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Evaluating the Erosive Potential of Beverages Sold at the Schofield Barracks Dental Clinic and Some Possible Less Erosive Alternative Beverages Sold at the Schofield Barracks Commissary

A REPORT ON

pH levels of select beverages sold at two different locations on a U.S. Army Base and the creation of a novel beverage labeling system

A Thesis

Presented to the Faculty of the Advanced Education in General Dentistry, Two-Year Program,
United States Army Dental Activity, Schofield Barracks, Hawaii

And the Uniformed Services University of the Health Sciences – Post Graduate Dental College
In Partial Fulfillment of the Requirements for the Degree of Master of Science in Oral Biology

By

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ABSTRACT

Purpose: The purpose of this study is to measure and compare the pH levels of beverages sold within the Schofield Barracks Dental Clinic as well as some possible less erosive beverages sold at the base Commissary. Previous studies have demonstrated that beverages with a pH below 3.0 are considered extremely erosive. In addition, the author has proposed a new beverage labeling system that takes added sugar and pH into account.

Methods: All 25 beverages sold from the Schofield Barracks Dental Clinic's two vending machines were purchased and their pH values were measured in triplicate. In addition, the pH's of 15 possibly less erosive alternative beverages, selected by the author, were measured.

Results: 19 of the 25 (76%) beverages from the Dental Clinic had pH values below 4.0. 10 of the 15 (67%) beverages that the author thought may be less erosive, also had pH values below 4.0. Even when searching for beverages with a higher, less erosive pH from the Commissary, only 33% of the beverages the author picked out had a pH value that was not considered erosive.

Conclusion: When a Soldier purchases a beverage from a healthcare setting, they may assume that it is healthy for them. By selling beverages that are damaging to teeth, we are not only sending mixed messages to our Soldiers, but over the long term we are also reducing the readiness and wellness of our force. The damage these acidic beverages cause increases the number of appointments required to keep our Soldiers healthy; therefore, reducing their ability to train and deploy. It is the long-term goal of this author to have a beverage labeling system warning service members about the erosive potential of their purchases.

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DISCLAIMER

The opinions or assertions contained herein are those of the author and are not to be construed as official or reflecting the view of the Department of Defense or the Uniformed Services University of Health Sciences.

INTRODUCTION

Dental erosion is the irreversible acidic dissolution of tooth structure by chemical means in the absence of micro-organisms (1). In contrast, dental caries (tooth decay), is the dissolution of tooth structure mediated by the metabolism of fermentable carbohydrates by oral bacteria (2). Dental erosion can be caused by intrinsic or extrinsic acids. Intrinsic acid is hydrochloric acid from our stomach, and it has a pH level around 1.5. People with gastroesophageal reflux disease (GERD) and those with frequent vomiting such as alcoholics and those with bulimia often show signs of severe dental erosion due to intrinsic acid attacks. Extrinsic acids can be any type of acid from our environment. Some interesting extrinsic acids that have caused dental erosion include aerosolized acids from battery factories and acidic swimming pool water due to chlorine content. The most common source of extrinsic acids comes from the food and drinks we consume. Certain fruits, such as lemons are very acidic and dental erosion can be seen in patients with a habit of holding them in their front teeth and sucking on them. Other common acidic foods that can lead to dental erosion include fruits, soft drinks, wine, fruit drinks, and energy drinks. The *daily* intake of soft drinks and *weekly* consumption of sports drinks is capable of significantly increasing the risk of dental erosion (3). A study by Larsen and Nyvad showed that beverages with a pH between 3.0 and 3.99 are considered moderately erosive, whilst beverages with a pH below 3.0 are considered severely erosive, and beverages with a pH above 4.0, but less than 5.5 are considered mildly erosive (4).

