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Quality Characteristics of Fermented Arabica CascaraTea using SCOBY-Kombucha Fermentation in Different Drying Methods

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Abstract: Arabica coffee processing generates coffee cherry skin or husk as a by-product that is often underutilized and treated as waste, despite its potential to be processed into cascara tea as a value-added functional beverage. The application of SCOBY-kombucha fermentation offers an innovative approach to improve the chemical and sensory quality of cascara tea. **Objective:** This study aimed to analyze the quality characteristics of cascara tea produced from Arabica coffee husks fermented with SCOBY-kombucha under different drying methods. **Method:** This study employed a quantitative experimental approach using a completely randomized design (CRD). The treatments consisted of fermentation and non-fermentation combined with two drying methods, namely tray-dryer and sun-dryer. Data were collected through laboratory analysis of moisture content, total phenol content, and tannin characteristics, as well as organoleptic testing of color, aroma, and taste. The data were analyzed using analysis of variance (ANOVA). **Results:** The results showed that drying methods had no significant effect on the quality of cascara tea in terms of moisture content and total phenol content. However, SCOBY-kombucha fermentation reduced tannin content and improved the aroma characteristics of the tea. The best treatment was obtained from SCOBY-kombucha fermentation combined with tray-dryer drying, producing cascara tea with 4.8% moisture content, total phenol content of 1191.6 mg GAE/100 g, lower tannin content, and acceptable sensory characteristics. **Implications:** The findings indicate that fermentation can enhance the quality and consumer acceptability of cascara tea, while supporting the utilization of coffee-processing by-products into value-added products in the agroindustrial sector. **Originality/Value:** This study provides a novel contribution by integrating SCOBY-kombucha fermentation and drying methods in cascara tea production, offering a comprehensive evaluation of their combined effects on chemical and sensory quality.

Keywords: cascara tea; SCOBY-kombucha fermentation; Arabica coffee husk; drying method; total phenol content.

INTRODUCTION

Coffee is one of Indonesia's most important plantation commodities and has considerable economic value compared with many other agricultural products. Indonesia is currently among the world's largest coffee-producing countries, and in 2022 it produced 654 thousand metric tons of coffee and exported 276.18 thousand tons, with an export value reaching US$915.91 million (Badan Pusat, 2023). This condition shows that coffee plays

a strategic role not only in national export performance, but also in supporting the livelihoods of farming communities in several producing regions. However, the increasing scale of coffee production is also followed by an increase in processing by-products, especially coffee husk, which is generated in large quantities during post-harvest processing.

The accumulation of coffee husk as a by-product may create environmental problems when it is not properly managed. The Directorate General of Plantations reported that coffee processing generated a substantial amount of coffee husk waste, indicating that the issue is relevant to sustainable agroindustrial management (Directorate General of Plantations (Directorate General of, 2016). In practice, this by-product is still not optimally utilized, even though it can be processed into cascara, a value-added beverage material derived from dried coffee husk (Aswanto et al., 2023). Cascara has attracted attention because it possesses a distinctive flavor and contains bioactive compounds, including tannins and other phenolic constituents, which contribute to its functional potential and sensory characteristics (Garis et al., 2019; Rahayu et al., 2020). Therefore, the development of cascara tea is important from environmental, economic, and food innovation perspectives.

Previous studies have shown that coffee husk can be transformed into cascara products with promising functional beverage potential. Research by Garis (Garis et al., 2019) emphasized the utilization of coffee skin waste as cascara tea, while Aswanto (Aswanto et al., 2023) highlighted the broader potential of coffee husk as a valuable agroindustrial resource. In addition, Rahayu demonstrated that cascara-based beverages contain important chemical and sensory characteristics that may be improved through suitable formulation and processing (Rahayu et al., 2020). These studies confirm that coffee husk is not merely an agricultural residue, but a raw material with potential for product diversification and value addition.

A second line of research has focused on the effect of drying methods on cascara quality, particularly its chemical characteristics. Nafisah and Widyaningsih found that drying conditions and brewing ratio influenced the quality of Arabica coffee cascara (Nafisah & Widyaningsih, 2018). Similarly, Puspaningrum and Sumadewi reported that drying treatment affected total phenol content and antioxidant capacity in Arabica coffee fruit husk (Puspaningrum & Sumadewi, 2019, 2020). More recently, Tampubolon also showed that drying method and temperature play an important role in determining cascara

tea quality (Tampubolon et al., 2024). These findings indicate that drying is a critical post-harvest stage because it can influence the stability of phenolic compounds and the final quality of cascara products.

