Effect of different edible fats on the spread ratio of sugar cookies

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Abstract

Fats are a crucial ingredient in baked goods as they can change the flavour, colour, texture, spreadability, and nutritional value of the product. For cookies, greater spreadability is considered more desirable. Although butter is typically used to enhance flavour and spreadability of cookies, there are many other types of fats that can be used as substitutes depending on their physicochemical properties and saturated fat content. However, consuming high levels of saturated fat is commonly associated with heart disease. The goal of the study is to determine the effect of saturated fat on cookie spreadability using different fats for healthier susbtitutes. Based on previous studies, cookies with higher saturated fats will have the lowest spread. We hypothesize that different substitute fats will result in different cookie spreads. A sugar cookie recipe was adapted to substitute butter for coconut oil, lard, avocado, and peanut butter with butter as the control. White, dark, semi-sweet chocolate, and sea salt caramel chips were also tested to determine additional spreadability of cookies made with butter. Cookie diameter was measured before and after baking to calculate the spreading ratio. Statistical analysis showed significant differences between all fat substitutes except for lard and butter, which shows that lard is an appropriate butter substitute. The additional fats added in butter cookies also showed a significant difference in cookie diameter ratio between caramel and other treatment groups. However, all chocolate fats were not significantly different from each other. Our results show how saturated fat content can affect cookie spreadability, which can inform butter substitution for healthier options at home or commercially.

Introduction

Lipids, which are a class of organic compounds commonly referred to as fats, are the richest source of energy in the human diet by providing substrates for biologically important synthetic reactions (Sikorski & Kolakowska, 2019). They serve as a carrier of fat-soluble vitamins and other lipophilic substances needed for metabolism. Fats and oils are also a crucial component of many foods, especially bakery products (Devi & Khatkar, 2017). Their reactions contribute significantly to the quality of bakery items as they may impact the flavor, color, texture, spreadability and nutritional value of the product (Sikorski & Kolakowska, 2019). Through thermal treatments such as baking, toasting, or pasteurizing, the chemical and physical properties of fats can be altered depending on the lipid composition and treatment conditions. As a result of the aforementioned alterations, they add their own attributes to various properties of many foods.

In cookie making, the main functional ingredients include flour, sugar, and fat (Maache-Rezzoug et al., 1998). The blending of these ingredients into the dough and the final dough rheology is extremely crucial as it affects processability and quality of cookies (Piteira et al., 2006). Increasing evidence indicates that the viscoelastic properties of the cookie dough is significantly impacted by the type of fats used in cookie formulation (Baltsavias et al., 1997). Previous studies reported that major fats and oils such as butter, lard, palm oil, and coconut oil had radical contributions in cookie quality and characteristics to different extent (Devi & Khatkar, 2016).

Among the rheological properties influenced by the type of fats, spreadability is one of the most fundamental features perceived by the consumers (Prentice, 1972). In general, cookies with higher spreadability (e.g. higher spread ratio) are more desirable according to Suriya et al. (2017), therefore, it is important to understand how different fat and oil types impact the cookie spread. Additionally, the relationship between saturated fats in diet and heart disease has been established since the 1900s (Anitschkow & Chalatow, 1983). As emphasized by the theory of diet-heart hypothesis, heart disease risk can be effectively reduced by restricting saturated fat intake through its ability to lower LDL-c (Sherwin, 1978). Thus, it is crucial to find alternative fats for cookie baking that maximize both cookie desirability and health benefits. By proposing a model of how physicochemical, rheological and functional properties of fats and oils influence the final cookie spread, it sets a solid foundation for future analysis on the molecular basis of cookie properties with different fats and oils.

According to preliminary discoveries, oils with lower saturated fat content tend to increase the dough spreadability in comparison to fats which have higher saturated fat content (Jacob & Leelavathi, 2007; Devi & Khatkar, 2017; Devi & Khatkar, 2016). Therefore, if the cookie rheology is affected by the fat type used, then we would observe different cookie spreadability when different fats or oils are used. If the cookie spreadability is negatively correlated with the saturated fat content, then we would observe significantly higher spreadability in cookies made with fats with lower saturated fat content.

