PROXIMATE COMPOSITION AND SENSORY EVALUATION OF PANCAKES MADE WITH EGGPLANT (*SOLANUM MELONGENA* L.) FLOUR AND CHIA SEED (*SALVIA HISPANICA* L.) POWDER AS WHEAT FLOUR REPLACERS

by

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

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CERTIFICATE

This is to certify that the dissertation entitled Proximate Composition And Sensory Evaluation of Pancakes Made With Eggplant (*Solanum Melongena* L.) Flour and Chia Seed (*Salvia Hispanica* L.) Powder as Wheat Flour Replacers is the bona fide record of research work done by Ms Cheong Yi Jing during the period from 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 fulfilment for the degree of Bachelor in Nutrition with Honours.

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DECLARATION

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

Signature

Cheong Yi Jing

Date:

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percentage
<	Less than
>	Greater than
±	Plus-minus
$^\circ C$	Degree Celsius
ALA	α-Linolenic Acid
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CGA	Chlorogenic Acid
CO_2	Carbon Dioxide
CSP	Chia Seed Powder
EF	Eggplant Flour
g	Gram
G'	Elastic (Storage) Modulus
G"	Viscous (Loss) Modulus
GI	Glycemic Index
H0	Null Hypothesis
HA	Alternative Hypothesis
H_2SO_4	Sulfuric Acid
HCl	Hydrochloric Acid
HSD	Honestly Significant Difference
IDF	International Diabetes Federation
kg	Kilogram

mg	Milligram
mL	Milliliter
MOH	Ministry of Health
N	Normality
n	Sample size
NaOH	Sodium Hydroxide
NCDs	Non-Communicable Diseases
NHMS	National Health and Morbidity Survey
OAC	Oil Absorption Capacity
p	Probability value
PEM	Protein-Energy Malnutrition
PPO	Polyphenol Oxidase
PUFAs	Polyunsaturated Fatty Acids
SD	Standard Deviation
SGAs	Steroidal Glycoalkaloids
tan δ	Phase angle
TBA	Trihydroxybenzacridine
TDF	Total Dietary Fibre
TPA	Texture Profile Analysis
WAC	Water Absorption Capacity
WHC	Water Holding Capacity

KOMPOSISI PROKSIMAT DAN PENILAIAN SENSORI PANKEK YANG DIPERBUAT DARIPADA TEPUNG TERUNG (*SOLANUM MELONGENA* L.) DAN SERBUK BIJI CHIA (*SALVIA HISPANICA* L.) SEBAGAI PENGGANTI TEPUNG GANDUM

ABSTRAK

Pankek adalah makanan berasaskan bijirin yang popular secara tradisinya diperbuat daripada tepung gandum halus yang selalunya kekurangan nutrien penting. Kajian ini bertujuan untuk menilai komposisi proksimat dan penerimaan sensori pankek yang diformulasikan dengan menggantikan sebahagian tepung gandum dengan tepung terung (EF) dan serbuk biji chia (CSP). Empat formulasi telah dibangunkan, iaitu kawalan (T0) dengan 100% tepung gandum dan tiga formulasi komposit yang mengandungi tahap EF dan CSP yang berbeza, T1 (5% EF + 2% CSP), T2 (7.5% EF + 4% CSP) dan T3 (10% EF + 6% CSP). Analisis proksimat dijalankan menggunakan kaedah AOAC untuk menentukan kandungan kelembapan, abu, protein kasar, lemak kasar, serat kasar dan karbohidrat. Penilaian sensori telah dijalankan oleh 50 ahli panel tidak terlatih menggunakan skala hedonik 7 mata untuk menilai rupa, warna, aroma, rasa, tekstur dan penerimaan keseluruhan. Keputusan menunjukkan bahawa penggabungan EF dan CSP meningkatkan profil pemakanan pankek secara signifikan ($p < 0.05$). Formulasi T3 menunjukkan nilai tertinggi bagi kelembapan (52.55%), abu (4.32%), protein (14.54%), lemak (15.59%), dan serat kasar (1.82%) berbanding kawalan. Kesannya, kandungan karbohidrat menurun secara signifikan daripada 71.72% dalam T0 kepada 63.73% dalam T3. Dari segi penilaian sensori, walaupun skor rupa dan warna menurun secara

signifikan ($p < 0.05$) akibat warna yang lebih gelap disebabkan oleh pengoksidaan fenolik, tiada perbezaan yang bermakna ($p < 0.05$) dicatatkan bagi aroma, rasa, tekstur dan penerimaan keseluruhan antara sampel kawalan dan sampel yang diperkaya. Secara khususnya, T3 menerima skor nominal tertinggi bagi tekstur dan rasa. Kajian ini menyimpulkan bahawa formulasi T3 (10% EF + 6% CSP) adalah formulasi optimum yang menawarkan kepadatan nutrisi yang lebih baik tanpa menjejaskan penerimaan pengguna, sekaligus membuktikan potensi terung dan biji chia sebagai bahan berfungsi dalam produk bakeri.

