

CHAPTER 2 - LITERATURE REVIEW

2.1. Kombucha

Kombucha is a fermented sparkling tea beverage known for its sweet and slightly acidic flavor and has been consumed in China since around 220 B.C. (Wang et al., 2022). This beverage is largely consumed due to its refreshing taste and perceived health benefits. Kombucha is commonly made from fermenting a sweetened tea solution with a starter culture called SCOBY (Symbiotic Culture of Bacteria and Yeast). SCOBY is a consortium composed from beneficial bacteria that contributes to the diverse microbial community found in kombucha such as acetic acid bacteria, lactic acid bacteria, and yeasts (Villarreal-Soto et al., 2018).

A proper kombucha is often characterized by its acidity expressed in pH between 2.5 - 4.2 and titratable acid 4 - 5g/L (Essiedu et al., 2024; Bishop et al., 2022), sugar content of approximately 2 - 4 °Brix (Wang et al., 2023), alcohol content commonly less than 1% (Bishop et al., 2022) (although up to 3% is also possible in homebrewed kombucha), and minimal presence of off-odor or off-flavor in the end product. The characteristics and functionality of kombucha aligns well with the benefits offered in coffee silverskin, where the ingredient contains high polyphenols (contributes to antioxidant activity), polysaccharides and dietary fiber for SCOBY support during fermentation (Navajas-Porras et al., 2025), and a toasty-cocoa flavor note that can potentially pair well with kombucha's acidity.

2.1.1. Production of Kombucha

In kombucha production, the most widely used substrate is black tea and sucrose is used as the carbon source during fermentation (Wang et al., 2022). Black tea is a variant of tea that usually undergoes multiple processing steps to produce its dark color and sweet aroma, mainly involving withering, rolling, fermentation, and drying (Yang et al., 2024). Based on Wang et al. (2022), a common method of producing kombucha is by dissolving 50-150 g/L (5% to 15% w/v) of sucrose into boiled water before tea leaves are added into the sugary solution. The mixture is heated up for approximately 5-10 minutes. The tea leaves in the

solution are later filtered out and the solution is left to cool down to room temperature. Due to its high water content, kombucha is prone to microbial contamination, therefore the production process requires a sanitary environment. The cooled down sweetened solution is then transferred to a sterile container before SCOBY is added. To prevent unwanted contamination from external physical sources, the container is covered with a sterile breathable cloth. Fermentation of the kombucha typically takes place at room temperature of 20 - 30 °C (Wang et al., 2022) and ranges from 7 to 60 days, with the optimum results obtained at an average of 15 days (Chu and Chen, 2006). Once the fermentation is complete, the SCOBY is filtered out and a small amount of solution is kept for future fermentation batches.

Table 1 Ranges of Ingredients in Kombucha Preparation in Previous Studies

Materials	Range	
	Lowest	Highest
Tea substrate (black tea)	4 g/L	30 g/L
Sucrose	50 g/L (5% w/v)	150 g/L (15% w/v)
Water	Commonly 1 liter per batch	
SCOBY	Commonly 1 culture layer per batch	

Table 1 summarizes the common ranges of ingredients (substrates) used in studies involving kombucha production. While the range of tea substrates used across studies is relatively large (4 - 30 g/L), 10 g/L amount of tea substrate is common for experiments using black tea (Soares et al., 2023).

2.1.2. Kombucha in the Functional Beverage Market

Following the increasing awareness of society on healthy lifestyles, a demand for convenient, accessible, and natural food and beverage products has been growing. According to Grand View Research (2023), the functional drinks market size is estimated at USD 149.75 billion in 2024 and is expected to reach USD 248.51 billion by 2030. This ever-growing market is highly influenced by the trends of consuming health-enhancing beverages, more specifically those containing amino acids, protein, and dietary fiber as an alternative to existing sugary

and carbonated beverages. This highlights the large demand for functional beverages including kombucha in the current and future market. The global market for kombucha in 2023 was valued at USD 2 billion and is expected to reach USD 5.9 billion by 2029 (MarketsandMarkets, 2024). The rising popularity of kombucha in recent years has been attributed to its relatively easy production, usage of accessible organic ingredients, and its high functionality and health benefits from probiotic and antioxidant properties.

