

**PROXIMATE COMPOSITION, PHYSICAL AND SENSORY
EVALUATION OF COOKIES MADE FROM WHOLE WHEAT
FLOUR INCORPORATED WITH FLAXSEED
(*Linum usitatissimum*) FLOUR**

by

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Dissertation submitted in partial fulfillment of the requirements
for the degree of Bachelor in Nutrition with Honours

January 2026

CERTIFICATE

This is to certify that the dissertation entitled Proximate Composition, Physical and Sensory Evaluation of Cookies made from Whole Wheat Flour Incorporated with Flaxseed (*Linum usitatissimum*) Flour is the bona fide record of research work done by Nur Anis Nadhirah Binti Zameri during the period of September 2025 to January 2026 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfillment for the degree of Bachelor of Health Science (Honours) (Nutrition).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole 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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LIST OF ABBREVIATIONS

AB	Arabinoxylan
ALA	Alpha-linoleic Acid
AOAC	Association of Analytical Communities
BMI	Body Mass Index
β-glucan	Beta-glucan
Cu	Copper
CVD	Cardiovascular Disease
Fe	Iron
FSF	Flaxseed flour
GI	Glycemic Index
HCL	Hydrochloric Acid
H ₂ SO ₄	Sulfuric Acid
K	Potassium
Mg	Magnesium
Mn	Manganese
Na	Sodium
NaOH	Sodium Hydroxide
NCD	Non-communicable Disease
NHMS	National Health Morbidity Survey
P	Phosphorus
T2DM	Type-2 Diabetes Mellitus
WWF	Whole Wheat flour
Zn	Zinc

LIST OF SYMBOLS

%	Percentage
°C	Degree Celsius
g	gram
ml	milliliter
mm	millimeter
N	Newtons

**KOMPOSISI PROKSIMAT, PENILAIAN FIZIKAL
DAN SENSORI BISKUT BERASASKAN TEPUNG
GANDUM PENUH YANG DIGABUNGKAN DENGAN
TEPUNG BIJI RAMI (*Linum usitatissimum*)**

ABSTRAK

Peningkatan yang meluas terhadap penyakit tidak berjangkit dan pengambilan serat diet yang rendah telah menyebabkan permintaan yang semakin meningkat untuk makanan berfungsi yang memberikan manfaat kesihatan melangkaui nutrisi asas. Sebagai snek yang konvensional, biskut kebiasaannya tinggi gula dan lemak, namun masih kekurangan nutrien penting seperti serat diet. Biji rami dipilih kerana ia mempunyai potensi manfaat untuk digunakan di dalam biskut kerana sifat teksturnya yang hampir sama dengan biskut konvensional. Kajian ini bertujuan untuk menentukan komposisi, sifat fizikal, dan penerimaan deria biskut yang diperbuat daripada tepung gandum penuh yang digabungkan dengan tahap peratusan tepung biji rami (*Linum usitatissimum*) yang berbeza. Selain itu, empat formulasi biskut telah disediakan dengan tahap peratusan tepung biji rami yang berbeza, dengan nisbah tepung gandum penuh kepada tepung biji rami yang berbeza: biskut gandum penuh kawalan T0 (100:0), manakala tiga sampel eksperimen yang lain, T1 (95:15), T2 (90:10), dan T3 (85:15). Data dianalisis menggunakan ANOVA sehalu. Keputusan menunjukkan bahawa peningkatan tahap tepung biji rami dengan ketara ($p < 0.05$) meningkatkan kandungan serat, protein, dan lemak biskut berbanding sampel kawalan. Tambahan pula, peningkatan penggabungan tepung biji rami juga mempengaruhi sifat fizikal, terutamanya tekstur dan nisbah sapuan.

Penilaian deria menunjukkan bahawa biskut yang mengandungi tepung biji rami secara amnya boleh diterima, dengan formulasi yang mengandungi 15% tepung biji rami mencapai penerimaan keseluruhan tertinggi di kalangan semua sampel. Tahap optimum ini memberikan keseimbangan yang baik antara nilai pemakanan yang dipertingkatkan dan pilihan pengguna, terutamanya dari segi tekstur, rasa dan kerangupan. Oleh itu, kajian ini menunjukkan bahawa biskut gandum penuh yang diperkaya dengan tepung biji rami menunjukkan peningkatan yang ketara dalam kualiti pemakanan, terutamanya serat makanan, protein dan kandungan lemak sihat, malah mengekalkan sifat deria yang boleh diterima oleh pengguna. Penemuan ini menunjukkan bahawa biskut gandum penuh yang diperkaya dengan biji rami mempunyai potensi yang kuat sebagai makanan ringan berfungsi yang boleh menyumbang kepada pengambilan serat makanan yang lebih baik dan menyokong kesihatan keseluruhan.

