ADHA/Sigma Phi Alpha Journalism Award: Baccalaureate

Is Your Drinking Water Acidic? A Comparison of the Varied pH of Popular Bottled Waters

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Abstract

Purpose: Dental professionals continually educate patients on the dangers of consuming acidic foods and beverages due to their potential to contribute to dental erosion and tooth decay. Excess acid in the diet can also lead to acidosis, which causes negative systemic side effects. However, water is not typically categorized as acidic. The purpose of this in-vitro study was to investigate the pH levels of several popular brands of bottled water and compare them to various other acidic beverages. Two different brands of marketed alkaline water (with a pH of 8.8 or higher) were also studied, tested for acidity and described.

Methods: A pilot in-vitro study was conducted to determine the pH levels of a convenience sample of popular brands of bottled water, tap water and other known acidic beverages in comparison with the pH values reported on the respective manufacturers' website. Each beverage was tested in a laboratory using a calibrated Corning pH meter model 240, and waters were compared to the corresponding company's testified pH value. Waters were also compared and contrasted based on their process of purification. The data was then compiled and analyzed descriptively.

Results: The pH values for the tested beverages and bottled waters were found to be predominantly acidic. Ten out of the 14 beverages tested were acidic (pH<7), 2 municipal (or "tap") waters were neutral (pH=7) and 2 bottled waters were alkaline (pH>7). The majority of waters tested had a more acidic pH when tested in the lab than the value listed in their water quality reports.

Conclusion: It is beneficial for the health care provider to be aware of the potential acidity of popular bottled drinking waters and educate patients accordingly.

Keywords: dental erosion; acidosis; streptococcus mutans; drinking water; alkaline (mineral) water; alkaline ionized water; electrolysis; water purification

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Introduction

Research substantiates that consumption of acidic beverages such as soft drinks and sports drinks is positively correlated with the incidence and prevalence of dental caries and dental erosion.[1-3] Dental erosion has been defined as the chemical removal of mineral from tooth structure.[4] Erosion of enamel and root surfaces of teeth is a potentially serious oral health concern in the U.S., and the consumption of acidic beverages is a contributing factor.[1] The overall consumption of carbonated soft drinks in the U.S. is continually increasing, with between 56 and 85% of school-age children consuming at least 1 per day.[5] The pH of most soft drinks is within the range of 2 to 4, indicating that it is very acidic. When the teeth are bathed in the acid from these drinks, they become susceptible to demineralization. Demineralization occurs when acidogenic bacteria, specifically Streptococcus mutans, colonize in the oral cavity, forming dental biofilm.[6] The biofilm metabolizes carbohydrates (such as sugars commonly found in soft drinks), which acidifies the saliva. The normal pH of the oral cavity is about 6.3, and when the pH falls below 5.5, tooth structure begins to demineralize.[5] The literature suggests that the lower the pH of the beverage, the high-

er the rate of demineralization of enamel.[1] Soft drinks are not the only acidic beverages that pose an oral health challenge in the U.S.; many Americans consume coffee and sports beverages as well, which are also acidic. Cochrane et al studied the pH of various sports drinks, finding that while not as low as Coca-Cola®, many Gatorade® and Powerade® drinks also had an acidic pH leading to dental erosion when tested.[7] While dental erosion can affect any individual, some are at increased risk for demineralization and, subsequently, dental caries. People with xerostomia (due to decreased saliva to buffer the acid content in the mouth), mouth breathers and those with orthodontic brackets are at increased risk for erosion.[5]

Acidosis is a pathologic condition of increased hydrogen ion concentration in blood and body tissues, and occurs when arterial pH falls below 5.55.[8] Harmful effects of acidosis may include increased bone resorption and decreased osteoblastic function, as evidenced in a study conducted by Brandao-Burch et al who found that as arterial pH drops, mineralization of bone reduces.[9] Alkaline mineral water (by definition, water with naturally occurring minerals such as calcium and magnesium and a pH above 7) has been shown to be therapeutic in decreasing bone resorption, increasing bone density and improving hydration.[10-12] Naturally alkaline artesian well water is beneficial due to its acid-buffering capacity and has been shown to be effective in adjunctively treating gastric reflux disease.[12,13] Additionally, there is some evidence that an alkaline diet may slow the progression of some chronic diseases, such as hypertension, muscle wasting and strokes.[14]

