyze the Role of Specific Ingredients

A more detailed chemical analysis of various energy drink brands is warranted to determine the specific contribution of ingredients like citric acid, phosphoric acid, and different types of sugars to dental demineralization. This would help in formulating targeted public health warnings and potentially influencing product reformulation [33].

Develop Targeted Public Health Campaigns

The results of this study should be used to inform the development of educational campaigns aimed at raising public awareness, especially among young people, about the specific pathogenic mechanisms and dental health risks associated with energy drinks. These campaigns should provide clear, evidence-based recommendations for safer consumption habits and alternatives [34].

CONCLUSION

Drawing a line between trend and threat, the widespread consumption of energy drinks poses a silent yet significant risk to oral health. Sugar-rich formulations foster bacterial proliferation in the oral cavity, while their consistently low pH values contribute to enamel erosion and heightened tooth sensitivity. The observed reduction in oral pH to 5.8 with only a limited rebound to 6.2 illustrates how even brief exposure can create an environment conducive to enamel demineralization. Compounded by the insufficient restorative capacity of the salivary buffer, this creates a persistent pathophysiological risk for early carious lesions.

These findings highlight the urgent need for public health initiatives to educate consumers, especially

adolescents about the dental consequences of energy drink consumption. Furthermore, the evidence reinforces the importance of implementing standardized preventive strategies within dental practice and public policy.
Looking ahead, targeted clinical and experimental research is essential to further elucidate how energy drinks alter the acid-base dynamics of oral fluids and impact the integrity of tooth structures. Such studies will not only enhance our understanding of their pathogenic potential but also support the development of evidence-based guidelines to mitigate their dental risks.

DECLARATION

Acknowledgement: All authors would like to thanks Osh State University for providing the support and research infrastructure.
Data availability statement: The original contributions and raw data presented in the study will be provided upon request as article/supplementary material. Further inquiries can be directed to the corresponding author.
Funding Statement: This research received no external funding.
Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Ethical Approval: The Institutional Review Board (IRB) of the Osh State University, Osh City, Kyrgyz Republic approved the study. Oral concent were taken while collecting data and permission by IRB was waived since the data were obtained anonymously, with no patient characteristics identified.

