

UTILIZATION OF JACKFRUIT SEED FLOUR
(*Artocarpus Heterophyllus Lam.*) AND
OVERRIPE BANANA SWEETENER (*Musa Spp.*) AS
PARTIAL SUBSTITUTE FOR WHEAT FLOUR AND WHITE
SUGAR IN KUIH LAPIS

MOGESSHINI A/P SURESH

Thesis submitted in partial fulfilment of the requirements for the
degree of Bachelor of Health Sciences (Honours) (Nutrition)

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CERTIFICATE

This is to certify that the dissertation entitled ‘Utilization of Jackfruit Seed Flour (*Artocarpus heterophyllus* Lam.) and Overripe Banana Sweetener (*Musa spp.*) as Partial Substitute for Wheat Flour and White Sugar in *Kuih Lapis*’ is the Bonafide record of research work done by Mogesshini A/P Suresh, Maric Number 164298, during the period of April 2025 to February 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 of Health Sciences (Hons) (Nutrition). Research work and collection of data belong to the Universiti Sains Malaysia.

Signature of Supervisor

.....

Prof. Dr. Wan Rosli Wan Ishak

Nutrition

School of Health Sciences

Universiti Sains Malaysia

Date:

DECLARATION PAGE

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at USM or other institutions. I acknowledged that the research work and collection of data belong to Universiti Sanis Malaysia.

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Mogesshini A/P Suresh

6 January 2026

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ABSTRAK

Hasil sampingan pemrosesan makanan, khususnya yang berasal daripada buah-buahan dan sayur-sayuran, merupakan sumber kaya dengan sebatian bioaktif seperti serat pemakanan, sebatian fenolik, vitamin dan antioksidan, sekali gus menjadikannya bahan yang berpotensi untuk pembangunan makanan fungsian. Pembaziran makanan telah muncul sebagai satu cabaran global yang kritikal, yang menyumbang kepada kemerosotan alam sekitar, kerugian ekonomi dan ketidakcekapan nutrisi. Sehubungan itu, kajian ini bertujuan untuk menilai potensi pemanfaatan semula bahan buangan makanan terpilih, Tepung Biji Nangka (JSF), Pemanis Pisang Terlalu Masak (OBS) dan Serbuk Buah Naga (DFP) dalam *kuih lapis*. Secara khusus, kajian ini menilai kesan penambahan JSF, OBS dan DFP terhadap komposisi proksimat, kandungan gula, ciri warna serta ciri sensori kuih lapis. Keputusan kajian menunjukkan bahawa penambahan JSF, OBS dan DFP telah mempengaruhi secara signifikan semua parameter yang dinilai. Secara keseluruhannya, dapatan ini menunjukkan bahawa JSF, OBS dan DFP mempunyai potensi yang besar sebagai bahan fungsian untuk menghasilkan kuih lapis yang lebih sihat tanpa menjejaskan penerimaan sensori berbanding formulasi kawalan.

ABSTRACT

Food processing by-products, especially from fruits and vegetables, are rich in bioactive compounds such as dietary fiber, phenolic compounds, vitamins, and antioxidants, making them promising ingredients for functional food development. This study focuses on evaluating the potential of selected food waste materials for valorisation into value-added food products. Food waste has emerged as a critical global challenge, contributing significantly to environmental degradation, economic losses, and nutritional inefficiencies. In response to this issue, the present study's objective was to evaluate potential valorisation of Jackfruit Seed Flour (JSF), Overripe Banana Sweetener (OBS) and Dragon Fruit Powder (DFP) affected the proximate composition, sugar content, colour attributes and sensory characteristics of *kuih lapis*. The results demonstrated that the incorporation of JSF, OBS, and DFP significantly influenced all evaluated parameters. Overall, these findings indicate that JSF, OBS, and DFP have strong potential as functional ingredients for producing a healthier *kuih lapis* without compromising the sensory acceptability compared to the control formulation.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABK	Apam Balik Kuih
ADP	Adenosine diphosphate
ANOVA	One-way Analysis of Variance
AOAC	Association of Official Analytical Chemists
ATP	Adenosine triphosphate
BMI	Body Mass Index
CCNFSDU	Codex Committee on Nutrition and Foods for Special Dietary Uses
CLR	C-type lectin receptor
CRP	C-reactive protein
DF	Dilution factor
DFP	Dragon Fruit Powder
DFPP	Dragon Fruit Peel Powder
DNA	Deoxyribonucleic Acid
DPPH	1,1-diphenyl-2-picrylhydrazyl
DW	Dry Weight
eGI	Estimated Glycaemic Index
EG	Enzymatic-Gravimetric
Et al.	And others
F6P	Fructose-6-phosphate
FOS	Fructooligosaccharides
G-6-P	D-glucose-6-phosphate
G6PDH	Glucose-6-phosphate dehydrogenase
GI	Gastrointestinal
HK	Hexokinase
HPLC	High Performance Liquid Chromatography
IBD	Inflammatory Bowel Disease
IDF	Insoluble Dietary Fibre
JSF	Jackfruit Seed Flour
kcal	Kilocalorie
LOCPF	Leftover Coconut Pulp Flour
LoQ	Limit of Quantification
mL	Millilitre
MW	Molecular Weight
NAD	Nicotinamide adenine dinucleotide
NADH	Reduced nicotinamide adenine dinucleotide
NO	Nitric Oxide
OBS	Overripe Banana Flour
OBP	Overripe Banana Powder
PGI	Phosphoglucose Isomerase

