The Impact of Light on the Browning Process of Apples

Aim

The topic of this investigation is to see whether light affects the change in color of an apple. I will be utilizing a colorimeter to test the absorbance of a 565-nanometer wavelength (yellow color) of solutions of apple slices that have been placed under light from varying distances. The absorbance value will indicate how opaque the solution is, indicating the extent of browning.

Question

How does light from varying distances (0, 1, 2, 3, 4 feet) affect the browning of an apple over a period of 48 hours?

Introduction

I tend to enjoy looking through my pantry or backpack and finding a snack to eat. By looking at the surface, I can infer whether something has been spoiled. However, apples always dupe me because I tend to believe that the browning of an apple indicates its expiration. Therefore, I set out to find out what conditions enable or expedite this process of browning.

An apple typically begins to brown due to a chemical reaction called oxidation. This is because apples possess an enzyme called Polyphenol Oxidase known as PPO as well as phenolic compounds (Ashish). After an apple is cut, oxygen enters the apple and oxidizes these compounds, producing colorless o-quinones that turn brown after reactions with amino acids (Ashish).

The idea that the browning of an apple comes from oxidation is the most common theory. However, I always believed that leaving apples in the sun is what expedites this browning process. After doing research, I realized this theory has some validity. This is because light energy that is emitted from excess light exposure can destroy vitamins, causing the coloration of the apple to change. Vitamins A, B2, B6, and B12 are sensitive to UV light therefore extended exposure can lead to the degradation of these vitamins (Koutchma).

To test how light impacts the browning of an apple, I will place pieces of apples from varying distances away from a light source over a specific time period and observe the browning

process. To gain a quantitative measure, a colorimeter can be utilized to measure how brown an apple is as it measures the absorption of certain wavelengths. The wavelength that represents the yellowish color on the inside of an apple is 570-590 nanometers, therefore the light that is shined through the colorimeter will possess that wavelength (Helmenstine). Placing an apple at different levels of exposure to light will distinguish whether light has an impact on the browning process.

Prediction

I think that there will be a negative correlation between the absorption of color and distance from the light, in other words, increased light exposure will brown the apples more. This is because intense light energy can cause the destruction of vitamin A in fruits as it creates an unsuitable environment for beta-carotene, a molecule within fruits and vegetables that reflects yellow and orange light.

Unit of Measurement

I understand that the preferred unit of measurement is the metric system, however, since this was a home experiment, I had access to a ruler that measured in feet instead of meters. This explains why the procedure and the research question utilize feet instead of meters.

Calculation Uncertainty

During the computation of values, I chose to round values to two decimal places. I understand this incites an additional sense of uncertainty when evaluating the data, however, I felt that this level of specificity is all that is necessary to communicate the possible correlation between the variables I have chosen.

Materials

- 25 apple slices
- One lamp
- 5 mL of water per apple slice solution
- 5 cuvettes
- Laptop
- Vernier Graphing Analysis Software
- Colorimeter

- Aluminum foil
- Timer
- Graduated Cylinder
- Mortar and Pestle
- Measuring tape

Independent Variable

- The distance of apples from the lamp being 0ft, 1ft, 2ft, 3ft, and 4ft.

Dependent Variables

- Apple substance absorbance of 565 nm (yellow) wavelength

Controlled Variables

- The amount of light that is exerted from the lamp
- The 5 mL addition of water to the apple solution
- The size of each apple slice (1/8 of each apple)
- The amount of peel on the apple (removed peel)

Uncontrolled Variables:

- The amount of sunlight that may have entered the room (there is a window, but the curtains were closed)
- The temperature of the room
- The temperature of the light
- The duration of how long the apple has been exposed to oxygen prior to this experiment
- The amount of oxygen in the room

Safety Statement

When having a lamp plugged into an electrical outlet for 48 hours, caution is necessary. This is because the lamp could heat up to high temperatures, making itself a fire hazard. That is why it is important to constantly check on the experiment to make sure the temperature of the lamp is not too high, as well as to not keep anything flammable nearby.

