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PREPARATION OF KOMBUCHA SCOBY CELLULOSE BY USING FRUIT PEEL WASTES AS FERMENTATION SUBSTRATES



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RUSYIDAH BINTI MAT ZIN BOESTAMI

UNIVERSITI PENDIDIKAN SULTAN IDRIS

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PEEL WASTES AS FERMENTATION SUBSTRATES**

RUSYIDAH BINTI MAT ZIN BOESTAMI

**DISSERTATION PRESENTED TO QUALIFY FOR MASTER IN SCIENCE
(RESEARCH MODE)**

**FACULTY OF SCIENCE AND MATHEMATICS
UNIVERSITI PENDIDIKAN SULTAN IDRIS**

2025



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ABSTRACT

This research aimed to produce bacterial cellulose through fermentation of kombucha symbiotic cellulose of bacteria and yeast (SCOBY) by using fruit peel wastes as fermentation substrates. This research is divided into three main studies, namely proximate analysis of fruit peel wastes, correlation studies of fermentation process and characterisation studies of kombucha SCOBY cellulose (KSC). The fruit peel wastes used in this study were dragon fruit, jackfruit banana, saba banana and pumpkin. Several proximate analyses were conducted to determine the composition of carbohydrate, protein, fibre and ash in fruit peel wastes. The characterisation studies of KSC were carried out using Fourier transform infrared (FTIR) spectrometer, X-ray diffraction (XRD) spectrometer, thermogravimetric analyser (TGA), differential scanning calorimeter (DSC), field emission scanning electron microscope (FESEM) and energy dispersive X-ray (EDX) spectrometer. Based on proximate analyses, dragon fruit peel waste produced the highest KSC (7.67%) due to high composition of carbohydrate and protein. Dragon fruit peel waste exhibited the highest correlation in the fermentation process at 12% (w/v) of sugar concentrations with R^2 value of 0.935. FTIR spectra of KSC produced from fruit peel wastes substrates confirmed the presence of methyl, hydroxyl and carbonyl functional groups which are identical to commercial cellulose. Meanwhile, results from XRD analysis revealed that the crystalline structures of KSC have prominent peaks at 2θ range of 14° - 15° , 16° - 17° and 22° - 23° which represent cellulose I β . The TGA and DSC analyses showed that KSC from fruit peel wastes is thermally stable. Morphology of KSC exhibited microfibrils network and composition consist of carbon (C), oxygen (O) and sodium (Na). In conclusion, fruit peel wastes are suitable as alternatives to commercial fermentation substrates to produce bacterial cellulose. In implication, using fruit peel wastes as fermentation substrates in bacterial cellulose preparation will underpin environmental sustainability by converting agricultural wastes into beneficial products.





PENYEDIAAN BAGI SELULOSA SCOBY KOMBUCHA DENGAN MENGUNAKAN SISA KULIT BUAH SEBAGAI SUBSTRAT PENAPAIAN

ABSTRAK

Penyelidikan ini bertujuan untuk menghasilkan selulosa bakteria melalui penapaian selulosa simbiotik kombucha bakteria dan ragi (SCOBY) menggunakan sisa kulit buah sebagai substrat penapaian. Penyelidikan ini dibahagikan kepada tiga kajian utama, iaitu analisis proksimat sisa kulit buah, kajian korelasi proses penapaian dan kajian pencirian selulosa SCOBY kombucha (KSC). Sisa kulit buah yang digunakan dalam kajian ini adalah buah naga, pisang nangka, pisang abu dan labu. Beberapa analisis proksimat telah dijalankan untuk menentukan komposisi karbohidrat, protein, serat dan abu dalam sisa kulit buah. Kajian pencirian KSC telah dijalankan menggunakan spektrometer inframerah transformasi Fourier (FTIR), spektrometer pembelauan sinar-X (XRD), penganalisis termogravimetri (TGA), kalorimeter pengimbasan pembezaan (DSC), mikroskop elektron pengimbasan pancaran medan (FESEM) dan spektrometer penyebaran tenaga sinar-X (EDX). Berdasarkan analisis proksimat, sisa kulit buah naga menghasilkan KSC yang paling tinggi (7.67%) disebabkan komposisi karbohidrat dan protein yang tinggi. Sisa kulit buah naga mempamerkan korelasi yang paling tinggi dalam proses penapaian pada kepekatan gula 12% (w/v) dengan nilai R^2 adalah 0.935. Spektra FTIR bagi KSC yang dihasilkan dari substrat sisa kulit buah mengesahkan kehadiran kumpulan berfungsi metil, hidroksil dan karbonil yang sama dengan selulosa komersial. Manakala, keputusan daripada analisis XRD mendedahkan bahawa struktur kehabluran KSC mempunyai puncak yang jelas pada julat 2θ 14° - 15° , 16° - 17° dan 22° - 23° yang mewakili selulosa I β . Analisis TGA dan DSC menunjukkan KSC daripada sisa kulit buah adalah stabil terhadap haba. Morfologi KSC mempamerkan rangkaian mikrofibril dan komposisi terdiri daripada karbon (C), oksigen (O) dan natrium (Na). Kesimpulannya, sisa kulit buah sesuai sebagai alternatif kepada substrat penapaian komersial untuk menghasilkan selulosa bakteria. Implikasinya, penggunaan sisa kulit buah sebagai substrat penapaian dalam penyediaan selulosa bakteria akan menyokong kelestarian alam sekitar melalui penukaran sisa pertanian menjadi produk yang bermanfaat.



