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A novel beverage with functional potential incorporating cascara (*Coffea arabica*), roselle (*Hibiscus sabdariffa*), and red ginger (*Zingiber officinale* Rosc. var. *rubrum*) extracts: chemical properties and sensory evaluation

Iffana Dani Maulida[1] · Muhammad Refa Al Marsam[1] · Indra Purnama[2,3] · Anisa Mutamima[4]

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Abstract
Cascara (*Coffea arabica*), roselle (*Hibiscus sabdariffa*), and red ginger (*Zingiber officinale* Rosc. var. *rubrum*) extracts are potential sources of bioactive compounds, with promising antioxidant properties. This study aims to evaluate the chemical properties and sensory attributes of a novel beverage with functional potential, incorporating these extracts. A randomized complete design was employed to assess different formulations of cascara:roselle, with the addition of red ginger extract. The analysis included pH determination, total phenolic content via the Folin-Ciocalteu method, antioxidant activity using DPPH assay, total anthocyanin content analysis, and sensory evaluation through hedonic testing. The formulation containing cascara:roselle (55%:25%) with 20% red ginger extract showed optimal results, with a pH of 3.83, total phenolic content of 15.53 mg GAE/g, total anthocyanin content of 11.79 mg/100 g, and antioxidant activity of 91.38%. This formulation exhibited enhanced consumer preference in terms of color, aroma, taste, and aftertaste. The findings highlight the potential of this novel beverage, offering both nutritional benefits and strong consumer acceptance.

Highlights

- Formulation with cascara, roselle, and red ginger extracts achieved the highest antioxidant activity, with up to 93.08% radical scavenging.
- Synergistic interactions between bioactive compounds in cascara, roselle, and red ginger significantly enhanced the beverage's effectiveness as a new beverage with functional potential.
- The combination of cascara, roselle, and red ginger contributes to a unique and appealing sensory profile

Keywords Beverage formulation · Bioactive compounds · Antioxidant properties · Consumer sensory perception · Functional beverage optimization

✉ Indra Purnama, indra.purnama@unilak.ac.id | [1]Department of Food Technology, Faculty of Science and Technology, Universitas Terbuka, 15437, Tangerang Selatan, Banten, Indonesia. [2]Graduate School of Agricultural Sciences, School of Graduate Studies, Universitas Lancang Kuning, Pekanbaru 28261, Riau, Indonesia. [3]Center for Sustainable Tropical Agricultural Research, Universitas Lancang Kuning, Pekanbaru 28261, Riau, Indonesia. [4]Department of Chemical Engineering, Faculty of Engineering, Universitas Riau, Pekanbaru 28293, Riau, Indonesia.

1 Introduction

Functional foods and beverages have emerged as key components of modern dietary patterns, offering not only basic nutrition but also additional health benefits beyond traditional foods [1–3]. Functional beverages, in particular, have gained widespread popularity due to their convenience, palatability, and perceived health-promoting properties [4, 5]. These beverages are formulated with bioactive compounds, vitamins, minerals, and other nutrients that provide physiological benefits beyond simple hydration [5–7].

Functional beverages represent a subset of functional foods, characterized by their liquid form and ability to deliver bioactive compounds in a convenient and palatable manner [6]. They encompass a diverse range of products, including fruit and vegetable juices [8, 9], herbal teas [10], probiotic beverages [7], fortified waters, and sports drinks [11]. The popularity of functional beverages has surged in recent years, with the global functional beverage market reaching approximately USD 204.8 billion in 2022 and projected to expand at a compound annual growth rate (CAGR) of 7.1% from 2023 to 2030 [12].

However, the functional beverage market is highly competitive, driving the need for continuous innovation and product development. As consumer preferences evolve and awareness of health and wellness grows, there is a growing demand for new and innovative functional beverages [13–15]. Over the years, there has been a surge in innovation in functional beverage development, with various studies exploring the utilization of diverse raw materials to create new beverages with numerous advantages and minimal drawbacks. Research endeavors have focused on identifying natural ingredients rich in bioactive compounds, such as polyphenols, flavonoids, vitamins, and minerals, known for their potential health benefits [13]. These bioactive compounds exhibit antioxidant, anti-inflammatory, antimicrobial, and other functional properties, contributing to the overall health-promoting effects of functional beverages [13, 16]. For instance, robusta coffee leaf herbal teas have gained popularity as functional beverages due to their rich antioxidant content and potential health benefits [10]. Similarly, probiotic-rich beverages, such as fermented dairy drinks and kombucha, have been extensively studied for their gut health-promoting effects [17].