Procedure

1. Slice and skin the apples into 25 pieces to get 5 slices per measurement mark.
2. Find a clear space that is dark so that a limited amount of exterior light is entering the apples. Also, make sure there is an outlet so that the lamp can be plugged in.
3. Mark where 0ft., 1ft., 2ft., 3ft., and 4ft. are from the lamp's light to indicate how far away the apples will be placed from the light source.
4. Rip out a piece of aluminum foil for the apples to rest on so that the moisture of the apple is not further compromised.
5. Place the strips of aluminum foil with the apples at each measurement.
6. Turn on the light.
7. Set a timer for 48 hours and wait till it alerts. This is because around 2-4 days is how long it takes for an apple to expire after being cut.
8. Collect the apples.
9. Using the mortar and pestle, mash up each apple slice. Add 5mL of water to the mashed apple in order to make it a substance that can be read by the colorimeter. This may consume a long period of time because I am mashing each apple individually.
10. Plug in and calibrate the colorimeter. Then set the wavelength to 565nm, as this is the wavelength that projects yellow light. Yellow light is important as yellow was the color of the apple's interior prior to step 9.
11. Pour the substance into a cuvette and place the cuvette into the designated area of the colorimeter.
12. Wait for 45 seconds for the data to be collected to get a consistent reading.
13. Repeat steps 11-14 for all apple slices.
14. Record data.

Preliminary Experiment

I am doing a home experiment. Therefore, I had to ensure that I could control as many variables as possible. This included trying to limit the number of whole apples used so that the number of varying factors between slices can be restricted. In addition, I utilized a dark room in my house so that no exterior light could affect the apples. After 48 hours, I noticed a variance in color between each set of apples, therefore I decided to embark on this experiment.

Exploration

Observations

- The light shining on the apples in the dark room demonstrated a clear distinction between which apples were getting light and which apples were not.
- After the first 12 hours, there was a slight coloration change in all the apples, however, it was not enough to distinguish which set of apples had changed the most.
- After 24 hours, it was noticeable that two of the apple slices furthest from the light were browner than two of the apple slices directly under the light.
- After 48 hours, I noticed that the apples directly under and near the light had dried up a little bit, making it harder to mash up with the mortar and pestle. These apples had decreased in size. Meanwhile, the apples furthest from the light had retained more moisture than the others.

Raw Data Table

Feet from Lamp vs. Absorption of Wavelength 565nm							
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	Standard Deviation
0ft.	0.55	0.58	0.44	0.33	0.27	0.43	0.12
1ft.	0.37	0.48	0.74	0.50	0.14	0.45	0.19
2ft.	0.46	0.35	0.66	0.42	0.47	0.47	0.10
3ft.	0.59	0.59	0.59	0.50	0.61	0.58	0.04
4ft.	0.6	0.63	0.66	0.74	0.44	0.61	0.10

Table 1

Error Bar Analysis

The standard deviation was calculated from each of the data points to calculate the amount of possible error that could have been possible throughout the data collecting process.

