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Research Article

Salivary pH Recovery: Analyzing the Buffering Capacity of Saliva After Consuming Basic, Neutral, and Acidic Drinks

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Abstract

This research examines the buffering capacity of saliva by determining the time it takes for the pH of saliva to neutralize after consuming acidic, basic, and neutral drinks. When salivary pH is above 5.5 (critical pH), saliva becomes supersaturated with respect to the tooth's enamel, making a basic oral cavity which results in the remineralization of the tooth's enamel. Conversely, when the pH is below the critical pH, saliva becomes unsaturated with respect to the tooth's enamel, making an acidic oral cavity which can lead to the demineralization of the tooth's enamel over time and increases the risk of cavities and tooth erosion. This experiment measured the pH of a sample of saliva every 10 minutes for 90 minutes after drinking unsweetened almond milk (basic liquid), purified drinking water (neutral liquid), and low-sugar orange juice (acidic liquid) to determine the time it takes for salivary pH to return to its baseline. The research concluded that purified drinking water returned to the baseline salivary pH the fastest (40 minutes), Orange juice took the longest time to return to the baseline salivary pH (90 minutes), and almond milk took between 50-60 minutes to return to salivary pH. It was also concluded that, when compared to earlier studies, low-sugar drinks do not lower salivary pH as drastically as drinks that are not. The results of this experiment indicate the importance of maintaining a healthy diet that supports tooth enamel (such as drinking basic liquids) and minimizes the risk for tooth decay by prolonged exposure to acidic drinks (e.g. orange juice). Future research should examine populations in regions where diets are typically richer in acidic foods and beverages, which could contribute to a lower baseline salivary pH.

Keywords: Salivary Buffering Capacity; Salivary PH; Tooth Demineralization; Tooth Remineralization; Dental Erosion; Oral Health; Enamel Health

Introduction

The pH of saliva is a critical component of maintaining good oral health. A healthy salivary pH ranges from 6.2 to 7.6 [1]. When the pH is above 5.5 (critical pH), the saliva becomes supersaturated with respect to the tooth's enamel, making a basic oral cavity. This results in the minerals from the tooth's enamel to precipitate out and form solid deposits of calcium and phosphate [5]. These solid deposits can remineralize the tooth's enamel, helping to repair it. Conversely, when the pH is below the critical pH, the saliva becomes unsaturated with respect to the tooth's enamel, making an acidic oral cavity. This causes the minerals from the tooth's enamel to dissolve and over time, leads to the demineralization of the tooth's enamel which increases the risk of cavities and tooth erosion [4]. Saliva is normally supersaturated with respect to the tooth's enamel which is why our teeth do not dissolve in saliva that is in a healthy pH range. However, consuming neutral, acidic, and basic drinks can influence salivary pH and disrupt this balance.

Dental enamel is composed primarily of hydroxyapatite: $Ca_{10}(PO_4)_6(OH)_2$. The following chemical reaction occurs when hydroxyapatite is in contact with water:

$$Ca_{10}(PO_4)_6(OH)_{2(s)} \leftrightarrows 10Ca^{2+}_{(aq)} + 6PO_4^{3-}{}_{(aq)} + 2OH^-_{(aq)}$$

When this reaction happens, a small amount of hydroxyapatite dissolves and releases calcium, phosphate, and hydroxyl ions. The reaction continues until the rate of the forward reaction (mineral dissolution) is equal to the rate of the reverse reaction (mineral precipitation).

When hydroxyapatite comes into contact with citric acid ($C_6H_8O_7$), found in orange juice, the following chemical reactions occur:

$$Ca_{10}(PO_4)_6(OH)_{2(s)} + 8H^+_{(aq)} \rightarrow 10Ca^{2+}_{(aq)} + 6HPO_4^{2-}{}_{(aq)} + 2H_2O_{(l)}$$

$$3Ca^{2+}_{(aq)} + 2C_6H_8O_{7(aq)} \rightarrow Ca_3(C_6H_5O_7)_{2(s)} + 6H^+_{(aq)}$$

In the first reaction, the H^+ ions from the citric acid break down the hydroxyapatite into calcium (Ca^{2+}) and phosphate ions (HPO_4^{2-}) that dissolve into the solution. In the second reaction, the calcium ions released from the hydroxyapatite bind with citrate ($C_6H_8O_7$) from the orange juice which prevents remineralization and keeps the calcium dissolved in the solution. The release of calcium and phosphate ions lead to the demineralization of the enamel, making teeth weaker. Because orange juice has a pH below the critical pH, it keeps the hydroxyapatite in a dissolved state which increases the risk of cavities and tooth erosion over time.

