

THE PHYSICOCHEMICAL, NUTRITIONAL AND SENSORY
PROPERTIES OF COOKIES MADE WITH GREEK YOGURT
AS A FAT REPLACER.

by

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Dissertation submitted in partial fulfillment of the requirements for the
degree of Bachelor of Health Science (Honours) (Nutrition)

January 2026

CERTIFICATE

This is to certify that the dissertation entitled 'THE PHYSICOCHEMICAL, NUTRITIONAL, AND SENSORY PROPERTIES OF COOKIES MADE WITH GREEK YOGURT AS A FAT REPLACER' is the record of research work done by SITI 'ALYAA MAISARAH BINTI ZAHAZUNIZAM, matric number 164025, during the period from August 2025 until January 2026 under my supervision. I have read this dissertation, and in my opinion, it conforms to the acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation to be submitted in partial fulfillment of the requirements for the degree of Bachelor of Nutrition with Honours.

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DECLARATION

I hereby declare that this dissertation is the result of my own investigation, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research, and promotional purposes.

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ACKNOWLEDGEMENT

First and foremost, I would like to express my most sincere gratitude and deepest appreciation to my supervisor, Dr. Marina. I am profoundly grateful for her invaluable guidance, intellectual support, and the immense patience she has shown me throughout the duration of this research. Her expertise, insightful critiques, and constant encouragement not only shaped the direction of this study but also challenged me to grow as a researcher. I am truly honored to have had the opportunity to work under her distinguished supervision.

My deepest gratitude goes to my beloved parents and family. No words can truly express how much I appreciate your endless love, prayers, and sacrifices. Your unwavering belief in my potential and your constant emotional and financial support provided me with the strength to persevere through the most challenging moments of my academic journey. This achievement is as much yours as it is mine.

A very special note of thanks is dedicated to my dear friends: Dalili, Afif, Munira, Elhanna, Yaya, Alya, and Aina. Thank you for being my pillars of strength and for providing the much-needed balance between work and life. From the late-night study sessions to the laughter that eased the stress of research, your presence made this journey significantly more meaningful and bearable. Thank you for your loyalty and for always believing in me.

I would also like to extend my sincere appreciation to the laboratory assistants: Kak Mira, Kak Ila, and Kak Zi. Your technical expertise and assistance were instrumental

in ensuring the smooth progress of my experimental work. I am truly grateful for your kindness, your willingness to share your knowledge, and for creating a helpful environment whenever I faced hurdles in the lab.

Finally, to my lab friends, thank you for the camaraderie and the shared experiences within the laboratory walls. The daily discussions, mutual assistance during long hours of data collection, and the shared struggles of research created a supportive community that I will always cherish. To everyone else who has contributed directly or indirectly to the completion of this thesis, I thank you for your kindness and for being a part of this significant milestone in my life.

Table of Contents

CERTIFICATE.....	2
DECLARATION.....	3
ACKNOWLEDGEMENT	4
List of Tables.....	9
List of Figures.....	10
List of Abbreviations	11
List of Symbols.....	12
ABSTRACT	13
ABSTRAK	14
CHAPTER 1	16
1.0 INTRODUCTION	16
1.1 Background of Study.....	16
1.2 Problem Statement	18
1.3 Objectives.....	19
1.3.1 General Objective.....	19
1.3.2 Specific Objective.....	19
1.4 Research Question	19
1.5 Hypothesis	20
1.5.1 Null Hypothesis	20
1.5.2 Alternate Hypothesis	20
1.6 Significance of Study	20
CHAPTER 2	21
2.0 LITERATURE REVIEW	21
2.1 The Role of Fat in Baking.....	21
2.1.1 The Role of Fat in Cookie Structure, Texture and Flavor.	21
2.1.2 Common Fat Replacers Used in Baked Goods.	21
2.1.3 The Impact of Fat Reduction on the Overall Quality of cookies.....	22
2.2 Greek Yogurt.	23
2.2.1 Composition of Greek Yogurt.....	23
2.2.2 Physicochemical Properties of Greek Yogurt.....	23
2.2.3 Nutritional Profile and Health Benefits of Greek Yogurt	24
2.3 Greek Yogurt as Fat Replacer in Baked Goods.....	25
2.3.1 The Effect of Greek Yogurt on Physicochemical Properties of Baked Goods.	25

2.3.2 The Nutritional Impact of Using Greek Yogurt as a Fat Replacer in Baked Goods.	25
2.3.3 The Sensory Evaluations of Baked Goods Using Greek Yogurt.	26
2.4 The Properties and Quality Attributes of Cookies.	27
2.4.2 Nutritional Aspects of Traditional Cookies.	27
2.4.3 Methods for Evaluating Physicochemical, Nutritional, and Sensory Properties of Cookies.	28
2.5 Ingredients Interactions in Cookies Systems.	29
2.5.1 Fat Interaction with Cookies Ingredients.	29
2.5.2 Greek Yogurt Interactions with Cookies Ingredients.	30
CHAPTER 3	31
3.0 RESEARCH METHODOLOGY	31
3.1 Research Design	31
3.2 Study Area	31
3.3 Subject Criteria	32
3.3.1 Inclusion Criteria	32
3.3.2 Exclusion Criteria	32
3.4 Sample size estimations	32
3.5 Research Tools	32
3.6 Data Collection Method	32
3.6.1 Preparation of Raw Materials	33
3.6.2 Preparation of Cookies	33
3.6.3 Proximate Analysis	35
3.6.4 Determination of Calorie	39
3.6.5 Texture Profile Analysis	40
3.6.6 Physical Properties	40
3.6.7 Colorimeter	42
3.6.8 Sensory Evaluation	42
3.7 Study Flowchart	43
3.8 Data Analysis	44
CHAPTER 4	45
4.0 RESULT AND DISCUSSION	45
4.1 Proximate Analysis	45
4.2 Calorie Content	48
4.3 Texture Profile Analysis (TPA)	49
4.4 Physical Properties of Cookies	50

