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The Impact of Drying Temperature and Duration on the Physicochemical and Sensory Properties of Cascara Powder Enriched with *Emprit* Ginger (*Zingiber officinale* var. amarum*)*

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ABSTRACT

Cascara, derived from dried coffee pulp, is abundant in polyphenols such as catechin and epicatechin, offering substantial potential for diverse uses. Enriching cascara powder (CP) with emprit ginger (EG) is an ideal innovation, as both are rich in antioxidants, enhancing sensory attributes and health benefits. This study contributed to the effect of different drying temperatures and durations on the physicochemical and sensory properties of CP with and without EG. This study utilized a completely randomized design (CRD) with two factors: drying temperature (45°C, 55°C, and 65 °C) and duration (24, 48, and 72 h). The physicochemical analysis included moisture content, ash content, pH, reducing sugars, total phenolic content, and antioxidant activity of RSA. Sensory evaluation assessed color, taste, and aroma. The results indicated that moisture, ash, pH, reducing sugar, and total phenol contents ranged from 3.82–7.45%, 3.59–10.79%, 4.26–6.51, 14.78–58.51%, and 10.34–50.37 mg GAE/g, respectively. The antioxidant activity of RSA ranged from 45.59% to 87.73%. The sensory tests showed that all formulations were liked by the panelists. Based on physicochemical and sensory properties, the F3t1 formulation with EG was of the best quality. The optimal drying temperature and duration were 45°C and 24 h, with 75% CP and 25% EG (F3t1+J1). This work significantly contributes to the field of food technology by offering valuable insights into the utilization of coffee by-products and the incorporation of bioactive-rich compounds to create innovative, health-focused functional beverages.

KEYWORDS

Antioxidant activity; Cascara powder; Drying temperature; Drying time; *Emprit* ginger

1. INTRODUCTION

Coffee is well known for its high caffeine content. A white, crystalline substance with euphoric properties, caffeine is a methylxanthine alkaloid. Caffeine in coffee has several health advantages when consumed in moderation, including improving mood, reducing fatigue, and increasing attentiveness [1], [2]. By boosting muscle contraction and endurance, caffeine also improves athletic performance. However, careful monitoring is necessary as excessive intake or consumption under specific medical conditions may have negative effects [3].

Numerous coffee kinds, such as Arabica, Robusta, Liberica, and Excelsa, are grown in Indonesia [4]. Among these coffee varieties, in Indonesia, Robusta is the most popular because it is more resistant to pests and diseases, requires less maintenance, and has a larger market demand [5]. In 2016, Robusta accounted for about 81.87% of the nation's total coffee bean yield. Interestingly, Robusta has higher levels of bioactive compounds, such as phenolic acids and chlorogenic acid, compared to Arabica and Liberica coffee [6].

Cascara, or the dried coffee peel, can be produced from Robusta cherries by heating. It has many health benefits and a unique flavour, promotes gastric health, increases skin suppleness, and aids in

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neutralizing free radicals [7]. Cascara's strong antioxidant activities make it a promising supplement for immune system support and cancer prevention [8]. Numerous bioactive compounds such as tannins (1.8–8.56%), pectin (6.5%), caffeine (1.3%), chlorogenic acid (2.6%), caffeic acid (1.6%), and anthocyanins (43%), are found in cascara [9], [10], [11].

However, the composition of bioactive compounds in cascara is affected by the processing parameters such as drying temperature and duration. Therefore, both drying temperature and duration must be maintained to ensure good quality cascara [12], [13]. In addition, the sensory and antioxidant qualities of cascara need to be ensured by adding emprit ginger, which has the strongest antioxidant activity and a unique taste [12]. This research evaluated the impact of both drying temperature and duration on the physicochemical and sensory properties of cascara with the addition of *emprit* ginger (EG). Hopefully, this work could be prepared with high-quality cascara.

2. MATERIALS AND METHODS

2.1. Materials

All materials, such as robusta peel, emprit ginger (EG) powder, and tea bags, were obtained from a market in Yogyakarta. Meanwhile, distilled water (DW), Nielson A:B (25:1) reagent, arseno-molybdate, lead acetate (Pb-Ac, 99%), sodium oxalate ($Na_2C_2O_4$, 99%, NaOH 97%, HCl 37%, D-glucose ($C_6H_{12}O_6$, 99%), methanol PA (CH_3OH, 99%), gallic acid 98%, Folin-Ciocalteu reagent, Na_2CO_3 99%, and 2,2-diphenyl-1-pychrilhydrazil (DPPH 95%) were purchased from the chemical shop in Yogyakarta.

