

Determining the Effect of Temperature and Airflow on Ripening of Bananas

Navdeep Binning, Harleen Dhaliwal, Simran Dhaliwal, Justine Grewal
navibinning99@gmail.com, harleen3514@gmail.com, simran14dhaliwal@gmail.com,
justine_g10@hotmail.com

Abstract

Bananas are a climacteric fruit, which means it is green when harvested and its ripening is initiated by the surrounding climate. In particular, the ripening is mainly controlled by temperature, the gaseous environment around the fruit and the atmospheric pressure. The aim of our project was to evaluate which areas of varying temperatures and airflow conditions in our homes will induce the slowest ripening in order to find the best storage spot. We placed three bananas in each of the six different storage spots ranging from 4°C to 22°C with varying airflow conditions and recorded the percent cover of brownness twice daily for 12 days. Analysis was performed on our data using a two-way ANOVA test and the results showed the difference was statistically significant ($F(5,24) = 11, p < 0.0001$). This states that the percent cover of brownness differs between the groups. However, the ANOVA test showed no significant difference in percent cover of brownness between the two times of measurements ($p = 0.8037$). A post-hoc test, Tukey's multiple comparisons test, was used to determine the specific six groups that differed. Areas of warmer temperatures and abundant amounts of airflow had the highest percent cover of brownness and increased ripeness in comparison to the colder and restricted airflow areas as we predicted, except for the bananas in the refrigerator. The best storage area for preserving bananas in our homes was found to be the garage.

Introduction

Bananas are a tropical fruit that is largely produced in the temperate and tropical zones of Asia, Latin America, and Africa. The fruit is climacteric, which means it is green when harvested and its ripening is initiated by the surrounding climate before the market (Du et al. 139). Bananas turn golden yellow due to Chlorophyll (Chl) breaking down in the peel with the help of ethylene, a hormone that aids in the fruit ripening (Du et al. 139). When the peel turns yellow, the fruit is soft and sweet, however, the banana starts to over-ripen when there are brown spots on the peel. The brown spots occur because of the increased concentration of ethylene gas that is produced by the peel (Jiang 109). Banana ripening is mainly controlled by temperature, gaseous environment around the fruit and the atmospheric

pressure (Thompson et al. 57). Canadians eat approximately three billion bananas a year and 100 million people worldwide use them as their main energy source (Ahmad et al. 224). Thus, we wanted to discover the best storage spots and their temperature and airflow conditions which allow for prolonged preservation of the bananas.

In our experiment, we will be storing bananas at varying locations around our homes to explore the effects of the different temperatures and airflow conditions in each location and how it alters on ripening of bananas over a twelve day period. Similar studies have also been conducted, showing that higher temperatures do in fact increase the rate of ripening. Ahmad et al. (224) found the temperature of increased ripening is around 14-30°C and anything above or below this temperature range can cause problems. Such problems include uneven ripening, decreased quality of ripe fruit and shortened storage life (Ahmad 224). However, Abdallah (15) found another important factor for ideal ripening is the surrounding amount of air flow and distribution. The airflow rate and room temperature affected the physical properties of bananas and its ripening with the quickest ripening of bananas occurs at an airflow rate of $0.3m^3/s$ and temperature of 21°C (Abdallah 15). Abdallah's research explains how important airflow can be for ripening, so we hope to test if the constriction of air flow slows down the process of ripening.

We aim to test which specific areas of varying temperatures and airflow conditions in our homes will induce the slowest ripening in order to find the best storage spot. We will observe what the ideal climate is and if abundant airflow is a confounding factor to either speed up or slow down ripening of the bananas. We hypothesize if bananas are kept in warmer spots with non-restrictive airflow, then they will ripen faster and have a higher percent cover of brownness than the bananas kept in cooler and restrictive airflow spots. This

study is important since we want to determine the best storage spot for the bananas to allow people to enjoy perfectly ripened bananas and prevent the waste of over ripe ones.

Methods

To conduct this experiment, we bought eighteen unripe Del Monte organic bananas to observe the amount brownness for each banana over a 12 day period. We placed the three bananas in different accessible locations around the home; the kitchen counter, in the oven, in the refrigerator, in the garage, in individual ziplock bags placed in a kitchen cabinet (Figure 1), and lastly in the broiler room/closet. These spots were chosen to have a range of warm, cold, restrictive and non-restrictive conditions. All of the bananas were placed with stem pointing to the right, as only the top side of the banana was observed and measured for brownness. The bananas were monitored twice daily and we recorded observations, the temperature using Accutemp: indoor or outdoor thermometer, the calculated amount of brownness using a 10 x 10 customized banana shaped grid (Figure 2), and the number observed from the banana ripening scale (Figure 3). The temperature of each location of bananas was checked and recorded in the morning (11AM) and evening (11PM) using the ACCU room thermometer. The banana ripeness scale (Figure 3) was used to match and compare the banana's appearance to the range in the chart. To calculate the percent cover of brownness, we used a transparent cover sheet to trace the shape of the banana and made a 10 x 10 grid as seen in Figure 3. The grid was placed on top of the banana and each square that has brownness was counted to represent one percent cover.

