The Power of Flour in Cookies

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Abstract

Gluten is the main structural protein found in wheat and it primarily contributes to the elasticity and plasticity found in wheat dough. The gluten protein networks vary across different types of flours, resulting in different structural properties which will affect the dimension properties of baked goods. Therefore, we hypothesize that using different flours with various gluten concentrations will change the spread of cookies. For this analysis, three flours that vary in their hard and soft wheat composition were chosen: all purpose flour, bread flour, and cake flour. The recipe produced two separate batches, each containing nine cookies, for each flour type group which totalled 54 cookies. To measure the spread of the cookies, the height and diameter were measured for each cookie and then averaged for the cookie flour type. Finally, we calculated the spread ratio to incorporate both variables by dividing the diameter by the height. The results supported our hypothesis that the flour with the highest protein concentration (bread flour) would showcase the least amount of spread while the one with the lowest amount of protein (cake flour) would exhibit the most spread. After conducting a one way ANOVA test, the p-value was discovered to be less than 0.00001, meaning it is less than 0.05 and thus, our results are statistically significant.

Introduction

The modern bread wheat we most commonly know have six sets of chromosomes and were created about 8000 years ago (McGee, 2004). As a result of having extra chromosomes, modern wheats have diversified immensely through varying the elasticity of their gluten proteins. Gluten is the term for the storage proteins found in wheat that are responsible for the structure of wheat dough. For instance, when gluten was discovered by Chinese noodle makers in the 6th century, it was regarded as *mien chin* which can be defined as the "muscle of flour," due to its plasticity and elasticity qualities (McGee, 2004). The various proteins found within gluten are not dissolvable in water but rather form associations with water molecules. As a result, dry dough will have motionless gluten proteins while wet dough will change in shape through the formation and breakage of various bonds. These characteristics allow for the protein molecules to hold firmly in place, contributing to the overall shape and structure of wheat dough.

Depending on the desired result, gluten development will often be limited by bakers as a tough dough is not always preferred. One way of doing so is through using different flours seeing that various wheat types will differ in their content and quality of gluten proteins. For instance, there are hard wheats that have higher amounts of strong gluten proteins while soft wheats produce weak gluten proteins (McGee, 2004). As one can imagine, hard wheats are preferred for bread making due to their strong protein matrix, while soft wheats would be preferred for pastries and cakes. Previous research in the field has primarily analyzed gluten's role in baking by comparing flours that contain gluten to those that are gluten-free (Nurminah & Nainggolan, 2019; Rai et al., 2011). There is a lack of research focusing exclusively on comparing flours with different gluten amounts instead of ones without gluten.

Seeing the major influence gluten properties can have on the quality of food products, we aimed to examine how the quantitative and qualitative properties of baked goods can be affected. For our analysis, we decided to focus on a simple recipe: the chocolate chip cookie. To examine the differences in the protein gluten, we studied three different flours that are known to contain different gluten concentrations: all purpose flour, bread flour, and cake flour. We sought to determine how various flours will affect the spread of cookies by measuring height and diameter, and then calculating the spread ratio. Given that higher gluten concentrations result in tougher dough, we predict the cookies made with bread flour to showcase the least amount of spread while the cookies made from cake flour will spread the most.

Methods

Figure 1: The final baked cookies for each batch: all purpose flour (A), bread flour (B) and cake flour (C).

All-purpose flour was used as the control group, while bread flour and cake flour were considered the treatment groups. The baking consisted of 2 batches that each contained nine cookies for each flour type group, totalling 54 cookies. To measure the spread of cookies in relation to the type of flour used, we followed the same chocolate chip recipe for all experimental groups. The following ingredients were used to make the chocolate chip cookies: ½ cup butter, ½ cup white sugar, ½ cup packed brown sugar, 1 egg, 1 teaspoon vanilla extract, ½ teaspoon baking soda, 1 teaspoon hot water, ¼ teaspoon salt, 188 grams all-purpose flour/bread flour/cake flour, and 1 cup semisweet chocolate chips.