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ABSTRACT

The increasing prevalence of non-communicable diseases and low consumption dietary fibre intake has led to a growing demand for functional foods that offer health benefits beyond basic nutrition. Conventional snacks such cookies are typically high in sugar and fat, however lack in essential nutrients such as dietary fibre. Flaxseed was chosen because it has the potential benefits to be used in cookies due to its texture properties that are closely similar to conventional cookies. This study aimed to determine the proximate composition, physical properties, and sensory acceptability of cookies made from whole wheat flour incorporated with different percentage levels of flaxseed (*Linum usitatissimum*) flour. Thereafter, four cookie formulations were prepared with different percentage level of flaxseed flour, with different ratios of whole wheat flour to flaxseed flour: control whole wheat cookies T0(100:0), while the other three experimental samples, T1 (95:15), T2 (90:10), and T3 (85:15). Data were analysed using one-way ANOVA. The results showed that increasing levels of flaxseed flour significantly ($p<0.05$) improved the fibre, protein, and fat content of the cookies compared to the control sample. Furthermore, increasing incorporation of flaxseed flour also influenced the physical properties, particularly texture and spread ratio. Sensory evaluation indicated that cookies containing flaxseed flour were generally acceptable, with the formulation

containing 15% of flaxseed flour achieved the highest overall acceptability among all samples. This optimal level provided a favourable balance between enhanced nutritional value and consumer preference, particularly in terms of texture, taste, and crispiness. Thus, this study demonstrated that whole wheat cookies enriched with flaxseed flour demonstrated a significant improvement in nutritional quality, especially dietary fibre, protein, and healthy fat content, while maintaining acceptable sensory attributes for consumers. These findings suggest that flaxseed-enriched whole wheat cookies have strong potential as a functional snack food that may contribute to improved dietary fibre intake and support overall health.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

There has been a significant increase in health-conscious food choices among consumers, largely influenced by developments in the global food industry. This shift has led to a growing demand for functional foods, as such products are formulated with a variety of nutrient-dense ingredients to provide benefits beyond basic nutritional requirements (Temple, 2022; Essa et al., 2021). Consequently, advancements in functional food product development have attracted major consumer interest and contributed to the rapid growth of the functional food market. Cookies, traditionally perceived as indulgent snack foods, have increasingly emerged as a novel vehicle for the incorporation of health-promoting ingredients (Chuk et al., 2022; Tarahai et al., 2023; Walsh et al., 2023; Nerin et al., 2024). Among baked product categories, which include bread, rolls, pies, pastries, biscuits and muffins, cookies are particularly suitable as commonly consumed snacks due to their convenience, extended shelf life and widespread consumer acceptance across different age groups. In Southeast Asia, biscuits and cookies are widely consumed, with nearly half of consumers reporting intake of sweet biscuits or cookies at least once per day, often to satisfy cravings, as a form of self-reward, or to enjoy their appealing taste and texture (Food Navigator Asia, 2024). A recent study in Malaysia (Noor et al., 2024) found that 95.3 % of respondents like eating biscuits, and about 74.5 % consume biscuits more than once per week, with many eating them multiple times weekly.

In Malaysia, there is a growing demand for healthy snacking choices including cookies, driven by the trend towards convenient food options. The development of products such as high-fibre, gluten-free, and sugar-free cookies, demonstrates the food industry's response to public concern over diet-related health issues. However, frequent consumption of biscuits which are often high in added sugars and refined carbohydrates, can lead to repeated spikes in blood glucose and insulin levels. Epidemiological studies have shown that diets high in added sugars and low in fibre are associated with an increased incidence of diabetes (Malik et al., 2010; Imamura et al., 2015). Additionally, the timing of biscuit consumption may affect the overall nutritional quality of the diet, as regular snacking on biscuits can potentially reduce the intake of fruits and vegetables (Zizza & Xu, 2012). Hence, increased consumer awareness of the possible relationship between nutrition and health that has driven substantial changes in dietary behaviour, leading people to choose healthier food options to enhance their overall well-being (Das et al., 2021).

Whole wheat is a nutritious grain rich in carbohydrates (approximately 68.5%), contains a significant amount of dietary fiber (11.3%), a good range of protein (8.9–12.6%), and a small amount of fat (1.2–2.0%). It also provides various beneficial micronutrients, including phenolic acids, flavonoids, gluten, lignan, folate, vitamin E, magnesium, and selenium (Adom et al., 2005; Dalton et al., 2012; Qu et al., 2005). Due to its high content of dietary fiber and phytochemicals, whole wheat flour (WWF) has attracted increasing interest in recent years (Y. Zhu & Sang, 2017). Arabinoxylan (AX), the main non-starch polysaccharide in WWF, is recognised for its potential health benefits (Zannini et al., 2022). AX is commonly categorised based on its water solubility into water-extractable AX (WEAX) and water-unextractable AX (WUAX) (Zannini et al.,

2022). Despite significant efforts to encourage the consumption of whole grains, refined flour remains the primary ingredient in most wheat-based foods, particularly in developed countries. The whole wheat flour market saw an increase in sales at a compound annual growth rate (CAGR) of 3.7% from 2020 to 2024. This positive trend is expected to continue, with a projected CAGR of 4.7% during the forecast period from 2025 to 2035 (Future Market Insights, 2025). The increasing demand for whole wheat flour is mainly influenced by its recognition as a natural functional food and its key main role within the broader healthy living trend. This growing consumer preference for healthier dietary options is influenced by several key challenges related to whole grain products. Firstly, whole grain products are often perceived as having less appealing sensory attributes. Secondly, public understanding of their considerable health advantages remains limited. Thirdly, the food industry may be hesitant due to a greater potential for contamination with mycotoxins and pesticide residues (Gomez et al., 2020). In contrast, whole wheat flour preserves the bran and germ of the grain, which are higher in dietary fiber, vitamins, and minerals compared to refined flour. Incorporating whole wheat into baked goods can help increase overall fiber intake and support bowel regularity.