PROXIMATE COMPOSITION AND SENSORY EVALUATION OF PANCAKES MADE WITH EGGPLANT (*SOLANUM MELONGENA* L.) FLOUR AND CHIA SEED (*SALVIA HISPANICA* L.) POWDER AS WHEAT FLOUR REPLACERS

ABSTRACT

Pancakes are a popular cereal-based food traditionally made from refined wheat flour, which is often low in essential nutrients. This study aimed to evaluate the proximate composition and sensory acceptability of pancakes formulated by partially substituting wheat flour with eggplant flour (EF) and chia seed powder (CSP). Four formulations were developed, which is a control (T0) with 100% wheat flour and three composite formulations containing varying levels of EF and CSP, T1 (5% EF + 2% CSP), T2 (7.5% EF + 4% CSP) and T3 (10% EF + 6% CSP). Proximate analysis was conducted using AOAC methods to determine moisture, ash, crude protein, crude fat, crude fibre and carbohydrate contents. Sensory evaluation was performed by 50 untrained panelists using a 7-point hedonic scale to assess appearance, colour, aroma, taste, texture and overall acceptability. The results showed that the incorporation of EF and CSP significantly ($p < 0.05$) improved the nutritional profile of the pancakes. The T3 formulation exhibited the highest values for moisture (52.55%), ash (4.32%), crude protein (14.54%), crude fat (15.59%) and crude fibre (1.82%) compared to the control. Consequently, carbohydrate content significantly decreased from 71.72% in T0 to 63.73% in T3. In terms of sensory evaluation, while appearance and colour scores significantly decreased ($p < 0.05$) due to the darker crumb color caused by phenolic oxidation, there were no significant differences ($p < 0.05$) in aroma, taste, texture and overall acceptability between the control and the fortified samples. Notably, T3 received the highest nominal scores for texture and taste. The study concludes that Formulation T3 (10% EF + 6% CSP) is the optimal formulation, offering superior nutritional density without compromising consumer acceptance, demonstrating the potential of eggplant and chia seeds as functional ingredients in bakery products.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Pancakes are a well loved cereal food that is made out of a pourable batter and cooked on a flat surface. They are prepared using wheat flour, sweetener, salt and leavening agents, and are eaten most often as a breakfast food, dessert or even as a supper food. Traditional pancake recipes use wheat flour as the main source of the protein content referred to as gluten. During baking, gluten is essential in the creation of dough and it influences the elasticity of dough greatly, as well as, in delivering the overall outlook and crumb texture of the final product that the baker aims at (Adonu et al., 2022).

The contemporary consumer environment has however changed radically because of the increase in the prevalence of non-communicable diseases associated with diets. The latest statistics presented by the International Diabetes Federation (2024) revealed that there are 589 million adults across the world with diabetes. An IDF the number projected is set to rise to 853 million by 2050. The increase in obesity and cardiovascular diseases related health issues are often linked to the overconsumption of refined carbohydrates. Therefore, healthy, functional foods and more so gluten-free food have risen in demand across the world. This phenomenon is demonstrated by the global market of functional foods which was estimated to reach USD 332 billion in 2024 and was largely motivated by the implementation of preventive healthcare.

However, refined wheat flour is a source of empty calories because it loses its nutrients during milling, removing the bran and the germ (Alrayyes, 2018). After processing, wheat flour was low in fibre and essential micronutrients and high in glycemic index (Lee, 2024). Moreover, the increasing anxieties about gluten intolerance and celiac disease have required the exploration of other sources of flour (Adonu et al., 2022).

The paper explored the possibilities of two plant-based ingredients, namely, eggplant flour and chia seed powder, as functional substitutes in the pancake recipes. Eggplant (*Solanum melongena* L.) is a commonly available vegetable that contains a lot of dietary fibre, polyphenols and antioxidants, most notably nasunin and chlorogenic acid (Soares, 2022). On the other hand, chia seeds (*Salvia hispanica* L.) are known as the superfood or the seed of the 21st century (Dincoglu and Yesildemir, 2019). They contain a lot of bioactive compounds, high quality vegetable proteins and omega-3 fatty acids, especially a-linolenic acid (ALA) (Rabail et al., 2022).

Although substituting these nutrients for wheat flour has obvious nutritional benefits, there have been frequent technological issues that impact texture, flavour and customer acceptance. Therefore, this research investigated the suitability of eggplant flour and chia seed powder as partial substitutes of wheat flour. This research establishes both the proximate composition and sensory acceptability in order to contribute to the production of healthier, functional pancake alternatives.

1.2 Problem Statement

The rising cases of gluten-related illnesses like celiac disease, non-celiac gluten sensitivity, and allergies to wheat have resulted in an excellent demand for gluten-free or low gluten food substitutes (Damat et al., 2024). At the same time, there is a serious threat to the health of the population by the high glycemic index and low nutrient density of foods made using refined wheat flour, including pancakes. The refined wheat flour lacks essential nutrients such as dietary fibre vitamins and antioxidants which have led to the increasing prevalence of diet-related diseases such as type 2 diabetes and obesity.