RAG	Rapidly Available Glucose
RB	Reagent Blank
RID	Refractive Index Detector
RNI	Recommended Nutrient Intake
ROS	Reactive Oxygen Species
rpm	Revolutions per minute
RS	Resistant Starch
RSD	Relative Standard Deviation
SAG	Slowly Available Glucose
SCFA	Short Chain Fatty Acids
SD	Standard Deviation
SDF	Soluble Dietary Fibre
SPSS	Statistical Package for the Social Sciences
Spp.	Species
TEA	Triethylamine
TDF	Total Dietary Fibre
USDA	United States Department of Agriculture
USA	United States of America
UV	Ultraviolet
UVB	Ultraviolet B
WAC	Water Absorption Capacity
%	Percentage
<	Less than
>	More than
±	Plus-minus
°C	Degree Celsius
\$	Dollar
α	Alpha
C	Carbon
g	Gram
g/kg/day	Gram per kilogram body weight per day
g/mol	Gram per mole
g/mL	Gram per millilitre
H	Hydrogen
kg	Kilogram
kg/cm ²	Kilogram per square centimetre
kJ	Kilojoule
mg	Milligram

mg/g	Milligram per gram
μg	Microgram
μL	Microlitre
μm	Micrometre
Nm	Nanometre
O	Oxygen
pH	Potential of Hydrogen
ppm	Parts per million
v	Sample volume
d	Optical path length
ε	Extinction coefficient

CHAPTER 1: INTRODUCTION

1.1 Background of Study

Malaysia, a Southeast Asian federation rich in multicultural heritage, thrives on its diverse population of Malays, Chinese, Indians, and indigenous communities (MyGOV – Government of Malaysia's Official Portal). This diversity is reflected in its vibrant food culture, particularly the role of kuih, which encompasses a variety of sweet and savoury delicacies enjoyed during festive celebrations and daily life (Kamaruzaman *et al.*, 2020). The significance of kuih is rooted in historical migration patterns, especially the Peranakan or Nyonya community, whose blending of Chinese and indigenous Malay traditions influenced the evolution of Malaysian cuisine. Western colonial influences also played a role in shaping its distinct culinary identity, making kuih a treasured part of Malaysia's gastronomic heritage (Asian Inspirations, 2018).

Kuih Lapis, one of Malaysia's top ten national heritage foods, was officially designated as such by the Heritage Commissioner of the National Heritage Department on February 4, under the National Heritage Act 2005 [Act 645] (Mel, 2024). This recognition underscores its cultural and historical importance, aligning with broader efforts to preserve Malaysia's intangible cultural heritage, including traditional cuisines that reflect the nation's diverse ethnic and culinary identity. The term "*lapis*", meaning "layers", is rooted in Malay and Indonesian languages, while the word "kue" originates from Chaozhou or Teochew, highlighting Chinese culinary influences in Southeast Asia. Additionally, Dutch colonial practices introduced layered cake traditions, which were later adapted into regional specialities such as *Kuih Lapis* (Lee, 2022).

The preparation of *Kuih Lapis* relies on fundamental ingredients such as all-purpose flour, rice flour, corn flour, and coconut cream, complemented by salt, sugar, cooking oil, and food colouring for enhanced texture and flavour. Steaming is the primary cooking method, ensuring the delicate layering and preserving natural flavours inherent to Malaysian culinary traditions (Che Nom, 2014). This technique maintains the structural integrity and visual appeal of *Kuih Lapis* while honouring its rich heritage. The layered cakes of Asia, including *Kuih Lapis*, exemplify cultural exchange and adaptation through trade and colonization, serving as a testament to the evolving nature of food traditions (Pietrantonio, 2025).

Beyond its cultural significance, *Kuih Lapis* presents dietary concerns due to its high sugar content. According to the study by Tee et al. (1989), *Kuih Lapis* has been identified to contain 32.2% carbohydrates, 63.7% moisture, 3.0% protein, 0.6% fat, and no crude fiber is detected. Furthermore, Azizah et al. (2015) conducted a study examining the quantity and types of sugar present in nine varieties of traditional Malaysian *kuih*. Among them, *Kuih Lapis* was identified as having the second highest sugar content, with 14.5 grams of sugar per 100 g of *kuih*. These studies highlight a potential nutritional gap and suggest that many local delicacies were high in sugar but lack dietary fiber and protein, which may contribute to concerns about dietary sugar intake and its potential health implications.

The increasing generation of food waste across processing, retail, and household levels represents a critical and interconnected challenge for food system sustainability, resource efficiency, and food security. Although large quantities of fruits such as jackfruit, banana, and red dragon fruit are processed annually, their by-products

including seeds, peels, and overripe pulp are frequently discarded due to perishability, aesthetic standards, and limited utilisation pathways, despite being rich in bioactive compounds and nutrients with functional potential (Dueñas & García-Estévez, 2020; Akter & Haque, 2020; Ng et al., 2020b; Rosidi et al., 2021). This underutilisation contributes to the broader global food waste problem, which reached approximately 1,052 million tonnes in 2022, accounting for nearly 19% of food available to consumers and directly undermining Sustainable Development Goal 12.3, which targets the reduction of food loss and waste across supply chains (FAO, 2022; United Nations Environment Programme, 2024). In Malaysia, the issue is particularly acute, with daily food waste generation accelerating landfill depletion, increasing methane emissions, and imposing substantial economic losses, while paradoxically coexisting with persistent food insecurity (Lai, 2025; Todd & Klingbeil, 2024). These interlinked challenges underscore the urgency of addressing food waste not merely as a disposal problem, but as a systemic inefficiency that demands innovative valorisation strategies to convert underused fruit by-products into value-added food ingredients, thereby advancing environmental sustainability, economic resilience, and responsible consumption and production.

