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Herb-Fortified Arabica Cascara Infusion as a Functional Beverage

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ABSTRACT – Cascara is a product derived from the drying of Arabica coffee pulp. It has potential as a functional beverage with health benefits. This study aims to produce a functional beverage from cascara and analyze its organoleptic properties, phytochemical content, antioxidant activity, total polyphenols, and caffeine content of cascara infusion fortified with medicinal plants. The methods utilized in this study included drying, grinding, and sieving, as well as the formulation of cascara with lemongrass (*Cymbopogon citratus*) and kaffir lime peel (*Citrus hystrix*) fortificants. The formulations included V1 (C : S = 75% : 25%); V2 (C : J = 75% : 25%); V3 (C : S : J = 50% : 25% : 25%); and V4 (C : S : J = 75% : 12.5% : 12.5%). The analysis included organoleptic evaluation, cascara brewing temperature and time optimization, gravimetric method moisture content evaluation, pH measurement, phytochemical content evaluation, DPPH method antioxidant activity assay, Folin-Ciocalteu method total polyphenol content measurement, and UV-Vis spectrophotometry caffeine content evaluation. The hedonic test results indicated that the most preferred sample was V1, with a score of 3.90 out of 5.00. Moisture content analysis showed that cascara contains 13.36 ± 0.0007% moisture, lemongrass stalks 11.10 ± 0.0043%, and kaffir lime peel 7.63 ± 0.0004%. The pH of all variants had met the standard with a range of 4.18 ± 0.05 – 4.24 ± 0.08. The phytochemical analysis indicated that the control variable of cascara infusion (C) and V2 contained alkaloids, phenolics, and tannins. Meanwhile, V1 contained alkaloids, phenolics, tannins, and terpenoids. All cascara infusion variants contains antioxidant activity ranged between 78.25 ± 0.25 – 79.50 ± 0.63%; total polyphenol 494.25 – 1,500 mg GAE/100g; and caffeine content 392.53 – 409.53 mg/100g. In conclusion, the study found that cascara infusion V1 was the most preferred by taste testers, and all the infusions were rich in antioxidants and other beneficial compounds.

KEYWORD : antioxidant; caffein; cascara; lemongrass; kaffir lime peel.

INTRODUCTION

Cascara is the dried pulp of Arabica coffee beans (*Coffea arabica*). Coffee production in Indonesian plantations reached 794,800 tons in 2022, with a plantation area of 1.24 million hectares (Badan Pusat Statistik, 2023). The high-level of coffee production naturally results in a high amount of coffee pulp waste. This is due to the more dominant utilization of coffee beans rather than the pulp. Coffee processing yields about 65% coffee beans and 35% coffee pulp waste (Azzahra & Meilianti, 2021). However, coffee pulp waste can be developed into a high-value product. One of Indonesia's Arabica coffee-producing regions is Campaka Mulya Village, Cimaung District, Gunung Puntang, Bandung Regency, West Java. Arabica cascara has a distinctive, more acidic taste compared to Robusta cascara. This characteristic acidity is due to the content of caffeic acid and chlorogenic acid (AL-Asmari et al., 2020). Cascara also contains beneficial compounds such as high antioxidant activity (Abduh et al., 2023) and relatively low caffeine content (Subeki et al., 2017). The processing method of coffee beans affects the chemical composition of the coffee pulp, such as a decrease in

protein, ash, and fat content, as well as an increase in fiber content in the dry processing method (Akmal & Filawati, 2008). Arabica coffee skin also contains active compounds such as tannins, caffeine, caffeic acid, chlorogenic acid, polyphenols, and antioxidants (Zai et al., 2023)

Zumalinda (2022) conducted a study on cascara infusions with the addition of cinnamon. The best results were obtained with the addition of 10% cinnamon, resulting in the highest antioxidant activity of 61.05% and polyphenol content of 7.30%. This study found that cascara infusions fortified with cinnamon bark increased antioxidant activity, but the sensory attributes of taste and aroma were less than satisfactory. Nashrullah et al., (2024) studied cascara infusions fortified with lime extract. The results of this study stated that the best treatment was obtained with the addition of 20% lime extract, with antioxidant activity of 93.88% and caffeine content of 0.84 mg/g. This study found that cascara infusions fortified with lime extract increased antioxidant activity but did not decrease caffeine content.