2.2. The Preparation of Cascara Powder

Cascara was prepared under different drying conditions, as shown in Table 1. A total of 25 g of the sorted Robusta peel was dried at 65 °C, 55 °C, and 45 °C for 24 h, 48 h, and 72 h, respectively. Each sample was assigned a specific code based on the drying temperature and duration (Table 1). Then, the dried robusta peel was ground in a blender, sieved through a 100-mesh sieve, and labelled as cascara powder (CP). This work consisted of nine treatments with triplicate analyses of physicochemical and sensory properties. The chosen formulations were subsequently utilized in further experiments.

Table 1. Cascara preparation at different drying temperatures and durations.

Symbols	Drying temperature (°C)	Duration (hours)
F1t1	65	24
F1t2	65	48
F1t3	65	72
F2t1	55	24
F2t2	55	48
F2t3	55	72
F3t1	45	24
F3t2	45	48
F3t3	45	72

2.3. The Preparation of Cascara Powder with *Emprit* Ginger

Three selected CP samples (F1t1, F2t1, and F3t1) were evaluated based on sensory properties. Among these, the most preferred CP sample was then selected and mixed with EG. In this study, the CP with the F3t1 formulation exhibited the highest quality, as assessed by physicochemical and sensory properties. A total of 1 g of F3t1 and EG was mixed in varying compositions. Specifically, the selected CP with EG was formulated as presented in Table 2. Finally, their physicochemical and sensory properties were assessed.

Table 2. The selected CP mixed with the EG

Treatment symbols	Cascara powder (CP)	*Emprit* ginger (EG)
F3t1+J0	100%	0%
F3t1+J1	75%	25%
F3t1+J2	50%	50%
F3t1+J3	25%	75%
F3t1+J4	0%	100%

2.4. Moisture Content of Cascara Powder

The moisture content of CP was analysed by using a gravimetry technique [14], [15]. A total of 2.0 g of CP was weighed into a weighing bottle and heated in an oven at 105 °C for one hour. Once the heating process finished, the sample was cooled in a desiccator for 15 minutes and weighed. The moisture content was calculated using equation (1). The W_0 refers to the weight of the empty sample bottle (g), W_1 is weight of bottle and sample in initial, and W_2 is weight of bottle and sample after heating.

$$Moisture\ content\ (\%) = \left(\frac{W_1 - W_2}{W_1 - W_0}\right) \times 100\% \quad (1)$$

2.5. Ash Content of Cascara Powder

The ash content of CP was calculated by using a gravimetric method [16]. Firstly, a cleaned crucible was dried in an oven at 105 °C for one hour. The dried crucible was then cooled in a desiccator for 15 minutes and weighed. Next, 2 g of CP was placed in a dried crucible and incinerated in a furnace at 600 °C for two hours. After the incineration was complete, the sample was cooled in a desiccator for 15 minutes before weighing. The ash content was calculated using equation (2). The W_0 weight of the empty dried crucible, W_1 and W_2 denote the weight of the crucible with the sample before and after incineration, respectively.

$$Ash\ content\ (\%) = \left(\frac{W_2 - W_1}{W_1 - W_0}\right) \times 100\% \quad (2)$$

2.6. Total Phenolic Content of Cascara Powder

A total of 2.5 g of CP was placed in a volumetric flask and diluted with distilled water (DW) to a total volume of 1000 mL. Then, 0.2 mL of this solution was mixed with 0.2 mL of gallic acid (GA) and 1.0 mL of Folin reagent, and the reaction was allowed to proceed for 3 minutes. Next, 0.8 mL of Na_2CO_3 solution (7.5%) and 3 mL of DW were added to the mixture, which was stirred until homogeneous. The solution was then incubated in a dark room for 30 minutes. Finally, the absorbance of the mixture was measured using a UV-Vis spectrophotometer at 753 nm [13]. The absorbance values were used to construct a standard curve, as represented in equation (3), where y denotes absorbance, x represents the sample concentration (ppm), and a and b are the slope and intercept, respectively. TPC was calculated using equation (4), where D_f is the dilution factor (400) and V is the sample volume (mL).

$$Ay = ax + b \quad (3)$$

$$TPC = x \times D_f \times V \quad (4)$$

2.7. Antioxidant Activity of Cascara Powder

The antioxidant activity of CP with and without EG was determined using the DPPH method [17], [18]. A 0.05 mL sample was placed in a test tube and mixed with 2.95 mL of 20, 40, 60, 80, and 100 ppm DPPH solution. The mixture was then incubated in a dark room for 30 minutes. Finally, absorbance was measured at 517 nm using a UV-Vis spectrophotometer, and the absorbance values were plotted on a standard curve. The antioxidant activity, expressed as radical scavenging activity (RSA), was calculated using the corresponding equation (5). The same procedure was conducted on the blank.