Jackfruit seed flour (JSF), overripe banana sweetener (OBS) and dragon fruit powder (DFP) offer promising alternatives to conventional ingredients, aligning with efforts to reduce food waste and improve dietary profiles. Jackfruit (*Artocarpus heterophyllus* Lam.) is recognised as the largest edible fruit worldwide. Native to the forests of the Western Ghats in India, it continues to flourish in the wild and is also found in the evergreen forests of Assam and Myanmar. Today, it is cultivated across various South and Southeast Asian countries, including Bangladesh, Burma, India,

Indonesia, Malaysia, the Philippines, Sri Lanka, and Thailand. This fruit is classified as a multiple fruit, composed of edible parts (pulp and seeds) and non-edible portions (rind and rachis). Its uses were remarkably diverse: the unripe green jackfruit is commonly prepared as a vegetable, while the sweet pulp of the ripe fruit is consumed fresh as a dessert. Additionally, the fruit is utilised in various industrial applications, such as the production of jams, beverages, candies, preserves, and dried products (Ajayi, 2011). The potential applications of JSF as a food ingredient have been the subject of various studies. Jannatul Hema et al. (2016) proposed that JSF could serve as a viable alternative to wheat flour in a range of products, including vada, chapati, bread, cake, buttered biscuits, pancakes, and noodles. Additionally, Hestiningtyas et al. (2022) substituted JSF and Branch Flour into noodles for diabetic patients. Their findings suggest that jackfruit seed flour not only offers functional versatility but also contributes positively to the sensory and textural qualities of these items. According to a study by Arefin et al. (2020), the nutrient composition of five different flours, jackfruit seed powder, rice powder, barley powder, wheat flour, and maize powder were analysed. The findings revealed that jackfruit seed powder has a notably high protein content, amounting to 17.04%, which is significantly greater compared to rice powder, wheat flour, and maize powder. Additionally, it was observed that jackfruit seed powder contains a significantly higher amount of dietary fiber when compared to rice and wheat. Despite the plentiful availability of jackfruits, their seeds remain largely underutilised (Amabile Manianga et al., 2024). This overlooked byproduct offers considerable nutritional benefits, including high protein content and dietary fiber, as highlighted by research. Encouraging the use of jackfruit seeds not only enhances dietary diversity but

also promotes sustainable practices by minimising food waste and unlocking their potential as a valuable ingredient in modern food applications.

On the other hand, the banana, a delectable and nutrient-rich fruit from the Musaceae family and classified under the genus *Musa*, is widely recognised for its affordability and accessibility across the globe, catering to all age groups. Its ease of digestion, low fat content, and ample supply of essential minerals and vitamins make it a preferred choice in specialised diets (Zahra et al., 2021). Bananas, like many fruits, interact with an airborne hormone known as ethylene, which plays a crucial role in signalling the ripening process. Upon exposure to ethylene gas, the fruit undergoes a transformation wherein acids were broken down, resulting in a softer texture. Simultaneously, the chlorophyll pigments degrade and were replaced by the yellow colouration typical of ripe bananas. This process leads to the reduction of acidity and the development of a sweeter and softer interior (Hogeback, 2019). While the health benefits and applications of bananas were extensively studied, the potential of overripe bananas remains relatively underexplored. Additionally, their enhanced sweetness and soft texture make them ideal for baking, smoothies, and even skincare applications (L, 2025). Exploring these aspects further could unlock valuable insights into their nutritional and functional benefits. Based on a study conducted by Kumar et al. (2019), banana powder derived from overripe bananas through microwave blanching demonstrated notably higher moisture content (3.80%), crude fiber (3.82%), and total phenolic compounds (14.22 mg/100 g) when compared to ripe banana powder. In conclusion, overripe bananas offer unique advantages that go beyond their traditional use as a food product. Their higher moisture, crude fiber, and phenolic content, as seen in overripe banana sweetener, suggest potential nutritional and functional benefits. They

were ideal for applications such as baking, and smoothies, leveraging their enhanced sweetness and antioxidant properties. Furthermore, utilising overripe bananas promotes sustainability by reducing food waste and expanding their value in modern culinary and industrial contexts.