This research aims to determine the effect of adding lemongrass stalk and kaffir lime peel fortifiers on the pH, phytochemical content, antioxidant activity, polyphenol content, caffeine content, hedonic test, and hedonic quality testing of cascara infusions. Practically, this research utilizes Arabica coffee pulp waste to create cascara infusions, as well as serving as an alternative beverage option for those who are intolerant to caffeine.

METHOD

The research on the production of fortified Arabica coffee (Coffea arabica L.) cascara infusions as functional beverages was conducted at the laboratory for approximately 3 months, from March 2024 to May 2024. The equipments used in the preparation and testing of fortified cascara infusions with lemongrass stalks and kaffir lime peel included an analytical balance from Mettler Toledo brand; an oven from B-One OV-45 brand; a blender from Vienta brand; porcelain crucibles; a desiccator; a pH meter from Mettler Toledo brand; standard laboratory glassware (test tubes; 1 mL, 5 mL, and 10 mL volumetric pipettes; 10 mL, 25 mL, 50 mL, 100 mL, and 500 mL volumetric flasks; 100 mL, 250 mL, and 500 mL beakers); a centrifuge from Kokusan H-103N brand; a water bath; a hotplate from Scilogex MS7 brand; a 100 ℃ thermometer; a vortex mixer from Scilogex MX-S brand; an incubator from B-One Cin-70 brand; a 100 mL separating funnel; and a Shimadzu UVmini-1240 UV-Vis spectrophotometer.

The main materials used in the production of cascara infusions include Arabica coffee (Coffea arabica L.) pulp obtained from the Gunung Puntang Coffee Plantation, Campaka Mulya Village, Cimaung District, Bandung Regency, West Java; lemongrass stalks; kaffir lime peel; and distilled water with a pH of 7 as the cascara brewing medium. Materials utilized for the chemical analysis include solid magnesium; 37% hydrochloric acid solution; chloroform; Mayer's reagent; 100% glacial acetic acid; 98% sulfuric acid; 1% and 5% ferric chloride solution; 2N hydrochloric acid solution; 2.2-diphenyl-1-picrylhydrazyl (DPPH) reagent; 80% ethanol solution; 70% methanol solution; 10% Folin-Ciocalteu reagent; 7.5% sodium carbonate solution; solid gallic acid; solid sodium carbonate; and solid caffeine. Other materials were aluminum foil, filter paper, and tea bag packaging.

The research procedures involved the following steps: material preparation, drying and size reduction of the fortifying ingredients, formulation of cascara with fortifying ingredients, optimization of brewing temperature and time, and organoleptic testing. The analytical procedures included testing for moisture content (SNI 3836:2013), pH (AOAC, 1995), phytochemical content (Ikalinus et al., 2015), antioxidant activity using the DPPH method (Abduh et al., 2023), total phenols (SNI 3836:2013), and caffeine content (Vuletić et al., 2021).

RESULTS AND DISCUSSION

Moisture Content

Moisture content analysis of cascara, lemongrass stalk, and kaffir lime peel was conducted to determine if the produced product met the established quality standards. The moisture content was analyzed using the gravimetric method, which involves evaporating free water molecules (H_2O) from the sample. The moisture content analysis, conducted with three replications, showed that cascara has a moisture content of 13.36 ± 0.0007%, with the value after ± representing the standard deviation (Table 1). This value is within the regulatory limits set by (EU) 2015/2283 regarding the food safety of dried coffee pulp (cascara) from Arabica

coffee as a Novel Food, which is in the range of 12.10 – 16.50%. The moisture content of lemongrass stalk and kaffir lime peel was 11.10 ± 0.0043% and 7.63 ± 0.0004%, respectively.

Table 1. Moisture content of cascara, lemongrass, and kaffir lime peel.