The final measured percent cover of brownness on the three banana replicates of each group was statistically analyzed. This was done by using a two-way ANOVA test on our day 12 data to check for a significant difference in mean percent cover of brownness between the six groups and the two different time measurements. Since our ANOVA results were significant we ran a Tukey's multiple comparisons test (post-hoc test) to determine which specific locations differed.



Figure 1. Bananas placed in ziplock bags for restricted airflow



Figure 2. Example of customized grid used to measure and record percent cover of brownness on the banana.

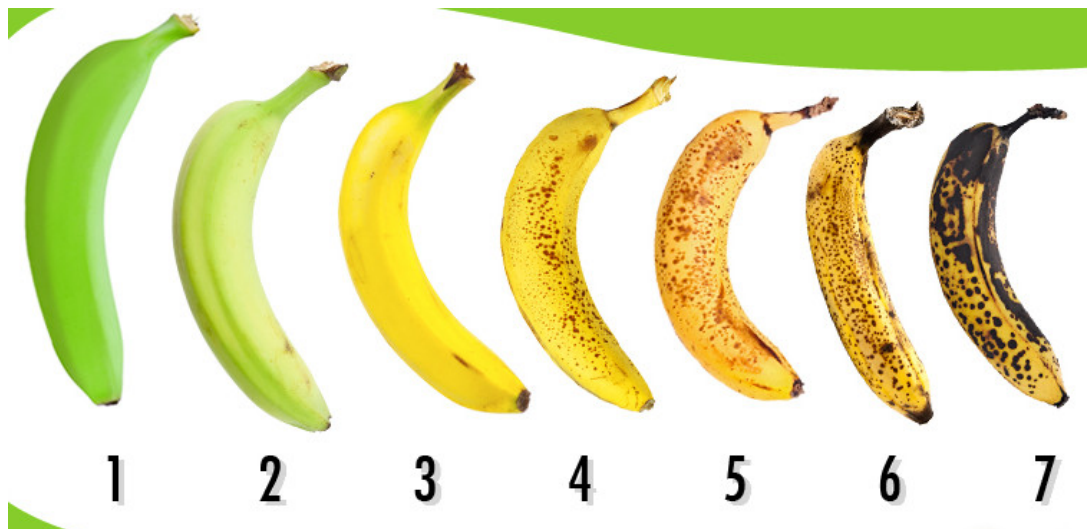


Figure 3. Banana ripeness scale (Retrieved from L.Mcbride via davidwolfe.com)

Results

After conducting a two-way ANOVA test on our data (N=18), the results showed the difference was statistically significant for the column factor ($F(5,24) = 11.94, p < 0.0001$).

The column factor compared the mean percent cover of brownness between the different storage areas. The ANOVA test also showed there no significant difference found for the row factor ($F(1, 24) = 0.06315, p = 0.8037$). The row factor compared the mean percent cover of brownness between the two times of measurements, at 11 AM in the morning and 11 PM at night.

The ANOVA results for percent cover of brownness on the 12th day of monitoring the bananas in each location at 11 AM and 11 PM at the average temperature are shown in Figure 7. We also measured the mean percent cover of brownness for each location at 11 AM and 11 PM. The mean percent cover did not change in the garage (2%) and in the ziplock (1.67%), but the counter had a very small increase from 21.67% to 21.76% between 11am and 11pm. The location with the largest difference in mean between the 12 hour period was the fridge as it increased from 43.33% to 46.33%. The broiler room also had an increase in mean percentage but not as much as the fridge as it went from 61.67% to 62.76%. Error bars represent the standard deviation of the means. The Tukey Test (post-hoc test) determined the six specific groups which had a significant difference ($p < 0.05$): the counter & broiler, fridge & garage, fridge & ziplock, broiler & oven, garage & broiler, ziplock & broiler. All other comparison wise treatments were found to not be significant ($p > 0.05$).

During the course of the experiment and at the end of the 12 day period, the broiler room had the highest percent cover of brownness as seen in Figure 5. On the other hand, the bananas placed in the ziplock bags with a restricted amount of air flow had the least amount of percent cover of brownness as seen in Figure 6. As shown in Figure 7, the bananas placed in the refrigerator at the coldest temperature of 4°C did not ripen however the bananas in the fridge appeared to have the second most highest percent cover of browning. Other warmer places with abundant airflow such as the oven, kitchen counter had increased ripening.