2.1.3. Functional Properties

As a fermented beverage made from organic ingredients and beneficial microbes from the starter culture, kombucha has been widely studied for its health benefits. Some studies have mentioned kombucha having antioxidant, antidiabetic, antimicrobial, and probiotic effects for human health (Onsun et al., 2025; Tandhanskul et al., 2025).

2.1.3.1. Antioxidant Properties

The antioxidant properties of kombucha can be attributed to its high polyphenol content. Polyphenols are antioxidant compounds that are able to neutralize free radicals, reducing oxidative damage in the cells (Onsun et al., 2025). Additionally, polyphenols have also been studied for its potential in reducing risk of cardiovascular diseases by suppressing inflammation (Truong and Jeong, 2022). A majority of the polyphenols present in kombucha is composed of flavonoids, which can reduce lipid oxidation and protect cells from oxidative stress (Oluwole et al., 2022). However, excessive fermentation duration may affect these bioactive compounds negatively. Massoud et al. (2021) reported that the antioxidant activity of kombucha changed throughout the fermentation process and reached its optimum level on the 7th day of fermentation (93.8%).

2.1.3.2. Antidiabetic Properties

Most of the antidiabetic effects of kombucha has been studied through in-vivo studies, where it shows inhibition of α -amylase and α -glucosidase, enzymes that are involved in carbohydrate hydrolysis (Onsun et al., 2025; Tandhanskul et al., 2025). This indicates the potential of consuming kombucha in delaying glucose uptake and prevents progression of diabetes. Another study also mentioned the ability of kombucha in balancing the gut

microbiota in mice by suppressing its harmful bacteria and increasing its beneficial ones, which may lead to a reduction in blood glucose levels (Xu et al., 2022).

2.1.3.3. Antimicrobial Properties

The study done by Tandhanskul et al. (2025) mentioned that compounds including organic acids, polyphenols, and lactic acid bacteria contribute to the antimicrobial properties in kombucha. The various metabiotics from the SCOBY consortium have been observed to synergistically inhibit harmful foodborne and human pathogens. Acetic acid possesses lipophilic properties that allows it to inhibit both positive and negative-gram bacteria. Polyphenols play a role in destabilizing microbial cell surfaces, reducing their viability. Lactic acid bacteria produces bacteriocins and enzymes with antibacterial and antifungal effects.

2.1.3.4. Probiotic Effects

Many studies have shown that kombucha has positive effects on the health of gut microbiota attributed to its short-chain fatty acids and metabolites (Sengun and Kirmizigul, 2020). The probiotic bacteria in kombucha is also observed to be able to support the growth of *Lactobacillus* and *Bifidobacterium* species in the intestinal tract (Vargas et al., 2021). However, this functional aspect of kombucha still requires further research and validation as there are studies that reported no changes in intestinal flora after consumption (Soysal et al., 2022).

2.1.4. Kombucha Production using Non-Tea Ingredients

While tea leaves are the most common substrate used in kombucha production, there have been many studies that explored alternative substrates to substitute this ingredient. Kombucha that uses non-tea ingredients are required to clearly specify their ingredients and production process to distinguish them from traditional, tea-based kombucha (Kombucha Brewers International, 2023). Studies that explored the feasibility of producing kombucha using non-tea ingredients include one by Tangapo et al. (2025), who studied and profiled metabolite changes of kombucha fermentation using substrates of clove, guava, mint, and morel berry leaves. Another study utilized coffee cascara as a tea substitute and found an increase in total phenolic and flavonoid content, significantly antioxidant, antibacterial, and prebiotic

characteristic of the kombucha (Xuyen et al., 2023). Kombucha production from dried and fresh coffee pulp has also been studied, indicating that it is also a promising alternative to tea-based kombucha due to its high phenolic content and antioxidant properties (Rojas-Orduña et al., 2023). Additionally, a scientific review has been made to compile various raw materials that have been studied as alternative substrates of tea in production of kombucha-like beverages (Barros et al., 2024). This review mentioned a variety of ingredients ranging from fruits (goji berry, snake fruit, papaya, etc.), flowers (hibiscus), and herbs (mint, rosemary, thyme, etc.).

While CBPs are categorized as non-tea ingredients with the potential to be utilized in kombucha, the exact range of amounts used in the formulation has yet to be established. Therefore, the production of a new product such as kombucha may refer to existing ranges of ingredient amounts from other food and beverage products (Table 2) (Soares et al., 2023; Muzaifa et al., 2023; Franca et al., 2024; Cantele et al., 2022).

