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Erosive Potential: Laboratory Evaluation of Sports Drinks Available in Nigerian Market

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Abstract: This in vitro study sought to evaluate nine different sport and energy drinks (B Star Energy drink, London Best Energy Drink, Hippo Energy drink, Lucozade Boost Energy fast, Hype Energy, Vita 500 Energy drink, Lucozade Sport, Power horse Energy drink and Red Bull Energy drink) in terms of initial pH and titratable acidity. Initial pH was measured in triplicate for the nine beverages. The titratable acidity of each beverage was assessed by measuring the volume of 0.10 M sodium hydroxide necessary for titration to pH level of 7.0. All the evaluated drinks were acidic with pHs that ranged from 2.7 to 3.4. London best Energy drink and Lucozade Boost Energy Fast produced the lowest mean pH of 2.7 while Lucozade Sport produced the highest pH. The mean titratable acidity ranges from 4.1 to 13.8 mls. Hype Energy produced the highest acidity (indicating the strongest potential for erosion of enamel), followed by Hippo Energy drink. The least was Lucozade Boost Energy fast. All the popular sports and energy drinks in the Nigerian market are acidic with pHs well below the critical pH (5.5) of enamel demineralization. Erosive cavities may develop in addicts.

Key words: Dental Erosion · Ph · Sport Drinks

INTRODUCTION

Dental erosion (erosive tooth wear) is the result of a pathologic, chronic, localized loss of dental hard tissue that is chemically etched away from the tooth surface by acid and/or chelation without bacterial involvement [1]. Over the last two decades, tooth erosion has become a significant clinical problem [2]. It is a common condition in developed societies that affects people of all ages and in many European countries the role of acid erosion has been recognized to be the most important component of toothwear.

Causative factors for tooth erosion are divided into extrinsic and intrinsic categories. Intrinsic causes include recurrent vomiting, such as due to bulimia or chronic alcoholism and gastric reflux; extrinsic causes are wide ranging and include ingestion of acidic foods and drinks as well as inhalation of corrosive industrial fumes. It has also been classified as environmental, medicaments, lifestyle and dietary factors [3, 4].

Dietary acids, however, are undoubtedly the principal causative factor for extrinsic tooth erosion. The most frequently consumed, potentially damaging acids are fruit acids and phosphoric acid in fruits juices and soft drinks. There is a considerable body of evidence from laboratory studies to indicate that the acidity of carbonated drinks, sports drink and fruit juice can cause tooth erosion. Research showed that drinks with pH 5.5 or less tend to erode and soften the enamel surface. Examples of such acidic food items that has high potential of causing tooth erosion are carbonated beverages [5,6], citrus fruits, fruit juices [7, 8] and sports and energy drinks [9-12].

Sports drinks were introduced to the commercial market in the late 1960s after the University of Florida's athletic teams started drinking a beverage containing carbohydrates and electrolytes and realized a significant improvement in their athletic performance [13]. They contain carbohydrates and electrolytes such as sodium, potassium and magnesium and were developed to prevent dehydration and replace carbohydrates and electrolytes lost during rigorous physical exercise [13, 14]. Energy drinks also gained popularity after the introduction of Red Bull in Austria in 1987 and in the United States in von Duvillard *et al*. [14]. They contain high and unregulated amounts of caffeine in addition to their carbohydrate content and were developed to improve energy, weight

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loss, stamina, athletic performance and concentration [15, 16]. Energy drinks are marketed to consumers as stimulants hence they often have catchy names that convey strength, power, speed, sexuality and often include appropriate background music (e.g., Power horse, Red bull e.t.c). Generally speaking, energy and sport drinks are marketed towards young people. von Fraunhofer and Rogers [17] studied enamel dissolution in 2005 and reported that energy/sports drinks are some of the drinks that showed the most aggressive dissolution of enamel, although they found no correlation between enamel dissolution and beverage pH.