A third line of research has examined the role of fermentation in modifying cascara quality. Agfarina reported that fermentation duration affects the characteristics of cascara tea (Agfarina, 2021), while Nurhayati found that kombucha fermentation changed the physicochemical and sensory properties of roasted coffee husk cascara (Nurhayati et al., 2020). In addition, Puspaningrum showed that fermentation influenced the chemical characteristics and antioxidant activity of Arabica coffee cascara (Puspaningrum et al., 2022), and Sugito further confirmed that fermentation duration contributed to variations in cascara quality and safety (Sugito et al., 2023). Although these studies provide important insights, most previous research has tended to examine drying effects and fermentation effects separately. Studies specifically investigating the combined effect of SCOBY-kombucha fermentation and different drying methods on the quality characteristics of Arabica cascara tea are still limited, particularly those integrating moisture content, total phenol content, tannin characteristics, and sensory evaluation in one experimental framework.

Based on these gaps, this study aims to analyze the quality characteristics of Arabica cascara tea produced with and without SCOBY-kombucha fermentation under two different drying methods, namely tray drying and sun drying. The study specifically evaluates moisture content, total phenol content, tannin characteristics, and organoleptic properties, including color, aroma, and taste. By combining fermentation treatment and drying method in a single design, this research is expected to address the limitation of previous studies that have generally focused on only one processing factor at a time.

This study argues that the quality of Arabica cascara tea is influenced by the interaction between fermentation treatment and drying method. SCOBY-kombucha fermentation is expected to improve the chemical and sensory properties of cascara tea through microbial and enzymatic activities that modify phenolic compounds, tannin intensity, and flavor development (Agfarina, 2021; Nurhayati et al., 2020; Puspaningrum et al., 2022; Sugito et al., 2023). At the same time, the drying method is presumed to affect the retention of functional compounds and the sensory profile of the final product (Nafisah & Widyaningsih, 2018; Puspaningrum & Sumadewi, 2019, 2020; Tampubolon et al., 2024). Therefore, the working hypothesis of this study is that SCOBY-kombucha fermentation

combined with an appropriate drying method will produce cascara tea with better chemical and sensory quality than non-fermented cascara tea.

RESEARCH METHOD

The unit of analysis in this study was Arabica cascara tea produced from coffee husk subjected to different processing treatments. The treatments consisted of non-fermented coffee husk and coffee husk fermented using a SCOBY-kombucha starter, followed by two drying methods, namely tray-dryer and sun-dryer. The quality characteristics observed in this study included moisture content, total phenol content, tannin characteristics, and sensory properties, including color, aroma, and taste. The main materials used were Arabica coffee husk and SCOBY-kombucha starter. The chemicals used for analysis included methanol, 3% $FeCl_3$, distilled water, gallic acid, deionized water, Folin–Ciocalteu reagent, and Na_2CO_3. The equipment used in the study included a cabinet dryer, coffee bean pulper, fermentor, dry blender, analytical balance, moisture meter, and spectrophotometer.

This study employed a quantitative experimental method using a completely randomized design (CRD). This design was selected because the study aimed to examine the effect of controlled treatments on the chemical and sensory quality characteristics of cascara tea under experimental conditions. The experimental factors consisted of fermentation treatment, namely non-fermentation (A1) and fermentation with SCOBY-kombucha (A2), and drying method, namely tray-dryer (B1) and sun-dryer (B2). The use of this experimental design made it possible to compare the effect of each treatment combination on the final characteristics of the product in a systematic and measurable way.

Figure 1. Coffee arabica husk (left) and cascara tea product (right)

The sources of data in this study consisted of primary laboratory data and primary sensory evaluation data. Laboratory data were obtained directly from the analysis of

cascara tea samples produced under each treatment combination, including measurements of moisture content, total phenol content, and tannin characteristics. Sensory data were obtained from 31 untrained panelists, consisting of male and female respondents aged 17 to 50 years, who assessed the organoleptic properties of the cascara tea samples. In addition, this study referred to previous analytical procedures and standards as methodological references, including total phenol analysis based on (Puspaningrum & Sumadewi, 2019) tannin analysis based on (Listiana et al., 2022) organoleptic testing based on (Isdar, 2023) and moisture content requirements based on SNI 3836:2013 (National Standardization, 2013). Data collection was carried out through sample preparation, laboratory testing, and sensory evaluation.