Table 2 Minimum and Maximum Limits of Kombucha Ingredients Used in Previous Studies
(Franca et al., 2024; Cantele et al., 2022; Muzaifa et al., 2023; Soares et al., 2023)

Ingredients	Min. Limit	Max. Limit	Control
Coffee Silverskin	0.5% w/v (5 g/L)	6% w/v (60 g/L)	0% w/v (0 g/L)
Coffee Cascara	1% w/v (10 g/L)	5% w/v (50 g/L)	0% w/v (0 g/L)
Coffee Pixel	1% w/v (10 g/L)	5% w/v (50 g/L)	0% w/v (0 g/L)
Black Tea	0.4% w/v (4 g/L)	3% w/v (30 g/L)	1% w/v (10 g/L)
Sugar	5% w/v (50 g/L)	20% w/v (200 g/L)	10% w/v (100 g/L)
Kombucha Starter	10% v/v (100 mL/L)	10% v/v (100 mL/L)	10% v/v (100 mL/L)

2.2. Coffee Industry and Its Waste

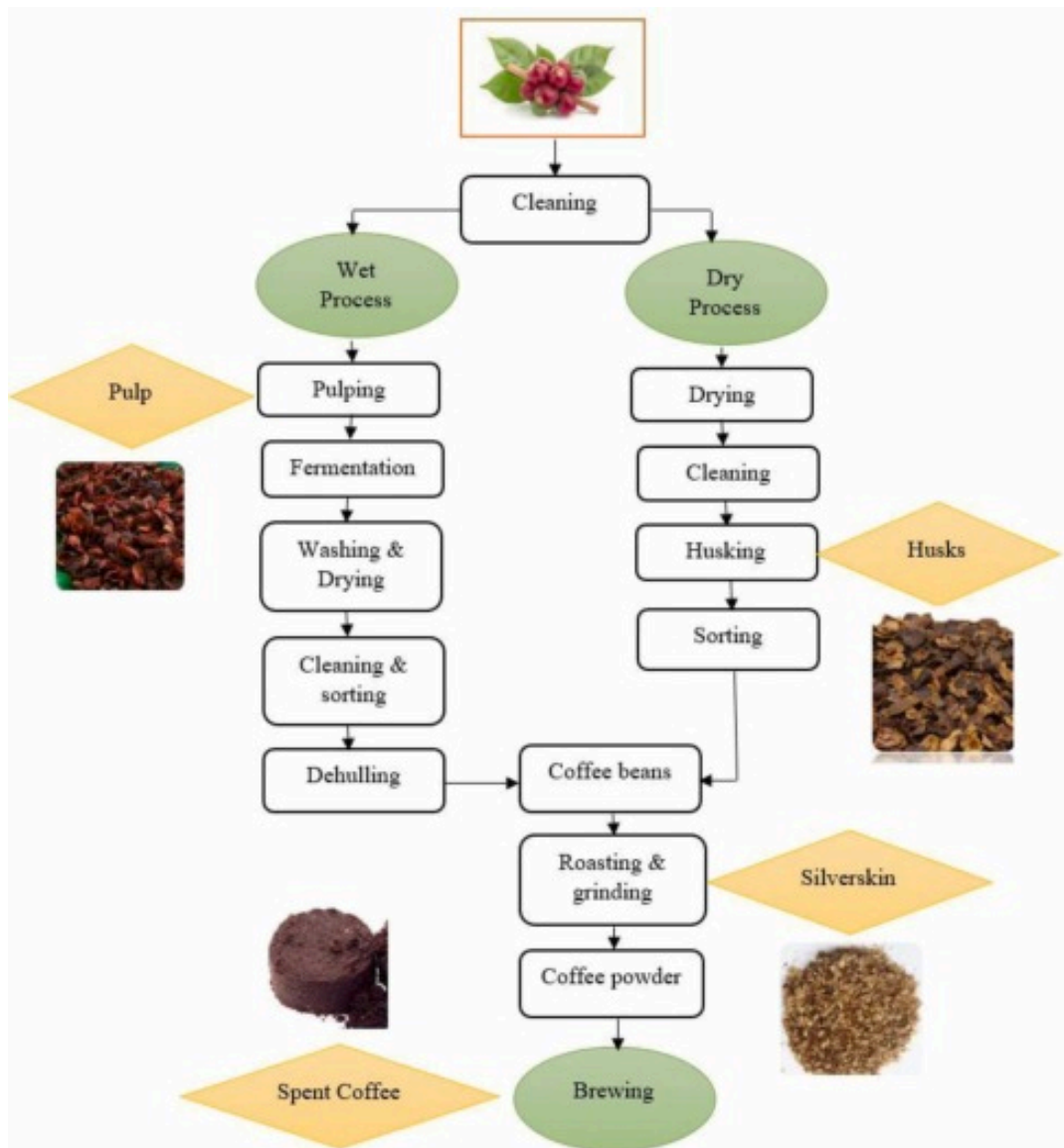


Fig. 2 Processing of Coffee Cherries into Coffee Powder (Oussou et al., 2023)

In the coffee industry, there are two known methods commonly used for coffee processing, that being dry processing (DP) and wet processing (WP) (Fig. 2). In the dry processing (also known as the natural process), the coffee cherries are sorted after harvesting, where the cherry fruits and beans are dried together using either natural or artificial drying (Febrianto and Zhu, 2023). In many coffee-producing countries, this is done by spreading the coffee cherries on large surfaces to dry under the sun until its moisture content reaches around 11-13% (National Coffee Association, 2024; Poltronieri and Rossi, 2016). The dried cherries

