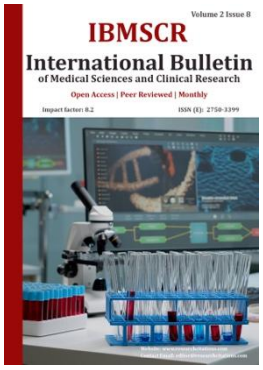

THE EFFECT OF ENERGY DRINKS ON HARD DENTAL TISSUES: A CHEMICAL, MORPHOLOGICAL, AND CLINICAL ANALYSIS

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Abstract: Energy drinks have become increasingly popular among young individuals due to their stimulating effects and energy-boosting properties. However, their high acidity and sugar content raise concerns regarding dental health, particularly the erosion and demineralization of hard dental tissues. This study aims to analyze the chemical, morphological, and clinical effects of energy drink consumption on enamel and dentin. Using a combination of pH measurements, scanning electron microscopy (SEM), and clinical assessments, the study investigated enamel surface alterations and mineral loss. The results revealed significant decreases in surface microhardness and visible morphological damage to the enamel, especially after prolonged exposure. Clinically, patients with frequent energy drink consumption demonstrated a higher prevalence of dental erosion and sensitivity. The findings suggest that energy drinks, due to their acidic pH (often below 3.5) and presence of citric acid, significantly compromise the integrity of dental hard tissues. Preventive strategies, including consumer education, limiting consumption frequency, and using remineralizing products, are essential to mitigate the detrimental effects.

Keywords: energy drinks, enamel erosion, dental hard tissues, citric acid, pH, demineralization, microhardness, dentin, morphology, oral health

Intradaction: Energy drinks have become a widely consumed beverage category, particularly among adolescents and young adults. Marketed for their ability to enhance physical and mental performance, these drinks often contain caffeine, sugars, amino acids, and acidic flavoring agents such as citric and phosphoric acids. While the stimulating properties of energy drinks attract consumers, their acidic composition poses significant risks to oral health. Dental hard tissues, particularly enamel and dentin, are susceptible to chemical dissolution when exposed to acidic environments.

Enamel, composed primarily of hydroxyapatite crystals, begins to demineralize at pH values below 5.5. Energy drinks often possess pH levels as low as 2.5–3.5, making them highly erosive. Continuous or frequent consumption results in surface softening, mineral loss, and ultimately irreversible erosion. Morphological changes such as surface roughness, porosity, and color alteration have also been observed.

1 Figure: Energy drinks have rapidly gained in popularity over the last two decades. They are a common beverage choice among teens and young adults, often replacing sodas and sports drinks. There are a wide variety of energy drink options on the market today, including Red Bull, Monster, Rockstar, and more.

Several studies have correlated the intake of energy drinks with increased incidence of dental erosion, hypersensitivity, and aesthetic concerns. However, many consumers remain unaware of the harmful effects of these beverages. Therefore, this study focuses on evaluating the chemical, morphological, and clinical effects of energy drinks on hard dental tissues. Through combined laboratory and clinical analyses, it aims to provide a comprehensive understanding of the mechanisms of erosion and propose preventive recommendations.

Materials and Methods: This study utilized both in vitro and in vivo methods to evaluate the effects of energy drinks on dental hard tissues. Thirty extracted, caries-free human premolars were collected, cleaned, and stored in artificial saliva prior to testing. The samples were randomly divided into three groups: (1) control (distilled water), (2) commercial energy drink A, and (3) commercial energy drink B. Each sample was immersed in 20 mL of its respective solution for 10 minutes daily over 14 days, simulating average daily consumption patterns.

Chemical analysis involved measuring the pH and titratable acidity of each beverage using a digital pH meter and titration with 0.1 N NaOH. Surface microhardness was assessed using a Vickers microhardness tester before and after exposure. Morphological evaluation was performed using scanning electron microscopy (SEM) to detect surface erosion and structural alterations.

For the clinical assessment, 50 patients aged 18–30 years who regularly consumed energy drinks were examined. Clinical findings such as enamel wear, sensitivity, and erosion index were recorded. Statistical analysis was performed using ANOVA and post-hoc Tukey tests, with significance set at $p < 0.05$.

Ethical approval was obtained from the university's dental research committee, and informed consent was obtained from all participants.

Results: Chemical analysis revealed that both energy drink samples exhibited highly acidic pH values: energy drink A (pH 2.8) and energy drink B (pH 3.2). Titratable acidity values were also high, indicating significant buffering capacity capable of prolonging enamel exposure to acidic conditions.

The microhardness results demonstrated a significant decrease in enamel hardness after exposure to energy drinks. The average baseline microhardness for all samples was 340 ± 15 VHN. After 14 days, group A samples showed a reduction to 245 ± 12 VHN, while group B decreased to 260 ± 14 VHN ($p < 0.01$). The control group showed no significant change (338 ± 13 VHN).