Beverage makers add acids to their drinks to counterbalance the sweetness of the sugar, giving them their unique flavor profile, and increasing shelf life. Citric acid is added to give a tangy taste and acts as a preservative. Malic acid enhances the intrinsic flavor of a beverage. Phosphoric acid is added to increase tartness and acts as a preservative. The carbon dioxide (CO₂), which is added to give the beverages their fizz, also decreases pH (1).

The pathophysiology of dental erosion is complex and depends on many factors including: the number of H⁺ ions the acid can donate, type of dental structure being dissolved, time of exposure, temperature of the reaction, buffering ability of the acid, buffering capability of saliva, quantity of saliva, and so on. Although many things can affect the erosive potential of a beverage, all studies agree that erosion increases as pH falls and it increases exponentially below pH of 4.0 (4, 5).

Dental erosion, depending on the severity, can have the following sequelae: yellowing of teeth due to loss of enamel, painful dentinal hypersensitivity, pulpal infection, and loss of vertical dimension of occlusion. Dentinal hypersensitivity is transient tooth pain not associated with pulpal infection. It usually does not warrant endodontic therapy or extraction but can require multiple applications of desensitizing medications (6). When the dentin covering the pulp is exposed and thin enough, bacteria can enter the pulp through the short dentinal tubules. This can then cause a pulpal infection necessitating root canal therapy (7). When pathological tooth wear is significant for most or all teeth in the mouth, the patient may require restorative care to compensate for the lost tooth structure, comprising of a full mouth rehabilitation at an increased vertical dimension of occlusion (8). Full mouth rehabilitation can be a very timely and costly treatment modality to return the patient back to proper form and function.

Although both involve the dissolution of tooth structure into an acidic solution, dental erosion differs from dental caries (decay) in that caries is a microorganism-mediated event. Dental caries is caused by the acid produced via metabolism of fermentable carbohydrates by oral bacteria. One of the most common cariogenic bacteria found in the mouth is *Streptococcus mutans* which produces tetramic acid inside dental plaque. *S. mutans* and other cariogenic bacteria metabolize simple carbohydrates (sugars) via the glycolytic pathway. Complex carbohydrates, such as starches from bread and crackers, are also cariogenic, but to a lesser degree than simple sugars because they need to be broken down into monosaccharides prior to entering the glycolytic pathway. Simple sugars such as sucrose, fructose and

glucose are metabolized by the bacteria in dental plaque much quicker and drop the pH at a faster rate, consequently, causing more demineralization (9). In the United States approximately 82% of adults aged 20-34 have had dental caries (10). The Food and Drug Administration's "Dietary Guidelines for Americans" recommends only 10% of total calories per day be from added sugars. For a 2,000-calorie diet, this would be 200 calories or 50g of added sugars per day. These added sugars include fructose, dextrose, sucrose, and sugars from honey, syrup or concentrated fruit and vegetable juice (11). A study of Puerto Rican children found that those who consumed higher amounts of sugar, more than 141g/day, were almost twice as likely to develop caries compared to those who consumed less than 69g/day (12).

Life in the military can be very difficult for a multitude of reasons. Even with all the challenges our service members face they need to maintain peak mental and physical performance. The Army is constantly trying to optimize Soldiers' performances and one such method was to introduce the Performance Triad. The Army's Performance Triad (P3) is the "synergy of the health behaviors of sleep, activity, and nutrition in balance (13)." Healthcare providers promote the Performance Triad by encouraging patients to get 8 hours of sleep, to exercise daily and to eat properly. In addition, oral health care providers are in a special situation to recommend food and drinks that are healthy for our patients' teeth. These should have low erosive and cariogenic potential.

It can be hard to distinguish which foods are healthy and which are not, especially for young servicemembers. In 2009 the US Army introduced the Go-For-Green (G4G) nutrition labeling system in its dining facilities (DFACs). The system uses stoplight colors to provide a quick nutritional overview and a recommendation for frequency of consumption. This style of labeling system can be easily adopted for use at point of sales for beverages as well.

