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Muffin Bake Heights

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1.1 Abstract

In this study, I investigated whether or not muffin rack location and the type of muffin had an effect on muffin bake height. It has been of great interest to me to determine if the placement of baked goods in an oven affects their growth, and I aimed to find out if one should bake on the top or the bottom of an oven to achieve the best muffins. I analyzed the data using SAS version 9.4 (SAS Institute Inc.) and Tableau (Tableau Foundation), conducting the baking on April 25th, 2023 in my home kitchen. Randomizing each muffin's rack level, I baked four separate batches of muffins (12 in each, for a total of 48 muffins.) I baked two batches on the top rack, and two batches on the bottom. What I found was that muffin height was actually not greatly impacted by the rack it was baked on, and that muffin type did affect the bake height. However, I also discovered that rack location changes muffin bake height depending on muffin type. If I were to repeat this study, I would either limit the brands to be different and the muffin types to be the same, the muffin types different and the brands the same, or for a larger study, introduce muffin brand as a blocking variable.

1.2 Introduction

Ever wonder if there is an optimal oven rack to bake your favorite sweet treats? I had an idea to investigate this one day, and decided to carry out statistical analyses to determine this. More specifically, I investigated if muffin rack location (top or bottom), and/or muffin type (blueberry or chocolate chip) had an effect on muffin bake height (in millimeters). Knowing which rack to bake your muffins or other baked goods on is important, because it can help to optimize muffin growth and provide more "muffin" from the same amount of baking time. In this report, I will go over the methods used (1.3), the results and discussion of the findings (1.4),

and a summation of the results and broader implications (1.5), as well as a list of references (1.6) and an appendix (1.7).

Figure 1: Picture of the Muffins Baked in the Study

1.3 Data and Methods

In this study, I aimed to test whether or not the location of oven rack and muffin type had a significant effect on muffin bake height. Specifically, I measured the top and bottom oven rack, and two different types of muffins (Betty Crocker's Chocolate Chip and Krusteaz's Blueberry.) The data was collected on April 25th, 2023 in my home kitchen.

The sample size consisted of 48 muffins, which I baked in four different batches with randomized combinations of both muffin types in each batch. I baked two batches on the top rack, two on the bottom. I included muffins that had the same general recipe and bake time, as well as muffins from two different brands so as not to generalize to only one brand and type. I randomized the location of muffin type in a standard muffin baking tin. For each bake trial, I randomly assigned the muffin tin to the top or bottom.

To measure muffin bake height, I marked a toothpick with millimeter measurements, and stuck it directly in the center of the fully baked muffin to determine the approximate height.

Again, I baked all the muffins in each trial for the same amount of time (20 minutes per trial) and used the same general recipe.

The variables incorporated in this study were: type of muffin (blueberry, chocolate chip) which is an explanatory categorical and nominal variable of two levels, type of rack (top, bottom) which is an explanatory categorical and nominal variable of two levels, and muffin bake height (measured in millimeters) which is a quantitative response variable.

I analyzed the data using SAS and Tableau, and a two by two factorial treatment structure between rack location and muffin type was used to determine if the type of rack had a significant effect on muffin bake height. The PROC GLIMMIX procedure in SAS was used to run a two-way ANOVA with interaction.

Table 1: Summary Statistics of Muffin Bake Height

Muffin Height (mm)

	Muffin Type / Rack			
	Blueberry		Chocolate Chip	
	Bottom	Top	Bottom	Top
Mean	52.17	46.83	37.67	39.33
SD	3.93	3.61	3.80	2.67
Minimum	45.00	39.00	32.00	34.00
Lower Quartile	49.75	44.75	35.50	38.00
Median	52.00	47.00	38.00	39.50
Upper Quartile	55.25	49.25	40.00	41.25
Maximum	58.00	52.00	45.00	43.00