To begin the experiment, the oven was preheated to 350 ℉ after being calibrated. In three separate bowls, butter, white sugar and brown sugar were creamed together until smooth. In each, one egg was added along with vanilla extract. Baking soda was dissolved in hot water separately and added to the three bowls, along with salt. At this point, the three batters were ready to have their respective flours added. First, the control group cookie dough was created. All-purpose flour was added, along with chocolate chips. Nine equally weighted (30.0g ± 2.0g) cookie dough balls were created using a kitchen scale and rolled into a smooth spherically shaped ball. The cookie dough balls were then placed onto a baking pan that was covered in parchment paper which entered the oven. The cookie dough was baked for 12 minutes at 350 ℉ Once the time was up, the freshly baked cookies were left out to cool for 10 minutes before further investigation. This procedure was repeated for the remaining control group batch and then the two batches corresponding to the bread flour treatment group and the two batches corresponding to the cake flour treatment group, which were only differnt in their respective flour types.

After the nine cookies in each batch cooled, their measurements were taken using a measuring tape. The height of the individual cookie was measured at eye level and recorded in centimeters. The same cookie then had its diameter measured in centimeters. The same procedure was done to each cookie in all control and treatment groups, yielding our raw data. The average height and diameter for the cookies of each flour type were then calculated. These values were then used to calculate the spread ratio of each experimental group. The method of calculating the spread ratio is dividing the average value of width (diameter) by the average thickness (height) of the cookies (Altındag et al., 2014). An one-way ANOVA test was then conducted using the calculated spread ratios to statistically analyze our results. We ensured that our data satisfied the ANOVA assumption of a normal distribution and equal variance. This was done to observe if there's any statistical significance in the differences between the means of our flour types.

Results

Flour Type	Diameter (cm)	Height (cm)	Spread Ratio
All Purpose Flour	6.248 ± 0.723	1.897 ± 0.113	3.294 ± 0.418
Bread Flour	6.063 ± 0.504	1.956 ± 0.121	3.099 ± 0.293
Cake Flour	6.598 ± 0.264	1.677 ± 0.098	3.934 ± 0.255

Table 1: The average diameter (cm) and height (cm) of the cookies made from each flour type with the standard deviation. The spread ratio was calculated by dividing the diameter by the height. The standard deviation is included.