Arabica coffee fruit skin was first prepared and washed to remove unwanted materials and maintain sample hygiene. The material was then subjected to fermentation treatment using a SCOBY-kombucha starter according to the designated treatment, while the non-fermented treatment was processed without fermentation. After fermentation, the coffee husks were washed again to remove remaining mucilage and impurities, and then dried using either a tray-dryer or direct sunlight. The dried husks were ground using a dry blender to obtain cascara tea powder. Moisture content was determined by weighing 2–5 g of sample, placing it on the measuring plate, flattening it, covering it, and reading the value displayed by the moisture meter directly. Total phenol content was analyzed using the Folin–Ciocalteu method following (Puspaningrum & Sumadewi, 2019). A standard curve was prepared from gallic acid at concentrations of 0, 10, 20, 40, 60, 80, and 100 mg/L, and absorbance was measured at 760 nm using a UV–Vis spectrophotometer. For the sample solution, 0.1 g of sample was extracted with 5 mL of 85% methanol, homogenized for 15 minutes, filtered, and reacted with Folin–Ciocalteu reagent and 5% Na_2CO_3 before incubation and absorbance measurement at 760 nm. Tannin content was analyzed qualitatively according to (Listiana et al., 2022) by dissolving 0.1 g of sample in 10 mL of methanol, pipetting 2 mL of the solution, and adding three drops of 3% $FeCl_3$ solution. A yellowish-green or black color indicated a positive tannin reaction.

Organoleptic testing was conducted for color, aroma, and taste using a five-point hedonic scale, namely strongly dislike (1), dislike (2), neutral (3), like (4), and very like (5), following (Isdar, 2023).

The data were analyzed using analysis of variance (ANOVA) with the assistance of STAR version 2.0.1 software. This analysis was used to determine whether fermentation

treatment and drying method affected the measured quality characteristics of cascara tea. Moisture content and total phenol content were analyzed quantitatively, while tannin test results were interpreted descriptively based on the color reaction formed after the addition of $FeCl_3$ solution. The total phenol content of the sample was calculated using a linear regression equation derived from the gallic acid calibration curve, expressed as

$$y = ax + b,$$

where $y$is the sample absorbance, $a$is the constant, $b$is the regression coefficient, and $x$is the sample concentration. Sensory data from panelist assessments were summarized and compared among treatment groups to identify the treatment combination that produced the most favorable characteristics of Arabica cascara tea.

RESULTS

Moisture Content

The moisture content in food ingredients is an important parameter for evaluating the condition of these ingredients. Figure 2 shows the results of moisture content testing on cascara tea, where the lowest average moisture content was found in the treatment using a Tray-dryer without fermentation at 4.3%, drying with a sun-dryer without fermentation at 6.6%, then drying with Tray-dryer and SCOBY-Kombucha fermentation at 4.8%, and Sun-dryer drying with SCOBY-Kombucha fermentation with the highest moisture content at 7.2%.

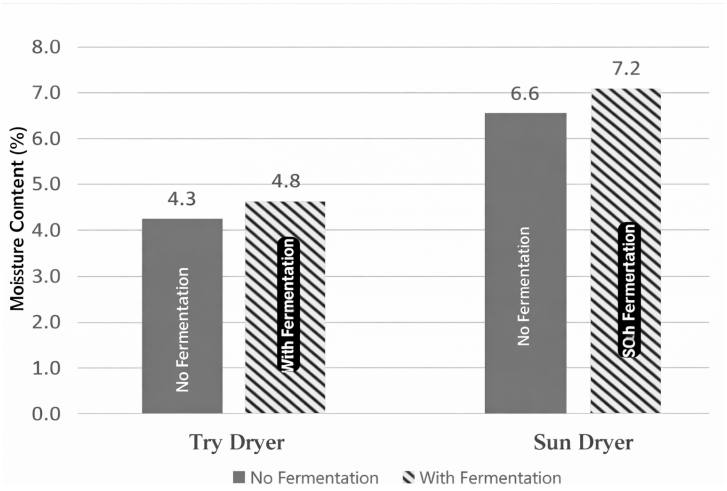

Figure 2. Moisture content of Fermented Cascara tea with SCOBY-kombucha and non-fermented on two drying methods

Total Phenol Content

The results of total phenol testing in cascara tea (Figure 3) showed that the highest average phenol content was in the drying formulation using the Sun-dryer Method with SCOBY-Kombuchan fermentation, producing 1191.6 mg GAE/100g, while the lowest average phenol content was found in the drying formulation using the Sun-dryer Method without Fermentation, which produced a total of 785.4 mg GAE/100 g.

