Research Article

# Development and Evaluation of a Rose-Based Functional Beverage Enriched with Apple, Lemon, and Red Ginger

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**Abstract** | Growing consumer demand for natural, health-promoting beverages has driven the development of functional drinks enriched with plant-derived bioactive compounds. Rose (*Rosa* spp.) is well recognised for its high phenolic, flavonoid, and anthocyanin contents, which confer strong antioxidant properties. However, its limited sensory balance and stability may restrict consumer acceptance. Combining rose extract with complementary natural ingredients such as apple, lemon, and red ginger represents a promising approach to enhance both functional value and palatability. Apples and lemons provide substantial vitamin C and polyphenols, while red ginger contributes additional bioactive compounds. This study aimed to develop and evaluate a novel rose-based functional beverage formulated with apple, lemon, and red ginger. A Completely Randomized Design (CRD) comprising seven formulations was applied. The beverages were evaluated for physicochemical properties (pH, colour, and total soluble solids), bioactive characteristics (vitamin C content, DPPH radical scavenging activity, and total anthocyanin content), and sensory acceptance. The results demonstrated that the addition of apple, lemon, and red ginger significantly influenced physicochemical attributes and bioactive profiles. The formulation containing 0.4 g rose extract and 2 g apple achieved the highest overall sensory acceptance (mean hedonic score), accompanied by a vitamin C content of 5.1 mg 100 $mL^{-1}$ and total anthocyanins of 27.3 mg $L^{-1}$. These findings indicate that the combination of rose extract and fruit–herb components enhances antioxidant capacity and consumer acceptability. The developed beverage shows strong potential as an innovative functional drink. This study is aligned with Sustainable Development Goal 3 (Good Health and Well-being). Future research should focus on storage stability, *in vivo* evaluation of the developed beverage to assess its health-related effects, optimisation using natural sweeteners, and investigation of the potential occurrence of microplastic contamination in both raw materials and finished beverage products.

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## Introduction

The global demand for functional beverages continues to rise as consumers increasingly seek products that provide both sensory satisfaction and additional nutritional value. Functional beverages are defined as drinks formulated with bioactive compounds that confer physiological advantages beyond basic nutrition, particularly antioxidant activity (Cao *et al*., 2020; Gutiérrez-Gamboa *et al*., 2021). The growing awareness of oxidative stress-related diseases has spurred research into natural plant-based ingredients as sources of antioxidants (Setyobudi *et al*., 2026) that can be incorporated into daily diets in an accessible and palatable form (Hermayanti *et al*., 2025; Hermayanti *et al*., 2026; Hidalgo-Fuentes *et al*., 2024). Consequently, the beverage industry has shifted toward utilizing botanical extracts, fruits, and herbs to develop innovative formulations that meet the dual expectations of functionality and flavor (Rahmawati *et al*., 2020; Saati *et al*., 2020).

Rose (*Rosa* × *damascena* Mill.), commonly used in herbal infusions and flavoring, is a rich source of phenolic compounds, flavonoids, and anthocyanins that contribute to strong antioxidant activity (Fayaz *et al*., 2024; Saati *et al*., 2018; Wojdylo *et al*., 2007; Vinokur *et al*., 2006). However, beverages based solely on rose extract may present limitations in flavor balance, stability, and consumer acceptability. Combining rose extract with complementary natural ingredients offers an opportunity to enhance both its functional properties and sensory appeal (Saati *et al*., 2021). Apples [*Malus domestica* (Suckow) Borkh] and lemons [*Citrus limon* (L.) Osbeck] are important sources of vitamin C and polyphenols, known for their contribution to antioxidant potential (Hasanuzzaman *et al*., 2020; Sir-Elkhatim *et al*., 2018). Red ginger (*Zingiber officinale* var. *rubrum* Theilade) further contributes bioactive compounds such as gingerol and shogaol, which are associated with antioxidant activity (Gupta *et al*., 2025; Rampengan *et al*., 2024; Suciyati *et al*., 2021).