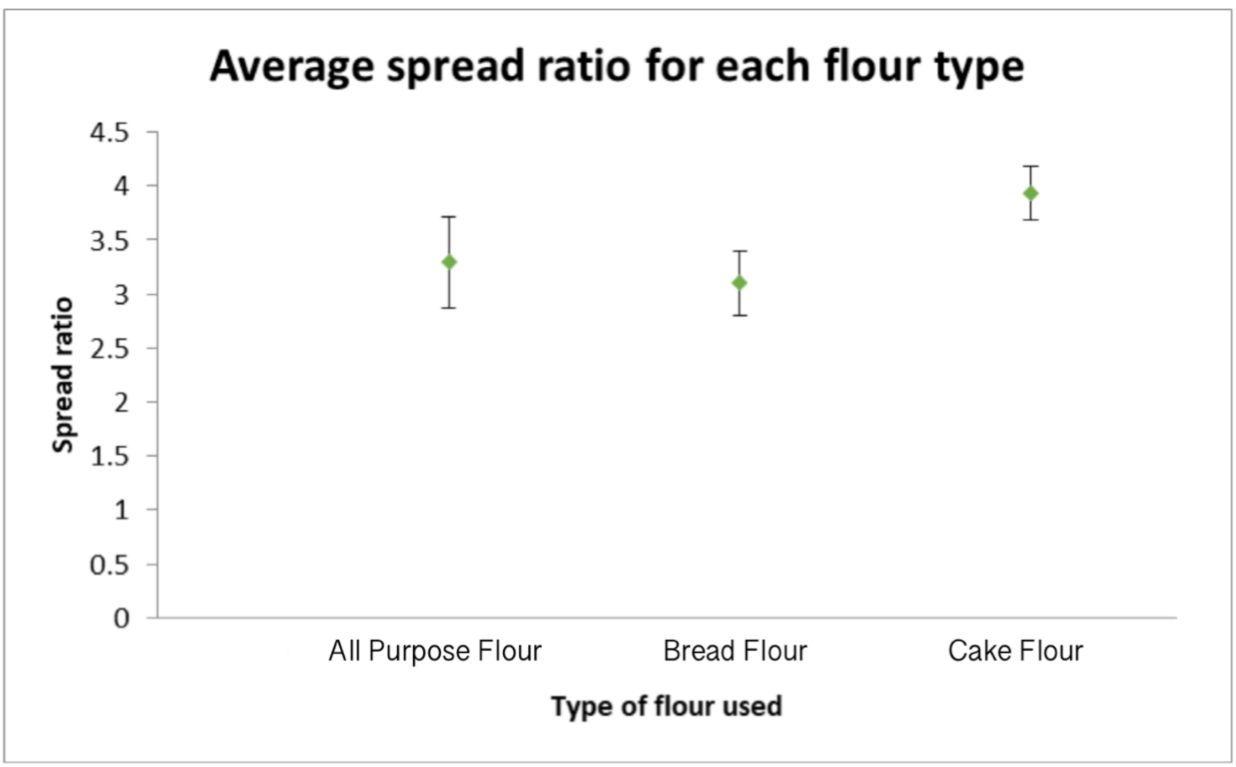

Figure 2: The average spread ratio was calculated by dividing the diameter by the height for each flour type. Error bars with standard deviation are included.

Using the data collected from the experiment, the mean cookie diameter and height were calculated for each flour recipe with their relative standard deviations (Table 1). As showcased, the spread ratio was greatest for the cookies baked with cake flour while cookies baked with bread flour displayed the lowest spread rate (Figure 2). In order to learn if these results are statistically significant, we performed a one-way ANOVA test. The results from the test revealed the p-value to be less than 0.00001 which means the p-value is less than the alpha value of 0.05 and thus, our results are statistically significant. Since the results from our one-way ANOVA revealed our results to be statistically significant while also having a significant f-ratio of 39.4, we ran Tukey's HSD to understand the pairwise significance between the treatment groups. The results suggest that all purpose flour and cake flour ($Q = 8.29$, p-value = 0.00000) significantly differ from one another along with the bread and cake flour ($Q = 10.80$ p-value = 0.00000). The results of the post-hoc test do not showcase all purpose flour and bread flour ($Q = 2.51$, p-value = 0.18712) to differ significantly from one another.

Discussion

Overall, we were able to observe how all-purpose flour, cake flour and bread flour affected the spread of cookies by measuring their height and diameter. As expected, the cookies made using bread flour had the smallest diameter on average, and a height that was slightly taller than the controls on average. The spread ratio of the cookies created using bread flour was the lowest, and lower than the control created by all-purpose flour. As expected, cookies crafted using cake flour had the largest overall spread ratio. These cookies were found to have larger diameters on average as well as shorter heights compared to the other flour types. All-purpose flour had a spread ratio that fits between that of bread and cake flour, with a diameter and height that were in between the other two types on average. These results were expected due to the gluten protein contents of the flour types. For instance, cake flour is known to have the lowest protein content out of the three averaging between 7-9%, while bread flour has the highest with about 12-16% (Al-Dmoor, 2013). All-purpose flour is in the middle with about 10-12% protein content (Rai et al., 2011).

Flour contains wheat which is mixed with water in its creation process; therefore, joining glutenin and gliadin amino acids to form the gluten protein (Shewry et al., 2002). The longer glutenin proteins form disulfide bonds to form strong, stretchy units of molecules. In contrast, gliadin proteins are more compact, allowing for a more fluid motion to take place. When gluten is mixed with water, it creates a matrix-like structure because the starch component of the flour creates space in between the proteins, allowing for a stretchy, elastic texture (Shewry et al., 2002). The gluten matrix within cookie dough is known to hold together both sugar and melted fat, even when fats interfere with the development of gluten since they halt the stretch capacity of gluten strands (Shewry et al., 2002). Additionally, the heat produced from the oven will melt sugars and fats but the gluten presence is what will hold the cookie structure together (Kaur et al., 2014). Therefore, this explains why similar experiments conducted in the past have yielded similar results to our own, where flours with greater gluten amounts yield cookies with harder textures and less spread ratio (Nurminah & Nainggolan, 2019; Kaur et al., 2014).