$$RSA\ (\%) = \frac{(A_{blank} - A_{sample})}{A_{blank}} \times 100\% \tag{5}$$

2.8. Reducing Sugar of Cascara Powder

Initially, a 10-ppm glucose standard solution was prepared by dissolving 10 mg of anhydrous glucose in 100 mL. Then, this solution was diluted to series concentrations of 2, 4, 6, and 8 ppm. The CP sample was prepared by brewing 2 g of the sample with 40 mL of DW, then stirring until completely dissolved. Next, the sample solution was filtered using a filter paper to obtain the filtrate. Furthermore, 10 mL of the filtrate was transferred into a 100 mL volumetric flask, and a few drops of lead acetate (Pb-Ac) and DW were added to reach the calibration mark. Subsequently, 50 mL of the mixture was transferred into a new 100 mL volumetric flask, and a few drops of sodium oxalate and DW were added to reach the calibration mark. The mixture was filtered using a filter paper to obtain a lead-free filtrate.

Furthermore, 1 mL of the glucose standard solution, 1.0 mL of DW, and 1.0 mL of lead-free filtrate were pipetted into the different test tubes. Each test tube was filled with 1 mL of Nelson C reagent and heated in boiling water for 20 minutes. Once the heating process was complete, the mixture was cooled in cooling water, then 1 mL of arsenomolybdate and 7 mL of DW were added. The mixture was homogenized using a vortex. The absorbances of the mixture were measured using a UV-Vis spectrophotometer. The absorbance values were plotted on a standard curve to determine the reducing sugar content [19]. The reducing sugar content in the cascara tea drink is determined using equation (6). Here, fp represents the dilution factor, x denotes the sugar concentration (g), V_{init} is the initial sample volume (mL), and W_s refers to the sample weight (g).

$$Reducing\ sugar\ content\ (\%) = (x) \times fp \times \frac{V_{init}}{W_s} \times 100\% \tag{6}$$

2.9. The pH Value of Cascara Powder

The pH value of CP was measured using a pH meter [20]. The sample (5 g) was placed in a beaker and brewed with 100 mL of hot water. After cooling, the pH meter was immersed in the solution and allowed to stabilize until a consistent reading was obtained.

2.10. Sensory Tests of Cascara Powder

Sensory tests were performed for CP with and without EG. Sensory properties were evaluated by 30 untrained panelists using both hedonic and descriptive tests [21], [22]. The evaluation included color, taste, and aroma, assessed based on preference levels and descriptive attributes using a scale of 1–5, as illustrated in Table 3 and Table 4.

Table 3. The hedonic tests used a 1–5 scale for evaluation.

Sensory tests	Scale				
	1	2	3	4	5
Color	Very dislike	Dislike	Slightly dislike	Like	Very like
Taste	Very dislike	Dislike	Slightly dislike	Like	Very like
Aroma	Very dislike	Dislike	Slightly dislike	Like	Very like

Table 4. The descriptive tests used a 1–5 scale for evaluation.

Sensory tests	Scale				
	1	2	3	4	5
Color	Light brown	Brownish yellow	Dark brown	Brownish orange	Orange
Taste	Slightly tastes like dried fruit	Dried fruit flavor	Slightly tastes like coffee peel	Distinct coffee peel flavor	Predominantly sour
Aroma	Slightly aromatic of coffee peel	Distinct aroma of coffee peel	Slightly aromatic of dried fruit	Aroma of dried fruit	Sour aroma

3. RESULTS AND DISCUSSION

3.1. Cascara Powder Products

As defined above, cascara is the dried husk of the coffee cherry and has significant potential for utilization due to its rich content of bioactive compounds [23]. The husks of Robusta and Arabica coffee can be used to create health beverages due to their high polyphenol content. Polyphenols are well known for their strong antioxidant activity, offering potential health-protective benefits [24]. Traditionally, coffee husk waste is primarily used as animal feed due to its carbohydrate, protein, and mineral content. However, in this study, coffee husks are processed to produce cascara. As illustrated in Figure 1, this study successfully produced nine different types of cascara powder. Figure 1 presents the CP, which was dried at varying temperatures and durations, then ground to an 80-mesh particle size. Visually, the color of CP was uniformly dark, with a distinct coffee-like aroma.