In addition to utilising banana and jackfruit, this study also incorporates dragon fruit peel as one of the key ingredients. Dragon fruit, also known as pitaya or pitahaya, belongs to the *Hylocereus* genus within the Cactaceae family and is native to tropical regions of Mexico, Central America, and South America (Mizrahi, Nerd, & Nobel, 1997). It is recognised as a commercially significant fruit crop and is widely cultivated across tropical and subtropical regions worldwide due to its nutritional value and functional properties. Dragon fruit is classified based on the colour of its flesh and peel, with three predominant varieties such as red flesh/red peel, white flesh/red peel, and white flesh/yellow peel. The most extensively grown and consumed species include *Hylocereus polyrhizus*, *Hylocereus undatus*, and *Hylocereus megalanthus*, each exhibiting distinct bioactive compounds, pigmentation properties, and sensory attributes (Jiang et al., 2021). Red-fleshed dragon fruit was first introduced to Malaysia in the late 1990s and has since grown into a significant fruit crop within the country, contributing to both agricultural production and commercial markets (Joanna & Ding, 2022). Beyond its nutritional benefits, dragon fruit also possesses valuable by-products, particularly its peels, which contribute to functional food applications. According to Jiang et al. (2014), dragon fruit peels have been found to contain higher ash content compared to by-products of other fruits, including pineapple, papaya, blueberry, olive, and pequi, indicating their potential to provide a richer mineral profile. Additionally, pitaya peels exhibit significantly greater dietary fiber concentrations, suggesting their viability as an

emerging source of dietary fiber for food applications. Based on the study by Komang & Artiningsih (2020), the results indicate that the natural food colouring properties derived from dragon fruit peel exhibit a bright and appealing hue, significantly enhancing the visual aesthetics and texture of food products. The distinct colouration contributes to the overall sensory appeal, making food formulations more attractive to consumers. The incorporation of dragon fruit peel supports sustainable ingredient application, repurposing agricultural by-products while contributing dietary fiber and antioxidants to the formulation. In this study, dragon fruit, including its peel was powdered and was employed as a natural substitute for synthetic pink food colouring. Given its non-toxic and flavour-neutral properties, dragon peel powder serves as a viable alternative to synthetic food dyes, promoting clean-label formulations for traditional desserts like *Kuih Lapis*.

There is a need for healthier alternatives in traditional Malaysian *kuih*, particularly *Kuih Lapis*. Using jackfruit seed flour and overripe banana sweetener as substitutes for wheat flour and white sugar, this study aims to improve nutritional value, enhance dietary fiber intake, and reduce reliance on refined sugar while maintaining sensory appeal. Additionally, the incorporation of red dragon fruit powder introduces natural betalain and anthocyanin pigments, enhancing visual appeal while contributing antioxidants to the formulation. Overall this study promotes sustainability by utilizing underutilized agricultural by-products and supports cultural authenticity while adapting recipes to modern dietary needs. By introducing alternative formulations, the initiative tackles key dietary concerns and fosters inclusivity, directly aligning with Sustainable Development Goal (SDG) 3: Good Health and Well-being, which advocates for enhanced nutrition and the reduction of non-communicable diseases. In addition to its

nutritional focus, the research promotes sustainable use of ingredients by repurposing typically discarded agricultural by-products like jackfruit seeds and overripe bananas. This not only reduces post-harvest waste but also supports value-added strategies for waste management, reinforcing SDG 2: Zero Hunger, which emphasizes food security, better nutrition, and sustainable agricultural practices. Finally, utilizing ingredients derived from natural sources supports SDG, particularly Goal 12: Responsible Consumption and Production. This approach emphasizes waste reduction and efficient resource use, aligning with sustainable practices that promote environmental responsibility (Wang et al., 2019). Additionally, the findings could contribute to food innovation, offering a healthier version of *Kuih Lapis* without compromising its traditional essence.

1.2 Problem Statement

Food processing and consumption generate substantial volumes of waste, posing serious economic, environmental, and nutritional challenges, despite many by-products being rich sources of bioactive compounds such as dietary fiber, phenolics, vitamins, carotenoids, and natural sugars with proven health benefits (Dueñas & García-Estévez, 2020). Increased global fruit consumption has intensified the accumulation of underutilised wastes, including jackfruit seeds and rinds, overripe bananas, and red dragon fruit peels, which are often discarded due to perishability, aesthetic rejection, and limited processing options, even though they retain significant nutritional and functional potential (Akter & Haque, 2020; Mohammed et al., 2024; Ng et al., 2020b; Rosidi et al., 2021). At the global level, food waste reached approximately 1,052 million tonnes in 2022, accounting for nearly one-fifth of food available to consumers and undermining

progress towards Sustainable Development Goal 12.3, which aims to halve food waste and reduce losses across supply chains (FAO, 2022; United Nations Environment Programme, 2024). Nationally, Malaysia faces an escalating food waste crisis, generating about 16,688 tonnes daily, contributing to landfill saturation, methane emissions, and significant economic losses, while exacerbating food insecurity and inefficient resource use (Lai, 2025; Todd & Klingbeil, 2024). Despite the global rise in demand for healthy products, adaptations of traditional Malaysian *kuih* that balance nutritional value and sensory appeal remain scarce. Leveraging the increasing interest in innovative ingredients, such as jackfruit seed flour, overripe banana sweetener, and red dragon fruit powder, offers a promising avenue to create healthier, inclusive versions of *kuih* that cater to diverse dietary needs while preserving cultural authenticity. Therefore, this study aims to address this gap by evaluating the feasibility of incorporating jackfruit seed flour and overripe banana sweetener as substitutes for wheat flour and white sugar in the formulation of *Kuih Lapis*.