The potential of cascara, roselle, and ginger as primary ingredients in formulating functional beverages has garnered significant interest in recent research due to their rich phytochemical composition and potential health benefits. Cascara, derived from the dried husk of coffee cherries, contains various bioactive compounds such as phenolic acids, flavonoids, and caffeine derivatives, which exhibit antioxidant, anti-inflammatory, and neuroprotective properties [18, 19]. Roselle, extracted from the calyx of *Hibiscus sabdariffa* flowers, is distinguished by its high content of anthocyanins, flavonoids, and vitamin C, which contribute to its antioxidant, cardioprotective, and hypolipidemic effects [20]. Roselle flowers also contain citric acid and malic acid [21], making them a widely consumed plant for beverages with a mild, refreshing, sweet-and-sour taste profile. Ginger, particularly the red variety (*Zingiber officinale* Rosc. var. *rubrum*), is abundant in gingerol and shogaol compounds, known for their anti-inflammatory, antiemetic, and digestive health benefits [22]. Red ginger additionally boasts a higher percentage of essential oil, ranging from 2.58% to 3.90%, compared to common ginger [23].

Numerous studies have individually investigated the health-promoting properties of cascara, roselle, and ginger extracts in various food and beverage applications. For instance, research has demonstrated the antioxidant effect of cascara in scavenging free radicals and modulating oxidative stress-related pathways [24]. Similarly, studies have highlighted the potential cardioprotective and anti-hypertensive effects of roselle extracts due to their ability to improve lipid profiles, reduce blood pressure, and inhibit angiotensin-converting enzyme (ACE) activity [25]. Additionally, ginger extracts have been shown to alleviate gastrointestinal disorders, reduce nausea and vomiting, and possess anti-cancer properties through modulation of various signaling pathways [26, 27].

Despite the individual benefits of cascara, roselle, and ginger, there is a lack of research on their combined effects in functional beverages. No studies have yet explored their synergistic or additive effects together. These ingredients were chosen not only for their rich bioactive compounds but also for their complementary sensory profiles and cultural significance. Cascara adds a mild sweetness, roselle provides a tart note, and red ginger contributes a unique spiciness, creating a balanced flavor profile. Additionally, their availability and sustainability make them ideal for large-scale production. In light of these considerations, this study aims to contribute to the advancement of the beverage with functional potential by developing and evaluating a novel beverage formulation incorporating cascara, roselle, and red ginger extracts. Through comprehensive chemical and sensory evaluations, we seek to assess the potential health benefits and consumer acceptance of this innovative beverage, thereby addressing the growing demand for new and improved functional beverage options in the market.

2 Materials and methods

2.1 Chemicals

All chemicals used in this study were of analytical grade. The following reagents were used: Folin-Ciocalteu reagent (Merck, USA) with 99% purity, sodium carbonate (Merck, USA) with 99.5% purity, methanol (OneMed, Indonesia) with 99.8% purity, and DPPH (Merck, USA) with 98% purity. These chemicals were procured from local suppliers to ensure high purity and consistency in experimental procedures.

2.2 Preparation of cascara-roselle-red ginger as functional beverages

The coffee husks, or cascara, were responsibly sourced from the local community in Puntang Mt., Bandung Regency, Indonesia, known for its longstanding tradition of organic coffee cultivation (*Coffea arabica*). Similarly, the roselle and red ginger used in this study were procured from local traditional markets in Bandung City, Indonesia. All plant materials were collected and prepared according to the specific guidelines established by the Plant Product Quality Testing Center, Ministry of Agriculture, Indonesia. This ensures that the practices followed are both sustainable and legally compliant [28].

In our study, cascara, roselle, and red ginger were first thoroughly washed and naturally dried for two days. The dried ingredients were then ground into fine powders using a Philips HR2115 blender. The extraction process involved hot water maceration, with modifications based on methods from previous research [10, 29]. Specifically, the powdered ingredients were mixed according to the ratios specified in Table 1, ensuring that each formulation contained a total of 3 g of the combined ingredients. Each formulation was steeped in 150 mL of hot water, stirred, and macerated for 7 min. There was no use of additional solvents or solvent evaporation in the extraction process. The filtered extracts were directly analyzed.