Now, when hydroxyapatite comes into contact with almond milk, it remains relatively stable. Since almond milk has a pH above the critical pH, there are few hydrogen ions to dissolve hydroxyapatite. In fact, almond milk is normally fortified with calcium carbonate ($CaCO_3$) or calcium phosphate ($Ca_3(PO_4)_2$) [2]. These release calcium and phosphate into the solution which help in remineralizing enamel by fortifying hydroxyapatite, as shown in this equation:

$$10Ca^{2+}_{(aq)} + 6PO_4^{3-}{}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca_{10}(PO_4)_6(OH)_{2(s)}$$

Many factors can influence salivary pH including diet, hydration, and oral hygiene [7]. Understanding how different beverages alter salivary pH can allow individuals to make informed dietary decisions regarding their oral health in order to maintain a balanced pH.

A recent study from 2024 tested multiple common soft drinks and their effect on the pH of saliva [6]. The study investigated the time it took for pH to neutralize. Most common soft drinks contain carbonic or citric acid, making them lower the pH of saliva. In addition, sugary drinks lower the pH of saliva even more. Another recent study from 2022 proved that sugar intake dramatically decreased salivary pH by almost 2.0 units [3]. The research that was conducted that will be discussed throughout this paper uses unsweetened almond milk, purified drinking water, and sugar-free orange juice as the selected drinks for the experiments. The research that was conducted has the potential to add onto these previous experiments by testing drinks that do not have any added sugars/low sugar to determine whether the hypothesis that low-sugar drinks are less detrimental to tooth enamel is true. This research will examine the buffering capacity of saliva by determining the time it takes for the pH of saliva to neutralize after consuming unsweetened almond milk (basic liquid), purified drinking water (neutral liquid), and low-sugar orange juice (acidic liquid).

Materials and Methods

The materials used in this study included three beverages with differing pH values: low-sugar orange juice (Tropicana brand) as the acidic liquid, unsweetened almond milk (Silk brand) as the basic liquid, and purified drinking water (Great Value brand) as the neutral liquid. Laboratory equipment used included a digital pH meter (Hanna HI98128 pHep®5 pH/Temperature Tester with 0.01 resolution) for measuring the pH of each sample, a pH 7.0 buffer solution to calibrate the pH meter, styrofoam saliva collection cups, 150 mL and 100 mL beakers, a stopwatch for timing sample collections, as well as proper PPE such as gloves and goggles, and napkins for safety and cleanliness.

Prior to each experiment, the pH of each beverage was measured in a 150 mL beaker using the calibrated pH meter. To standardize the oral environment, the researcher rinsed their mouth with purified drinking water before saliva collection. The baseline saliva samples were collected in styrofoam cups, and the pH of each sample was measured using the pH meter. Following baseline measurement, the researcher consumed 150 mL of each test beverage. Saliva samples were collected and measured at intervals of 0, 10, 20, 30, 40, 50, 60, 70, 80, and 90 minutes after consumption, using a stopwatch to record the time elapsed. The pH of each sample was recorded and the time required for salivary pH to return to the neutral baseline was determined for each beverage.

The study was conducted over four separate laboratory sessions lasting 3 hours each. The first session was devoted to testing saliva collection methods and evaluating measurement tools. The second laboratory session focused on collecting baseline and post-consumption saliva pH data for unsweetened almond milk. The third session involved similar measurements for purified drinking water and the fourth followed the same measurements for low-sugar orange juice. In each session, the data was compiled into a pH versus time graph to visualize changes in salivary pH and recovery rates. Statistical analysis was performed to compare the time required for salivary pH to return to baseline across the three beverages, allowing for assessment of their impacts on oral pH regulation.

Results and Discussion

Lab session 1: Collection and trial experiment

The collection sample methods were tested to see which produced the most viable results. The use of pH strips was determined to not be accurate and precise in measuring the pH of saliva. It was determined that a two-decimal point pH meter would be the best at yielding the most accurate pH reading. In addition, it was deemed that the use of small, narrow, styrofoam cups would allow for the pH meter to measure the salivary pH the best. A trial run of the experiment was conducted, and it was determined that the pH should be measured every 10 minutes instead of the initial plan to measure every 15 minutes due to the quickly stabilizing oral pH.