Flaxseed (*Linum usitatissimum* L.), also known as flax or linseed, is an annual plant primarily cultivated for its oil, fiber, and use in food and animal feed. Flaxseed is rich in nutritional content and bioactive compounds which are widely used as food ingredients. Its antioxidant properties can be attributed to the presence of various phenolic compounds such as lignans, phenolic acids, flavonoids, phenylpropanoids, and tannins (Hanaa, M. H. et al., 2017). Additionally, flaxseed is a potent source of both soluble and insoluble fiber, along with omega-3 fatty acids and plant-based proteins. The mucilage gum found in flaxseed acts as a natural laxative by increasing stool bulk and water content,

which can help ease the symptoms of constipation. Flaxseed mucilage is a good source of soluble dietary fiber, which has been found useful in the prevention of chronic ailments such as diabetes, obesity, cardiovascular diseases, and certain types of cancers including colon and rectal melanomas (Nowak and Jeziorek (2023). Moreover, the inclusion of flaxseed in the diet has been associated with other health benefits, such as reduced cholesterol levels and improved cardiovascular health. A study by Mani et al. (2011) found that providing individuals with type 2 diabetes with 10 g of flaxseed powder daily for a month reduced their fasting blood glucose by 19.7% and glycated haemoglobin by 15.6%. This is closely related to the lower concentration of glycaemic carbohydrates and the higher concentration of dietary fibre present in flaxseed. Globally, flaxseed either in whole or ground form is a popular ingredient in many packaged foods such as cereals, bread, biscuits, fortified energy bars, soups, and snacks, primarily because of its beneficial properties (Manthey et al., 2002b; Muir and Westcott, 2000). Flaxseed is high in mucilage (gums), which can increase the water absorption properties of dough, and affect mixing time and dough handling characteristics.

Cookies are among the most popular bakery items consumed by people of all ages in society. Their popularity as a snack food arises from their wide range of tastes, crispness, and digestibility. Cookies are ideal for nutrient availability, palatability, compactness and convenience (Kumar et al., 2013). Cookies constitute major component of human snacks in most parts of the world. A cookie is an unleavened crisp, made from lighter wheat flour, shortening (hydrogenated fat) and sugar and is usually made light by the addition of baking powder. Wheat flour is the basic ingredient in cookies production because of its gluten proteins, which are not present in the flour of other cereals (Kishorgoliya et al., 2018). Within the advances in nutrition science, new process

technologies and the modern consumer demand for low-calorie foods with various health benefits. There is a focus on disease prevention and optimising health through the use of functional food ingredients. Functional foods are defined as foods and food components that offer additional health benefits beyond basic nutrition for the intended population. Examples include conventional foods; fortified, enriched or enhanced foods, and dietary supplements (MacAulay et al., 2005).

Despite these nutritional advantages, flaxseed is not widely used in mainstream food products. Its incorporation into baked goods, especially cookies, offers a functional food solution that addresses fibre intake for improved bowel health, weight management, and a reduced risk of heart disease, type 2 diabetes, and certain cancers. However, it is essential to understand how the addition of flaxseed flour affects the physical and sensory qualities of cookies. Changes in ingredient composition can influence the texture, spread, moisture content, and overall acceptability of the final product. Therefore, the purpose of this study is to develop a modified whole wheat cookie by incorporating different percentage levels of flaxseed flour. The nutritional composition including the moisture, ash, protein, fat, fibre, and carbohydrate content, as well as physical properties (weight, diameter, thickness, spread ratio and texture), and the sensory properties of cookies made from whole wheat flour enriched with different percentage levels of flaxseed flour, will be evaluated.

1.2 Problem Statement

Obesity is a global concern, affecting individuals of all ages and socioeconomic backgrounds. Over the past three decades, no country has successfully reduced obesity rates. This trend is expected to continue, particularly in low- and middle- income countries (The et al., 2024). Individuals with a Body Mass Index (BMI) exceeding 25 kg/m² face a threefold risk of developing diabetes (Eckel et al., 2005). According to the World Obesity Atlas, 2024, published on World Obesity Day, by 2035, more than half of the global population will be overweight or obese, with the majority living in middle-income countries. These countries often lack the knowledge and resources to effectively address obesity. In 2020, over 65% of adults with obesity lived in low- and middle- income countries, a figure projected to reach 70% by 2030. The accumulation of excess weight and fat in the body contributes to insulin resistance and, eventually, type 2 diabetes. This occurs through the production of inflammatory cytokines by adipose (fat) tissue, which has endocrine effects (Eckel et al., 2010). Approximately 39% to 49% of the global population, or between 2.8 and 3.5 billion people, are estimated to be overweight or have obese (Maffetone et al., 2017). The Global Burden of Disease (GBD) Obesity Collaborators in 2015 indicated that over two-thirds of deaths attributable to a high body-mass index (BMI) were due to cardiovascular disease. This highlights the significant impact of BMI-defined obesity on cardiovascular disease. According to (WHO, 2023), cardiovascular diseases (CVDs) are the leading cause of death worldwide. About 17.8 million people died from CVDs in 2017, accounting for approximately 32% of all global fatalities. The main cause of the rising prevalence of obesity worldwide is an imbalance in food intake, with diets high in fat and cholesterol but low in fiber (Phupakdi et al., 2015; Sakinah et al., 2012).

Constipation is a common condition in the community that poses a significant burden for both individuals and health care systems (Dennison et al., 2005). It is a gastrointestinal problem affecting a large portion of the global population, typically characterised by infrequent bowel movements, difficulty passing stool, and a general sense of incomplete bowel movement. Constipation is a prevalent digestive issue in Malaysia, affecting people of all ages. According to a study by Lim et al. (2016), the prevalence of functional constipation among students was 16.2% with a significantly higher prevalence among women (17.4%) than men (12.5%). While constipation can result from various underlying medical conditions, the most common cause particularly in the general population is inadequate dietary fiber intake.

