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Effects of brewing conditions and organoleptic assessment of cascara from *Coffea arabica* L.

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ABSTRACT

The conversion of coffee cherries into coffee beans results in notable by-products, particularly coffee pulp. This by-product, such as cascara, has the potential for further valorisation to produce bioproducts with economic value, possessing high levels of antioxidants and ascorbic acid. This study aimed to determine the optimize variations in brewing conditions of Arabica (*Coffea arabica* L.) cascara on antioxidant activity and ascorbic acid. This study encompassed three brewing conditions, including temperature (80, 85, 90, and 95 °C), time (2, 4, 6, and 8 min), and volume (100, 150, 200, and 250 mL). The results revealed that the optimal brewing conditions in terms of antioxidant activity in Arabica cascara were brewing at a temperature of 90 °C for 2 min, using 100 mL of water while in terms of ascorbic acid content were brewing at a temperature of 80 °C for 8 min, using 250 mL of water. Subsequently, organoleptic assessments were conducted using brewing at a temperature of 90 °C for 2 min, using 200 mL of water with the mass ratio of cascara to herbal extracts (4:1, 4:2, and 4:3) including mint leaf, lychee, strawberry, and raspberry extracts. The preferred formulation for Arabica cascara tea involves brewing with a 4:1 mass ratio of cascara to mint leaf based on taste, aroma, and color. These findings provide valuable insights into the optimal brewing conditions for Arabica cascara on maximizing the antioxidant activity and ascorbic acid, and the inclusion of herbal extracts enhances its overall preference among panellists.

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1. Introduction

Coffee stands as a popular beverage cultivated in over 70 countries (Alves et al., 2017), celebrated for its distinctive flavor, aroma, and acknowledged health benefits (Nieber, 2017). The projected global coffee consumption for the 2022/2023 period was anticipated to reach 173.1 million bags, reflecting a 1.3% increase compared to the preceding year (ICO, 2024). The escalation in coffee consumption levels correlates with a heightened generation of by-products, underscoring the crucial necessity for effective by product management. Coffee cherries, inclusive of their beans, encompass up to 30% coffee pulp as a component of their total dry matter (Braham, 1978). Consequently, the conversion process of coffee cherries into beans yields substantial residues, particularly in the form of coffee pulp.

Coffee pulp has been reported to contain cellulose (13–27%), lipids (2–17%), proteins (9–11%), tannins (4.5%), pectin matter (6.5%), reducing sugars (12.4%), and non-nitrogen extract (57–63%) (Pleissner et al., 2016; Woiciechowski et al., 2000), in addition to other polyphenolic compounds. The coffee cherry pulp has primarily found application as a fertilizer (Arisandy et al., 2020), animal feed (Sastra and Bawono, 2018), or has been discarded altogether (Ariadi, 2015). While utilizing coffee cherry pulp as fertilizer or animal feed presents avenues to diminish wastage, these practices face limitations, particularly concerning the optimal execution of using it as fertilizer, as it necessitates a considerable amount of time for the coffee cherry pulp to undergo decomposition (Pandey et al., 2000).

Coffee skin demonstrates commendable antioxidant activity and contains ascorbic acid, contributing beneficial properties for bodily health. An effective approach to harnessing the potential of coffee skins involves their conversion into an herbal beverage commonly known as cascara (Heeger et al., 2017). Cascara, derived from coffee cherry pulp, commands a market value ranging from US$13 to US$17 per kg (Ciummo, 2014). Renowned for its potent antioxidant activity, largely attributed to the presence of phenolic compounds, notably chlorogenic acid (Rodríguez-Durán et al., 2014; Oktaviani et al., 2020), cascara offers a versatile and sought-after product. The safety assessment conducted by the European Food Safety Authority Panel on Nutrition, Novel Foods, and Food Allergens for the dried husk from the fruit of Arabica (*Coffea arabica* L.) concludes that cascara is considered safe under the proposed conditions of use (Turck et al., 2022). An additional initiative involves incorporating cascara into herbal drinks containing

antioxidants and ascorbic acid content, further diversifying its potential applications. However, there is still a lack of understanding regarding the brewing conditions necessary to enhance the levels of antioxidants and ascorbic acid in Arabica cascara.

Arabica cascara inherent sour taste, combined with its remaining coffee flavor, may not appeal to some individuals. To address this issue, incorporating fruit extract into Arabica cascara can mitigate the coffee flavor, potentially making it more appealing. Furthermore, the addition of fruit extract enhances the beverage's antioxidant and phenolic content (Tarko et al., 2015). While the addition of fruit extract to Arabica cascara is expected to enhance its appeal, the specific fruit extract and optimal quantity preferred by consumers remain unknown. Further study and consumer preference studies would be essential to determine the ideal fruit extract and its quantity for achieving the highest preference in Arabica cascara tea.

