Title

The Effect on Cookie Diameter of Altering the Flour to Butter Ratio

Abstract

Altering the ratio of flour to butter content in a cookie recipe can affect how far the dough spreads out while baking. A cookie recipe was baked in 9 variations to see if a change in the butter quantity would have a greater effect on diameter than a proportional change in flour quantity. The results instead showed that a change in flour content would have a greater effect, although the variance in the methods might justify improved experimentation before rejecting the hypothesis.

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Introduction

Chocolate Chip Cookies are a widely loved treat and there are many unique recipes for making them. What are the effects of the subtle variations between the ratio of ingredients in these recipes? What happens if someone messes up their ingredient amounts or tries to experiment? A fascinating article on the cooking website SeriousEats.com, titled “The Food Lab: The Science of the Best Chocolate Chip Cookies”, goes into the science of various cookie ingredients and the things they tested on their journey to make their perfect cookies. They alter the quantity and treatment of ingredients, as well as trying substitutions. Along the way they give a bit of info as to what the results are and why that might be. In altering butter and flour content, they note that doing so can alter the diameter of the resulting cookie, although they do not go into detail about how significant the effect is or display a photo of the difference.

If someone wanted to make a cookie that was of a larger or smaller diameter by altering their flour to butter ratio, which ingredient do they alter? The ratio of flour

to butter can change by the same amount with an increase in one or a decrease in the other. The resulting ratio of flour or butter to the other ingredients would not be the same with both alterations. Flour interacts with eggs and sugar in the Maillard reaction and the liquid from butter helps to dissolve baking soda so it can act as a leavening agent. My hypothesis was that changing the flour to butter ratio by altering the butter quantity would have a greater effect on the diameter than a proportional alteration in the ratio by altering the flour quantity. My theory was that the interaction between the butter's liquid and the other ingredients would be of greater effect on the resulting diameter than the interaction between flour and the other ingredients. In order to test this hypothesis, 9 batches of a cookie recipe were baked with alterations to either the flour or butter content.

Methods

9 batches of the same chocolate chip cookie recipe with slight variations. The base recipe used was a slightly modified version of the recipe provided by the article from The Food Lab:

Half of a 2 cup stick of butter
One cup + 40mg of flour
1 teaspoon of baking soda
1 tablespoon of salt
½ Cup + 20ml of White Sugar
½ Cup + 20ml of Brown Sugar
2 Large Eggs
2 teaspoons of vanilla extract
1 Cup of Chocolate Chips

Preparation instructions:

- Soften Butter
- Whisk together flour, baking soda, and salt
- In a separate bowl, whisk together white sugar, vanilla, and eggs until the mixture is pale brownish-yellow and falls off the whisk in ribbons
- Add the butter and brown sugar to the egg and sugar mixture, and mix until fully combined

- Add dry ingredient mix and mix until combined, then add chocolate chips and mix again

One batch was made following these instructions, another was made with 20 less mg of flour, another with 40 less, one with 20 more than the recipe, and one with 40 more. There was also a recipe with 10 percent less butter, one with that extra 10%, one with 20% less, and one with that extra 20%.

Cookies were baked at 325 degrees Fahrenheit. After 7 minutes the baking sheets were rotated, and if more than one sheet of cookies was being baked at a time the positions of the two sheets were changed, then they were baked for 7 more minutes. Once the cookies sufficiently cooled, the diameter of the cookie was measured from the widest point. The amount of batter and the quantity used per cookie was sufficient to bake 40 cookies per recipe. Cookies were either baked 6 on each of two baking sheets or 8 on a single baking sheet of a different design.