Sample	Moisture content (%)
Cascara	13.36 ± 0.0007
Batang Serai	11.10 ± 0.0043
Kulit Jeruk Purut	7.63 ± 0.0004

The moisture content of kaffir lime peel meets the quality standards of SNI 3836:2013 for dried tea, while the moisture content of lemongrass does not meet this regulation, possibly due to lemongrass having a higher bound water content compared to kaffir lime peel.

Degree of Acidity (pH)

Figure 1 shows the pH analysis, conducted with three replications, showed that cascara with lemongrass and kaffir lime peel fortifying agents had significantly different pH values based on ANOVA ($\alpha = 0.05$). Duncan's Multiple Range Test (DMRT) was used to determine the significant differences in pH values between samples. According to the DMRT, the pH of cascara infusions with lemongrass and kaffir lime peel was not significantly different from the control cascara infusion, while the pH of lemongrass and kaffir lime peel infusions differed significantly from the control cascara infusion and varied among themselves.

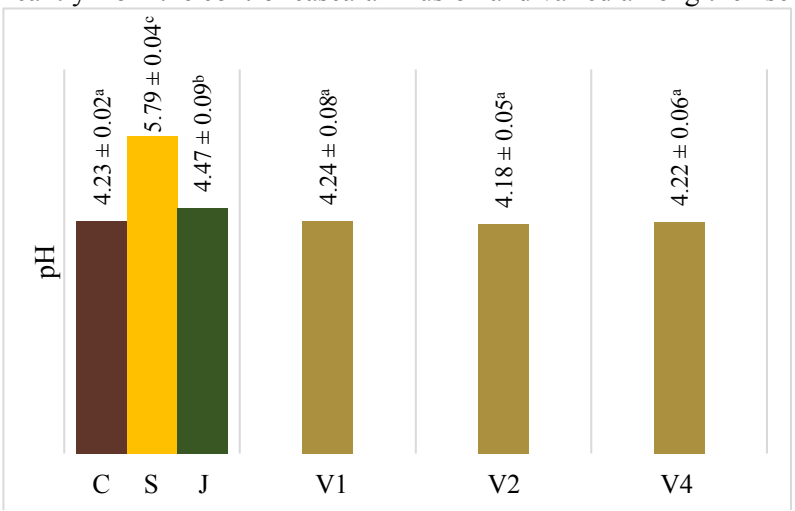

Figure 1. Results of the pH analysis on cascara infusions fortified with lemongrass stalk (S) and kaffir lime peel (J).

The pH values of cascara, lemongrass, and kaffir lime peel infusions were 4.23 ± 0.02^{a}, 5.79 ± 0.04^{c}, and 4.47 ± 0.09^{b}, respectively. Arabica cascara infusions are acidic due to the presence of chlorogenic acid (85.805 – 256.046 µg/mL), caffeic acid (0.695 – 2.288 µg/mL), and total non-volatile organic acids (0.557 – 1.280 mg/mL) (Pua et al., 2021). Cascara infusions also have the lowest pH compared to lemongrass and kaffir lime due to the fermentation process involved in drying. Cascara contains several nutritional components such as carbohydrates, fats, proteins, vitamins, minerals, alkaloids, and polyphenols (de Mejia & Ramirez-Mares, 2014). Lemongrass infusion has a higher pH compared to cascara and kaffir lime. This is because kaffir lime peel contains citric acid (1.25%) (Escobedo-Avellaneda et al., 2014). The pH of cascara infusions, which falls within the acidic range, is considered safe for consumption as the pH values are not lower than the pH of gastric acid (H. A. Jonathan et al., 2022) which has a normal range of 2.0 – 3.5 (Muhammad et al., 2016).

Phytochemical Content

Table 2 shows the Results of analysis of phytochemical content in cascara, lemongrass, kaffir lime peel, and cascara brewing variants. The alkaloid analysis was conducted by mixing chloroform and Mayer's reagent. A positive alkaloid test was indicated by the formation of a white precipitate. All infusion variants had a similar composition of precipitate. The white precipitate formed is presumed to be a K-alkaloid complex. Alkaloid compounds contain nitrogen with a lone pair of electrons, which can be used to form covalent bonds with metal ions. It is estimated that this nitrogen will react with the K^+ metal ion from potassium tetraiodomercurate (II) (Marliana et al., 2005).