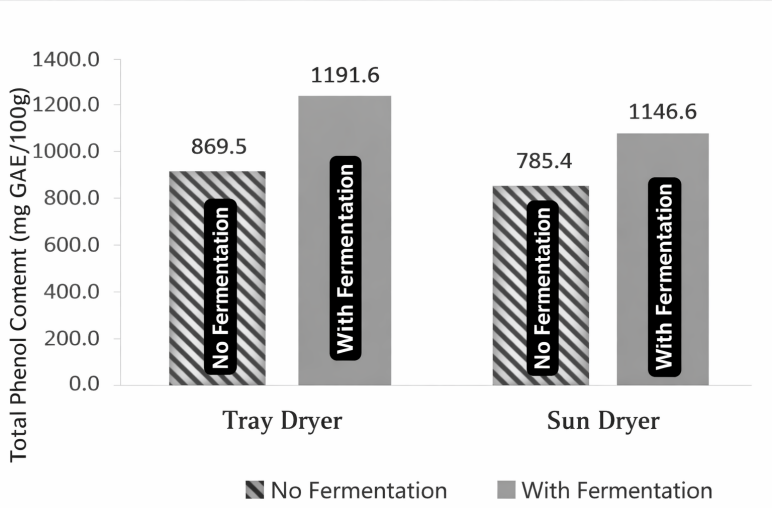

Figure 3. Total Phenol Content of Fermented Cascara tea with SCOBY-Kombucha and non-fermented on two drying methods

Tannin Content

Testing of tannins as secondary metabolites in Cascara tea was conducted qualitatively using methanol and 3% $FeCl_3$ reagents. The test results are shown in Table 1.

Table 1. Qualitative test results of secondary metabolite tannin levels in fermented cascara tea with SCOBY-kombucha and non-fermented at different drying methods

Fermentation/Non-Fermentation	Drying Method	Level of Color (+)
Non-fermented	Tray-dryer	+ + Yellowish green
Fermented with SCOBY-kombucha	Tray-dryer	+ Yellowish green
Non-fermented	Sun-dryer	++ Yellowish green
Fermented with SCOBY-kombucha	Sun-dryer	+ Yellowish green

Note: (+) contains less tannin/less concentrated
(++) contains more tannin compounds/more concentrated color

Sensory Analysis (Organoleptic)

The sensory evaluation results include color, aroma, and taste, as shown in the diagram in Figure 4, where the sides indicate the tendency of the values for the four treatments on a scale of 0 to 5.

Colour is an important aspect for consumers because it can be seen immediately before consuming a product. According to SNI 3836:2013, dried tea that meets the standard must have a characteristic tea color, which is reddish yellow or golden yellow. Based on the results of the organoleptic test related to the colour of cascara tea, the average organoleptic score for cascara tea is an average rating of 3 (Neutral/Ordinary) for cascara tea dried using a Tray-dryer without fermentation, then for Cascara Tea dried using a Sun-dryer without fermentation, the average rating was also 3 (Neutral/Ordinary), while the SCOBY-kombucha fermentation treatment with Tray-dryer or Sun-dryer drying was rated 4 or Quite Like. Fermented cascara tea and both Tray-dryer and Sun-dryer drying methods have a golden copper color, while unfermented cascara tea has a darker color.