4.5 Colorimeter.....	52
4.6 Sensory Evaluation	54
CHAPTER 5.....	57
5.0 CONCLUSION	57
RECOMMENDATION	59
LIMITATION.....	60
References.....	62
APPENDIX.....	68
Appendix 1.....	68
Appendix 2.....	70
Appendix 3.....	72
INTRODUCTION.....	72
PURPOSE OF THE STUDY	72
PARTICIPANTS CRITERIA.....	72
STUDY PROCEDURES	73
RISKS	73
REPORTING HEALTH EXPERIENCES.	73
PARTICIPATION IN THE STUDY.....	73
QUESTIONS.....	74
CONFIDENTIALITY	75
SIGNATURES.....	75

List of Tables

Table 3.6: Recipes of Cookies.....	33
Table 4.1: Nutritional Composition of Cookies	46
Table 4.2: Calorie Content of Cookies.....	47
Table 4.3: Texture Profile Analysis of Cookies	48
Table 4.4: Physical Properties of Cookies	50
Table 4.5: Colour Analysis of Cookies.....	51
Table 4.6: Sensory Properties of Cookies	54

List of Figures

Figure 4.5: Colour of Cookies	52
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List of Abbreviations

TPA	Texture Profile Analysis
OECD	The Organization for Economic Cooperataion and Development
ANOVA	One-Way Analysis of Variance
LDL	Low Density Lipoprotein
WHC	Water-Holding Capacity

List of Symbols

H_0	Null hypothesis
H_a	Alternative hypothesis
$^{\circ}\text{C}$	Degree Celsius
$>$	Greater than
$<$	Lower than
cm	Centimeter
%	Percentage
g	Gram
mm	Millimeter
mm/s	Millimeter/second
mL	Milliliter
kcal	Kilo calory

ABSTRACT

The reformulation of baked products with reduced fat content remains a major challenge due to the functional role of fat in determining product quality. This study investigated how replacing butter with Greek yoghurt affected the physicochemical, nutritional, and sensory properties of cookies. Greek yoghurt was used in place of butter at 25%, 50%, and 75% levels in cookie formulations, along with a control formulation. Standard analytical methods were used to analyse the proximate composition, caloric value, texture profile, physical characteristics, colour parameters, and sensory attributes. The quality of cookies was significantly impacted by the substitution of Greek yoghurt ($p < 0.05$). Protein and moisture contents increased as substitution levels increased, while fat and calorie values significantly decreased. Physical analysis revealed that as thickness increased, the diameter and spread ratio decreased, indicating limited dough flow and improved structural setting during baking. Significant differences in hardness and fracturability were found by texture profile analysis, with higher substitution resulting in firmer and less brittle cookies. Increased lightness, redness, and yellowness were found in colour analysis, which was explained by stronger Maillard reactions. Consumer acceptability decreased at higher substitution levels, according to sensory evaluation, but cookies with 25% Greek yoghurt retained favourable sensory qualities. Overall, Greek yoghurt works well as a partial fat replacement in cookies, improving nutritional quality while reducing energy density. Greek yoghurt has the potential to be used in the creation of healthier baked goods; a substitution level of 25% was found to be ideal for striking a balance between health benefits and sensory acceptability.

ABSTRAK

Reformulasi produk bakeri dengan kandungan lemak yang dikurangkan kekal menjadi cabaran utama disebabkan oleh peranan fungsian lemak dalam menentukan kualiti produk. Kajian ini menyiasat bagaimana penggantian mentega dengan yogurt Greek mempengaruhi sifat fizikokimia, pemakanan, dan sensori biskut. Yogurt Greek telah digunakan bagi menggantikan mentega pada tahap 25%, 50%, dan 75% dalam formulasi biskut, bersama dengan satu formulasi kawalan. Kaedah analisis piawai telah digunakan untuk menganalisis komposisi proksimat, nilai kalori, profil tekstur, ciri-ciri fizikal, parameter warna, dan atribut sensori.

Kualiti biskut terjejas secara signifikan oleh penggantian yogurt Greek ($p < 0.05$). Kandungan protein dan kelembapan meningkat seiring dengan peningkatan tahap penggantian, manakala nilai lemak dan kalori menurun secara ketara. Analisis fizikal mendedahkan bahawa apabila ketebalan meningkat, diameter dan nisbah hamparan berkurang, yang menunjukkan aliran doh yang terhad dan penambahbaikan penetapan struktur semasa pembakaran. Perbezaan signifikan dalam kekerasan dan keterpatuhan ditemui melalui analisis profil tekstur, yang mana penggantian yang berlebihan menghasilkan biskut yang lebih keras dan kurang rapuh. Peningkatan kecerahan, kemerahan, dan kekuningan ditemui dalam analisis warna, yang dijelaskan oleh tindak balas Maillard yang lebih kuat. Menurut penilaian sensori, penerimaan pengguna menurun pada tahap penggantian yang lebih tinggi, namun biskut dengan 25% yogurt Greek mengekalkan kualiti sensori yang baik. Secara keseluruhannya, yogurt Greek berfungsi dengan baik sebagai pengganti lemak separa dalam biskut, meningkatkan kualiti pemakanan sambil mengurangkan ketumpatan tenaga. Yogurt Greek mempunyai potensi untuk digunakan dalam penghasilan barangan bakar yang lebih sihat; tahap

penggantian sebanyak 25% didapati ideal untuk mencapai keseimbangan antara manfaat kesehatan dan penerimaan sensori.

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of Study

Greek yoghurt, sometimes referred to as strained yoghurt, is a dairy product that differs from ordinary yoghurt in that it has a thick, creamy consistency that is obtained by straining out the lactose-containing liquid called whey (Burgess, 2024). In comparison to its unstrained counterpart, this produces a yoghurt with a higher protein content and a lower level of lactose and carbohydrates (Leal & Leal, 2025). Greek yoghurt can be used in savoury and sweet recipes, or it can be eaten on its own as a healthy snack. (Anonymous, 2023). Greek yoghurt has many health benefits that have been proven by numerous studies. When paired with resistance training, its high protein content helps to maintain muscle mass and promotes satiety, both of which can help with weight management (Burgess, 2024; Bridge et al., 2019). Probiotics promote a healthy gut microbiota, potentially enhancing digestion and lowering the risk of gastrointestinal problems. Additionally, Greek yoghurt contains calcium and vitamin D, which are vital for healthy bones and the prevention of osteoporosis (Ai, 2024). Some research suggests a link between regular yoghurt consumption and a reduced risk of type 2 diabetes and cardiovascular disease (Moore et al., 2018).