2.3 Chemical analysis

Chemical analysis of the functional beverages was conducted to determine the composition of bioactive compounds and other chemical constituents. Each formulation underwent pH analysis using an F20 pH meter (Mettler Toledo, Switzerland) and total phenol analysis measured using the Folin-Ciocalteu method, as described in previous studies [29, 30]. In this method, 0.5 ml of the beverage sample was mixed with 2.5 ml of 1 N Folin-Ciocalteu reagent, followed by the addition of 2 ml of 7.5% sodium carbonate solution after 10 min. The mixture was incubated in the dark, and absorbance was measured at 760 nm using a spectrophotometer (Spectrophotometer SP-V1100, China), consistent with previous research [30]. Antioxidant activity was analyzed using the DPPH method, where 0.1 ml of the extract was combined with 2 ml of DPPH solution (60 µg/ml in methanol) and 2 ml of methanol, then vortexed and incubated in the dark at room temperature for 30 min, as previously reported [31, 32]. Absorbance was measured at 515 nm. Total anthocyanin content analysis was also conducted by measuring absorbance at two pH levels (1.0 and 4.5) with corrections at 700 nm, following established protocols [33].

2.4 Sensory evaluation

Sensory evaluation was performed to assess the organoleptic properties of the functional beverages derived from cascara, roselle, and red ginger. A total of 30 untrained panelists, who had not previously tasted beverages containing cascara (ranging from 20 to 65 years of age; 15 women and 15 men), were recruited for this study. The use of untrained panelists was chosen specifically to evaluate consumer preferences towards the product [34]. Organoleptic analysis was

Table 1 Formulation of cascara-roselle-red ginger functional beverage production

Formulation	Composition (%)			Water (mL)
	Cascara	Roselle	Red ginger	
A	55	25	20	150
B	65	20	15	150
C	75	15	10	150

performed using a hedonic test with a 4-point Likert scale, consisting of: 1. Dislike Very Much; 2. Dislike; 3. Like; and 4. Like Very Much [35]. This scale was intentionally chosen to avoid a neutral option, compelling the panelists to make a clear decision regarding their preferences. This approach was aimed at obtaining more honest and definitive responses, ensuring that panelists clearly indicated whether they liked or disliked each attribute. Panelists were instructed to evaluate various attributes, including overall appearance, color, aroma, flavor, aftertaste, and overall acceptability. Data collected from the sensory evaluation were meticulously analyzed to discern sensory characteristics that significantly influenced consumer preference.

2.5 Statistical analysis

The experimental design employed in this study was a completely randomized design (CRD) with one factor consisting of three treatment levels, and each treatment was replicated three times. All treatments utilized formulations as shown in Table 1. Statistical analysis was performed to scrutinize the experimental data gathered from both chemical analysis and sensory evaluation. The data obtained were then subjected to analysis of variance (ANOVA) at a significance level of 0.05. If significant differences were found, the Duncan's test would be utilized to determine significant differences among treatments at a 5% significance level using SPSS ver. 24 (IBM, USA).

3 Results and discussion

3.1 Chemical evaluation

3.1.1 pH

The analysis of variance results indicated significant differences in pH values due to variations in formulation compositions, as shown in Table 2. Formulation A exhibited a pH of 3.83 ± 0.05, Formulation B had a pH of 3.91 ± 0.03, and Formulation C recorded a pH of 4.06 ± 0.04. The observed pH discrepancies among the formulations could be attributed to variances in the composition and concentration of acidic and alkaline components present in cascara, roselle, and red ginger extracts. According to Quitmann et al. [36], the pH of beverages may be influenced by the presence of organic acids, such as citric acid and malic acid, which are naturally abundant in plant extracts. Anthocyanins, which are a type of flavonoid pigment, also contribute to the overall acidity of the beverage. This is due to their ability to form complexes with acids, thus affecting the pH level. Additionally, the presence of organic acids, which are often found alongside anthocyanins in roselle, further impacts the pH. Yenrina et al. [37] highlight that ferulic acid in *Ajuga pyramidalis* increases in concentration alongside anthocyanins, and when *Ajuga pyramidalis* cultures are treated with a specific anthocyanin inhibitor, the ferulic acid content decreases. This relationship is also assumed for roselle-based beverages, where the acidity and overall pH are closely tied to both the concentration of anthocyanins and the presence of organic acids.