According to Al Okbi (2005), functional food consists of food or food ingredients that provide physiological benefits and help prevent and/or cure diseases. Consequently, the growing demand for functional foods has prompted the exploration of ingredients that enhance nutritional value while maintaining acceptable sensory qualities. Functional foods, which offer health benefits beyond basic nutrition, such as lowering cholesterol, improving blood sugar control, and reducing inflammation could play a vital role in managing and preventing non-communicable diseases, (NCDs). However, public awareness, affordability, and proper regulation are essential to ensure these foods are accessible and effectively integrated into daily diets. Consumers are increasingly conscious of their health and are adopting the food products that provide additional functional benefits, such as improved digestion, enhanced immunity and better cardiovascular health. Whole wheat flour is a healthier alternative to refined wheat flour due to its higher fiber and micronutrient content, but consumers often seek further health benefits such as increased omega-3 fatty acids, protein, and antioxidants.

Additionally, flax is a versatile functional food, available as whole, milled, or roasted seeds, oil, or flour. Beyond its basic nutritional value, it offers significant health benefits, such as reducing the risk of cancer and cardiovascular diseases, lowering LDL-cholesterol, and enhancing vasodilatory functions. (Goyal et al., 2014). Flaxseed flour is rich in alpha-linolenic acid (ALA), dietary fiber, and lignans (Soni et al., 2017), making it a promising supplement for developing nutritionally enhanced bakery products. Although the health benefits of whole wheat flour and flax seed are well known, their incorporation into widely consumed such as cookies remains limited, and the impact on proximate composition (moisture, protein, fat, ash, fiber, and carbohydrate content) is not well documented. Despite growing nutritional interest in functional foods and the existence of a wide range of healthy cookie formulations, there is a notable gap in knowledge and information on this topic of interest. Globally, numerous studies have investigated cookies made from whole wheat and various functional ingredients. However, research on the nutritional content and sensory acceptance of cookies made from whole wheat incorporating flaxseed among consumers remains limited.

Therefore, the incorporation of edible seeds such as flaxseed in the form of flour into commonly snacks like cookies may be beneficial in addressing consumer needs. The goal is to create a nutritionally enriched, fiber-dense snack that serves as a convenient dietary option for health-conscious individuals seeking functional foods with enhanced nutritional value.

1.3 Research Objectives

1.3.1 General Objective:

To determine the proximate composition (moisture, ash, protein, fat, fibre, and carbohydrate) content, physical and sensory of evaluation of the cookies made from whole wheat enriched with different percentage level of flaxseed flour.

1.3.2 Specific Objective:

1. To determine the proximate composition (moisture, ash, protein, fat, fibre, and carbohydrate) of cookies made from whole wheat enriched with different percentage levels of flaxseed flour.
2. To evaluate the sensory characteristics (appearance, aroma, colour, texture, taste, crispiness, and overall acceptability) of the cookies made from whole wheat enriched with different percentage level of flaxseed flour.
3. To examine the texture profiles of the cookies incorporating with different percentage level of flaxseed flour such as (weight, diameter(width), thickness, spread ratio and texture)

1.3 Research Questions

1. Which formulation of whole wheat cookies incorporated with different percentage levels of flaxseed flour provides the best proximate composition?
2. What are the sensory characteristics (appearance, aroma, colour, texture, taste, crispiness, and overall acceptability) of the cookies made from whole wheat enriched with different percentage level of flaxseed flour?
3. How does the incorporation of different percentage level of flaxseed flour affect the physical properties such as (weight, diameter(width), thickness, spread ratio

and texture) of whole wheat cookies?

1.5 Research Hypothesis

Null hypothesis

There is no significant difference in the proximate composition, physical and sensory attributes of cookies made from whole wheat flour incorporating with different percentage levels of flaxseed flour.

Alternative hypothesis

There is a significant difference in the proximate composition, physical and sensory attributes of cookies made from whole wheat flour incorporating with different percentage levels of flaxseed flour.

1.6 Significant of Study

The purpose of this study to provide valuable insights into the effects on the nutritional composition, and physical characteristics of the cookies, while observing sensory acceptance among consumers and highlighting their potential as a functional food product. This study is expected to demonstrate that modified whole wheat cookies enriched with flaxseed flour have enhanced nutritional value and can offer a healthier and enjoyable snack option for inclusion in the daily diet, thereby contributing to the prevention of diseases such as obesity and constipation in the community.

CHAPTER 2

LITERATURE REVIEW

2.1 Global Diet-Related Disease Trends

The World Health Organization (WHO, 2000) defines obesity as a chronic, relapsing condition resulting from complex interactions among genetic factors, neurobiological mechanisms, eating behaviours, access to healthy foods, market influences, and the wider environment. The prevalence of obesity has increased globally as nations have achieved greater food security and socioeconomic progress, accompanied by changes in dietary patterns, physical activity levels, and both societal and individual behaviours shaped by globalisation and industrialised food systems. In 2022, 2.5 billion adults aged 18 years and older were categorised overweight, while 890 million adults were living with obesity. Of those overweight, 43% were men while 44% were women (Phelps et al., 2024). In Malaysia, approximately 1 in 2 adults is affected by overweight and obesity, along with unhealthy dietary practices and a high level of physical inactivity (NHMS, 2024). The burden of diet-related disease is increasing significantly, resulting from dietary and physical activity patterns that strongly influenced by environmental and societal conditions affecting individual's choice. Therefore, obesity should be regarded as a societal responsibility rather than solely an individual one, with supportive environments and communities facilitating better access to balanced diets and regular physical activity as part of daily life.