are then cleaned and peeled to expose the green coffee beans (GCB) inside. On the other hand, the wet processing involves peeling the coffee cherries to remove the pulp from the beans. These beans are later fermented for a certain period of time (commonly between 12-48 hours). Once the beans complete the fermentation stage, they are washed, dried and peeled (Febrianto and Zhu, 2023). There are other methods developed outside of these two methods, namely semi-dry processing (also known as honey processing) and wet hulling processing (Poltronieri and Rossi, 2016). The former involves removing the skin and pulp of coffee cherries and keeping a various amount of the mucilage intact to produce shades of yellow, red, and black honey coffee. The latter follows a similar procedure of keeping the mucilage on the beans, but washes them off using a semi-wet process before drying them until 30-35% moisture content. Once the GCBs are separated from the outer layers, they undergo a roasting process that builds pressure inside the beans, which results in them expanding and “cracking”; this is the stage where silverskins are produced (Java City, 2026).

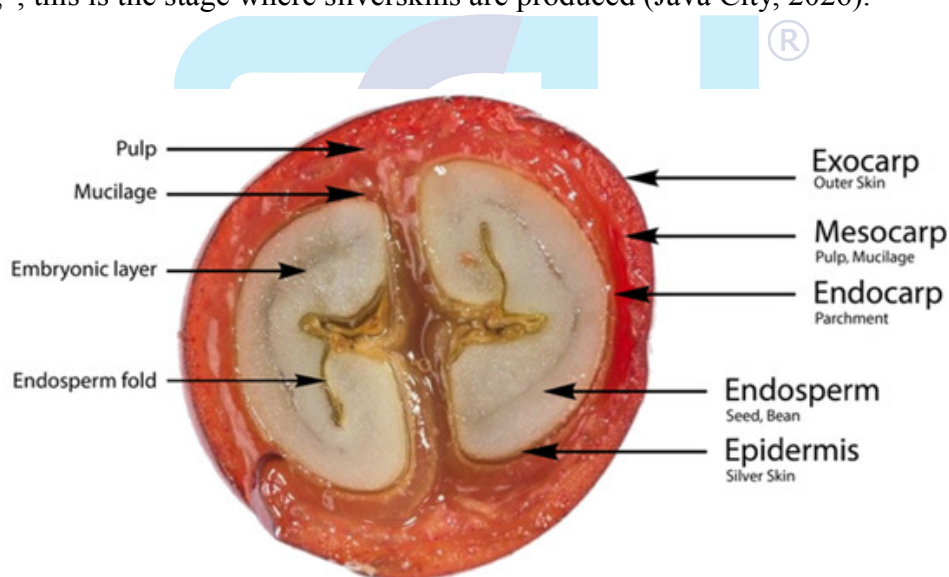


Fig. 3 Anatomy of a Coffee Cherry (Bastian et al., 2021)