Solanum melongena L. eggplant is a potentially potent solution because it is a fibre-rich functional ingredient with antioxidants, including nasunin, which remains in the product (harvested during the processing of the product into the flour) (Rodriguez-Jimenez et al., 2018). However, past research proposes a texture-adverse impact of adding large proportions of eggplant flour since it increases the crumb density and can introduce an unwanted bitter taste because of phenolic compounds (Soares, 2022; Styrev et al., 2023). Thus, this is a challenge to consumer acceptance of baked goods prepared using high portions of eggplant flour.

Chia seeds are characterized by large dietary content of fibre (36-40%), and unusual mucilaginous attributes. They make them absorb the water and create a gel that resembles the gluten viscoelastic net (Ashura et al., 2021; Matita et al., 2024). Previous research on the independent food fortification of baked foods has focused on the use of eggplant flour or chia seed powder. Nevertheless, the scientific research of the synergistic effect of the two ingredients in pancake recipes has been lacking. This paper addressed this gap by developing a gluten-reduced and more nutritious pancake. It is a balance between the nutritional value of eggplant and structural value of chia seeds.

1.3 Research Questions

1. Which formulation provides the optimal balance between improved nutritional content and sensory acceptability?
2. How does the different substitution of wheat flour with eggplant flour and chia seed powder influence the proximate composition of pancakes?
3. How does the different substitution of wheat flour with eggplant flour and chia seed powder influence sensory attributes and overall acceptability of pancakes?

1.4 Objectives

1.4.1 General Objective

To evaluate the impact of replacing wheat flour with eggplant flour and chia seed powder on the proximate composition and sensory attributes of pancakes.

1.4.2 Specific Objectives

1. To identify the formulation that achieves the optimal balance between improved nutritional content and sensory acceptability.
2. To compare the proximate composition (ash, moisture, protein, fat, fibre and carbohydrate content) of different pancake formulations.
3. To compare the sensory attributes (appearance, colour, aroma, taste, texture and overall acceptability) of different pancake formulations.

1.5 Hypothesis

1.5.1 Null hypothesis (H_0)

There is no significant difference in nutritional and sensory attributes of pancakes substituted with varying levels of eggplant flour and chia seed powder.

1.5.2 Alternative hypothesis (H_A)

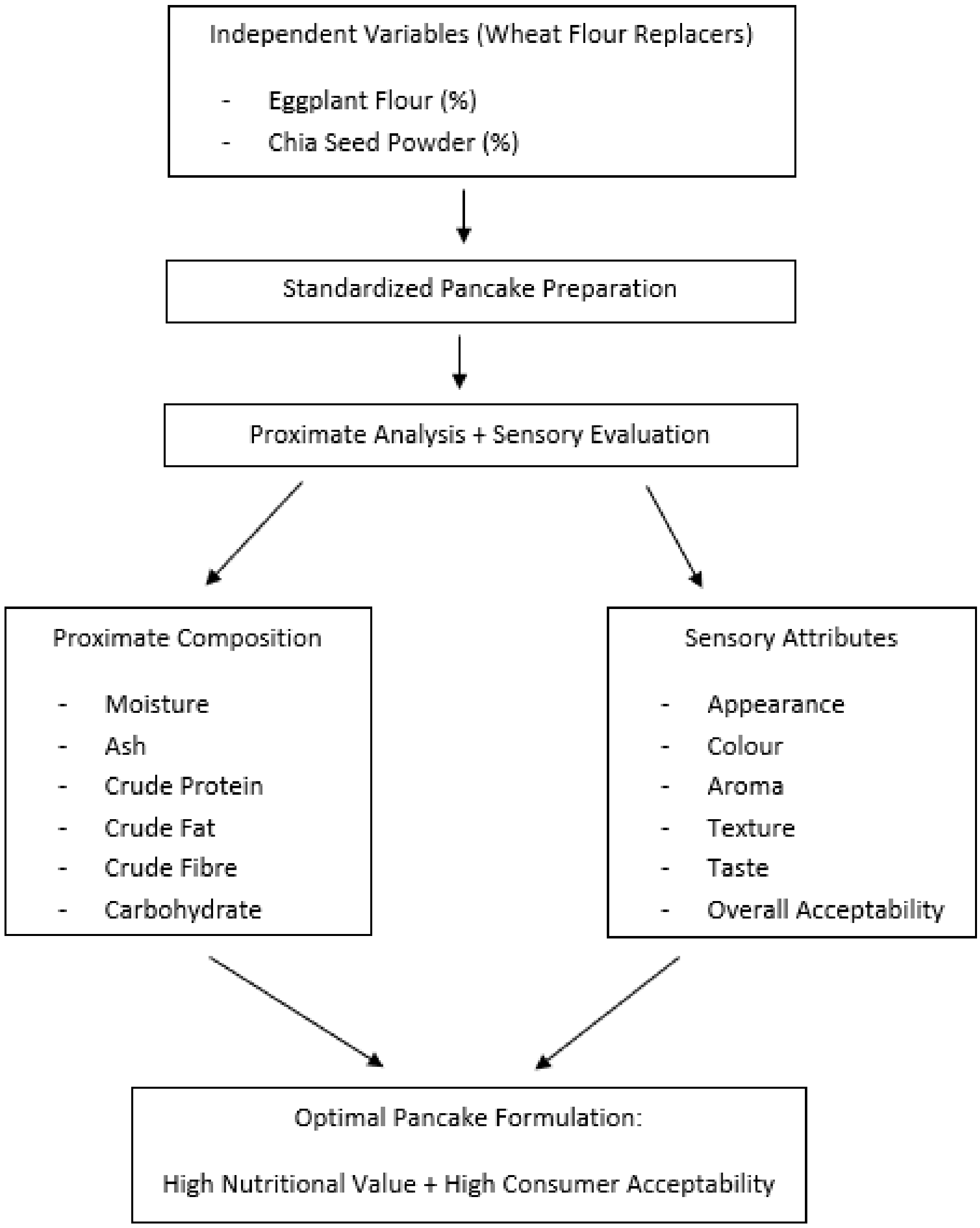
There is a significant difference in nutritional and sensory attributes of pancakes substituted with varying levels of eggplant flour and chia seed powder.

