The Effect of Temperature on Banana Ripening and Ethylene Concentration

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Abstract

Bananas are a climacteric fruit, so once they are harvested, they enter a “climate phase” where they continue to ripen. Many people can also attest to purchasing green bananas at the supermarket, and waiting for it to ripen over time so it becomes sweet enough to consume. From this universally shared experience, the ripening of the bananas was studied to see temperature as a controllable measure, by adding three banana replicates in three different temperature conditions, of 4ºC, 25ºC, and 40ºC for 5 days. The bananas were monitored and observations were recorded once a day over the duration of the experiment with visual ripeness and mass documentations. Other environmental conditions were controlled by wrapping and storing each banana in plastic wrap to minimise ripening prior to the experiment, and keeping the bananas in incubators of constant temperatures. It was found that bananas at 25ºC were qualitatively closest to the ideal “ripe” yellow colour and bananas at 40ºC had the greatest decrease in weight (ie. released the most amount of ethylene gas) by the end of the 5 days.

Introduction

The *Musa acuminata*, also known as the common banana, is one of the most consumed fruits in the world. An estimated 120 million tons of bananas were produced in 2021 globally, being one of the most produced fruits in the global fruit market (Markets and Trade 2023). The task of banana transportation from the hot climate where it is grown to the neighbourhood grocery store is a monumental task (Markets and Trade 2023). Food transporters across the globe aim to transport fresh picked bananas to stores at the exact moment of ripeness. One of the primary determinants for banana ripeness is ethylene gas. Ethylene gas is a plant hormone that is produced as the fruit ripens (Iqbal et al., 2017).

To provide some insight into the task of banana transportation, we want to analyse how temperature affects banana ripening and ethylene concentrations. Fruit ripening is closely linked to ethylene, which is a phytohormone that can trigger the fruit to initiate ripening (Maduwanthi et. al, 2019). We aim to use a colour scale to determine the most optimal banana appearance. We deemed this to be "C5", from Figure 1(Gomez et al., 2013). We hypothesized that if the bananas are stored at a higher temperature (ie. 40ºC), they will be the ripest at the end of 5 days, containing the least ethylene gas concentration.

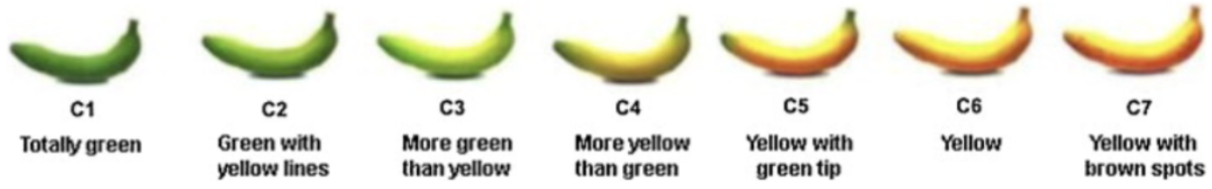

Figure 1*. Colour scale used as a reference to compare ripeness of our bananas. C5 is considered to be a perfectly ripe banana. (Gomez, et. al, 2013)*

Methods

Nine bananas were bought from a grocery store called No Frills located in Vancouver. 7 of the bananas were connected by the stem coming from one bunch, while the other two bananas were retrieved from a separate bunch of bananas. At the time of purchase, each banana was totally green and can identically be ranked as C1 using the colorimetric indicator in Figure 1. Bananas were spaced evenly (roughly 25 cm) apart on a desk at room temperature. Each banana was also separately and completely wrapped in plastic wrap, as this reduces ethylene gas release from bananas which can accelerate the ripening process (Choehom et al., 2004). Bananas were left on the desk for 24 hours prior to being brought to the lab.

At the lab, bananas were randomly labelled on the peel by their treatment (4°C, 25°C, or 40°C) and banana number (#1, #2, or #3) using a pen. Separate photos of each labelled banana were then taken. Additionally, each banana was separately recorded for their weight and photographed on the scale. Qualitative observations were also taken prior to treatment. Then, 3 bananas were placed in the fridge at 4°C, another 3 bananas were placed in an incubator set at 25°C, and the remaining 3 bananas were placed in an incubator set at 40°C.