Integrating these ingredients into a single formulation represents a promising approach to developing a functional beverage with improved physicochemical characteristics and antioxidant properties. Despite the individual benefits of rose, citrus, and ginger extracts, limited studies have explored their combined application in relation to antioxidant activity, color stability, and sensory properties of functional beverages. However, there is still a lack of systematic studies evaluating how the combined use of *R. damascena* with locally relevant fruits and herbs (apple, lemon, and red ginger) affects both the antioxidant profile and sensory acceptance of functional beverages.

Previous studies have reported various rose-based functional beverages and blended formulations, including rose beverages enriched with spices (Saati *et al*., 2021), fermented rose-based drinks (Qiu *et al*., 2023), rose syrup-containing functional beverages (Kumar *et al*., 2021), anthocyanin-enriched rose–lemon beverages (Das *et al*., 2024), and formulations combining rose extracts with other plant-derived ingredients (Destiyana *et al*., 2018). However, limited information is available regarding the comparative effects of combining rose extract with apple, lemon, and red ginger at different formulation levels on physicochemical characteristics, antioxidant activity, anthocyanin content, and sensory acceptance within a single beverage system. Therefore, the novelty of this study lies not in the use of rose as a beverage ingredient itself, but in the integrated evaluation of rose–apple, rose–lemon, and rose–red ginger formulations through the simultaneous assessment of multiple quality attributes and consumer acceptance.

Therefore, this study aimed to formulate and evaluate a rose-based functional beverage enriched with apple, lemon, and red ginger extracts. The investigation focused on determining the effects of these natural ingredients on physicochemical characteristics, antioxidant activity, anthocyanin content, and sensory acceptance. This research contributes to the development of locally sourced, plant-based functional beverages and is aligned with Sustainable Development Goal 3 (Good Health and Well-being) (United Nations, 2025).

## Materials and Methods

*Materials and instruments*

Fresh red rose (*R. damascena*) petals were obtained from local flower farmers (Sastro rose garden, coordinate: S 7°50'37.8132" E 112°31'25.8636") in Batu City, East Java, Indonesia. Apple (*M. domestica*), lemon (*C. limon*), and red ginger (*Z. officinale* var. *rubrum*) were purchased from local traditional markets in Malang (Oro-oro Dowo market, coordinate:

S 7°58'7.302" E 112°37'41.448"). Analytical-grade reagents, including methanol, 2,2-diphenyl-1-picrylhydrazyl (DPPH), buffer solutions (pH 1.0 and 4.5), standard iodine, and starch indicator, were supplied by Merck (Germany).

A digital pH meter (Hanna Instruments, USA), colorimeter (Konica Minolta, Japan; CIELAB system), digital refractometer (Atago, Japan), and UV–Visible spectrophotometer (Shimadzu, Japan) were employed for analytical measurements.

*Experimental design*

The study was conducted using a Completely Randomized Design (CRD) with a single factor—formulation type—comprising seven treatments, each replicated three times, as shown in Table 1. This design allowed for the evaluation of the effects of different formulations on physicochemical properties, antioxidant activity, and sensory acceptance.

*Preparation of a rose-based beverage*

*Rose* spp. petals were washed, drained, and extracted with deionized water at room temperature to obtain a concentrated rose extract. The extraction was carried out using an aqueous medium, followed by filtration to remove solid residues.

The extract was blended with sugar syrup, citric acid, sodium benzoate (Saati *et al.*, 2012), and the respective fruit or herbal ingredient according to each formulation. The mixtures were homogenized and allowed to rest for 20 min, then pasteurized at 80 °C to 85 °C for 15 min.

The beverages were subsequently filtered, bottled in sterilized glass containers, and stored at 4 °C prior to analysis. All analyses were conducted within a defined storage period to minimize degradation of bioactive compounds.

*Physicochemical properties*

Several physicochemical properties were studied in this work, including pH, color analysis, total soluble solids (TSS), vitamin C content, antioxidant activity, and total anthocyanin content.

The pH was determined using a calibrated digital pH meter. Color analysis was conducted using a colorimeter in the CIELAB system, where L represents brightness, a indicates redness, and b indicates yellowness (Damat *et al.*, 2021). TSS was determined using a digital refractometer and expressed in °Brix (Saati, 2016).