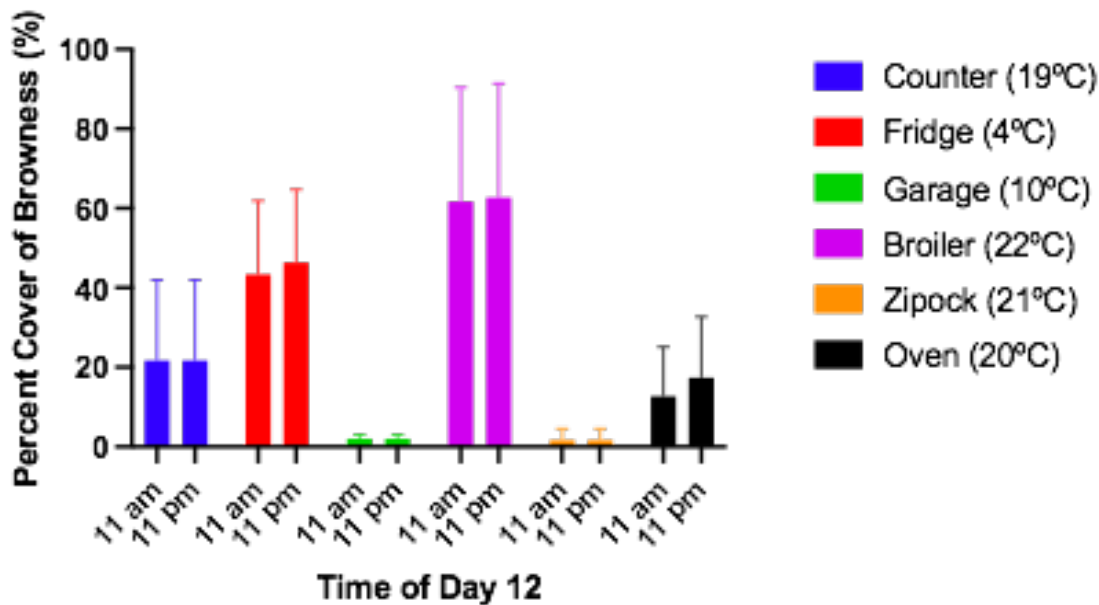


Figure 5. Percent cover brownness on the 12th day of monitoring the bananas in each location at 11 am and 11pm at the average temperature. N=3 for each site, with the total N=18. The calculated p-value < 0.0001 between groups and p=0.8037 between the two times. Error bars indicate standard deviation. Taking the results of the experiment, two-way ANOVA analysis ($\alpha = 0.05$, 95% CI) was performed using Graphpad Prism V.90 which showed that the average percent changes in temperature between the 6 different locations are statistically different ($df_{\text{freedom}}=5$, $df_{\text{residual}}=24$, F= 11.94) A Tukey Test was performed to determine the significance between groups and found that the 6 groups were significant. The mean differences in temperature for the comparisons that were significant were found to be: -40.50 (Counter 19°C vs Broiler 22°C), 42.83 (Fridge 4°C vs Garage 10°C), 43.17 (Fridge 4°C vs Ziplock 21°C), -60.17 (Garage 10°C vs Broiler 22°C), 60.50 (Broiler 22°C vs Ziplock 21°C), 41.7 (Broiler 22°C vs Oven 20°C). The data was normal and did not require any transformations since the assumptions for ANOVA were met.



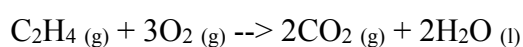
Figure 5. Broiler room (N=3) **Figure 6.** Ziplock bags(N=3) **Figure 7.** Refrigerator (N=3)

Discussion

Our purpose of the study was to see how different areas in our home and their associating temperatures affect the ripeness of bananas. After conducting the two-way ANOVA, we found that the results are statistically significant between groups ($p < 0.0001$), thus we reject the null hypothesis that there are no differences in percent cover of brownness in the varying locations. We accept the alternative hypothesis and can conclude bananas kept in warmer places with abundant airflow, will ripen faster and have a higher percent cover of brownness than the bananas kept in cooler and restricted airflow places. However, the ANOVA test showed no significant difference in percent cover of brownness between the two times of measurements of 11 AM and 11 PM ($p = 0.8037$).

After running the Tukey Test (post-hoc test), we see that the comparisons between the locations that are statistically significant include the counter & broiler, fridge & garage, fridge & ziplock, broiler & oven, garage & broiler, ziplock & broiler. The last two groups (garage & broiler and ziplock & broiler) reveal the most significance. The remaining comparisons were not statistically significant since the p value is greater than 0.05. Bananas that were stored in the warmest area, which was the broiler at 22°C, had the greatest percent cover of brownness, which is consistent with our hypothesis.

Bananas release ethylene (C₂H₄) which is a colorless gas, and it causes bananas to ripen as it is linked with respiration of bananas (Burg et al.). Ethylene reacts with oxygen in the air to form carbon dioxide and water (Burg et al.), which is why airflow speeds up the ripening process, as shown below.



Ethylene stays constant throughout the growth of the banana up until the banana starts to ripe which is when there is an abrupt increase in ethylene synthesis, causing an increase in

banana ripening (Burg et al.). Thus, in areas with restricted amounts of air flow, such as the ziplock bags, there is not enough O₂ to react with ethylene to cause ripening.