An 8-ounce (226 g) portion of low-fat Greek yoghurt typically has about 150 calories, 19 grams of protein, 5 grams of fat, and 9 grams of carbohydrates, with less than 1 gram of fibre. However, the nutritional value of Greek yoghurt varies based on its fat content. (Anonymous, 2023). The FDA suggests that eating at least two cups (3 servings) of Greek yoghurt per week may lower the risk of type 2 diabetes, but they do not provide specific daily intake recommendations for Greek yoghurt alone (FDA, 2024). Most adults

should consume three cups of dairy per day, including yoghurt, according to the US recommendations. (*MyPlate.gov | Dairy Group – One of the Five Food Groups*, n.d.).

Macronutrient fat has many vital roles in the human body, such as supplying energy, promoting cell division, shielding vital organs, and facilitating the absorption of fat-soluble vitamins (Powell, 2024). Fat is a key ingredient in baking because it affects the cookies' overall mouthfeel, texture, and spread. It prevents gluten from forming by coating flour particles, giving them a crumbly, soft texture (Ferrerias et al., 2011). Excessive consumption of some fats, especially saturated and trans fats, can be detrimental to health even though they serve a functional purpose in food. These fats increase the risk of heart disease and stroke by raising levels of low-density lipoprotein (LDL) cholesterol (Department of Health & Human Services, n.d.).

Cookies are basically little, flat, sweet baked goods that are usually made with flour, sugar, and fat (Gisslen, 2013). The main difference between cookies and cakes, muffins, or cupcakes is the proportions of ingredients and the way they are mixed; cookies have a higher fat-to-flour ratio and less moisture than these other baked goods (Labensky et al., 2019). Due to a higher liquid content and distinct gluten development, cakes and cupcakes are typically lighter and airier than cookies, which have a denser, frequently crispier or chewy texture (Friberg, 2016).

1.2 Problem Statement

Consumers and food manufacturers have been looking for healthier options in baked goods in recent years due to growing awareness of the health risks linked to excessive consumption of saturated fats. Cookies, which are typically high in fat, are consumed in large quantities and make up a substantial portion of the daily fat intake. Although fat is necessary for the mouthfeel, flavour, and texture of cookies, too much of it can be harmful to the nutritional value and health of the consumer. Greek yogurt's nutritional profile and creamy consistency have made it a promising fat substitute in a variety of food products. It is low in fat and high in protein. However, replacing fat in cookies with Greek yoghurt might change their physicochemical makeup, nutritional value, and sensory appeal, which could have an impact on consumer acceptance. Despite growing interest, little scientific research has been done on the overall effects of using Greek yoghurt in place of fat in cookie recipes. To close that gap and ultimately aid in the creation of healthier baked goods without sacrificing quality, this study examines the effects of Greek yoghurt on the texture, nutritional makeup, and sensory aspects of cookies.

1.3 Objectives

1.3.1 General Objective

To investigate the effects of substituting fat with Greek yogurt on the physicochemical, nutritional, and sensory properties of cookies.

1.3.2 Specific Objective

1. To analyze the physicochemical properties of cookies formulated with varying levels of Greek yogurt as a fat replacer.
2. To determine the nutritional composition of cookies made with Greek yogurt in place of traditional fats.
3. To assess the sensory attributes of the Greek yogurt-substituted cookies through a consumer panel evaluation.

1.4 Research Question

1. How does the replacement of fat with Greek yogurt affect the physicochemical properties of cookies?
2. What changes occur in the nutritional composition of cookies when Greek yogurt is used as a fat replacer?
3. How does the substitution of fat with Greek yogurt influence the sensory attributes of cookies as perceived by a sensory panel?

1.5 Hypothesis

1.5.1 Null Hypothesis

H₀= There is no significant difference in physicochemical, nutritional and sensory properties between control cookies and cookies made with Greek yogurt.

1.5.2 Alternate Hypothesis

H_a= There is a significant difference in physicochemical, nutritional and sensory properties between control cookies and cookies made with Greek yogurt.

1.6 Significance of Study

The findings of this study will contribute greatly as it addresses the growing demand for healthier food options without compromising taste and quality. For society, developing cookies with Greek yoghurt as a fat replacer has the potential to reduce unhealthy fat intake, promote better nutritional habits, and contribute to the prevention of diet-related chronic diseases such as obesity and cardiovascular conditions. Furthermore, this study gives students a real-world example of how to use food science concepts to create and enhance common food items, which helps them better understand food chemistry, nutrition, and sensory evaluation. In the meantime, this study can help researchers better understand the functional qualities of Greek yoghurt as a fat substitute, opening the door for more research into substitute ingredients that enhance food quality and healthfulness and furthering the fields of nutrition science and food technology.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 The Role of Fat in Baking

2.1.1 The Role of Fat in Cookie Structure, Texture and Flavor.

According to Manley (2001), the amount of fat added is essential in determining the cookies' flavour profile, texture, and structural integrity. Ghotra *et al.* (2002) state that fat serves as a functional shortening agent by lubricating the flour particles and preventing the development of a strong gluten network, which gives the flour a crumbly and tender texture. Additionally, as noted by Pareyt *et al.*, (2008), fat helps make cookie dough more spreadable during baking, which affects the cookie's final thickness and diameter. According to Jacob & Leelavathi, (2006), fat itself contributes to the overall richness and mouthfeel of the cookie by carrying specific flavour compounds and enhancing the perception of the flavours of other ingredients. These qualities are greatly influenced by the kind and quantity of fat; according to Mamat & Hill, (2012), variations in the solid fat content and fatty acid composition result in variations in the rheology of the dough and the final sensory qualities of the baked product.

