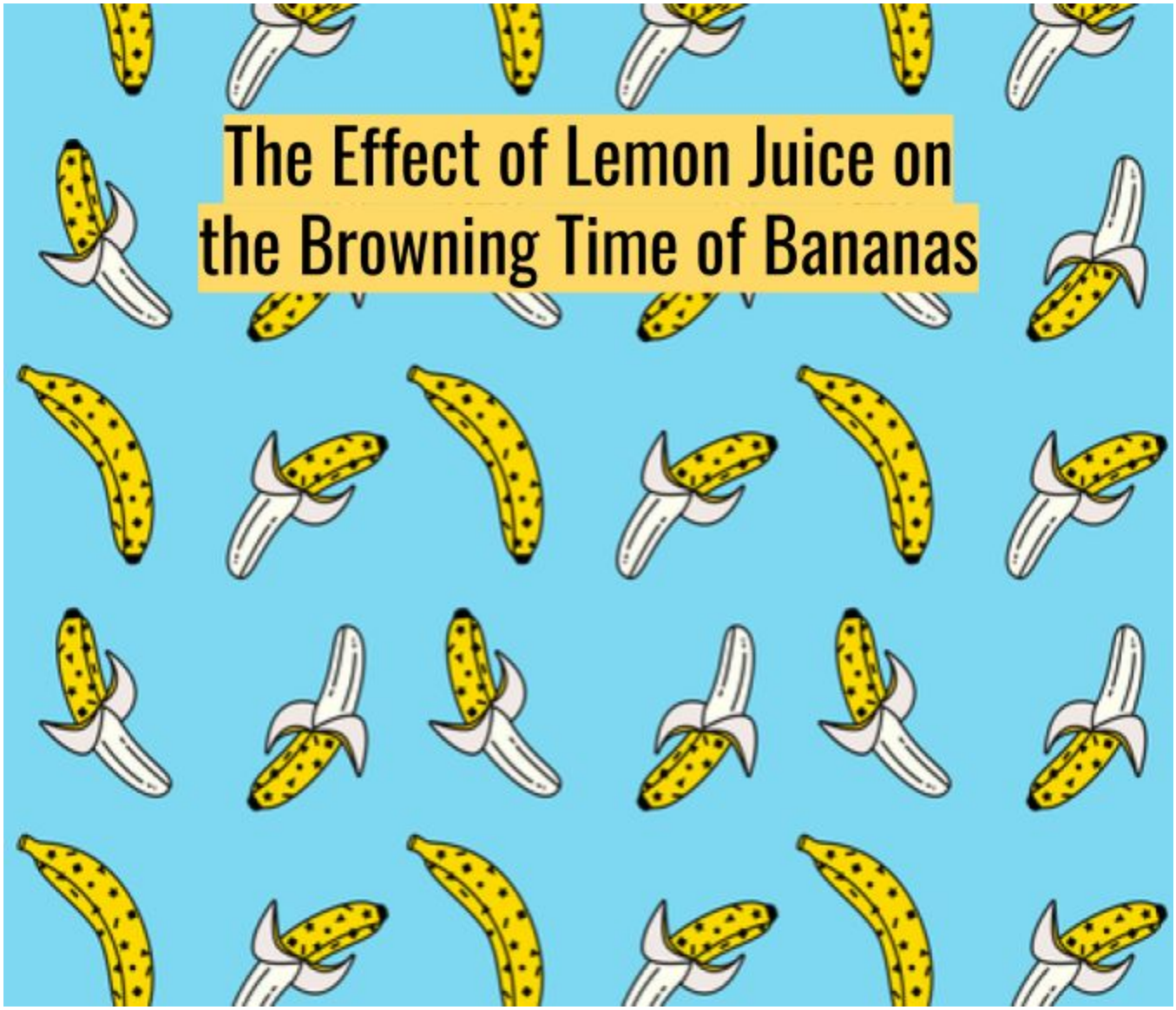

The Effect of Lemon Juice on
the Browning Time of Bananas

Introduction and Background:

After a hard day at school a healthy afternoon snack is a great thing to come home to. After slicing up some bananas, the leftover slices start to turn brown and soft. Now, no one wants to eat those banana slices and they go to waste. Many online sources say that applying lemon juice to an banana slice can slow the browning process. Juicing a lemon is a rigorous activity, so we need to know for sure if lemon juice can prevent browning before you waste your time juicing a lemon.

When a banana is cut, it is exposed to air, and an enzyme called polyphenol oxidase is released from the cells of the banana which reacts with the oxygen to produce o-quinones which are the precursors to a brown colored secondary product. It is speculated that plants use this as a defense mechanism; Therefore, when the plant is damaged, the browning will discourage animals from consuming it. In addition, browning helps the plant heal by creating an antibacterial effect, preventing further damage by bacteria.