Methods

Ingredients were acquired from various grocery stores in the Vancouver area. Unsalted butter and eggs were taken out of refrigeration to achieve room temperature before baking. Robin Hood® Original All Purpose Flour was used by each experimenter to reduce variation between doughs. Butter, baking soda, baking powder, white sugar, eggs, and vanilla extract were not standardized by brand. Each oven used had been previously calibrated before the experiment and temperature adjusted accordingly. Before baking, all ovens were set to 190ºC (375º F) and left to preheat before cookie insertion. The recipe used was adapted from “Easy Sugar Cookies” at https://www.allrecipes.com/recipe/9870/easy-sugar-cookies/.

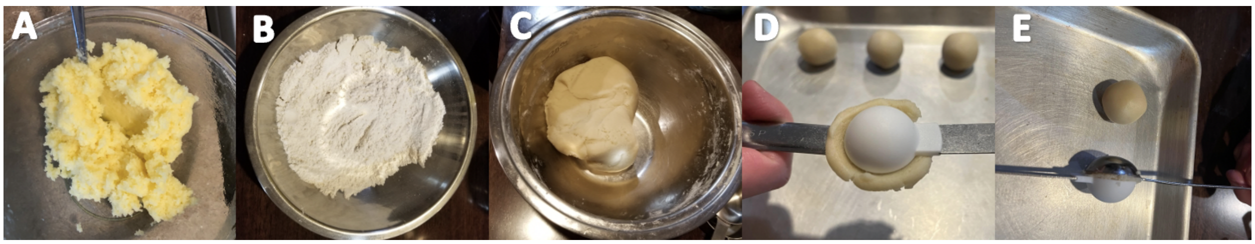

Figure 1. Control Cookies. A. Creamed butter and sugar. B. Dry ingredients. C. Completed dough. D. Dough being formed into a ball with two teaspoons. E. Completed dough ball.

For the control batter, 250.0 ml of room temperature butter and 375.0 ml of white sugar were added together in a bowl. For the Signature Farms Hass Avocado batter, avocados were de-pitted, peeled, and mashed. Next, 250 ml of avocado mash was added in place of butter to the wet mixture. For the Tenderflake Pure Lard, Compliments Smooth Peanut Butter, and Vietcoco Coconut oil batters, 250 ml of each fat was added in lieu of butter to the wet mixture. All subsequent steps are the same for all batters. For treatment batters, some experimenters opted to half the recipe.

Table 1. Ingredients and volumes of control cookies.

Control Ingredients	Volume Added (ml)

Robin Hood® Original All Purpose Flour	687.5
Baking Soda	4.9
Baking Powder	2.5
Unsalted Butter	250.0
White Sugar	375.0
Egg	59.1
Vanilla Extract	4.9

The fat and sugar mixtures were creamed together with a fork or other cooking utensil until a homogenous mixture was achieved (Figure 1A). Next, a room temperature medium egg was cracked in a separate bowl and beaten with a fork. 59.1 ml of the beaten egg was added to the creamed butter and sugar along with 4.9 ml of vanilla extract. This mixture was creamed with a fork until a homogenous batter was achieved. In a separate bowl from the wet ingredients, 687.5 ml of all-purpose flour, 4.9 ml of baking soda, and 2.5 ml of baking powder were added together then mixed with a fork (Figure 1B). Next, half of the dry mixture was added to the wet batter and mixed with a fork till the batter was homogenous. The rest of the dry mixture was then added into the wet mixture and again mixed till homogenous (Figure 1C).

A 10 ml aliquot of batter was used for each cookie (Figure 1D). For the chips treatments (Kirkland Signature Semi-Sweet Chocolate Chips, Hershey chipits dark chocolate, Hershey's Chipits Pure White Chocolate Chips, and Hershey’s Chipits Seasalt Caramel) 3 chips were inserted by hand into half of the control batter aliquots. All subsequent steps are the same for all treatments. Each aliquot was rolled into a ball using one's hands. Cookie dough balls were then evenly spaced on an ungreased metal cooking sheet (Figure 1E). Cookies were then measured for height using a ruler. Next cookies were photographed from a top view with a ruler in frame for later diameter analysis using ImageJ (Figure 2A).