Sport drinks are consumed on daily basis and the ingested amount can easily reach more than 1 L per day. Since sports drinks are usually ingested a sip at a time, the drinks' residue remains in the oral cavity for quite some time. This can influence tooth health because such drinks do have a low pH value, which in turn is related to dental erosion [18]. An animal study showed that acidic sport drink caused severe erosion with total loss of supragingival enamel and exposure to dentin [19]. Meurman *et al*. [18] reported that nine out of 13 sports drinks evaluated contained citric acid, two contained malic acid and two contained an unknown acid. Furthermore, the citric acid based drinks were more erosive than the malic acid containing drinks. The erosive effect of the drinks was found to increase markedly with decreasing pH.

In 1997, an association between erosive tooth wear and sports drink consumption was studied in 25 competitive swimmers and 20 cyclists [20]. The pH, titratable acidity and concentrations of calcium, phosphate and fluoride and viscosity of the sport drinks were analyzed. The cyclists had significantly more maxillary palatal tooth wear ($p<0.001$) and greater consumption of sports drinks ($p<0.05$), than the swimmers. Although no association between erosion and sports drinks consumption was found in either group, most sports drinks have pH levels below the critical pH of 5.5 for enamel demineralization and consequently have the potential to be erosive. Few other studies have revealed the potential of commercial sports drinks to erode teeth [18, 21-23].

Titratable acidity is another determinant shown to be a better indicator of dental erosive potential, because it indicates the total amount of H' able to dissociate rather than just the H' concentration of the solution [24, 25].

While information on the carbohydrate type and content are normally displayed on the food package label of energy drinks, data on titratable acidity and pH are usually missing. This laboratory-based study was designed to investigate the pHs and titratable acidity of nine popular sport drinks in Nigeria.

MATERIALS AND METHODS

For this *in vitro* study 9 commercially available energy and sport drinks were tested. B Star Energy drink, London Best Energy Drink, Hippo Energy drink, Lucozade Boost Energy fast, Hype Energy, Vita 500 Energy drink, Lucozade Sport, Power horse Energy drink and Red Bull Energy drink.

pH Measurement: The initial pH of each drink was measured using a pH meter (Hanna Instrument; Serial number S358236). 10ml of freshly opened drink at room temperature was placed in a beaker and stirred using a non heating magnetic stirrer until a stable reading was obtained. Three readings were taken of each drink to give a mean measurement for that drink.

Buffering Capacity: 100ml of each drink was titrated with 1M NaOH added in 0.2ml increments until the pH reached 7. This was done by using a non heating magnetic stirrer until a stable pH reading was obtained after each increment (0.2ml) of NaOH. This was done to measure the total titratable acidity. [26] Titrations were repeated in triplicate for all drinks to check for reproducibility and to give a mean value for that drink. Titratable acidity of a solution is usually measured by reacting the acids present with a base such as sodium hydroxide (NaOH) to a chosen end point, close to neutrality. The amount of NaOH required to raise the pH to 7 is then noted for each solution.

RESULTS

Nine popular energy and sports drinks were evaluated in the study. All the drinks were acidulated with citric acid except B star energy drink and Lucozade boost that had lactic acid in addition. Table 1.

pH Measurement: The pH and standard deviation values of the sport drinks were shown in Table 2. All the tested drinks were acidic and had pH well below 5.5. The initial pH was lowest for London Best Energy drink and Lucozade Boost energy fast (2.7) and highest for Lucozade sport (3.4).