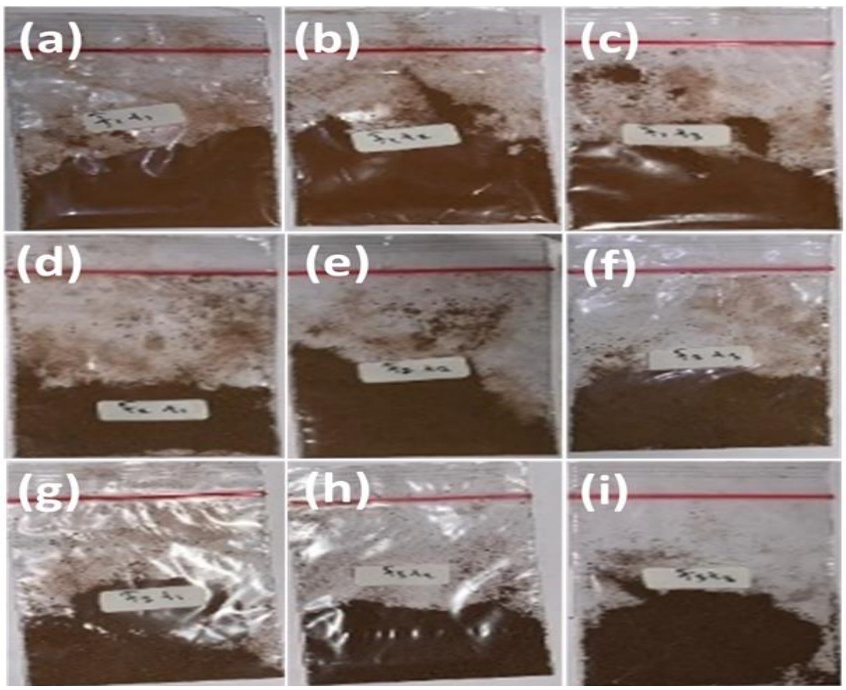

Figure 1. Nine formulations of CP based on the drying temperature and duration.
(a) F1t1 (65°C, 24 h); (b) F1t2 (65°C, 48 h); (c) F1t3 (65°C, 72 h); (d) F2t1 (55°C, 24 h); (e) F2t2 (55°C, 48 h); (f) F2t3 (55°C, 72 h); (g) F3t1 (45°C, 24 h); (h) F3t2 (45°C, 48 h); (i) F1t3 (45°C, 72 h).

3.2. Moisture Content of Cascara Powder

Water is an essential component in food as it significantly affects the appearance, texture, and flavor of the product. Moisture content refers to the amount of water contained in food, expressed as a percentage. High moisture content in food tends to accelerate the growth of microorganisms, thereby increasing the rate of product spoilage [25]. Water content in food plays a vital role in determining the product's quality, acceptability, and shelf life. Also, water in food is a key component that influences its appearance, texture, and flavor [26]. The trend in moisture content in CP is shown in Figure 2.

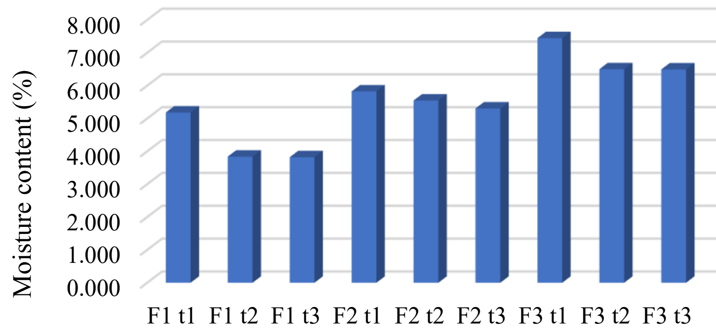

Figure 2. The moisture content of nine formulations of CP.

Based on Figure 2, the moisture content of CP decreases as both drying temperature and duration increase. The highest moisture content was observed in F3t1 (7.44%), which was dried at 45 °C for 24 h. This suggests that lower temperatures and shorter drying times may be insufficient to reduce moisture levels effectively. Conversely, the lowest moisture content was observed in F1t3 (3.82%), which was dried at 65 °C for 72 h. Statistical analysis indicates a significant inverse correlation ($p < 0.05$) between drying temperature, duration, and moisture content, suggesting that higher temperatures and longer drying durations enhance moisture reduction efficiency. The variation in moisture content across samples highlights the importance of optimizing drying parameters to achieve the desired moisture levels, which are crucial for ensuring product quality and shelf stability.