Related to the processing of coffee cherries, the complete anatomy of the fruit is shown in Fig. 3. As mentioned before, during the harvesting process, most of the exocarp and mesocarp of the fruit are removed, which results in CBP such as coffee cascara, mucilage, and coffee pixel. The epidermis of the coffee cherry which consists of the silverskin is removed during the roasting process due to high heat and pressure. Consequently, most post-harvesting processing methods of coffee beans produce a large amount of CBP,

including coffee pixels obtained from defective beans. Muzaifa et al. (2023) noted that dry coffee processing produces around 45% husk, while wet processing produces 39% pulp—a large quantity of waste to be managed by farmers. On the other hand, silverskin poses a greater burden on coffee roasters, as improper management of the waste may lead to hazards due to the silverskin's flaky and flammable properties. In order to salvage these wastes, there have been several efforts to valorize the CBPs into various products including food and beverages.

2.2.1. Review of Previous Studies on Coffee Silverskin Applications

Existing papers and literature have studied the utilization of coffee silverskin (CS) in a wide range of food products, starting from cookies, cakes, gummy candies, yogurt, bread, meat, and others. A majority of these studies grounded their research of using coffee silverskin in food products due to its functional and nutritional benefits (Zoccatelli and Ciulu, 2025). Based on findings from Costa et al. (2018), high amounts of dietary fiber (insoluble and soluble) and protein can be found in coffee silverskin. Insoluble fiber has been studied to contribute to an improved intestinal motility that reduces the chances of intestinal cancer, while soluble fiber is beneficial in decreasing the absorption of sterol and glucose in the intestines (Cantele et al., 2022). Other than dietary fiber and protein, CS also contains polyphenols such as phenolic acids and flavonoids that contribute to its antioxidant properties (Zoccatelli and Ciulu, 2025). According to the study done by Machado et al. (2023), CS contains total phenolic content (TPC) of 1.28 g CGAE/100g dw and total flavonoid content (TFC) of 0.70 g CE/100g dw. In addition, melanoidins are present in CS, which possess antimicrobial properties that can help combat against pathogenic bacteria in food products (Jiménez-Zamora et al., 2015).

2.2.1.1. Coffee Silverskin Application in Baked Products

In baked products, such as biscuits, cakes, and bread, CS gives effect in varying degrees on both nutritional content and consumer acceptability of the end product. In the production of vegan biscuits, three types of CS (Arabica, Robusta, and decaffeinated) were used as a replacement for wheat flour in various percentages (Cantele et al., 2022). In the study of chocolate cake production, CS was ground and sieved to be used as a replacement for pre-made cake mixture (Franca et al., 2024). In gluten-free bread making, the CS went

through an aqueous extraction and freeze-dried before being mixed with a gluten-free baking mix (Guglielmetti et al., 2019). In all three types of baked products, a significant increase of phenolic content and antioxidant activity was observed from the addition of CS. Aligned with that, an increase in CS amount in these baked products resulted in a darker color and harder (vegan biscuits) or more fibrous (cake) texture of the finished product. While the CS-added products are generally accepted in sensorial tests, the odor acceptability in vegan biscuits are lower compared to the control. This is likely due to the formation of volatile compounds from the Maillard reaction during roasting that produce off-flavor. This problem is not very evident in the formulation of CS chocolate cake, mainly due to the CS color and odor being masked by the chocolate cake mixture.

2.2.1.2. Coffee Silverskin Application in Gummy Candies

Similar to baked products, incorporation of coffee silverskin in gummy candies also contributed to dark-brown colors due to its melanoidin contents. In the study done by Boninsegna et al. (2024), the CS was dehydrated, grounded and extracted (liquid form) to be added to the gummy candies mixture upon cooling down. The samples enriched with CS extracts experienced significant moisture loss and delayed stabilization. This was likely due to the hydroalcoholic nature of the CS extract which evaporates more easily and contributes to the loss of moisture. Despite that, the enriched samples maintained better structural characteristics (stickiness, springiness, hardness) compared to non-enriched samples resulting from the presence of fibers in their formulations. On the other hand, CS impact on the phenolic content in gummy candies were found similar to baked products, where the phenolic compounds in enriched candies were significantly higher than non-enriched samples. However, during storage, the candies suffered a significant decrease in phenolic compounds, likely due to the presence of oxygen and room temperature that triggered natural degradation and other chemical reactions. Contrary to the phenolic content, the antioxidant activity of enriched samples were significantly higher than non-enriched samples and remained stable until the end of storage period.