2.1.2 Common Fat Replacers Used in Baked Goods.

Extensive research has been conducted on fat substitutes other than yoghurt to create healthier baked goods. Based on research by Yazar & Rosell, (2022); Nikolić *et al.*, (2024) the most popular are carbohydrate-based replacers, which include modified starches, maltodextrins, various dietary fibres (like inulin, pectin, and cellulose derivatives), and hydrocolloid gums. According to Raibagkar *et al.*, (2023), these ingredients frequently work by binding water, giving food a mouthfeel and texture akin

to fat, and adding bulk. The textural characteristics of fat in baked goods can also be replicated by protein-based fat substitutes, such as egg white protein or microparticulate whey, according to Abbas *et al.*, (2024). Furthermore, as noted by Raibagkar *et al.*, (2023), lipid-based fat substitutes, such as structured lipids and emulsifiers, are being investigated to alter the fat composition and enhance the general quality of low-fat products. According to the study Colla *et al.*, (2018), the final baked product's desired textural and sensory qualities as well as the desired level of fat reduction are important factors in choosing a particular fat replacer or combination of them.

2.1.3 The Impact of Fat Reduction on the Overall Quality of cookies.

Cookies' distinctive texture, spread, flavour, and general acceptability are all influenced by fat, which is a critical component of cookie quality. Despite being desirable for nutritional enhancement, lowering the fat content of cookie formulations frequently poses significant challenges in preserving these physicochemical and sensory qualities. According to researcher Pareyt *et al.*, (2008), reducing fat can increase the dough's elasticity and hardness, which can result in cookies that break more firmly and spread less. Fat contributes to the tender texture by preventing the formation of gluten networks; as a result, reducing it may result in a more rigid structure. Additionally, as explained by Swanson & Perry, (2006), the lack of fat can have a detrimental effect on mouthfeel and flavour release, causing products to be perceived as dry or less appetising. Based on research by Swanson & Perry, (2006); Anggraeni *et al.*, (2024), different fat substitutes are investigated to replicate the functional qualities of fat, such as aiding in structure, moisture retention, and desirable sensory qualities, to mitigate these negative effects and create palatable reduced-fat cookies.

2.2 Greek Yogurt.

2.2.1 Composition of Greek Yogurt.

Greek yoghurt is a concentrated dairy product that is well-known for its unique flavour, texture, and high nutritional content. According to Kim *et al.*, (2023), its composition varies based on the milk source and processing techniques, but it typically contains between 79 and 80% moisture, which adds to its creamy consistency. According to Pappa *et al.*, (2024), Greek yoghurt has a higher protein content than regular yoghurt, with an average protein content of 7.4 to 8.0 g per 100 g. Depending on whether the yoghurt is full-fat, low-fat, or non-fat, the amount of fat can vary greatly; according to Pappa *et al.*, (2024), full-fat types have about 6.05 g of fat per 100 g. Based on research by Rashwan *et al.*, (2023), plain Greek yoghurt has 6.6 g of carbohydrates per 100 g, mostly in the form of lactose. A rich source of vital minerals like calcium and phosphorus is indicated by the ash content, which represents the total mineral content and ranges from 1.39 to 1.64 g per 100 g, as explained by Pappa *et al.*, (2024); Kim *et al.*, (2023). Greek yogurt's compositional qualities make it an ideal fat substitute for baked goods like cookies, providing nutritional advantages without sacrificing functionality.

2.2.2 Physicochemical Properties of Greek Yogurt

Greek yoghurt is well known for its distinct texture and structural integrity, which are primarily caused by its physicochemical characteristics. Protein content, fermentation conditions, and storage time are some of the factors that affect viscosity, a crucial determinant of mouthfeel and product stability Hoxha *et al.*, (2023). According to Meletharayil *et al.*, (2016), research has demonstrated that Greek yoghurt has a non-Newtonian, shear-thinning behaviour and viscosity values that vary from 0.25 to 0.74 Pa·s, depending on processing conditions and protein content. Another crucial feature of

Greek yoghurt is its water-holding capacity (WHC), which indicates how well it holds water when subjected to centrifugal forces. In the article by Meletharayil *et al.*, (2016), research shows that Greek yoghurt that has undergone hydrodynamic cavitation exhibits noticeably higher WHC than commercially strained Greek yoghurt, indicating improved texture and moisture retention. Furthermore, as claimed by Karastamatis *et al.*, (2022), Greek yogurt's pH normally falls between 3.7 and 3.8, which influences the formation and stability of protein gels and adds to its distinctive tartness. These physicochemical characteristics are essential for comprehending Greek yogurt's structural and sensory qualities, particularly when it is used to replace fat in cookie recipes.

2.2.3 Nutritional Profile and Health Benefits of Greek Yogurt

Greek yogurt serves as a nutritious fat replacer in cookies, offering a favorable nutritional profile and multiple health benefits. It is rich in protein, which enhances satiety and supports muscle mass, while its lower sugar content compared to regular yogurt makes it a healthier alternative as stated by Burgess, (2024); Digvijay, (2023). The probiotics in Greek yogurt contribute to gut health by promoting beneficial bacteria, and its high calcium content supports bone health based on findings by Burgess, (2024); Digvijay, (2023). Additionally, studies suggest that regular consumption of Greek yogurt may reduce the risk of type 2 diabetes and improve cardiovascular health by regulating blood pressure as said by Yanni et al. (2020). Based on Tastyfables, (2025), Greek yoghurt can effectively lower fat and calorie content while increasing protein levels when used in baking. This is evidenced by recipes that use it in place of butter or oil without sacrificing texture. Studies utilising alternative replacers, such as glucomannan, as noted by Anggraeni et al. (2024), show that such substitutions can preserve sensory acceptability and physical characteristics. Therefore, adding Greek yoghurt to cookies improves their nutritional content and complies with dietary trends that emphasise health.