After measurements, the cookie dough balls were placed in a 190º C oven until the cookies had slight browning which took about 10-15 minutes. The cookies were then taken out of the oven and left to cool for 10 minutes before additional measurements were taken. Once cooled, height was taken using a ruler and cookies were photographed from the top view with a ruler in frame for later diameter analysis using ImageJ (Figure 2B).

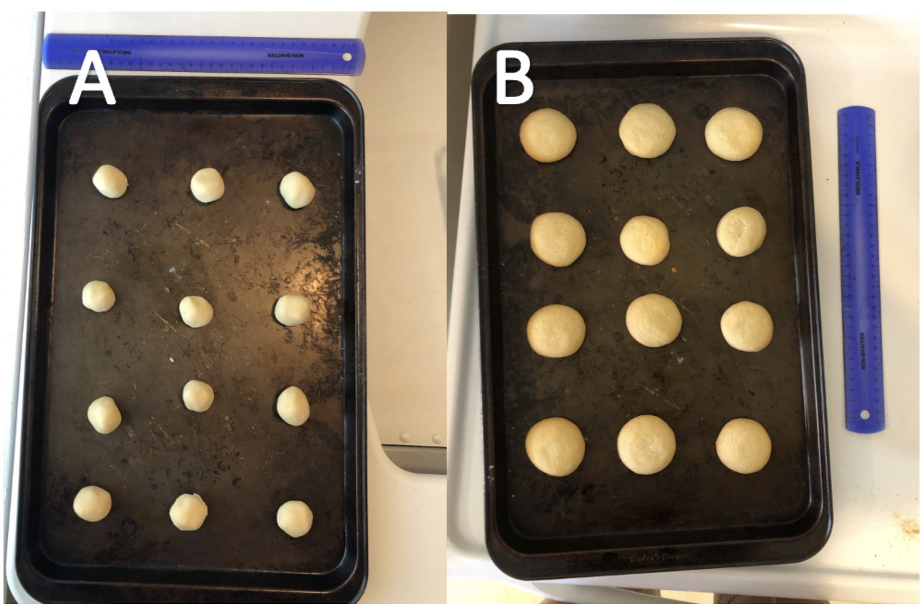

Figure 2. Control Butter Cookies Before and After Baking. Control cookies photographed for diameter analysis via ImageJ. A. Before cooking. B. After cooking.

Cookie diameter was measured using ImageJ. The scale was set using the ruler photographed in frame with the cookies. Cookie diameter was then measured using the straight line tool. Cookie diameters for each treatment were compiled in an excel sheet then were analyzed using an ANOVA in R.

Figure 3. Baked Cookies in order from left to right: Control, Avocado, Peanut butter, Lard, Coconut oil. Images not to scale.

Table 2. Fat content of edible fats and chips used. Fat contents were calculated by dividing serving size by mass of fat on nutrition fact labels. Fat content values for coconut oil and avocado were retrieved from USDA FoodData Central (U.S. Department of Agriculture, 2019).

	Total Fat Content (%)	Saturated Fat Content (%)	Trans Fat Content (%)
Fat			
Dairyland Unsalted Butter	80	50	2
Lactantia Unsalted Butter	80	50	3
Vietcoco Organic Extra Virgin Coconut Oil	99.1	82.5	0.028
Tenderflake Pure Lard	100	40	1
Compliments Smooth Peanut Butter	47	7	0
Haas Avocado	15.4	2.13	0
Chips			
Hershey's Chipits Sea Salt Caramel Chips	30	23	0.7
Hershey's Chipits Dark Chocolate Chips	33	20	0

Hershey's Chipits Pure White Chocolate Chips	27	17	0.7
Kirkland Signature Semi-Sweet Chocolate Chips	30	17	0

Total, saturated, and trans fat content for each fat and chip was calculated by dividing the mass of fat by the serving size as indicated on the nutrition facts label (Table 2). Since avocados are not sold with a nutrition facts label, fat content was calculated from data found on USDA FoodData Central (U.S. Department of Agriculture, 2019). The units of serving size for Vietcoco Organic Extra Virgin Coconut Oil was milliliters and the fat was in grams, so data from USDA FoodData Central was used instead.