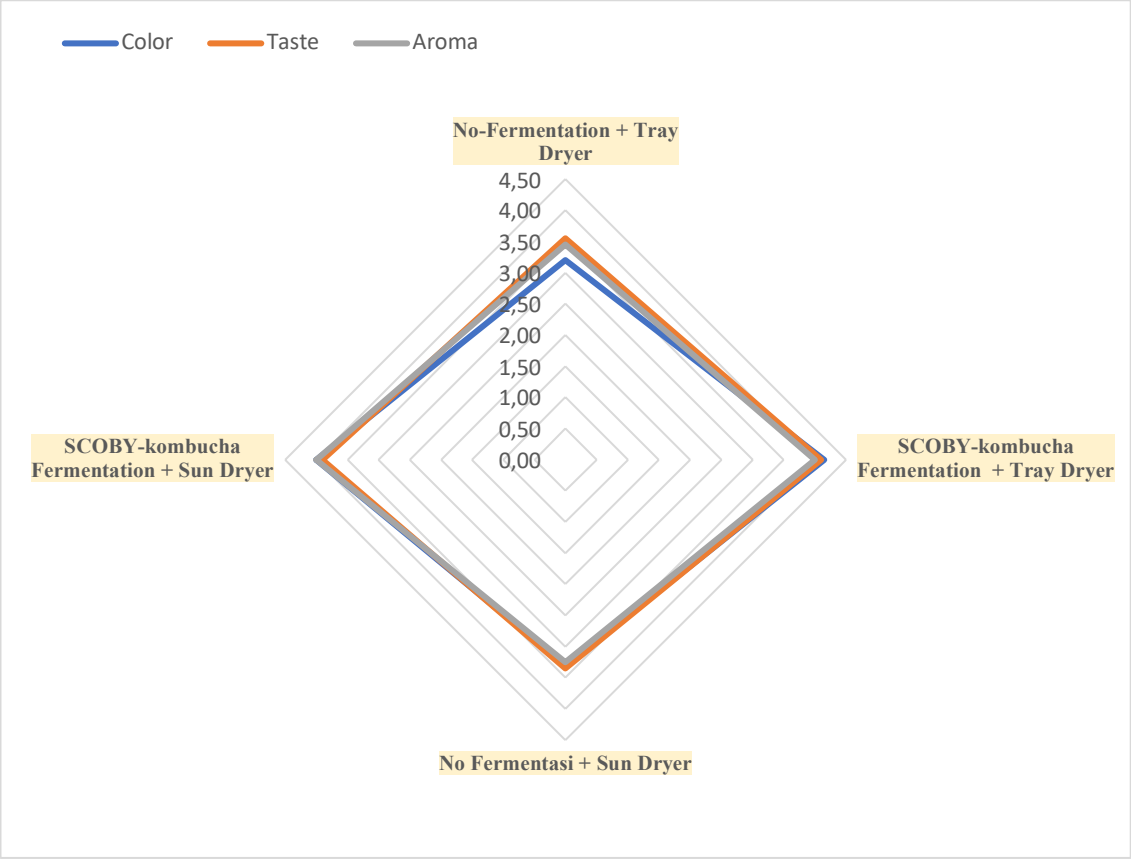

Figure 4. Diagram of sensory test value trends for color, aroma, and taste of cascara tea with SCOBY-Kombucha fermentation and non-fermented in different drying methods

DISCUSSION

The Moisture content (Figure 2) results of the analysis of variance show that the moisture content in cascara tea is not significantly affected by the type of drying (0.763), P>0.05, indicating that fermentation and drying methods did not significantly affect the

moisture content of cascara tea. The moisture content in dried cascara tea in this study ranged from 4.3% to 7.2%. According to SNI standards on dried tea quality, the maximum moisture content is 8% (SNI 3836-2013) (National Standardization, 2013). This means that dried tea that meets this standard must have a moisture content of no more than 8% of the total weight of the material. This standard is important to ensure the quality and safety of tea products, as well as to minimize the risk of microbial growth and other damage that can be caused by excessive moisture.

The fermentation process in coffee using *Saccharomyces cerevisiae* can cause coffee beans to absorb more water, thereby increasing the weight of fermented coffee beans. Microbial activity, such as *Saccharomyces cerevisiae* in this fermentation, will break down complex compounds in coffee beans into simpler compounds. This allows water to diffuse into the cells inside the coffee beans, enabling them to absorb more water during the fermentation process (Larassati et al., 2021).