Each recipe was mixed on the same day, and then transferred to sealed bags, and left in the fridge overnight. Initial plans were to bake all 9 recipes the next day and to use a large ice cream scoop with a mechanism to free the scooped food which would make it easier to make the initial dough balls consistent in shape and size. Unfortunately, the scoop created cookies that were far too large and 6 cookies on one 10x15 inch baking sheet spread out to all 4 corners of the sheet, making the data unusable. The best solution found was to put the dough from the bag back into a bowl and scoop up the dough with a spoon against the side of the bowl. This enabled the creation of dough balls that were relatively consistent in size and shape in a manner that was reasonably efficient. The time needed was underestimated and the baking process had to be spread out over 3 days, the base recipe also had to be baked again after the first batch was used testing the ice cream scoop.

An ANOVA or ANalysis Of VAriance test was performed twice, once to compare the base recipe and recipes with altered flour content, and another time to compare the base recipe and recipes with altered butter content. These ANOVA tests produced histograms to visually compare the range and variance of the data, as well as p-values to determine the significance of the relationship. In addition, the mean diameter of each recipe was calculated as well as the slope of the relationship between the flour/butter content and the mean diameter.

Results

Not including the initial attempt at baking the base recipe with ice cream scoop dough balls which failed, a total of 360 cookies were baked and had their diameter measured; 40 cookies were baked and measured for each of the 9 recipes.

Results for flour ANOVA:

P-value: 1.001497 x 10 ^ -41

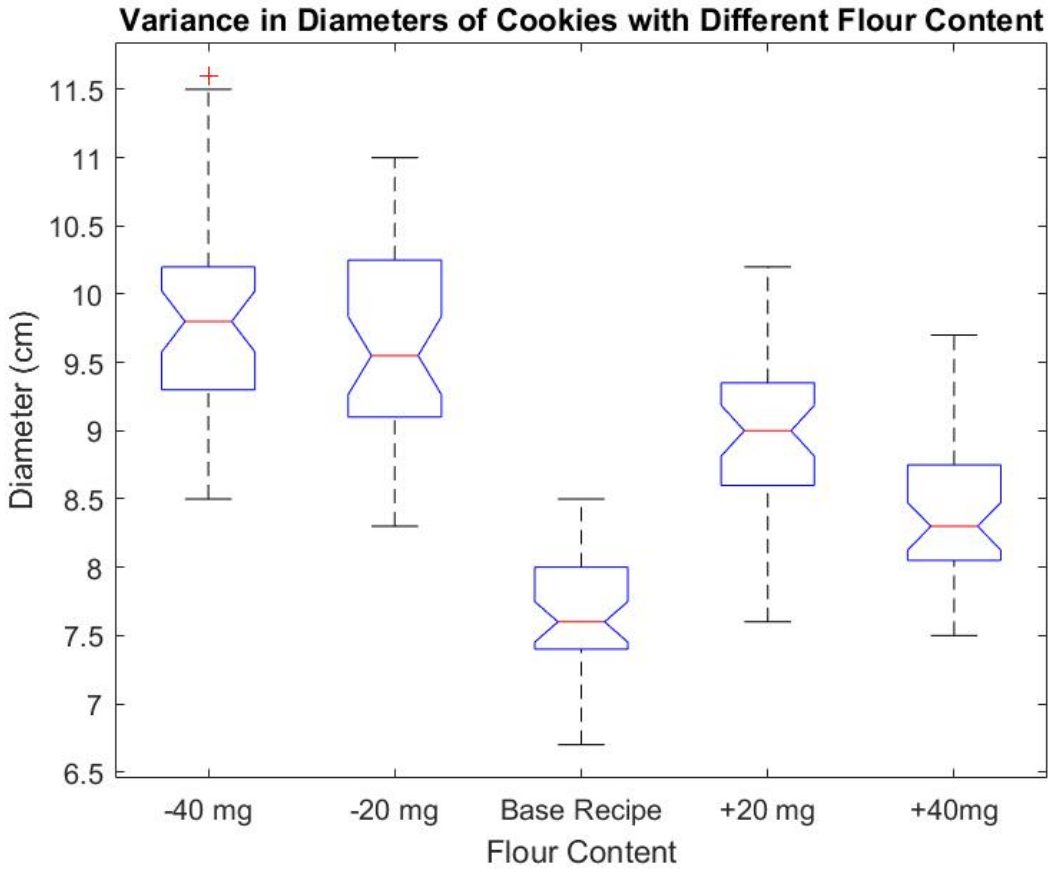

Figure 1: Histograms of the Base Recipe and Altered Flour Content recipes, produced by the MatLab function anova1. The red bar represents the median value, the top and bottom of the surrounding box represent the 75th percentile and 25th percentile respectively, the upper whisker is the highest value and the lower whisker is the lowest.