This study aimed to determine the optimize brewing conditions of Arabica cascara including temperature, time, and water volume on antioxidant activity and ascorbic acid. Furthermore, this study also aimed to examine the effects of varying the ratio of cascara mass to herbal mass including mint leaf, lychee, strawberry, and raspberry extracts on the preference level for herbal drinks. These findings offer valuable insights into optimal cascara brewing conditions, and the most preferred mass ratio of cascara to herbal extracts.

2. Materials and methods

2.1. Materials

The materials including Arabica cascara (Mahadaya), lychee extract (Delifru), strawberry extract (Delifru), raspberry extract (Monin), and mint leaf (Inagreen) were purchased from online shops in Bandung, West Java, Indonesia. While for materials of 2,2-diphenyl-1-picrylhydrazyl (Smart Lab), starch (Avebe), iodine (Polylab), and ethanol (Supelco) were obtained from the Department of Chemical Engineering, Catholic Parahyangan University, Bandung, Indonesia.

Table 1. Variations in brewing conditions of Arabica cascara on antioxidant activity and ascorbic acid

Parameter	Condition	Cascara mass (g)	Temperature (°C)	Time (min)	Volume (mL)
Temperature	80 °C	4	80	4	250
	85 °C	4	85	4	250
	90 °C	4	90	4	250
	95 °C	4	95	4	250
Time	2 min	4	T optimum	2	250
	4 min	4	T optimum	4	250
	6 min	4	T optimum	6	250
	8 min	4	T optimum	8	250
Volume	100 mL	4	T optimum	t optimum	100
	150 mL	4	T optimum	t optimum	150
	200 mL	4	T optimum	t optimum	200
	250 mL	4	T optimum	t optimum	250

T = temperature; t = time.

2.2. Methods

2.2.1. Brewing conditions of Arabica cascara

Variations in brewing conditions of Arabica cascara were based on temperature, time, and volume of water (Table 1). The brewing process for cascara was conducted in several stages to determine the optimum brewing conditions. The optimal brewing conditions for cascara were reported as 77 °C for 8 min to achieve high antioxidant and phenolic content of cascara (Abduh et al., 2023). In the initial brewing stage of this study, 4 g of cascara was used with 250 mL of water (Icyer, 2019). The water temperatures were varied at 80, 85, 90, and 95 °C, maintaining constant time and the sample to water ratio, and subsequent analysis was conducted on the samples. After determining the optimal water temperature (yielding the highest antioxidant activity), the subsequent brewing was conducted to determine the optimal brewing time.

The second brewing was conducted to identify the optimal brewing time at the optimal water temperature, using a cascara mass of 4 g and water with a volume of 250 mL. The brewing time was varied between 2, 4, 6, and 8 min (with the sample to water ratio kept constant), followed by sample analysis. Upon determining the optimal brewing time, which yielded the highest antioxidant activity, the subsequent brewing process was initiated (Oktaviani et al., 2020). The third brewing was conducted at the optimal water volume. Variations were introduced by altering the ratio of a 4 g sample to water volumes of 100, 150, 200, and 250 mL. The optimization was assessed by measuring the antioxidant activity of cascara tea at each stage using the IC_{50} value, categorizing it as very strong (less than 50 ppm), strong (50-100 ppm), moderate (101-150 ppm), weak (151-200 ppm), or very weak (more than 200 ppm) (Molyneux, 2004). The analysis utilized a DPPH solution and spectrophotometric method, measuring absorption at 517 nm. The color change from brown to purple indicates the antioxidant reaction (Zuhra et al., 2008).

2.2.2. Formulation of Arabica cascara tea

Arabica cascara tea formulation variations were determined by organoleptic based on cascara and herbal extracts, including lychee, strawberry, raspberry, and mint leaf (Table 2). Arabica cascara tea formulation involves mixing 4 g of Arabica cascara with extracts of lychee (L), mint leaf (M), strawberry (S), and raspberry (R) in mass variations, namely 4:1, 4:2, 4:3, and 4:4. The various masses are then placed into a tea bag and brewed with 200 mL of water with brewing at a temperature of 90 °C for 2 min.