2.3 Greek Yogurt as Fat Replacer in Baked Goods.

2.3.1 The Effect of Greek Yogurt on Physicochemical Properties of Baked Goods.

The addition of yoghurt to baked product formulations has been demonstrated to affect several important physicochemical characteristics, affecting both overall quality and consumer acceptance. According to research, adding yoghurt can improve texture, frequently resulting in softer crumb and more volume in bread formulations. This may be done by altering the rheology of the dough and simulating the properties of the gluten network, especially in gluten-free applications, as noted by Graça *et al.*, (2020); Graça *et al.*, (2022). Additionally, as reported by Graça *et al.*, (2020); Im *et al.*, (2023), the proteins and exopolysaccharides in yoghurt help to improve its water-holding capacity, which can result in a higher moisture content and a lower staling rate in the finished baked product, extending shelf life. Studies on yoghurt itself indicate that the addition of dairy ingredients and related compounds can affect colour parameters, as explained by Turgut & Diler, (2025), even though the direct effect of plain yoghurt on the colour of baked goods is less well-documented than its effects on texture and moisture. The precise impact on colour in baked matrices would probably rely on the fat content of the yoghurt, the presence of whey proteins, which are capable of Maillard reactions, and how the yoghurt interacts with other ingredients while baking.

2.3.2 The Nutritional Impact of Using Greek Yogurt as a Fat Replacer in Baked Goods.

Greek yoghurt has substantial nutritional benefits when used as a fat substitute in baked goods, mostly because it changes the final product's macronutrient composition. According to Anonymous (2023), studies and nutritional comparisons show that replacing fat with Greek yoghurt can result in a significant increase in protein content

because Greek yoghurt is a concentrated source of dairy protein. Additionally, this substitution successfully lowers the overall fat content, especially saturated fat, which helps to create a healthier fatty acid profile Companaro (2013). As a result, baked products that use Greek yoghurt instead of fat frequently have lower total calorie counts than their conventional counterparts, which is consistent with the need for lower-energy foods as stated by the Juniper, (2025). Greek yoghurt is therefore a useful component for creating baked goods with higher nutritional value.

2.3.3 The Sensory Evaluations of Baked Goods Using Greek Yogurt.

Recent studies demonstrate how Greek yoghurt significantly affects baked goods' sensory attributes, especially texture and moisture retention. According to Desai *et al.*, (2013), Greek yoghurt has distinct sensory qualities that consumers greatly value, such as increased firmness, density, and creaminess, because of its higher protein content and concentrated nature from the straining process. Written by Kristina (2024), Greek yogurt's natural acidity serves as a leavening agent, resulting in lighter and fluffier textures, and its interaction with flour proteins tenderises gluten, creating a softer, more delicate crumb when added to baked goods. In a study by Kristina (2024); Desai *et al.*, (2013), sensory evaluation studies have demonstrated that baked goods made with Greek yoghurt frequently have better mouthfeel, increased moisture, and a richer flavour profile. They also enable a reduction in fat content without sacrificing sensory appeal. Furthermore, as stated by Gyawali *et al.*, (2022); Desai *et al.*, (2013), sophisticated sensory evaluation methods, such as descriptive analysis and consumer acceptance testing, have continuously shown that products containing Greek yoghurt are preferred for their creamy texture, moderate sourness, and overall palatability. These results imply that Greek yoghurt is a useful component for improving baked goods' nutritional value and sensory appeal.

2.4 The Properties and Quality Attributes of Cookies.

2.4.1 Factors Influencing Physicochemical Properties of Cookies.

Various factors, such as the type and quantity of fat substitutes, flour composition, moisture content, and processing conditions, affect the physicochemical characteristics of cookies. Reducing fat, such as by using Greek yoghurt or other fat substitutes like glucomannan and inulin, has a big impact on the moisture retention, spread ratio, cookie texture, and dough rheology. For example, according to research by Lourencetti (2013); Kumar & Sudha (2020); Anggraeni *et al.*, (2024), and others, substituting inulin or glucomannan for some of the fat in dough can enhance its texture and sensory acceptability while lowering its overall lipid content. The physical structure and sensory qualities of the cookie are changed by the interaction between the protein and fibre content added by fat substitutes and the networks of starch and gluten. Furthermore, as Ayşe Özer *et al.*, (2022) point out, composite flours and the addition of dairy products like Greek yoghurt can raise protein content and affect moisture and fat levels, which in turn can affect cookie thickness, spread ratio, diameter, and overall sensory quality. While the fat content regulates mouthfeel and caloric density, the pH and acidity of yoghurt help with leavening and texture modification. When creating reduced-fat cookies that satisfy consumer demands for texture, flavour, and nutritional content, these physicochemical modifications are essential.

2.4.2 Nutritional Aspects of Traditional Cookies.

The nutritional profile of traditional cookies is typically defined by a high fat and carbohydrate content and comparatively low levels of dietary fibre and protein. Recent study research, however, has concentrated on adding plant proteins, seeds, nuts, and flours

high in fibre to cookies to increase their nutritional content. According to research by Martínez *et al.*, (2022); Avila-Nava *et al.*, (2022); Kulthe *et al.*, (2011), these substitutions have been demonstrated to lower the total caloric value of cookies by increasing protein content, dietary fibre, and vital minerals like calcium, iron, and zinc while decreasing fat and simple carbohydrate levels. Additionally, according to a study by Nemš *et al.*, (2022), adding plant-based protein preparations from sources like pea, hemp, pumpkin, and sunflower seeds enhances the amino acid profile, especially by supplementing lysine and threonine, which are frequently lacking in wheat-based products. By adding bioactive compounds with antioxidant qualities, such nutrient-dense ingredients also contribute to functional health benefits that go beyond simple nutrition. Reformulated cookies are a promising way to improve the nutritional value of traditional snack foods since they meet consumer demands for healthier baked goods without sacrificing their sensory acceptability.

