Muffin Madness

I. Introduction

Watch any YouTube video on "Baking Tips" and there will most likely be a segment on coating fruit with flour before adding it to batter. The reasoning is as follows: by adding flour, the fruit's moisture will be partially absorbed, making it easier to cling to the batter and rise with the batter as it bakes; thus, the fruit will not sink to the bottom of the pan.

As our group members are all enthusiastic bakers, we decided to test this tip through a controlled experiment. After discussing the pros and cons of various dessert recipes, we drew a consensus on blueberry muffins, the obviously superior breakfast food. Our goal was to evaluate whether coating the blueberries with flour would, in fact, prevent them from sinking in the muffin batter while baking in the oven.

II. Statistical Question

Do blueberries coated in flour rise significantly higher than non-coated blueberries while baking muffins?

$H_0 : \mu_d = 0$

$H_a : \mu_d > 0$

Where μ_d is the true average difference in distance of the highest blueberry from the bottom of the pan between the two treatments (coated - non-coated)

III. Data Collection

We agreed on a muffin recipe that seemed both scrumptious and perfect for our experiment. However, we did make a few adjustments. The original recipe called for two cups of blueberries, mashing half of them before adding to the batter. Because our experiment attempted to measure the height of whole blueberries, we decided to keep the blueberries whole, and decreased the amount from two cups to one-and-a-half. Additionally, we cut the sugar level in half, as many people in the comments claimed it was too sweet.

One of the possible confounding variables was the location of the muffins in the oven during baking. Because we did not have commercial-grade, convection ovens, there might have been certain parts of the oven that ran hotter than others. Thus, in order to minimize this confounding, we randomly assigned treatments and created matched pairs. First, we divided our standard muffin pan into six sections of two spots each. Then, we randomly assigned which muffin batter (either muffins with coated or non-coated blueberries) would go into each spot by flipping a virtual coin. We repeated this process for six pans, as we planned to create six batches of muffins.

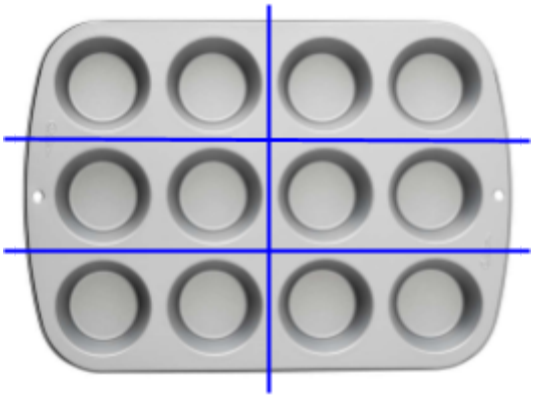

Figure 1. A diagram of our method to divide the muffin pans.

Another confounding variable would be our individual baking skill. All of us were at different levels of baking proficiency, and we had planned to bake the muffins individually in our own homes, with little outside help. We also had different brands of ingredients, tools, bowls, and pans, which all could influence the final height of the blueberries. However, the design of our matched-pairs test reduces the effect of these confounding variables by canceling them out with each other. This is because each muffin was matched to another muffin made by the same baker, from the same batter.

To bake the muffins, we first made a double-batch (doubled the recipe) of the batter without blueberries in a single bowl. Then, we divided the batter evenly into two bowls. From there, we took half of our blueberries, coating them with flour, and leaving the other half uncoated. For the first bowl, we added the coated blueberries, and for the second, the uncoated. After mixing thoroughly, we poured each batter into the corresponding spots that were randomly assigned to one of the two treatments. Then we baked them for the recommended time.

We collected the data by cutting each muffin in half and measuring the height of the tallest blueberry to the bottom of the muffin using a ruler. Since we used a matched-pairs test, we then subtracted the height of the non-coated blueberry muffins from the coated blueberry muffins, to find the average difference between them.

IV. Data Display

Muffin Pair Number	Flour height (cm)	Non-flour height (cm)	Difference (Flour-Non Flour)
1	3	3.5	-0.5

2	5	3	2
3	4.5	4.5	0
4	4	5	-1
5	3	4.5	-1.5
6	4.5	3.5	1
7	4.5	3.5	1
8	4	4	0
9	4.5	3.5	1
10	5.5	4	1.5
11	3	3.5	-0.5
12	4.5	4	0.5
13	3.5	4.0	-0.5
14	2.5	2.5	0.0
15	4.5	4.0	0.5
16	4.5	4.0	0.5
17	4.5	3.5	1.0
18	4.0	3.5	0.5
19	4.5	5.0	-0.5
20	4.0	3.0	1.0
21	4.0	3.0	1.0
22	3.0	4.0	-1.0
23	4.0	4.0	0.0
24	4.0	4.0	0.0
25	3	3	0
26	3.5	4	-0.5
27	4	4	0
28	3.5	4	-0.5
29	3.5	3	0.5
30	4.5	3	1.5

31	4	3.5	0.5
32	3	4	-1
33	4	3	1
34	4	4	0
35	5	3	2
36	4	3	1

Figure 2. A table of our collected data.