PURPOSE

The purpose of this study was to figure out if the beverages sold from the Schofield Barracks Dental Clinic's waiting room were erosive or not. It was also in the interest of the author to see if less erosive beverages could be found at the base Commissary. In the end, a novel beverage labeling system was designed taking pH and added sugar into account.

HYPOTHESIS

The null hypothesis is that the beverages sold from the Schofield Barracks Dental Clinic's vending machines have pH values greater than 4.0 and can be considered non-erosive.

METHODS & MATERIALS

All twenty-five beverages were purchased from the vending machines at the Schofield Barracks Dental Clinic (Figure 1). Fifteen beverages were purchased from the Schofield Barracks Commissary that were believed to be less erosive alternatives e.g. alternative sports drinks, alternative energy drinks, alternative carbonated beverages (Figure 2).

A pH meter (Mettler Toledo, Ohio) was calibrated with pH buffers of 4.0, 7.0, and 10.0 prior to testing (Figures 3 and 4). The beverages were opened at room temperature and 25mL were poured into a beaker (Pyrex, Arizona). The pH of each beverage was measured in triplicate at one-minute intervals. The pH probes were rinsed with reagent grade water between measurements. The average pH of the three measurements was calculated and recorded.



Figure 1. All twenty-five beverages available for purchase at the Schofield Barracks Dental Clinic.



Figure 2. Fifteen beverages thought to be less erosive that were purchased at the Schofield Barracks Commissary.



Figure 3. Buffer solutions used to calibrate pH meter.



Figure 4. Calibrating the pH meter.

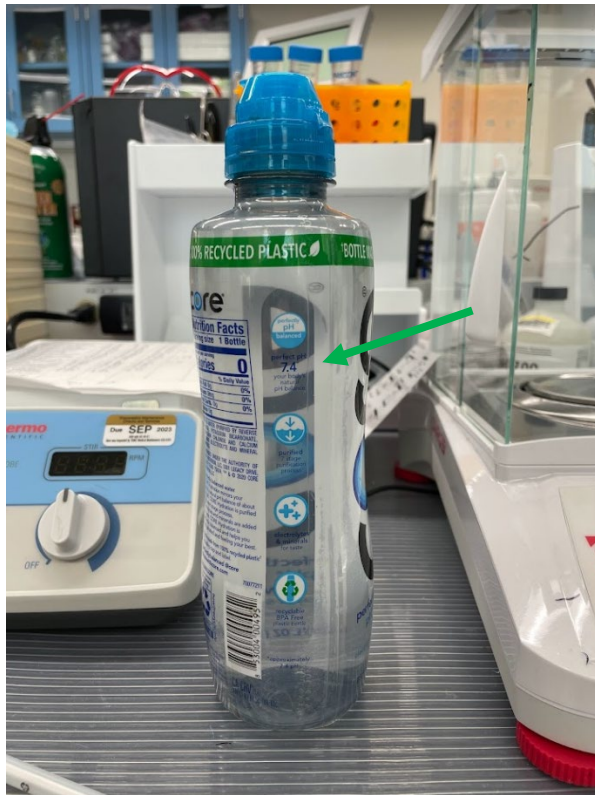


Figure 7. Core Hydration states it has a pH similar to the body of 7.4.

RESULTS

Of the 25 beverages from the Schofield Barracks Dental Clinic vending machines, 6 (24%) had pH values less than 3.0; 13 (52%) had pH values between 3.0 and 4.0; and 6 (24%) had pH values above 4.0 (Table 1). Overall, 76% of the beverages sold from the Dental Clinic vending machines had pH values below 4.0 and can be considered at least moderately erosive.

Out of the 15 potentially less erosive beverages purchased at the Schofield Barracks Commissary, 4 (27%) had pH values below 3.0; 6 (40%) had pH values between 3.0 and 4.0; and 5 (33%) had pH values above 4.0 (Table 2). Overall, 67% of the beverages that the author thought may have higher pHs still had pH values below 4.0 and can be considered at least moderately erosive.