According to the Indonesian National Standard (SNI) 01-3832-2013, the maximum permissible moisture content for dried tea products is 8% [27]. This indicates that all CP formulations subjected to the drying process comply with the quality standards. This confirms that all CP formulations fall within the safe limits necessary to ensure product quality, inhibit microbial growth, and maintain stability during storage. Optimized drying parameters are critical for achieving moisture levels that comply with regulatory standards. Thus, the drying process applied in this study effectively reduces moisture content, ensuring the product meets national and global quality standards for market suitability [28], [29].

3.3. Ash Content of Cascara Powder

Ash content is the residual inorganic matter left after combustion and serves as an indicator of the substance's mineral composition. Determining ash content is closely related to assessing the purity and cleanliness of the material and reflects the mineral composition that influences the quality and nutritional value of food products. This process involves burning the material at high temperatures (≥400 °C) until all organic components are completely incinerated, leaving behind inorganic residue [15]. The trend of ash content is presented in Figure 3.

Based on Figure 3, the ash content in all CP formulations ranged from 3.58% to 10.78%. The highest ash content was observed in sample F1t3, which was dried at 65 °C for 72 hours, while the lowest was found in sample F3t1. Statistical analysis showed a significant effect ($p<0.05$) of drying temperature and duration on ash content. This indicates that higher drying temperatures and longer durations tend to increase ash content. This phenomenon may be attributed to the evaporation of certain inorganic elements during incineration. As the drying temperature increases, water evaporates more intensively, leading to a higher concentration of inorganic substances or minerals. This, in turn, increases the ash content relative to the material's total mass. The ash content in food products is influenced by several factors, including the type of material, drying duration, and drying temperature [30].

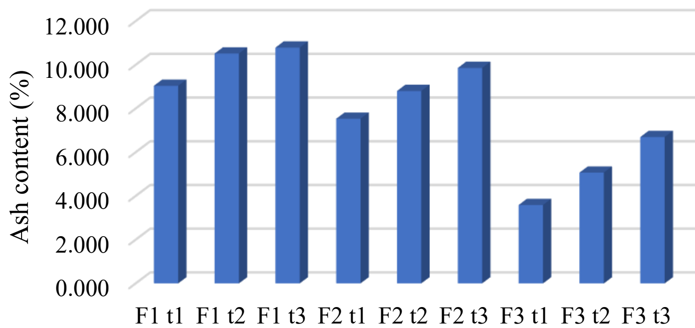

Figure 3. The trend in ash content of cascara tea at different drying temperatures and durations.

The Indonesian National Standard (SNI 01-3832-2013) specifies a maximum ash content of 8% for dried tea products. This indicates that only a limited number of samples conform to this standard. Maintaining ash content within safe limits is essential to ensure product quality, inhibit microbial growth, and enhance stability during storage. The findings suggest that the applied drying process effectively reduced ash content to meet national standards, making the product suitable for commercialization in compliance with regulatory requirements.

3.4. Total Phenolic Content of Cascara Powder

Phenolic compounds are the primary natural antioxidants in plants, consisting of single (phenol) or multiple (polyphenol) aromatic rings with hydroxyl groups. Their structure allows easy oxidation by donating hydrogen atoms to neutralize free radicals. During oxidation, phenolic compounds form stable phenoxy radicals, enhancing their antioxidant efficacy. Naturally, phenolics are often found as polyphenols in the form of ethers, esters, or glycosides, including flavonoids, tannins, tocopherols, coumarins, lignin, cinnamic acid derivatives, and multifunctional organic acids [31].

As shown by Figure 4, the TPC of all CP formulations was observed in the range of 10.34–50.36 mg GAE/g. The highest TPC was observed in F3t1, which was dried at 45 °C for 24 h, while the lowest was observed in F1t3, which was dried at 65 °C for 72 h. This suggests that higher drying temperatures and longer drying times contribute to the thermal decomposition of phenolic compounds. The variation in total phenolic compound (TPC) across cascara tea powders underscores the importance of optimizing drying conditions to preserve these bioactive compounds, which play a vital role in antioxidant properties and overall functional quality in cascara tea drinks.

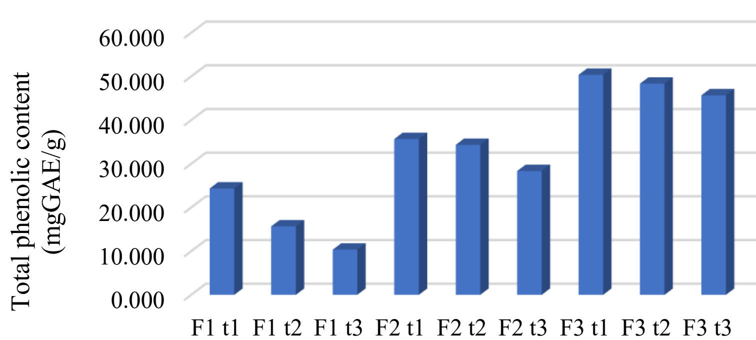

Figure 4. The TPC of CP at different drying temperatures and durations.