Overall, the ziplock had the least amount of browning as two out of the three banana replicates had zero percent browning over the twelve-day period. The ziplock location had extremely restricted airflow, while the refrigerator and the oven had some restrictive airflow. Since the ziplock was completely sealed for a long period of time, one of the replicants started to mold. This mold formed due to the large amount of ethylene trapped in the ziplock causes the banana to ripen itself all the way to rot (Hogeback). The oven also had a small amount of browning on two of its replicants and a similar average temperature that the ziplock was exposed too. These two have ripened very slowly with minimal brownness observed compared to the fridge. The fridge bananas were exposed to a cold temperature of 4°C and restrictive airflow, even though the fridge was opened quite frequently through the day. The fridge bananas remained unripe throughout the entire 12-day period at the banana ripeness scale number 2 but still had a lot of brownness all over. This is due to the cold temperature of the fridge which stops and drastically slows down the ripening process, due to the slow conversion of starch into sugars (Hiskey). The peel resembles rotting of the outer peel because of the polyphenol oxidase enzyme in the bananas (Hiskey). The cold temperature had the biggest toll on the ripening but the restrictive airflow also managed to slow the ripening process.

In our study we focused on the percent brownness on the banana peel to evaluate the ripeness of the banana; however, ripening is also associated with other factors like the loss in firmness of the pulp, increase in total soluble solid contents of the pulp, and the color of the peel (Smith and Thompson 43). Since we used the amount of percent cover of brownness for our statistical analysis and did not take into account the colour of the peel other than

brownness, our hypothesis of bananas ripening faster in warmer and less airflow restricted places was not fully supported. Specifically, the bananas that were kept in the refrigerator at 4°C had the second most amount of percent cover but the peel stayed green. In the refrigerator, the airflow was fairly restricted and decreased the rate of ripening. Thus, the bananas seemed to be ripening at this low temperature faster than ones at warmer temperatures, which was against our hypothesis. However, percent cover of brownness is not the only factor that indicates ripeness, so for next time we should take into account the firmness to see if the bananas are truly ripe. On the contrary, if initial ripening temperatures are too high (> 25 °C), the fruit develops a soft, ripe pulp while the skin colour is only greenish yellow (Abdallah 15). This further justifies that we should have studied additional factors, such as firmness, because the color of the peel can be a misleading factor to determine ripeness. Other possible errors could be that temperature is not always constant throughout the day and it could have fluctuated between the times we checked. We only took data at 11AM and 11PM, however, there is a large window of time where temperature could potentially change. In future studies the time and temperature should also be monitored more frequently, which maybe could have shown that other groups were also significant.

Conclusion

Overall, our study showed that if bananas are kept in warmer places with abundant airflow then they will ripen faster. However, our hypothesis was not entirely correct as some warm areas did not have a higher percent cover of brownness than the bananas kept in the fridge with a cooler temperature and restricted airflow. The two-way ANOVA test showed the difference was statistically significant between groups ($p < 0.0001$), meaning that

temperature and airflow do affect percent cover of brownness on bananas. Time of measurements (morning vs night) had no significance ($p = 0.8037$). The Tukey Test (post-hoc test) determined the six specific groups which differed: the counter & broiler, fridge & garage, fridge & ziplock, broiler & oven, garage & broiler, ziplock & broiler. In the end, we determined that the best storage area to preserve bananas the longest would be the garage as it has an ideal temperature of 10°C and abundant amounts of air flow.

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Appendix

Raw Data for each day of the experiment:

Day 1

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 20th					
11:00 AM 11:00 PM	Counter #1	0% 0%	2 2	15 °C	No brownness was observed
11:00 AM 11:00 PM	Counter #2	0% 0%	2 2	15 °C	No brownness was observed
11:00 AM 11:00 PM	Counter #3	0% 0%	2 2	15 °C	No brownness was observed
11:00 AM 11:00 PM	Fridge #1	0% 0%	1 1	4°C 4°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Fridge #2	0% 0%	1 1	4°C 4°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Fridge #3	0% 0%	1 1	4°C 4°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Garage #1	0% 0%	1 1	11°C 11°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Garage #2	0% 0%	1 1	11°C 11°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Garage #3	0% 0%	1 1	11°C 11°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Broiler #1	0% 0%	1 1	22°C 21°C	Green with a slight yellow strip at tops. Stem facing right. Large in size.

11:00 AM 11:00 PM	Broiler #2	0% 0%	1 1	22°C 21°C	Green with a slight yellow strip at tops. Stem facing right. Large in size
11:00 AM 11:00 PM	Broiler #3	0% 0%	1 1	22°C 21°C	Green with a slight yellow strip at tops. Stem facing right. Large in size
11:00 AM 11:00 PM	Ziplock #1	0% 0%	1 1	17°C 15°C	Eveningly green. Stem facing right. Large in size
11:00 AM 11:00 PM	Ziplock #2	0% 0%	1 1	17°C 15°C	Eveningly green. Stem facing right. Large in size
11:00 AM 11:00 PM	Ziplock #3	0% 0%	1 1	17°C 15°C	Eveningly green. Stem facing right. Large in size
11:00 AM 11:00 PM	Oven #1	0% 0%	1 1	17°C 18°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Oven #2	0% 0%	1 1	17°C 18°C	Green with very slight yellow Stem Facing right Large in size
11:00 AM 11:00 PM	Oven #3	0% 0%	1 1	17°C 18°C	Green with very slight yellow Stem Facing right Large in size