2.2.1.3. Coffee Silverskin Application in Meat Products

Not only in baked or sweets products, researchers have also studied the feasibility of utilizing coffee silverskin in meat products to inhibit lipid oxidation and extend their shelf life. Studies

done on the application of CS on chicken meat patties and pork sausages showed that CS significantly affected the lipid oxidation in the samples. In studies done by Martuscelli et al. (2021) and Özhamamcı (2024) related to incorporation of CS in chicken meat patties, they both used grounded CS, but landed on different results: the former reported a decrease in thiobarbituric acid reactive substances (TBARS) value in the samples (indicating a good antioxidant property from the CS), while the latter reported an increase in TBARS value. Özhamamcı (2024) noted that these contrasting results likely happened due to differing cooking processes in both studies (the former used an electric griddle, while the latter used a hotplate). In line with the results from Martuscelli et al. (2021), the pork sausages samples enriched with a solution made from a combination of CS extract and powder showed an inhibitory effect on the lipid oxidation due to the presence of phenolics from the CS (Mesárošová et al., 2025). Effects of CS incorporation in chicken meat patties resulted in a darker color of meat, which was still acceptable until 2% addition (Özhamamcı, 2024). This finding is also supported by a similar result found in the pork sausages. The addition of CS in chicken meat patties also contributed to a decrease in moisture content, resulting in a harder texture (similar to the findings in baked products), although this impact is minimal in the pork sausages. In terms of sensorial properties, CS contributes to a bitter and astringent taste when used in chicken meat patties but does not have a significant difference compared to the control (Martuscelli et al., 2021).

2.2.1.4. Coffee Silverskin Application in Dairy Products

CS's wide application range also includes dairy products such as yogurts and kefir. Bertolino et al. (2019) added CS extracts onto inoculated yogurt and observed an increase in its phenolic content and antioxidant properties, similar to the findings from baked products, gummy candy, and meat products. In contrast, a study conducted by Iriondo-Dehond et al. (2025) on yogurts made from coffee and wine-making byproducts, found that the addition of aqueous CS extract in the yogurt formulation impacted very minimally in terms of its TPC and antioxidant properties. The TPC of CS-enriched yogurt is comparably lower than the other samples, likely due to the differing polyphenol composition and extract concentration of the raw materials (Iriondo-DeHond et al., 2025). The study also noted that further study is needed to investigate the effects of yogurt starter culture to the phytochemical structure in the coffee and wine-making byproduct extracts during fermentation. This aspect is mentioned in

a different study, which is the study of CS incorporation in kefir (Ozmen-Togay, 2021), where they found that the addition of CS improved the survivability of lactic acid bacteria in the product. Overall, the finding from Iriundo-DeHond et al. (2025) in yogurt contrasts with the result found from baked products and gummy candy, where the latter reported a significant increase in TPC and antioxidant properties of the CS-enriched samples. Despite that, the addition of CS still contributes to an increase in dietary fiber content in both yogurt (Bertolino et al., 2019) and kefir products (Ozmen-Togay, 2021). Also contrasting to the baked products and meat products, the incorporation of CS had no significant effect on the yogurt samples in terms of texture (Iriundo-DeHond et al., 2025). This directly contrasts with the study done by Bertolino et al. (2019), where the incorporation of CS contributes to a lower firmness compared to the control. The findings in the chicken meat patties also fall in line with the sensory acceptability in the yogurt samples, where CS-enriched samples had the lowest overall acceptability in terms of taste.

The findings from the mentioned studies share similar patterns of increased antioxidant activity related to the increase of phenolic content in their products from the incorporation of coffee silverskin. Most of the studies also mentioned coffee silverskin contributing to a hardened texture and darker color values in the products. A summary of these findings is compiled in Table 3 below.

Table 3 Summary of Previous Studies on Impact of Coffee Silverskin on Various Food and Beverage Products

Topic	Application	Findings
Baked Products	Gluten-Free Bread (Guglielmetti et al., 2019)	Increase in phenolic content and antioxidant activity; good overall sensorial acceptance.