1.6 Significance of the Study

The results of this research can be vital in the process of developing functional foods. Functional foods are products aimed at enhancing health and preventing chronic diseases in particular. As the global functional food industry is set to grow by a significant margin by 2030, there is the business-level and nutritional need to recreate the staple food products such as pancakes.

Importantly, this study reveals the possibility of repurposing an agricultural resource that is not fully utilized in the potential of eggplant into a high-value flour that will meet the food sustainability and waste minimization objectives. Justifying a compound mixture between eggplant flour and chia seed powder, the given study can serve as a practical solution to the development of bakery goods that maintain glycemic control and cardiovascular health without affecting the palatability of consumers. These results can be especially helpful to food producers who want to attract the increased number of health-focused and gluten-intolerant customers.

1.7 Conceptual Framework



CHAPTER 2

LITERATURE REVIEW

2.1 Functional Bakery Products

2.1.1 Consumer Demand for Nutritionally Enhanced Foods

The modern food culture is in the process of entering a paradigm shift characterized by dichotomy, which is the rejection of empty calorie foods and the active pursuit of physiological health benefits. Empty calories refer to processed foods that either have lots of added solid fats, sugars, and sodium, but the food does not provide much to no micronutrients (Sarkingobir and Miya, 2024). The category includes traditional pancakes based on wheat since refining of wheat flour removes the bran and germ, depriving the product of fibre and vitamins (Alrayyes, 2018). The recent studies show that the consumers are becoming more concerned about these foods not only because they are not densely nutritional but also because of their negative physiological implications. According to Sarkingobir and Miya (2024), empty calories are usually characterized by a high glycemic index, which causes a sudden increase in blood sugar levels followed by a loss of satiety, or insatiety, that creates the desire to overeat and become addicted.

The so-called “Food as Medicine” paradigm has become commonplace and consumers perceive their diet as a more fundamental source of disease prevention rather than just sustenance. This trend is typified by a certain need in bioactive substances, which are able to address the pathophysiology of chronic diseases, including probiotics to protect gut health, omega-3 fatty acids to protect cardiometabolism, and polyphenols to counteract oxidative stress (Fekete et al., 2025). This is directly in line with the growing consumer concern with functional ingredients such as chia seeds and eggplant flour that have high fibre content and antioxidant qualities (Rodriguez-Jimenez et al., 2018).

This is a tendency that is highly observed in the Malaysian market. According to a recent feasibility study by Aida et al. (2024), post-pandemic health consciousness is on a high spurt with awareness of the benefits of functional foods portrayed by 96.9% of Malaysian respondents. Increasing energy and endurance (70.1%) and improving the immune system (57.7%) are the main motivators of the Malaysian consumers. Most importantly, this need is very knowledgeable as about 88% of Malaysian buyers claim that they use information about food labels to make buying choices (Aida et al., 2024). This fact implies that reformulated pancakes with the ability to make nutritional claims have a strong market viability that can balance the coming together of the convenience of the traditional bakery product and the nutritional strictness offered by contemporary consumers (Hassan et al., 2023; Lee, 2024).

2.1.2 Epidemiology of Non-Communicable Diseases (NCDs) in Malaysia

The increasing rates of non-communicable diseases (NCDs) in Malaysia are one of the main issues in public health that is closely associated with eating habits. According to the National Health and Morbidity Survey (NHMS) 2023, the prevalence of the overweight and obese in adults in Malaysia has reached 54.4% and abdominal obesity has affected 54.5% of adults in Malaysia (IPH, 2024). Such statistics are representative of a larger trend in the entire world in which diet-related conditions like obesity, type 2 diabetes and cardiovascular diseases are rising because of the excessive changes in refined carbohydrates (Bigliardi and Galati, 2013; Lee, 2024).

One of the most important causes of this epidemiological burden is the consumption of high-glycemic, nutrition-poor foods. A common staple ingredient in most Malaysian bakery products such as pancakes is wheat flour that leads to high glycemic responses that may worsen the insulin resistance and metabolic dysfunction (Augustin et al., 2015; Adonu et al., 2022). The excessive consumption of refined carbohydrates and sugars is also supported by the recent research which found that 53.6% of Malaysian adults drink the sugar-sweetened drinks on a daily basis (IPH, 2024). The shift to the use of functional foods based on low-glycemic products, including chia seeds and eggplant flour, is a possible dietary option to alleviate these dangers (Abdi et al., 2025). The glycemic index of the staple foods can be reduced by substituting refined wheat flour with alternatives that contain a good amount of fibre which may help in controlling obesity and diabetes among the Malaysian population.