Lemon juice helps keep the banana from browning because it is full of ascorbic acid and has a low pH level. Oxygen will react with the ascorbic acid before it reacts with the polyphenol oxidase, which should slow browning but not prevent it. Polyphenol oxidase's enzymes also become inactive when exposed to a pH under 3, and lemon juice has a pH of 2.0

Statistical Question:

Does lemon juice significantly slow down the browning process for bananas when applied to the surface of the banana?

Data Collection:

At the grocery store, there were 37 bunches of bananas, so I labeled each bunch in my head, and used a random number generator on my phone to select the bunch I was going to buy. In addition, there were 48 lemons and I repeated the same process as the bananas to select the lemon I was going to juice.

At home, I juiced the lemon and strained the juice with a cheesecloth to remove the pulp to ensure that the lemon treated bananas had a very similar consistency of juice. I took out all ten bananas and lined them up. I cut two slices out of every banana as quickly as possible. Because this is a matched pairs design I had to randomly select which slice was going to receive the lemon treatment, the first slice or the second slice. I used a random coin generator to generate 10 coin flips. If the coin was heads, the first slice got the lemon treatment, If the coin was tails the seconds slice got the lemon treatment. I made sure that the slices were as close in thickness as possible and cut from the same part of each banana. I then oriented the bananas on the cutting board so that the slices assigned to the lemon treatment were placed on the right in order to prevent confusion during the lemon application process. Next, I had already prepared an eye drop bottle full of lemon juice which is a simple and accurate way of ensuring each slice receives the same amount of lemon juice. I gave each banana slice three drops of lemon juice and used a small table spoon to spread the juice on the surface of the banana as evenly as possible. After using the bottle I immediately discarded it so none of my family members would mistake it for eye drops. The cutting and lemon application process was done as quickly as possible to reduce the amount of time between steps so that browning time is as accurate as possible. However, I

was unable to do these steps simultaneously. As soon as I was done applying the juice to ten of the twenty banana slices, I started the stopwatch. Because I don't have time to watch the bananas for hours and record the time it takes for each to brown, I set up my phone to record a video of the bananas, with the stopwatch in frame in order to keep time. This way, the video allows me to review it several times to get an accurate time for browning for each banana. The banana slices are placed together on a cutting board to keep all slices in a similar environment, since factors such as humidity and sun exposure can affect browning time.

When reviewing the video, my main issue was what I could classify as browned. I realized that the center of the bananas browned first, so I used the centers of the banana as a reference for browning. I analyzed the video frame by frame and used a color finder application on my laptop to pinpoint the moment that the color at the center of the banana reached a brown shade that I had already predetermined. The color finder application on my laptop allows me to select a pixel on a photo and it will give me the color ID of the color. I compared the color ID of the brown on the bananas to ID of the predetermined brown color. Because the lighting during the day changed and bananas are not all the same color, I used the RGB numbers for the color to determine once the color reached the same "darkness" as the brown I had predetermined. RGB numbers break down a color into Red, Green, and Blue values. Using my knowledge of RGB, I can determine the "darkness" of a color with those values. Finally, I recorded the time to brown for each banana slice.

Bananas after slicing vs. Bananas after eight hours

Pairs of banana slices from one banana are lined up side-by-side horizontally. First column had no lemon; second column had lemon; third column had no lemon; fourth column had lemon.

Banana Time Lapse Video feat. Fruit Flies
https://youtu.be/H4lWMPhlp0w

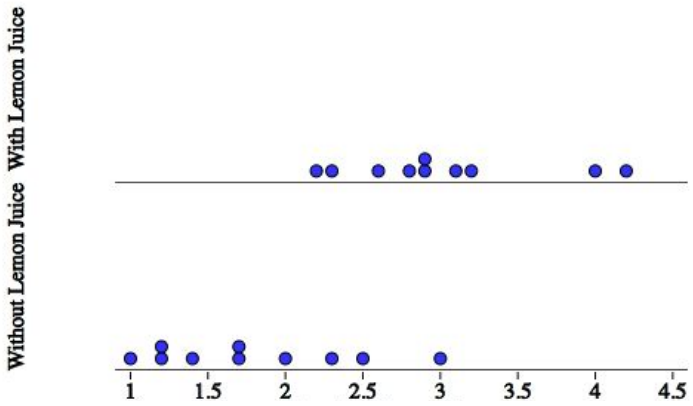
Data Display:

Banana	browning Time with Lemon (hours)	browning Time without Lemon (hours)	browning Time with Lemon - browning Time without Lemon
1	3.100	1.4500	1.6500
2	3.2830	1.0500	2.2330

3	4.0667	3.0007	1.0660
4	4.2667	2.5333	1.7334
5	2.9333	1.7833	1.1500
6	2.6667	1.2500	1.4167
7	2.800	1.2667	1.5333
8	2.3667	1.7667	0.6000
9	2.2500	2.3833	-0.1333
10	2.9333	2.0500	0.8833