Phenolic compounds are one of the most commonly produced secondary metabolites by plants. These compounds have more than one hydroxyl group attached to an aromatic ring and are known to have antioxidant, antitumor, antiviral, and antibiotic activities. These compounds are also a type of antioxidant commonly found in everyday foods (Puspaningrum & Sumadewi, 2019)

The results of the variance analysis show that the total phenol content in cascara tea is not significantly affected by the type of drying or fermentation (0.998 >0.05). The best phenolic compound content produced in previous studies was 743.8 mg/L, but in this study was was 1191.6 mg GAE/100g (Try dryer-with fermentation) (Figure 3), so the SCOBY-Kombucha fermentation process in cascara tea production was able to increase the total phenolic content compared to previous studies (Nafisah & Widyaningsih, 2018).

Fermentation affects the characteristics of cascara tea, including its physical, chemical, organoleptic, and functional properties. In theory, the longer the fermentation duration, the more time is available for enzymes in the cytosol to interact with substrates in the vacuoles. This process produces new chemical compounds that affect the quality of cascara tea, such as the color of the brew, taste, and functional compound content. The new compounds formed are polyphenols, which play an important role in determining the character and benefits of cascara tea (Sugito et al., 2023)

Low-temperature drying has the advantage of maintaining and producing high total phenol content in the material, while the use of higher drying temperatures can reduce the

activity of polyphenol oxidase enzymes through inactivation, resulting in less oxidation of phenols to quinones. However, phenol stability can also be compromised by excessive increases in drying temperature. At high temperatures, the total amount of phenols detected can reach a maximum peak, but then stabilize and tend to decrease over time. Therefore, selecting the right temperature in the drying process is very important to maintain the quality of phenols in the material without reducing its stability excessively (Puspaningrum & Sumadewi, 2020)

In addition to the drying method used in cascara production, the fermentation treatment of coffee fruit skins can also affect the phenolic content of the resulting cascara. The increase in total phenols in cascara tea is thought to be caused by the formation of phenolic compounds through enzymatic activity by bacteria and yeast in SCOBY-kombucha microbes, which degrade other matrix components. The degradation of chlorogenic acid by microbes produces caffeic acid, which can then be broken down into cinnamic acid. Caffeic acid belongs to the flavonoid group as one of the phenolic compounds. Saccharomyces cerevisiae present in kombucha culture has the ability to produce phenol reductase enzymes, which play a role in the decarboxylation of cinnamic acid (Puspaningrum et al., 2022).

Tannins are a group of compounds that belong to the polyphenol category and are found naturally in various parts of plants, such as leaves, nuts, fruits, bark, and stems. The function of tannins in plants is as a defense mechanism against pests. In general, natural tannins have larger molecules than other types of polyphenols (Isdar, 2023).

The results of qualitative tannin testing on Cascara coffee husk tea in Table 1 show that tannin content is considered positive if the sample changes color to green, yellow, or yellowish green after adding methanol and 3% $FeCl_3$.The test gave a positive reaction in the tannin test (Fajrina et al., 2017) explained that this phenomenon occurs because the phenol group in tannin is able to bind with ferric chloride ($FeCl_3$), forming a complex that produces a green or black color.

In line with the organoleptic test, the qualitative test of tannin secondary metabolites also showed that the color of unfermented cascara tea was brown and the color of fermented cascara tea was golden yellow. This identified that microbial activity in kombucha culture can cause the degradation of alpha-diketones and tannins. Kombucha culture contains *Saccharomyces cerevisiae*, which has the ability to produce tannase enzymes that play a role in degrading tannins during the fermentation process. In addition, during fermentation,

alpha diketones and tannins also undergo degradation, so that the color of the cascara tea produced becomes brighter and fades (Nurhayati et al., 2020).

Based on the results of the organoleptic test related to the colour of cascara tea, the average organoleptic score (Figure 4), Panelists generally prefer golden yellow tea color, unlike the dark black color often found in regular tea. High tannin content in tea causes the brew to become more concentrated, as tannins dissolve and oxidize, forming theaflavins and thearubigins that make the tea color darker (Baihaqi et al., 2023).

The drying process using a tray-dryer produces the expected color of cascara tea. In contrast, when drying using sunlight, some polyphenol enzymes undergo oxidation, causing the polyphenol compounds in the material to undergo a browning reaction and produce a darker color (Baihaqi et al., 2023).