The -40 mg recipe has two values marked as outliers by Matlab, judging from the data as there are two values of 11.6 and one value of 11.5.

There is a trend in decreased diameter with decreased flour content. The base recipe is far outside of this trend, with much lower values than even the +40mg recipe. The -40mg recipe appears to be the most varied but not massively different than the others.

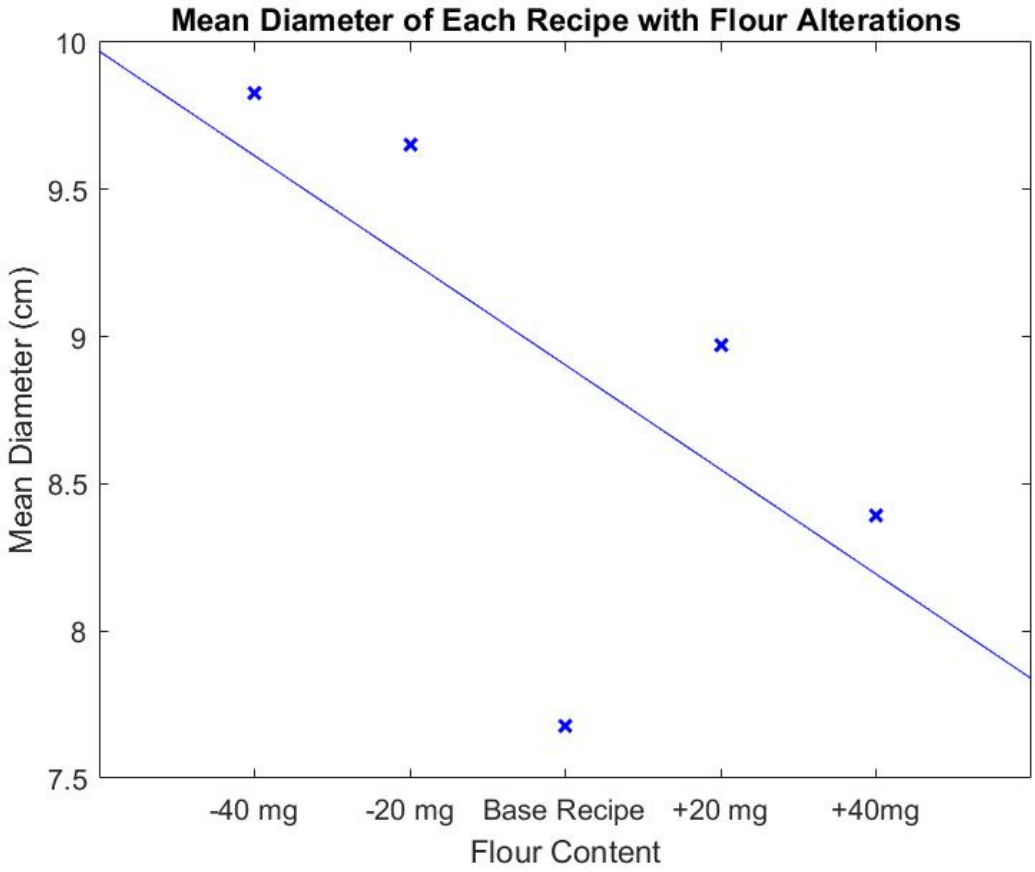

Figure 2: Mean diameter of each recipe with flour content altered, with a least-squares line.