Vitamin C concentration was quantified by iodometric titration and expressed as mg ascorbic acid per 100 mL sample (Setyobudi *et al.*, 2021). Antioxidant activity was evaluated using the DPPH radical scavenging assay, and results were expressed as percentage inhibition of DPPH radicals (Damat *et al.*, 2022).

Anthocyanin levels were determined using the pH differential method by measuring the absorbance at 520 nm and 700 nm, with the results expressed as mg $L^{-1}$ cyanidin-3-glucoside equivalents (Setyobudi *et al.*, 2022).

*Hedonic sensory analysis*

A sensory panel of 30 untrained panelists evaluated color, aroma, taste, and overall acceptability using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely). The sample presentation was randomized to minimize bias under controlled sensory laboratory conditions (Damat *et al.*, 2020). Results were expressed as mean hedonic scores.

**Table 1:** *Experimental design and formulation of rose-based functional beverages*

| Code | Formulation description |
|---|---|
| Control | Rose extract |
| F1–MA | Rose 0.4 g + Apple 2 g |
| F2–MA | Rose 0.8 g + Apple 4 g |
| F1–MJM | Rose 0.4 g + Red ginger 0.5 g |
| F2–MJM | Rose 0.8 g + Red ginger 1.0 g |
| F1–ML | Rose 0.4 g + Lemon 3.2 mL |
| F2–ML | Rose 0.8 g + Lemon 6.4 mL |

*Note: All formulations were prepared using the same beverage base and processing conditions as described in the Materials and Methods section.*

## Results and Discussion

*Antioxidant activity and vitamin C content*

The antioxidant activity and vitamin C content in the formulated rose-based beverages are shown in Table 2. The results showed that the type and proportion of added ingredients significantly affected both parameters ($p < 0.05$). The combination of rose extract with apple (F1–MA) exhibited the highest DPPH

radical scavenging activity (71.7 % ± 0.9 %), followed closely by the rose–red ginger formulation (F1–MJM) and the higher-apple formulation (F2–MA). In contrast, the lemon-enriched formulation (F2–ML) demonstrated the lowest antioxidant inhibition (52.7 % ± 0.7 %).

**Table 2:** *Antioxidant activity and vitamin C content of rose-based functional beverages*

| Formulation | DPPH inhibition (%) | Vitamin C (mg 100 mL$^{-1}$) |
|---|---|---|
| Control | 62.47 ± 0.65c | 4.64 ± 0.05a |
| F1–MA | 71.70 ± 0.91e | 5.14 ± 0.07b |
| F2–MA | 70.99 ± 1.92e | 7.19 ± 0.09d |
| F1–MJM | 71.35 ± 1.00e | 5.11 ± 0.02b |
| F2–MJM | 68.14 ± 0.14d | 6.27 ± 0.03c |
| F1–ML | 55.57 ± 0.49b | 9.52 ± 0.02e |
| F2–ML | 52.71 ± 0.71a | 13.75 ± 0.05f |

*Note: Values are expressed as mean ± standard deviation (n = 3). Different superscript letters within the same column indicate significant differences according to Duncan's Multiple Range Test (DMRT) at $p < 0.05$.*

These findings suggest that the inclusion of apple and red ginger may enhance the antioxidant capacity of rose extract, likely due to the combined contribution of phenolic compounds, flavonoids, and ascorbic acid. Apples contain polyphenols and flavonoids that can donate hydrogen atoms to stabilize DPPH radicals (Damayanti, 2026; Gulcin and Alwasel, 2023). Meanwhile, red ginger is rich in gingerol and shogaol, which are known to exhibit strong radical-scavenging and metal-chelating abilities (Mao *et al.*, 2019; Widodo *et al.*, 2019).