Results

After baking the different treatment groups with different fats, there was evident spreading of the cookie in all treatment groups, except for the peanut butter treatment group. The calculated means of cookie diameter ratio before and after is shown in Figure 2 (see Appendix A). Lard has the highest mean cookie spread ratio compared to butter, whereas peanut butter has the lowest. Coconut oil, avocado, and peanut butter all have smaller cookie diameter ratios compared to the control (Figure 3). A one-way ANOVA test was used to test for any significant cookie spread differences between the treatment groups. As ANOVA assumes equal variance and normal distribution, QQplots and the standard deviation were used to confirm assumptions. The results yielded a P-value of 2.2e-16. Since the P-value is less than α (0.05), there are statistically significant differences between the cookie diameter means of different treatment groups. The post-hoc Tukey test revealed that every treatment group was statistically different from the control (butter) and other treatment groups except for the comparison between lard and butter (P = 0.1246).

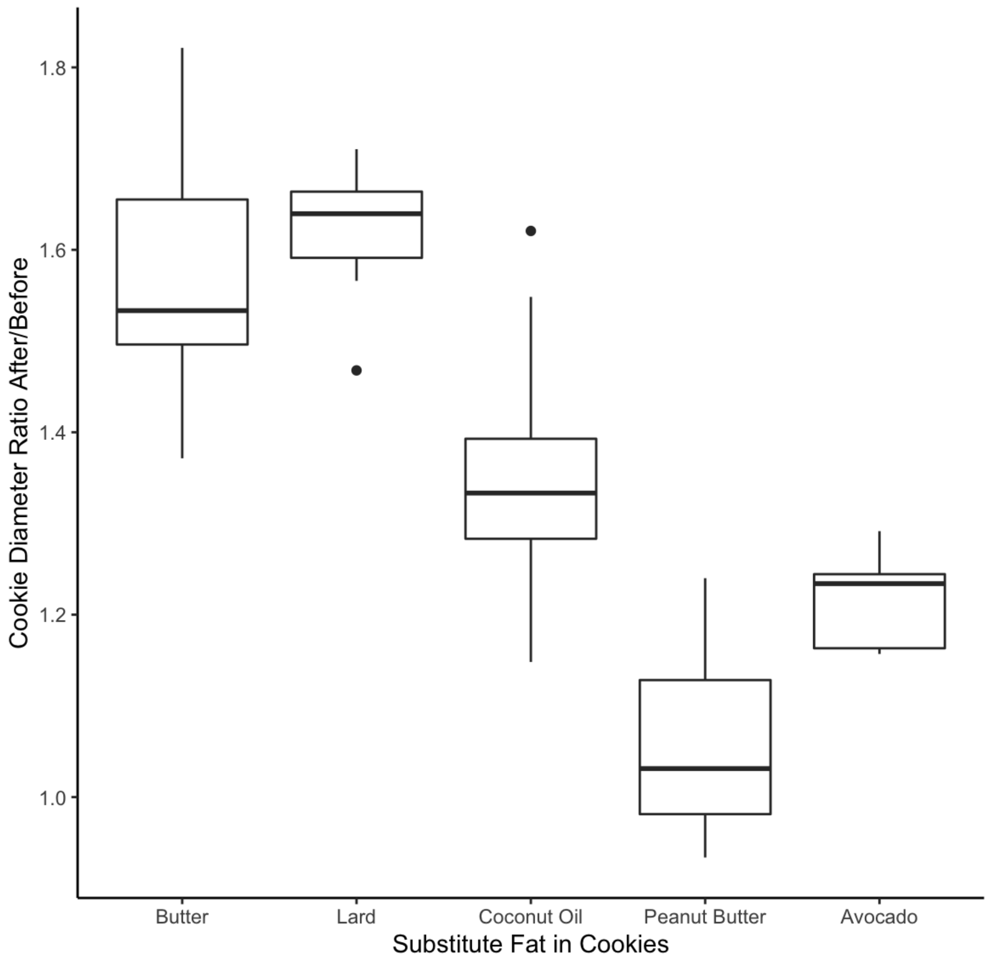