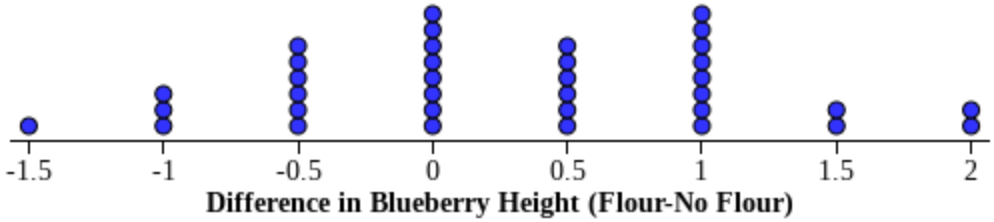

Figure 3. A dot plot showing the distribution of the differences in blueberry heights.

V. Data Analysis

We conducted a matched pairs t-test for the mean difference using a significance level of $\alpha = 5\%$. Our conditions for inference are as follows:

1. *Random:* We ensured the random condition was met by randomly assigning the placement of our two treatments. We decided to bake six total batches for each treatment, so we repeated this process for each tin.
2. *Independence:* Since each muffin is completely separate from one another, we know that the final results of one muffin will not affect the results of any other muffins, therefore we have passed the independence condition.
3. *Normal/Large Sample Size:* We decided to bake six batches of muffins, which is a total of 36 muffins that have coated blueberries and 36 muffins of uncoated blueberries. Because

of the Central Limit Theorem, a sample size of over 30 would allow us to assume that the sampling distribution will be approximately Normal. Therefore, it is appropriate to use a matched pairs t-test for the mean difference.

The results of our significance test are as follows:

Degrees of Freedom	**Test Statistic *t****	**p-value**
df = n - 1 = 36 - 1 = 35	$t^* = \frac{0.292-0}{0.857} = 2.043$	0.024

VI. Conclusion

Because our p-value, 0.024, is less than our significance level, $\alpha = 0.05$, we reject the null hypothesis. There is convincing evidence that coating blueberries in flour before adding them to muffin batter prevents them from sinking to the bottom of the pan while baking.

VII. Reflection

The goal of our project is to evaluate whether or not coating blueberries before mixing them into the batter truly prevents sinkage. Overall, we baked 72 muffins. In order to prevent confounding, we prepared two batches worth of batter by doubling the recipe, split them equally, and then mixed our blueberries in. Since we did not have the same ovens, we conducted a matched pairs test between each of our two batches of muffins. Although we implemented random assignment and each used the same procedure, there were some areas we could have improved on.

First of all, we did not place the same amount of blueberries in each muffin. This is because we did not count the number of blueberries in each scoop of batter. Second, we did not

weigh or portion each muffin out, so there were some muffins that were bigger than others. This would've caused certain muffins to expand and the blueberries were more likely to be higher than others, even if they sank. We also believe the muffins with more blueberries piled top of one another, causing the height of the top berry to be partially dependent on how many were in each scoop.

We fully acknowledge the fact that our experiment had flaws, however, we feel our matched pairs test eliminated the most important confounding variables needed to accurately carry out our experiment.

There is a chance that we made a Type I error. In the context of this experiment, that means that we found significant evidence that coating blueberries with flour allows them to rise higher than blueberries without flour in muffin batter, when in reality, there is no difference. The probability of a Type I error is our significance level, 0.05.

Our research does not end here. To further test this baking tip, we could use different recipes, such as cake or cupcake recipes. That might lead to different results, as the consistency of cake batter is typically much more thin than muffin batter. We could use different recipes for each type of dessert as well—for example, sponge cake and a denser, lava cake. Because our muffin batter was very thick, we might not have noticed a dramatic difference in blueberry height. Moreover, instead of measuring the height of the highest blueberry, we could implement different measuring methods. One method would be tracking the percentage of blueberries that sank. This would lessen the effect of the confounding variable of batter volume in each muffin.

Although we can conclude that the mean difference in height of the flour coated blueberries and non-coated blueberries is statistically significant, we believe that the flour used

to coat the blueberries would be better used in other recipes than to raise the blueberry height by mere millimeters. Save your flour, and your time.

Figure 4. Two muffin halves. Flour coated on the left, non-coated on the right. Could you spot the difference between these two muffins?

Works Cited

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