A recent study has highlighted that obesity is linked to various health diseases due to excess adipose tissue, substantially increasing the risk morbidity and mortality. Obesity is at the risk of developing type 2 diabetes, hypertension, and dyslipidaemia, conditions

that together contribute to metabolic syndrome and drive cardiovascular complications (Wiley et al., 2021). In recent decades, the increased availability and affordability of energy-dense, nutrient-poor foods often high in fats and sugars and aggressively marketed together with the higher cost of healthier options, have promoted excessive caloric intake, particularly among lower-income populations, thereby contributing to rising obesity rates (Ahmed & Mohammed, 2025).

Constipation is a common condition that often remains undetected until the individual experiences pain following a prolonged symptoms or develops anorectal disorders. Constipation is one of the most common gastrointestinal issues and can be categorised into several subtypes, each with unique symptoms and underlying factors. For example, chronic idiopathic constipation is a prevalent subtype, characterised by irregular bowel movements and difficulty in passing stool. In contrast to functional constipation, where identifiable underlying factors may contribute to symptoms, chronic idiopathic constipation is marked by persistent defecatory irregularities and discomfort without clear evidence of physiological or anatomical basis (Diaz et al., 2023b). A reduction in total caloric intake or infrequent eating may contribute to the constipation by reducing the gastrocolic reflex, which is normally stimulated by food intake (Bouchoucha et al., 2006). Constipation has been linked to low daily stool weight, although threshold values vary across studies, with some researchers defining it as less than 35 g per day (Longstreth et al., 2006). Obesity associated gut microbiota dysbiosis alters short chain fatty acid (SCFA) production and bile acid metabolism, both of which directly regulate colonic smooth muscle activity and can precipitate constipation (Fayfman et al., 2019, Zhang et al., 2021).

2.2 Low Intake of Whole Grain and Dietary Fiber

Despite the increasing burden of non-communicable diseases (NCDs) worldwide, public awareness of the role of whole grain and dietary fibre intake in daily diets remains limited. Mann et al. (2015) indicate an age dependent trend in whole grain intake, with higher intake levels among older age groups and the lowest among teenagers (13–17 years) and younger adults up to of 34 years. A significant portion of the population approximately 18 % of adults and 15 % of children and teenagers report a total absence of whole-grain foods in their diets. Similar to previous studies, income and food cost have been identified as confounding factors affecting whole grain intake (McMackin et al., 2012; Lang & Jebb, 2003) and present major barriers to compliance with dietary guidelines. Another barrier to whole grain intake is negative perceptions, such as dislikes related to organoleptic properties including the taste, texture, appearance, and smell (Kamar et al., 2016). This is further exemplified by palatability and sensory preferences, as whole grain products are commonly perceived as "gritty" or less flavourful than refined forms. Lack of nutritional literacy also arises from consumers confusion regarding food labelling, especially in distinguishing “multigrain” from whole grain. Whole grain foods are commonly identified through food labels, as well as by their appearance and colour. Taken together, findings outside Australia have highlighted several barriers to adequate whole grain consumption, including taste, lack of understanding of health benefits, family influence, price, and availability of the whole grain product options (Kuznesof et al. 2012; Pollard et al., 2017).

The World Health Organization (WHO) recommends that adults consume at least 25 g of naturally occurring dietary fibre daily (WHO, 2023). According to European health claim regulations related to bowel function, foods classified as ‘high in’ the specified fibre must provide at least 6 g per 100 g or 3 g per 100 kcal (418 kJ), equivalent to a minimum of 7 g/M (Stephen et al., 2017). The study by Sonnenburg and Sonnenburg, (2014), highlights the biological consequences of inadequate fibre intake, which leads to microbial “starvation”. This deprivation the gut microbiota reduces diversity and lowers the production of short-chain fatty acids (SCFAs), which are critical for colon health. Additionally, a lack of dietary fibre removes the buffering effect that slows carbohydrate absorption. Recent research by Reynolds et al. (2019) indicates that dietary fibre and whole grain are more appropriate indicators of carbohydrate quality than glycaemic index, GI. It is encouraging that fibre-related sources in food and their overall health benefits are positive findings. The health benefits most commonly associated with whole grains include their dietary fibre content, improving digestion, bowel and gut health and low glycaemic index (GI).

2.3 Therapeutic Potential of Functional Foods

In recent years, consumer demand in food production has changed significantly, as consumers have become increasingly aware of their food quality and the health benefits associated with various products. Many commercially available cookies have suboptimal ideal nutritional content, typically containing high levels of sugar, saturated fats, and preservatives (Gupta & Singh, 2024; Luo et al., 2019). Consequently, these products often lack beneficial ingredients such as vitamins, minerals, dietary fibres, and other bioactive compounds. Food fortification aims to increase the consumption of certain vitamins or nutrients considered deficient in the food supply (Sharma et al., 2011). Cookies made

from whole wheat flour may represent a healthier option for snacking. This involves substituting and adding nutrient-rich foods during the cookie-making process. To make cookies a high-energy and protein-rich food, it is crucial to replace and incorporate ingredients that are rich in nutrients (Tiar Lince Bakara et al., 2023).

