



THE EFFECTS OF ENERGY DRINKS ON ORAL HEALTH AND TEETH.

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ORIGINAL ARTICLE

ABSTRACT

Recently, the use of energy drinks has been increasing among young people, adults and athletes. As a result of this increase, the negative effects of these drinks on human health are becoming more apparent. These drinks contain high levels of carbohydrates and caffeine. The pH level of energy drinks (2.5-3.5) is quite low. Frequent and excessive consumption of these drinks causes dental erosion, dental caries and damage to restorative materials. In order to reduce these effects, individuals should be informed about the negative effects on human and oral health and the use of these drinks should be reduced. In addition, experimental, clinical and laboratory studies should be conducted to examine the effects of energy drinks on human and oral health in larger populations. In this article, it is aimed to provide up-to-date information on the effects of energy drinks on oral health and teeth and methods of protection from these effects.

Key words: Dental caries, critical pH level, energy drinks, tooth erosion.

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Introduction

Energy drinks are beverages that contain sugar, caffeine, and other stimulating ingredients (taurine, ginseng, ginkgo biloba, B vitamins) to improve mental and physical performance, concentration, and endurance. They have been first started to be produced in Austria as a response to consumer demand for meeting increased personal energy requirements [1]. The demand for energy drinks have been increased day by day. these drinks have taken their place on market shelves where people can easily reach them under different brand names. [1] (Figure 1).



Figure 1. Some energy drinks sold on market shelves under different brand names

The target audience for energy drinks primarily include athletes, young individuals, and adults. Athletes need to consume energy drinks to enhance endurance and fulfill the energy required during sports activities. Students and night-shift workers, also, consume these drinks to stay more energetic and alert [2,3].

In most societies sports and energy of drinks are thought to be the same drinks due to the influence of advertisements. Sports drinks are drinks that can be used before, during and after exercise and contain liquid, carbohydrate and electrolytes in their composition. Sports drinks are mainly used for three purposes. These are preventing fluid loss during exercise, providing carbohydrate support as an energy source and replacing electrolytes lost through sweating [4]. Energy drinks are used to increase physical endurance and concentration and to feel better during exams, sports, driving and leisure time activities [5,6].

The main difference between energy drinks and sports drinks is that energy drinks contain caffeine, which is a primary ergogenic aid [7]. Many different commercial energy drink

brands contain caffeine ranging from 8.5-580mg/100ml [8]. It is thought that the caffeine present in energy drinks has effects on both physical and mental functions, including enhancing attention, concentration, and mood improvement (cognitive performance) [9]. In addition to caffeine, energy drinks contain a variety of stimulating and nutritive substances such as taurine, herbal extracts, and B vitamins to help enhance both energy and mental performance [1,4,5].

According to current research, sports and energy drinks have many effects on teeth and human health. In addition to their positive effects on human health, it has been shown in various studies that they may have negative effects and may lead to dental caries [10-12]. It has also been reported that energy drink consumption can lead to health problems such as central nervous system disorders (headache, anxiety, nervousness, agitation, dizziness), obesity, cardiovascular problems (heart palpitations, chest pain, increased heart rate and hypertension), platelet-related diseases, electrolyte-related renal problems [13].

Energy drinks, like addictive drugs, can cause excessive secretion of dopamine, serotonin, noradrenaline and adrenaline, depleting neurotransmitter stores in the body and causing a negative balance in the body. In a study conducted in American soldiers, it was shown that suicidal tendency was higher in soldiers who used energy drinks and those who took them with alcohol had a higher suicidal tendency [14].

Due to the high caffeine and sugar content in energy drinks, they have been associated with adverse effects on the cardiovascular system [15-17]. It was observed that a seventeen-year-old male patient consuming two or more energy drinks a day, experienced a case of coronary artery spasm [15]. In other case, another person who consumes the same amount of energy drinks had a cardiac arrest [16]. In these cases, it has been noted that the caffeine and components such as glucuronolactone, carnitine, and ginseng in energy drinks lead to endothelial dysfunction by increasing platelet aggregation and triggering an increase in blood pressure [15-17].

Energy drinks have a high carbohydrate content (about 11-12%). Studies suggest that energy drinks may pose a risk factor for obesity due to their high sugar content [18, 19].