	Vegan Biscuits (Cantele et al., 2022)	Increase in phenolic content and antioxidant activity; darker color and harder texture of biscuits; low odor acceptance.
	Chocolate Cake (Franca et al., 2024)	Increase in phenolic content and antioxidant activity; darker color and more fibrous texture in cakes.
Gummy Candy	Boninsegna et al. (2024)	Increase in phenolic content and antioxidant activity; better structure compared to control; darker color gummy candies.
Meat Products	Chicken Meat Burgers (Martuscelli et al., 2021)	Significant antioxidant effect from phenolic compounds; contribution in bitterness and astringency; darker meat color.
	Fat Replacer in Chicken Patty (Özhamamcı, 2024)	Significant antioxidant effect; increased hardness; decrease in pH, moisture content, water activity, and color values.
	Pork Sausages (Mesárošová et al., 2025)	Significant antioxidant effect from phenolic compounds; darker meat color.

Dairy Products	Yogurt (Bertolino et al., 2019)	Increase in phenolic compounds and antioxidant capacity; decrease in moisture, fat, carbohydrate; decrease in pH; lower firmness compared to control.
	Kefir (Ozmen-Togay, 2021)	Increase in survivability of microbes (lactic acid bacteria); higher nutritional value from increased dietary fiber and antioxidant.
	Yogurt (Iriundo-DeHond et al., 2025)	Minimal impact on phenolic content, antioxidant activity, and texture; lower taste acceptance than control.

2.2.2. Coffee Cascara and Coffee Pixel

2.2.2.1. Review of Previous Studies on Coffee Cascara and Coffee Pixel Applications

Similar to coffee silverskin, coffee cascara has also been studied for its feasibility to be valorized into more valuable materials or ingredients in the food industry, some of which has been proven in several studies related to functional drinks, jams, baked goods and flour, as well as substrates to support plant productions. Aside from its characteristics of having fruity-like aroma that is deemed attractive to be incorporated into food or beverage products, coffee cascara also contains a substantial amount of dietary fiber (26-32 g per 100 g) and low amounts of lipids (0.5-3g per 100 g) (Wibowo et al., 2024). Coffee cascara also has been found to possess quite significant amounts of phenolic content ranging from 2.65-8.09 mg GAE/g and antibacterial properties, especially in the Robusta bean type (Sholichah et al., 2021). However, Komaria et al. (2021) mentioned that coffee cascara still contains some free amino acids and caffeine that exhibit a slightly bitter taste that may be found unpleasant upon consumption.

According to Politeknik Negeri Lampung (2026), around 5-20% of coffee harvest fail to meet the established standard, commonly due to their small sizes or being broken during harvesting. These defective coffee byproducts are called coffee pixels or undergrade coffee. Despite its history of being regarded as a commodity with an extremely low economic value and often discarded as organic waste, there have been efforts to valorize this material into products such as essential coffee oil for aromatherapy diffuser (Tami, 2021) or processed under specific conditions and blended with higher quality coffee to turn them into consumable coffee products. Despite its potential to be used in either the food or pharmaceutical industry, coffee pixel has not been largely studied yet for its nutritional value, especially when used as a substrate for functional drinks such as kombucha.

2.2.2.2. Coffee Cascara Application in Beverages

Contrasting to coffee silverskin and coffee pixel, coffee cascara has been studied in several functional drinks including kombucha (Xuyen et al., 2023; Muzaifa et al., 2023), yogurt (Iriondo-DeHond et al., 2025), and even powder-form instant beverage as an alternative for instant coffee (Iriondo-DeHond et al., 2020). In kombucha-related studies, the coffee cascara was often treated similarly to tea leaves, where they were brewed with hot water to extract the compounds within its solid matrix before mixing them together with sugar, filtered and cooled down, and finally added with SCOBY and fermented for a certain period of time. The processing and treatment of yogurt products from coffee cascara was also similar to methods used by Iriondo-DeHond et al. (2025), where aqueous extracts of the cascara were freeze-dried and dissolved into the milk used for the yogurt base. This method also was applied in the study of producing instant cascara beverages (Iriondo-DeHond et al., 2020). All three types of studies mentioned a significant increase in antioxidant activity in samples with cascara compared to their other samples. Xuyen et al. (2023) noted that the antioxidant potential of cascara-based kombucha had a similar trend to kombucha made from black tea or oolong tea, where it showed highest antioxidant activity at 14 days before declining at 21 days. The increase in antioxidant activity of these cascara-based beverages are possibly attributed to the free phenolic compounds released during fermentation. In terms of sensorial acceptance, cascara-based products were generally well-accepted. Cascara kombucha drinks that were fermented for 12-14 days obtained a balance in its sweetness, sourness, scent, as well as its nutritional value. This finding also aligns with the high acceptance of cascara

yogurt compared to control yogurt that were not significantly different from each other (Iriondo-DeHond et al., 2025).