Cookies are a type of baked soft-wheat dough snack and have become one of the most desirable snacks for large groups of people around the world due to their low manufacturing cost, convenience, and long shelf life attributable to low moisture content as well as their function as carriers for essential and non-essential nutrients (Akubor, 2003; Hooda & Jood, 2005). This makes them ideal for development into improved products that meet special dietary needs. Cookies are usually made with ingredients such as cereal flours, sugar, and fat, which results in as a snack that contains lower protein (~7%) and is high in sugar (~24%) and fat (~18%), as reported in studies by Al Masoud et al. (2024a) and Dall'Asta et al. (2020). Several researchers have attempted to improve cookies formulation by fortifying wheat flour with legumes or other cereals (Singh et al., 1993). The majority of consumers prefer health-oriented foods with nutritional and functional components (Park et al., 2021). There have been many prior developments in cookie products, such as formulating cookies with added Bambara groundnut and soy protein isolates (Arise et al., 2021; Park et al., 2021).

2.4 Raw Materials and Their Nutritional Profiles

2.4.1.1 Whole Wheat Flour

Wheat is a global dietary staple, consisting primarily of starch (60 - 70% of the grain, or 70 - 80% of flour) and proteins (8 - 20%). It also contains non-protein compounds such as cellulose, hemicelluloses, polyphenols, and minerals. Both refined wheat flour (with bran removed) and whole wheat meal (bran included) are important in diets worldwide due to their high nutritional value and taste (Zheng et al., 2021). Whole wheat flour, also known as wholemeal flour is a powdery substance, mainly used as a basic food ingredient. Wheat flour is produced by milling wheat grain and provides daily energy requirements to people worldwide in various products. The milling process was revolutionised in the second half of the 19th century by the introduction of roller mills, which led to the practice of separation wheat's starchy endosperm, bran, and germ (Jones et al., 2015).

Whole-wheat flour (WWF) is well recognised for its higher levels of vitamins, minerals, dietary fibre (non-starch polysaccharides), antioxidants, and other phytochemicals such as carotenoids, flavonoids, and phenolic acids (Gomez et al., 2020; Tebben et al., 2018). Specifically, WWF provides non-starch polysaccharides and various micronutrients and phytochemicals associated with bran in the diet (Chris & Frank, 2018). Additionally, whole wheat products are known for their distinct sensory characteristics, such as a dark, speckled appearance and a coarse hard texture. Their taste can also vary, presenting the bitterness, sourness, maltiness or even mustiness (Heinio et al., 2016). Whole wheat flour contains a number of volatile compounds and is considerably higher in amino acids (Czerny & Schieberle, 2002). Historically, researchers have indicated that aldehydes, ketones and alcohols are examples of volatile compounds that responsible for odour. These compounds also contribute to flavour that produce the notes such as green,

sweet, and fruity (Kirchhoff & Schieberle, 2002; Heinio et al., 2003). Moreover, phenolic compounds in cereal foods often function as antioxidants, providing health benefits (Bondia-Pons et al., 2009). The bran in whole wheat flour also slows glucose release, making whole wheat bread a medium glycemic index food that supports a healthy diet (Lin et al., 2022).

Whole grains contain numerous micronutrients and bioactive compounds such as B vitamins, minerals, phenols, antioxidants, and phytoestrogens, which may protect against colorectal cancer (CRC) (Slavin et al., 1999; Fardet, 2010). Whole grain intake has been associated with health benefits, including a decreased risk of chronic diseases such as cardiovascular disease, diabetes, cancer, obesity, and all-cause mortality (Jacobs, Meyer, Kushi, & Folsom, 1998; Jonnalagadda et al., 2011; Slavin, 2004). Evidence suggests that elevated consumption of antioxidants and dietary fibre is inversely associated with blood pressure, serum cholesterol, and the prevalence of diabetes. This dietary pattern also appears to facilitate weight reduction and may positively influence immune responses (Borghi & Pavanelli, 2023). However, barriers to increasing whole grain consumption are often related to texture and sensory qualities, as well as the higher cost of whole grain products, confusion in identifying whole grain foods, and lack of knowledge regarding the health benefits of whole grain consumption (Bakke and Vickers, 2007; Kantor, Variyam, Allshouse, Putnam, & Lin, 2001).

2.4.1.2 Dietary Fibre of Whole Wheat Flour

Dietary fiber as defined by (Theander et al., 1995), as the sum of non-starch polysaccharide residues, amylase-resistant starch, and Klason lignin. Beyond that, whole grains are an excellent source of fiber. This fiber helps in several ways: it increases stool bulk, which can dilute potential carcinogens; it speeds up the movement of stool through the digestive system; and it leads to the production of short- chain fatty acids (SCFAs), which are believed to protect against colorectal cancer, (CRC) risk (Slavin et al., 1999; Lipkin et al., 1999). Furthermore, whole grains and fiber can indirectly reduce CRC risk by helping to control weight gain and prevent type 2 diabetes, both of which are known risk factors for colorectal cancer, CRC. Moreover, these findings highlight the importance of focusing on whole foods for cancer prevention, rather than relying solely on individual components like fiber supplements (Bazzano et al., 2005). Besides, whole grains benefited to digestive health. By keeping the stool soft and bulky, the fiber in whole grains helps prevent constipation, a common, costly, and irritating issue. It also helps prevent diverticular disease (diverticulosis) by decreasing pressure in the intestines (Strate et al., 2017). A study by Reynolds et al. (2019), published in *The Lancet* and based on systematic reviews and meta-analyses performed by New Zealand experts, demonstrated that increased dietary fiber consumption is linked to a lower risk of death and chronic illness. Whole grains may reduce the risk of type 2 diabetes involves their insoluble fiber. The insoluble fiber contents contribute to delayed gastric emptying and decrease the rate of glucose absorption, which optimizes postprandial glucose and insulin profile (Kaline et al., 2007).