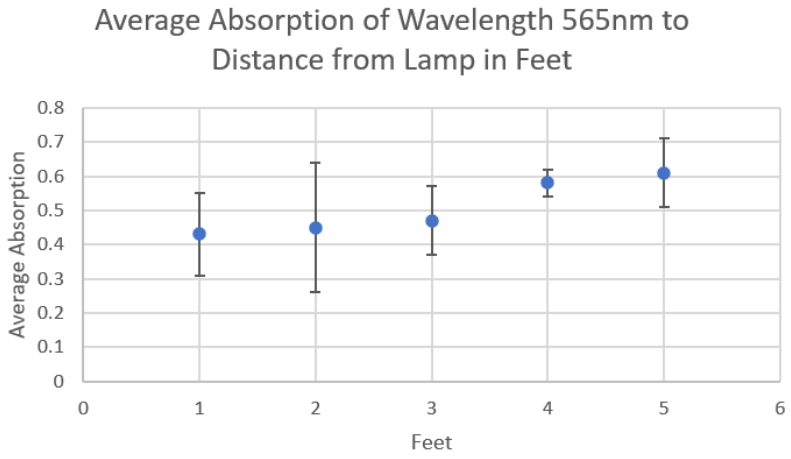

Figure 1

The error bars represent the possible deviation from the points that are plotted on *Figure 1*. Therefore, if they are large, that represents a great amount of error occurred during the data collecting process, possibly indicating that the two variables are not correlated, or that the environment which they were tested upon was not controlled enough.

These data points are a representation of the averages from each trial. I noticed that they are quite close together in the graph. They are close to an extent where some of the error bars engulfs the other points, therefore demonstrating a possible lack of correlation between distance from the light and the browning of the apple. However, there are possibilities that could have explained why there was larger deviation in some trials rather than others.

One possibility is that during the process of mashing the apples, some of the apple slices may have turned browner than others because I had to mash the apple slices one by one, giving time for the later recorded apple slices to be impacted by exterior factors. Some of those exterior factors include possible oxygen they may have entered the apple slice, causing the later tested apple slices to be browner than others. A possible way to fix this error would be to have the apples mashed all at once, however, that is out of my scope of capabilities.

Another possibility is that some apple slices became drier than others. The heat of the lamp may have caused the moisture of the apples to evaporate at an unknown rate. Therefore, this could cause the variance shown in the error bars because temperature was an uncontrolled variable in my procedure.

Pearson's Correlation Coefficient

When measuring how strongly two variables impact each other, one can utilize Pearson's Correlation Coefficient. This value measured in the variable, *r*, determines the strength of the correlation between two sets of data by providing a value on the spectrum of -1 to 1. If *r* produces a value closer to 1, then there is a strong positive correlation between the data, and if it is closer to -1, then there is a strong negative correlation between the data. However, if the value is closer to 0, then that indicates that there is a weak or no relationship between the variables. Since the experiment aims to determine if there is a correlation between light and the browning of an apple, I will utilize the Pearson's Correlation Coefficient Formula to determine the strength of correlation. For my prediction to be true, there needs to be a strong negative correlation since I hypothesized that the increase in light will lead to further destruction of the vitamins in the apples, expediting the browning process.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma \mathrm{y})}{\sqrt{[n\Sigma x^2 - (\Sigma \mathrm{x})^2][n\Sigma y^2 - (\Sigma \mathrm{y})^2]}}$$

$$r = 0.95$$

The *r*-value of 0.95 indicates a very strong positive correlation in the browning. This disproves my prediction as this represents that the less light the apple had, the more it browned. This does not align with my initial theory. This may be because during the data collection process, I could not test upon all the apples simultaneously, and since I tested the further apples last, they had the possibility to undergo more oxidation which is a heavy contributor to the browning process.

Linear Regression and R-Squared

Despite the fact that the results that have been produced are an accurate representation of light expediting the browning process within an apple, they represent a strong positive

correlation. And with that strong positive correlation, it has produced a linear regression trend line with this equation:

$$y = 0.05x + 0.36$$

This indicates that the results depict that with each increment in distance away from the light, the absorbance of the 565nm wavelength increases by 0.05 from the initial absorbance of 0.36. While Pearson's Correlation Coefficient measures the strength of the correlation between two variables, squaring that value depicts how accurately the trend line for that correlation fits. This value is known as R^2 and the closer that value is to 1 demonstrates less variance from the original data points.