The pH of a beverage plays a pivotal role in shaping its sensory attributes and overall acceptability. According to Monteiro et al. [38], beverages with lower pH values tend to exhibit a sharper taste profile, while those with higher pH values may be perceived as milder. Optimizing the pH of functional beverages is essential for achieving desired sensory attributes and ensuring consumer acceptance, as emphasized by Yamahata et al. [39] in their study on beverage formulation strategies.

Table 2 Results of chemical analysis and antioxidant activity of functional beverages incorporating cascara-roselle-red ginger

Formulation	Parameter		
	A	B	C
pH	3.83 ± 0.05^a	3.91 ± 0.03^b	4.06 ± 0.04^c
Total phenolic content (mg GAE/g)	15.35 ± 0.11^a	15.76 ± 0.23^b	18.55 ± 0.35^c
Total anthocyanin content (mg/100 g)	11.79 ± 0.29^a	9.98 ± 0.21^b	2.57 ± 0.14^c
Antioxidant activity (%)	91.38 ± 1.15^a	93.08 ± 1.89^b	92.48 ± 1.04^c

Mean ± SD

Different letters in row denote mean values that statistically ($p < 0.05$) differ one from another

3.1.2 Total phenolic content

The analysis of variance for total phenolic content (TPC) based on Table 2 revealed significant differences in the total phenolic content among the formulations. Formulation A exhibited a TPC of 15.35 ± 0.11 mg GAE/g, Formulation B had a TPC of 15.76 ± 0.23 mg GAE/g, and Formulation C recorded the highest TPC of 18.55 ± 0.35 mg GAE/g. The observed increase in phenolic content is hypothesized to be influenced by variations in pH values across the formulations. According to Belwal et al. [40], pH values can affect the extraction of phenols, with total phenolic content increasing as pH increases. Addition of acid or base can induce hydrolysis of polyphenols, leading to the transformation of phenolic compound glycosylated forms into aglycone forms. Aglycone phenols produced through acid hydrolysis exhibit lower solubility in water [41], resulting in a decrease in total phenolic content as pH decreases. In addition to pH values, heat treatment during brewing can also affect the total phenolic content produced. Excessive heat can cause polyphenol degradation, leading to a decrease in phenolic content.

Formulation C, exhibiting the highest TPC of 18.55 mg GAE/g, showed a significant elevation in phenolic content compared to Formulations A and B, as well as previous studies [18]. This observation suggests that the addition of red ginger extract likely contributed to the augmented phenolic content in the beverage. Red ginger extract is recognized for its phenolic compounds such as gingerol and shogaol, renowned for their robust antioxidant properties [22, 42]. The discernible differences in TPC among the formulations underscore the potential health-enhancing attributes of the functional beverages. Phenolic compounds have been linked to various health advantages, including antioxidant, anti-inflammatory, and cardioprotective effects [19]. The variations in TPC among the formulations could be ascribed to the diverse phenolic profiles of cascara, roselle, and red ginger extracts. Previous investigations have documented the presence of assorted phenolic compounds, encompassing phenolic acids and flavonoids, in cascara extracts, contributing to their antioxidant potency [18]. Similarly, roselle extracts are recognized for containing anthocyanins and other phenolic compounds, augmenting their antioxidant capacity [20].

3.1.3 Total anthocyanin content

The results of the total anthocyanin content (TAC) analysis in cascara-roselle functional beverages with the addition of red ginger are presented in Table 2, demonstrating significant differences in TAC based on the formulation composition. Formulation A exhibited a TAC of 11.79 ± 0.29 mg/100 g, Formulation B had a TAC of 9.98 ± 0.21 mg/100 g, and Formulation C recorded the lowest TAC of 2.57 ± 0.14 mg/100 g. The variations in total anthocyanin content (TAC) among the formulations could be ascribed to variances in the anthocyanin levels present in cascara, roselle, and red ginger extracts. Previous studies have elucidated the presence of anthocyanins in roselle extracts, contributing to their antioxidant capacity and potential health benefits [20]. Formulation A exhibited the highest TAC among the formulations, indicating a higher concentration of anthocyanins [43]. According to Suzery et al. [43], the anthocyanin content in roselle flowers is reported to be 128.76 mg/100 g. This condition may arise because anthocyanins are more stable under acidic conditions. Therefore, the anthocyanin content tends to decrease with increasing pH due to degradation [44–46].