Table 1: The drinks, Manufacturers and the Acidulants Used

S/N	Soft drink	Manufacturer/Marketer/Distributor	Packaging	Acidulant
1	B Star Energy drink with Taurine	JD Drinks	Can	Citric acid, lactic acid
2	London Best Energy Drink	London Best Food Ltd	Can	Citric acid
3	Hippo Energy drink	Hummer Bonus Int'l Ltd	Can	Citric acid
4	Lucozade Boost Energy fast	Glaxo Smith Kline Consumer	Paper casing	Citric acid, lactic acid
5	Hype Energy	HMM INT	Can	Citric acid
6	Vita 500 Energy drink	Mescon Industries Ltd	Can	Citric acid
7	Lucozade Sport	GlaxoSmithKline Consumer	Plastic bottle	Citric acid
8	Power horse Energy drink	Power Horse Energy drinks	Can	Citric acid
9	Red Bull Energy drink	Red Bull/Arizona Trading Ltd	Can	Regulator Sodium citrate

Table 2: The pHs of the tested Drinks

S/N	Soft drink	1st Reading	2nd Reading	3rd Reading	Mean:SD
1	B Star Energy drink with Taurine	3.3	3.3	3.3	3.3:0
2	London Best Energy Drink	2.7	2.7	2.6	2.7:0.1
3	Hippo Energy drink	2.8	2.8	2.8	2.8:0
4	Lucozade Boost Energy fast	2.7	2.7	2.7	2.7:0
5	Hype Energy	3.3	3.3	3.2	3.3:0.1
6	Vita 500 Energy drink	2.8	2.8	2.8	2.8:0
7	Lucozade Sport	3.5	3.4	3.4	3.4:0.1
8	Power horse Energy drink	3.2	3.2	3.2	3.2:0
9	Red Bull Energy drink	3.3	3.3	3.3	3.3:0

Table 3: The amount of NaOH needed to raise the pH to 7

S/N	Soft drink	1st Titration (ml)	2nd Titration (ml)	3rd Titration (ml)	Mean:SD
1	B Star Energy drink with Taurine	9.2	9.2	9.2	9.2:0
2	London Best Energy Drink	7.8	8.2	8.2	8.1:0.2
3	Hippo Energy drink	13.5	13.5	13.5	13.5:0
4	Lucozade Boost Energy fast	4.1	4.1	4.1	4.1:0
5	Hype Energy	13.5	14.0	14.0	13.8:0.3
6	Vita 500 Energy drink	7.3	7.2	7.2	7.2:0
7	Lucozade Sport	6.6	6.6	6.7	6.6:0.1
8	Power horse Energy drink	9.8	10.0	10.0	9.9:0.1
9	Red Bull Energy drink	10.2	10.3	11.1	10.5:0.5

Buffering Capacity: Table 3 shows the amount of NaOH needed to raise the pH of the drinks to 7. Hype energy and Hippo Energy drink required the maximum amount of NaOH 13.8 and 13.5 mls respectively to raise the pH to 7. Lucozade boost energy fast required the minimum amount of base; 4.1 mls to raise the pH to 7. From the results lucozade boost energy fast had the lowest pH and lowest buffering capacity while Hype energy drink had highest buffering capacity.

DISCUSSION

The increased consumption of soft drinks has been linked to an increase in dental erosion but there is generally a widespread ignorance about the damaging effects of acid erosion due to packaged soft drinks and fruit juices. There are many signs of dental erosion like sensitivity and significant loss of enamel. It has been well documented that the drop in pH of the oral cavity below critical pH i.e. 5-5.5, leads to demineralization of dental hard tissue leading to dental erosion.

Erosion depends on several intrinsic and extrinsic factors. Acidic drinks and foods lower the pH level of oral cavity hence their consumption causes the teeth to demineralise [11]. Acids are used in the manufacture of soft drinks to fulfill two main functions; to inhibit the growth of micro-organisms such as yeasts, moulds and bacteria and to improve the taste profile of a drink by balancing the sweetness [27]. A number of acids have being used in the manufacture of soft drinks including tartaric and lactic acids. However, the three most commonly used acids are citric, malic and phosphoric.

Citric acid (E330) is found in citrus fruits, blackcurrants, strawberries and raspberries. Malic acid (E296) is found in apples, cherries, plums and peaches. Phosphoric acid is a strong mineral acid used in cola drinks to provide their characteristic taste. The amount of acid used in soft drinks depends on the individual product recipe and the type of acid used; the stronger the acid the less is required to make the final drink.