For the following 4 days of the experiment, each of the four members of the experiment took turns to come into the lab and record observations. For each of the four days, bananas were taken out of the incubator or fridge. Each banana was then photographed (on the table and scale), as well as weighed and recorded for their weight. Additionally, observations regarding their

degree of ripeness, browning, weight change, and overall appearance was recorded for each day. Bananas were then placed back into their corresponding treatment (incubator or fridge).

Results

After careful monitoring of our nine bananas in three different environments, we were able to collect our data from taking pictures and monitoring the colour scale, weighing the bananas, and recording any different textures of the bananas. The most interesting finding we had was the three bananas kept in each temperature roughly had the same amount of weight loss. The bananas kept in the fridge of 4ºC, had respectively a weight loss of 5.0g, 4.8g, and 9.8g. The bananas in the 25ºC incubator had respectively 23.7g, 21.3g, and 22g weight loss. The 40ºC incubator bananas had a higher discrepancy, of 50.9g, 55.5g, and 55.8g loss in weight.

On the last day, the bananas kept in the fridge were still firm and green, with a lot of new brown lines and specks. However, the bananas were going from a green-ish colour to brownish, with barely any yellow shown. From the colour scale, we concluded the final stages were at "C2".

The bananas in the 25ºC incubator were very slightly green but mostly yellow. It had a few scratches but the least brown specks compared to the other temperatures, however, these bananas had the least amount of scratches in the beginning. We can conclude from the colour scale, the final stages were at "C4" with some brown spots.

The bananas in 40ºC incubators were very soft and mushy upon picking them up. It also looked much smaller than the other bananas, which explains why these bananas had the largest discrepancy when weighing. The stems were completely black, and the banana itself had lots of brown and black spots. It still looked quite green rather than yellow, but seemed to turn brown very quickly. From the colour scale, we concluded the final stages were at “C3” with a lot of additional brown spots and stripes.

Table 1.1 Summarizes the mean weight discrepancies using 3 bananas (ie. replicates) for each of the 3 temperatures (4ºC, 25ºC, and 40ºC)

	4ºC	25ºC	40ºC
Mean weight discrepancy	6.4 g	22.3 g	54.1 g

Table 1.2 Raw collected data that summarizes the weights of each of the 3 bananas for each temperature, and the weight discrepancies for the 5-day experimental period.

Temperature:	Fridge (4)	25	40
Day 1	**Initial mass:**	**Initial mass:**	**Initial mass:**
Banana #1	221.9g	195.1g	172.8g
Banana #2	175.7g	200.1g	197.9g
Banana #3	195.7g	180.8g	215.9g
Day 2 Jihee			
Banana #1	220.5g	188.3g	157.8g
Banana #2	174.4g	193.9g	181.9g
Banana #3	192.4g	174.5g	199.5g
Day 3 Orissa			
Banana #1	219.3g	182.3g	145.1g
Banana #2	173.2g	188.7g	167.9g
Banana #3	190.1g	169.0g	185.5g
Day 4 May			
Banana #1	218.1g	176.5g	133.0g
Banana #2	171.9g	183.4g	154.1g
Banana #3	187.8g	163.6g	152.9g
Day 5 Michelle	**Final mass:**	**Final mass:**	**Final mass:**
Banana #1	216.9	171.4	121.9
Banana #2	170.9	178.8	142.4
Banana #3	185.9	158.8	160.1
Weight Discrepancies			
Banana #1	5g	23.7g	50.9
Banana #2	4.8g	21.3g	55.5
Banana #3	9.8g	22g	55.8

This is the chart we used to keep track of the weight of each banana every single day for 5 days. At the end of Day 5, we were able to calculate the total difference of weight from Day 1 to Day 5 that we can attribute to ethylene concentration.