The slope of the least-squares line is -0.355 cm per 20mg of flour.

Results for butter ANOVA:

P-value: 0.07301875 x 10 ^ -29

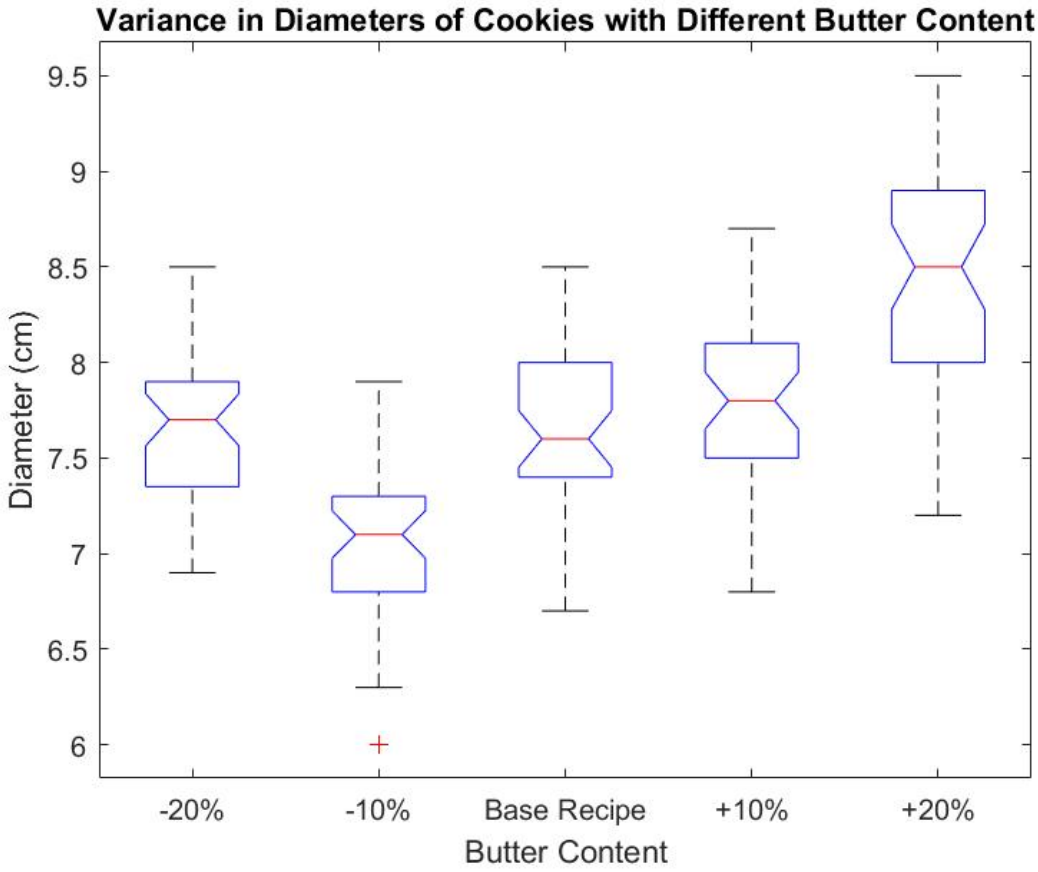

Figure 3: Histograms of the Base Recipe and Altered Flour Content recipes, produced by the MatLab function anova1. The red bar represents the median value, the top and bottom of the surrounding box represent the 75th percentile and 25th percentile respectively, the upper whisker is the highest value and the lower whisker is the lowest.

One value was marked as an outlier by the Matlab function, a value of 6 cm.

There is an overall trend in increased diameter with increased butter content, although this is largely supported by the -10% and +20% data, with the +10% and -20% being nearly identical in mean and variance to the bare recipe.