With the growth of the energy drinks industry, it is critical to understand the effects of energy drinks on the body. The lack of sufficient knowledge on their health effects raises concerns about the risks associated with high doses. It is thought that more experimental, clinical and laboratory studies on energy drinks will fill this gap [13,14].

Energy Drinks and Oro dental Effects

Teeth consist of three layers known as enamel, dentin, and cementum. Enamel is the hardest and outermost layer of teeth. Enamel is the part of the teeth that is visible in the oral cavity and is constantly exposed to acidic substances produced by foods and bacteria [21]. Foods with a low pH and rich in carbohydrates have a negative impact on enamel; on the other hands foods with a high calcium (Ca^{+2}) content and a near-neutral pH have a positive effect on enamel.

The pH level of fluids in the oral cavity (saliva, dental plaque, tooth surfaces) is close to neutral. This pH level is constantly changing with the consumption of different foods and beverages [21, 22]. In cases where oral hygiene is not adequately maintained, frequent consumption of refined carbohydrates, low pH foods consumed, and acids produced by bacteria are known to cause demineralization of enamel tissue [20,22].

The loss of minerals from dental tissues is called demineralization and the restoration of these minerals to the tooth tissue is called remineralization. The pH level at which the fluid on tooth-surfaces is unsaturated with hydroxyapatite and allows for the dissolution of calcium phosphate-from the enamel is referred to as the "acidic pH" level. This level is pH 5. 5 for the oral environment [23]. Enamel is resistant up to a pH of 5. 5, and demineralization of enamel tissue begins at values below this level [24]. In contrast, the critical pH level for the initiation of demineralization in root dentin tissues is 6. 8. Demineralization starts at values below this threshold [25, 26]. Unlike demineralization, consumed foods, agents used for oral hygiene, and ions like calcium (Ca^{+2}) and phosphate (PO_4^{-3}) found in saliva contribute to remineralization. The demineralization-remineralization cycle in enamel tissue continues happen recurrently [27, 28].

It has been shown that frequent and continuous consumption of energy drinks lowers the pH of the oral environment below the critical level [29]. Due to acidic oral environment, the hydrogen ions in oral environment, by dissolving minerals in tooth tissues, causes calcium and phosphate ions to diffuse out of the teeth [30]. As a result of this chemical process, "acidic erosion" occurs in the teeth.

Acidic dental erosion refers to the irreversible and progressive destruction of hard tooth tissues resulting from chemical processes carried out by acids in the absence of bacterial agents [31]. These acids may be intrinsic, such as stomach acid, or extrinsic, originating from food. Excessive acid consumption may not be solely responsible for dental erosion. Dental erosion

occurs as a result of continuous and direct contact of tooth surfaces with acidic substances [32]. Dental erosion is a pathological event that occurs slowly [33]. It is characterized by the initial softening of enamel surfaces, which leads to further dissolution of enamel crystals, it results in permanent loss of tooth volume and a softened surface layer. Many biological factors, such as an individual's oral hygiene, eating and drinking habits, saliva content, and saliva buffering capacity, play a role in the formation of dental erosion. Clinical and experimental studies show that the erosion mechanism in individuals is influenced by various factors interacting with each other [34-36].

The timing and frequency of consuming acidic beverages, as well as the immediate tooth brushing process afterward, can increase the risk of erosion. A significant relationship has been found between the occurrence of toothbrush abrasion following demineralization after exposure to dietary acids [37, 38]. It has been stated that brushing teeth 30-60 minutes after an acid attack is not very effective in causing dental erosion [36].

The Acidity of Energy Drinks

The pH values of commercially available energy drinks are shown in Table 1 [40]. The high acidity of these beverages, indicated by their significantly low pH values, has a negative impact on oral and dental health. The acidity of many sports drinks is much lower than the critical pH of 5.5, which has been shown to cause dental erosion [39,40].

Table 1: pH Values of the most commonly available commercial energy drink brands.