The drying process can degrade certain phenolic compounds, often leading to a reduction in phenolic content as drying temperatures increase [32]. Since TPC is directly proportional to antioxidant activity, higher drying temperatures also result in reduced antioxidant activity. Additionally, prolonged drying durations further contribute to the decline in TPC in CP.

3.5. Antioxidant Activity of Cascara Powder

Antioxidants are stable molecules or compounds that can donate electrons or hydrogen atoms to free radicals, effectively neutralizing them and preventing chain reactions. Consequently, antioxidants play a crucial role in delaying or inhibiting cellular damage, primarily through their free radical scavenging mechanism [33], [34]. The antioxidant activities (reported in RSA) of cascara tea powder are shown in Figure 5. Antioxidant activity tends to decrease with increasing drying temperature and extended duration. This trend aligns with TPC, which also declines at higher drying temperatures and longer drying durations. The lowest antioxidant activity was shown by F1t3 (RSA 45.58%), which was dried at 65 °C for 72 h, while the highest antioxidant activity was observed in F3t1 (RSA 87.72%), which was dried at 45 °C for 24 h. This pattern highlights the sensitivity of antioxidants to thermal processing. Furthermore, a comparative analysis reveals that the antioxidant activity of cascara tea powder is slightly lower than that of vitamin C (used as a standard), underscoring its potential as a functional beverage with significant antioxidant properties.

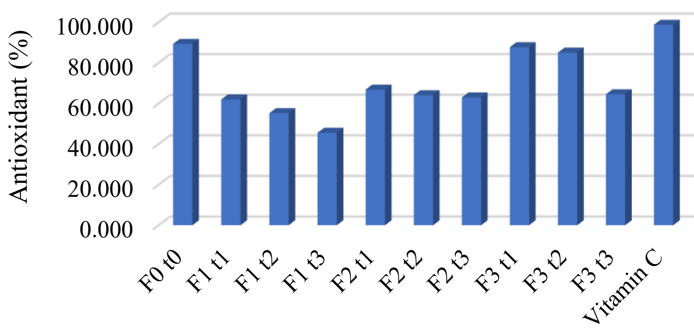

Figure 5. The patterns of antioxidant activity of CP.

Antioxidant activity in cascara decreases with increasing drying temperature and duration [20]. This might be primarily due to the sensitivity of antioxidant compounds, such as phenolic acids and flavonoids, to thermal conditions. At elevated temperatures, antioxidant compounds undergo oxidation reactions in which their molecules interact with oxygen, leading to a loss of stability and antioxidant activity. This oxidation reaction can accelerate the formation of by-products that lack antioxidant properties [35], [36]. Furthermore, prolonged drying times increase the likelihood of thermal reactions that lead to the denaturation of antioxidant compounds' chemical structures [37]. Consequently, the combined effects of higher temperatures and extended drying times reduce the concentration and effectiveness of antioxidant compounds in cascara, thereby diminishing its functional potential as an antioxidant source.

3.6. Reducing sugar of Cascara Powder

Reducing sugars are a type of sugar that can reduce other compounds due to the presence of free aldehyde or ketone groups. Sugars classified as reducing sugars include glucose, fructose, lactose, and maltose [38]. The reducing ability of these sugars is based on the presence of reactive free hydroxyl groups. Reducing sugar analysis typically relies on the reactivity of monosaccharides to reduce other compounds, and the polymerization of monosaccharides can influence their reducing properties [39]. The composition of reducing sugars at different drying temperatures and durations is presented in Figure 6.

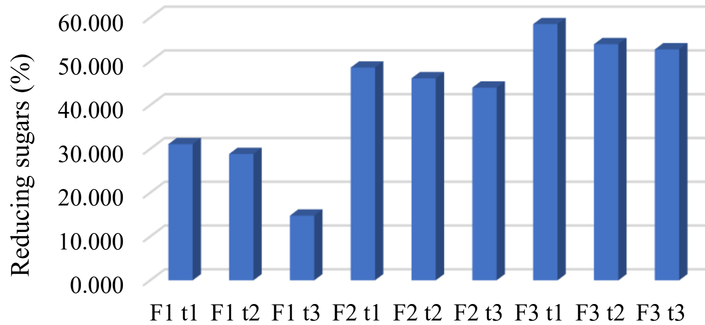

Figure 6. The trend of reducing sugar in CP at different drying temperatures and durations.