Figure 3. The Mean and Standard Deviation of Cookie Diameter Ratio With Different Fat Substitutes. The calculated mean ratios were 1.57 (σ= 0.109, n = 48) for butter (control), 1.63 (σ= 0.0532, n = 24) for lard, 1.34 (σ= 0.0994, n = 36) for coconut oil, 1.22 (σ= 0.0481, n = 9) for avocado, 1.05 (σ= 0.0894, n = 24) for peanut butter.

Different types of chocolate chips were also used to test the amount of cookie spread in butter cookies including: white chocolate, dark chocolate, and semi-sweet chocolate, and seasalt caramel. Butter cookies were used as control without having any additional fats added. As shown in Figure 4, adding caramel to butter cookies resulted in the greatest cookie diameter ratio, followed by the control. The addition of dark, white, and semi-sweet chocolate did not result in an increase in cookie diameter compared to the control.

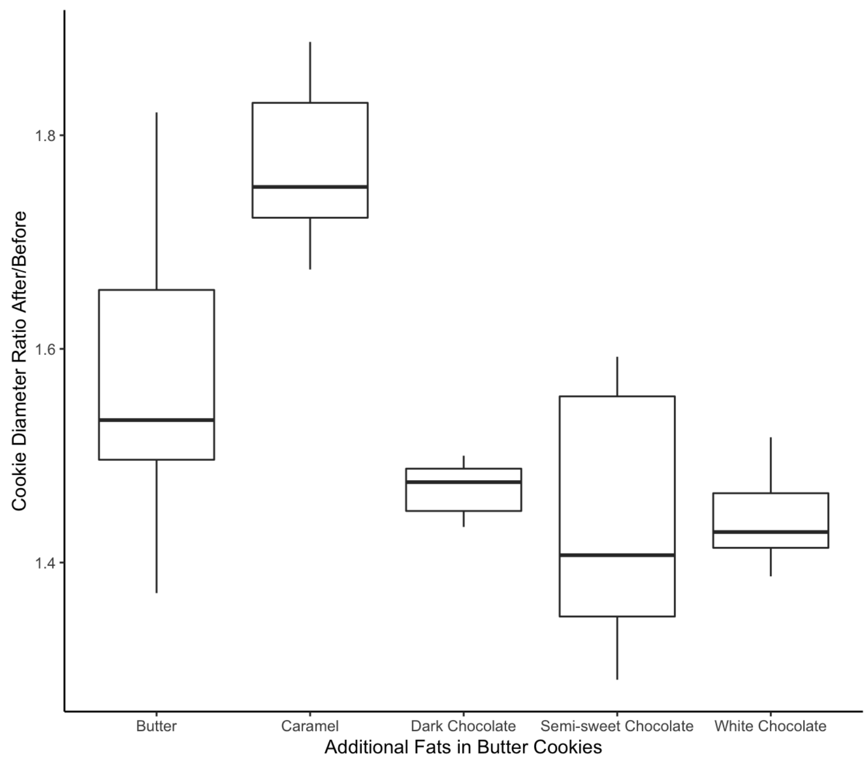

Figure 4. The Mean and Standard Deviation of Cookie Diameter Ratio of Butter Cookies Containing Different Additional Fats. The calculated mean ratios of cookie diameter after and before are 1.57 (σ= 0.109, n = 48) for butter as control, 1.77 (σ= 0.0697, n = 15) for caramel, 1.47 (σ= 0.0259, n = 12) for dark chocolate, 1.44 (σ= 0.111, n = 12) for semi-sweet chocolate, and 1.44 (σ= 0.0396, n = 12) for white chocolate.