Day 2

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 21st					
11:00 AM 11:00 PM	Counter #1	0% 0%	2.5 2.5	13 °C 13°C	No brownness was observed Slightly more yellow
11:00 AM 11:00 PM	Counter #2	0% 0%	2.5 2.5	13 °C 13°C	No brownness was observed Slightly more yellow
11:00 AM 11:00 PM	Counter #3	0% 0%	2.5 2.5	13 °C 13°C	No brownness was observed Slightly more yellow

11:00 AM 11:00 PM	Fridge #1	0% 0%	1 1	4°C 4°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Fridge #2	0% 0%	1 1	4°C 4°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Fridge #3	0% 0%	1 1	4°C 4°C	Mainly green with little bit of yellow in centre No brownness was observed
11:00 AM 11:00 PM	Garage #1	0% 0%	1 1	9°C 8°C	Mainly green with little bit of yellow in centre No brownness was observed
11:00 AM 11:00 PM	Garage #2	0% 0%	1 1	9°C 8°C	Mainly green with little bit of yellow in centre No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	1 1	9°C 8°C	Mainly green with little bit of yellow in centre No brownness was observed
11:00 AM 11:00 PM	Broiler #1	0% 0%	2 2	22°C 21°C	More yellow along the middle, stems and edges are still green.
11:00 AM 11:00 PM	Broiler #2	0% 0%	2 2	22°C 21°C	Slightly more yellow along the middle, stems and edges are still green.
11:00 AM 11:00 PM	Broiler #3	0% 0%	2 2	22°C 21°C	Slightly more yellow along the middle, stems and edges are still green.
11:00 AM 11:00 PM	Ziplock #1	0% 0%	1.5 1.5	18°C 17°C	Slightly more yellow along the middle
11:00 AM 11:00 PM	Ziplock #2	0% 0%	1.5 1.5	18°C 17°C	M: Slightly more yellow along the middle
11:00 AM 11:00 PM	Ziplock #3	0% 0%	1.5 1.5	18°C 17°C	M: Slightly more yellow along the middle
11:00 AM 11:00 PM	Oven #1	0% 0%	1 1	19°C 18°C	Still green with slight yellow No brownness was observed

11:00 AM 11:00 PM	Oven #2	0% 0%	1 1.5	19°C 18°C	Green with slight yellow
11:00 AM 11:00 PM	Oven #3	0% 0%	1.5 2	19°C 18°C	Mainly yellow with slight green

Day 3

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 22nd					
11:00 AM 11:00 PM	Counter #1	0% 0%	2.5 2.5	16 19	Slightly more yellow, especially around the middle
11:00 AM 11:00 PM	Counter #2	0% 0%	2.5 2.5	16 19	Slightly more yellow, no brownness observed
11:00 AM 11:00 PM	Counter #3	0% 0%	2.5 2.5	16 19	No brownness observed
11:00 AM 11:00 PM	Fridge #1	0% 0%	2 2	4°C 4°C	Green
11:00 AM 11:00 PM	Fridge #2	0% 0%	2 2	4°C 4°C	Green
11:00 AM 11:00 PM	Fridge #3	3% 7%	2 2	4°C 4°C	Green but starting to brown
11:00 AM 11:00 PM	Garage #1	0% 0%	2 2	13°C 11°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #2	0% 0%	2 2	13°C 11°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	2 2	13°C 11°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	0% 0%	2.5 2.5	22°C 21°C	M: Slight more yellow along the middle
11:00 AM 11:00 PM	Broiler #2	0% 0%	2.5 2.5	22°C 21°C	M: Slightly more yellow along the middle
11:00 AM 11:00 PM	Broiler #3	0% 0%	2.5 2.5	22°C 21°C	M: Slightly more yellow along the middle, stems and edges are still green.

11:00 AM 11:00 PM	Ziplock #1	0% 0%	1.5 1.5	19°C 17°C	M: Slightly more yellow in patches
11:00 AM 11:00 PM	Ziplock #2	0% 0%	1.5 1.5	19°C 17°C	M: Slightly more yellow
11:00 AM 11:00 PM	Ziplock #3	0% 0%	1.5 1.5	19°C 17°C	M: Slightly more yellow
11:00 AM 11:00 PM	Oven #1	0% 0%	1.5 1.5	19°C 20°C	Green with slight yellow
11:00 AM 11:00 PM	Oven #2	0% 0%	2 2	19°C 20°C	Green with slight yellow
11:00 AM 11:00 PM	Oven #3	0% 0%	2 2.5	19°C 20°C	Mainly yellow with slight green More yellow since morning

Day 4

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 23rd					
11:00 AM 11:00 PM	Counter #1	0%	2.5 2.5	16 19	Slightly more yellow all- around, the top and bottom are still green, and no brownness observed
11:00 AM 11:00 PM	Counter #2	0%	2.5 2.5	16 19	Slightly more yellow, edges are still green, and no brownness observed
11:00 AM 11:00 PM	Counter #3	0%	2.5	16 19	Slightly more yellow, no brownness observed
11:00 AM 11:00 PM	Fridge #1	0% 2%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #2	4% 7%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	12% 17%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Garage #1	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed