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LIST OF ABBREVIATIONS

A.A.B	Acetic acid bacteria
BAP	Saba Banana Peel
BC	Bacterial Cellulose
BNP	Jackfruit Banana Peel
DFP	Dragon Fruit Peel
DSC	Differential Scanning Calorimetry
EDX	Energy Dispersive X-Ray (EDX) Spectroscopy
FESEM	Field Emission Scanning Electron Microscopy
FTIR	Fourier Transform Infrared Spectroscopy
HS	Hestrin Schramm
KSC	Kombucha SCOBY Cellulose
PC	Plant Cellulose
PP	Pumpkin Peel
SCOBY	Symbiotic Culture of Bacteria and Yeast
T	Tea
TGA	Thermogravimetric Analysis
WHC	Water Holding Capacity
XRD	X-ray Diffractogram spectroscopy



LIST OF APPENDICES

- A Publication
- B Copyright
- C Conference
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CHAPTER 1

INTRODUCTION



In recent years, there has been a rising understanding of the importance of revolutionise materials from biological sources. Biopolymers have attracted considerable attention in diverse fields requiring eco-friendly and degradable alternatives (Das et al., 2022). Enhanced environmental consciousness regarding sustainability, regulations on contaminants and management of urban solid waste are all accelerators for the evolution of materials based on biopolymers (Cruz et al., 2024). The utilisation of biopolymers reduces carbon dioxide discharges, urban solid waste and dependency on petroleum-derived resources (Acquavia et al., 2021). Besides, the objective of the sustainable economy is to perceive waste as valuable resources that can be integrated into the production cycle of future products, creating a closed-loop system for non-renewable raw materials. Poorly managed utilisation of natural resources and disposal





of waste result in detrimental consequences, the magnitude of which can be challenging to increase (Aguilar et al., 2019).

Monomers are basic units or small molecules that combine to form more complex structures like polymers. There are four primary categories of monomer such as a compound of carbohydrates, proteins, lipids and nucleic acids. A polymer is a material composed of many molecules with a high molecular mass. It is formed by the repetitive element of a monomer sequence, which may arise organic polymer or be produced artificially which is a synthetic polymer (Das et al., 2022).

Biopolymers are macromolecules derived from living organisms. The term 'biopolymer' implies that it is a polymer capable of undergoing biological degradation. Biopolymers have existed on earth for billions of years and predate manufactured polymers like plastics. These compounds have a crucial function in the natural world. They are highly valuable in carrying out tasks such as retention of energy, safeguarding and transmission of hereditary details, and formation of cellular framework (Mohini Chandrashekhar Upadhye et al., 2022). Biopolymer market was valued at USD 33 billion in 2022 and is projected to reach approximately USD 90.78 billion by 2032, indicating a compound annual growth rate (CAGR) of 10.7% from 2023 to 2032 (Biopolymer Market, 2023).

Synthetic biopolymers are macromolecules that have been altered from organic polymers or chemically synthesised from artificial monomers so that they can decompose naturally without leaving behind substances that are harmful to organisms and the environment. Synthetic biopolymers have garnered considerable attention in