Vitamin C content varied significantly among treatments, with the highest concentration observed in rose–lemon (F2–ML) at (13.8 ± 0.1) mg 100 mL$^{-1}$, owing to the naturally high ascorbic acid content of lemon juice (Ramful *et al.*, 2011). This confirms that formulation composition strongly influences vitamin C retention during beverage preparation. The progressive increase in vitamin C content observed in lemon-containing formulations is consistent with the increasing proportion of lemon juice added to the beverage matrix. Similar trends were reported by Ghanem *et al.* (2024), who found that the type and concentration of vitamin C–rich fruits directly affect the antioxidant potential of functional drinks.

Overall, the results suggest that blending rose extract with fruit and herbal ingredients may enhance antioxidant activity, supporting the potential application of these beverages as natural sources of dietary antioxidants.

*Color characteristics*

Color attributes (L*, a*, b*) are crucial indicators of visual quality and consumer acceptance in functional beverages. As shown in Table 3, the color parameters did not differ significantly across formulations ($p > 0.05$). However, variations in mean values were observed among treatments. The highest L* value (30.8 ± 0.9) was recorded in rose–red ginger (F1–MJM), indicating a relatively brighter appearance, whereas rose–lemon (F2–ML) exhibited the highest a* value (4.0 ± 1.3), corresponding to a deeper red tone. The b* value was most pronounced in rose–apple (F1–MA), giving the beverage a slightly yellow hue.

These variations may be associated with differences in pigment composition and pH conditions among formulations. Although no significant differences were detected, lemon juice, with its acidic pH, may contribute to the stabilization of anthocyanins and enhance red coloration, consistent with previous findings by Yang *et al.* (2025). In addition, processing conditions such as pasteurization may influence pigment stability. The observed trends are in line with the concept that beverage color is influenced by anthocyanin structure, pH, and co-pigmentation effects (Qiu *et al.*, 2025; Tan *et al.*, 2025).

**Table 3:** *Lab color measurements of rose-based functional beverages*

| Formulation | L* (Brightness) | a* (Redness) | b* (Yellowish) |
|---|---|---|---|
| Control | 29.77 ± 1.20$^{a}$ | 2.53 ± 0.75$^{a}$ | 2.44 ± 0.06$^{b}$ |
| F1–MA | 30.43 ± 1.25$^{a}$ | 2.77 ± 1.22$^{a}$ | 2.73 ± 0.12$^{a}$ |
| F2–MA | 29.23 ± 1.13$^{a}$ | 3.73 ± 1.00$^{a}$ | 1.67 ± 1.45$^{ab}$ |
| F1–MJM | 30.83 ± 0.87$^{a}$ | 2.47 ± 0.95$^{a}$ | 2.97 ± 0.50$^{ab}$ |
| F2–MJM | 29.50 ± 0.75$^{a}$ | 2.73 ± 0.46$^{a}$ | 1.63 ± 0.83$^{ab}$ |
| F1–ML | 29.90 ± 1.35$^{a}$ | 3.70 ± 2.60$^{a}$ | 2.13 ± 0.50$^{ab}$ |
| F2–ML | 29.00 ± 1.40$^{a}$ | 4.00 ± 1.31$^{a}$ | 2.13 ± 1.24$^{ab}$ |

**Note:** *Values are presented as mean ± standard deviation of three replications. Means followed by different letters within the same column indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at the 5 % significance level ($p < 0.05$).*

*TSS and pH*

Table 4 presents the mean values of TSS (Total

Soluble Solids) and pH across treatments. The highest TSS value [(8.0 ± 0.10) °Brix] was observed in rose–lemon (F1–ML), while the control exhibited the lowest [(6.9 ± 0.10) °Brix]. The increase in TSS with lemon addition may result from soluble carbohydrates, organic acids, and vitamin C contributing to total soluble solids (Balık *et al.*, 2023; Sdiri *et al.*, 2012).

The pH values ranged from 2.8 ± 0.1 to 3.3 ± 0.1, with the lowest pH found in rose–lemon (F2–ML) and the highest in rose–apple (F2–MA). Lower pH values in lemon-based formulations are associated with higher citric acid content, contributing to increased beverage acidity (Penniston *et al.*, 2008; Tiencheua *et al.*, 2021). Such acidity may contribute to microbial stability and color preservation, although excessive acidity may influence sensory perception (Musyoka *et al.*, 2018). These findings suggest that the choice and ratio of added ingredients influence beverage acidity and total soluble solids, which are important parameters affecting flavor characteristics and shelf stability.