1.3 Significance of Research

This study pioneers a transformative approach to *Kuih Lapis* formulation, integrating functional ingredients such as jackfruit seed flour, overripe banana powder, and dragon fruit powder to enhance its nutritional profile while preserving cultural authenticity. In light of growing public health concerns related to excessive sugar consumption, this research aligns with current dietary trends emphasizing functional ingredients and reduced reliance on refined carbohydrates. This initiative promotes inclusive nutrition by developing alternative formulations that address dietary challenges, aligning with Sustainable Development Goal (SDG) 3: Good Health and

Well-being. It also supports SDG 2: Zero Hunger by repurposing often-discarded agricultural by-products like jackfruit seeds, dragon fruit and overripe bananas, reducing post-harvest losses and enhancing food security. Additionally, by modernizing traditional recipes through sustainable practices, it advances SDG 12: Responsible Consumption and Production without compromising cultural integrity.

1.4 Research Questions

1. What is the optimal substitution level of jackfruit seed flour and overripe banana sweetener in the development of *Kuih Lapis*?
2. How do varying substitution levels of jackfruit seed flour and overripe banana sweetener affect the proximate composition (moisture, protein, fat, ash) of *Kuih Lapis*?
3. How do the sensory attributes (e.g., taste, texture, colour, aroma, overall acceptability) differ among *Kuih Lapis* at different levels of substitution by jackfruit seed flour and overripe banana sweetener?
4. How does the sugar profile (fructose, glucose, sucrose, maltose) of *Kuih Lapis* vary with different substitution levels of jackfruit seed flour and overripe banana sweetener?
5. What were the colour variations among different substitution levels of jackfruit seed flour and overripe banana sweetener in *Kuih Lapis*?

1.5 Objectives

1.5.1 General Objectives

To evaluate the feasibility of substituting wheat flour and white sugar with jackfruit seed flour and overripe banana sweetener at different levels in the development of *Kuih Lapis*.

1.5.2 Specific Objectives

1. To identify the optimal substitution levels of jackfruit seed flour and overripe banana sweetener in the development of *Kuih Lapis*.
2. To determine the proximate composition (moisture, protein, fat, ash) of *Kuih Lapis* at different levels of substitution by jackfruit seed flour and overripe banana sweetener.
3. To evaluate the sensory attributes (taste, texture, colour, aroma, overall acceptability) of *Kuih Lapis* at different levels of substitution by jackfruit seed flour and overripe banana sweetener.
4. To investigate the sugar profile (fructose, glucose, sucrose, maltose) of *Kuih Lapis* at different levels of substitution by jackfruit seed flour and overripe banana sweetener.
5. To assess the colour variations among different levels of substitution by jackfruit seed flour and overripe banana sweetener in *Kuih Lapis*.

1.6 Study Hypothesis

1.6.1 Null Hypothesis

1. There is no significant difference among the different substitution levels of jackfruit seed flour and overripe banana sweetener in the development of *Kuih Lapis*.
2. The varying substitution levels of jackfruit seed flour and overripe banana sweetener do not significantly affect the proximate composition (protein, ash, moisture, fat) of *Kuih Lapis*.
3. The sensory attributes (appearance, texture, taste, aroma, and overall acceptability) of *Kuih Lapis* formulated with different levels of jackfruit seed flour and overripe banana sweetener do not differ significantly.
4. The sugar profile (fructose, glucose, sucrose, maltose) of *Kuih Lapis* at different levels of substitution by jackfruit seed flour and overripe banana sweetener does not differ significantly.
5. The colour properties of *Kuih Lapis* formulated at different substitution levels of jackfruit seed flour and overripe banana sweetener do not differ significantly.

1.6.2 Alternative Hypothesis

1. There is a significant difference among the different substitution levels of jackfruit seed flour and overripe banana sweetener in the development of *Kuih Lapis*.
2. The varying substitution levels of jackfruit seed flour and overripe banana sweetener significantly affect the proximate composition (protein, ash, moisture, fat and sugar content) of *Kuih Lapis*.

3. The sensory attributes (appearance, texture, taste, aroma, and overall acceptability) of *Kuih Lapis* formulated with different levels of jackfruit seed flour and overripe banana sweetener significantly differ.
4. The sugar profile (fructose, glucose, sucrose, maltose) of *Kuih Lapis* formulated at different levels of substitution by jackfruit seed flour and overripe banana sweetener differs significantly.
5. The colour properties of *Kuih Lapis* formulated at different substitution levels of jackfruit seed flour and overripe banana sweetener differ significantly.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to the Research Problem

Food processing generates substantial volumes of waste, posing a major economic, environmental, and nutritional concern. While these by-products, produced during cleaning, processing, cooking, and packaging are often discarded, they are in fact rich sources of bioactive compounds such as phenolics, dietary fiber, vitamins, carotenoids, and oils, which have documented health benefits (Dueñas & García-Estévez, 2020).

According to the review by Ung et al. (2025), the global fruit consumption has risen markedly over time, leading to the accumulation of substantial amounts of non-edible fruit by-products, especially seeds. These fruit seeds are frequently discarded even though they are valuable sources of macronutrients such as proteins, carbohydrates, and lipids. Jackfruit, especially generates more waste by-products than many other tropical fruits, particularly rind and seeds, which possess significant nutritional value. In India, approximately 75% of jackfruit products in India are wasted, representing an estimated economic loss of 20,000 million INR in Kerala and Karnataka (Mohammed et al., 2024). Similarly in Bangladesh, Jackfruit, locally known as *kathal*, is the national fruit of Bangladesh due to its widespread cultivation and popularity. The country's climate is highly suitable for jackfruit growth, with an annual production of about 1.03 million metric tonnes from approximately 27,316 acres of land (Akter & Haque, 2020). Its wastes can be classified into non-edible components, such as peel and central axis, and edible parts, such as seeds and perianth, the later representing an underutilized nutritional resource.