It is important for the oral health care provider to be aware of the relative acidity of the beverages consumed daily and how they affect oral health. Some waters, primarily bottled waters which people generally believe are safer than tap water, are actually acidic and potentially harmful to the teeth. For the reasons listed above, consumption could pose a threat to the oral and overall health of those who consume acidic water. Water's mineral content determines its pH and is dependent upon the source, in addition to the purification process.

Prior to discussing specific brands, it is necessary to distinguish between different types of bottled water. Natural spring water is derived from specific natural springs, where the earth filters it naturally. Some springs are naturally alkaline, while others are more acidic. Natural spring water is typically filtered and disinfected using processes including, but not limited to activated carbon filtration to remove added chlorine, microfiltration to remove particles and ultraviolet light sanitation to destroy bacteria.[15] The original mineral content of the natural spring water is retained during the filtration process, thus making the pH correspond exactly to the alkaline (or acidic) mineral content of the water. Another term for the total mineral content of water is total dissolved solids (TDS), which refers to the inorganic and organic substances present in solution in water and able to survive filtration through a small filter.[15] TDS constituents include, but are not limited to, calcium, sodium, potassium, magnesium, chloride, sulfate and nitrate.[15] Artesian well water comes from a confined aquifer containing groundwater under positive pressure.[16] Like natural spring water, it also retains its mineral content during filtration. The pH of artesian water will depend on the acidity or alkalinity of the artesian well. Purified drinking water is derived from a public water supply of a given area and then filtered by reverse osmosis, distillation or another process.[17] The mineral content in the water is removed during the filtration process, and some brands subsequently add minerals and/or electrolytes for taste. Because the alkaline minerals are removed during filtration, it is possible that purified drinking water will have a lower pH than naturally occurring spring or well water (depending on the nature of the source).

Alkaline water, or mineral water, is becoming increasingly popular worldwide, but it is important to distinguish between naturally occurring alkaline (mineral) water and alkaline ionized water. It is not possible to differentiate between the two based on pH alone. The U.S. Food and Drug Administration requires naturally occurring alkaline water to contain at least 250 parts per million TDS from a geologically and physically protected underground water source, and the water is not to contain added minerals.[18] Naturally occurring alkaline water contains a high concentration of minerals directly from the source, and its pH corresponds exactly to its mineral content. Alkaline ionized water is source-independent (and frequently starts as tap water); the water pH is altered through electrolysis, or the splitting of the water molecule into hydrogen and hydroxide ions with an electric current.[19] Therefore, the alkaline pH is created artificially, and does not match the mineral content of the water. Ionized water can be

Table I: pH Values Compared

	Ozarka Natural Spring Water	Aquafina	Dasani	Nestlé Pure Life	Evian	Fiji
pH when tested in lab	5.16	5.63	5.72	6.24	6.89	6.9
pH reported in water quality report or website	5.7 to 7.3	NR*	NR*	6.6 to 8.0	7.3	7.7
	Smartwater	Houston Tap	Pasadena Tap	Evamor	Essentia	
pH when tested in lab	6.91	7.29	7.58	8.78	10.38	
pH reported in water quality report or website	NR*	8.0	7.8	8.8	9.5	

*Not Reported

produced with a home appliance called a water ionizer, or can be purchased commercially. Proponents of alkaline ionized water claim that it is an antioxidant, increases hydration and energy, and can even slow the aging process.[19] However, there is a lack of scientific research available to support these claims. In fact, one clinical trial involving rats detected damage to the myocardial muscle following the consumption of alkaline ionized water.[20-22]

A clinical trial by Koufman and Johnston found naturally occurring alkaline water (pH 8.8) to be therapeutic in the treatment of acid reflux disease.[13] Alkaline water was found to denature human pepsin 3b, which is the enzyme that breaks down protein in the digestion process.[13] Sufferers of acid reflux experience painful, burning sensations due to acidic foods and beverages activating the pepsin that has been pushed into the airway from the stomach. It is imperative to recognize that this study highlighted the therapeutic benefits of naturally occurring alkaline water, as opposed to alkaline ionized water.