2.4.3 Methods for Evaluating Physicochemical, Nutritional, and Sensory Properties of Cookies.

Evaluating the physicochemical, nutritional, and sensory properties of cookies involves a combination of standardized analytical techniques and sensory assessment methods to comprehensively characterize product quality. Physicochemical analyses typically include measurements of moisture content, water activity, texture profile analysis (TPA), and spread ratio, which provide insights into the structural and physical characteristics of cookies, based on findings by Ayşe Özer *et al.*, (2022); Lourencetti, (2013). Nutritional evaluation often involves proximate analysis to determine macronutrient composition-protein, fat, carbohydrates, fiber-and caloric content, alongside mineral profiling using techniques such as atomic absorption spectroscopy or inductively coupled plasma mass spectrometry (ICP-MS) as mentioned by Martínez *et*

al., (2022). A study by Desai *et al.*, (2013); Gyawali *et al.*, (2022) found that sensory evaluation uses both descriptive and consumer acceptance tests. Descriptive analysis uses trained panels to quantify attributes like texture, flavour, aroma, and appearance, while hedonic tests evaluate consumer liking and preference. To validate results, instrumental texture analysis is often correlated with sensory texture perception. These interdisciplinary approaches allow for a comprehensive understanding of how ingredient changes, like using Greek yoghurt in place of fat, affect cookie quality and consumer acceptability.

2.5 Ingredients Interactions in Cookies Systems.

2.5.1 Fat Interaction with Cookies Ingredients.

Fat has a major impact on the final product's texture, structure, and overall quality through its interaction with the cookie ingredients. According to Lourencetti (2013), fat serves as a tenderiser in cookie formulations by coating flour particles, preventing the formation of gluten and producing a softer, crumblier texture. Furthermore, fat helps the dough aerate during creaming by capturing air bubbles that expand during baking to improve volume and lightness. Ayşe Özer *et al.* (2022) found that the interaction between fat and starch affects moisture retention and mouthfeel, contributing to the perceived richness and palatability of cookies. The rheology and baking behaviour of dough are changed when fat is replaced, either completely or partially, by ingredients like Greek yoghurt. Compared to traditional fats, Greek yogurt's protein and moisture content interact with flour ingredients differently, frequently changing the spread ratio, hardness, and sensory qualities as explained by Gyawali *et al.*, (2022). These interactions emphasise how crucial it is to comprehend the various roles that fat plays in cookie systems to

maximize texture and sensory quality, particularly when using healthier fat substitutes like Greek yoghurt.

2.5.2 Greek Yogurt Interactions with Cookies Ingredients.

When Greek yoghurt is substituted for fat in cookie recipes, it interacts with other ingredients in a special way that greatly affects the finished product's physicochemical and sensory characteristics. According to research by Ayşe Özer et al. (2022), Greek yogurt's high protein content and acidity alter the dough matrix by improving protein-starch interactions and aiding in the modification of the gluten network, which may lead to a softer and more tender crumb structure. Greek yogurt's moisture content also influences how the flour ingredients hydrate, which could make the dough stickier and change the spread ratio when baked. Furthermore, Gyawali et al. (2022) found that the lactic acid in Greek yoghurt may function as a mild acidulant, affecting leavening reactions and causing subtle flavour changes that improve the cookies' sensory appeal. These interactions improve the nutritional profile by raising protein content and lowering saturated fat levels while preserving desired textural qualities despite fat reduction. Greek yogurt's ability to serve multiple purposes in cookie systems shows that it can be a useful ingredient that strikes a balance between product quality and health benefits.

CHAPTER 3

3.0 RESEARCH METHODOLOGY

3.1 Research Design

This study utilized an experimental design to investigate the impact of using Greek yogurt as a fat replacer in cookies. Both control cookies prepared with butter and cookies formulated with varying levels of Greek yogurt substitution were analyzed for their physicochemical, nutritional, and sensory properties to determine the effects of the replacement.

3.2 Study Area

Greek yogurt, used as a fat replacer, and other essential cookie ingredients were sourced from local supermarkets near Kubang Kerian, Kelantan. The experimental work for this study was conducted at the School of Health Sciences (Pusat Pengajian Sains Kesihatan), Universiti Sains Malaysia (Health Campus), 16150 Kubang Kerian, Kota Bharu, Kelantan. Cookie preparation was carried out in the food preparation laboratory, while physicochemical, nutritional, and texture profile analyses were performed in the nutrition laboratory. These laboratories were selected due to their adequate sample storage facilities and the availability of equipment required for all planned analyses.

3.3 Subject Criteria

3.3.1 Inclusion Criteria

- Consume cookies.
- Currently enrolled as a student in Year 1 through Year 4 of the School of Health Sciences (PPSK).
- Aged 19 years or older.

3.3.2 Exclusion Criteria

- Have known allergies or sensitivities to any of the ingredients used in the cookies (e.g., flour, sugar, eggs, dairy products from Greek yogurt).
- Feeling sick or unwell, particularly if it affects their sense of taste and smell, at the time of the sensory evaluation.

3.4 Sample size estimations

In laboratory testing, 25 to 50 subjects per product were considered sufficient for sensory evaluation sessions, as reported by Hough et al. (2006); Aminah et al. (2000). Therefore, a total of 50 participants were recruited for this study.

3.5 Research Tools

The research tool used in this study was a sensory evaluation form.

3.6 Data Collection Method

Cookies formulated with Greek yogurt as a fat substitute were prepared in the food preparation laboratory of the School of Health Sciences and subsequently stored in the nutrition laboratory. The nutritional composition, caloric content, and texture profile of each cookie sample were analyzed, and all data were systematically recorded using

Microsoft Excel. Following these objective analyses, sensory evaluation was conducted for each cookie sample. Sample preparation for analysis was carried out using specific procedures appropriate to each test type, including physicochemical, nutritional, and sensory analyses.

3.6.1 Preparation of Raw Materials

The main ingredients for making cookies in this study, especially the Greek yoghurt that was used as a fat substitute, as well as other necessary baking ingredients (such as flour, sugar, butter, and eggs), were purchased from nearby supermarkets in Kubang Kerian, Kelantan. The Greek yoghurt and any other perishable ingredients were stored in a refrigerator in Universiti Sains Malaysia (USM) Health Campus's food preparation laboratory after they were purchased until they were further processed for cookie making.