2.2.3. Determination of antioxidant activity

The measurement of antioxidant activity was conducted using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method with two replicates each sample. Each cascara tea sample (4 mL) was mixed with 1 mL of 0.4 mM DPPH solution. The resulting solution was homogenized and allowed to stand in the dark for 30 min. Subsequently, absorbance measurements were performed on the samples at a wavelength of 517 nm using a Single Beam UV–Visible Spectrophotometer (LX540SS, Labdex, London, United Kingdom), with methanol pro analysis serving as the blank (Raharjani et al., 2021). The antioxidant activity indicated by the DPPH activity was calculated using Eq. (1):

$$DPPH\ scavenging\ activity\ (\%) = \frac{(Ac-As)}{Ac} x100\% \quad (1)$$

Where A_c is the absorbance of the control solution, and A_s is the absorbance of the sample solution. The IC_{50} value was calculated from the graph of DPPH free radical scavenging activity measured

against the concentration of the samples. A smaller IC_{50} value corresponds to a higher antioxidant activity (Geremu et al., 2016).

2.2.4. Determination of ascorbic acid content

The determination of ascorbic acid (vitamin C) levels was conducted through the titration method with two replicates each sample. Initially, a solution was prepared by combining 5 mL of cascara tea sample with 50 mL of water, and 2 mL of 1% starch was added as a solution indicator. The resulting solution was then titrated using 0.01 N iodine until the solution changed its colour to blue violet (Agustin et al., 2022). The concentration of ascorbic acid (vitamin C) levels was calculated using Eq. (2):

$$Concentration\ of\ Vitamin\ C\ (mg/g\ of sample) = 0.8\ x\ V_{Titration}\ (mL)\ x \frac{2500}{mass\ of\ sample\ (g)} \quad (2)$$

Table 2. Formulation of Arabica cascara tea with herbal extracts

Sample	Cascara mass (g)	Lychee (g)	Mint leaf (g)	Strawberry (g)	Raspberry (g)
K	4	-	-	-	-
L1	4	1	-	-	-
L2	4	2	-	-	-
L3	4	3	-	-	-
M1	4	-	1	-	-
M2	4	-	2	-	-
M3	4	-	3	-	-
S1	4	-	-	1	-
S2	4	-	-	2	-
S3	4	-	-	3	-
R1	4	-	-	-	1
R2	4	-	-	-	2
R3	4	-	-	-	3

Samples: K = Control; L = Lychee; M = Mint leaf; S = Strawberry; R = Raspberry.

2.2.5. Organoleptic assessment

The preference for Arabica cascara tea was established through an organoleptic assessment. The conditions for Arabica cascara tea involved a brewing temperature of 90 °C, a brewing time of 2 min, and a water volume of 200 mL to standardize the size of brewed tea drinks commonly consumed in the community, assuming there was no need to adjust the preparation method. To enhance the taste profile, organoleptic testing was conducted by mixing Arabica cascara with various leaf and fruit extracts including mint, lychee, strawberry, and raspberry extracts. The samples were randomly distributed among 20 untrained panellists for the evaluation of cascara tea in terms of taste, aroma, and color. Panellists were requested to provide their feedback on the prepared cascara samples using a hedonic scale of 1 (immensely dislike), 2 (dislike), 3 (standard), 4 (like), and 5 (immensely like) (Abduh et al., 2023).

3. Results and discussion

3.1. Effects of brewing conditions on the antioxidant activity of Arabica cascara

The effect of brewing conditions on antioxidant activity from Arabica cascara tea varied, and overall, the antioxidants were very strong (less than 500 ppm) (Molyneux, 2004) (Table 3). The brewing temperature indicates a general trend of strengthening antioxidant activity with increasing brewing temperature (lower ppm values). However, an exception was observed at a temperature of 95 °C, where the antioxidant activity was lower than the sample of 90 °C. This phenomenon may be attributed to the potential damage and alterations in antioxidants induced by elevated treatment temperatures. Albab et al. (2018) elucidates this process, noting its rapid occurrence in two stages. Initially, hydrolysis takes place at the glycosidic bond, yielding a labile aglycone. Subsequently, the aglycone ring opens to form colorless carbinol and chalcone groups, eventually leading to the formation of a brown alpha-diketone. The generation of alpha-diketones results in a reduction of hydroxyl groups, which function as hydrogen donors to free radicals, thereby diminishing the antioxidant activity value. Additionally, secondary metabolite compounds such as flavonoids are not resistant to high temperatures. Consequently, the temperature of 90 °C showcasing the strongest antioxidant activity, has deemed the optimal brewing temperature.