A one-way ANOVA test showed that there is a significant difference between the cookie diameter means with the different chocolate chips used (P= 2.2e-16). The post-hoc Tukey test was used to confirm the pairwise significance between the treatment groups (See Appendix E). It showed a significant difference for both butter and caramel when they are each compared to all other treatment groups. There was no significance detected between the pairwise comparisons between semisweet and dark, white and dark, and white and semisweet.

Discussion

Our results showed that the spread ratio of the lard cookies was not significantly different from the spread ratio of the butter control cookies (Figure 3). This result is not surprising because both butter and lard share similar total, saturated, and trans fat contents (Table 2). This finding shows that lard may be a practical substitute for butter in cookies. The coconut oil cookies had a significantly lower spread ratio compared to the butter control cookies (Figure 3) as well as an almost doubled saturated fat content (Table 2). Since cookie spreadability is negatively correlated with the saturated fat content, the decreased spread ratio supports our prediction that significantly higher spreadability in cookies would be observed in cookies made with fats with lower saturated fat content. This findings from other studies investigating fat type and cookie spread showed the same relationship (Jacob & Leelavathi, 2007; Devi & Khatkar, 2018). However, both the avocado and peanut butter cookies had very low saturated fat contents, and had spread ratios that were significantly lower than the spread ratio of the butter control cookies. This result did not support our hypothesis that cookie spreadability is negatively correlated with the saturated fat content. This is likely due to the lower total fat contents of the two edible fats (Table 2). Other components of both ingredients, such as fiber and water in the avocados and protein in the peanut butter, could potentially interfere with the spreadability of the cookies. Additionally, the avocado cookies had sub-par taste and the peanut butter cookies were too dry, suggesting that these ingredients are poor choices to substitute butter with in a 1 to 1 ratio. Difficulty shaping peanut butter, hard to form balls, and avocado, super sticky and wet, and coconut oil, hard and dry, cookies was also observed.

Our results from the cookies with added chips supports our first hypothesis because the addition of chips had a significant effect on mean cookie spread. Specifically, caramel and the chocolate chips had a significant effect (Figure 4). However, the results did not support our second hypothesis, where we hypothesized that fats with lower saturated fat content would increase the amount of spread. Compared to the total fat and saturated fat contents of butter, all four chips used in this study had lower total fat and saturated fat contents. The decreased spreadability of the chocolate chips may be due to their lower total fat contents in comparison to butter (Table 2). The high caramel chip spread ratio was unexpected and may be attributed by the sugar in the chips. Previous research has shown that increasing sugar levels is correlated to an increase in cookie spread (Koh & Noh, 1997), but the white chocolate chips had the greatest amount of sugar and had a low spread ratio. The lower observed spread ratios of the chocolate chips could also be caused by other ingredients in the chips, such as the cocoa, or differences in the way the chips were added between experimental groups that were not controlled for. The effect between the different chocolate chips was not significant, so further could investigate if this trend is true for all types of chocolate (Figure 4). Additionally, different levels of chip melting were observed, which could further explain the spread ratios if quantitatively measured. Further studies shuld further investigate the effect of chocolate and other chips on the spreadability of cookies.

There are many possible sources of uncertainties that may have impacted the results of this study. The brand of baking soda and baking powder were not controlled for, although their impact on the data was probably insignificant since they are not expected to play a role in cookie spreadability. However, the brand of unsalted butter was not controlled for any may have introduced slight variations. Compacting dry ingredients in measuring cups to different degrees may have resulted in differences in amount of dry ingredients, which may have altered the wet/dry ratio of the dough. Ambient room temperature while making dough, cooking sheet thickness and the frequency of opening the oven doors during baking were also not controlled for. Calibrations of the ovens used assumed that the oven temperature error was linear. It is possible that the corrected temperatures were not the same in each oven. An oven thermometer should be used in any further studies using ovens. Different techniques used to make the dough, such as level of creaming the butter and sugar together may have had an effect. All of these factors may have affected the spreadability of the cookies

Future studies should investigate the effect of shortening, ghee, clarified butter, margarine, salted butter, cocoa butter, and various cooking oils on the spreadability of cookies. Different edible fats should also be tested in different cookies recipes, such as chocolate chip and oatmeal cookies. Different substitution ratios should be considered for more practical cookies1:1

butter substitution is not always practical for baking. There are different substitution ratios for different edible fats that are commonly used in hobby cooking.