This study suggests that roselle extracts may contribute to the elevated anthocyanin content in the beverage. Previous studies have demonstrated synergistic effects between plant extracts in enhancing the bioactive properties of functional beverages [47]. In contrast, Formulation C displayed the lowest TAC, possibly due to the lower concentration of roselle extracts in the formulation. Additionally, the decreased TAC in Formulation C may be attributed to the dilution effect caused by the higher proportion of cascara extract, which is not a significant source of anthocyanins. The observed differences in TAC among the formulations highlight the importance of ingredient selection and formulation in determining the anthocyanin content of functional beverages.

3.1.4 Antioxidant activity

The antioxidant activity was assessed using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method, which relies on the ability of compounds to scavenge free radicals. DPPH acts as a radical compound serving as an indicator of the reduction process of antioxidant compounds. This method aims to identify free radical compounds that can be reduced by the sample. The primary parameter used is the percentage of inhibition (% inhibition), reflecting the ability of antioxidant compounds in the sample to scavenge free radicals at various concentrations of test solutions [48]. The results of the analysis of variance for antioxidant activity in Table 2 indicate significant differences. Formulation A exhibited an antioxidant activity of 91.38 ± 1.15%, Formulation B had an antioxidant activity of 93.08 ± 1.89%, and Formulation C recorded an antioxidant activity of 92.48 ± 1.04%. Antioxidants play a pivotal role in mitigating oxidative stress-induced cellular damage, thus reducing the risk of chronic diseases and promoting overall health [49]. The variations in antioxidant activity among the formulations could be attributed to differences in the composition and concentration of bioactive compounds present in cascara, roselle, and red ginger extracts.

Previous studies have reported the presence of various antioxidants, including phenolic compounds and flavonoids, in cascara and roselle extracts, contributing to their antioxidant capacity [18, 20, 50, 51]. Specifically, the phenolic profile of cascara includes four major classes: flavan-3-ols (monomers and procyanidins), hydroxycinnamic acids, flavonols, and anthocyanidins, with chlorogenic acid being the predominant phenolic compound [18]. Roselle extracts are also rich in antioxidants, particularly phenolic acids, polyphenols, vitamin C, and flavonoids, with anthocyanins playing a major role in its high natural antioxidant activity. Furthermore, red ginger extract is also known to possess significant antioxidant properties due to its high content of gingerol and shogaol compounds [22, 42]. To date, over 160 compounds, including volatile oils, gingerol analogues, diarylheptanoids, and other phenolic compounds, have been isolated from ginger, further underscoring its potent antioxidant effects [22].

Formulation B exhibited the highest antioxidant activity among the formulations, indicating a greater ability to scavenge free radicals. This finding suggests that the combination of cascara, roselle, and red ginger extracts may synergistically enhance the antioxidant capacity of the beverage. Synergistic interactions between bioactive compounds in plant extracts have been reported to amplify their antioxidant effects [47]. In contrast, Formulation A and Formulation C demonstrated slightly lower antioxidant activities compared to Formulation B. These differences could be attributed to variations in the concentration of specific antioxidants present in each formulation.

The variations in antioxidant activity among the formulations can be attributed to differences in the concentration and composition of bioactive compounds. Previous studies have demonstrated that synergistic interactions between bioactive compounds in plant extracts can amplify antioxidant effects [47]. To fully understand these effects, it is essential to profile the bioactive compounds, including total phenols and flavonoids, in each extract. Research has shown that even with lower TPC and total flavonoid content (TFC), some mixtures exhibit higher antioxidant activity due to synergistic effects of compounds such as hydroxybenzoic acids, flavonols, and hydroxycinnamic acids [47]. Phenolic acids with electron donor groups and the configuration of hydroxyl groups in flavonoids significantly influence antioxidant activity [52, 53].