2.1.3 Dietary Fibre and Protein Gap

Fibre in the diet is an important nutrient in terms of digestive health, blood glucose and non-communicable diseases (NCDs). The Malaysian Dietary Guidelines recommend a daily dietary fibre intake of 20g to 30g for adults (Ministry of Health Malaysia [MOH], 2020). Nevertheless, there is a wide gap in these recommendations and the reality of the routine consumption of the Malaysian people. It has been shown that the fibre intake target might be exceedingly high at the present level and the remainder of the population might not be able to attain it without intervention of functional food; it has been seen that Malaysian adults are taking an average of 10.7g to 16.1g fibre per day and about 75.95% of the population is not able to reach the minimum RNI of 20g (Ng et al., 2010).

This general lack of adequacy is supported by more recent statistics. Mamat Ibrahim et al. (2022) have noted that 84.6% of adults in Malaysia take less than the 25g of dietary fibre suggested by the World Health Organization and the median is only 12.02g. This is a deficiency that is closely associated with diet patterns that have a low intake of whole plant foods. According to the National Health and Morbidity Survey (NHMS) 2024, only 17% of the adult population in Malaysia consume 2 portions of fruits and only 12% for 3 portions of vegetables daily (IPH, 2025). This fibre deficiency, in turn, adds to the occurrence of the so-called functional constipation and the risk of developing obesity based on so-called modern or western nutrition patterns with a high content of refined grains and food rich in energy (Noor et al., 2024; Mamat Ibrahim et al., 2022).

This "fibre gap" is also worsened by the fact that refined wheat flour that is used in bakery items is defibrillated of its bran and germ in the mills (Alrayyes, 2018). To overcome this inadequacy the strategic redesigning of staple foods is necessary. Eggplant flour is a thick source of fibre, with about 33.79% of crude fibre, which is much higher as compared to refined wheat flour (Uthumporn et al., 2014). Moreover, chia seeds are an effective functional ingredient. 100g of the product contains 30g to 40g of dietary fibre that is equivalent to the daily health recommendation of 100g (Rani et al., 2023; Paramita et al., 2022). This paper will seek to manufacture a functional food item by including these high-fibre ingredients in pancakes, that directly overcomes the deficit of fibre in the general population but does not compromise the consumer acceptability.

In spite of sufficient caloric intake of contemporary foods, protein-energy malnutrition (PEM) is still a prominent health issue of the population, especially when the diet of the population depends heavily on single-source cereal staples. Dietary protein is not just a source of energy but a very important provider of essential amino acids needed to grow, develop immunity and sustain lean body mass (Wu, 2016). Poor consumption of high quality protein shows a strong correlation with stunting in children and sarcopenia in the elderly.

One of the main factors that cause this quality difference is the nutritional value of the wheat flour. Although wheat has been a major food source of dietary energy in the world, Shewry and Hey (2015) point out that gluten proteins are grossly lacking lysine, which is the first limiting essential amino acid. Such amino acid imbalance limits the body in the ability to use the protein intake absorbed effectively, essentially wasting part of the nutritional intake. To counter this, cereal-based foods would be reformulated through complementary plant proteins (Day, 2013). Food formulators can adjust the amino acid score by adding ingredients like chia seed to wheat-based matrices to change a normal bakery product into a functional delivery system of full nutrition.

2.2 Pancake Formulation

2.2.1 Functional Role of Wheat Gluten

In the traditional pancakes, the main structural ingredient is wheat flour and this is mostly so because of its special protein complex called gluten (Adonu et al., 2022). The gluten proteins, in particular gliadins and glutenins, when hydrated and mixed build a continuous cohesive network, which provides the batter with viscoelastic qualities (Day et al., 2005). According to Mioduszewski and Cieplak (2021), this interaction occurs due to the synergistic effect of glutenins that are the giants of polymeric networks that give rise to elasticity and mechanical strength and gliadins that are the plasticizers that give rise to viscosity. This molecular structure may be referred to as the loops and trains model, and it forms a tangled web that can stretch without breaking (Mioduszewski and Cieplak, 2021).

The viscoelastic network plays a vital role in the formation of the structure. It captures gases of carbon dioxide that are emitted by the raising agents and stops them escaping the batter (Shewry, 2009). This is what makes the pancake rise and acquire its typical soft, airy and porous crumb texture when cooked because of the ability to retain gases (Adonu et al., 2022). In particular, in the special case of pancake manufacturing, where the fluid batter is confined and it is not a stiff dough, the functional activity of gluten is expanded to control batter rheology. The concentration of flour protein is one of the dominant factors that determine the batter flow (viscosity) and the end size of pancakes. Although the pancakes are traditionally prepared using soft wheat flours to ensure that the dough is not too thick, a minimum concentration of protein activity is necessary. Lack of protein may cause low viscosity and poor gas bubble retention, whereas too much protein can cause an extremely thick pancake dough that cannot be spread sufficiently over the griddle (Fajardo & Ross, 2015).