PRODUCT	pH
Monster Assault	3. 49
Red Bull	3. 37
Gatorade Fruit Punch	3. 27
Propel Mango	3. 23
Gatorade Lemon-Lime	3. 07
Full Throttle Energy Drink	2. 94
Gatorade Cool Blue	2. 92
5-Hour Energy	2. 81
Powerade Red	2. 77

Rockstar	2. 53
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Studies have indicated that the lower the acidity level of energy drinks, the more potential they can cause to demineralization in tooth tissues [29,41-43]. The energy drinks can remove the protective layer on the root surfaces of teeth, which leads to increased tooth sensitivity [44]. It is thought that energy drinks contribute to tooth sensitivity due to two natural properties: The first is their low pH and their high carbohydrate content [44].

In a study conducted in 2017 by Al Anazi et al. [45] on Saudi youth, it was reported that energy drinks with low pH and high sugar content had a stronger erosive potential on tooth surfaces. Researchers also found a relationship between the consumption of energy drinks and increased tooth sensitivity. In the same study, it was also noted that tooth sensitivity could increase in the 19-22 age group who consumed both energy drinks and cigarettes [45]. Additionally, Pinto et al. [46] stated that energy drinks could lead to tooth sensitivity by removing the smear layer on the cervical dentin.

The Effects of Energy Drinks on Restorative Materials

In recent years, people have placed a greater emphasis on dental aesthetics, partly due to technological advancements. In response to this aesthetic demand, companies have also introduced tooth-colored restorative materials to the use of dentists. These aesthetic restorative materials include silicate cements, acrylic resins, glass ionomer cements, and composite resins. The ease of application, concerns about mercury release in amalgam restorations, and the increasing demand for aesthetics have resulted in the increased use of resin-based restorative materials in dentistry.

Along with the aesthetic advantages of these materials, there are also some disadvantages. Such as dimensional shrinkage after polymerization, discoloration, the risk of secondary caries, and increased plaque accumulation [47].

Both the widespread use of aesthetic dental materials and the increasing use of energy and sports drinks have led researchers to conduct studies on the effects of these drinks on restorative materials.

In a study conducted by Al-Samadani in 2013 [48], it was reported that energy drinks had an adverse effect on the surface roughness of resin composites. The impact of energy drink

solutions on the surface roughness parameter of resin composites was found to be dependent on the type of solution and its acidity content [48].

In a study conducted by Al Sarheed et al. [49] in 2021, it was shown that energy drinks caused a high degree of discoloration on Nano-hybrid resin composite (NRC), silver glass ionomer cement (SGI), and resin-modified glass ionomer cement (RMGI). The least color change was observed in composite resin, while the highest color change was reported in resin-modified glass ionomer cement [49].

Various food additives such as citric acid, maleic acid, pantothenic acid can be found in energy drinks. Citric acid is a common food additive used as an acid regulator, flavor enhancer and preservative in the food and beverage industry [50]. In some studies, have stated that drinks containing citric acid and having low pH have the greatest erosive capacity on tooth surfaces [51-53]. It has also been reported that citric acid can be harmful to restorative materials containing organic filler [51,54,55]. Similar studies have compared sports and energy drinks, containing citric acid and containing maleic acid. It has been found that drinks containing citric acid have a higher erosive potential compared to those containing maleic acid [51,53].

The Relationship Between Energy Drinks and Dental Caries

Dental caries is the irreversible damage to tooth enamel and dentin caused by the acid released by bacteria in the oral environment as a result of the fermentation of dietary carbohydrates. It is the most common cause of pain and tooth loss. Dental caries is a multifactorial and infectious disease that arises from the interaction of many factors, including microbial, genetic, immunological, personal habits, and environmental factors. It is generally accepted that the presence of a susceptible host, cariogenic oral flora, and cariogenic foods for a sufficient period of time is necessary for dental caries to occur [56].

For dental caries to develop, microorganisms need adhere to the tooth surface for a certain period. Bacterial plaque plays a significant role in the development of caries by enabling the attachment of these microorganisms to the tooth surface [57]. Bacteria in the plaque metabolize the carbohydrates in the environment to meet their energy needs. As a byproduct of this chemical process, organic acids are released. These acids lower the pH of the environment, leading to mineral loss on the tooth surfaces. Under normal conditions, the inorganic component of enamel is rapidly repaired by the minerals and enzymes in saliva [58].