Lab Session 2: Unsweetened almond milk data collection

The use of a buffer pH 7 solution was determined to be useful in stabilizing the pH meter in between each trial. In addition, it was also deemed viable to rinse the pH meter with distilled water (pH 5.80) in between each trial. Below are the results for salivary pH after drinking unsweetened almond milk. The specific brand of almond milk that was used was Silk Almond Milk (Unsweet).

pH of rinsing water: 5.80

Baseline salivary pH: 6.85

Unsweetened almond milk pH: 7.21

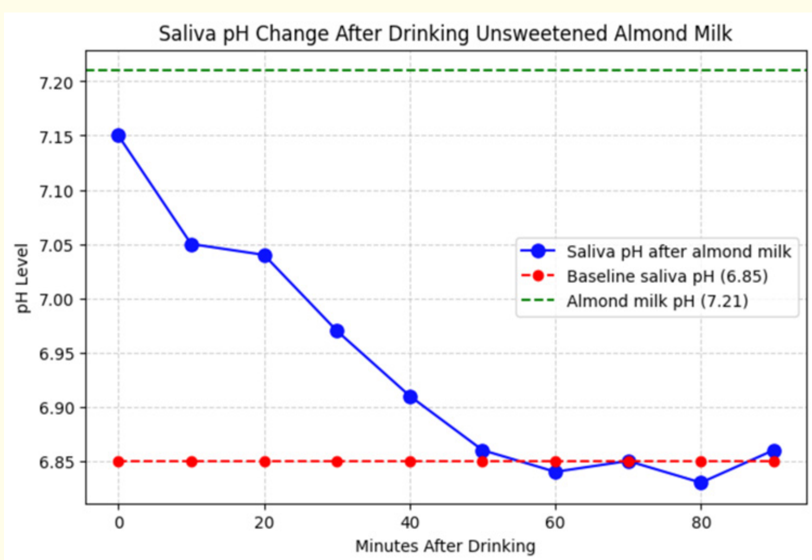

Chart 1: Saliva pH change after drinking unsweetened almond milk.

Minutes After Drinking	0	10	20	30	40	50	60	70	80	90
Salivary pH	7.15	7.05	7.04	6.97	6.91	6.86	6.84	6.85	6.83	6.86

Table 1: pH after drinking unsweetened almond milk (in minutes).

The data that was collected reveals that salivary pH increased immediately after drinking unsweetened almond milk. Baseline salivary pH was recorded to be 6.85 and increased by 0.30 units to a pH of 7.15 after drinking the almond milk. The increase in salivary pH can be explained due to the alkaline nature of almond milk (pH 7.21). The initial increase in salivary pH indicates the effective buffering capacity of unsweetened almond milk to combat an acidic oral cavity. As time progressed, salivary pH began to decrease back to the baseline pH. In accordance with the data, it took approximately 50-60 minutes for the salivary pH to return to its baseline. The steady decrease back to the baseline salivary pH indicates that although almond milk could initially act as a good oral buffer, its buffering capacity is temporary and does not offer prolonged tooth protection. Curiously, it was recorded that salivary pH reaches a low of 6.83 which is below the initial baseline pH. This can possibly be explained by the fluctuating nature of salivary pH.

Lab session 3: Purified drinking water data collection

Below are the results for salivary pH after drinking purified drinking water. The specific brand of water that was used was Great Value Purified Drinking Water (with flavor-enhancing minerals (calcium chloride and sodium bicarbonate)).

Baseline salivary pH: 6.90

Purified drinking water pH: 6.67

Minutes After Drinking	0	10	20	30	40	50	60	70	80	90
Salivary pH	6.75	6.40	6.70	6.86	6.90	6.92	6.89	6.89	6.90	6.91

Table 2: pH after drinking purified drinking water (in minutes).