Dental Clinic Vending Machines

Beverage	Test 1 pH	Test 2 pH	Test 3 pH	Average pH	Added Sugars
Coca-Cola Classic	2.26	2.26	2.26	2.26	65g
Powerade Mountain Berry Blast	2.52	2.51	2.48	2.5	35g
Dr. Pepper Zero	2.86	2.9	2.09	2.62	0g
Dr. Pepper	2.74	2.72	2.72	2.73	65g
Vitamin Water XXX	2.89	2.89	2.93	2.9	26g
Sprite	3.13	3.13	3.1	3.12	63g
Hawaiian Sun Green Tea	3.18	3.19	3.18	3.18	26g
Monster Aussie Lemonade	3.19	3.18	3.17	3.18	46g
Monster Energy	3.36	3.39	3.36	3.37	54g
Red Bull	3.37	3.4	3.41	3.39	26g
Body Armor Blackout Berry	3.78	3.79	3.82	3.8	26g
Coke Zero	2.79	2.79	2.76	2.78	0g
Diet Coke	3	3	3.01	3	0g
Izze Sparkling Apple	3.35	3.34	3.35	3.35	0g
Red Bull Sugar Free	3.45	3.45	3.46	3.45	0g
Monster Zero	3.47	3.47	3.43	3.46	0g
Dole Pineapple Juice	3.55	3.5	3.57	3.54	0g
Monster Zero Peach	3.6	3.59	3.48	3.56	0g
Body Armor Lyte Peach Mango	3.73	3.74	3.8	3.75	0g
V8 Original Vegetable Juice	4.13	4.1	4.15	4.13	0g
Kirkland Cold Brew Coffee	5.56	5.6	5.65	5.6	0g
Dasani Water	5.92	5.95	5.96	5.94	0g
Aquafina Water	6.13	5.98	6.07	6.06	0g
Ito En Green Tea	6.39	6.4	6.44	6.41	0g
Muscle Milk Protein Shake	6.65	6.64	6.72	6.67	0g

Table 1. pH measurements and averages of beverages sold from the Dental Clinic vending machines. Added sugars of each beverage are also included. Beverages are color-coded based on where they would fit into the new proposed beverage labeling system.

Commissary Beverages

Beverage	Test 1 pH	Test 2 pH	Test 3 pH	Average	Added Sugars
Lemon Perfect Lemon Water	2.51	2.59	2.62	2.57	0g
Spindrift Sparkling Water	2.7	2.7	2.69	2.7	0g
Sparkling Ice Black Raspberry	2.86	2.86	2.86	2.86	0g
Fresca Sparkling Soda Water	2.98	2.98	2.93	2.96	0g
Tippy Toes Electrolyte Solution	3.96	3.97	3.97	3.97	28g
Propel Electrolytes	3.07	2.98	3.02	3.02	0g
La Croix Sparkling Water	3.3	3.28	3.3	3.29	0g
Aha! Sparkling Water	3.65	3.68	3.69	3.67	0g
Bubly Sparkling Water	3.71	3.73	3.73	3.72	0g
Pure Leaf Unsweet Tea	3.96	3.93	3.96	3.95	0g
San Pellegrino Sparkling Water	5.02	5.03	5.07	5.04	0g
Waikoko Coconut Water	5.26	5.24	5.21	5.24	0g
Starbucks Nitro Cold Brew	5.71	5.71	5.71	5.71	0g
Core Hydration pH Balanced Water	7.27	7.06	7.17	7.17	0g
Essential Alkaline Water	10.15	10.06	10.14	10.12	0g

Table 2. pH measurements and averages of beverages sold from the Schofield Barracks Commissary. Added sugars of each beverage are also added. Beverages are color-coded based on where they would fit into the new proposed beverage labeling system.

