

CHAPTER 1 - INTRODUCTION

1.1. Background

Being one of the most widely consumed and globally traded commodities in the world, coffee holds great significance in the global economy. According to reports from the USDA, global coffee consumption in the 2024-2025 period reached 166.5 60-kg million bags and is expected to continue rising (Ecofin Agency, 2025). However, this increasing demand also introduces a challenge in managing the waste generated from coffee processing, especially in the form of coffee byproducts (CBP). An estimated over 10 million tonnes of waste is produced annually from worldwide coffee production (Echeverria and Nuti, 2017). CBP ranges from pulp, husk, mucilage and parchment from the processing of green beans, as well as silverskin and spent coffee grounds from its roasting and brewing process (Pongsiriyakul et al., 2024). CBP are often discarded into landfills, undergo decomposition processes and produce methane gas that could be harmful to the environment, especially in terms of contributing to global warming (Roychand et al., 2023).

Some of the CBPs that are particularly intriguing in terms of their potential in being valorized into food and beverage products include coffee cascara, silverskin, and pixel (Fig. 1).



Fig. 1 Coffee Byproducts (CBP) With Potential to be Valorized as Food and Beverage Products

Note: (a) = coffee cascara, (b) = coffee silverskin, (c) = coffee pixel

Coffee cascara, also known as coffee husk, is a byproduct obtained from dried coffee cherry

skins. This ingredient consists of a relatively high amount of carbohydrates and fibre, and also contains a small amount of protein, lipids and minerals (He et al., 2025). Coffee silverskin, a coating layer byproduct generated from the roasting process of coffee beans, has recently been studied to be valorized into various products including nanocellulose packaging, biobutanol production, cosmetic ingredient, and a range of food and beverage products (Garcia and Kim, 2021; Hijosa-Valsero et al., 2018; Rodrigues et al., 2014). Coffee pixels is a term given to low grade or defective coffee beans obtained during the harvesting and drying process of coffee beans.

Numerous efforts have been made to valorize these CBP into valuable products in industries such as pharmaceuticals, food, energy, and cosmetics (Navajas-Porras et al., 2025). Coffee cascara has been studied as a possible functional ingredient to enrich baked-goods flours with dietary fibres as well as a substrate for plant protein production (Gil-Gómez et al., 2024). Additionally, coffee cascara also showed a promising potential to be incorporated into other food and beverage products such as purees, jelly, and tea drinks due to its nutritional and functional properties (Bojórquez-Quintal et al., 2024). Coffee silverskin was previously utilized in the formulation of skin gel with antioxidative properties (Kusumocahyo et al., 2019) as it has been reported in several studies to possess beneficial bioactive compounds, showing promising potential to combat against free radicals that contribute to aging processes (Hayes et al., 2023). Existing research shows that coffee silverskin contains caffeine, polyphenols (including phenolic acids, flavonoids, and secoiridoids), and alkaloids (Brzezińska et al., 2023; Nzekoue et al., 2020) which contribute to the ingredient having good antioxidant properties. Several researches have studied coffee silverskin's potential application in a range of food and beverage categories, including bakery products, candies, meat, and fermented drinks (Franca et al., 2024; Cantele et al., 2022; Boninsegna et al., 2024; Martuscelli et al., 2021; Iriondo-DeHond et al., 2025). Most of these studies utilized coffee silverskin as an ingredient to boost the dietary fiber and antioxidant activity in aforementioned food and beverage products. On the other hand, while coffee pixels or low grade coffee beans are often separated during the harvesting process and discarded as animal feed or directly into landfills, there have been some efforts to use them in a blend with higher grade coffee and as essential oil for aromatherapy (Politeknik Negeri Lampung, 2026; Tami, 2021).

Societal focus on health in recent years has begun to shift towards the tendency to consume perceived healthier foods, including fermented products such as kombucha, a beverage commonly made from tea (generally black tea or green tea), sugar, and SCOBY (Symbiotic Culture of Bacteria and Yeast) (Kapp and Sumner, 2019). The characteristics and functionality of kombucha aligns well with the benefits offered in CBPs, where the ingredients contains polyphenols (contributes to antioxidant activity), polysaccharides and dietary fiber for SCOBY support during fermentation (Navajas-Porras et al., 2025). Several studies utilizing non-tea ingredients to produce kombucha have been done. Most of these studies valorize waste ingredients such as coffee husk or cascara, coffee pulp, defective fruits, cocoa bean shells, and herb waste that contributes to reducing the impact of these wastes into the environment (Xuyen et al., 2023; Rojas-Orduña et al., 2023; Tandhanskul et al., 2025).

Unlike coffee cascara, no study has been done yet in the utilization of coffee silverskin and pixel in kombucha production. The use of coffee cascara as a non-tea substrate is a promising reference point for the valorization of other CBP, such as coffee silverskin and coffee pixel. Given that these are non-conventional ingredients (as tea is the traditional substrate), it is important to characterize the raw materials, investigate the impact of the kombucha fermentation on these ingredients, and determine the physicochemical properties of the resulting kombucha.

Ultimately, the success of any new food product is heavily influenced by two primary quality attributes: compliance to standards and consumer satisfaction. This compliance involves adherence to regulatory guidelines, while satisfaction is driven by desirable organoleptic (sensory) characteristics. Consequently, optimization targeting a final product that meets both is an essential step for non-conventional fermented beverages development such as kombucha produced from CBP.

1.2. Problem Statement

Coffee byproduct (CBP) is a non-conventional ingredient in kombucha production. There is a lack of information regarding its physicochemical characteristics related to its function as raw materials for kombucha, as well as the changes that occur post kombucha fermentation. As CBP kombucha is not yet commercially available, it is also not known whether it can comply

with the general standards as well as consumer expectation of kombucha.

1.3. Research Questions

- 1) What are the characteristics of different CBP raw materials and how do they affect the physicochemical and antioxidant properties of kombucha?
- 2) How to optimize CBP kombucha that complies with standards and consumer acceptance?

1.4. Research Objectives

- 1) To determine the characteristics of different CBP raw materials and how they affect the physicochemical and antioxidant properties of kombucha.
- 2) To optimize CBP kombucha that complies with standards and consumer acceptance.

1.5. Hypotheses

- 1) All CBP materials exhibit different characteristics in terms of physicochemical and antioxidant properties when utilized in kombucha production.
- 2) CBP kombucha can comply with existing standards and is accepted by consumers by optimizing the ingredient ratio and fermentation duration.

1.6. Significance of the Study

Despite the numerous potential of CBPs valorization as an ingredient in numerous food products, packaging materials and even cosmetics, the commercial product is yet to be widespread. The relatively simple production method and formula in kombucha can be a promising path in the developed product commercialization. Additionally, as this study also tries to address the product compliance to standard and consumer acceptance, it might give a head start for further development in commercialization.

1.7. Scope and Limitations

The scope of the research will focus on Robusta CBP supplied by PT. Cahya Aroma Inti in Tangerang, which were coffee cascara, silverskin, and pixel. The kombucha production will be done in lab-scale using tea kombucha production method as reference. The kombucha product evaluation will only consider parameters such as pH, titratable acidity, SCOBY growth, and overall sensory acceptance. The functional activities (total phenolic content and antioxidant activity) of the CBP ingredients will be characterized only in the raw material.