Table 3. Effects of brewing temperature on antioxidant activity of Arabica cascara

Brewing temperature (°C)	Antioxidant activity (IC_{50}, ppm)
80	41.10 ± 1.5
85	33.58 ± 1.7
90	30.61 ± 1.9
95	38.27 ± 1.8

Data of mean ± standard deviation were from the triplicate experiment

Table 4. Effects of brewing time on antioxidant activity of Arabica cascara

Brewing time (min)	Antioxidant activity (IC_{50}, ppm)
2	21.95 ± 1.6
4	30.61 ± 1.4
6	50.10 ± 1.3
8	50.75 ± 1.5

Data of mean ± standard deviation were from the triplicate experiment

The effect of brewing time on antioxidant activity content in Arabica cascara tea revealed that the longer the brewing time, the lower the level of antioxidant activity (Table 4). Antioxidants have been demonstrated to be highly susceptible to degradation, thus, an extended brewing time can result in a reduction in antioxidant content within the brew (Sasmito et al., 2020). These findings are consistent with those of Dwiyanti (2014) that the shortest brewing time is best for achieving high antioxidant activity levels. Despite the general tendency for antioxidant activity to decrease with longer brewing times, the findings show that antioxidant activity remains strong. The optimal brewing time was determined to be 2 min, which has the highest antioxidant activity.

The effects of the ratio of cascara mass to water volume on antioxidant activity were revealed, indicating that a higher water volume ratio had shown a lower level of antioxidant activity (Table 5). This decline in antioxidant activity was attributed to the difference in concentration between solids and water. Diffusion events occurred when there was a concentration gradient, causing molecules to move from an environment with a higher concentration to one with a lower concentration. In smaller volumes of water, the concentration of solid was relatively higher, resulting in more compounds diffusing from the solid into the water at the same temperature and brewing time (Nafisah and Widyaningsih, 2018). Despite the antioxidant activity to decrease, the results indicated that it still fell under the classification of very

strong antioxidant activity. These experimental findings revealed that the strongest antioxidant activity occurred at 100 mL. Additionally, an increase in cascara mass increased antioxidant activity (Nafisah and Widyaningsih, 2018).

Table 5. Effects of ratio cascara mass and water volume on antioxidant activity

Comparison	Origin (Province)	Cascara:Water (g:mL)	Antioxidant activity (IC50, ppm)
Current study	Jambi	4:100	17.23 ± 1.1
		4:150	18.85 ± 1.1
		4:200	20.45 ± 1.3
		4:250	21.95 ± 1.5
Nafisah and Widyaningsih (2018)	Jawa Timur	5:100	130
		3:100	234
		1:100	275

Data of mean ± standard deviation were from the triplicate experiment

Under optimal brewing conditions, testing was conducted on black tea (*Camellia sinensis* L.), and the results showed that the antioxidant content was only 40 ppm. This indicates that Arabica cascara produces higher antioxidants. Furthermore, differences in Arabica cascara brewing methods can cause variations in the antioxidant content obtained. Using the maceration and Soxhlet extraction methods on Arabica cascara produced 277.9 and 286.9 ppm (very weak antioxidant), respectively (Angelia, 2019; Arlene, 2019). The utilization of the brewing method in this study yielded a higher antioxidant content.

3.2. Effects of brewing conditions on the ascorbic acid content of Arabica cascara

The investigation into brewing conditions on ascorbic acid content revealed a distinct pattern in the relationship between ascorbic acid and both brewing temperature and brewing time. The water volume also exhibited a similar pattern to brewing time (Fig. 1). The results of the ascorbic acid content show an inverse relationship between higher brewing temperatures and the ascorbic acid content in the samples. Brewing temperature emerges as a crucial factor influencing the stability of ascorbic acid in a solution, given its high sensitivity to oxidation. Ascorbic acid undergoes rapid degradation post-harvesting and continues to diminish over time. This study was consistent with the previous study, that the ascorbic acid content experiences a substantial decrease when the temperature surpasses 80 ˚C (Wolska et al., 2016).