**Table 4:** *TSS and pH measurements of rose-based functional beverages*

| Formulation | TSS | pH |
|---|---|---|
| Control | 6.90 ± 0.10$^{a}$ | 3.03 ± 0.01$^{b}$ |
| F1–MA | 7.43 ± 0.15$^{de}$ | 3.16 ± 0.07$^{bc}$ |
| F2–MA | 7.10 ± 0.10$^{bc}$ | 3.26 ± 0.09$^{c}$ |
| F1–MJM | 7.10 ± 0.10$^{bc}$ | 3.18 ± 0.08$^{c}$ |
| F2–MJM | 7.03 ± 0.06$^{ab}$ | 3.24 ± 0.12$^{c}$ |
| F1–ML | 8.00 ± 0.10$^{e}$ | 3.11 ± 0.07$^{bc}$ |
| F2–ML | 7.23 ± 0.06$^{cd}$ | 2.83 ± 0.06$^{a}$ |

**Note:** *Values are expressed as mean ± standard deviation (n = 3). Means followed by different letters within the same column indicate significant differences according to Duncan's Multiple Range Test (DMRT) at the 5 % significance level (p < 0.05).*

*Total anthocyanin content*

Anthocyanin concentration varied significantly between the control [(44.8 ± 0.3) mg $L^{-1}$] and the rose–apple formulation (F1–MA) [(27.3 ± 2.0) mg $L^{-1}$] ($p < 0.05$), as shown in Table 5. The reduction in anthocyanin content upon blending with apple is likely associated with the presence of ascorbic acid, which can promote anthocyanin degradation through oxidative mechanisms (Gérard *et al.*, 2019; Lemmens *et al.*, 2020). Additionally, the mild heat during pasteurization may contribute to anthocyanin breakdown via glycosidic cleavage or polymerization (Enaru *et al.*, 2021; Patras *et al.*, 2010).

Although anthocyanin content decreased, the antioxidant activity remained relatively high, suggesting that non-anthocyanin phenolic compounds and vitamin C also contributed to antioxidant capacity (Bolling *et al.*, 2013; Nisar, 2022). This finding suggests that the combination of phenolic-rich ingredients with ascorbic acid–containing fruits may enhance overall antioxidant activity, despite partial pigment degradation.

**Table 5:** *Anthocyanin concentration in rose-based functional beverages*

| Formulation | Total Anthocyanin (mg $L^{-1}$) |
|---|---|
| Control | 44.80 ± 0.30$^{b}$ |
| F1–MA | 27.30 ± 2.00$^{a}$ |

*Values are expressed as mean ± standard deviation (n = 3). Different superscript letters within the same column indicate significant differences according to DMRT at p < 0.05.*
*Control = rose extract beverage without additional fruit or herbal ingredients; F1–MA = rose extract (0.4 g) + apple (2 g).*

*Sensory evaluation*

The sensory analysis revealed that the rose–apple formulation (F1–MA) received the highest overall acceptability score, primarily due to its balanced sweetness, acidity, and aroma. Panelists generally showed greater preference for this formulation than for those containing higher concentrations of ginger or lemon, which may be related to differences in flavor balance and overall sensory perception (Santos *et al.*, 2023). The favorable sensory acceptance of F1–MA suggests that the combination of rose extract and apple contributes positively to consumer preference while maintaining desirable functional characteristics.

## Conclusions and Recommendations

The present study demonstrated that the combination of *R. damascena* extract with apple (*M. domestica*), lemon (*C. limon*), and red ginger (*Z. officinale* var. *rubrum*) significantly influences the physicochemical properties, antioxidant activity, and sensory characteristics of the formulated functional beverage. Among all treatments, the formulation containing 0.4 g rose extract and 2 g apple (F1–MA) exhibited the highest sensory acceptance, along with high antioxidant activity (71.7 % DPPH inhibition), and moderate levels of vitamin C (5.1 mg 100 $mL^{-1}$) and anthocyanin (27.3 mg $^{-1}$).