11:00 AM 11:00 PM	Garage #2	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	0% 0%	3 3	21°C 21°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Broiler #2	0% 0%	3 3	21°C 21°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Broiler #3	0% 0%	3 3	21°C 21°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #1	0% 0%	2.5 2.5	20°C 18°C	M: Most green patches have turned yellow
11:00 AM 11:00 PM	Ziplock #2	0% 0%	2.5 2.5	20°C 18°C	Most green patches have turned yellow
11:00 AM 11:00 PM	Ziplock #3	0% 0%	2.5 2.5	20°C 18°C	Most green patches have turned yellow
11:00 AM 11:00 PM	Oven #1	0% 0%	2 2.5	20°C 19°C	Yellow with slight green
11:00 AM 11:00 PM	Oven #2	0% 0%	2 2.5	20°C 19°C	Yellow with slight green
11:00 AM 11:00 PM	Oven #3	0% 0%	3 3	20°C 19°C	Mainly yellow

Day 5

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 24th					
11:00 AM 11:00 PM	Counter #1	1% 1%	3 3	18°C 14°C	Yellow but small dots brown starting to appear
11:00 AM 11:00 PM	Counter #2	1% 1%	3 3	18°C 14°C	Yellow but tiny small dots starting to appear
11:00 AM 11:00 PM	Counter #3	0% 0%	3 3	19°C 12°C	Yellow all over, no brownness
11:00 AM 11:00 PM	Fridge #1	1% 3%	2 2	4°C 4°C	Green but starting to brown all over

11:00 AM 11:00 PM	Fridge #2	10% 12%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	24% 28%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Garage #1	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #2	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	0% 5%	3 3.25	21°C 21°C	Appearance of very small brown speckles/striations
11:00 AM 11:00 PM	Broiler #2	0% 10%	3 3.25	21°C 21°C	Appearance of very small slight brown speckles/striations
11:00 AM 11:00 PM	Broiler #3	0% 5%	3 3.25	21°C 21°C	Appearance of slight brown speckles/striations
11:00 AM 11:00 PM	Ziplock #1	0% 0%	3 3	19°C 18°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #2	0% 0%	3 3	19°C 18°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3 3	19°C 18°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Oven #1	0% 0%	2.5	20°C 19°C	Yellow with slight green
11:00 AM 11:00 PM	Oven #2	0% 0%	2.5 2.5	20°C 19°C	Yellow with slight green
11:00 AM 11:00 PM	Oven #3	0% 0%	3 3	20°C 19°C	Mainly yellow

Day 6

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 25th					
11:00 AM 11:00 PM	Counter #1	1% 1%	3 3	20°C 18°C	The banana is a bright yellow, with no brownness. There are small brown dots.

11:00 AM 11:00 PM	Counter #2	1% 1%	3 3	20°C 18°C	The banana is yellow, no brownness. The stem is still a faded green. There are small brown dots
11:00 AM 11:00 PM	Counter #3	0%	3 3	20°C 18°C	The banana is a bright yellow, there does not appear to be any brownness.
11:00 AM 11:00 PM	Fridge #1	5% 6%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #2	15% 18%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	33% 35%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Garage #1	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #2	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	2 2	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	0% 5%	3 3.25	21°C 21°C	Appearance of very small brown speckles/striations
11:00 AM 11:00 PM	Broiler #2	0% 10%	3 3.25	21°C 21°C	Appearance of very small slight brown speckles/striations
11:00 AM 11:00 PM	Broiler #3	0% 5%	3 3.25	21°C 21°C	Appearance of slight brown speckles/striations
11:00 AM 11:00 PM	Ziplock #1	0% 0%	3 3	19°C 19°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #2	0% 0%	3 3	19°C 19°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3 3	19°C 19°C	Fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Oven #1	0% 0%	2 2.5	20°C 19°C	Yellow
11:00 AM 11:00 PM	Oven #2	0% 0%	2 2.5	20°C 19°C	Yellow

11:00 AM 11:00 PM	Oven #3	0% 0%	3 3	20°C 19°C	Bright yellow
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Day 7

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 26th					
11:00 AM 11:00 PM	Counter #1	1% 1%	3	18°C 15°C	The banana is yellow, with no brownness.
11:00 AM 11:00 PM	Counter #2	1% 1%	3	18°C 15°C	The banana is yellow, no brownness.
11:00 AM 11:00 PM	Counter #3	0% 0%	3	18°C 15°C	The banana is yellow with no brownness.
11:00 AM 11:00 PM	Fridge #1	7% 10%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #2	19% 20%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	37% 40%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Garage #1	0% 0%	2 2.5	11°C 10°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #2	0% 0%	2 2.5	11°C 10°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	2 2.5	11°C 10°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	12%	4 4	22°C 21°C	A lot of brown speckles/ striations One large fully brown circle
11:00 AM 11:00 PM	Broiler #2	33%	4.25 4.5	22°C 21°C	A lot of brown speckles/ striations
11:00 AM 11:00 PM	Broiler #3	10%	4 4	22°C 21°C	A lot of brown speckles/ striations
11:00 AM 11:00 PM	Ziplock #1	0% 0%	3 3	18°C 16°C	Almost fully yellow on front and wrapping around sides