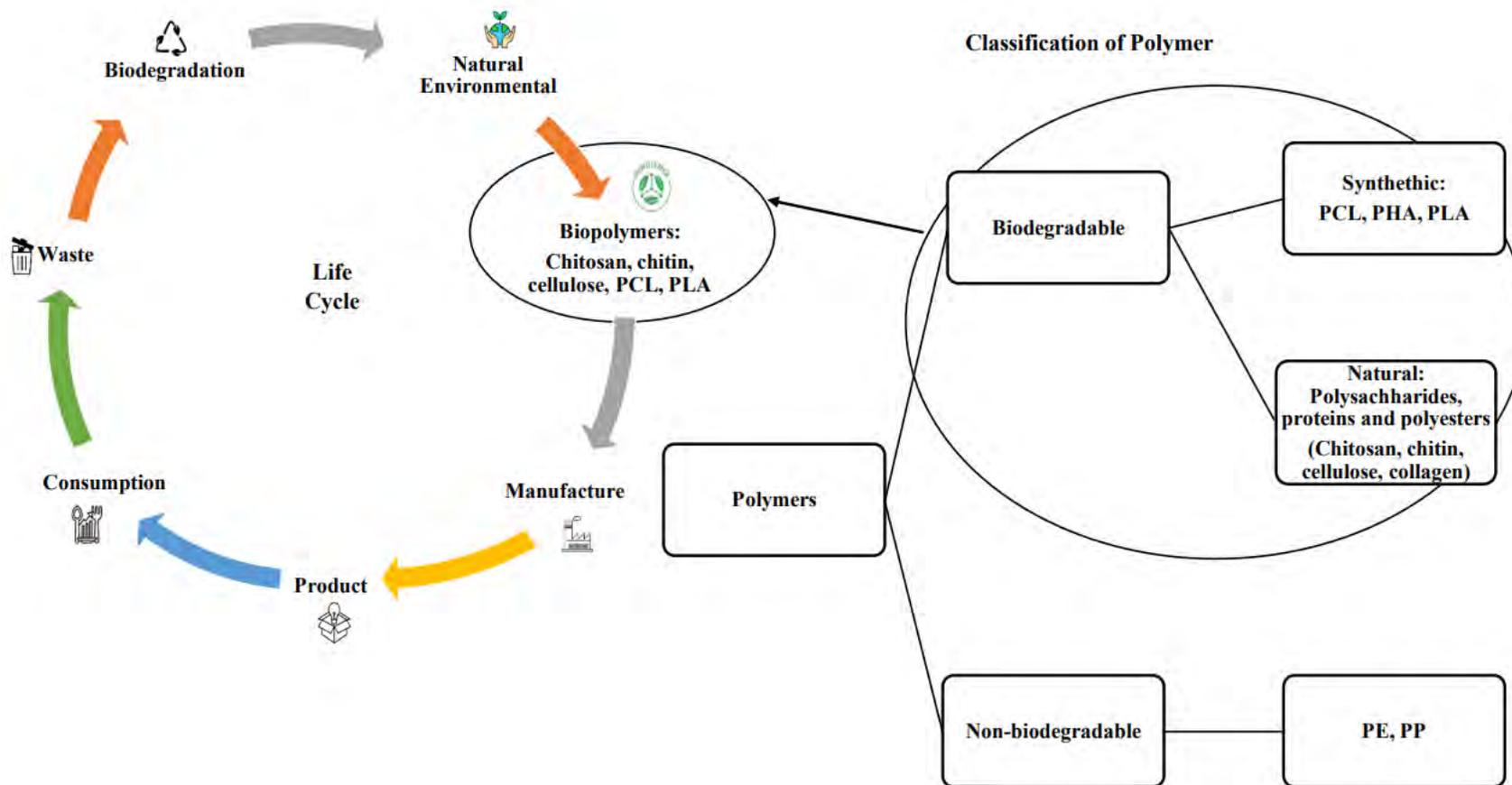
recent times owing to their significant benefits over organic polymers in terms of durability and adaptability to suit a wide array of uses. Conversely, synthetic biomolecules are favoured over artificial polymers because of their ability to decompose and their ecologically friendly property. Synthetic biopolymers are commonly categorised into two groups, namely non-biodegradable and biodegradable biopolymers (Andreeßen & Steinbüchel, 2019; Das et al., 2022). A comprehensive range of petroleum-derived synthetic polymers is produced globally, reaching approximately 140 million tonnes each year, with substantial volumes of these polymers being released into the ecosystem as industrial by-products (Nampoothiri et al., 2010; Melchor-Martínez et al. 2022).

From Figure 1.1, synthetic polymers such as polycaprolactone (PCL) polyhydroxyalkanoates (PHA) and polylactide (PLA) are categorised as synthetic polymers that have great potential to substitute petroleum-derived materials including polypropylene (PP) and polyethylene (PE) and can be utilised in many applications such as phenol-formaldehyde (PF) resins, carbon fillers, bactericides and composites (Dziuba et al., 2021).



Figure 1.1

Life cycle and classification of polymers



Adapted from Dziuba et al., (2021)

Plants, animals, microorganisms and agricultural by-products represent typical natural sources of natural biopolymers. For plants, cassava, potatoes, rice, corn, banana and cotton can undergo chemical production from individual components such as sugars, oils and amino acids. Animals like cattle, goat and buffalo are the predominant sources, while marine sources commonly include fish, corals, sponges, shrimp and lobster. Algae, bacteria and yeasts are frequently found as microbiological sources (Baranwal et al., 2022). Biodegradable polymer from natural sources includes natural rubber, lignin and polysaccharides such as cellulose, collagen, chitosan and chitin (Dziuba et al., 2021) as shown in Figure 1.1.

Furthermore, Table 1.1 shows the benefits and drawbacks of synthetic and natural biopolymers. Hence, natural biopolymers can produce biodegradable of polymers that can save the environment (Baranwal et al., 2022).

Table 1.1

The main benefits and drawbacks of biopolymers

Biopolymers	Benefits	Drawbacks
Natural	Biocompatible, biodegradable, biologically renewable, bioadhesive material, biofunctional and non-toxic.	Structurally more complex, low melting, less stable, point and high surface tension.
Synthetic	Better physical and chemical stability, biocompatibility and higher reproducibility.	High cost in synthesis product, non-biodegradable and toxic.

Adapted from Baranwal et al., (2022)



1.2 Kombucha SCOBY

Kombucha is globally recognised as a fermented drink containing beneficial bacteria. This beverage is crafted by fermenting sweetened tea with a symbiotic culture of bacteria and yeast (SCOBY). The most common bacteria genera consist of *Acetobacter xylinum* and yeast, which belong to *Brettanomyces* and *Saccharomyces*. Conventional or traditional way, it is made using black tea, which imparts advantageous qualities to individuals because of the primary components present in this variety of tea such as alkaloids, including caffeine, theobromine and polyphenol compounds such as catechins and theaflavins (Tapias et al., 2023). Through kombucha and SCOBY relationships, these bacteria produce metabolites like acetic acid, gluconic acid, citric acid and other acids; water-soluble vitamins like B1, B2, B6, and C, ethanol, carbon dioxide and cellulose (Gaggia et al., 2019; Leonarski et al., 2021). The growth of kombucha production, including home manufacturing, has resulted in many firms expanding the beverage rapidly (Kim & Adhikari, 2020).

