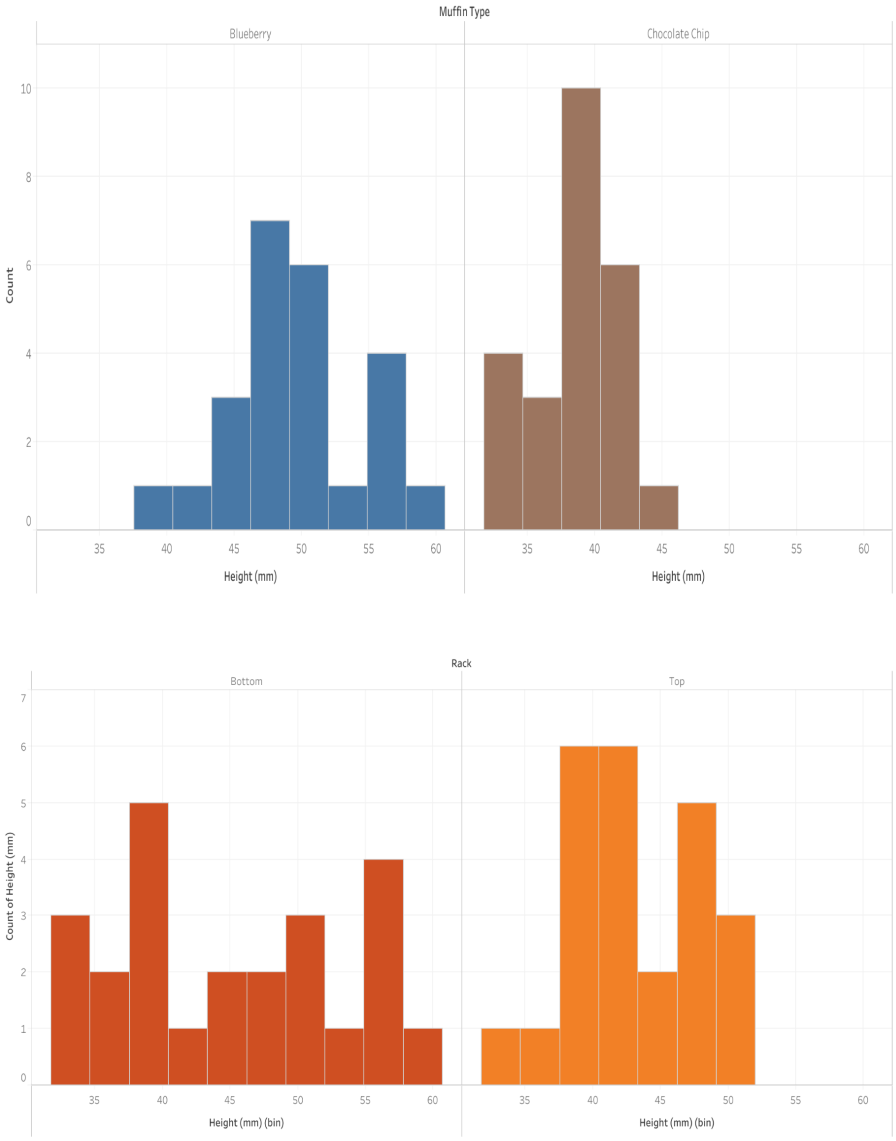
1.4 Results and Discussion

I used SAS and Tableau to carry out the following analyses. I wanted to test the effects of both the level of rack (top or bottom) and type of muffin (blueberry or chocolate chip) on muffin bake height. Before any procedures were carried out, I formatted the data into histograms in Tableau, displaying the distributions of various heights among both rack level and type of muffin.