Table 2. Results of analysis of phytochemical content in cascara, lemongrass, kaffir lime peel, and cascara brewing variants

Sample	Flavonoid	Alkaloid	Terpenoid	Phenolic	Tannin	Saponin
	Mg + HCl 37%	Mayer	CH_3COOH + H_2SO_4	$FeCl_3$ 5%	$FeCl_3$ 1%	H_2O (hot) + HCl 2N
C	-	+	-	+	+	-
S	-	+	+	+	+	-
J	-	+	-	+	+	-
V1	-	+	+	+	+	-
V2	-	+	-	+	+	-
V4	-	+	-	+	+	-

The analysis for terpenoid compounds in lemongrass stalk and cascara infusion V1 resulted in a color change to red. This test was conducted by adding acetic acid, which aims to form an acetyl derivative from the acetylation reaction of the OH group, forming a blue/green ring for steroids and a red/purple color for terpenoids (Harborne, J., 1996). This color change occurs due to oxidation (the release of a hydrogen group along with its electrons) in the terpenoid compound group through the formation of conjugated double bonds. The principle of the reaction in the terpenoid test is condensation (the release of water molecules and the combination of carbocations) (Jafar et al., 2020).

The analysis for phenolic compounds in cascara infusions fortified with lemongrass stalk and kaffir lime peel resulted in a bluish-black color change. This test was performed by adding 5% $FeCl_3$, which functions to form a ferric hexafolate complex, resulting from the release of H^+ ions and the formation of phenoxide ions that react with $FeCl_3$ (Kusumo et al., 2022). Arabica cascara contains 35 polyphenol compounds, including chlorogenic acid (85,805 – 256,046 µg/mL), caffeic acid (0.695 – 2.288 µg/mL), pyrochatechol (11,908 – 86,533 µg/mL), and others. These polyphenols were identified by LC-QTOF. Other polyphenols such as benzenediol and benzenetriols (e.g., catechol, pyrogallol), as well as one coumarin (scopoletin), were also identified (Pua et al., 2021). Lemongrass stalk contain the phenolic compounds elemicin, catechol, chlorogenic acid, and caffeic acid (Shah et al., 2011). Kaffir lime peel has four phenolic acid compounds, including vanillic acid, chlorogenic acid, caffeic acid, and ferulic acid (Zhao et al., 2023).

The analysis for tannin compounds in cascara infusions fortified with lemongrass stalk and kaffir lime peel resulted in a greenish-black color change. This analysis was performed by adding 1% $FeCl_3$, which reacts with one of the hydroxyl groups present in the tannin compound (Manongko, *et al*., 2020). A complex compound is formed due to the presence of the Fe^{3+} ion as the central atom, and the tannin compound has a lone pair of electrons and can bind to the central atom as a ligand (Widayanti et al., 2022). All samples (cascara, lemongrass, kaffir lime, and their combinations) tested positive for alkaloids, phenolics, and tannins. Lemongrass also tested positive for terpenoids. The presence of these phytochemicals was confirmed using colorimetric tests, which involved reactions with specific reagents that produced characteristic color changes.

Antioxidant Activity (%)

Figure 2 shows diagram of antioxidant activity in cascara infusions fortified with lemongrass stalk (S) and kaffir lime peel (J). Based on the results of the antioxidant activity analysis, the cascara infusion had an average antioxidant activity value of 76.50 ± 0.63^a %. Meanwhile, the infusions fortified with lemongrass stalk

and kaffir lime peel had higher average antioxidant activity values, at 83.00 ± 0.50^{c} % and 85.38 ± 0.63^{d} %, respectively. The antioxidant activity value of the cascara infusion fortified with lemongrass stalk and kaffir lime peel showed a significant increase compared to the control, which was 78.25 ± 0.25^{b} % for V1; 79.50 ± 0.38^{b} % for V2; and 78.50 ± 0.63^{b} % for V4.