REFERENCES

1. Y. Louzon, I. Vaknin, A. Wolfoviz-Zilberman, E. Sharon, Y. Houri-Haddad, and N. Beyth, “In Vitro Effect of Streptococcus mutans Biofilm Produced in Sugar-Free Coca-Cola on Enamel,” Int. Dent. J., vol. 75, no. 2, pp. 752–760, Apr. 2025, doi: 10.1016/j.identj.2024.05.008.
2. A. A. Alsunni, “Energy Drink Consumption: Beneficial and Adverse Health Effects,” Int. J. Health Sci., vol. 9, no. 4, pp. 468–474, Oct. 2015.
3. Q. Du et al., “Sucrose promotes caries progression by disrupting the microecological balance in oral biofilms: an in vitro study,” Sci. Rep., vol. 10, no. 1, 2020, doi: 10.1038/s41598-020-59733-6.
4. A.-K. Johansson, R. Omar, G. E. Carlsson, and A. Johansson, “Dental Erosion and Its Growing Importance in Clinical Practice: From Past to Present,” Int. J. Dent., vol. 2012, p. 632907, 2012, doi: 10.1155/2012/632907.
5. M. Lutovac et al., “Testing the Effect of Aggressive Beverage on the Damage of Enamel Structure,” Open Access Maced. J. Med. Sci., vol. 5, no. 7, pp. 987–993, Dec. 2017, doi: 10.3889/oamjms.2017.180.
6. R. Touger-Decker and C. van Loveren, “Sugars and dental caries23,” Am. J. Clin. Nutr., vol. 78, no. 4, pp. 881S-892S, Oct. 2003, doi: 10.1093/ajcn/78.4.881S.
7. Т. А. Абдирасулова, А. М. Ешиев, and А. А. Зулпуева, “ВЛИЯНИЕ ЭНЕРГЕТИЧЕСКИХ НАПИТКОВ НА ТВЕРДЫЕ ТКАНИ ЗУБОВ,” 2023, doi: 10.24412/2500-1000-2023-10-1-50-53.
8. [“World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects,” JAMA, vol. 310, no. 20, Nov. 2013, doi: 10.1001/jama.2013.281053.
9. [9] B. Calkovsky, L. Slobodnikova, S. Kalmanova, and M. Janickova, “The Benefits of a Dental Operating Microscope for Tooth Extractions: A Case Report,” Dent. J., vol. 13, no. 6, p. 243, June 2025, doi: 10.3390/dj13060243.
10. “Dental Enamel Formation and Implications for Oral Health and Disease - PMC.” Accessed: Aug. 08, 2025. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC6151498/
11. K. A. Schulze, N. M. Santucci, B. Surti, S. Habelitz, M. Bhattacharyya, and W. Noble, “Evaluation of Enamel Volume Loss after Exposure to Energy Drinks,” Oral, vol. 4, no. 1, pp. 101–112, Mar. 2024, doi: 10.3390/oral4010009.
12. S. V. Dorozhkin, “Calcium orthophosphates (CaPO4): occurrence and properties,” Prog. Biomater., vol. 5, pp. 9–70, Nov. 2015, doi: 10.1007/s40204-015-0045-z.
13. “Dental Caries Aetiology, Pathology and Prevention | SpringerLink.” Accessed: Aug. 08, 2025. [Online]. Available: https://link.springer.com/book/10.1007/978-1-349-16547-6
14. J. L. Baker et al., “Transcriptional profile of glucose-shocked and acid-adapted strains of Streptococcus mutans,” Mol. Oral Microbiol., vol. 30, no. 6, pp. 496–517, Dec. 2015, doi: 10.1111/omi.12110.
15. J. L. Baker, R. C. Faustoferri, and R. G. Quivey, “Acid-adaptive mechanisms of Streptococcus mutans–the more we know, the more we don’t,” Mol. Oral Microbiol., vol. 32, no. 2, pp. 107–117, Apr. 2017, doi: 10.1111/omi.12162.
16. S. R. Aspinall, J. K. Parker, and V. V. Khutoryanskiy, “Oral care product formulations, properties and challenges,” Colloids Surf. B Biointerfaces, vol. 200, p. 111567, Apr. 2021, doi: 10.1016/j.colsurfb.2021.111567.