Aroma is one characteristic that is often difficult to measure accurately because it is subjective. Therefore, assessments of aroma can vary from one individual to another. The results of organoleptic testing of the aroma of cascara tea showed an average score of 4.1 (Quite Like) for fermented tea dried using both a tray-dryer and a sun-dryer. The highest average score was found in SCOBY-kombucha fermented tea with tray-dryer drying, with an average rating of Quite Like (4.1), while the lowest score was found in the Sun-dryer drying formulation without fermentation (3.2). This indicates that panelists tend to prefer the aroma of fermented tea formulations, as the fermentation process and appropriate drying method produce a distinctive aroma that is more enjoyable. The distinctive aroma of fermented Cascara coffee husk tea is similar to that of regular tea, while the aroma of non-fermented tea is more astringent/bitter.

The highest value in cascara tea infusion is cascara tea dried with a tray-dryer compared to that dried under the sun (sun-dryer) due to slower drying under the sun and lower temperatures (Baihaqi et al., 2023; Tampubolon et al., 2024). Coffee fruit skin also contains compounds such as catechins in relatively low amounts. During the drying process, the oxidation of catechins in tea produces theaflavins and thearubigins, which affect the aroma of the tea infusion. The more theaflavins and thearubigins that are formed, the stronger the aroma of the tea. Therefore, the slow sun-drying process allows sufficient time for the catechins to oxidize, which in turn affects the aroma profile of the brewed tea (Subeki et al., 2019). Taste is the second factor that determines the flavor of a beverage after its physical appearance. An attractive appearance can stimulate the sense of sight and increase the desire to taste the beverage. The results of organoleptic testing of tea flavor in

cascara tea brews obtained an average score of 3 (Neutral/Ordinary) for unfermented tea in both Tray Dryer and Sun Dryer drying, whereas fermented tea in both Tray Dryer and Sun Dryer drying obtained an average score of 4 (Quite Like It).

In Generally, the taste of cascara tea is the most important aspect and is often the main focus of beverage evaluation. The taste of cascara tea, which comes from coffee husks, can differ from regular tea depending on the drying method used. Several factors, including chemical compounds and temperature during drying, can affect the taste. Many panelists preferred cascara tea with the fermentation in the Tray Dryer treatment because it offered a better flavor combination compared to other drying methods, which tended to produce a flavor that was too bitter.

In general, tea tends to taste bitter due to its high tannin content, which produces an astringent taste. Puspaningrum stated that the catechin compounds in tea from coffee husks create a bitter taste when consumed because of the tannin compounds contained in coffee husks (Puspaningrum et al., 2022). According to (Nurhayati et al., 2020) during the fermentation process, the tannin content decreases due to the activity of microorganisms in kombucha starters such as *Acetobacter* sp, Lactobacillus sp, and Saccharomyces sp in degrading complex compounds into simpler ones, such as tannin compounds, during fermentation, so that the taste of the cascara tea produced is not too astringent.

CONCLUSION

The main finding of this study indicates that differences in drying methods did not significantly affect the quality characteristics of cascara tea in terms of moisture content and total phenol content. However, SCOBY-kombucha fermentation played an important role in improving product quality by reducing tannin content and enhancing the aroma profile of cascara tea, resulting in a more distinctive and fragrant beverage. Among the treatment combinations, cascara tea produced through SCOBY-kombucha fermentation combined with tray-dryer drying showed the most favorable characteristics, with a moisture content of 4.8%, total phenol content of 1191.6 mg GAE/100 g, lower tannin intensity, and acceptable sensory properties, including neutral color and a fairly pleasant aroma and taste.

The scientific contribution of this study lies in providing an integrated evaluation of fermentation and drying processes in cascara tea production, particularly highlighting the

role of SCOBY-kombucha fermentation in modifying chemical and sensory properties of Arabica coffee husk-based beverages. This study enriches the existing literature by demonstrating that fermentation can be a key factor in improving cascara tea quality, even when variations in drying methods do not produce statistically significant differences in certain parameters. Furthermore, this research supports the valorization of coffee-processing by-products into value-added functional beverages, contributing to sustainable agroindustrial development.

Despite these contributions, this study has several limitations. The tannin analysis was conducted qualitatively, which limits the ability to quantify the extent of tannin reduction accurately. In addition, detailed control of fermentation conditions, such as duration, temperature, and microbial activity, was not extensively analyzed, and the number of experimental replications was not explicitly discussed. Future research is recommended to include quantitative tannin analysis, more controlled fermentation parameters, and advanced statistical approaches to better understand the interaction effects between fermentation and drying methods on cascara tea quality.

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