2.4.2.1 Flaxseed (*Linum usitatissimum*)

The taxonomy of flax was first and termed by Carl Linnaeus in 1753 (Hyam and Pankhurst, 1995). Flax, scientifically known as *Linum usitatissimum*, belongs to the plant kingdom (Plantae). It is classified under the division Magnoliophyta, which encompasses flowering plants, and specifically within the class Magnoliopsida (dicotyledons). Further down the taxonomic hierarchy, flax is found in the order Malpighiales, and is a member of the Linaceae family. *Linum usitatissimum* (Linn.), also most commonly known as flaxseed or linseed, belongs to the family Linaceae, recognized by their blue flowers and small, flate seeds. Flax seeds, which range in color from golden yellow to reddish-brown, it has a crispy texture and nutty taste (Morris 2007; Rubilar et al., 2010). The yellow flax variety known as solin (marketed as Linola) with a distinctly different oil profile, which is very low in omega-3 fatty acids (Dribnenki et al. 2007). While for the brown flax become a common ingredient in paints, varnish, fiber and cattle feed (Drouillard et al. 2000; Kozłowska et al. 2008; Singh et al. 2011; Faintuch et al. 2011). Whole flaxseeds are flat and oval-shaped with pointed ends. It can typically measure around 2.5 x 5.0 x 1.5 mm (Freeman, 1995). Flaxseed is structurally composed of a seed coat that called as testa or true hull, a thin endosperm, two embryos, and an embryo axis. The embryos composed the largest portion, contributing 55% of its total weight. The combined weight of the seed coat and endosperm accounts for 36%, while the embryo axis makes up 4% of the total flaxseed weight (Bhatty,1995). Every part of the flaxseed plant has commercial value, whether used in its natural state or after processing. The seed itself is a rich source of beneficial compounds like lignans, easily digestible proteins with essential amino acids, and omega-3 fatty acids (Bernacchia et al., 2014), the shell is valued for its distinct properties. The shell provides high-quality fiber known for its low density and favorable mechanical characteristics (Bernacchia et al., 2014).

Flax is not a new crop, it originated in West Asia and the Mediterranean coastal regions, including Asia Minor, Egypt, Algeria, Tunis, Spain, Italy, and Greece. In these areas, only fiber flax is cultivated. Conversely, in Southwest Asia, specifically Turkestan, Afghanistan, and India, only oil-producing flax varieties are grown (Krishnamurthi, 1962). In North America, the term "flaxseed" is commonly used for flax intended for human consumption, while Europeans refer to edible flax as "linseed." Historical evidence suggests flaxseed cultivation dates back to approximately 9000– 8000 BC in Turkey, Iran, Jordan, and Syria. Today, flaxseed is grown in about 50 countries, predominantly in the Northern Hemisphere. In 2002, Canada was the leading producer, accounting for roughly 33% of the 2 million metric tons produced, followed by China (20%), the United States (16%), and India (11%) (Hall et al., 2006). Nevertheless, there are various kind of edible form of flax available in the food markets, such as whole flaxseeds, milled flax, roasted flax and flax oil.

Flaxseeds are naturally rich in several beneficial compounds. Flaxseed has become a significant area of interest for nutritionists and medical researchers. This is due to its potential health benefits, which are attributed to its biologically active components: alpha-linolenic acid (ALA), the lignan secoisolariciresinol diglycoside (SDG), and dietary fiber (Toure and Xueming, 2010). Compared to other cereal grains, flaxseeds contain around 75 to 800 times larger portion of lignans (Kajla et al., 2014). Additionally, flaxseeds are a source of anti-cancer agents and other bioactive compounds (Kajla et al., 2015). Flaxseed is known for its rich physicochemical composition, functioning as a system packed with bioactive plant substances. These include oil, protein, dietary fiber, soluble polysaccharides, lignans, phenolic compounds, vitamins (A, C, F, E), and minerals (P, Mg, K, Na, Fe, Cu, Mn, Zn) (Bhatty 1995; Jheimbach and Port Royal 2009). These

components give flaxseeds preventive and therapeutic effects against a range of health issues, including cardiovascular diseases (CVDs), diabetes, hyperglycemia, obesity, breast and prostate cancer, osteoporosis, and reproductive problems (Ebrahimi et al., 2021). Various edible flaxseed products are available, such as whole flaxseed, ground meal, mucilage, and extracted oil. These products can also be used to fortify a wide array of commercial foods, including fiber bars, spaghetti, breakfast cereals, bread and biscuits (Singh et al., 2011).

2.4.2.2 Dietary Fibers of Flaxseed

Early research by Jenkins et al. (1987) and Cunnane et al. (1994) first suggested the hypocholesterolaemia effects of flaxseed's soluble gum, a finding consistently supported by flaxseed have a significant dietary fiber content, up to 40%. This fiber is comprised of 25% soluble fiber and 75% insoluble fiber. Soluble fiber, including gums, pectin, and β -glucan, plays a crucial role in health. Furthermore, soluble fiber serves as a dietary source for beneficial gut bacteria and can be converted into short-chain polyunsaturated fatty acids (SC-PUFA), which positively impact human health (Nowak and Jeziorek, 2023). Moreover, the primary components of insoluble fiber in flaxseed are cellulose and lignin, while the soluble fiber fraction is mainly composed of mucilage gums (Qian, 2012; Cui et al., 1996).