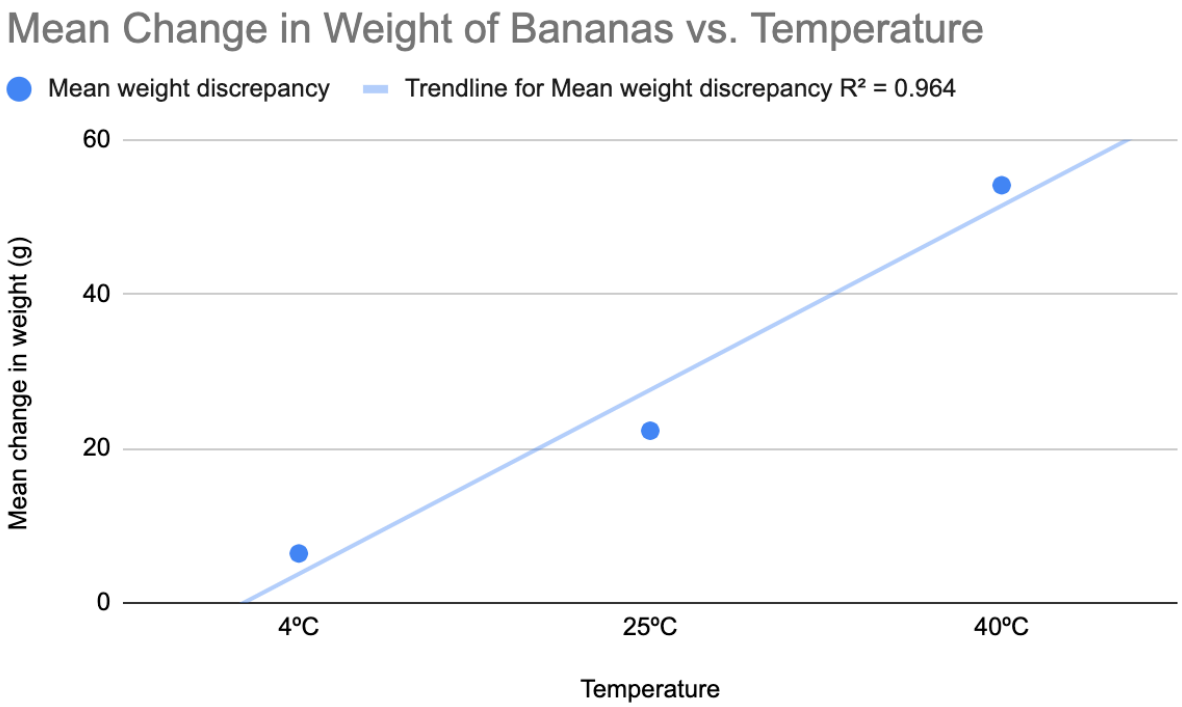

Figure 2. Mean changes in weight versus temperature. The graph displays the relationship between temperature (ºC) and mean change in weight (g). Mean values were calculated using three bananas (ie. replicates) for each temperature. A trendline of best fit is shown with the R^2 value being 0.964.