Equipped with a knowledge base on the important differences between types of bottled waters, the dental hygienist will be better prepared to educate and inform patients about water consumption. However, awareness of the water's pH and TDS value (which is often not found even online) will also play an important role in the provider's patient recommendations. The aim of this study was to research, test and compare specific brands and types of bottled water for potential acidity.

Methods and Materials

A pilot in-vitro study was conducted to determine the pH levels of a convenience sample of popular beverages, including 9 brands of bottled water, 2 municipal (or "tap") water supplies and 3 additional beverages. Among the beverages tested were Coca-Cola® (Coca-Cola Co., Atlanta, Ga), VitaminWater® (Coca-Cola Co., Whitestone, NY), Gatorade® (PepsiCo Inc., U.S.), Ozarka Natural Spring Water® (Nestlé Waters, North America), Aquafina® (PepsiCo Inc., Purchase, NY), Dasani® (Coca-Cola Co., U.S.), Nestlé PureLife® (Nestlé Waters, North America), Evian Natural Spring Water® (Danone Group, France), Fiji Water® (Los Angeles, Calif), Smartwater® (Coca-Cola Co., Whitestone, NY), Evamor Natural Artesian Water® (Covington, La), Essentia® (Essentia Co. LLC, Bothell Wash), and tap water from Houston, Texas and Pasadena, Texas. All beverages (excluding the municipal waters) were obtained in unopened bottles from Houston, Texas. The pH values for each beverage were tested in the laboratory using a calibrated Corning pH meter model 240. The pH meter was calibrated by the researchers prior to testing the beverages. The tested pH values of each beverage were then compared with the pH values reported in the corresponding manufacturers' water quality reports found on their respective websites. The results were descriptively analyzed and compiled into tables and figures.

Results

Table I and Figure 1 show that most of the waters tested had an acidic pH. Compared with

Figure 1: Tested pH Values on a Spectrum

2.24 2.49 2.92 5.16 5.63 5.72 6.24 6.89 6.90 6.91 7.29 7.58 8.78 10.38

Note: Water displayed under the red portion of the arrow indicates water that falls within an acidic pH range; water displayed under the blue portion indicates water that falls within a basic pH range.

Table II: Purification Process and Total Dissolved Solids

	Ozarka Natural Spring Water	Aquafina	Dasani	Nestlé Pure Life	Evian	Fiji
Type of Water	Natural Spring	Purified	Purified	Purified	Natural Spring	Natural Artesian
TDS	34 to 97 mg/l	ND*	ND**	61 to 100	340	220
	Smartwater	Houston Tap	Pasadena Tap	Evamor	Essentia	
Type of Water	Purified	Tap	Tap	Natural Artesian	Purified	
TDS	36	359	250	181	62	

*Not detected; at or above minimum reporting level
**Not detected; magnesium sulfate, potassium chloride and salt added

the most acidic non-water beverage (Coke®), which tested at a pH of 2.24, Ozarka Natural Spring Water® was the most acidic water, with a pH of 5.16. The following waters had a pH just below neutral (or pH=7): Nestlé PureLife® (6.24), Evian Natural Spring Water® (6.89), Fiji Water® (6.90) and Smartwater® (6.91). Both municipal (or public) water supplies (Houston and Pasadena) had a neutral pH, with Houston's being 7.29 and Pasadena's 7.58. The 2 commercially available alkaline bottled waters evaluated were Evamor® and Essentia®, either of which can be purchased online or in specialty grocery stores and guarantee an alkaline pH. Each of these, as evidenced in Table I, was found to have a pH above 7, with Evamor® testing at 8.78 and Essentia® at 10.38. Table II illustrates the type of filtration process by which each brand of bottled water is purified, along with the reported TDS.