Based on Figure 6, the reducing sugar contents increased with decreasing the drying temperature and duration. The reducing sugar composition ranged from 14.78–58.51%. F1t3 shows the highest reducing sugar content, while F1t3 shows the lowest. This trend might be due to the thermal degradation and Maillard reactions, which occur more rapidly at elevated temperatures. During the drying process, reducing sugars (such as glucose and fructose) may participate in these reactions, leading to the formation of non-reducing end products and browning compounds. Additionally, prolonged drying may promote further degradation of reducing sugars through caramelization, resulting in lower reducing sugar levels [40]. These findings emphasize the importance of optimizing drying conditions to preserve the nutritional and functional properties of cascara powder, as these sugars contribute to both flavor and potential health benefits [41].

3.7. The pH Value of Cascara Powder

The pH is a crucial parameter for determining the acidity or alkalinity of CP; values below neutral (pH<7) indicate its acidic nature. At the lowest drying temperatures and shorter durations, the acidity of cascara tea powder was more pronounced, as observed in sample F3t1 (pH 4.26). On the other hand, the acidity of CP tends to be neutral (pH 6.51) at the highest drying temperature and the longest drying duration, as shown in F1t3.

This trend can be attributed to the thermal degradation of organic acids in cascara during the drying process, resulting in lower concentrations and a shift in pH toward a more neutral range. Additionally, the Maillard reaction, which is more pronounced at elevated temperatures, may contribute to pH elevation by producing neutral or basic by-products [7]. As shown in Figure 7, increasing drying temperature and duration reduces volatile compounds, such as organic acids, which play a crucial role in determining pH [42].

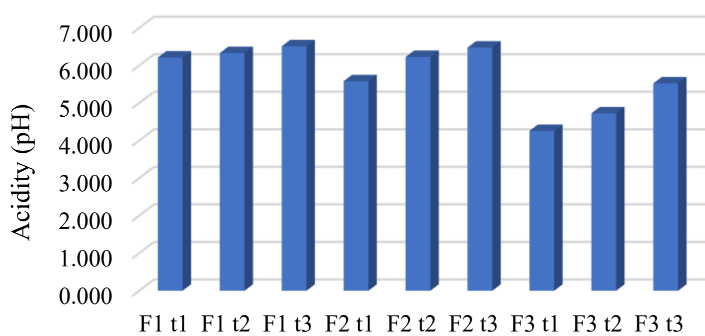

Figure 7. The pH values of cascara tea powder at different drying temperatures and durations.

3.8. Sensory of selected Cascara Powder

Table 5 presents the sensory properties of the three selected CP samples of F1t1, F2t1, and F3t1. Based on preferences for color, taste, and aroma, F3t1 was the most preferred, followed by F1t1 and F2t1. The color of F3t1 was brownish-orange, whereas F1t1 and F2t1 were dark brown. In contrast, the taste and aroma parameters of F3t1 showed a slight coffee-peel flavor and a mild dried-fruit aroma. Based on these facts, a higher drying temperature for the same duration led to changes in color, taste, and aroma [43]. Variations in drying temperature and duration significantly affect the sensory and chemical properties of food materials [44].

Table 5. Sensory properties of selected CP.

Sensory parameters		F1t1	F2t1	F3t1
Color	Hedonic	$3.27^{a} \pm 1.11$	$3.50^{ab} \pm 0.97$	$3.90^{b} \pm 0.66$
	Descriptive	$2.63^{ab} \pm 1.13$	$2.30^{a} \pm 0.92$	$3.20^{b} \pm 1.16$
Taste	Hedonic	$2.70^{a} \pm 0.95$	$3.27^{ab} \pm 0.94$	$3.37^{b} \pm 1.03$
	Descriptive	$2.67^{ab} \pm 1.09$	$2.37^{a} \pm 0.85$	$3.20^{b} \pm 1.16$
Aroma	Hedonic	$2.83^{a} \pm 1.02$	$3.47^{b} \pm 0.90$	$3.60^{b} \pm 0.81$
	Descriptive	$2.57^{a} \pm 1.16$	$2.37^{a} \pm 0.89$	$3.23^{b} \pm 1.10$

Note: The different superscript symbols in each result indicate a significant difference.