3.6.2 Preparation of Cookies

3.6.2.1 Preparation of Greek Yogurt

The commercially purchased Greek yoghurt was gently stirred to achieve a uniform consistency prior to being weighed and added to the cookie dough to guarantee consistency in its use as a fat substitute. According to Uysal et al. (2003), the total solids content and overall consistency of yoghurt are known to have a significant impact on the final product characteristics in food formulations, making this step essential for maintaining consistent physicochemical and sensory properties across all experimental batches.

3.6.2.2 Recipe of Cookies

Ingredients	Control	25% Greek Yogurt	50% Greek Yogurt	75 % Greek Yogurt
Salted butter	1 cup	$\frac{3}{4}$ cup	$\frac{1}{2}$ cup	$\frac{1}{4}$ cup
All-purpose flour	3 cups	3 cups	3 cups	3 cups
White Sugar	$\frac{1}{2}$ cup	$\frac{1}{2}$ cup	$\frac{1}{2}$ cup	$\frac{1}{2}$ cup
Brown Sugar	$\frac{1}{2}$ cup	$\frac{1}{2}$ cup	$\frac{1}{2}$ cup	$\frac{1}{2}$ cup
Large Eggs	2 eggs	2 eggs	2 eggs	2 eggs
Vanilla Extract	2 teaspoons	2 teaspoons	2 teaspoons	2 teaspoons
Baking Soda	2 teaspoons	2 teaspoons	2 teaspoons	2 teaspoons

Table 3.6 shows recipe of cookies

3.6.2.3 Procedure

In a large mixing bowl, the softened salted butter and Greek yogurt were creamed with sugar and brown sugar at medium speed until the mixture became light in texture and pale in color. Eggs and vanilla extract were then added one at a time, with mixing performed at low speed until fully incorporated. In a separate bowl, flour, baking soda, and salt were combined. The dry ingredients were gradually incorporated into the creamed mixture to form the cookie dough. The prepared dough was chilled in the refrigerator for one hour. For baking, the oven was preheated to 190 °C. The dough was shaped using a piping tube and placed onto ungreased or parchment-lined baking sheets.

The cookies were baked for 9 to 11 minutes or until golden brown. Before analysis, the baked cookies were cooled in sealed bags, as described by Strahs and Strahs (2013).

3.6.3 Proximate Analysis

3.6.3.1 Determination of Moisture Content

The moisture content of the cookie samples was determined using the air-oven method. A precisely weighed portion (approximately 5 g) of each homogenized cookie sample was placed into a pre-weighed, dried dish. The dishes containing the samples were dried in a hot air oven at 105 °C overnight. After the initial drying period, the dishes were removed from the oven and immediately transferred to a desiccator to cool to room temperature. The dishes were then weighed. This drying, cooling, and weighing process was repeated until a constant weight was attained, defined as a negligible difference between two consecutive weighings (typically less than 0.0005 g). The moisture content of the sample was expressed as the percentage loss in weight, calculated from the difference between the initial wet weight of the sample and its final constant dry weight after the drying process. The moisture content was calculated using the following formula:

$$\text{Moisture (\%)} = \frac{w_1 - w_2}{w_1} \times 100$$

w_1 = weight (g) of sample before drying

w_2 = weight (g) of sample after drying

3.6.3.2 Determination of Ash

The ash content of the cookie samples was determined using the dry ashing method. For this analysis, representative homogeneous cookie samples were obtained by grinding the cookies into a fine powder. A carefully weighed portion of the prepared sample (approximately 1–10 g) was used for ash content determination. When the cookie samples had high moisture or fat content, they were pre-dried or defatted using solvent extraction, respectively, to prevent spattering during the ashing process. To avoid mineral contamination, all glassware, crucibles, and grinding tools used during the analysis were thoroughly cleaned. Deionised water was used for all related sample preparation procedures.

A sanitised shallow crucible was dried in an air oven at 105 °C for three hours. After cooling to room temperature in a desiccator, the crucible was precisely weighed to obtain its constant weight (W1). Approximately 0.500 ± 0.001 g of the prepared cookie sample was then accurately weighed into the pre-weighed crucible, and the combined weight was recorded as W2. The crucible containing the sample was carefully pre-ashed on an electronic coil heating rack until smoking ceased. Subsequently, the crucible was transferred to a cold muffle furnace and gradually heated to 550 °C. Complete combustion was indicated when the residue appeared ash-coloured or greyish. After ashing, the crucible was allowed to cool inside the muffle furnace to a safe handling temperature and was then transferred to a desiccator to cool to room temperature. The crucible containing the ash was weighed to obtain the final constant weight (W3). Heating in the muffle furnace was repeated until a stable weight was achieved, indicating complete ashing. The total ash content of the cookie samples was calculated using the following formula:

$$\% \text{ Ash} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

$$= \frac{(W3 - W1)}{(W2 - W1)} \times 100$$

3.6.3.3 Determination of Protein

The Kjeldahl method was used to determine the total nitrogen content of the cookie samples, which was then used for calculating the protein content. A Kjeldahl digestion flask was filled with a precisely weighed 1.000 ± 0.001 g of homogenised cookie sample. The digestion flask was then carefully charged with 20 mL of concentrated sulphuric acid and two catalyst tablets. A blank sample containing only sulphuric acid and catalyst tablets, without the cookie sample, was also prepared for correction. The mixture in the digestion flask was heated on an electronic coil heating rack inside a fume cupboard, positioned at an angle. After initial frothing subsided, the solution was heated to approximately 400 °C for about 60 minutes, or until boiling occurred at an appropriate rate. Heating was discontinued once digestion was complete, as indicated by the solution becoming clear and colourless.