The kombucha industry is projected to expand by 20% in 2025 on the strength of the beverage's fizzy, sugary soda-like qualities and health advantages (Global Kombucha Tea Market Research, 2020). The number of kombucha-producing companies has grown significantly, leading to the establishment of Kombucha Brewers International (KBI) in 2014. The organisation promotes commercialisation and assists members with product regulations, with over 300 companies registered on KBI's website in 2021. Besides tea substrate, other materials such as herbs, fruits, milk and a wide variety of agro-industrial ingredients such as mostly from by-products of fruit





industries, are being used as substrates in kombucha fermentation (Emiljanowicz & Malinowska-Pańczyk, 2020; Kim & Adhikari, 2020).

Kim and Adhikari (2020) have reviewed several papers on kombucha. They subsequently derived common attributes or characteristics: (1) it is a drink generated through the fermentation of tea and sugar, (2) black tea is the main substrate; however, other substrates such as green tea, oolong tea and other varieties source such as empty fruit bunch, acerola by-product or apple powder can also be employed, (3) sugar as a base in a traditional approach as carbon source, however, other sweetness sources such as molasses can be utilised, (4) a SCOBY is employed and (5) is distinguished by slight sweetness and sourness with effervescence.



Studies published in SCOPUS-indexed journals search for keywords related to

kombucha SCOBY cellulose and kombucha substrates in publication. Figure 1.2 (a) reveals that in the years 2019 to 2024 present, the highest number of publications was recorded in 2023, followed by 2022, 2021 and 2019. Meanwhile, for 2024, 44 papers were published from January to June. Due to the COVID-19 epidemic that affected the world in 2020, there was a significant decrease in the number of papers compared to previous years. Furthermore, most substrates used in kombucha fermentation are made using green or black tea, as shown in Figure 1.2 (b), due to higher antioxidant activities found in black tea kombucha and green tea kombucha had higher antibacterial and antiproliferative activities (Cardoso et al., 2020). Then, 27% of substrates are made of herbs, leaves and plants such as oolong, rooibos tea, mint, cinnamon and African mustard leaves. Fruits like grape, apple, pineapple and guava are used in 9.0% of the studies. Milk, skim, and yoghurt are used in 7.0% of the studies. 6% of the studies focus





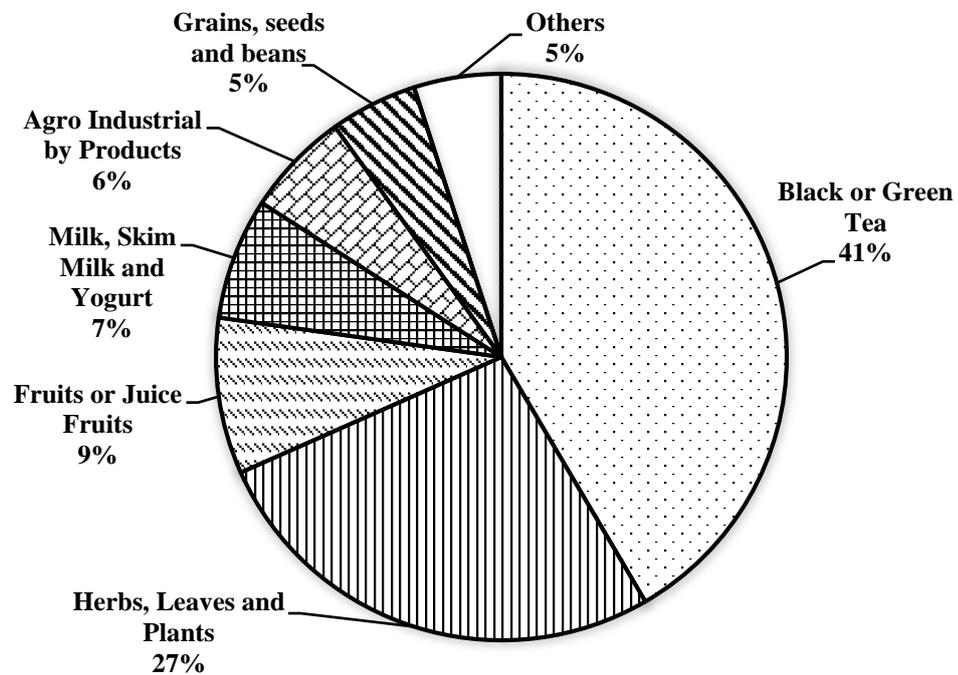
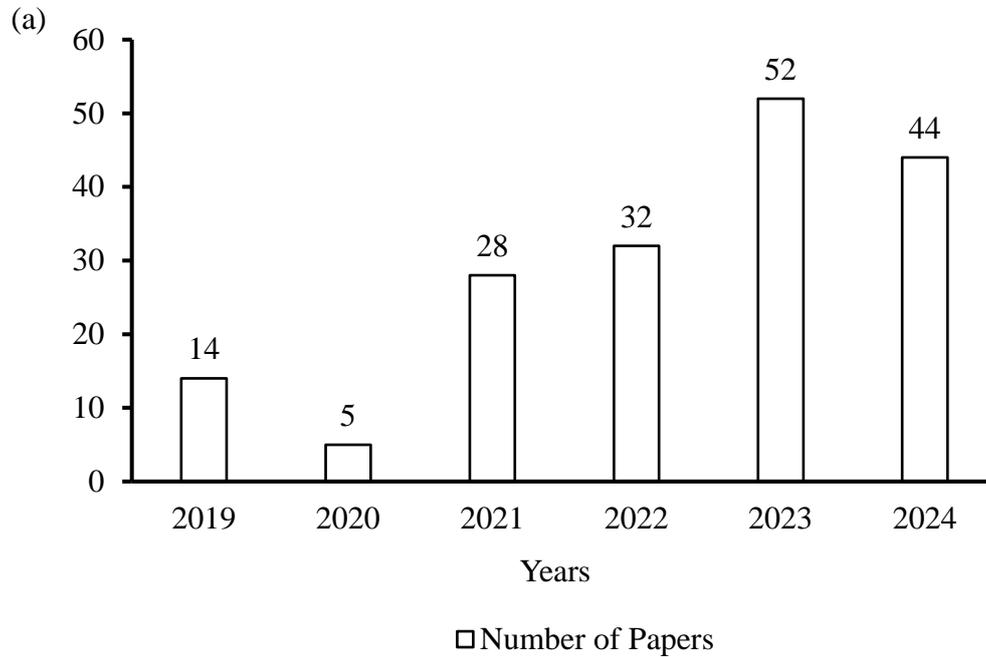
on agro-industrial raw materials such as acerola by-products, banana peel, winery effluent and soy whey. Then, 5% of the studies show that grain, seeds and beans account. Other ingredients include red seaweed, soymilk, date syrup, black carrot juice, red raspberry and coconut water. These raw materials impart distinct properties to kombucha.

