The Effects of Dissolved Table Sugar on the Browning of Apple Slices

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Abstract

Sugar has historically been used as a food preservative. Usually, the article of food is covered in sugar either in a solid or liquid form. For example, both Akkadians and ancient Greeks would preserve fruit by mixing it with honey (Nummer, 2002; Chavis, 2019), forming what we know as a jam and/or jelly today. The preservation works because sugar is a humectant (Dowse), reducing the water content inside the food through osmosis, and interferes with enzyme activity (Scientific American, 2006). In this experiment, different concentrations of sugar were tested to see if they reduced polyphenol oxidase (PPO) oxidation - better known as browning - in apple slices. Four treatment groups were used - 250ml of tap water, 250ml of water with 1tbsp of table sugar dissolved, 250ml of water with 3tbsp of sugar dissolved, and 250ml of water with 6tbsp of sugar dissolved. Apple slices were then submerged in the sugar water treatments. The amount of browning was recorded over 24 hours based on percentage cover of browning and darkness of browning. Significant differences were found using an ANOVA test and a post hoc Tukey's test found that the mean comparisons involving plain tap water were statistically different whereas mean comparisons between the groups with sugar water were not. This suggests that sugar is a preservative in dilute forms and that sugar concentration has little effect on fruit browning.

Introduction

Sugar has a rich history of being used as a preservative. The ancient Greeks, Romans, and Akkadians used honey as a preservative by mixing fruits in it (Nummer, 2002; Chavis, 2019). Sugar is a humectant (Dowse) and therefore inhibits microbial growth through osmosis, which regulates the water content in the food (Scientific American, 2006) creating an environment not suitable for microbial activity. Additionally, sugar also interferes with enzymatic activity in food (Scientific American, 2006).

Apples brown because of enzymatic activity. Polyphenol oxidase (PPO) is the enzyme responsible for fruit browning (Queiroz et al. 2011). After tissue damage, such as being cut, PPO oxidizes phenolic compounds to quinones which then produces the coloured pigments (Queiroz et al. 2011). In other words, PPO reacts with oxygen, producing compounds which cause the browning of fruits.

This experiment tests the ability of sugar to preserve the colour of apple slices. To perform this experiment, three solutions of sugar water with varying concentrations were prepared. Plain water was also used as a control. An apple was sliced into pieces and submerged

into the different solutions. The experiment was performed under the hypothesis: If the apple pieces are submerged in sugar water, then there will be less browning. An ANOVA test and Tukey's test was performed to determine the validity of our hypothesis: If apple slices were submerged in water with higher concentrations of sugar dissolved, then they will brown slower/ less.

Methods and Materials

In this experiment, four samples of four different treatments were prepared. The first treatment was plain tap water. The second treatment was tap water with 1 tablespoon of dissolved table sugar. The third treatment was tap water with 3 tablespoons of dissolved table sugar, and the last treatment was tap water with 6 tablespoons of dissolved sugar. 16 plastic cups were labelled with their corresponding treatment and sample number. 250ml of water was then poured into each cup and the corresponding amount of sugar was added and dissolved into the water. An ambrosia apple was then cut into sixteenths. First it was halved, then quartered, then into eighths, forming 8 apple slices. Those slices were then cut in half so there were 16 half slices of apple. A photo of a single piece was taken as reference. One apple slice was placed into each plastic cup. Floating pieces were speared down using clean metal forks. The time was noted, and the experiment was periodically checked over 24 hours.

The % amount of browning was eyeballed by comparing the slices to the initial photo taken and to the apple slice with the darkest and largest surface area of browning. Percentage area cover and darkness of browning was considered. The exposed (non-skin) surface area of each apple piece was divided into 10 sections. The darkness was graded from a value of 0 to 10, with 10 being the darkest/most browned and 0 being no browning. Each section of the surface area was then graded. Each individual grade was then summed, and then divided by the maximum grade to produce a percentage.

An ANOVA test was then performed using the final set of data gathered after 24 hours. A Tukey's test was also performed to determine the area of significance.

Figures 1a & 1b. 1a is the ambrosia apple used in the experiment. 1b is the apple in the process of being cut into sixteenths. Note that the skin of the apple was not peeled.