11:00 AM 11:00 PM	Ziplock #2	0% 0%	3 3	18°C 16°C	Almost fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3 3	18°C 16°C	Almost fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Oven #1	0% 0%	2.5 3	20°C 19°C	Yellow
11:00 AM 11:00 PM	Oven #2	0% 0%	2.5 3	20°C 19°C	Yellow
11:00 AM 11:00 PM	Oven #3	2% 4%	3.5 3.5	20°C 19°C	yellow with some brown speckles

Day 8

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 27th					
11:00 AM 11:00 PM	Counter #1	1% 1%	3 3	19°C 10°C	Very tiny brown spots started to appear, no significant browning. Banana is still yellow.
11:00 AM 11:00 PM	Counter #2	3% 3%	3 3	19°C 10°C	Very tiny brown spots started to appear, the banana is still yellow.
11:00 AM 11:00 PM	Counter #3	0% 0%	3 3	19°C 8°C	The banana is yellow, has some brown bruises, but no significant browning.
11:00 AM 11:00 PM	Fridge #1	12% 15%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #2	21% 23%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	41% 42%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Garage #1	0% 0%	2.5 2.5	10°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Garage #2	0% 0%	2.5 2.5	11°C 9°C	Slightly more yellow No brownness was observed

11:00 AM 11:00 PM	Garage #3	0% 0%	2.5 2.5	11°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	27%	4.25 4.25	11°C 9°C	A lot of brown speckles/ striations One large fully brown circle
11:00 AM 11:00 PM	Broiler #2	41%	4.5 4.5	22°C 21°C	A lot of brown speckles/ striations
11:00 AM 11:00 PM	Broiler #3	12%	4 4	22°C 21°C	A lot of brown speckles/ striations
11:00 AM 11:00 PM	Ziplock #1	0% 0%	3 3	17°C 16°C	Almost fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #2	0% 0%	3 3	17°C 16°C	Almost fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3 3	17°C 16°C	Almost fully yellow on front and wrapping around sides
11:00 AM 11:00 PM	Oven #1	0% 0%	3 3	20°C 19°C	Yellow
11:00 AM 11:00 PM	Oven #2	0% 0%	3 3	20°C 19°C	Yellow
11:00 AM 11:00 PM	Oven #3	6% 7%	3.5 3.5	20°C 19°C	yellow with some brown speckles

Day 9

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 28th					
11:00 AM 11:00 PM	Counter #1	4% 4%	3.5 3.5	16°C 14°C	Tiny specks of brown dots are starting to appear. The banana is golden yellow.
11:00 AM 11:00 PM	Counter #2	4% 4%	3.5 3.5	16°C 14°C	Tiny specks of brown dots are starting to appear. The banana is golden yellow.
11:00 AM 11:00 PM	Counter #3	2% 2%	3.5 3.5	17°C 14°C	The banana is golden yellow. The bruising on the banana is getting darker.

11:00 AM 11:00 PM	Fridge #1	17% 19%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #2	25% 28%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	44% 46%	2 2	4°C 4°C	Green but brown all over
11:00 AM 11:00 PM	Garage #1	0% 0%	3 3	11°C 9°C	No brownness was observed
11:00 AM 11:00 PM	Garage #2	0% 0%	3 3	11°C 9°C	No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	3 3	11°C 9°C	No brownness was observed
11:00 AM 11:00 PM	Broiler #1	35%	4.5 4.5	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #2	74%	5 5	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #3	22%	4 4	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Ziplock #1	0% 0%	3.75 3.75	17°C 16°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Ziplock #2	0% 0%	3.75 3.75	17°C 16°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3.75 3.75	17°C 16°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Oven #1	0% 0%	3 3	20°C 19°C	Yellow
11:00 AM 11:00 PM	Oven #2	0% 0%	3 3	20°C 19°C	Yellow
11:00 AM 11:00 PM	Oven #3	8% 8%	3.5 3.5	20°C 19°C	yellow with some brown speckles

Day 10

Date and Time of morning/night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 29th					
11:00 AM 11:00 PM	Counter #1	8%	3.75 3.75	19°C 19°C	Small dots of brown are starting to appear, there is also dark brown bruising on the edges of the banana. The banana feels much softer.
11:00 AM 11:00 PM	Counter #2	4%	3.75 3.75	19°C 19°C	Small dots of brown are appearing on the banana, the bruising is dark brown on the edges. The banana also feels softer.
11:00 AM 11:00 PM	Counter #3	15%	4 4	19°C 19°C	Small dots of brown are appearing everywhere, and big batches of browning.
11:00 AM 11:00 PM	Fridge #1	20% 21%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #2	29% 30%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	48% 50%	2 2	4°C 4°C	Green but brown all over
11:00 AM 11:00 PM	Garage #1	0% 1%	3 3	10°C 10°C	Very small amount of brownness
11:00 AM 11:00 PM	Garage #2	0% 0%	3 3	10°C 10°C	No brownness was observed
11:00 AM 11:00 PM	Garage #3	0% 0%	3 3	10°C 10°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	48%	6.5 6.5	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #2	80%	6 6.5	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #3	25%	6 6	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size