3.9. Antioxidant and Sensory Properties of the Selected Cascara Powder

Based on the sensory evaluation of the three CP samples, F3t1 was selected as the most preferred by the panelists. F3t1 was then blended with EG in varying compositions to develop a new formulation with enhanced antioxidant and sensory properties. Table 6 shows the antioxidant activities of five CP with EG formulations. From these data, the CP blended with EG shows higher antioxidant activity than CP alone. The higher RSA value might be due to the EG containing strong antioxidants such as gingerol, shogaol, and zingerone. The highest RSA value of 92.98% was shown by the F3t1+J3 with a ratio of 25:75. In comparison, the lowest RSA value of 87.77% was observed by the F3t1+J0 with a ratio of 100:0. Overall, the antioxidant activities of CP with and without EG could be categorized as strong activity [45].

Table 6. Antioxidant activity of five selected CP.

Formulations	Antioxidant activities (RSA, %)
F3t1+J0	87.77 ± 4.03^{a}
F3t1+J1	91.58 ± 0.94^{a}
F3t1+J2	91.58 ± 1.29^{a}
F3t1+J3	92.98 ± 0.64^{a}
F3t1+J4	88.22 ± 0.58^{a}
Vitamin C	95.76 ± 0.62^{a}

Note: The different superscript symbols in each result indicate a significant difference.

Furthermore, the CP with EG (F3t1+J1) was rated higher in preference than the other formulations. The color, taste, and aroma preference scores ranged from 3.17 to 3.97, 3.17 to 3.97, and 2.83 to 3.70, respectively. Additionally, the CP without EG received a preference score of 3.90, placing it in the "like" category. On the other hand, the preference for EG alone was slightly negative due to its brownish-yellow color, dried-fruit flavor, and sour aroma. A detailed summary of all sensory properties is presented in Table 7. Overall, the blending with CP and EG significantly influenced the sensory properties of cascara tea drink. The combination of CP and EG not only provides functional benefits, such as improved antioxidant properties, but also enhances the sensory experience, potentially boosting consumer acceptance.

Table 7. Sensory properties of five selected CP.

Sensory parameters		F3t1+J0	F3t1+J1	F3t1+J2	F3t1+J3	F3t1+J4
Color	Hedonic	$3.90^{bc} \pm 0.66$	$3.97^{c} \pm 1.35$	$3.17^{ab} \pm 0.91$	$3.17^{ab} \pm 1.12$	$2.83^{a} \pm 1.32$
	Descriptive	$3.20^{b} \pm 1.16$	$3.03^{b} \pm 1.61$	$2.00^{a} \pm 1.26$	$1.90^{a} \pm 0.84$	$1.83^{a} \pm 1.32$
Taste	Hedonic	$3.90^{bc} \pm 0.66$	$3.97^{c} \pm 1.35$	$3.17^{ab} \pm 0.91$	$3.17^{ab} \pm 1.12$	$2.83^{a} \pm 1.32$
	Descriptive	$3.20^{b} \pm 1.16$	$3.03^{b} \pm 1.61$	$2.00^{a} \pm 1.26$	$1.90^{a} \pm 0.84$	$1.83^{a} \pm 1.32$
Aroma	Hedonic	$3.60^{bc} \pm 0.81$	$3.70^{c} \pm 1.24$	$2.97^{abc} \pm 1.19$	$2.83^{ab} \pm 1.21$	$2.73^{a} \pm 1.02$
	Descriptive	$3.13^{ab} \pm 1.28$	$2.33^{a} \pm 1.27$	$2.67^{a} \pm 1.12$	$3.90^{bc} \pm 1.16$	$4.23^{c} \pm 0.68$

Note: Different superscripts in each value indicate a significant difference.

4. CONCLUSION

This study demonstrates that different drying temperatures and durations significantly impact the physicochemical and sensory characteristics of CP. F3t1 exhibited the best results, with the optimal drying condition achieved at 45 °C for 24 h. The physicochemical properties of F3T1 were observed as follows: moisture content (3.82%), ash content (3.59%), pH (6.51), reducing sugar (58.51%), total phenolic content (50.37 mg GAE/g), and antioxidant activity (87.73%). The CP could be blended with EG to enhance antioxidant activity and sensory properties. The CP with the addition of EG, labeled as F3T1+J1, was identified as the best formulation, exhibiting the highest antioxidant activity and the highest preference among panelists.

AUTHOR CONTRIBUTION

All authors contributed equally as the main contributors to this paper. All authors have read and approved the final version of the manuscript. **Ibdal Satar**: Writing (review & editing, conceptualization). **Adinda Yuniarti**: Writing (review & editing), writing (original draft), and formal analysis. **Nurhayati Yusof**: Reviewing and editing the manuscript. **Waled Abdo Ahmed**: Reviewing and editing the manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest to declare.

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