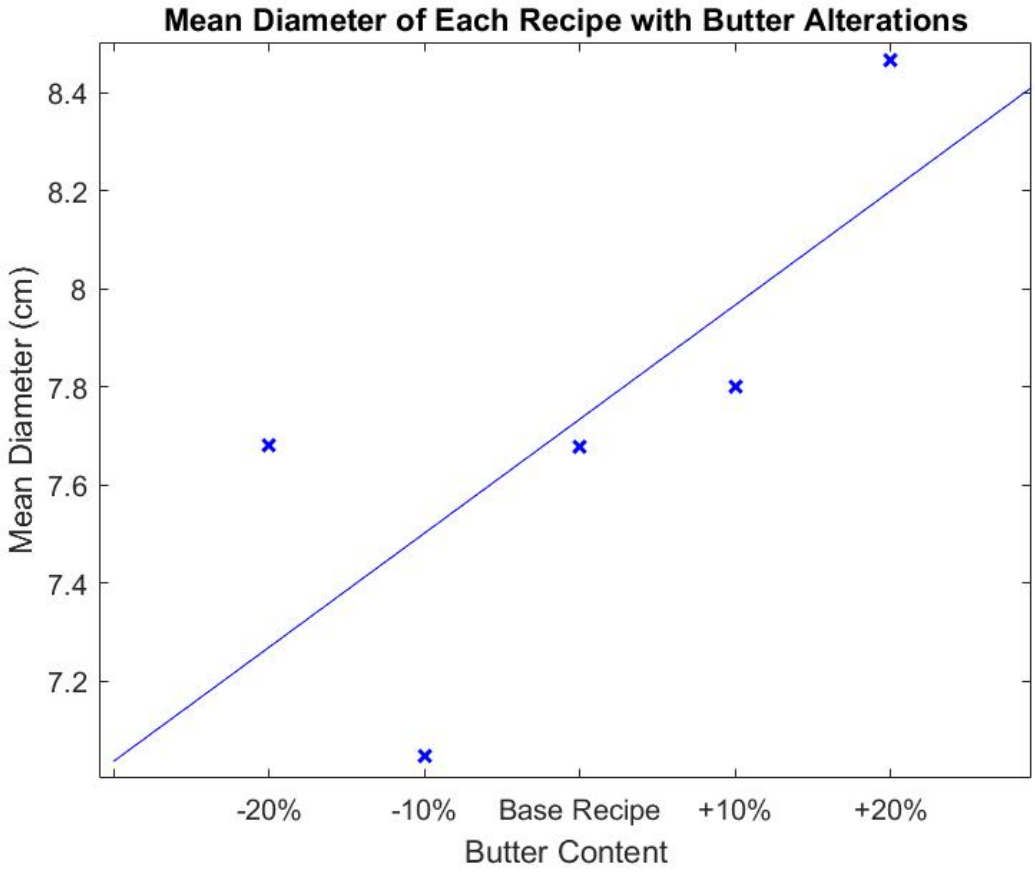

Figure 4: Mean diameter of each recipe with butter content altered, with a least-squares line

The slope of the least-squares line is 0.2325 cm per 10% increase

Discussion

The slope of the flour recipes is -0.355 cm per 20 mg. We use 280mg of flour in the base recipe, and 240mg of butter. So the ratio of flour to butter is 1.166 to 1. A 20 mg increase in flour brings the ratio of flour to butter up to 1.25. So a 20mg increase is approximately equal to an 8.3% increase in the ratio of flour to butter. A 1% increase in flour to butter ratio by flour quantity change should decrease diameter by 0.0427 cm

The slope of the butter recipes is 0.2325cm per 10% increase in butter. A 10% increase in butter is a 24mg increase in butter quantity, as the base recipe used

280mg of flour and 240mg of butter. So a 24mg or 10% increase in butter changes the ratio of flour to butter content from 1.166 to 1, to 1.0606 to 1. A 10% decrease in ratio. So a 1 percent increase to flour to butter ratio by butter quantity change should decrease diameter by 0.0219cm

The change in diameter resulting from proportional changes in the ratio of flour to butter seems to be larger when the change in ratio is the result of a change in flour than a change in butter. In other words, changing the quantity of flour had a bigger impact on spread than changing the quantity of butter, which is the opposite of the hypothesis. I must have underestimated the interaction with flour and the other ingredients. The butter is not the only source of liquid in the recipe, the eggs, and even the vanilla can interact with the flour to alter the spread. Commercially available butter is approximately 16% water (Dairy Australia) so the 240ml of butter was about 36ml of butter, which isn't much compared to the approximately 150ml of water from the two eggs (Johnson and Ridlen).