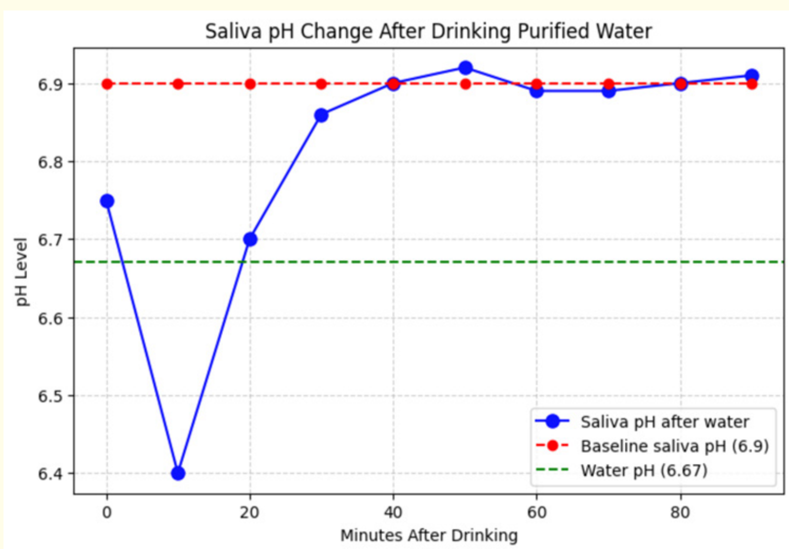

Chart 2: Saliva pH change after drinking purified drinking water.

The data that was collected reveals that salivary pH slightly decreased after drinking the water. Baseline salivary pH was recorded to be 6.90 and decreased by 0.15 units to a pH of 6.75 after drinking the water. The slight decrease in salivary pH can be explained due to the pH (6.67) of the purified drinking water being lower than the baseline salivary pH. As time progressed, salivary pH quickly increased back to the baseline pH. In accordance with the data, it took approximately 40 minutes for the salivary pH to return to its baseline. The quick increase back to the baseline salivary pH was expected as it is a neutral liquid and has relatively no effect on salivary pH. As can be observed, a pH of 6.40 was recorded at 10 minutes. This can possibly be explained by an error in not properly cleaning and rinsing the pH meter. Another reason this could have happened was if not enough sample was collected and the pH meter failed to properly read the pH of the saliva.

Lab Session 4: Orange juice data collection

Below are the results for salivary pH after drinking low-sugar orange juice. The specific brand of orange juice that was used was Tropicana Light No Pulp.

Baseline salivary pH: 6.89

Low-sugar orange juice pH: 2.93

Minutes After Drinking	0	10	20	30	40	50	60	70	80	90
Salivary pH	5.79	5.83	5.88	5.99	6.07	6.21	6.45	6.67	6.79	6.90

Table 3: pH after drinking low-sugar orange juice (in minutes).

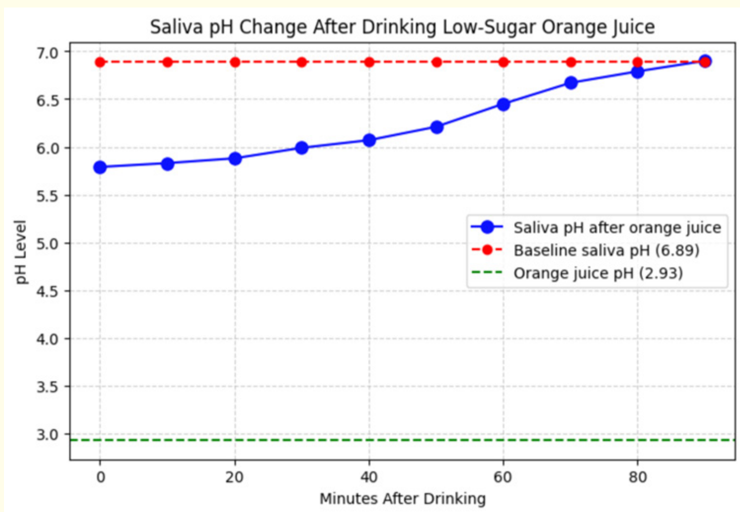

Chart 3: Saliva pH change after drinking low-sugar orange juice.

The data that was collected reveals that salivary pH decreased tremendously after drinking the low-sugar orange juice. Baseline salivary pH was recorded to be 6.89 and decreased by 1.10 units to a pH of 5.79 after drinking the orange juice. The sharp decrease in salivary pH can be explained due to the high acidity of orange juice (pH 2.93). This immediate decrease in salivary pH puts the oral cavity close to the critical pH threshold. As time progressed, salivary pH very slowly began to increase back to the baseline pH. In accordance with the data, it took approximately 90 minutes for the salivary pH to return to its baseline. The slow increase back to the baseline salivary pH depicts the risks of drinking highly acidic liquids too much due its drastic effects of reducing salivary pH buffering abilities and prolonging an acidic oral cavity.