Overall, we can reject our null hypothesis because all the cookies with different edible fats and chips did not have the same mean spread ratio as the cookies made with butter, with the exception of the lard cookies. The lard cookie spread ratio can be explained by the effect of saturated fat content and total fat content on cookie spreadability. Good substitutes for butter that have similar spreadability have similar total fat content and saturated fat content. This study also highlights the considerations one should make when choosing a fat substitute. Practicality for baking, impact on taste, texture, and spreadability, and risk for heart disease are all important factors to consider when substituting fats in a commercial setting or in the kitchen.

Conclusion

The results of the study suggest that fat substitutes with lower saturated fat content can increase the spreadability of the cookie, however some of the treatment groups with lower fat content did not lead to an increase in spreadability due to other ingredients in the fat substitute.

Acknowledgements

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Appendix

Appendix A: Sample Calculation of Cookie Ratio

Cookie Diameter Ratio: $\frac{Cookie\ Diameter\ After\ Baking\ (cm)}{Cookie\ Diameter\ Before\ Baking\ (cm)}$

Appendix B: ANOVA table for fat substitutes

ANOVA Table	Df	Sum Sq	Mean Sq	F Value	P Value
Treatment of different fats	4	5.9660	1.49151	172.87	2.2e-16
Residuals	136	1.1734	0.00863		

Appendix C: Tukey test summary for fat substitutes

Treatment Comparison	Difference in Mean	P Value <0.05
Butter-Avocado	0.35434330	Yes
Lard-Avocado	0.40981644	Yes
Coconut Oil-Avocado	0.12537230	Yes
Peanut butter-Avocado	-0.16573568	Yes
Coconut Oil-Butter	-0.22897101	Yes
Lard-Butter	0.05547314	No
Peanut butter-Butter	-0.52007899	Yes
Lard-Coconut Oil	0.28444414	Yes
Peanut butter-Coconut Oil	-0.29110798	Yes
Peanut butter-Lard	-0.57555212	Yes

Appendix D: ANOVA table for additional fat substitutes in butter cookies

ANOVA Table	Df	Sum Sq	Mean Sq	F Value	P Value

Treatment of different chocolate chips	4	1.1573	0.289325	34.509	2.2e-16
Residuals	94	0.7881	0.008384		

Appendix E: Tukey test summary for additional fat substitutes in butter cookies

Treatment Comparison	**Difference in Mean**	**P Value <0.05**
Caramel-Butter	0.201340129	Yes
Dark Chocolate-Butter	-0.103942480	Yes
Semi-sweet Chocolate-Butter	-0.137299551	Yes
White Chocolate-Butter	-0.134037455	Yes
Dark Chocolate-Caramel	-0.305282610	Yes
Semi-sweet Chocolate-Caramel	-0.338639681	Yes
White Chocolate-Caramel	-0.335377584	Yes
Semi-sweet Chocolate-Dark Chocolate	-0.033357071	No
White Chocolate-Dark Chocolate	-0.030094974	No
White Chocolate-Semi-sweet Chocolate	0.003262097	No

Appendix F: Fat and Chips treatments and brands.

Fat Treatments			
Signature Farms Hass Avocados	Tenderflake Pure Lard	Compliments Smooth Peanut Butter	Vietcoco Organic Extra Virgin Coconut Oil
Chocolate Chips Treatments			
Kirkland Signature Semi-Sweet Chocolate Chips	Hershey Chipits Dark Chocolate Chips	Hershey's Chipits Pure White Chocolate Chips	Hershey’s Chipits Seasalt Caramel