On the other hand, banana (*Musa* spp.) is a globally important fruit, with an estimated annual production of about 70 million tonnes. Despite its recognised nutritional value and health benefits, banana is highly perishable and has a short post-harvest shelf life. Overripe bananas are often rejected by consumers due to quality deterioration, such as browning and reduced pulp firmness, leading to substantial food waste as preference is given to yellow fruit. Nevertheless, overripe bananas remain a valuable source of vitamins, minerals, dietary fiber, and natural sweeteners (Darvari et al., 2010; Sidhu & Zafar, 2018; Karim et al., 2018; Symmank et al., 2018; Mattsson et al., 2018; Kumar et al., 2012, *as cited in* (Ng et al., 2020b)). Similarly, the substantial generation of red dragon fruit by-products, especially the peels commonly discarded by the food industry, has emerged as a significant waste management challenge. Valorising these by-products into value-added products with desirable physicochemical properties offers a promising strategy to mitigate environmental pollution and enhance resource efficiency (Rosidi et al., 2021).

The scale of global food waste underscores its systemic nature. In 2022, global food waste was estimated at 1,052 million tonnes, corresponding to an average of 132 kg per capita per year, with households responsible for 631 million tonnes (79 kg per capita), food service contributing 290 million tonnes (36 kg per capita), and retail accounting for 131 million tonnes (17 kg per capita). This wasted volume represents approximately 19% of food available for consumption at these stages, in addition to an estimated 13% of food lost earlier in the supply chain, from post-harvest through to just before retail (FAO, 2022), *as cited by* United Nations Environment Programme (2024). These figures underscore the significant inefficiencies in the food system and highlight the critical need for action.

These patterns of loss and waste directly undermine Sustainable Development Goal 12: Responsible Consumption and Production, Target 12.3 (SDG 12.3), which commits nations to halve per capita global food waste at the retail and consumer levels and to reduce food losses along production and supply chains, including post-harvest losses. The scale of current waste both edible and inedible, demonstrates the gap between present conditions and the target set by SDG 12.3, reinforcing the imperative for systemic interventions. By prioritising waste reduction and the valorisation of underutilised by-products (such as seeds, peels, and overripe produce), strategies can not only improve resource efficiency but also contribute to achieving SDG 12.3, while advancing food security and environmental sustainability (United Nations Environment Programme (2024)).

At the national level, Malaysia is experiencing a critical and escalating food waste crisis that poses serious economic, environmental, and food security challenges. An estimated 16,688 tonnes of food waste are generated daily, amounting to over 6 million tonnes annually, or approximately 260 kg per capita per year. This volume alone is sufficient to feed 12 million people multiple times daily, underscoring a profound inefficiency in the national food system. Food waste constitutes approximately 44% of Malaysia's total solid waste, with substantial contributions from households (38.32%) and restaurants (23.35%), alongside significant but often underreported losses from hotels, catering services, institutional kitchens, and commercial food production facilities. Regionally, Malaysia ranks among the highest food wasters in Southeast Asia, reflecting a persistent disconnect between widespread awareness of food waste impacts and the implementation of effective reduction strategies (Lai, 2025).

Moreover, from an environmental and policy perspective, food waste significantly contributes to ecological degradation and climate change (Todd & Klingbeil, 2024). The continued disposal of food waste is unsustainable, as Malaysia is projected to reach landfill capacity by 2050 (Lai, 2025), while the discarded food in landfills decomposes anaerobically, producing methane, a greenhouse gas with a global warming potential substantially higher than carbon dioxide. Additionally, wasted food exacerbates water pollution through leachate, increases pressure on limited landfill capacity, and represents the unnecessary consumption of natural resources used in production (Todd & Klingbeil, 2024).

Beyond environmental impacts, food waste has significant social and economic consequences, undermining food security and exacerbating inequality, even in developed countries where many individuals cannot access sufficient nutrition. Substantial quantities of edible food are lost across the supply chain, from production to retail and household consumption representing critical inefficiencies that squander resources such as water, energy, labour, transportation, and storage, thereby compounding economic losses (Todd & Klingbeil, 2024).

Despite the potential of these agricultural by-products, the food industry largely underutilizes these materials, reflecting inefficiencies in resource management and lost opportunities for innovation. Strategic characterization and valorisation of these wastes could transform them into functional ingredients, novel food products, or natural additives, while also supporting applications in pharmaceuticals, agriculture, and other sectors. Effective reutilization not only enhances sustainability but also addresses

broader environmental challenges, including reducing the industry’s contribution to climate change (Dueñas & García-Estévez, 2020).

2.2 Jackfruit (*Artocarpus heterophyllus*) Species

2.2.1 Overview of Jackfruit and Its Culinary Applications

Scientific Classification

Kingdom	: Plantae
Phylum	: Tracheophyta
Class	: Magnoliopsida
Order	: Rosales
Family	: Moraceae
Genus	: Artocarpus
Species	: <i>Artocarpus heterophyllus</i>

Figure 2.2.1 Taxonomy background of Jackfruit (U.S. Department of Agriculture, 2024).