DISCUSSION

Over time dental erosion can cause irreversible damage to teeth. It is important for people to limit the number of extrinsic sources of acids that can cause erosion. Today, people are consuming more carbonated beverages than ever before. Most are probably not aware of the acidity these beverages have. Even when trying to purchase less acidic beverages from the Commissary, only 33% of the beverages purchased had pH values greater than 4.0. Without pH labels on drinks, it seems an impossible task to pick out non-erosive drinks based on manufacturer packaging.

Another factor that causes harm to teeth is the amount of sugar consumed. *Added sugars* are those which are added during the processing of food and drinks. Naturally occurring sugars are those that are found in milk, fruits or vegetable juices. *Total sugars* are the sum of the naturally occurring sugars in food plus the added sugars. The FDA recommends a daily consumption of no more than 50g of added sugar for a 2000 calorie diet. Of the 25 beverages sold from the Dental Clinic Vending Machines, 4 (16%) had over 50g of sugar in them. If a Soldier consumed one of these beverages, they would be consuming more than their daily recommended allowance of added sugars. In addition, 10 (40%) of the beverages sold from the Dental Clinic Vending Machines had over 25g of added sugar or more than half of the recommended daily allowance.

For young Soldiers it can be challenging figuring out what is healthy and what is not. In 2009 the US Army introduced the Go-For-Green (G4G) nutrition labeling system in its dining facilities (DFACs). The system uses stoplight colors to provide a quick nutritional overview and a recommendation for frequency of consumption. One study at Ft. Bliss, Texas demonstrated that the use of the labeling system by Soldiers decreased the amount of fat consumed by those who ate at a dining facility that implemented the G4G labeling system (14).

The Army's Performance Triad (P3) is the "synergy of the health behaviors of sleep, activity, and nutrition in balance (13)." Everyone would agree that it is important to get proper amounts of sleep, exercise daily, and have a healthy diet. The military requires service members to exercise daily in the form of organized physical training. For service members to have proper nutrition, food and drinks offered at base dining facilities, restaurants and vending machines should be overwhelmingly healthy.

It is not the author's intent to take away all unhealthy options from Soldiers; everyone needs the occasional reward or cheat meal. With that being said, however, food and beverage options offered in healthcare settings should only be healthy so that we do not send mixed messages to patients by telling them to stay away from unhealthy foods and then allow them to purchase them in the building. Healthcare facilities should not offer the very products that cause many of the diseases they are trying to treat.

Indubitably, most beverages sold either in vending machines or grocery stores are not good for teeth. People should be drinking water more than anything. But when they do want some variety, they may need more help with deciding what drinks are less damaging to teeth. If they have information on an easy-to-read label, they can make more informed decisions. The beverage makers are not going to warn consumers that their beverages are harmful to teeth, in fact, they are misleading customers. On the Coca-Cola website, under their FAQ "Why is phosphoric acid added to some Coca-Cola drinks?" they answer, "to add to their taste." They continued "Did you know? Phosphoric acid contains small amounts of the mineral phosphorus. Phosphorus is found widely in nature and helps give our bodies energy. It is also a big component of bones and teeth. (15)" They give the impression that the phosphoric acid they add to their drinks is good for teeth. It has been estimated that 25,000 deaths per year in the United States can be linked to the consumption of sugary drinks and the diseases they cause (16). The beverage companies are not in the healthcare business, but we are.