Diets high in calcium, such as milk, yogurt, and cheese, may help to improve the repair process on the tooth surface. However, consumption of acidic and cariogenic beverages and

foods (candy, sugary drinks, tea sugar, cookies and cakes, sweets) are factors that negatively affect the repair process on the tooth surface [59-61].

Continuous and frequent consumption of energy drinks has been reported to reduce individuals' water intake, which leads to a decrease in saliva production and potentially accelerating the formation of dental caries [17]. Due to their low pH and high carbohydrate content [6], excessive consumption of energy drinks promotes the formation and accumulation of a biofilm layer on the teeth. Within this biofilm layer, *St. Mutans* and other cariogenic bacteria can cause damage to tooth tissues, making the tooth's hard surface more porous and vulnerable, which ultimately leads to the development of dental caries [60]. According to the American Dental Association (ADA), the frequency and quantity of exposure to sugar-sweetened foods and beverages are significant factors in cariogenic potential and can increase the risk of dental caries.

In 2022, a study, conducted in Pakistan, reported that high percentage of elite athletes, who consumed a significant amount of sports and energy drinks experienced poor overall oral health, although they practised good oral hygiene. Specifically, 63.5% of athletes had dental caries, 46.1% had gingivitis, 26.9% had periodontitis, and 21.2% experienced erosive tooth wear issues. More than a quarter of athletes (28.8%) evaluated their oral health as moderate to very poor [61]. Excessive and continuous consumption of energy drinks can increase the risk of dental caries. Therefore, limiting or completely eliminating the consumption of energy drinks in communities is an important factor in preserving oral and dental health.

The Impact of Energy Drinks on Periodontal Health

Recently studies have shown that the high sugar content in sports and energy drinks can affect periodontal health locally and systemically [62-65]. High sugar intake through the diet can negatively affect the composition of the oral biofilm layer, potentially leading to diseases such as dental caries and periodontitis [63, 64]. In addition, it has been stated that the consumption of foods with a high glycemic index can increase gingival inflammation and may lead to gum bleeding [66].

Clinical Appearance of Acidic Dental Erosion

The development of erosive lesions due to the acidic environment in the mouth results in superficial demineralization of dental hard tissues. When erosions occur in conjunction with poor oral hygiene, they are characterized by white spots and line-shaped marks on the enamel surrounding the lesions [67] (Figure 2).



Figure 2. The clinical image of a 22-year-old male patient who consumes energy drinks at least twice a day (660 ml).

Initially, the erosion may affect only the enamel, which appears matte, while the abraded enamel has a shiny surface. As the lesion progresses into the dentin, various colors ranging from yellow to brown can be observed, and the tooth becomes sensitive to temperature changes. In the early stages, the shallow lesions exhibit a white or light yellow appearance, indicative of exposed dentin. Later, the lesions become round-edged, wide, irregular, and discolored. Consequently, the affected dentin displays a dark yellow and brownish appearance, which does not change with a physical manipulation [68] (Figure 3).



Figure 3. The clinical image of a 33-year-old male patient who consumes energy drinks at least six times a day (1980 ml).

Approaches to Prevention of Dental Effects of Energy Drinks

Various methods and effective agents have been tried to protect dental tissues from tooth erosion and to repair the substance loss that occurs. Two main approaches have been emphasized in the protection against erosion: Strengthening dental tissues or consuming foods with a low erosive potential [69]. To achieve this, topical applications of gels, mouthwashes, and varnishes containing fluoride or calcium phosphate have been used. Besides toothpaste formulations have been enriched with components such as calcium, phosphate, iron, ferrous sulfate, tin ions, and sodium hexametaphosphate. Laboratory and clinical studies have indicated that fluoride toothpaste containing potassium nitrate (5%) or potassium citrate (5.5%) (1500 ppm sodium monofluorophosphate) can block dentin tubules and reduce teeth sensitivity [70]. Application of high-fluoride varnishes by dentists has been found to protect teeth against secondary acid attacks and enhance resistance to acids [71, 72].