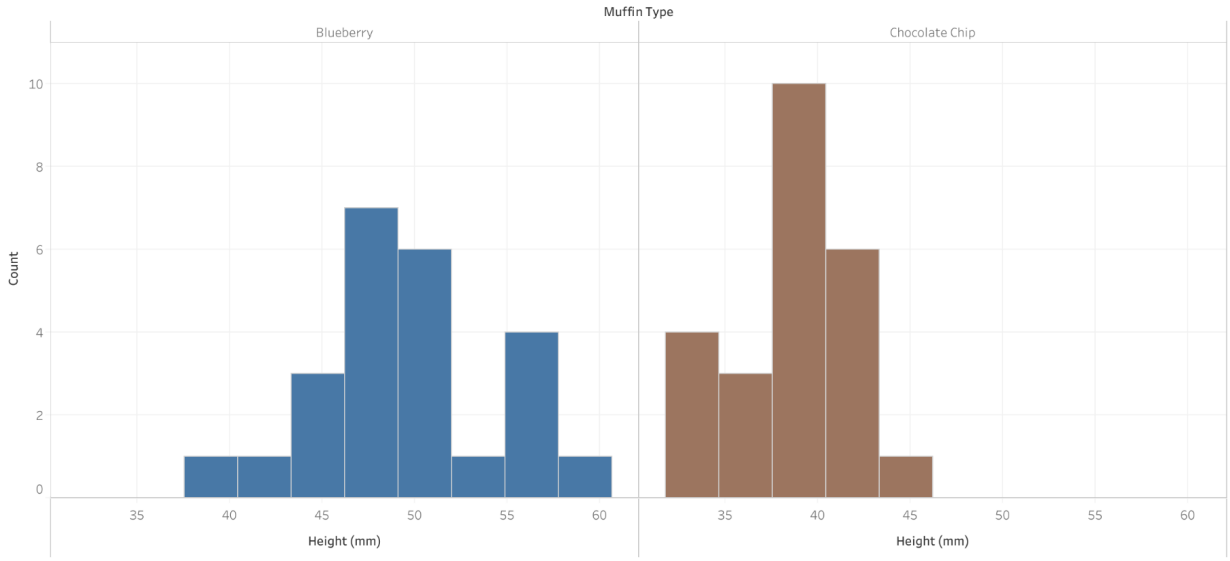
There were a couple of flaws in designing and carrying out the study. One of these was the muffins used in the study. Both muffin flavors typically tend to have different baking heights in general, so this proved to be a key reason why muffin heights differed based on type in analyzing the results.

Another potentially flawed factor was measurement of the muffins. The precision of such varied due to a roughly estimated demarcation of a toothpick, and observing the height at eye level. Some muffins had various lumps around the middle and some were somewhat flatter, so measurements varied based on how each rack of muffins turned out. Additionally, some muffins were in the oven at the same time, and at different spots on the rack. This also causes variation in the bake heights, as it would have been ideal to bake each muffin separately.

1.4 Results and Discussion

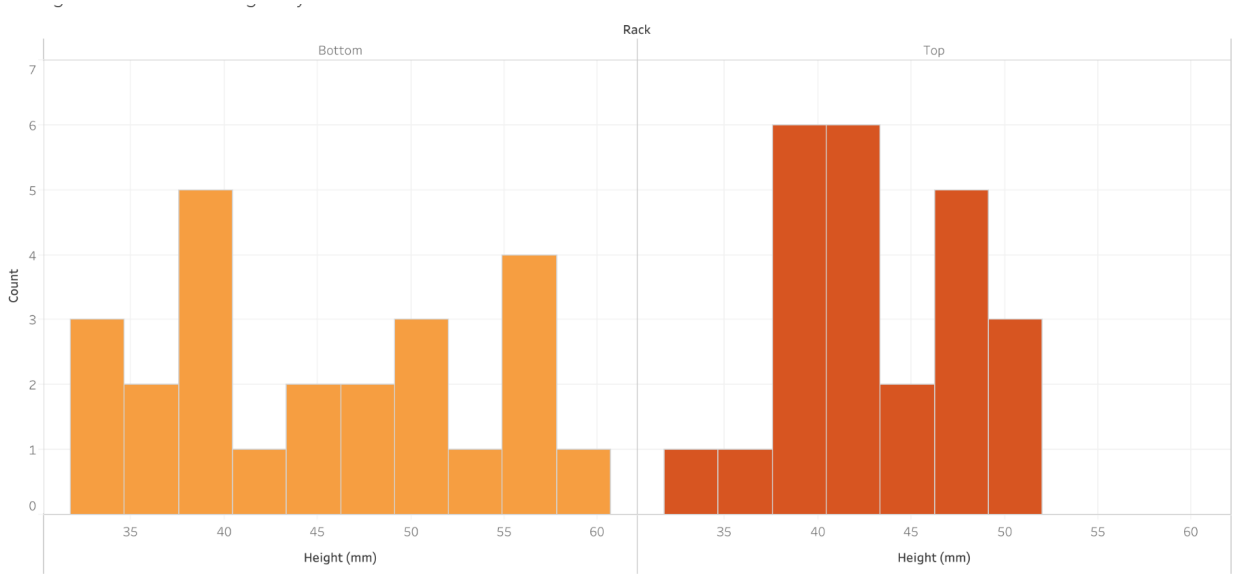
To carry out the following analyses, I wanted to determine the effects of both the level of rack (top or bottom) and type of muffin (blueberry or chocolate chip) on muffin bake height.