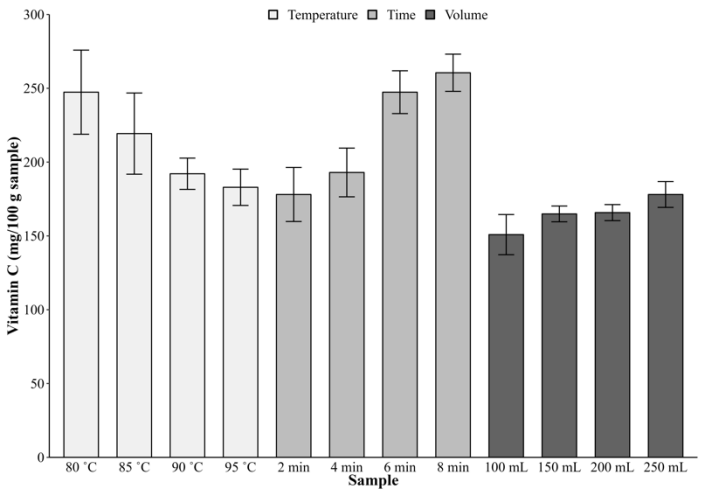

Fig. 1. Ascorbic acid (vitamin C) content of Arabica cascara on brewing conditions including temperature, time and water volume. Data represent mean from three replication and error bars indicate standard deviation

Furthermore, an increase in brewing time corresponds to a rise in ascorbic acid content. This phenomenon occurs because, during extraction, ascorbic acid diffuses into the water, and consequently, the longer the extraction duration, the greater the diffusion of ascorbic acid. In this study, the ascorbic content was determined using a titration method where the reagent used will react specifically only with the ascorbic acid yielding a reliable value of ascorbic acid content. After determining the brewing temperature and time, the volume of water for brewing cascara tea was established. An elevation in the amount of ascorbic acid was observed with an increase in the volume of water for brewing drinks. Despite this increase, no significant difference was observed. The ascorbic acid content under the optimal brewing conditions, represented by volume 250 mL with the highest ascorbic acid content, was recorded at 178.07 mg/100 g of the sample. Notably, the ascorbic acid content of coffee pulp extract surpasses that of other ingredients such as oranges, lemons, red cayenne peppers, and red peppers, with reported ascorbic acid contents of 40.6, 53.0, 120.3, and 135.5 mg/100 g, respectively (Lee and Coates, 1999; Mohanapriya et al., 2013; Shaha et al., 2013).

3.3. Organoleptic assessment of Arabica cascara tea

Organoleptic assessment of Arabica cascara tea revealed that panellist have preference on taste, aroma, and color (Table 6). The assessment of Arabica cascara tea color preferences indicates that sample L1 (4 g of cascara and 1 g of lychee extract) received the highest preference for tea color. This preference for L1 was ascribed to its more intense color in comparison to other samples, rendering it visually appealing and contributing to the overall attractiveness of the tea.

Next, the taste assessment of cascara tea revealed a general preference for teas with added herbal extracts comparing without extract. Among the seven tea samples (M1, M2, M3, L1, L3, S1, S2) incorporating added extracts received higher scores compared to samples containing only Arabica cascara. The most favored taste was found in tea with added mint leaf, renowned for its refreshing flavor. The same results revealed on the assessment of aroma preferences in cascara tea indicated an inclination towards teas with added extracts of mint leaf and fruit in comparison to those without. Teas exclusively composed of Arabica cascara exhibited a strong sour aroma from the cascara itself, whereas teas incorporating herbal extracts provided a more nuanced aroma that complemented the added extracts. These results support previous research findings, indicating that adding fruit extract to drinks increases consumer preferences (Tarko et al., 2015). Arabica cascara tea samples containing 1 g of mint leaf, the infusion presented a refreshing mint aroma, enhancing the overall preference for Arabica cascara tea.

Table 6. Organoleptic test result for the preference of cascara tea

Sample	Taste	Aroma	Color	Total
K	27	27	32	86
M1	37	36	30	103
M2	29	35	28	92
M3	30	36	29	95
L1	28	36	34	98
L2	25	32	31	88
L3	30	33	32	95
S1	33	33	27	93
S2	29	31	23	83
S3	26	29	19	74
R1	26	30	33	89
R2	27	29	29	85
R3	25	28	28	81

Samples: K = Control; M = Mint leaf; L = Lychee; S = Strawberry; R = Raspberry.

4. Conclusion

The results revealed that the optimal brewing conditions in terms of the antioxidant activity in Arabica cascara tea were

brewing at a temperature of 90 °C for 2 min, using 100 mL of water whereas in terms of the ascorbic acid content were brewing at a temperature of 80 °C for 8 min, using 250 mL of water. Subsequently, the formulation of Arabica cascara tea showed that incorporating herbal extracts enhances the sought-after benefits of the tea for the panellists. The preferred formulation for Arabica cascara tea involves brewing with a 4:1 mass ratio of cascara to mint leaf with brewing at of 90 °C for 2 min, using 200 mL of water. However, further study was required to determine the best brewing conditions for increasing antioxidants and ascorbic acid in Arabica cascara tea.

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Conflict of interest

The authors declare there is no conflict of interest in this research.

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