Lab Session 4: Combined Graph Analysis

This graph depicting the average baseline pH (6.88) showcases how each experiment differed in the time it took for salivary pH to

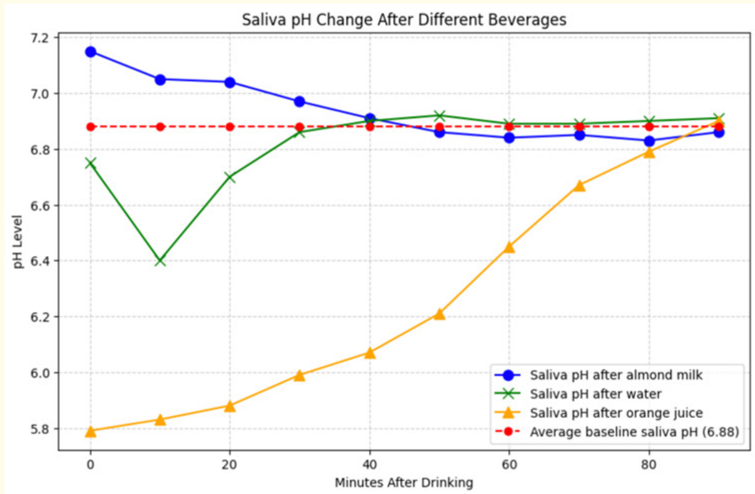

Chart 4: Comparison of saliva pH change after drinking basic, neutral, and acidic drinks

neutralize. Clearly, water had the least effect on salivary pH with the least amount of initial pH change of 0.15 units, while orange juice had the biggest initial pH change of 1.10 units. Both water and almond milk were relatively quick to neutralize salivary pH which indicates that they are healthy, non-erosive drinks that support oral health. Meanwhile, orange juice sharply decreased salivary pH and took the most time to neutralize (90 minutes). This has potentially lasting effects due to prolonged acidity that increases the risk of enamel demineralization and tooth erosion.

Conclusion

Based on the data collected throughout this research, it was concluded that drinking different beverages can significantly affect salivary pH. While unsweetened almond milk (basic liquid) and purified drinking water (neutral liquid) did not affect salivary pH significantly, orange juice (acidic liquid) had drastic and prolonged effects, lowering the pH of saliva by 1.10 units. The slight increase in pH after drinking the almond milk is due to the alkaline nature of almond milk. Additionally, an even slighter change in pH was recorded after drinking purified drinking water due to the pH of the water being relatively neutral and close to the baseline salivary pH. Orange juice drastically decreased the pH of saliva due to its highly acidic nature; thus, giving it the longest pH recovery time. Although the pH of saliva decreased drastically after consuming orange juice (pH 2.93), it did not decrease as much as when a high-sugar and acidity beverage is consumed [3]. The conclusion that can be drawn from this is that low-sugar drinks do not lower salivary pH as drastically as drinks that are not. In regard to almond milk (pH 7.21), it is often fortified by added calcium and vitamin D which are essential for maintaining healthy bones and teeth [9]. Not only this, but the calcium and phosphate released by the almond milk fortifies hydroxyapatite, which dental enamel is made primarily of. Lastly, purified drinking water, which had the fastest pH recovery time, experienced this due to having the most neutral pH of 6.67. Additionally, the specific brand of water used contained added sodium bicarbonate and calcium chloride. Sodium bicarbonate, commonly found in baking soda, acts as a buffer to neutralize acidity in the oral cavity [11]. In addition, calcium that is released in solution helps to fortify hydroxyapatite, as discussed earlier, so overall, purified drinking water is the best beverage to support oral health.

Although this research was successfully conducted and the results that were obtained strongly support the hypothesis, it does contain limitations. This can be seen by the unexpectedly low reading at the 10-minute mark of the purified drinking water data. This limitation could have been due to human error of not producing enough of the saliva sample for the meter to read. Another limitation this research possesses is that the conclusion obtained by the data results from the purified drinking water, almond milk, and orange juice can only be used for those specific brands of beverages and cannot be generalized for all purified drinking water, almond milk, and orange juice, as all brands have varying levels of pH. Lastly, and most importantly, the sample size for this research was based on a single person (the researcher's). The effects on salivary pH that each of these beverages has varies from individual to individual and differs largely based on demographics [8]. The researcher is a 20-year-old, Hispanic, female with a moderately healthy diet and lifestyle and good oral hygiene. Further research could conduct this experiment on a different demographic of people; for example, in Italy, wine is widely consumed so it can be hypothesized that the baseline pH for someone living in Italy is lower due to the high acidic nature of wine, thus salivary pH would take less time to neutralize after drinking acidic beverages [10].

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Conflict of Interest

The author declared no conflict of interest with respect to the research, authorship, and/or publication of this article.

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