This study demonstrates that the antioxidant activity of the cascara functional beverage with the addition of roselle and red ginger is higher compared to the findings of Abduh et al. [50] and Oktaviani et al. [51], who reported that cascara exhibited antioxidant activity ranging from 5.2 to 8.2% and 11.9 to 18.2%, respectively, without the addition of other natural ingredients. Several studies have investigated the addition of other natural ingredients to cascara, such as lemon (*Citrus limon*) and honey [54], cinnamon (*Cinnamomum Burmannii* BL) [55], red ginger (*Zingiber officinale* var. *Rubrum*) [56], as well as roselle (*Hibiscus sabdariffa*) and pineapple (*Ananas sativus*) [34], all of which have shown a significant influence on the antioxidant activity of cascara. The comparison presented in Table 3 illustrates that the antioxidant activity observed in this study aligns with or exceeds the values reported in previous research, indicating the effectiveness of the formulated beverages in scavenging free radicals. The observed differences in antioxidant activity among the formulations underscore the importance of ingredient selection and formulation in determining the overall antioxidant capacity of functional beverages.

Table 3 Comparison of antioxidant activity in cascara tea with additional natural ingredients

Formulation	Antioxidant activity (%)	Ref.
Cascara + roselle + red ginger	93.08	This study
Cascara + roselle + pineapple	91.34	[41]
Cascara + lemon + honey	75.79	[57]
Cascara + cinnamon	82.51	[58]
Cascara + red ginger	68.11	[59]

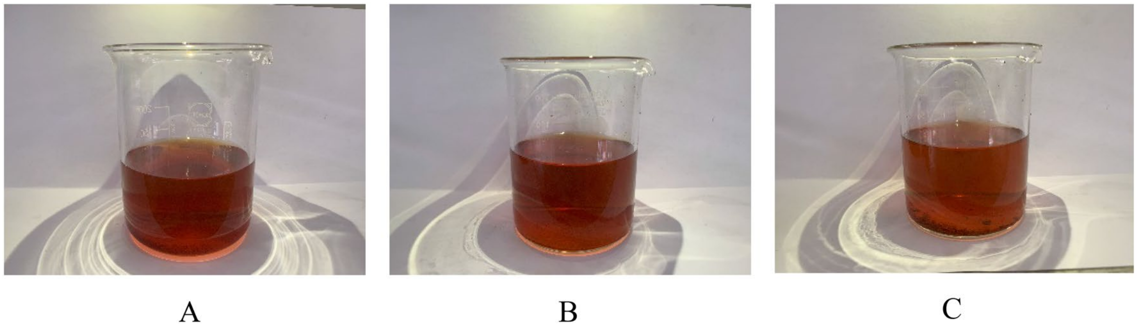

Fig. 1 Results of brewing functional beverages made with cascara-roselle-red ginger with various formulations: **A**, **B**, **C**

Table 4 The sensory evaluations of the beverages made with various formulation

Formulation	Color	Aroma	Taste	Aftertaste
A	3.07 ± 0.25^{a}	2.93 ± 0.33^{a}	2.63 ± 0.22^{a}	2.77 ± 0.29^{a}
B	2.90 ± 0.28^{ab}	2.83 ± 0.21^{ab}	2.60 ± 0.25^{ab}	2.47 ± 0.30^{ab}
C	2.63 ± 0.31^{b}	2.53 ± 0.24^{b}	2.37 ± 0.25^{b}	2.30 ± 0.27^{b}

Mean ± SD

Different letters in row denote mean values that statistically ($p < 0.05$) differ one from another. Formulations preferred more are indicated by higher numbers

3.2 Evaluation of sensory properties

3.2.1 Color

Consumer assessment of a product is influenced not only by intrinsic factors but also by extrinsic factors, including color [55]. The color assessment was conducted using a visual inspection method, where panelists evaluated the hue, intensity, and overall visual appeal of the beverages. The results of the color evaluation are presented in Fig. 1 and Table 4. Formulation A exhibited a color score of 3.07 ± 0.25, Formulation B had a slightly lower score of 2.9 ± 0.28, and Formulation C recorded the lowest score of 2.63 ± 0.31. These variations in color score among the formulations could be attributed to differences in the concentration and interaction of pigments present in cascara, roselle, and red ginger extracts. The color of beverages is influenced by the presence of natural pigments, such as anthocyanins, carotenoids, and chlorophylls, which contribute to the perceived hue and intensity [56].