Therefore, previous research demonstrates that kombucha beverages could be produced from other materials as substrates. As with the traditional way by tea substrates, the alternative raw materials as substrates, as shown in Figure 1.2(b), are also abundant in bioactive compounds such as polyphenols' antioxidants, one of the most prominent characteristics of kombucha. Therefore, it is crucial to comprehend how to prepare alternative raw materials for fermentation and how fermentation impacts the cellulose layer generated (Vitas et al., 2020; Vukmanovi'c et al., 2020).



Figure 1.2

Studies published in SCOPUS-indexed journals: (a) Number of publications on kombucha (b) Main substrates used in kombucha fermentation





1.3 Cellulose from Kombucha SCOBY

The Kombucha SCOBY ecosystem is a symbiosis beneficial to bacteria and yeasts. Yeasts produce invertase, which releases monosaccharides into carbon-rich media accessible to all microorganisms. Bacteria metabolise released sugars, resulting in an environmental depletion of monomers and an increase in the frequency of invertase-producing yeast. Microbes protect themselves from external adversaries by acidifying the medium and forming a physical barrier by producing organic acids and a surface deposit, respectively. In addition, yeast-produced ethanol stimulates the bacterial cellulose-synthase mechanism to produce cellulose film (May et al., 2019; Ramírez Tapias et al., 2022).



In addition to gluconic, acetic and ethanol, minor quantities of amino acids, polyphenols, minerals and soluble vitamins have been reported in fermented media. The pellicle produced at the interface between air and liquid consists primarily of cellulose (Villarreal-Soto et al., 2018; Laavanya et al., 2021). Similar forms of bacterial cellulose have been known for decades and have traditionally been isolated from nata de coco, a gelatinous Southeast Asian confection made with coconut water (Potočnik et al., 2023).

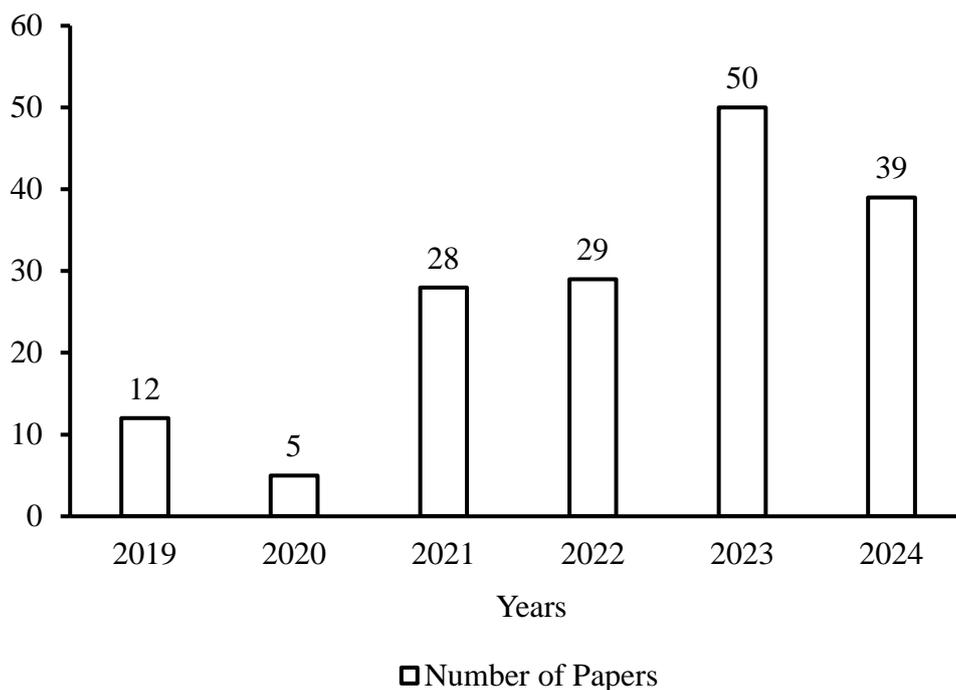
In recent years, many research organisations worldwide have examined the microbial culture, the composition of the fermented liquid and the bacterial cellulose at the water-air interface in response to the growth of the kombucha beverage industry. Figure 1.3 presents the number of papers published in years 2019 to 2024 with keywords of cellulose from kombucha SCOBY fermentation as recorded by the