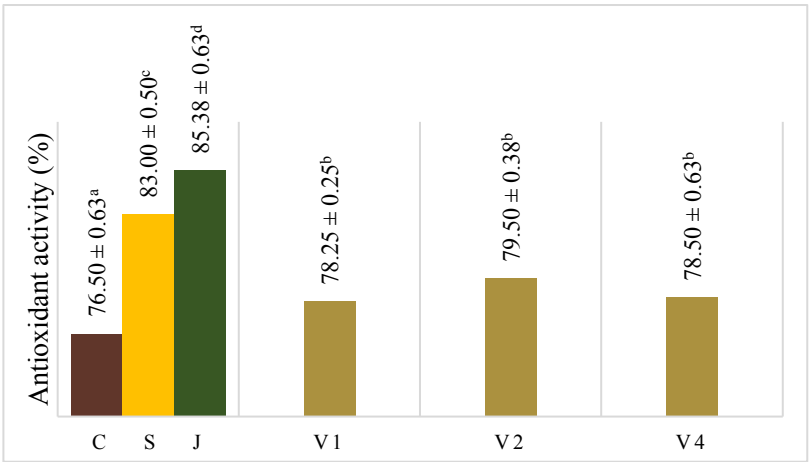

Figure 2. Diagram of antioxidant activity in cascara infusions fortified with lemongrass stalk (S) and kaffir lime peel (J).

The fortification of cascara infusions with lemongrass stalk and kaffir lime significantly increased the antioxidant activity compared to the control cascara infusion. This study found that the antioxidant activity of cascara varied based on factors such as growing conditions and drying methods. This aligns with previous research (Sholichah et al., 2019) which showed that higher altitude cultivation and lower drying temperatures resulted in higher antioxidant content. The high antioxidant activity of lemongrass was attributed to its rich content of terpenoids, phenolics, and tannins. This is consistent with previous studies (Shadri et al., 2018; Sufyan et al., 2018; Putri et al., 2023) which have reported the antioxidant properties of lemongrass and its constituent compounds. The high antioxidant activity of kaffir lime was attributed to its flavonoid content, particularly naringenin and hesperidin. This is in line with previous research (Atikawati, 2022; Nathanael et al., 2015; Wijaya et al., 2017) which has highlighted the antioxidant potential of citrus peels. The increased antioxidant activity in the fortified infusions can be directly linked to the presence of phytochemicals such as alkaloids, terpenoids, phenolics, and tannins. These compounds act as antioxidants by neutralizing free radicals, thereby reducing oxidative stress.

Total Polyphenol

The cascara infusions fortified with kaffir lime peel had a significantly higher total polyphenol content compared to the control cascara infusion and the infusions fortified with lemongrass stalk. Figure 3 shows the total polyphenol content in the lemongrass stalk infusion was 235.63 mg GAE/100g, while the total polyphenol content in the kaffir lime peel infusion was 3,712.64 mg GAE/100g. This study found that the total polyphenol content of cascara varied based on factors such as growing conditions, drying methods, and extraction techniques. This aligns with previous research (Sholichah et al., 2019) which showed that different extraction methods can significantly influence the yield of polyphenols. The higher total polyphenol content in kaffir lime compared to lemongrass is consistent with previous studies (Lubinska-Szczygeł et al., 2023) which have reported high levels of polyphenols in citrus peels. The lower polyphenol content in lemongrass compared to kaffir lime is also supported by the literature.

The higher total polyphenol content in the infusions fortified with kaffir lime peel correlates with the higher antioxidant activity observed in those samples. Polyphenols are known for their antioxidant properties, and their abundance in a sample is often associated with higher antioxidant capacity. However, the lower total polyphenol content in the infusions fortified with lemongrass does not necessarily mean lower antioxidant

activity. This discrepancy can be attributed to the presence of other antioxidant compounds, such as terpenoids, which may contribute significantly to the overall antioxidant capacity of lemongrass.