Previous studies have highlighted the role of roselle and red ginger extracts in determining the color characteristics of functional beverages. Roselle extracts are recognized for their vibrant red color, attributed to the presence of anthocyanins [60, 61], whereas red ginger extracts may contribute to a golden-yellow hue owing to the presence of carotenoids [62, 63]. In this study, it was observed that an increase in the content of roselle and ginger in the beverage led to a brighter red color with slight brownish tones, while lower additions of both resulted in a more yellow–brown color. The analysis of variance in the panelists' preference for color attributes revealed significant differences between Formulations A and C. However, Formulations A and B, as well as Formulations B and C, did not exhibit significant differences. These findings underscore the potential for ingredient selection and formulation to impact the visual perception of functional beverages.

3.2.2 Aroma

Aroma plays a crucial role in enhancing consumer interest in a product, complementing its visual appeal. The aroma of a food product significantly influences consumer interest due to its association with sensory experiences and taste perception [64]. In this study, aroma evaluation was conducted to assess the olfactory perception of the beverages, focusing on the intensity and character of the scent. Formulation A demonstrated an aroma rating of 2.93 ± 0.33, while Formulation B scored slightly lower at 2.83 ± 0.21, and Formulation C obtained the lowest rating of 2.53 ± 0.24 (see Table 4). These differences in aroma score among the formulations may be attributed to variations in the composition and concentration of volatile compounds present in cascara, roselle, and red ginger extracts. The aroma of beverages is influenced by the presence of volatile organic compounds, such as terpenes, eugenol, and citral, which contribute to the perceived scent profile [57].

The addition of red ginger to the beverage imparts a distinct spicy aroma characteristic of ginger, with its main components being zingiberene, gingerol, and shogaol [58]. Conversely, reducing the amount of roselle while increasing the proportion of coffee husks leads to a milder aroma in the beverage. The results of the sensory evaluation of aroma quality among the panelists revealed significant differences between Formulations A and C. However, there were no significant differences between Formulations A and B, as well as between Formulations B and C. Previous research has highlighted the contribution of roselle and red ginger extracts to the aroma profile of functional beverages. Roselle extracts are known for their floral and fruity aroma, while red ginger extracts may impart a spicy and pungent scent due to the presence of gingerol and shogaol compounds [20, 59].

3.2.3 Taste

Wilanda et al. [65] stated that the appealing presentation of a beverage can pique consumers' interest in tasting the beverage. Taste evaluation focused on assessing the gustatory perception of the cascara, roselle, and red ginger functional beverages, particularly evaluating the score and quality of the flavor profile. Based on Table 4, the sensory evaluation of taste quality revealed that Formulation A had a higher score compared to Formulations B and C. Specifically, Formulation A displayed a taste rating of 2.63 ± 0.22, whereas Formulation B garnered a slightly lower rating of 2.60 ± 0.25, with Formulation C registering the lowest score at 2.37 ± 0.25.

The observed variations in taste score among the formulations may be attributed to differences in the composition and concentration of flavor compounds present in cascara, roselle, and red ginger extracts. The taste of beverages is influenced by various factors, including sweetness, bitterness, acidity, and umami, which are perceived by taste receptors on the tongue [66, 67]. Increasing the amount of roselle and ginger in the beverage resulted in increased acidity with a subtle warm sensation (spiciness) characteristic of ginger in the mouth. The results of the sensory evaluation of taste quality among the panelists revealed significant differences between Formulations A and C. However, there were no significant differences between Formulations A and B, as well as between Formulations B and C. Cascara extracts may impart a slightly bitter and astringent taste due to the presence of caffeine and phenolic compounds, while roselle extracts contribute a tangy and tart flavor profile attributed to organic acids like citric acid and malic acid [50, 68]. Red ginger extracts may add a warm and spicy taste sensation attributed to gingerol and shogaol compounds [58, 69].