11:00 AM 11:00 PM	Ziplock #1	0% 0%	3.75 3.75	18°C 19°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Ziplock #2	0% 0%	3.75 3.75	18°C 19°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3.75 3.75	18°C 19°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Oven #1	1% 2%	3 3	20°C 19°C	Yellow, speckles starting to appear
11:00 AM 11:00 PM	Oven #2	0% 1%	3 3	20°C 19°C	Yellow, speckles starting to appear
11:00 AM 11:00 PM	Oven #3	9% 10%	3.5 3.5	20°C 19°C	yellow with some brown speckles

Day 11

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 30th					
11:00 AM 11:00 PM	Counter #1	10% 10%	3.75 3.75	18°C 18°C	Small dots of brown are starting to appear, there is also dark brown bruising on edges
11:00 AM 11:00 PM	Counter #2	6% 6%	3.50 3.50	18°C 18°C	Yellow with brown spots. The bruising on the banana is really brown, in certain spots.
11:00 AM 11:00 PM	Counter #3	25% 25%	4 4	18°C 18°C	Yellow with large brown bruises.
11:00 AM 11:00 PM	Fridge #1	24% 27%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #2	32% 36%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	55% 60%	2 2	4°C 4°C	Green but brown all over
11:00 AM 11:00 PM	Garage #1	1% 2%	3 3	10°C 9°C	Very small amount of brownness
11:00 AM 11:00 PM	Garage #2	1% 1%	3 3	10°C 9°C	Very small amount of brownness

11:00 AM 11:00 PM	Garage #3	0% 0%	3 3	10°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	56%	7 7	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #2	85%	6.75 6.75	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #3	30%	6 6	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Ziplock #1	0% 0%	3.75 3.75	20°C 21°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Ziplock #2	0% 3%	3.75 3.75	20°C 21°C	Fully yellow and very slight brown shading Mold growing on bottom end
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3.75 3.75	20°C 21°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Oven #1	2% 3%	3 3	19°C 21°C	Yellow. Little specks of brown
11:00 AM 11:00 PM	Oven #2	3% 4%	3 3	19°C 21°C	Yellow, little specks of brown
11:00 AM 11:00 PM	Oven #3	16% 20%	3.5 3.5	19°C 21°C	Yellow, a lot more speckles

Day 12

Date and Time of morning/ night	Type	Percent Cover of Brownness	Banana scale number	Temperature	Observations
March 31st					
11:00 AM 11:00 PM	Counter #1	12% 12%	3.80 3.80	20°C 19°C	Yellow with brown speckles and bruising
11:00 AM 11:00 PM	Counter #2	8% 8%	3.60 3.60	20°C 19°C	Yellow with a lot more bruising in multiple spots.
11:00 AM 11:00 PM	Counter #3	45% 45%	4 4	20°C 19°C	Yellow with large brown spots all over one side
11:00 AM 11:00 PM	Fridge #1	28% 32%	2 2	4°C 4°C	Green but starting to brown all over

11:00 AM 11:00 PM	Fridge #2	38% 40%	2 2	4°C 4°C	Green but starting to brown all over
11:00 AM 11:00 PM	Fridge #3	64% 67%	2 2	4°C 4°C	Green but brown all over
11:00 AM 11:00 PM	Garage #1	3% 3%	3 3	10°C 9°C	Very small amount of brownness
11:00 AM 11:00 PM	Garage #2	2% 2%	3 3	10°C 9°C	Very small amount of brownness
11:00 AM 11:00 PM	Garage #3	1% 1%	3 3	10°C 9°C	Slightly more yellow No brownness was observed
11:00 AM 11:00 PM	Broiler #1	66% 67%	7 7	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #2	88% 89%	7 7	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Broiler #3	31% 32%	6 6	22°C 21°C	A lot of brown speckles/ striations Brown spots increasing in size
11:00 AM 11:00 PM	Ziplock #1	0% 0%	3.75 3.75	21°C 21°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Ziplock #2	5% 5%	3.75 3.75	21°C 21°C	Fully yellow and slight brown shading Mold growing on bottom end: is brown/white fuzz
11:00 AM 11:00 PM	Ziplock #3	0% 0%	3.75 3.75	21°C 21°C	Fully yellow and very slight brown shading
11:00 AM 11:00 PM	Oven #1	5% 7%	3 3	20°C 21°C	Yellow. Little specks of brown
11:00 AM 11:00 PM	Oven #2	6% 10%	3 3	20°C 21°C	Yellow, little specks of brown
11:00 AM 11:00 PM	Oven #3	27% 35%	3.5 3.5	20°C 21°C	Yellow, a lot more speckles