P-value represents the chance that the difference between groups would be at least as significant as this if there was no relationship between diameter and flour/ butter content. Most experiments will only conclude that there is a relationship between the variables if they get a p-value that is lower than a maximum threshold of 0.05, 0.01, or even lower. In this case, the p-values are very low so we can confidently conclude that changing flour or butter content will indeed alter the resulting diameter. So at least the results do support that there is some change in the diameter despite my choice to keep the changes in butter or flour small so the cookies remain somewhat tasty.

The ability to bake 9 batches of the recipe in one day was an overestimation, in part due to some complications with my method of forming the dough balls. As a

result they were not all baked on the same day and some cookies spent 2 or 3 nights in the fridge instead of 1, however there is no apparent reason why this would affect the spread, and any trends consistent with the different days would be more likely due to inconsistency in the size of the dough balls due to human error. The only reference for the size that each cookie dough ball should be was memory and the dough already on the sheet. The same spoons and bowl were used each time to help with consistency. Due to the inconsistency in leftover dough quantity, something that in hindsight should have been measured, the dough balls sizes were not consistent between recipes.

The flour data is pretty consistent, with a steady trend to lower diameter with increased flour, mostly disrupted by the outlier of the normal recipe being much smaller than the rest. The butter data is less consistent in trend, with the -20%, +10% and base recipe all having basically the same mean and variance, and a trend of increasing diameter with butter content appearing with the smaller -10% and the larger +20%. The base recipe and butter recipes expect the -10% were baked on the last day, with the other recipes being baked the previous days. It is possible that over time the method for making the dough balls slightly changed so that by the time the last recipe was prepared, the base recipe, the dough balls were smaller than when the first flour recipes were made and the data doesn't match up.

Ultimately, while I hoped a large sample size would help with consistency in my data, I believe that much of the variance in the recipe results was the result of my own inconsistency in preparing the dough balls. If I were to redo this experiment I would ensure I had access to a kitchen scale to make more precise measurements and adjustments, especially for the butter which I had to eyeball, and to measure any differences in remaining dough quantity. I would also find a more consistent way to

prepare the dough balls without needing to make them massive, such as a much smaller but similar ice cream scoop. I would also probably make less recipes or prepare them in a better schedule so I don't have unexpected variance like the time in the fridge. I also would have started with a recipe I had already tested and knew would make a consistent and tasty cookie.

Conclusion

I was incorrect in my hypothesis that a change in the quantity of butter used in the recipe would have a greater effect on the resulting diameter than a proportional change in flour quantity. My errors in the experimental design limited the consistency and accuracy of my results such that I would make significant changes if I redid the experiment, but not such that I believe the rejection of my hypothesis to be premature.

Citations and Literature Cited

Dairy Australia. *Butter Nutritional Information: Butter Benefits & Types*. www.dairy.com.au/products/butter.

Lopez-Alt, J. Kenji. “The Science of the Best Chocolate Chip Cookies: The Food Lab.” *The Science of the Best Chocolate Chip Cookies | The Food Lab | Serious Eats*, Serious Eats, 25 Aug. 2020, sweets.seriouseats.com/2013/12/the-food-lab-the-best-chocolate-chip-cookies.html.

Johnson, H.S., and S. F. Ridlen. “Incubation and Embryology - University of Illinois.” *Structure of the Egg - Incubation and Embryology - University of Illinois Extension*, web.extension.illinois.edu/eggs/res16-egg.html.