The protective effect of fluoride varnishes against enamel erosion has been demonstrated through laboratory-based analyses of changes in both hardness and roughness [73, 74]. However, it is not fully understood how varnishes interact with tooth wear. In a study comparing fluoride varnish, CPP-ACP (Casein Phosphopeptide-Amorphous Calcium Phosphate) cream, and glass ionomer fissure sealant, it was observed that glass ionomer-based dental materials enhanced remineralization on the enamel surface more effectively than sodium fluoride-containing materials. Varnish and fissure sealant exhibited more controlled remineralizing agent release, while CPP-ACP cream showed no significant advantage over fluoride-containing varnishes [75].

The addition of phosphate and calcium to the composition of highly acidic beverages has been shown to significantly reduce their erosive potential [76]. In a study, it was found that adding 40 mmol/L of calcium and 30 mmol/L of phosphate to orange juice decreased its erosive potential [77]. Another emerging approach involves inhibiting the activity of matrix metalloproteinase (MMP) enzymes found in dentin's structure, which are believed to play a role in the progression of erosion. The use of MMP inhibitors is seen as a new strategy to strengthen the tooth's inorganic structure and prevent the chemical processes responsible for erosion [78].

Individuals themselves can reduce the negative dental effects of energy drinks by applying some methods and being more careful. These methods can be listed as follows. The

frequency of consuming high-acidity energy drinks should be reduced and, if necessary, limited to main meals. Instead of sipping and swishing acidic drinks in the mouth, they should be swallowed quickly, and if possible, a straw should be used when consuming them. After consuming acidic drinks, the mouth should be rinsed with water and the teeth should not be brushed immediately. Chewing sugar-free gum after acidic drink consumption increases saliva flow, allowing for the benefits of its protective properties [79,80].

Consuming acidic drinks at a cooler temperature can help reduce their erosive effects. After consuming acidic drinks, consuming alkaline foods (such as cheese and yogurt) can help strengthen tooth enamel. Consuming high-acidity energy drinks before bedtime can lead to more enamel erosion. Therefore, avoiding the consumption of these drinks before bedtime is essential [79].

For individuals at risk of dental erosion, it is recommended to use soft-bristle toothbrushes and toothpaste with low abrasiveness and a high fluoride content. Tooth brushing should be performed before exposure to acidic substances. Brushing the teeth should be avoided after consuming acidic foods or during erosive conditions such as vomiting. If tooth brushing is necessary, at least 30-60 minutes of waiting is necessary to allow the acid-attacked tooth surface to recover [67, 79].

Treatment Approaches

The treatment of dental erosion caused by energy drinks can involve conservative approaches if diagnosed early. The primary goal of erosion treatment should be to preserve the maximum amount of tooth structure in both anterior and posterior teeth without the need for any preparation. Different treatments can be applied based on the depth of erosion, the area it covers on the tooth surface, its location within the oral cavity (anterior or posterior), and the surface (vestibular, palatal, or occlusal) it affects.

For initial stages of dental erosion, fluoride applications, transparent fissure sealants, or varnishes may be considered. In cases with significant esthetic loss and tooth sensitivity, adhesive materials (glass ionomer, compomer, and composite resin) can be beneficial. In situations with extensive loss of tooth tissue or requiring occlusal rehabilitation, indirect treatments (prosthetic restorations such as fixed prosthesis, porcelain laminates, inlays and onlays) can be preferred [80].

Conclusion

There is limited literature available on the oral effects of sports and energy drinks, particularly among athletes, night-shift workers, and young individuals who are known to excessively consume these beverages. This situation concerning human health should be taken seriously by scientists and experimental, clinical and laboratory studies should be conducted to examine larger populations. These drinks have a pH well below the critical value of pH 5.5 for the oral environment. Due to their low pH and high carbohydrate content, such beverages can lead to dental erosion, cavities, and periodontal problems. Additionally, they can cause discoloration of restorative materials and surface roughness. Reducing or completely preventing the consumption of these drinks by children and young people is crucial for maintaining oral and dental health.

Patients with dental problems associated with energy and sports drinks should undergo regular dental check-ups, depending on etiological factors, disease severity, and progression. During these follow-up appointments, any new dental tissue loss and the condition of existing restorations should be assessed, and if needed, preventive and necessary treatments should be administered. Furthermore, patient motivation should be provided to enable lifestyle and behavioral changes, when necessary.

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