Results

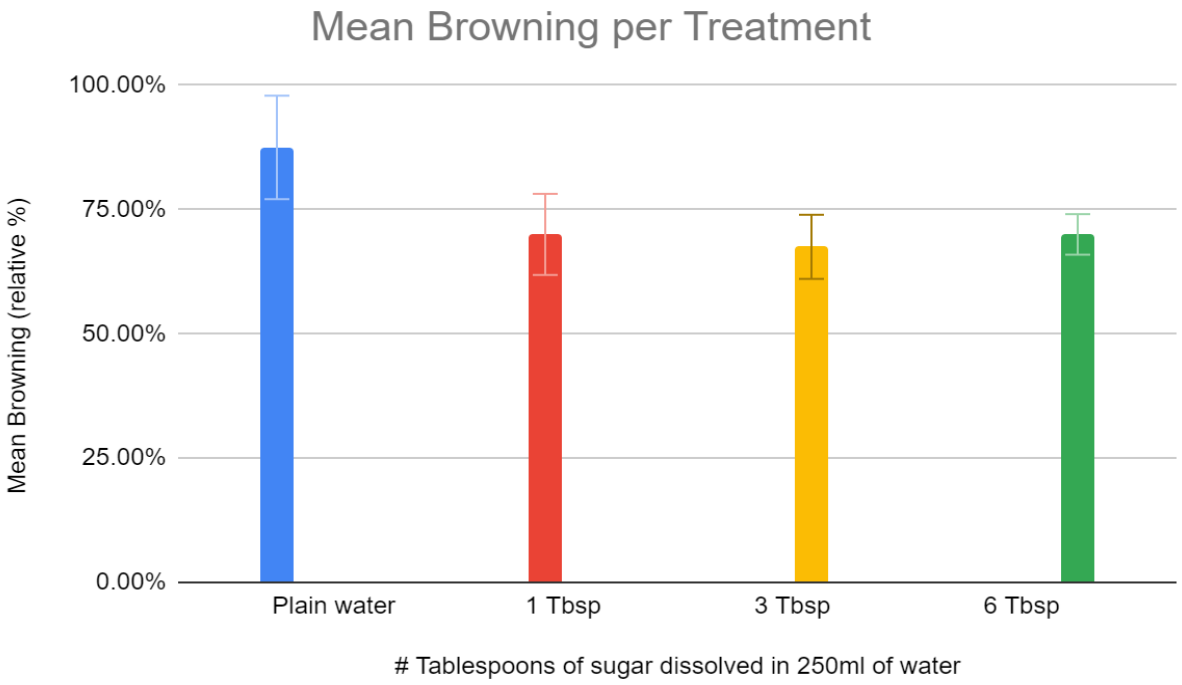

Figure 2. Mean % Browning of apple slices per treatment and standard deviation within treatment. Browning % is relative to the apple slice that was most browned. Mean % Browning for plain water: 87.50 ± 10.41 %, for 1 Tbsp: 70.00 ± 8.16, for 3 Tbsp: 67.50 ± 6.45, for 6 Tbsp: 70.00 ± 4.08.

The ANOVA test produced a P-value of 0.01056774715, F-value of 5.857142857, and a F_{crit}-value of 3.490294821. Since the P-value > 0.05 and F-value > F_{crit}-value, we can reject the null hypothesis.

The post hoc Tukey test found that q-values for comparisons between water and sugared water were greater than the studentized critical value (4.2) whereas comparisons between sugar water groups resulted in q-values lower than the critical value.

Table 1. Tukey's test results. Studentized critical value is 4.2.

Treatment 1	Treatment 2	q-value
Water	Water with 1tbsp Sugar	4.582575695
Water	Water with 3tbsp Sugar	5.237229366
Water	Water with 6tbsp Sugar	4.582575695
Water with 1tbsp Sugar	Water with 3tbsp Sugar	0.6546536707
Water with 1tbsp Sugar	Water with 6tbsp Sugar	0
Water with 3tbsp Sugar	Water with 6tbsp Sugar	0.6546536707

Discussion

The results of the ANOVA test and Tukey's test suggest that there are significant differences in browning amount between plain water and sugar water as the q-values involving plain water are greater than the 4.2 critical value. Therefore, the results reject the null hypothesis and support that dissolved sugar is capable of reducing fruit browning. Tukey's test q-values between sugar water treatments were much lower than the critical value. This suggests that there were no significant differences between the means of the sugar water treatments. This means that sugar does play a role in food preservation outside of being a barrier to oxygen. The lack of difference between sugar water treatment groups suggest that the amount and concentration of sugar does not matter only the presence of sugar does, or that the amount and concentrations of sugar used in this experiment are not varied enough to produce significant results.

Other observations noted during this experiment was that there were differences in the hardness of the apple slices after 24 hours. The slices that were in regular water were much softer than the apple slices submerged in sugar water. The slices submerged in water with 1tbsp of sugar added were slightly softer than the slices in the 3tbsp and 6tbsp treatment, which didn't feel any different from each other. Additionally, the plain water treatments seem to have suffered more evaporation than their sugar water counterparts.

These results are inline with previous and contemporary research results. Goszcynska et al. (1990) found that germicides with 2% sugar was able to preserve the size, quality, and water content of rose petals better than water or germicides alone. They also found that sugar molecules seem to interact with cell membranes differently, affecting microviscosity relative to sugar concentration. Sugar is a known stabiliser, regulating water content, increasing viscosity, and acts as an anticoagulant (Dowse), all which help maintain the structural integrity, colour,

texture, and taste of food. These stabilising effects appear to be what is preserving the apple slices in this experiment.

This experiment has many limitations. Firstly, only one apple was tested. Other apples from the same species and other species may interact differently to the presence of sugar and produce different results. Seasonal and annual differences may also be a factor. Secondly, only one type of sugar, sucrose, was tested. Thirdly, the water used was simple tap water, not deionized water which would have produced better control over the experiment.

Sources of error include the measurement of both water and sugar. The water was measured using a measuring cup and differences of a couple ml of water is likely. The sugar was measured by volume using measuring spoons instead of mass, which would have given a more precise measurement. Most majorly, the measurement of browning is largely estimation based on photos and comparisons between slices and not a precise quantitative measurement. Although quantitative components were part of the estimation (such as browning surface area), a major component of the estimation was qualitative.

Future studies should take a look at other foods, historical usage of sugar as a preservative, and conduct a more refined and controlled experiment. Additionally, more quantitative measurements and qualities should be considered. For example, hardness of the apple slices could be measured quantitatively.

Conclusion

The experiment found that the presence of sugar does improve the preservation and reduce the rate of browning of apple slices. Significant differences were found between the plain water and sugar water treatments but we fail to reject the null hypothesis for comparisons between the sugar water treatments. This suggests that either the concentration of sugar does not play a significant role in apple slice preservation, or that the concentrations of sugar used in this experiment were not varied enough to produce significant differences.

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