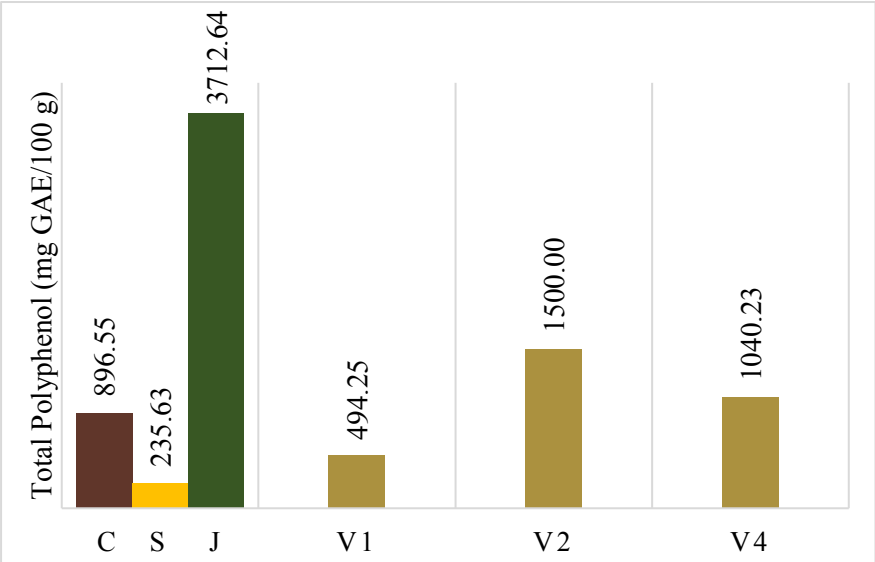

Figure 3. Diagram of total polyphenol content in cascara infusions fortified with lemongrass stalk (S) and kaffir lime peel (J).

Caffeine Content

Figure 4 shows the diagram of caffeine content in cascara infusions fortified with lemongrass stalk (S) and kaffir lime peel (J). Cascara arabica obtained from Gunung Puntang has a lower caffeine content compared to cascara robusta from Jember Regency in Neilasari's research (2019), which had a caffeine content of 1,150 mg/100g. This statement aligns with the review by Aryadi et al. (2020) which stated that the caffeine content in robusta coffee is higher (690 mg/100g - 2,150 mg/100g) compared to arabica coffee (970 mg/100g - 1,770 mg/100g). The caffeine content in black tea (*Camellia sinensis*) ranges from 1,430 mg/100g to 3,480 mg/100g (Tfouni et al., 2018).

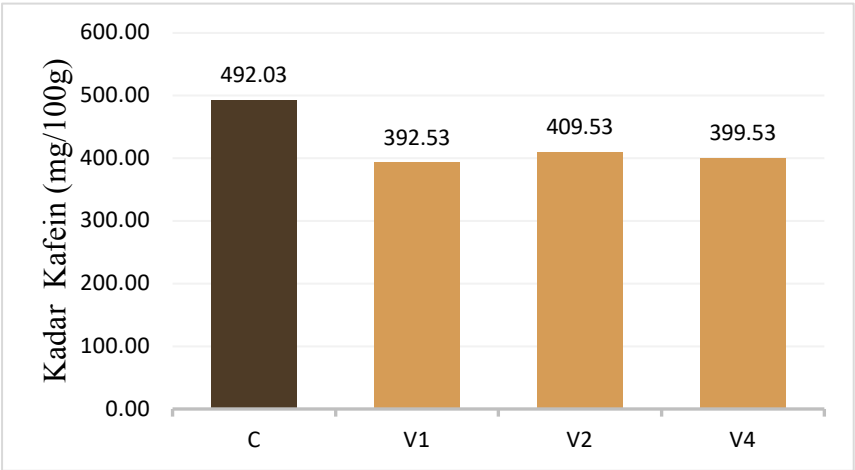

Figure 4. Diagram of caffeine content in cascara infusions fortified with lemongrass stalk (S) and kaffir lime peel (J).