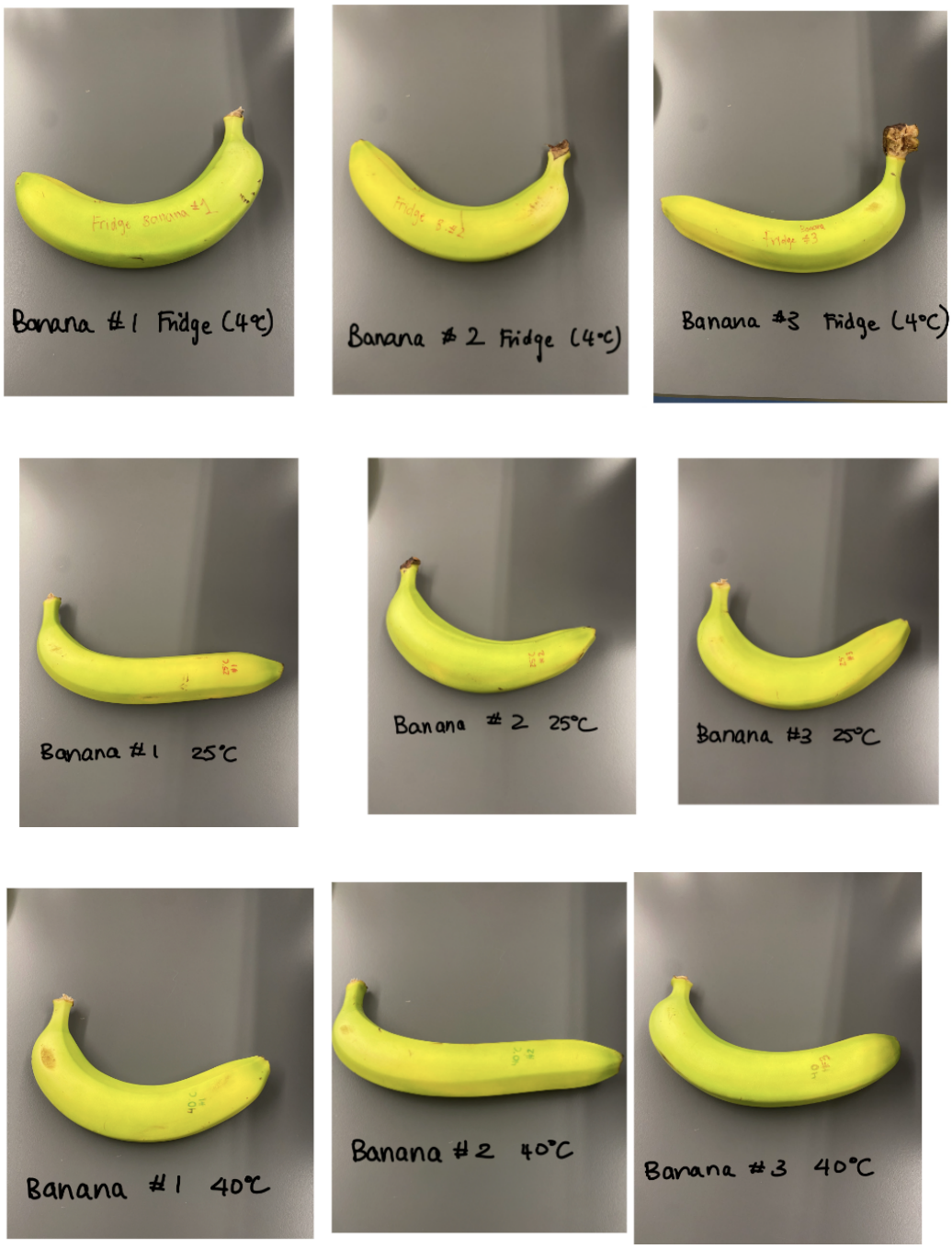

Figure 3: The 3 sets of bananas on Day 1, before adding them to their respective new environments in the Fridge (4ºC), 25ºC incubator, and 40ºC incubator.

Fridge

Banana #1	Banana #2	Banana #3
		

25ºC

Banana #1	Banana #2	Banana #3
		

40ºC

Banana #1	Banana #2	Banana #3
		

Figure 4: The 3 sets of bananas on Day 5, (the last Day).

We concluded the bananas in the fridge to be “C3” in the colour scale, the 25ºC incubated bananas as between “C4” and “C5”, and the 40ºC incubated bananas as “C3”.

Discussion

In this study, the effect of temperature on banana ripening and ethylene concentration was investigated for the purposes of increasing shelf life and slowing down browning. The largest decrease in weight occurred for the bananas at the highest experimental temperature, 40ºC. This indicates that the highest amount of ethylene gas was released in these bananas. The relationship between mean weight discrepancy (ie. change in weight) and temperature was illustrated in a scatter plot (Figure 2). There was a relatively strong positive correlation, with the R-squared value being close to 1 (0.964), in that higher temperatures were associated with greater changes in weight, and therefore greater concentrations of ethylene gas released.

In terms of the ripeness that we measured qualitatively, we found that the bananas at 25ºC were more consistently "C4" (more yellow than green) on the colorimetric indicator. In other words, they displayed the ideal yellow colour that we and other papers defined as "ripe" (Butola et al., 2015). This also relates with what Moreno (2021) stated: "Bananas turn yellow when at ripening temperatures below 30ºC". On the last day of the experiment, we recorded the bananas at 40ºC to have a "C3" colour (more green than yellow) referring to Figure 1. The overall colour of the banana was greener, despite all the dark brown spots. From this, we can conclude that although the bananas at 40ºC had many other physical properties that indicated ripening (eg. the fact that they were the softest to touch, and had the most brown spots), they still did not display the "most ripe" yellow colour of "C5" on Figure 1. One reason for this may be the greater decrease in abundance of proteins involved in chloroplast function as temperature increases, also suggesting that banana ripening is sensitive to high-temperature conditions in general (Du et al., 2016). Chlorophyll, a pigment that gives the banana its green colour, is sensitive to mild thermal

stress and thus degrades as temperature increases, which may explain why the bananas at 40ºC appeared the colour they were (Moreno, 2021).