Furthermore, bread flour has also been found to have significantly more viscosity in dough compared to cake flour after undergoing a hydrothermal treatment (Bucsella, 2015). For instance, cake flour had a lower viscosity value in each case when compared to bread flour in the same study (Bucsella, 2015). During the creation of the cookie dough used in our experiment, it was observed that the bread flour yielded a more dense batter, meaning it was less runny, dry and more elastic in texture. In contrast, the cake flour batter was runnier, stickier and wetter. Previous studies also supported our results because they discovered lower amounts of wet gluten in cake flour compared to bread flour after being treated with water (Buscella, 2015).

Moreover, the amount of starch damage present in the different flour types may also play a role in the structure of the resulting cookies. It has been recorded that the level of soluble starch in flour affects the spread ratio of cookies since higher levels of starch increase dough viscosity, allowing for a smaller spread ratio (Miller et al., 1997). Seeing that bread flour has a 70-73% starch content while cake flour has about 72-74% starch, they share very similar starch contents. Starch damage is a factor that affects the water absorbing properties of flour: more starch damage equates to more water absorbed. Large levels of damaged starch have yielded cookies with smaller diameters and increased dough viscosity (Zucco et al., 2011). Generally, flours with a larger gluten content have more starch damage present. Spread ratio in cookies was found to be negatively affected by damaged starch content in different flour types (Barak et al., 2014). Therefore, starch damage may also play a role in the spread ratio of cookies as it is possible that our bread flour contained the most starch damage out of the three flour types.

On another note, sucrose levels present in the cookies during baking have also been found to affect the spread of cookies depending on how much gluten is present. Cookies with higher gluten content were set earlier in the oven and were found to stop spreading earlier than those with a lower gluten content (Miller & Hoseney, 1997). The ratio of sucrose to protein was higher in lower gluten content flour which in turn affects the spread of cookies. For instance, sugar acts as an anti plasticiser compared to the effects of water, which is plasticing in cookie dough due to its high molecular weight (Miller & Hoseney, 1997). Therefore, seeing that greater gluten-containing flours house more damaged starch and therefore absorb larger quantities of water, it is expected this will yield cookies that spread less. As displayed, sucrose levels present in the cake flour may also explain why our cookies have a larger spread ratio.

An additional potential factor that may have had an effect on the spread ratio of the cookies that was not originally taken into account, is how long and what speed the cookie batter was mixed for. We did not set a specific time for the mixing of the batter, therefore each batch and flour type differed. Fat has the ability to prevent the formation of gluten protein during mixing (Jacob & Leelavathi, 2007). Furthermore, mixing generates air cells and allows for gluten proteins to form as they come into contact with water (Jacob & Leelavathi, 2007). Therefore, due to inconsistent mixing times and speeds, the fat and water content in the cookie dough may not have evenly been dispersed to affect the gluten proteins. As a result, the lack of consistent mixing may have affected our results and yielded cookies with spread ratios that are not comparable. Human error may have also caused variation in our results, such as the accuracy of how the ingredients were measured and how accurately the data was recorded.

Conclusion

Using information from previous studies we predicted that bread flour would have the smallest spread ratio, while cake flour would have the highest due to gluten protein contents. Statistical evidence was then provided that supports our prediction that the type of flour used to bake cookies affects their height and diameter, therefore their overall spread. By using a one-way ANOVA test, the null hypothesis that the flour types would not affect the spread ratio of the cookies was rejected. Therefore, the statistical results of our experiment align with our hypothesis that due to the differing gluten content in the flours we used, the spread of the resulting cookies would be affected. Further research can be done to determine the effects of other factors of flour on the spreading of cookies such as starch damage and sucrose levels.

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