3.2.4 Aftertaste

Aftertaste refers to the residual taste sensations that persist in the mouth following the ingestion of a beverage and is considered a critical factor in consumer acceptance and an indicator of product quality [57, 58, 70]. The results of the aftertaste evaluation, as presented in Table 4, reveal discernible differences among the formulations. Formulation A exhibited an aftertaste score of 2.77 ± 0.29, characterized by its relatively higher intensity compared to Formulation B, which scored 2.47 ± 0.30, and Formulation C, which recorded the lowest score at 2.30 ± 0.27. These observed variations in aftertaste score could be attributed to the diverse composition of flavor compounds present in cascara, roselle, and red ginger extracts. Increasing the content of roselle resulted in a more acidic aftertaste, while a higher concentration of ginger in the beverage contributed to a warm aftertaste sensation in the mouth and throat. The results of the sensory evaluation of aftertaste quality among the panelists revealed significant differences between Formulations A and C. However, there were no significant differences between Formulations A and B, as well as between Formulations B and C.

Previous research has suggested that the aftertaste of beverages is influenced by various factors, including the presence of specific aroma compounds, bitterness, sweetness, and acidity [71]. Cascara extracts may contribute bitterness and astringency to the aftertaste due to the presence of caffeine and phenolic compounds, while roselle extracts may impart tanginess and tartness attributed to organic acids like citric acid and malic acid [68, 72]. Additionally, the presence of red ginger extracts may influence the aftertaste with warm and spicy notes attributed to gingerol and shogaol compounds [58, 69]. The disparities detected in aftertaste scores among the formulations underscore the influence of ingredient selection and formulation on consumers' sensory experiences.

3.2.5 Overall acceptability

The evaluation of overall acceptability is essential for understanding consumer preferences for functional beverages. This assessment encompasses various sensory attributes, including taste, aroma, color, and aftertaste, to gauge the product's overall appeal. As presented in Table 4, Formulation A received the highest rating in terms of overall acceptability among the tested formulations. Although the average scores for individual sensory attributes were below 3, suggesting a tendency towards "I don't like," it is crucial to consider that the panelists were untrained and had limited experience with beverages containing cascara, roselle, or red ginger. Their unfamiliarity with these ingredients likely influenced their evaluations. Consequently, while the average scores may seem modest, they offer a preliminary indication that Formulation A has potential for commercialization with further refinement. The higher overall acceptability of Formulation A suggests that with adjustments, it could appeal to a broader consumer base.

To gain a more accurate understanding of consumer preferences and enhance the product's market potential, future research should involve a larger, trained panel of sensory evaluators. This would provide more detailed insights into the sensory characteristics of the beverage and allow for more precise optimization of the formulation. Additionally, expanding the panel size would help address the current limitations and provide a more robust evaluation of the functional beverage's appeal.

4 Conclusion

This study demonstrates that beverages formulated with cascara, roselle, and red ginger extracts offer promising antioxidant activity and sensory appeal. While Formulation B had the highest antioxidant activity (93.08% DPPH scavenging), Formulation A was most preferred, balancing bioactive properties with consumer acceptance. Sensory scores below 3 may reflect untrained panelists and limited exposure to such beverages, affecting generalizability. Despite this, Formulation A shows strong potential for commercialization. The high antioxidant activity, especially in Formulation B, likely results from the synergistic interaction of bioactive compounds in the extracts. These findings suggest the formulation provides both health benefits and sensory qualities that could appeal to consumers. Future research should further explore phytochemical profiles, such as shogaol, gingerol, flavonoids, and vitamin C, and conduct sensory evaluations of individual extracts with trained panelists. Additionally, assessing shelf life and storage conditions will be crucial for ensuring product quality and safety.

Author contributions I.D.M. and M.R.A.M. conceptualized and designed the study. M.R.A.M. conducted the experiments and collected the data. I.P. and A.M. analyzed the data and interpreted the results. I.P. also contributed to the literature review and manuscript finalization. All authors reviewed and approved the final version of the manuscript.

Data availability The authors affirm that the data underpinning the results of this study are contained within the manuscript. Raw data files are accessible in alternative formats upon request from the corresponding author.

Declarations

Ethics approval and consent to participate The research protocol for this study was approved by the Ethics Committee of Universitas Terbuka in accordance with Decision of the Rector of Universitas Terbuka Indonesia No. 769/H31/KEP/2010.

Informed consent The authors confirm that all human research participants provided informed consent to participate in this study.

Consent for publication The authors confirm that all human research participants involved in the study provided explicit consent for the publication of their data and images.

Competing interests The authors declare no competing interests.

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