SCOPUS database. The analysis shows that the number of papers increased from 28 in 2021 to 50 in 2023. Due to developments in the fermentation process, microbiological activities and physicochemical analyses on the production of cellulose from kombucha (Barakat et al., 2022). Other studies also mentioned that for reuses of substrates from agro-industrial by-products, the use of regional substrates attention consumers and enrichment of phytonutrients in substrates used in kombucha (Leonarski et al., 2022).

Figure 1.3

Number of papers published from 2019 to 2024 on the SCOPUS database for keyword cellulose from kombucha SCOBY fermentation.





1.4 Problem Statement

Microfibril cellulose from plants and wood is a non-toxic polymer that can be used for energy storage and fuel cell membranes. It is a promising source of biopolymer materials that can replace petroleum-based polymers. The benefits of cellulose from natural sources were bio-renewability and biodegradability (Shaghaleh et al., 2018). However, in plants, cellulose contains impurities such as lignin (5% - 30%) and hemicellulose (15% - 35%) (Onwucha et al., 2023). Plant cellulose production reduces crystallinity by 40% - 60% (Huang et al., 2013; Seddiqi et al., 2021). As mentioned by Peelman et al. (2013) and Antunes et al. (2022), the percentage of yield cellulose from plants is low, about 40% - 50%.



In addition, the extraction of plant-derived cellulose involves an acid hydrolysis

process which consumes hazardous chemicals such as sulphuric acid, hydrochloric acid and nitric acid that are harmful to human skin (Chen, 2015; Poulouse et al., 2022). In order to make the acid pretreatment process economically viable, it is necessary to recover and recycle the acid due to its high consumption and concentration. Nevertheless, acid recovery requires a significant amount of energy, and it is impossible to recover the acid fully. Additional drawbacks of acid pretreatment include the requirement for a substantial quantity of neutralising agents and the production of gypsum during the process of neutralisation and detoxification. Substant amounts of calcium sulphate are produced when lime is employed to neutralise sulphuric acid. Disposing of gypsum necessitates extra energy and cost. Hence, it harms human consumption and the environment due to its corrosive and high toxicity (Jung & Kim, 2015; Johannes & Xuan, 2024).





The hydrophilicity of plant cellulose can be low at 25% - 35% (Petrosian, 2021). This is mainly due to the free hydroxyl group in the amorphous structure, which enhances the hydrogen (H_2) bond formation, making it harder for cellulose fibres to dissolve in water (Solhi et al., 2023). As a result, swelling of fibres occurs. The moisture in the H_2 bond reduces its hydrophilicity on cotton cellulose (Naomi et al., 2020).

Besides, cellulose may also be produced from algae, oomycetes and bacteria (Aditiawati et al., 2023). Commercial cellulose production from bacteria using the Hestrin Schramm method is widely used worldwide. Utilising bio-wastes from food processing industries or agriculture as nutrient sources and growth media for microorganisms greatly reduces the cost of bacterial cellulose (BC) production. It facilitates the treatment of substantial amounts of waste produced by food industries. This approach indirectly decreases environmental pollution and promotes sustainability (Nguyen et al., 2021). Multiple independent reports have documented using alternate sources to produce kombucha SCOBY cellulose (Ul-Islam et al., 2020).

Furthermore, a cost-effective medium was utilised to lower the cost of producing bacterial cellulose. In addition, the high-cost nutrient sources in preparation media Hestrin Schramm method that limits in commercial production. In preparation for Hestrin Schramm media, the standard media used are yeast extract and peptone as nitrogen sources, phosphate solution, sulphate solutions and additional substances like nicotinamide. Besides, the selected bacteria and yeast strains were also included in the preparation standard media. Due to examining cellulose production in non-optimised, optimised and commercial media in the Hestrin Schramm method, further research has





identified the best economically efficient medium for bacterial cellulose production (Avcioglu et al., 2021).