The digest was allowed to cool for approximately 30 minutes or until it reached room temperature. The contents of the digestion flask were then quantitatively transferred to the distillation unit along with the receiver flask. The unit was primed by passing steam through it for three to four minutes prior to distillation. Distilled ammonia was collected in a receiving flask containing a known volume of boric acid solution and an indicator. The collected distillate was titrated with 0.1 N standardized hydrochloric acid until the indicator returned to its initial purplish colour. The prepared blank digest underwent the

same distillation and titration procedures. Protein content was calculated using the following formula:

$$\% \text{ Protein} = \frac{(\text{ml HCL} - \text{ml HCL blank}) \times 14.008 \times 0.1 \text{NHCL} \times \text{protein factor}}{\text{Weight in mg of the sample}} \times 100$$

3.6.3.4 Determination of Fat

The Soxhlet extraction method was used to determine the fat content of the cookie samples. Prior to extraction, the cookie samples were dried to enhance fat extraction efficiency. The dried samples were subsequently ground and homogenised into a fine powder to maximise extraction efficiency by increasing the surface area of lipids exposed to the solvent. To minimise lipid oxidation, the grinding process was carried out at a moderate temperature. A dry extraction thimble was filled with a precisely weighed 3.000 ± 0.0001 g portion of the prepared cookie sample and placed inside the Soxhlet extraction apparatus. The extraction setup included a clean extract collection flask that had been pre-dried to a constant weight (W1). Subsequently, 80 mL of petroleum ether was added as the extraction solvent.

Once the extraction apparatus was fully assembled and sealed, the heating unit was switched on and cooling water flow was initiated. When the solvent began to boil, the system was set to the immersion phase, allowing the thimble to be completely submerged in the boiling solvent. After approximately 30 minutes of immersion, the thimble was raised and the system was shifted to the washing (reflux) phase to allow continuous solvent reflux. After about 30 minutes of reflux washing, the stopcock beneath the water-cooled condenser was closed, enabling the solvent to evaporate fully from the

extraction vessel and collect in the receiving flask. Following extraction, the extract collection flask containing the crude fat was placed in a high-temperature oven for approximately 45 minutes to ensure complete removal of residual solvent. The flask was then transferred to a desiccator and allowed to cool to room temperature before recording its final constant weight (W2). The fat content was calculated using the following formula:

$$\begin{aligned}\% \text{ Fat} &= \frac{\text{Weight of fat (g)}}{\text{Weight of sample (g)}} \times 100 \\ &= \frac{(W2 - W1)}{\text{Weight of sample (g)}} \times 100\end{aligned}$$

3.6.3.5 Determination of Carbohydrate

The total of carbohydrate content was calculated by using formula:

$$\% \text{ total carbohydrate} = [100\% - (\text{moisture} + \text{fat} + \text{ash} + \text{protein})]$$

3.6.4 Determination of Calorie

A bomb calorimeter was used to measure the caloric content of the cookie samples. A representative cookie sample weighing 1.000 ± 0.001 g was accurately weighed for analysis. To ensure sample homogeneity, the sample was freeze-dried and finely ground. The prepared sample was then compressed into a pellet using a pelleting press, as described by Flowers et al. (2019). After placing the pelleted sample into the crucible, the decomposition vessel was assembled and inserted into the filler head of the bomb calorimeter measuring cell, and the measuring cell was sealed. Upon completion or interruption of the combustion measurement, the inner vessel was carefully emptied. The bomb calorimeter signalled the end of the measurement cycle, after which the

decomposition vessel was removed from the measuring cell. The venting button was then used to safely release the pressure within the decomposition vessel, preferably under a laboratory fume hood. The decomposition vessel and crucible were inspected for any residues of unburned sample to detect incomplete combustion. In cases of incomplete combustion, the measurement was repeated according to standard operating procedures, and the affected results were discarded.

3.6.5 Texture Profile Analysis

A TA.XTPLUS texture analyser was used to evaluate the texture characteristics of the cookie samples. Each cookie sample was prepared into a standardised shape or section to ensure uniform thickness and consistency during testing. The samples were subjected to a double compression test using a cylindrical probe with a diameter of 2 mm, fitted with a 5 kg load cell, and a heavy-duty platform with a hole plate was employed to measure the cookies' hardness and fracturability. The test was conducted at a constant speed of 0.5 mm/s, with pre-test and post-test speeds set at 1.0 mm/s and 10.0 mm/s, respectively. Each sample was compressed to 25% of its original height. Instrumental texture parameters, including hardness and fracturability, were measured in triplicate.

3.6.6 Physical Properties

3.6.6.1 Determination of cookies' thickness, diameter and spread ratio

To calculate the average diameter of the cookies, six cookies were randomly selected and arranged edge-to-edge in a straight line. The total length of the six cookies was measured in one direction (horizontal) and recorded as L_1 . The same six cookies were

then rotated by 90° and rearranged in a straight line, and the total length in the perpendicular direction (vertical) was measured and recorded as L_2 . The sum of these two measurements ($L_1 + L_2$) was divided by 12, representing six cookies measured in two directions, to obtain the average diameter per cookie. To determine the average thickness (height), the same six cookies were stacked vertically, and the total height of the stack was measured and recorded as H_1 . The cookies were then restacked, and the height was measured again as H_2 . The sum of these two height measurements ($H_1 + H_2$) was divided by 12, representing six cookies measured twice, to calculate the average thickness per cookie. This method provided a reliable and representative measurement of the cookies' dimensions, which was essential for evaluating physical properties such as the spread ratio.

The spread ratio was calculated by dividing the average diameter by the average thickness. This ratio, which reflects the shape and texture of the cookie, served as an important physical quality indicator of cookie spread during baking. In general, cookies with higher spread ratios were thinner and wider, characteristics often preferred in sensory evaluation. This method ensured accurate assessment of the physical properties of cookies formulated with fat substitutes such as Greek yogurt and was consistent with established protocols reported in cookie quality studies, including those by Chauhan et al. (2016). The spread ratio was calculated using the following formula:

$$\text{Spread Ratio} = \frac{\text{Average diameter (cm)}}{\text{Average thickness (cm)}}$$