17. M. F. Siddiqui, "IoMT Potential Impact in COVID-19: Combating a Pandemic with Innovation," in Computational Intelligence Methods in COVID-19: Surveillance, Prevention, Prediction and Diagnosis, vol. 923, K. Raza, Ed., in Studies in Computational Intelligence, vol. 923. , Singapore: Springer Singapore, 2021, pp. 349–361. doi: 10.1007/978-981-15-8534-0_18.
18. R. Hans, S. Thomas, B. Garla, R. J. Dagli, and M. K. Hans, "Effect of Various Sugary Beverages on Salivary pH, Flow Rate, and Oral Clearance Rate amongst Adults," Scientifica, vol. 2016, p. 5027283, 2016, doi: 10.1155/2016/5027283.
19. R. Hans, S. Thomas, B. Garla, R. J. Dagli, and M. K. Hans, "Effect of Various Sugary Beverages on Salivary pH, Flow Rate, and Oral Clearance Rate amongst Adults," Scientifica, vol. 2016, p. 5027283, 2016, doi: 10.1155/2016/5027283.
20. L. Hassanali, F. S. Wong, R. J. M. Lynch, and P. Anderson, "A Novel Kinetic Method to Measure Apparent Solubility Product of Bulk Human Enamel," Front. Physiol., vol. 8, p. 714, Sept. 2017, doi: 10.3389/fphys.2017.00714.
21. R. Q. Catunda, K. Altabtbaei, C. Flores-Mir, and M. Febbraio, "Pre-treatment oral microbiome analysis and salivary Stephan curve kinetics in white spot lesion development in orthodontic patients wearing fixed appliances. A pilot study," BMC Oral Health, vol. 23, p. 239, Apr. 2023, doi: 10.1186/s12903-023-02917-z.
22. M. Fiyaz, A. Ramesh, K. Ramalingam, B. Thomas, S. Shetty, and P. Prakash, "Association of salivary calcium, phosphate, pH and flow rate on oral health: A study on 90 subjects," J. Indian Soc. Periodontol., vol. 17, no. 4, pp. 454–460, 2013, doi: 10.4103/0972-124X.118316.
23. A. Alam, N. Imam, M. F. Siddiqui, Md. K. Ali, M. M. Ahmed, and R. Ishrat, "Human gene expression profiling identifies key therapeutic targets in tuberculosis infection: A systematic network meta-analysis," Infect. Genet. Evol., vol. 87, p. 104649, Jan. 2021, doi: 10.1016/j.meegid.2020.104649.
24. "Efficacy of an Experimental CPP-ACP and Fluoride Toothpaste in Prevention of Enamel Demineralization: An In Vitro Study on Bovine Enamel - PMC." Accessed: Aug. 08, 2025. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC11936538/
25. J.-G.-V.-C. Silva et al., "Influence of energy drinks on enamel erosion: In vitro study using different assessment techniques," J. Clin. Exp. Dent., vol. 13, no. 11, pp. e1076–e1082, Nov. 2021, doi: 10.4317/jced.57788.
26. J. A. von Fraunhofer and M. M. Rogers, "Effects of sports drinks and other beverages on dental enamel," Gen. Dent., vol. 53, no. 1, pp. 28–31, 2005.
27. E. A. Abou Neel et al., "Demineralization–remineralization dynamics in teeth and bone," Int. J. Nanomedicine, vol. 11, pp. 4743–4763, Sept. 2016, doi: 10.2147/IJN.S107624.
28. "The effects of beverage erosion on enamel: evaluating surface characteristics and loss of calcium and phosphate ions | Discover Applied Sciences." Accessed: Aug. 10, 2025. [Online]. Available: https://link.springer.com/article/10.1007/s42452-024-06153-0
29. K. Khan et al., "Sports and Energy Drink Consumption, Oral Health Problems and Performance Impact among Elite Athletes," Nutrients, vol. 14, no. 23, p. 5089, Nov. 2022, doi: 10.3390/nu14235089.
30. A. Alam et al., "An Integrative Network Approach to Identify Common Genes for the Therapeutics in Tuberculosis and Its Overlapping Non-Communicable Diseases," Front. Pharmacol., vol. 12, p. 770762, Jan. 2022, doi: 10.3389/fphar.2021.770762.
31. [B. M. Malinauskas, V. G. Aeby, R. F. Overton, T. Carpenter-Aeby, and K. Barber-Heidal, "A survey of energy drink consumption patterns among college students," Nutr. J., vol. 6, p. 35, Oct. 2007, doi: 10.1186/1475-2891-6-35.
32. M. Arunakul, B. Thaweboon, S. Thaweboon, Y. Asvanund, and K. Charoenchaikorn, "Efficacy of xylitol and fluoride mouthrinses on salivary mutans streptococci," Asian Pac. J. Trop. Biomed., vol. 1, no. 6, pp. 488–490, Dec. 2011, doi: 10.1016/S2221-1691(11)60106-8.
33. "Impact of soft drinks to health and economy: a critical review | European Archives of Paediatric Dentistry." Accessed: Aug. 10, 2025. [Online]. Available: https://link.springer.com/article/10.1007/s40368-019-00458-0
34. K. M. Gurav, V. Shetty, V. Vinay, K. Bhor, C. Jain, and P. Divekar, "Effectiveness of Oral Health Educational Methods among School Children Aged 5–16 Years in Improving their Oral Health Status: A Meta-analysis," Int. J. Clin. Pediatr. Dent., vol. 15, no. 3, pp. 338–349, 2022, doi: 10.5005/jp-journals-10005-2395.