Discussion

Most patients in the dental office will not be aware of the potential acidity of bottled water. It is the dental professional's responsibility to educate patients on the importance of limiting intake of acidic foods and beverages in order to prevent acid erosion and to maintain good oral and dental health. The dental hygienist has a professional duty to educate patients and to provide recommendations about the most current evidence regarding healthy drinking water. A knowledge of the differences between various water purification processes will aid the health care provider in determining which bottled wa-

ters to advocate. Furthermore, appropriate expertise on the difference between naturally occurring alkaline water and alkaline ionized water will ensure that patients reap optimal benefits of alkaline drinking water. The results of this pilot study indicate that some brands of popular bottled water have a low pH, which could potentially contribute to dental erosion and tooth decay.

Being the most acidic water evaluated in this study, it can be assumed that the natural source of the Ozarka® water had a lower pH (or fewer alkaline minerals), as the pH of natural spring water will correspond directly to its mineral content. The public water supplies from Houston and Pasadena had a neutral pH, likely because the minerals are retained in tap water during the filtration process. Interestingly, the total dissolved solids were higher in the natural artesian waters and tap waters, likely because the natural minerals are retained when the water is filtered. The 2 natural spring waters had TDS values that corresponded to their pH, one being acidic and the other closer to neutral. All the purified drinking waters evaluated, including Essentia® alkaline water, had either a low or undetected TDS value. This can likely be explained due to the removal of the water's natural minerals during filtration.

The two alkaline bottled waters evaluated were found to have an important difference. While both Evamor® and Essentia® waters guarantee an alkaline pH, the alkalinity is not achieved the same way. Evamor® water is sourced from a naturally alkaline artesian aquifer in Covington, La, and all of its minerals are kept during filtration. As a result, the mineral content in Evamor® water will match its pH exactly.[16] Essentia® however, is sourced from the public water supply; minerals are filtered, and then the water is artificially made alkaline by electrolysis.[23] Therefore, the high pH does not match the mineral content in the water (Table II), and is rather a result of the abundance of hydrogen ions created with the electric current. As mentioned previously in this paper, the health benefits of these two waters may be significantly different. If possible, the health care provider should be aware of not only the pH of a given bottled water, but also the total dissolved solids, in order to provide the best recommendation to patients.

Possible limitations of this study include small sample size of waters and beverages tested and unknown length of time spent in the bottle prior to opening. Variability of water source and location is also a limiting factor. Further research is necessary to evaluate whether bottled water is acidic and to determine relationships between acidic water and dental erosion and caries formation. Additional study is also indicated to conclude whether or not there are additional oral or systemic benefits to drinking alkaline water (naturally occurring or ionized).

Conclusion

It is beneficial for the practitioner to obtain baseline knowledge of various types of bottled water and their pH, and subsequently make patient recommendations. It is also prudent for the health care provider to be aware of the potential systemic risks and benefits of acidic and alkaline water. One can assume that both naturally alkaline water and alkaline ionized water will be safe for the protection of teeth from decay, as the critical pH for caries formation is 5.5 (or 6.7 for cementum).[5] However, familiarity with the therapeutic uses of naturally alkaline water and risks of alkaline ionized water will equip the dental hygienist in making recommendations to patients with specific health conditions.

The results of this study suggest that there may be several brands of widely accepted bottled water that have a pH between 5.16 to 10.38. The values found were lower than those reported in the manufacturers' online water quality reports for all but one water, excluding those that did not have a reported pH value online. While continued research on the pH of bottled water is essential, this pilot study provides a baseline for practitioners to study and adapt in practice as necessary.

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