In addition, dietary fibers found in flaxseed have been linked to improved body weight regulation. This is achieved through two mechanisms: suppressing hunger and reducing nutrient absorption (Kristensen et al., 2012). It is also important to note that soluble fiber, a key component of flaxseed, generally forms a gel-like substance when mixed with water. Hence, flaxseed also plays role to manage the blood glucose level by

the forming gel formed. Research has indicated that the insoluble fiber found in flaxseed is particularly effective at slowing down the rate at which sugar is released into the bloodstream, thereby helping to substantially reduce overall blood glucose levels (Nowak and Jeziorek , 2023). The dietary fiber present in flaxseed is fermented by the colonic microflorara, that lead to the production of short-chain fatty acids (SCFAs), hydrogen, carbon dioxide, methane and biomass, in which resulting in laxative effects (D Kritchevsky, 1979). Consequently, by adding just 10 g of flaxseed in the daily diet contributes an additional 1 g of soluble fiber and 3 g of insoluble fiber. Insoluble fiber beneficial to improve bowel function and constipation prevention, largely by increasing fecal bulk and reduced bowel transit time (Greenwald et al. 2001).

2.4.2.3 Alpha linoleic Acid (ALA) of Flaxseed

Flaxseed is a great source of α -linolenic acid (ALA). ALA is an essential omega-3 polyunsaturated fatty acids (n-3 PUFA), predominantly found in vegetable sources. Flaxseed oil typically contains a high concentration of ALA, ranging from 50 to 62 %, while whole flaxseed itself provides approximately 22 % of its total fat contents as ALA (Hajiahmadi et al., 2020). The type of flax ingested influences the bioavailability of ALA, it is highest in oil form, followed by milled seed and lowest in whole seed (Austria et al. 2008). Additionally, ALA increases insulin sensitivity by regulating the secretion of intestinal digestive hormones, inducing insulin secretion, and improving insulin signaling (Li et al., 2022). Moreover, a systematic review and meta-analysis study conducted by (Mohammadi-Sartang et al., 2018) found that supplementing with whole flaxseed led to improved glycemic indices in individuals with Type 2 Diabetes (T2DM). In advance, adding whole flaxseed to the diet helped better manage blood sugar levels in people with T2DM.

Other than that, an obesity individual, they tend to consumed high-calorie diet, which can lead to elevated plasma leptin levels. This may be because adipose tissue under-expresses leptin or leptin receptors become down-regulated (Dubey et al. 2006). According to McCullough et al. (2011), flaxseed consumption significantly raised ALA levels in both plasma and adipose tissue. Changes in leptin expression showed a strong positive correlation with adipose ALA levels, and an inverse correlation with risk of atherosclerosis (Goyal et al., 2014), in which one of the cardiovascular diseases. In advance, Alpha-linolenic acid (ALA), an essential polyunsaturated fatty acid, has been reported to possess anti-inflammatory, anti- thrombotic, and anti-arrhythmic properties (Simopoulos 1999). Among various foods, flaxseed contains the highest potassium content, ranging from 5600–9200 mg/kg. High potassium intake has been inversely associated with blood platelet aggregation, free radical levels in the blood, and the incidence of stroke (Carter 1993). Based on World Health Organization, 2023, recommends that adults increase their dietary potassium intake, at least 90 mmol/day (3510 mg/day), to reduce blood pressure and the associated risk of cardiovascular disease, stroke and coronary heart disease.

2.5 Sensory Evaluation in Product Development

Hedonic scale is a fundamental tool for measuring overall liking, a primary indicator of consumer acceptance. Nevertheless, perception is driven by more than just sensory appeal, it is also shaped by extrinsic factors such as quality, wellness, and perceived benefits (Gupta et al., 2021). Hedonic Test is a subjective test, or known as the sensory test as the evaluation for the food quality rely completely on sensory characteristics and personal preferences as perceived by the five senses (Brown, 2011). Food industry have been using various methods to measure the sensory elements related

to consumer preferences, to evaluate food quality and determine the overall palatability of food products.

The history of development 9-point hedonic scale has been used widely as a common scale for sensory testing on consumer preference and acceptability of foods, which developed in 1947 at the Quartermaster Food and Container Institute for the Armed Forces (Peryam & Girardot, 1952; Peryam & Pilgrim, 1957). The 9-point hedonic scale is widely accepted compared to other scaling methods, as the limited choices and classified in categorical nature easy for participants and researchers to adapt (Lim, 2011). The scale ranges used in Hedonic Test from 1 to 9 to measure the palatability of the food products where the scale 1 represents as “dislikes the most” and 9 represents the “like extremely” (Peryam & Girardot, 1952). Sensory characteristics of products such aroma, colour, texture, taste and overall acceptability will be evaluated. However, Hedonic Test are usually given to the untrained panelists to reduce bias at the end of the results collected (Brown, 2011).

Food preferences among consumers play a crucial role in the prediction of human food choices, that may impact on further development towards their overall health, in which tend to be overlooked. Food choices represent one of the most complex behaviors in life and influenced by number of factors, including biological and physiological (e.g., genetics, sensory acuity, age, gender), psychological (e.g., behavioral traits) and environmental factors (e.g., situational and socio-cultural factors) as well as intrinsic (appearance, smell, taste and somatosensory characteristics) and extrinsic (e.g., claims and food labels) food properties (Köster, 2009). While palatability and sensory appeal are critical factors of individual's consumption towards food, it is not necessarily acceptable