Therefore, this research aims to develop kombucha SCOBY cellulose from kombucha broth using different fruit peel wastes, namely dragon fruits, jackfruit bananas, saba bananas and pumpkin as substrates. By using carbon sources of white sugar at 6%, 9% and 12% (w/v) concentrations, SCOBY can interact chemically with the substrate. Besides, fruit peel waste can also supply good nutrients during the fermentation of kombucha SCOBY. Utilising different fruit peel wastes and sugar concentrations could influence the production of kombucha SCOBY cellulose. Thus, cellulose is produced from kombucha SCOBY; the yield of cellulose products will characterise it. Hence, the characterisation study of the physical and chemical properties of the yielded cellulose products is being carried out to facilitate industry development.

1.5 Research Gap

Based on the literature reviews, although several studies have successfully developed and assessed the potential of kombucha SCOBY for cellulose production, some important research gaps need to be investigated.

1. Researchers have evaluated several materials, such as acerola by-products, apple powder, mango peel and coconut water, as alternative substrates for fermentation to produce SCOBY cellulose. It is attractive to study the growth of fermented SCOBY on different food waste using different fruit peel wastes.



Therefore, this study used different fruit peel wastes: dragon fruit peel, jackfruit banana peel, saba banana peel and pumpkin peel. Applying fruit peel wastes could be a strategy to lower the cost of preparation media in cellulose production.

2. Researchers have evaluated several volume solutions, such as 700 mL, 1000 mL and 1500 mL, that were used to prepare the media for the fermentation broth. In this research, the media preparation for fermentation broth was prepared using 250 mL of solutions. The volume of 250 mL was chosen to create an economic fermentation process.
3. Researchers have evaluated several materials such as molasses, honey, syrup, dates and sugar cane, as alternative carbon sources with certain concentrations, such as 5%, 8% and 10% (v/v), for fermentation to produce SCOBY cellulose.

It is important to study the growth of fermented SCOBY on white sugar at 6%, 9% and 12% (w/v) of sugar concentrations.

4. Researchers have evaluated several optimum parameters, such as the fermentation period in 17 and 60 days. It is interesting to conduct the fermentation study within 14 days of the fermentation period to create a short period of fermentation process. Moreover, the correlated study effect of fruit peel wastes with sugar concentrations towards KSC growth on the weight and yield of KSC at 6%, 9% and 12% (w/v) sugar concentrations, productivity rate of KSC by fruit peel wastes with sugar concentrations at 6%, 9% and 12% (w/v) and correlation of fruit peel wastes at 6%, 9% and 12% (w/v) sugar concentration which affects pH of kombucha broth and total weight of container to get R^2 value by using SPSS analysis.



5. In some research projects, bacterial cellulose was characterised using a few scientific analyses. This results in insufficient data to describe the bacterial cellulose's chemical and physical properties features. Therefore, the novelty and uniqueness of the research project are unable to be highlighted. In this study, it is imperative to conduct a characterisation study of fermented SCOBY using several instruments, such as a Fourier Transform Infrared (FTIR) Spectrometer and an X-ray Diffraction (XRD) spectrometer and the physical properties of water holding capacity (WHC) for KSC. Besides, the kombucha SCOBY cellulose will also be determined by Field Emission Scanning Electron Microscopy (FESEM) with Energy Dispersive X-ray (EDX) spectrometer, Thermogravimetric Analyser (TGA) and Differential Scanning Calorimeter (DSC) instruments.



1.6 Research Aim

The overall aim of this research is to produce cellulose from the fermentation of kombucha SCOBY by using fruit peel wastes as fermentation substrates. It is hoped that the fruit peel wastes used in this study can be alternatives to black tea fermentation substrate. In addition, it is also hoped that cellulose in KSC can be an alternative to plant-derived cellulose.



1.7 Research Objectives

1. To determine the chemical composition of dragon fruit, jackfruit banana, saba banana and pumpkin peel wastes by using proximate analysis.
2. To correlate the effect of fruit peel substrates with sugar concentrations on weight, yield, productivity rate, pH and total weight of Kombucha container by using Excel and SPSS.
3. To characterise the physical and chemical properties of kombucha SCOBY cellulose by using FTIR, WHC, XRD, TGA, DSC, FESEM and EDX analyses.

1.8 Research Scope

This research consists of three main studies. The first study was to determine the properties of the fruit peel waste. This study uses four different fruit peel wastes namely dragon fruit peel, jackfruit banana peel, saba banana peel and pumpkin peel. Using a standard method, these fruit peel wastes were characterised based on several proximate analyses, including carbohydrate, protein, crude fibre and ash.

The second study focused on the cultivation of SCOBY through the fermentation process. SCOBY was inoculated into the substrate using fruit peel wastes and left for natural fermentation. The differences in the fermentation process will be measured by monitoring the formulation process, which involves the pH condition, percentage of fruit peel waste, percentage of sugar added and type of fruit peel waste,



using experimental analysis data. The growth development of SCOBY was monitored by evaluating the individual weight.

The third study was on the characterisation of KSC production. In the characterisation study, the yield of cellulose products in KSC is determined by measuring functional groups and crystallinity index using FTIR and XRD instruments. Then, the hydrophilicity measurement is used to determine the water-holding capacity (WHC) of cellulose products in KSC. In addition, the production of cellulose products in KSC will be characterised based on thermal stability, surface morphology and elemental compositions using the TGA, DSC, FESEM and EDX.