Graph 1: Histograms of Muffin Height by Type and Rack Level



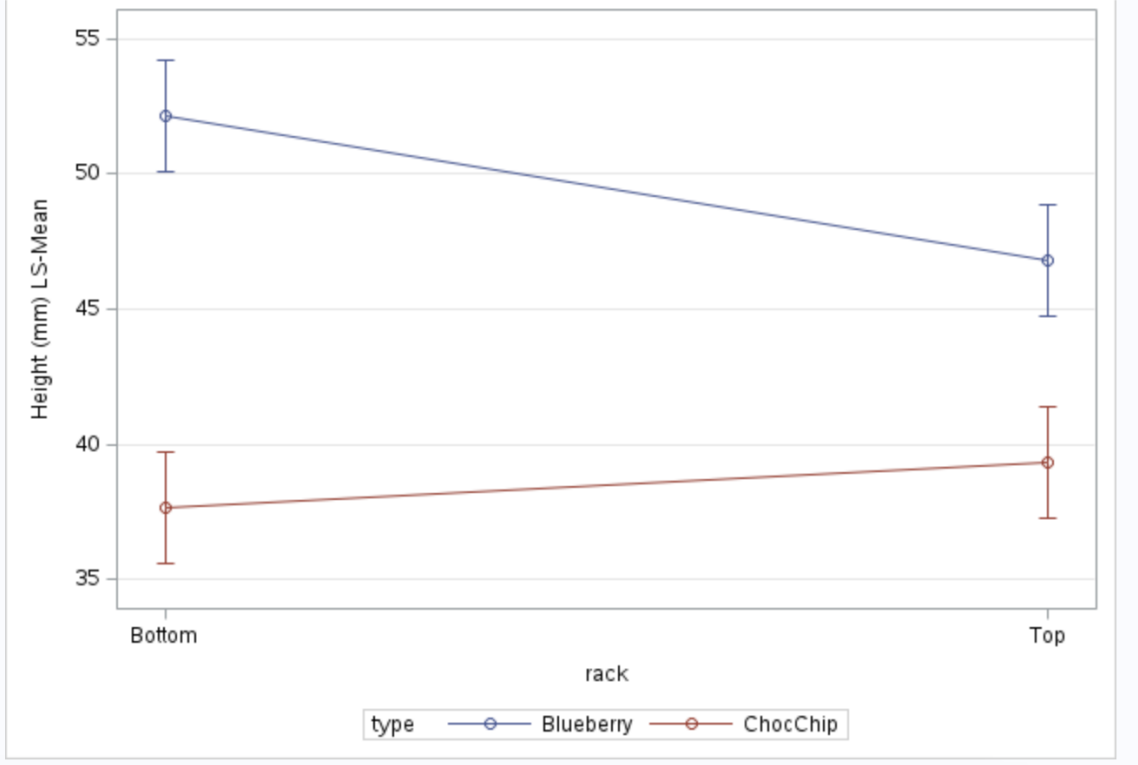
Based on the histograms for type, it is apparent that blueberry is centered around the mean, while chocolate chip displays a slight right skew. Blueberry muffins had a mean of 49.50 mm, with a standard deviation of 4.587 mm, and chocolate chip muffins had a mean of 38.50 mm with a standard deviation of 3.323 mm. For rack level, the bottom rack appears to have a bimodal distribution, and the top rack is slightly right skewed. The bottom rack had a mean of 44.917 mm with a standard deviation of 8.314 mm, and the top rack had a mean of 43.083 mm with a standard deviation of 4.934 mm. 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 fitted a generalized linear mixed model with the PROC GLIMMIX procedure in SAS. Testing the effects of both the rack level, muffin type, and the interaction, it is evident that at a 5% significance level, rack level does not have an effect on muffin bake height (F-score 3.22, p-value 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 (F-score 116.02, p-value < 0.0001.) This is not surprising, since blueberry muffins tend to bake higher than chocolate chip muffins in general. Finally, the interaction effect says that there is sufficient evidence that rack level changes muffin bake height depending on muffin type (F-score 11.75, p-value 0.0013.)

Because I discovered an interaction effect, I decided to create an interaction plot in SAS. Based on the plot below, for blueberry muffins, muffins tend to bake higher on the bottom rack

than the top, whereas 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.

Graph 2: Interaction Plot of Muffin Height by Rack and Type



1.4.1 Discussion

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.

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 2 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.)