2.2.2 Mechanisms of Chemical Leavening

Chemically leavened products such as pancakes are produced in a manner that the inorganic salts are reacted instead of fermented by bioorganisms to produce porosity and texture. Chemical leaveners work by reacting with the batter to form gases, which are mainly carbon dioxide (CO_2), which causes the expansion or levitation of the product (De Leyn, 2014). The fundamental mechanism usually involves the interaction between an alkaline soda (baking soda) and an acidic salt. These components combine in the presence of moisture and heat during the cooking process to yield carbon dioxide gas, water and salt (De Leyn, 2014) which are important factors in developing the crumb structure. The resulting carbon dioxide gas is diffused into air bubbles added at the mixing step and hence making them expand and raise the batter. This growth generates the pancake lightness characteristic that has a direct effect on other pancake properties, including volume, shape, tenderness and brittle nature (De Leyn, 2014). Moreover, the physical leavening agents have a supporting function. The evaporation of water into steam and thermal extension of the entrained air are also additional contributors of the end volume and open structure of the baked product (De Leyn, 2014). The effective use of chemical leavening is especially crucial in reformulated pancakes, where the ingredient composition of the final product must remain soft and palatable through the use of fibre-rich materials such as eggplant flour and chia seeds that make pancakes heavy.

2.2.3 Mechanism of Batter Viscosity

The rheological parameter of pancake batter viscosity has a great influence because it determines the texture, volume and mouthfeel of the end product. Primarily, the viscosity of batter depends on the hydration of biopolymers which are starch and proteins as well as their interactions in the aqueous phase. The studies of pancake dough rheology revealed that viscosity is strongly temperature-sensitive. The dynamic viscosity decreases exponentially with temperature, which can be explained by the fact that more energy is transformed into kinetic energy and intermolecular forces become weaker (Hlaváč & Božiková, 2013). Nevertheless, in composite flour systems whereby the wheat is substituted with fibre-containing products such as eggplant and chia, the process of thickening also changes to something involving a more intricate hydrocolloid interaction besides starch-based gelatinization.

The addition of chia seed powder gives the batter matrix a potent hydrocolloid. The mucilage which is a soluble fibre secreted by the seeds has non-Newtonian and pseudoplastic (shear-thinning) flow characteristics, meaning its viscosity decreases under shear stress like mixing and recovered when at rest (Capitani et al., 2015). This is a rheological characteristic that is essential in the making of pancakes. The batter can be poured freely by the griddle without losing its integrity such that it does not spread too wide before the heat solidifies the crumb. Chia mucilage is concentration-dependent in causing the thickening effect, which occurs by entangling the strands of its polysaccharide chains that form a weak gel-like network, resembling the viscoelastic effect of gluten (Capitani et al., 2015).

Besides the hydrocolloid activity, the elevated content of fibre in eggplant and chia flours is important in having an impact on batter viscosity by the physical absorption of water. Composite flours have a potential of higher water absorption capacity (WAC) than a normal wheat flour because the hydroxyl groups of the fibre bind hydrogen bonds with water molecules (Hasmadi et al., 2020). This reduces the swelling rate of the starch granules during the initial mixing stage but causes rapid rise in the consistency when the fibre particles become completely hydrated. As a result, batters made with these high-fibre ingredients are seen as being physically thicker and they need to have their moisture levels altered accurately to ensure flowability. Moreover, the interaction of the protein content and amylose in the flour also further determine the pasting behavior. Protein can regulate swellings of starch particles and modify the final profile of viscosity in the course of heating (Zhou, 2014).

2.3 Eggplant (*Solanum melongena* L.)

2.3.1 Fibre and Ash Content

Analytical studies of eggplant have always found it to be a good source of dietary fibre and mineral constituents expressed analytically as ash content. Although the fresh vegetable has a high moisture content with an average of 80.29% to 95.0%

depending on the type of vegetable (Chuku et al., 2020; Ebiringa, 2021), the transformation of the fruit to flour substantially concentrates the solids, which is why it is a powerful functional ingredient. The levels of ash in fresh cultivars are typically between 0.52% and 1.0% (Chuku et al., 2020; Ebiringa, 2021). There is no even distribution of ash content, the peel (coat) has been observed to be coated with much higher ash contents, ranging up to 3.5% while the flesh, which ranges at an average of approximately 1.0% to 2.1% (Asaolu and Asaolu, 2002; Mohamed et al., 2019). After being turned into flour, the values increase significantly. The investigation of eggplant flour found that pulp flour had ash contents of 4.22% and peel flour had up to 6.20%, while composite flours made with eggplant had ash contents of 7.09% (Chamba et al., 2024).