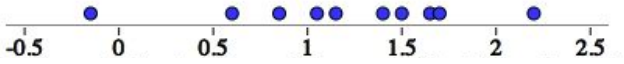
	browning Time with Lemon (hours)	browning Time without Lemon (hours)	browning Time with Lemon - browning Time without Lemon (hours)
Minimum	2.25	1.05	-0.133
Q1	2.667	1.267	0.883
Median	2.933	1.775	1.283
Q3	3.283	2.383	1.65
Maximum	4.267	3.001	2.233
Range	2.017	1.951	2.366
Mean	3.067	1.853	1.213
Standard Deviation of Sample	0.659	0.635	0.664
Sample Size	10	10	10

Dot Plots for for Browning Time of Both Bananas with and without Lemon Juice:



Browning Time of Bananas (Hours)

Dot Plot for the Differences in Browning Time of Bananas (time with lemon - time without lemon):



Differences in Browning Time of Bananas (time with lemon - time without lemon)

Data Analysis:

The distribution of "Bananas with Lemon Juice" has a mean of 3.067 hours and a standard deviation of 0.659 hours, while the distribution of "Bananas without Lemon Juice " has a mean of 1.853 hours and a standard deviation of 0.635 hours. The mean and standard deviation

of “Bananas with Lemon Juice” are greater than the mean and standard deviation of “Bananas without Lemon Juice.” The distribution of “Bananas with Lemon Juice” is strongly right skewed, with one outlier at 4.267 hours. However, the distribution of “Bananas without Lemon Juice”does not have any strong skewness or outliers. Even though one of the sample distributions, the distribution of “Bananas with Lemon Juice,” shows strong skewness and has an outlier, the distribution of “Differences in browning Time of Bananas (With Lemon-Without Lemon),” does not show any strong skewness or outliers, so we can assume that the normal condition is met for the one-sample paired t test. The distribution of “Differences in browning Time of Bananas (With Lemon-Without Lemon)” has a mean difference in browning time of 1.213 hours and a standard deviation of 0.664 hours.

One-sample Paired t-test for the Population Mean:

State: μ_{diff} = the true mean difference (banana browning time with lemon - banana browning time without lemon) of browning times of organic Sprouts bananas like the ones we used in the experiment

H_0: $\mu_{diff} = 0$

H_a: $\mu_{diff} > 0$ → one-sided alternative hypothesis

Plan: We will use a one-sample paired t test for the population mean with $\alpha = .05$.

Conditions- Random: Met; the bananas were randomly selected from the population of organic Sprouts bananas and were randomly assigned lemon or no lemon.

Normal: Even though the Central Limit Theorem is not satisfied because the sample size is 10, which is less than 30, the sample distribution of the differences in browning times of the bananas

does not show any skewness or outliers. Thus, we will assume the sample distribution is approximately Normal, but we will proceed with caution.

Do: We can calculate the following for the sample data of the differences between browning times of the bananas:

$\bar{x}_{\text{diff}}$ is the mean of the differences in the browning times from the sample

$\bar{x}_{\text{diff}} = 1.213$

$s_{\text{x diff}}$ is the standard deviation of the differences in the browning times from the sample

$s_{\text{x diff}} = 0.664$

df = n-1 =10-1 = 9

Test statistic: t = 5.77687

p-value = .000134

Conclude: Because the p-value of .000134 is less than the significance level of $\alpha = .05$, we can reject the null hypothesis. We have convincing evidence that the banana browning time with the lemon is greater than the banana browning time without the lemon.

Reflection:

Originally, we decided to do an experiment on browning apples because we noticed that apples tend to brown once cut. However, either due to the apple type we had selected, or other environmental factors, the apples would not noticeably brown. After 32 hours of observation the apples remained a light color and the difference between the lemon treated apples and the non treated apples were hard to distinguish. We tried many fruits like pears, other types of apples, and peaches. We reached the conclusion that bananas turn a very noticeable dark brown after a

short period of time. The most difficult part of the experiment was determining when the bananas were considered “browned”. The color finding method was the most feasible and accurate way to determine the time a banana oxidized. However, if there were a device to measure levels of o-quinones, then we could achieve a very high level of accuracy. Another difficult part of our study was being as fast as possible when slicing the bananas and applying lemon juice. Because we could not do this all simultaneously, bananas sliced first will be exposed to air longer than the bananas after it. In order to fix this we could have multiple people working at once to do it simultaneously.

To further our study, we could either use a larger sample of bananas to produce a more comprehensive report on the effects of lemon juice on bananas browning; a larger sample would reduce the sampling variability, thus, producing more accurate data. We could also expand our study by looking at different types of bananas in different stores and different brands to widen our scope of inference. In addition, other variables could also affect the browning time for banana slices, not just lemon juice, such as temperatures. We could compare the browning time of the banana in cold temperatures versus in hot temperatures, or we could wrap the stems of bananas in the peel and seeing how that affects the browning time. Furthermore, browning times across different fruits are comparable, and we could test how different fruits respond distinctly to the lemon juice or lack thereof. Finally, please enjoy the time lapse we made of the bananas browning!

Works Cited:

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“80s Banana Print Blue Fabric - magic_circle.” Spoonflower, www.spoonflower.com/fabric/5353807-80s-banana-print-blue-by-magic_circle.