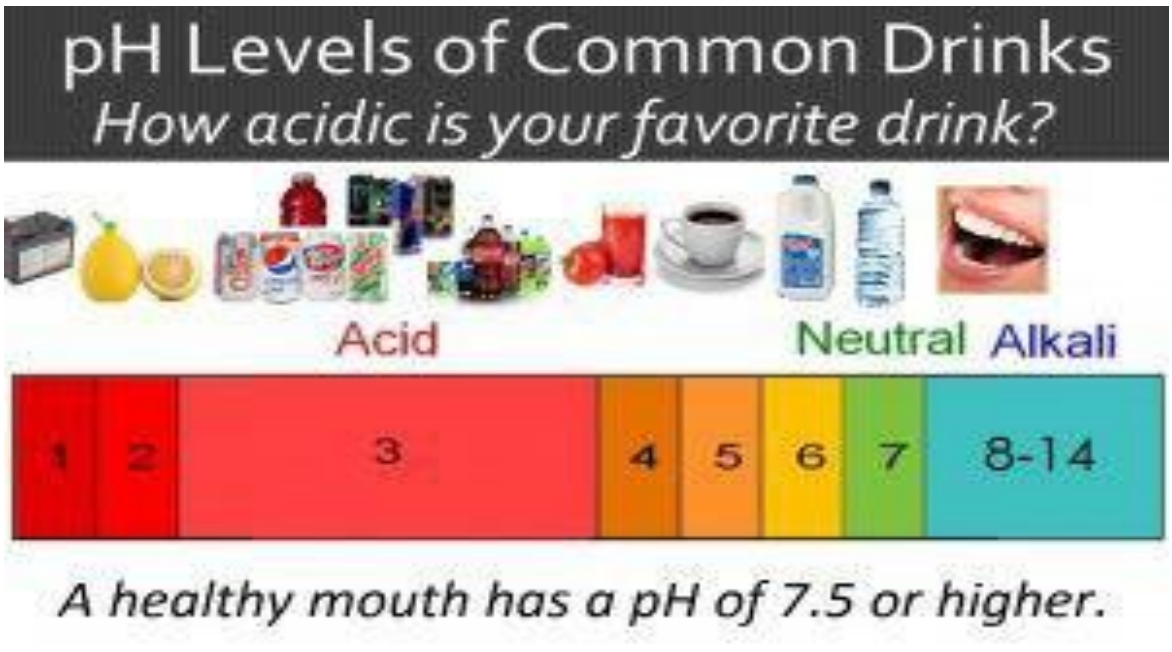
SEM images showed clear morphological differences between the control and exposed groups. The control enamel displayed smooth and compact surfaces, whereas energy drink–exposed samples exhibited roughened surfaces, microcracks, and loss of prismatic structure. The enamel rods appeared irregular, and areas of demineralization were clearly visible, particularly in group A.

Clinically, 68% of energy drink consumers showed early signs of enamel erosion, predominantly on the labial surfaces of anterior teeth. About 45% reported hypersensitivity to thermal and sweet stimuli. Patients consuming more than two cans per day demonstrated significantly higher erosion scores compared to occasional consumers ($p < 0.05$).

A positive correlation was observed between consumption frequency and erosion severity. Moreover, individuals who did not rinse their mouth or brush immediately after consuming energy drinks experienced greater enamel wear.

The combined data suggest that the low pH, high citric acid concentration, and frequent exposure time contribute synergistically to enamel softening and mineral loss. The findings confirm that energy drinks are strongly erosive and can lead to irreversible damage of dental hard tissues.

Discussion: The present study demonstrates that energy drinks exert substantial chemical and physical effects on dental hard tissues, primarily through acid-induced demineralization. The low pH values and high buffering capacities observed indicate the strong erosive potential of these beverages. Citric acid, a common ingredient in energy drinks, not only lowers pH but also acts as a chelating agent, binding to calcium ions and enhancing mineral loss from the enamel surface.



2 Figure: Acidic pH: The second problem with energy drinks is their acidic pH. The pH of energy drinks ranges from 1.5 to 3.3, which is extremely acidic. When bacteria

cause cavities on the teeth, they eat sugar in order to produce acid. It is actually the acid that softens and weakens tooth enamel enough that the bacteria can penetrate into the tooth and cause decay. When you drink beverages that are acidic, you are bringing the pH in the mouth down to an acidic level. That means the enamel is already in a compromised state, and it is easier for the bacteria to penetrate. They have to make less acid to get through enamel in an already-acidic environment.

The decrease in surface microhardness aligns with findings from previous studies, which show that exposure to acidic beverages significantly weakens enamel integrity. SEM analyses confirmed visible surface degradation, indicating that demineralization had progressed beyond subsurface layers. These morphological alterations explain the increased sensitivity and roughness reported in clinical observations.

Clinically, energy drink consumers exhibited erosion patterns similar to those caused by carbonated soft drinks and fruit juices but with higher severity. The frequent consumption and lack of post-consumption oral hygiene practices intensify the erosive process. Furthermore, individuals with xerostomia or reduced salivary buffering capacity are at higher risk, as saliva plays a crucial role in neutralizing acids and promoting remineralization.

Preventive strategies are essential to mitigate the detrimental effects. Educating the public about the risks of frequent energy drink consumption, encouraging the use of straws, rinsing with water afterward, and avoiding immediate toothbrushing can reduce enamel exposure to acids.

Additionally, using fluoride-containing toothpaste or remineralizing agents such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) can help restore mineral balance.

From a clinical perspective, early detection of enamel erosion is crucial. Dentists should inquire about patients' dietary habits, particularly the consumption of acidic beverages, and provide preventive counseling accordingly.

Overall, this study highlights the importance of integrating chemical, morphological, and clinical analyses in understanding dental erosion. The synergistic use of laboratory data and clinical findings strengthens the conclusion that energy drinks pose a serious threat to enamel health. Continued research should explore long-term effects and potential protective formulations to minimize dental damage while maintaining beverage appeal.

Conclusion: This study confirms that energy drinks cause significant chemical and morphological damage to hard dental tissues. Their low pH and high citric acid content lead to enamel demineralization, microhardness reduction, and surface erosion. Clinical findings also indicate increased sensitivity and visible enamel wear among frequent consumers. Preventive measures such as limiting intake, rinsing with water after consumption, and using remineralizing products are recommended to reduce harm. Dental professionals should educate patients about these risks and encourage healthier beverage alternatives. Further studies are warranted to evaluate the long-term effects of different energy drink formulations on dental structures and to develop effective protective strategies.

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