1.9 Research Significance



This research is both relevant and significant to Sustainable Development Goal (SDG) 12, ensure sustainable consumption and production patterns and SDG 15, protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss. Additionally, it is also pertinent to the National Policy on the Environment, with a focus on Continuous Improvement in the Quality of the fermentation of SCOBY and Waste Management Regulations by using the fruit peel wastes for cellulose production.



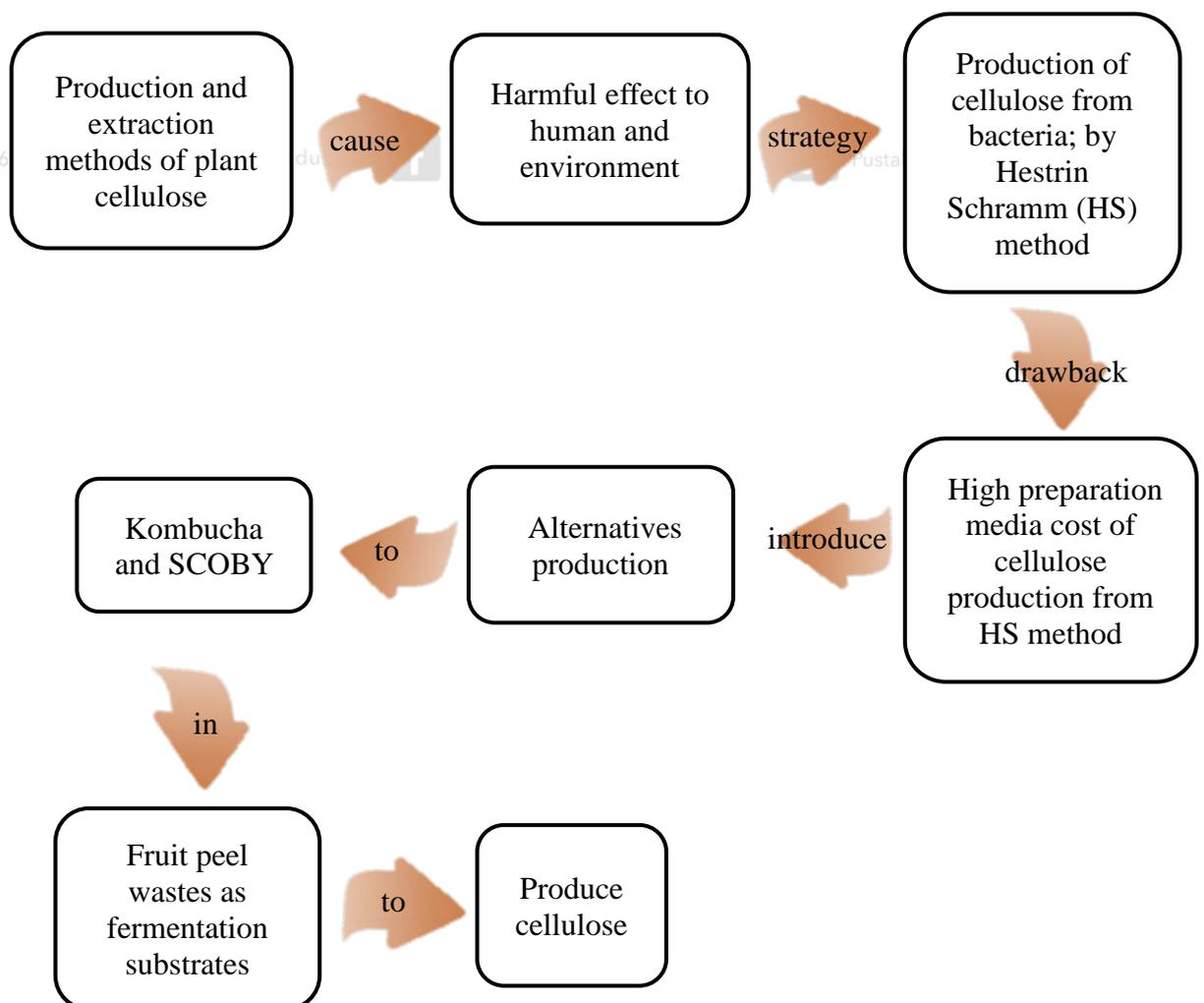
1.10 Hypothesis

The fermentation of SCOBY by using selected fruit peel wastes that are rich in nutrition as substrates could generate cellulose.

1.11 Research Overview

Figure 1.4

Diagram of research overview





1.12 Thesis Organisation

This thesis contains five chapters. Chapter 1 is dedicated to the introduction which covers the research background, problem statement, research gap, research aim, research objectives, research overview, research significance and hypothesis. Chapter 2 explains the biopolymer of cellulose from plant-based and bacteria cultured, the development of kombucha by SCOBY, factors affecting the growth SCOBY, the medium of substrates, type of fruit peel waste, a metabolite involved in the production of kombucha SCOBY cellulose. Chapter 3 describes a detailed methodology involved in the KSC production from SCOBY fermentation and characterisation techniques used to determine the physical and chemical properties of cellulose using fruit peel wastes as a medium through the fermentation process. Chapter 4 explains and discusses the findings of this research. The result includes the chemical and physical characteristics of SCOBY cellulose product production from SCOBY through the fermentation process. Finally, Chapter 5 will draw several conclusions from this research and suggestions for future research.