The mineral profile as indicated by the ash content implies that potassium is the dominant mineral in *Solanum melongena*. Several of the studies recognize potassium (K) as the most common element and its levels in eggplant flour can be up to 23,801 27,889 mg /kg (Mohamed et al., 2019; Ayaz et al., 2015). In addition to potassium, magnesium and calcium are also abundant in the flour, containing on average 2000 to 2200 mg/kg of magnesium and different amounts of calcium that are useful in metabolic health (Mohamed et al., 2019). The iron content is also striking with certain flour formulations measuring 51.57 mg/100g, which is already a lot higher than most of the other common flours such as sorghum (Chamba et al., 2024). It is also worth mentioning that the composition of the minerals may also be different depending on the cultivar. For example, the *Solanum anguivi* cultivar was identified to contain more iron and calcium than *Solanum macrocarpon* or commercial varieties such as Black Beauty (Ebiringa, 2021).

When it comes to fibre, the eggplant has been known to have an advanced soluble and insoluble fraction matrix, which is essential in the formation of texture in bakery products. In a fresh eggplant, the crude fibre content measures 2.02% to 2.86% (Ebiringa, 2021). In eggplant flour, the concentrations are enormous, the complete eggplant flour may contain total dietary fibre as high as 36.64%, and the peel flour may have it as high as 43.62% (Mohamed et al., 2019). The primary components of this fibre are the cellulose and lignin fractions (insoluble), particularly in the peel, the cellulose content can reach 27.2% relative to 6.8% in the flesh (Higuera-Coelho et al., 2025). The flour also has a good amount of soluble fibre, including pectic materials (uronic acids), which are between 14.1% in the flesh and 23.9% in the peel (Higuera-Coelho et al., 2025). These pectic compounds play a crucial role in the hydration qualities, which may affect the viscosity of the batter and keeping of moisture in product formulations.

The technology applied in the production of the flour has an influence on the nutrient retention that is left behind. In contrast with vitamins, which can be damaged by heat, the contents of ash and fibre do not change significantly during thermal processing but, as with wet-heating processes, there is a possibility of a leaching of minerals into the water due to wet-heating (Asaolu and Asaolu, 2002). Nevertheless, the addition of eggplant flour into bakery items has not been in vain. The studies of cookies replaced with 15% eggplant flour showed a massive rise in the amount of crude fibre content up to 400 times higher than wheat cookies made with control agglomerates proving that the fibre is also functional even after baking (Uthumporn et al., 2014). It is therefore advisable to use the entire fruit which retain the peel in the manufacturing process of flour to maximize the proportion of minerals as well as the functional dietary fibres in the end product.

2.3.2 Impact of Drying on Nutrient Retention

Eggplant drying into flour using ovens at 55℃ is a very important procedure that is aimed at increasing the shelf life and maintaining the quality of macronutrients. Fresh eggplant is a very perishable product with a moisture content of over 90%. The drying of the moisture to less than 10% prevents the growth of microorganisms and solids the nutritional components of it (Rodriguez-Jimenez et al., 2018). It has been found that drying temperatures between 45℃ and 55℃ are the most suitable in reducing nutrient damages and providing sufficient dehydration performance (Asemave et al., 2023).

Proteins and crude fats in eggplant show a lot of stability to mild thermal processing with respect to macronutrients. Comparative studies have revealed that eggplants dried in an oven at moderate temperatures have retained a high protein and fat content on a dry weight basis. Moreover, the results of the comparative study between flours dried at 45℃ and 55℃ showed that proximate parameters, especially ash and lipid contents were maintained, which means that moderate heat treatment does not cause any essential oxidative degradation of the lipid fraction (Asemave et al., 2023).

This stability is important in maintaining that the resultant flour can be used as an effective nutritional ingredient in composite food preparations.

Drying is also essential in preservation and concentration of the dietary fibre and carbohydrates. Air drying does not cause the solubilization and leaching of water-soluble carbohydrates found in food, unlike wet-thermal processing which causes solubilization and leaching of such compounds (Kane et al., 2024). Under these conditions, the total dietary fibre content of eggplant flour is high and it is usually higher than 34% (Blumenthal-Rodriguez et al., 2025). This retention is explained by the relatively low temperature of 55℃, which reduces the hardening mechanism that can preserve nutritional integrity and enables the retention of the crude fibre content (Rodriguez-Jimenez et al., 2018). Oven drying at 55℃ is therefore an effective way of transforming the perishable vegetable into a shelf-stable flour which still maintains its original macronutrient profile in a concentrated form.

2.3.3 Sensory Limitations of Vegetable Flours

Although there are benefits associated with the nutritional fortification of bakery products using vegetable flours, this has great sensory challenges which may hinder consumer acceptance of the products in terms of flavor profile and visual qualities. One of them is the introduction of bitter or astringent aftertastes. In eggplant flour, this bitterness is much related to the presence of steroidal glycoalkaloids (SGAs) namely solamargine and solasonine. These secondary metabolites appear as a natural defense mechanism to the plant but even when low concentration is taken (Al Sinani and

Eltayeb, 2017), the compound gives the plant a characteristic bitter flavor that may be perceived by consumers. This would require careful control of levels of substitution as studies have shown that at a certain threshold, one can no longer taste the product because of the level of intensity of these particular phytochemicals.