The genus *Artocarpus* belongs to the Moraceae family and consists of approximately 50 species of evergreen and deciduous trees, valued for their edible fruits, timber, and medicinal properties. The name ‘*Artocarpus*’ originates from the Greek words ‘artos’ (bread) and ‘karpos’ (fruit), reflecting its association with breadfruit. The species name ‘*heterophyllus*’ is derived from the Latin term for varied leaves, referencing the diverse sizes and shapes of its foliage. The term ‘jackfruit’ is derived from the Portuguese ‘jaca’, which is believed to stem from the Malayalam word ‘chakka’, linked to the Proto-Dravidian root ‘kā(y)’, meaning fruit or vegetable. A jackfruit tree is a medium-sized evergreen species, typically reaching 8 to 25 metres in

height, though it can grow up to 30 metres in some cases. It has a straight stem with a diameter ranging from 30 to 80 cm, occasionally extending to 200 cm. The dense crown is typically dome-shaped or pyramidal in form. It originates from Bangladesh, India, and Malaysia.

Jackfruit (*Artocarpus heterophyllus* Lam.) shares close genetic proximity with chempedak (*Artocarpus integer* (Thunb.) Merr.), both of which trace their origins to India and Malaysia. The Indo-Malayan tropics exhibit a higher diversity of *Artocarpus* species compared to Australia, with recent taxonomic assessments refining their classification. Jackfruit cultivars fall into two main groups, distinguished by either soft or hard rinds, influencing their texture and culinary applications. Jackfruit is recognized by various names across different regions, including 'jacquier' in French, 'nangka' in Java and Malaysia, 'langka' in Filipino, 'khnaor' in Cambodian, 'makmi, khanum, and banum' in Thai, and 'mit' in Vietnamese (Bakewell-Stone, 2022).

Jackfruit, often referred to as the poor man's fruit, is increasingly recognized as a miracle food across South and Southeast Asia due to its potential to mitigate food insecurity in the face of staple crop failures such as wheat, corn, and rice under adverse climatic conditions. Known for its heat tolerance, jackfruit has been identified as a promising alternative to conventional staple crops, with its large, bumpy exterior, soft pulp, and distinct aroma. The young jackfruit pulp is commonly cooked as a vegetable, pickled, or canned in brine or curry, while the ripe fruit is consumed fresh or processed into traditional delicacies such as dodol and kolak in Java, as well as chutney, jam, jelly, and paste. Additionally, the pulp can be preserved as candies through drying or mixing with sugar, honey, or syrup. It is also utilized as a flavouring agent in ice creams and

beverages, or converted into jackfruit honey, concentrate, or powder for drink formulations (Bakewell-Stone, 2022). Additionally, raising animals for meat production contributes to climate change, and hence, reducing livestock numbers could help mitigate environmental impacts, though it may also result in lower meat availability. Thus, unripe jackfruit is used as an ideal plant-based alternative to meat, as it closely resembles chicken in texture. Due to its fibrous nature and mild flavor, canned jackfruit is often referred to as "vegetable meat," highlighting its utility in vegetarian and vegan cuisine (Kumar et *al.*, 2017).

Jackfruit is a versatile and nutrient-rich food source widely used in both savoury and sweet applications. Its unripe pulp serves as a plant-based meat substitute, while the ripe fruit enhances desserts and beverages. Jackfruit seeds offer protein and functional benefits, making them valuable in baked goods. As interest in sustainable crops grows, jackfruit presents a promising climate-resilient option for food security and innovation.

2.2.2 Nutritional Properties of Jackfruit Seeds



Figure 2.2.2 (a) Jackfruit seeds and fruits (*Moraceae, Artocarpus Heterophyllus, Jackfruit*, 2010).

The seeds account for 18 to 25% of the total fruit weight, with an individual fruit containing approximately 100 to 500 seeds. Each jackfruit seed is enclosed in a white aril, surrounding a thin brown endosperm, which encases the fleshy white cotyledon. Although jackfruit seeds were edible, they were often discarded as waste due to their perishable nature. They can be preserved for up to a month in a cold, moist environment. Once roasted, the seeds can be ground into powder and incorporated into various products, enhancing their shelf life and nutritional value (Rangina Brahma & Ray, 2023).

Jackfruit seed flour (JSF), as analyzed by Arefin et al. (2020), presents a well-balanced nutritional profile, making it a valuable functional ingredient. It primarily consists of 73.75% carbohydrates, serving as a rich energy source, while its 17.04% protein content enhances its potential for protein-enriched formulations. 7.15% fiber supports digestive health, and a low 0.87% fat content aligns with healthier formulations. Additionally, its 8.58% moisture affects stability and shelf life, whereas 1.57% ash contributes to its mineral content. JSF boasts a rich mineral profile, with a high potassium content (446 mg/100 g), significantly surpassing that of rice, wheat, and maize flour. Its calcium concentration (37.54 mg/100 g) also exceeds that of conventional flours, reinforcing its nutritional value. Additionally, JSF provides notable amounts of magnesium, iron, phosphorus, zinc, manganese, and copper, making it a valuable source of essential micronutrients. Beyond minerals, JSF contains substantially higher levels of vitamin C (8.57 mg/100 g) compared to other flours, enhancing its antioxidant benefits. While its vitamin A content (16.58 mg/100 g) is comparable to wheat and maize flour, JSF stands out for its rich thiamine and riboflavin composition,

supporting metabolic functions. The riboflavin concentration (0.18 mg/100 g) is statistically similar to wheat flour but combined with its broader nutrient spectrum.