Figure 1: Histograms of Muffin Height by Type



The trend of count of Height (mm) for Height (mm) (bin) broken down by Muffin Type. Blue color represents blueberry muffins, brown color represents chocolate chip.

Figure 2: Histograms of Muffin Height by Rack Level



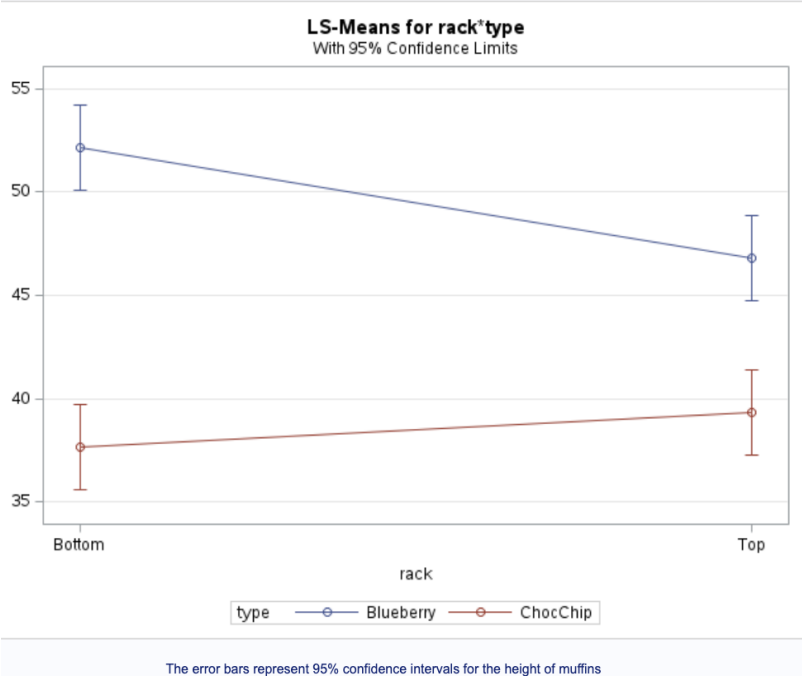
The trend of count of Height (mm) for Height (mm) (bin) broken down by Rack. Color shows details about Rack. Orange color represents bottom rack muffins, and red color represents top rack muffins.

Figure 1 shows the distribution of height for each muffin type, and it is apparent that blueberry is centered around the mean (49.50 mm), while most of the chocolate chip data is clumped toward the right. Blueberry muffins had a mean of 49.50 mm, (SD 4.587 mm), and chocolate chip muffins had a mean of 38.50 mm, (SD 3.323 mm). Blueberry muffins had a much higher bake height. Figure 2 shows the distribution of height for each rack level. The bottom rack appears to have a bimodal distribution, and the top rack is clumped more toward the right. The bottom rack had a mean of 44.917 mm, (SD 8.314 mm), and the top rack had a mean of 43.083 mm, (SD 4.934 mm). Bottom rack muffins had a higher bake height on average than top. From these initial observations, blueberry muffins tended to bake higher on average compared to chocolate chip, and muffins baked on the bottom rack tended to bake slightly higher on average than muffins baked on the top. I am not surprised by the distributions of blueberry and chocolate chip muffins, as these tend to have varying bake heights regardless of other factors. Rack level was a little bit more unexpected, however, as my intuition had said that the rack closer to the top would have higher baking heights, yet that wasn't the case for all muffins in the study.

Next, I fit a two-way ANOVA in SAS. Testing the effects of both the rack level, muffin type, and the interaction, it is evident that at a 5% significance level, the interaction effect says there is sufficient evidence that rack level changes muffin bake height depending on muffin type (interaction F = 11.75; df 1, 44; p = 0.0013.) Next, rack level does not have an effect on muffin bake height (rack level F 3.22; df = 1, 44; p = 0.0795). There would be some evidence that there is an effect if tested at a 10% level of significance, but standard testing procedures call for 5%. Muffin type, on the other hand, does have an effect on muffin bake height (muffin type F = 116.02; df = 1, 44; p < 0.0001.) This is not surprising, since blueberry muffins tend to bake higher than chocolate chip muffins in general.