Furthermore, the presence of these polybasic acids in beverages is a concern because it has been noted that their ability to chelate calcium at higher pHs means they can be very erosive to dental enamel [28]. In addition, polybasic acids exhibit buffering capacity that can maintain pH below the threshold value (that is, at low or acidic pH values), even with marked dilution [29]. All the sports drinks tested were acidified with citric acid except two that have lactic acid in addition. Citric acid is by far the most important, versatile and widely used organic acid in food products, drinks and in the pharmaceutical industry. Citric, malic and tartaric acids are considered to be especially erosive because of their acidic nature and the ability to chelate calcium at higher pH [30]. Citric acid was more erosive than malic acid when formulated to experimental drinks at high pH [18, 31].

Little is known about the erosive potential of soft drinks within the first minutes of exposure to teeth. Jensdottir *et al.* [32] opined that within the first minutes of exposure, the erosive potential is determined solely by the pH of the drink. The erosive potential of fruit juices and beverages has been suggested to have a relationship with their pHs. In an in vitro study to look at the effects of pH and concentration of citric, malic and lactic acids on enamel, numerical data and contour plots for each acid showed a similar pattern for increasing erosion with decreasing pH and increasing acid concentration and vice versa for decreasing erosion [31].

The pH of nearly all analyzed sports drinks was in the range of 2.7 to 3.4, considerably lower than the critical pH of enamel demineralization. This finding is similar to that of Milosevic in the UK [20]. This is of some concern because of the potential of low pH solutions to erode teeth. Other studies have also detected the potential of commercial sports drinks to erode teeth [18, 21-23]. In view of this, various ways to significantly influence the pH and erosive potential of sports drinks have been suggested [21, 22, 31].

The underlying acidity of beverages is believed to be the primary factor in the development of dental erosion; this total acid level (known as titratable acid), rather than the pH, is thought to be an important factor in erosion because it determines the actual hydrogen ion availability for interaction with the tooth surface [33, 34]. The measurement of a beverage's total acid content is said to be a more realistic and more accurate method for predicting erosive potential [28, 29, 35, 36]. In agreement, Larsen and Nyvad [37] state that the potential of a soft drink to erode dental enamel depends not only on the pH, but also on its buffering capacity or titratable acidity that is the ability of the drink to resist a change of pH (to maintain its pH). The higher the titratable acidity of a drink the higher its erosive effects. This shows that London Best Energy Drink and Lucozade Boost Energy Fast that presented the lowest pH (2.7), are probably not as erosive as Hippo Energy drink and Hype Energy that have mean titratable acidity of 13.5 and 13.8 respectively.

The popularity of energy drinks is on the rise in most countries, especially among adolescents and young adults. Their permanent teeth are more susceptible to attack from the acids found in soft drinks, due to the porous quality of their immature tooth enamel. As a result, there is high potential for erosion among this age demographic to increase. Also regular use may produce unwanted side effects in people who already have their dental health compromised. This invariably makes the low pH and acid content found in the evaluated energy and sport drinks a matter of concern. It's been said that raising the pH may solve this problem, but at the same time it increases the risks of spoilage or presence of pathogenic bacteria. This has left dentists and allied professions no other option than to lay emphasis on correct drinking habit in counseling sessions and oral health campaign programmes in order to reduce the adverse public impact of these drinks.

CONCLUSION

All the analyzed drinks were acidulated with citric acid. Their pHs were in the range of 2.7 to 3.4 and titratable acidity ranged from 4.1mls to 13.8mls. Notably is the fact that the pHs were considerably lower than the critical pH of enamel demineralization. Therefore, dental practitioners should watch for sports and energy drinks incited erosive cavities in addicts.

Assessment of beverages is multifaceted and there are diverse determinants of acid erosion, further studies would be needed to provide other parameters as per the erosivity of the evaluated drinks.

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