Compared to wheat flour, JSF boasts significantly higher carbohydrate, protein, and dietary fiber levels, reinforcing its nutritional benefits. Functionally, JSF demonstrates a least gelation concentration of 16%, water absorption capacity (WAC) of 230%, oil absorption capacity (OAC) of 280%, and a bulk density of 0.6 g/ml (Kumar *et al.*, 2017).

According to Shafi *et al.* (2024), jackfruit seeds contain two types of lectins, including jacalin, a bioactive compound which plays a role in preventing herpes simplex virus type 2 and enhancing immune function in individuals with Human Immunodeficiency Virus (HIV)-1. Jacalin is also utilised in plasma glycoprotein isolation, immunoglobulin (Ig)A nephropathy studies, glycoprotein analysis, and tumour detection. In China, jackfruit pulp and seeds were valued for their cooling and nutritive properties, particularly for their ability to counteract the effects of alcohol consumption. Meanwhile, in Southeast Asia, seed starch is traditionally used to alleviate biliousness, and roasted seeds were regarded as possessing aphrodisiac qualities, demonstrating their functional role in traditional medicine (Bakewell-Stone, 2022).

Jackfruit seeds contain a diverse range of bioactive compounds, including lignans, flavones, and saponins, which exhibit significant antioxidant, anticancer, antiulcer, antihypertensive, and anti-aging properties. Lignans, secondary metabolites formed through the oxidative dimerization of phenylpropanoid units, include antiviral compounds such as podophyllotoxin and bicyclol, which have demonstrated efficacy against venereal warts and chronic hepatitis B (Cui *et al.*, 2020). Flavones, an important

class of dietary bioactive compounds, possess anti-inflammatory effects, making them beneficial for health and disease prevention. Saponins, amphiphilic compounds of pharmacological significance, exhibit cytotoxic, hemolytic, and fungicidal properties, primarily due to their membranolytic capabilities (Rangina Brahma & Ray, 2023).

Jackfruit seeds were rich in dietary fiber, contributing to heart health, digestive regulation, and potential weight management benefits. They also serve as an excellent source of B-complex vitamins, supporting metabolic functions. The starch in jackfruit seed flour aids in gut health and blood sugar regulation, while its anti-microbial properties may help prevent foodborne illnesses. Additionally, the seeds contain magnesium, which could lower blood pressure and support bone health by enhancing calcium absorption. Their nutrient profile includes essential carbohydrates, sugars, dietary fiber, and minerals such as calcium, magnesium, phosphorus, potassium, sodium, and iron. The highly soluble protein in the seeds is believed to aid in stress and anxiety management, while their low water and fat absorption capacity supports obesity prevention. Furthermore, flavonoids and potassium contribute to cardiovascular health by reducing blood clot risks and maintaining optimal blood pressure (Dhani et al., 2025)

2.2.3 Use of Jackfruit Seed Flour in Food Products

Jackfruit seed flour (JSF) is gaining recognition as a nutrient-dense and functionally versatile ingredient in various bakery and extruded products. Due to its high carbohydrate content, JSF serves as an energy-rich component while simultaneously enhancing the nutritional profile of food formulations. When incorporated into baked goods alongside wheat flour, JSF improves dietary fiber intake without compromising functional or sensory properties (Kumar et al., 2017). In bread

formulations, replacing 10 to 20% of wheat flour with JSF lowers gluten content, offering potential digestive benefits. Similarly, in cake formulations, 5 to 15% JSF substitution enhances protein content while reducing fat levels, improving overall nutritional quality. Noodles benefit from up to 20% JSF incorporation, increasing protein and dietary fiber content (Fabil et *al.*, 2024). Chapatti formulations can accommodate up to 25% JSF substitution, with preservatives extending shelf life to 3 to 4 days at ambient temperature and 30 days under refrigeration.

Beyond direct bakery applications, JSF serves as a valuable starch source due to its high amylose content, enhancing paste stability during heating. Additionally, roasting jackfruit seeds at 160°C for an hour significantly reduces moisture content, thereby increasing protein, carbohydrate, and mineral concentrations while lowering fat levels and fat absorption capacity. This process has contributed to the popularity of roasted jackfruit seeds as a nutritious snack, especially in regions where jackfruit is widely cultivated (Fabil et *al.*, 2024).

Moreover, JSF's gluten-free properties make it a viable alternative to wheat flour, particularly for individuals with gluten intolerance or specific dietary restrictions. In South Indian cuisine, JSF is commonly blended with rice flour for traditional preparations such as dosa, dhokla, and idli. Additionally, whole jackfruit seeds were consumed as salted nuts or preserved in brine, further expanding their culinary applications (Fabil et *al.*, 2024).

Biscuit formulations incorporating JSF at various inclusion ratios have demonstrated optimal functionality, leading to a deep brown colouration upon baking at 150°C following conventional biscuit-making processes (Fabil et *al.*, 2024).