Another essential sensory weakness is color degradation. The addition of eggplant flour generally causes the crumb to be very dark, changing the appearance of the product to a darker, less traditional color than the common golden-brown of wheat pancakes. When eggplant powder was used as a tartlet ingredient increasing the eggplant powder content of the product during the formulation of the product, the color of the product gradually changed to become dark coffee (Styrev et al., 2023). This coloration is normally stimulated by enzymatic browning reactions (polyphenol oxidase) in the flour processing and oxidation of the phenolic compounds during baking.

Furthermore, at high substitution rates, textural attributes can be adversely affected. According to Styrev et al. (2023), a 10% to 20% substitution produced a consistency that was similar to the control but a 30% substitution produced a much drier and more crumbly product. Thus, in order to effectively introduce such functional ingredients as eggplant flour and chia seeds, a scientifically needed range of substitution, which is expected to be between 10% to 20%. The balance is achieved through this variety of substitution, where bioactive compounds (SGAs and phenolics) can be executed without compromising on acceptable sensory characteristics in terms of color, texture and taste.

2.4 Chia Seed (*Salvia hispanica* L.)

2.4.1 Protein and Lipid Profile

Chia (*Salvia hispanica* L.) is gaining growing popularity in food science as a food functional ingredient because of its high density of bioactive macromolecules or proteins and lipids. Unlike typical cereal grains, chia seeds possess a protein content ranging between 15% and 25%, significantly exceeding that of wheat, corn and rice (Julio et al., 2019; Din et al., 2021). In addition, chia seeds contain about 30% to 40% lipids with most of them being polyunsaturated fatty acids (PUFAs) and as such; the seeds are a significant source of nutritional fortification in bakery preparations (Din et al., 2021).

The protein fraction of chia is distinct from wheat gluten, composed primarily of globulins (52%) and albumins (17.3%), with lower quantities of glutelins and prolamins (Sandoval-Oliveros & Paredes-López, 2013). This distribution is technologically significant for product development. Globulins, as the dominant fraction, have been shown to exhibit superior emulsifying stability at neutral pH, which can enhance batter consistency in the absence of wheat gluten (Julio et al., 2019). From a nutritional perspective, chia protein is considered high quality due to its balance of essential amino acids. While lysine is the limiting amino acid, chia is notably rich in sulfur-containing amino acids (methionine and cysteine), which are often deficient in other legumes

(Sandoval-Oliveros & Paredes-López, 2013; Din et al., 2021). Additionally, the absence of gluten makes chia an essential texturizing alternative for developing gluten-free or composite flour pancakes, as the protein network can mimic the viscoelastic properties required for gas retention during cooking (Fatima et al., 2025).

The lipid profile of chia is characterized by an exceptionally high ratio of polyunsaturated fatty acids. Analysis of chia oil reveals that α-linolenic acid (Omega-3) constitutes approximately 60% of the total fatty acids, followed by linoleic acid (Omega-6) at roughly 20% and oleic acid at 10% (Ghafoor et al., 2020; Din et al., 2021). This composition provides a high nutritional index (n-3/n-6 ratio) that is beneficial for cardiovascular health (Fatima et al., 2025). However, the high degree of unsaturation presents a challenge during thermal processing. Research indicates that exposure to temperatures exceeding 90°C can induce lipid peroxidation, leading to an increase in peroxide values and a degradation of bioactive tocopherols (Ghafoor et al., 2020). Therefore, when analyzing the approximate composition of cooked products like pancakes, particular attention must be given to the retention of crude fat and the potential oxidative changes occurring during the frying process.

2.4.2 Mimicking Gluten Viscoelasticity

Absence of gluten in composite flour formulations is a structural problem, since gluten is the one that gives the formulation the gas retentiveness and elasticity needed to ensure texture (Day et al., 2005). Chia seeds may be utilized as a gluten mimetic due to the mucilaginous property. When hydrated, chia seeds are capable of producing a gel-like texture that has the capacity to resemble gluten viscoelasticity and consequently may aid in the formation of the structures in gluten-free and low-gluten food (Ixtaina et al., 2011). Rheological experiments prove that chia seed hydrogels possess viscoelastic solid properties when elastic (storage) modulus (G') predominates over the viscous (loss) modulus (G''). According to which, the gel assumes a stable inner structure that is capable of resistance to deformation (Tomic et al., 2022). The values of the phase angle ($\tan \delta = G''/G'$) are usually less than 1, which points to an elastic behavior and makes the hydrated mucilage a weak gel (Tomic et al., 2022). It is an inner structure with the ability to maintain the geometry of the product and also a certain volume even without gluten or hard fats (Tomic et al., 2022).

Moreover, hydrated chia seeds are reported to enhance the elasticity of the dough systems when introduced (Švec and Hrušková, 2015). Although the replacement of wheat flour causes the dilution of gluten proteins, in addition to hydrated chia, it keeps the dough elastic and machinable without affecting the specific volume of the final baked product adversely (Svec and Hruskova, 2015). Therefore, the chia seed gel addresses the structural deficiencies of gluten-free and low-gluten products with raising moisture retention and entrapment of air bubbles to create an integrated crumb structure (Matita et al., 2024).

2.4.3 Impact of Lipid Contribution and Oil Absorption on Mouthfeel

The sensory characteristic which is determined as the mouthfeel of the bakery products is inherently connected with lipids' dynamic interaction with the protein-fibre