The FDA (Food Drug Administration) in 2021 stated on its website that the permissible caffeine dose is 200 mg/day with consumption twice a day. Consumption should be 3-4 hours apart per serving and not exceed 400 mg/day. According to the Indonesian National Standard (SNI) 01-7152-2006, the consumption limit for caffeine in both food and beverages is 150 mg/day or 50 mg/serving. Cascara infusion is a beverage

that can replace black tea and coffee because it has a high antioxidant content and a lower caffeine content than both black tea and coffee. The lowest caffeine content was found in V1 at 392.53 mg/100g, while the highest caffeine content was found in V2 at 409.53 mg/100g.

Hedonic Test

Figure 5. shows the results of hedonic testing on cascara infusions with lemongrass (S) and kaffir lime (J) fortifying agents. The analysis on fortified cascara infusions found that the addition of lemongrass stalks and kaffir lime peel significantly improved the sensory attributes of the beverage, particularly the taste and aroma. While the control cascara infusion was preferred for its color, the lemongrass-fortified version was favored overall with a hedonic score of 3.85 ± 0.79 for taste, 3.95 ± 0.80 for aroma, and 3.85 ± 0.57 for overall impression compared to the control's 4.15 ± 0.65 for color. Statistical analysis confirmed that these differences were significant and not by chance. Additionally, the research identified the optimal brewing temperature and time for cascara infusions as 80°C and 4 minutes, respectively, contributing to the development of a high-quality and appealing functional beverage.

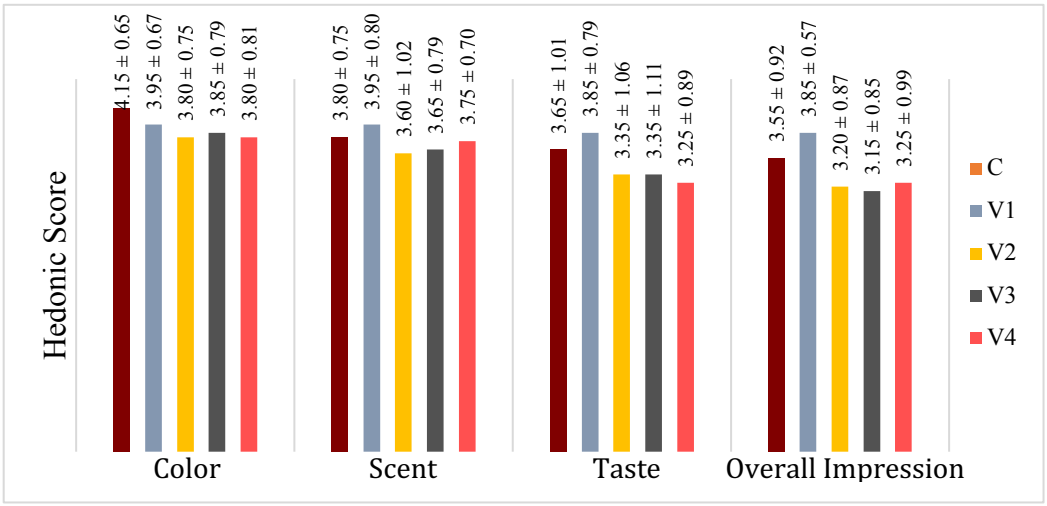

Figure 5. Results of hedonic testing on cascara infusions with lemongrass (S) and kaffir lime (J) fortifying agents.

Quality Hedonic Testing

Figure 6 delves into the specific sensory attributes of each cascara infusion variant. This research has evaluated color, turbidity, fruity aroma, acidity, bitterness, and astringency. The control cascara (unfortified) had the darkest color, which is attributed to the formation of alpha-diketones during the drying process. The addition of fortifying agents, especially in excessive amounts (V3), lightened the color. The control cascara had the deepest brown color due to the formation of alpha-diketones from the degradation of anthocyanins during the drying process. This aligns with previous research by (Nurhayati et al., 2020; Patras et al., 2010) which highlights the role of anthocyanins, temperature, and light in color development. There was no significant difference in turbidity among the variants, except that V3 was slightly more turbid due to its higher proportion of fortifying agents. V3 had the highest fruity aroma, likely due to the combination of cascara's natural aroma compounds and the additional aroma from lemongrass and kaffir lime. This is supported by studies by Pua et al., (2021) on cascara aroma compounds and Shah et al., (2011) on lemongrass essential oils.