The author of the current study has created a color-coded beverage label, similar to the Go-For-Green labels found in military dining facilities, that takes pH value and added sugar into account (Figure 8). Drinks that have a pH greater than 4.0 and less than a quarter (12.5g) of the recommended daily added sugars will fall into the green category. Some examples from this study include Starbucks Nitro Cold Brew (pH- 5.71, added sugars – 0g); Muscle Milk Protein Shake (pH – 6.67, added sugars – 0g); and Dasani Water (pH – 5.94, added sugars – 0g). Yellow beverages will have pH values between 3.0 and 4.0 and/or between a quarter to half (12.5-25g) of the recommended daily added sugars. Examples from this study include Izze Sparkling Apple Juice (pH – 3.35, added sugars – 0g); Pure Leaf Unsweet Tea (pH – 3.95, added sugars – 0g); and Diet-Coke (pH – 3.00, added sugars – 0g). Red beverages are those with pH values less than 3.0 and/or over half (25g) of the recommended daily added sugar. A few examples of beverages that would be labeled red from this study include Fresca Sparkling Water (pH – 2.96, added sugar – 0g); Body Armor Blackout Berry (pH- 3.80, added sugar – 26g); Dr. Pepper (pH – 2.73, added sugar – 65g). Soldiers should be encouraged to consume mostly water throughout the day, but if they did want some variety, green beverages should be their “go-to” drinks. Yellow beverages should be consumed less frequently than green beverages and red beverages should only be drunk on rare occasions.

The labeling system presented in this paper can easily be created anywhere beverages are sold. There are many papers that have documented the pH values of most beverages sold in the U.S. and it is easy to do a quick internet search to see how much added sugar is in any beverage. Place the beverages into their respective category based on pH and added sugar and place the information wherever beverages are sold. This is a great way to get people to “rethink their drink” and educate them about what they are putting into their bodies.

One limitation of this beverage labeling system is that it only takes added sugar into account. This was done because the FDA has only put out a recommendation for added sugars in the belief that

sugars which occur naturally in fruits, vegetables and dairy products contain vitamins and minerals that are essential for a healthy diet. However, many fruit juices have over 25g of sugar and should not be considered non-cariogenic. Another limitation is that this labeling system only takes total added sugars in the drinks into account versus added sugars per unit of volume. This was done assuming the consumer will drink the entire drink in one sitting. This can be modified however facilities see fit.

The following beverages have minimal potential to cause tooth erosion because they have pH values greater than 4.0. They also have less than 12.5g of added sugar making them less likely to cause tooth decay.

GO FOR GREEN!



(pH > 4.0 and sugar < 12.5g)

- Dasani Water
- Kirkland Cold Brew
- V8 Vegetable juice
- Ito En Green Tea
- Muscle Milk Protein Shake
- Aquafina Water

The following beverages have pH values between 3.0 and 4.0, and/or have 12.5-25g of sugar. These factors can cause tooth erosion and decay in addition to other health problems.



(pH 3.0-4.0 and/or sugar 12.5-25g)

- Body Armor Lyte
- Izze Sparkling Apple
- Monster Zero Peach
- Diet Coke
- Monster Zero
- Red Bull Sugar Free
- Dole Pineapple Juice

The following beverages have pH values below 3.0 and/or they have over 25g of added sugar – *more than half the daily recommended value*. These beverages can dissolve tooth structure and cause dental decay as well as other health problems. These beverages should not be consumed on a regular basis.



(pH<3.0 and/or sugar >25g)

- Body Armor Blackout Berry
- Monster Energy
- Vitamin Water XXX
- Dr. Pepper
- Dr. Pepper Zero
- Powerade Mountain Berry Blast
- Hawaiian Sun Green Tea
- Red Bull
- Monster Energy Aussie Lemonade
- Coca-Cola Classic
- Sprite
- Coke Zero

Figure 8. Beverage labeling system with the Schofield Barracks Dental Clinic vending machine beverages placed into their respective categories.

CONCLUSION

Extrinsic acids can have detrimental effects to the human dentition. Previous studies, based on hydroxyapatite solubility, have demonstrated that beverages with pH values below 3.0 are considered extremely erosive to teeth (4). 25% (6 of 25) of the beverages sold at the Schofield Barracks Dental Clinic had pH values below 3.0. Moreover, 40% (10 of 25) had over half of the recommended daily added sugars (25g). Carbonated beverage consumption has been on the rise for decades and is believed to be the main cause of dental erosion (3). Consumers should be aware of the potential harm their beverages can cause them. This can be accomplished with an easy-to-understand labeling system that takes pH and added sugar content into account.

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