The results suggest that phenolic compounds, flavonoids, and ascorbic acid derived from fruit and herbal ingredients may contribute to antioxidant activity and consumer acceptance of the developed beverage.

*Future perspectives*

Future studies should prioritize the evaluation of the stability and bioavailability of bioactive compounds in rose-based functional beverages during storage, as well as *in vivo* studies to evaluate the physiological effects of the developed beverage using *Rattus norvegicus* as an experimental model (Garfansa *et al*., 2024; Hermayanti *et al*., 2024). In addition, the incorporation of natural sweeteners such as *Stevia rebaudiana* (Melviana *et al*., 2021) may improve nutritional quality, sensory acceptance, shelf stability, and suitability for consumers with diabetes.

Future research may also investigate the potential occurrence of microplastic (MPs) contamination in both raw materials and finished beverage products, as this has emerged as a growing global concern (Li *et al*., 2024a; Saati *et al*., 2025). Previous studies have reported the presence of MPs in plant-based food systems, including fruits and root crops (Aydın *et al*., 2023; Conti *et al*., 2020; Setyobudi *et al*., 2024a, 2024b. 2024c, 2025). Although MPs were not analyzed in the present study, their possible presence in plant-derived ingredients and processed beverages warrants further investigation to ensure product safety and quality (Setyobudi, 2026). Although the health implications of dietary microplastic exposure are still being actively investigated, accumulating evidence suggests that long-term ingestion of microplastics may contribute to oxidative stress, inflammation, cellular dysfunction, and the transfer of associated contaminants, highlighting an emerging concern for human health and food safety (Setyobudi *et al*., 2026). Therefore, monitoring and mitigating potential microplastic contamination in functional beverages represent an important emerging research direction and support the achievement of Sustainable Development Goal 12 (Responsible Consumption and Production).

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## Novelty Statement

Previous studies have reported various rose-based functional beverages and blended formulations, including rose beverages enriched with spices (Saati *et al*., 2021), fermented rose-based drinks (Qiu *et al*., 2023), rose syrup-containing functional beverages (Kumar *et al*., 2021), anthocyanin-enriched rose–lemon beverages (Das *et al*., 2024), and formulations combining rose extracts with other plant-derived ingredients (Destiyana *et al*., 2018). However, limited information is available regarding the comparative effects of combining rose extract with apple, lemon, and red ginger at different formulation levels on physicochemical characteristics, antioxidant activity, vitamin C content, anthocyanin content, and sensory acceptance within a single beverage system.

Therefore, the novelty of this study lies not in the use of rose as a beverage ingredient itself, but in the integrated evaluation and optimization of rose–apple, rose–lemon, and rose–red ginger formulations through the simultaneous assessment of multiple quality attributes and consumer acceptance. This study provides additional insights into the development of rose-based functional beverages using locally available natural ingredients with desirable antioxidant properties and sensory characteristics.

## Authors' Contribution

**Elfi Anis Saati:** Conceptualized and designed the study, performed literature searches, manuscript preparation, funding acquisition, supervision, and project administration.

**Roy Hendroko Setyobudi:** Elaborated the intellectual concept, performed the literature search, manuscript review, manuscript revision, and served as guarantor.

**Sukarsono Sukarsono, Hanif Alamudin Manshur**: Manuscript review.

**Ayu Diawi Ismayawati and Ike Susanti**; Data curation and formal analysis

**Muhammad Luthfi Abdulrohman, Silvia Feby, Muhamad Efendi, and Elly Yuliasari**: Carried out experimental studies.

All authors have read and approved the final manuscript.

*Generative AI and AI-assisted technology statement*

The authors stated that they used Grammarly Proofreader and Meta AI (Liama 4), both generative AI and AI-assisted tools, in the preparation of this manuscript, primarily to enhance the quality of the English language.

*Conflict of interest*

The authors have declared no conflict of interest.

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