Figure 3 displays an interaction plot of muffin height by rack location and muffin type, and this shows that, (for blueberry muffins), muffins tend to bake higher on the bottom rack than the top. For chocolate chip muffins, muffins tend to bake slightly higher on the top rack than the bottom, but not by the same amount as blueberry muffins.

Figure 3: Interaction Plot of Muffin Height by Rack and Type



1.4.1 Discussion

I found that muffin type does have an impact on how high it bakes, (regardless of rack), and that rack location does not have an impact on muffin bake height, (regardless of type). Also, I found that rack location changes muffin bake height depending on muffin type. From the start of data collection, it was apparent that blueberry muffins were going to bake higher than chocolate chip muffins, simply due to the design of the muffins. The initial plan was to perform analysis on two different brands of chocolate chip muffins, but due to a shortage of one brand, I had to continue the experiment with blueberry muffins instead. Based on the fact that two different types of muffins were used, I initially believed muffins with blueberries would bake higher in my study than muffins with chocolate chips (and I was right.)

Causality is able to be stated for the results, as a completely randomized study design was implemented. So, it is viable to say in the context of the study that muffin rack level does not have an effect on muffin bake height, muffin type has an effect on muffin bake height, and rack level changes muffin bake height depending on muffin type. Because two brands were used in this study (Betty Crocker chocolate chip and Krusteaz blueberry), I am able to generalize the results to the population of all muffins from the two brands/types baked under similar conditions.

1.4.2 Considerations for Future Studies

As mentioned before, there is a portion of error that explains why the results turned out the way they did. Aside from the types of muffins used in the study, there was also an issue with how muffin “height” was measured. In the materials section, I mentioned that I used to collect measurements, simply by sticking the toothpick (demarcated with millimeter markings) in the center of each muffin to measure. The difficulty lay in the fact that some muffins had abnormal centers that poked up in almost a cone or dome shaped way, while some muffins were baked

relatively flat and while they may have risen in height, they did not have protrusions like some muffins did. This could be due to the distribution of blueberries or chocolate chips between each muffin, as likely no two muffins had the exact same amount. There also was some slight human error in measuring out each amount of batter per muffin liner. Some muffins needed more than two scoops, some needed a little bit less, depending on when I filled them. I did my best to readjust accordingly, but there is no stopping the inevitable human error that comes with a study like this.

In the future, this study could be expanded to more types of muffins (perhaps cornbread or simply vanilla, which do not have extra "items" such as blueberries or chocolate chips within them.) To see if physical brand had an impact on muffin height (not "type" - e.g. each brand would have the exact same "type" of muffin, but are different brands,) a block study design could be implemented with brand being the blocking variable, and measuring height from a much larger sample of muffins (than 48.) A test for the middle rack could also be beneficial in future replications of the study, as perhaps that rack bakes higher muffins than the bottom or top.

1.5 Conclusion

As a result of our analyses, I can say that muffins baked on the top rack have no substantial difference in bake height from those baked on the bottom rack, and that blueberry muffins tend to bake higher on average than chocolate chip muffins. Also, rack location changes the bake height of muffins depending on the type of muffin. It's viable to generalize the results of the study to all chocolate chip muffins from Betty Crocker and all blueberry muffins from Krusteaz, baked under similar conditions using a similar recipe. I should not generalize outside of this population, because only these brands were used, and the sample size was fairly small (only 48 muffins were baked). Because I randomly assigned muffins to their racks, I can infer

causality in this study. I think in a real world context, it is important to know if baking your muffins a certain way influences their height. Even though in this study, bottom rack muffins baked one millimeter higher than top rack muffins on average, it still might be nice to know that you can get a little more out of your muffins by baking them away from the top. There's still the questions of whether the middle rack might bake higher than the bottom or top, and if different brands of the same muffin type bake higher than one another, (both of which could be addressed in a future study).

1.6 References

SAS Institute Inc. 2015. SAS/IML® 14.1 User's Guide. Cary, NC: SAS Institute Inc.

https://support.sas.com/en/software/enterprise-guide-support.html

Tableau Foundation. (2003, January). Tableau.

https://www.tableau.com/why-tableau/what-is-tableau

1.7 Appendix

A: Project Protocol

B: Muffin Study data.xlsx