In addition to ethylene concentration, we should also consider the possibility of other factors and gases in the mix that contributed to the decrease in banana weight. As bananas ripen, they undergo “enzymatic browning”, which is essentially when starches and complex sugars break down into simple sugars (Hogeback). This process releases not only ethylene gas, but also carbon dioxide, which is therefore why weight decreased. The breakdown of starches is also what caused the bananas to become softer. Bananas also lose moisture (and weight) as they ripen via another process called respiration. So from this, since they were the softest and lightest in weight, we can conclude that bananas at higher temperatures (40ºC) had higher rates of starch breakdown, respiration, and ethylene gas production (Ahmad et al., 2001).

In terms of the significance of this work, we conducted this experiment for various reasons that can be applied to the real world. Firstly, we now have a better idea of the optimal temperature to keep bananas at to increase their shelf life and slow down the ripening process, which would be 25ºC in our experiment. There are environmental implications that are also significant to note. Overripe or spoiled bananas are a major source of food waste, so by conducting such an experiment and understanding the relationship between temperature and ripening, we can also reduce the amount of food waste we produce. Lastly, very ripe bananas are a crucial ingredient when baking banana bread. Therefore, we can use and apply knowledge from this work in the development of banana products that may favour a faster ripening time like banana bread. For the future, we can expand upon this study by testing other temperatures,

specifically a temperature range that is more narrow. For instance, we can test 5ºC, 10ºC, 15ºC, and 20ºC to determine more precise effects of temperature on banana ripening and ethylene concentrations.

Conclusion

According to the results and plotted data in Figure 2, we can conclude that our hypothesis, *"If the bananas are stored at a higher temperature (ie. 40ºC), they will be more ripe at the end of 5 days and would have the least ethylene gas concentration"* was not supported. The 25ºC bananas were the most ripe after the 5 days, as it achieved the closest "C5" colour from Figure 1, as we determined the bananas were in between "C4" and "C5". The 40ºC bananas that we predicted to be the most ripe and "C5", ended up being more of a "C3", due to some green undertones present. The 40ºC bananas also ended up having the *most* ethylene gas concentration, as it had the largest weight decrease from Day 1 to Day 5, with around 50.9g - 55.8g. Our hypothesis was not supported at the end of our project.

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References:

Ahmad, Saeed & Thompson, Anthony & Hafiz, Ishfaq & ASI, ALI. (2001). Effect of Temperature on the Ripening Behavior and Quality of Banana Fruit. Int J Agric Biol. 3.

Butola, B. S., Sharma, P. K., Singh, Y., & Amin, Y. (2015). Arduino based supervision of banana ripening stages. 2015 1st International Conference on Next Generation Computing Technologies (NGCT). https://doi.org/10.1109/ngct.2015.7375254

Choehom, R., Ketsa, S., & van Doorn, W. G. (2004). Senescent spotting of banana peel is inhibited by modified atmosphere packaging. *Postharvest Biology and Technology*, *31*(2), 167-175. https://doi.org/10.1016/j.postharvbio.2003.07.001

Du, L., Song, J., Forney, C., Palmer, L. C., Fillmore, S., & Zhang, Z. (2016). Proteome changes in banana fruit peel tissue in response to ethylene and high-temperature treatments. Horticulture research, 3, 16012. https://doi.org/10.1038/hortres.2016.12

Gomes, J. F., Vieira, R. R., & Leta, F. R. (2013). Colorimetric indicator for classification of bananas during ripening. *Scientia Horticulturae*, *150*, 201–205. https://doi.org/10.1016/j.scienta.2012.11.01

Hogeback, J. (n.d.). Why do bananas turn brown? Encyclopædia Britannica. https://www.britannica.com/story/why-do-bananas-turn-brown#:~:text=High%20amounts%20of%20ethylene%20cause,observed%20when%20fruits%20become%20bruised.

Iqbal, N. (2017). Ethylene Role in Plant Growth, Development and Senescence: Interaction with Other Phytohorones. *Frontiers in Plant Science*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5378820/

Moreno, J. L. (2021). Physicochemical and physiological changes during the ripening of banana (musaceae) fruit grown in Colombia Published for the Institute of Food Science and Technology (U.K.) by Blackwell Scientific Publication. https://doi.org/10.1111/ijfs.14851

Markets and Trade – Food and Agriculture Organization of the United Nations. FAO. (n.d.). Retrieved March 19, 2023, from https://www.fao.org/markets-and-trade/commodities/bananas/en/

Maduwanthi, S. D., & Marapana, R. A. (2019). Induced ripening agents and their effect on fruit quality of banana. *International Journal of Food Science*, *2019*, 1–8. https://doi.org/10.1155/2019/2520179