V4 had the highest acidity, attributed to the combined acidity of cascara, citric acid from kaffir lime, and chlorogenic acid. The high acidity in V4 was attributed to citric acid from kaffir lime and chlorogenic acid from cascara, as reported by Escobedo-Avellaneda et al., (2014). V3 had the highest bitterness. The bitterness in V3 was mainly due to hesperidin in kaffir lime peel, according to Lou & Ho (2017). V3 also had the highest astringency, likely due to the high polyphenol content in kaffir lime peel, as supported by Setyabudi et al., (2015). To sum up, Variant V1 (with lemongrass) was generally preferred due to its balanced flavor profile and lack of excessive bitterness or astringency. Variant V3 was the least preferred due to its excessive bitterness, astringency, and slightly turbid appearance.

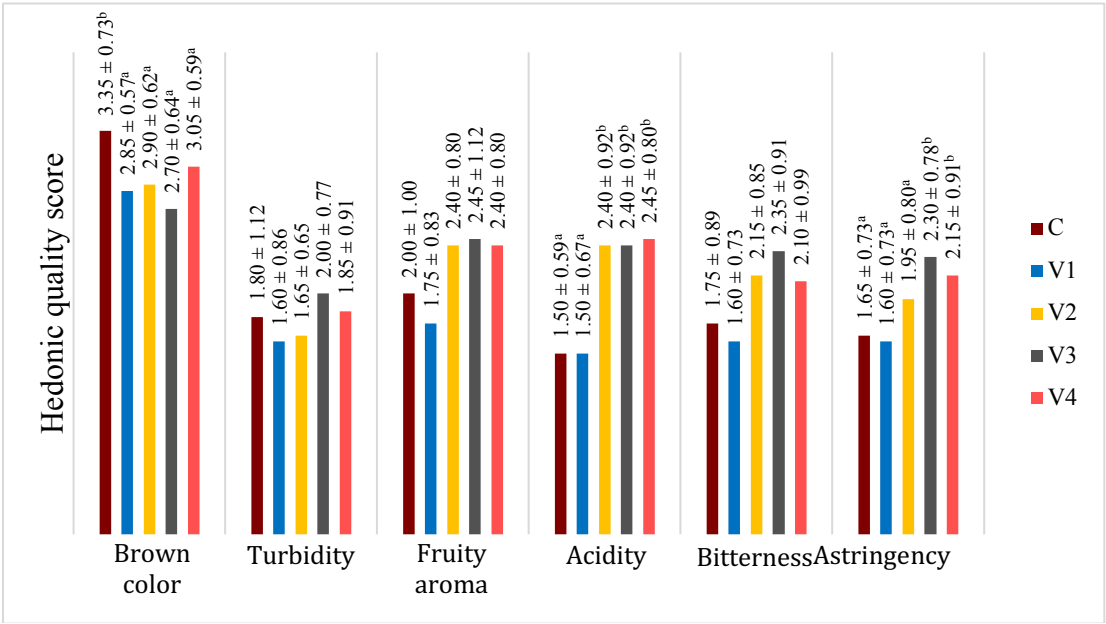

Figure 6. Results of hedonic quality testing on cascara infusions with lemongrass (S) and kaffir lime (J) fortifying agents.

CONCLUSIONS

This research has found that Variant V1 received the highest average scores for taste, aroma, and overall impression, with a less pungent aroma, a taste that was neither too acidic nor bitter, and the best overall impression. Variant V3 had the lowest sensory quality scores and was therefore excluded from further analysis. The pH of the cascara infusions ranged from 4.18 ± 0.05 to 4.24 ± 0.08. All cascara infusion variants (control, V2, and V4) contained alkaloids, phenolics, and tannins. Variant V1 additionally contained terpenoids. All cascara infusion variants had antioxidant activity ranging from 78.25 ± 0.25 to 79.50 ± 0.63%; total polyphenols ranging from 494.25 to 1,500 mg GAE/100g; and caffeine content ranging from 392.53 to 409.53 mg/100g.

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