2.2.2.3. Coffee Cascara Application in Jelly and Puree

Exploration on the feasibility of incorporating coffee cascara in sweet goods, such as jelly and puree had also been conducted. In jelly production (Devoney, 2021), cascara was cooked alongside sugar, lemon juice and pectin, whereas in puree production (Buck et al., 2021), water, citric acid, and sugar was cooked with ground coffee cascara. While the study of cascara jelly product did not conduct a thorough analysis of its antioxidant nor phenolic properties, it mentioned that the jelly product had a possibility of being a good source of chlorogenic acids (CGA) due to its processing methods. On the other hand, the processing methods of cascara puree resulted in an improved antioxidant capacity compared to its unprocessed counterpart. Similar to cascara beverage studies, both products were relatively well-received in regards to their sensory evaluation, where the most dominant flavors associated with the jelly being plum, honey, fig, and date. This finding aligns with the results in the puree study, where sweet and sour are the dominant taste, followed by fruity and botanical notes for its aroma profile.

2.2.2.4. Coffee Cascara Application in Bread

Valorization of coffee cascara has also been studied in various novel bread formulation, as done by Guglielmetti et al. (2019) and Rios et al. (2020) with gluten-free bread, Rosas-Sanchez et al. (2021) with conventional bread, and Elsayy and El-Din (2021) with balady bread (traditional Egyptian flatbread). Similar to findings in aforementioned cascara-based products, gluten-free bread formulations incorporated with coffee cascara experienced an increase in its nutritional value, especially in dietary fibre and antioxidant capacity compared to the control formulation. Interestingly, the addition of coffee cascara in all of the bread products resulted in a significant darkening of crumb color, similar to the findings of coffee silverskin-added baked products. This attribute is still accepted to a certain threshold as it gives off the color of typical wholemeal breads (Guglielmetti et al., 2019). Additionally, bread formulations with high concentrations of cascara also increased flavor notes associated with “toasted”, “coffee”, “bitterness”, and “sourness” as noted by Rios et al. (2020). In regards to texture, coffee cascara resulted in increased crumb firmness in

conventional bread, while decreasing it in gluten-free bread and balady bread.

2.3. Formulation Process

In researching a topic with limited previous studies to use as reference, formulating a beverage product may not be efficient or cost effective when using trial-and-error approach due to the abundance of possibilities of combinations between ingredients. This highlights the importance of utilizing software that is able to support designing experiments for mixture studies. Design Expert® is a widely used software to help with this aspect as it provides users a “mixture design” feature that works specifically for formulations and optimization (Hidayat et al., 2020). This software is useful to keep experimental runs cost-effective due to its design only focusing on optimizing mixture of ingredients in a certain range (which is normally more efficient than trial-and-error or full-factorial designs) (Assalam, 2022). Additionally, Design Expert® software is also able to optimize various responses simultaneously and features a “desirability” function to show which formulation has the highest predicted acceptance (Hidayat et al., 2020). Not only providing support in designing formulations, the software also is known to be a powerful tool to analyze the obtained results from experiments and generate statistical models from it.

2.4. Research Gap and Novelty

Based on the many studies conducted to investigate the feasibility and range of usage of CBPs in food products, it can be concluded that most of them utilized the byproducts as a functional ingredient to boost the nutritional value and shelf life of the samples. All of the aforementioned products in the literature review section above were relatively successful in achieving an improved version of the standard product they studied. However, from the range of product types in existing research, it can be seen that the inclusion of CBPs still vary, where coffee cascara has been utilized in several studies to produce kombucha, while coffee silverskin and coffee pixel have not been widely studied (silverskin have only been studied in yogurt and kefir in terms of functional drinks). Therefore, this research revolving around the optimization of kombucha made from CBPs aims to contribute in exploring the feasibility of using these ingredients in fermented beverages such as kombucha.