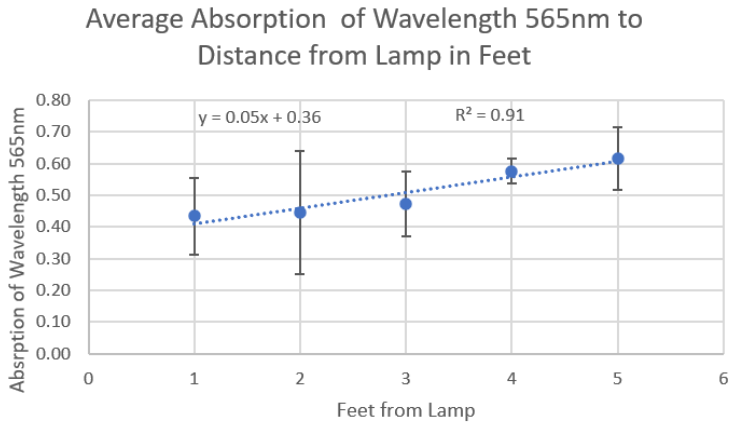

Figure 2

The R^2 value of 0.91 represents that the linear regression line of y = 0.05x + 0.36 is an almost accurate representation of the correlation between the increasing distance from the lamp, and the absorption of the color.

Conclusion

After conducting this experiment, I have deduced that there is little to no correlation between light and the browning of an apple. The most common theory for why apples brown in the first place is oxidation. Oxidation occurs in apples when the interior of the apple is exposed to oxygen, allowing the enzyme Polyphenol-Oxidase to react with phenolic compounds within the apple, turning the apple into a brown color (Ashish). However, I wanted to discover whether light had an impact on the changing color of an apple. I know that light is responsible for the

reflection of color, but I was eager to discover if the amount of light could impact the change in color of an object. This was because I had a long-lasting assumption that the rays from the light were harmful to the color of an apple because it was harmful to the color-reflecting vitamins, making it spoil faster. Therefore, I put my theory to test through this experiment by testing the browning of an apple over a specified time period through restricting some sets of apples to different levels of light by varying the distance they were placed from direct light.

After performing this experiment, the data indicated that the variables positively correlate with each other, disproving my prediction. However, the larger error bars signify that there is too much variance. The correlation between the distance from the light and the absorbance of the color wavelength is demonstrated in the 0.95 *r*-value, which indicates a strong positive correlation. The data also conveys an accurate linear trend through the r^2 of 0.91 and the positive slope of the regression line of 0.05. This demonstrates that there is indeed a trend between the two variables. However, the data I collected also possesses a significant amount of variance which is depicted through the error bar analysis. Each of the error bars engulf at least one other point, demonstrating that in each of sets of apples at different distances, there were multiple points recorded that did not fit the linear trend of the dataset. Despite the large variance existing in the points recorded, there was indeed a trend.

The reasons why there was an unexpected positive correlation in the data were that there were variables that were jeopardizing the control of this experiment which were out of my scope of abilities to contain. The first variable is the idea that the apples under the light were receiving direct heat, causing the moisture in the apples to evaporate in the air. Therefore, when mixing 5mL of water with the apple to create a solution that could be read by the colorimeter, the drier apples did not dissolve as well, making the solution less concentrated and absorb less light than the apples that were further away from the heat exposure. The second variable was the idea that I mashed the apples and recorded data in the order of closest to the light to furthest. Since this process took around two hours to record all the data, that gave the further away apples more time to undergo oxidation, therefore browning.

In my experiment I believe I did a good job of setting up a home lab that tested the color variation in apples under a specific condition. I utilized the resources available to produce data that signified a trend. Although I attempted to set up a controlled home experiment, it created the

possibility for the experiment to possess more uncontrolled variables such as the heat from the lamp, or variance in oxidation for different sets of apple slices. Therefore, to improve this experiment, I should have found a way to control the oxidation in different apple slices, and maintain the same temperature for all apples, so that there are fewer uncontrolled variables in the experiment. This relates to the idea that when measuring an uncontrolled variable relative to an independent variable, it is important to limit the experiment only to the aspects that one desires to measure to discover whether two variables correlate. This demonstrates why the use of controlled settings, such as mesocosms, are utilized for experiments as they measure their intended variable with less uncontrollable factors.

References

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