Physicochemical and organoleptic properties of moringa instant (*Moringa oleifera Lam*) drink enriched with ginger, turmeric, galangal, and lemongrass

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Abstract

This research aimed to evaluate the impact of various herbal additions on the quality and sensory attributes of moringa (*Moringa oleifera Lam*)-based instant beverages. The study was conducted in several laboratories at Tadulako University and the Goods Quality Testing and Certification Unit in Palu. Physicochemical properties (water content, vitamin C, antioxidants, solution pH, and dissolution time) were evaluated using a completely randomized design. At the same time, sensory attributes such as color, aroma, and taste were examined using a randomized block design. The experiment tested six different herbal additions: P0 (no herbs), P1 (red ginger), P2 (lemongrass), P3 (galangal), P4 (white turmeric), and P5 (yellow turmeric), with each treatment repeated three times. Results showed that yellow turmeric yielded the best physicochemical outcomes, with a dissolution time of 83 seconds, a water content of 5.27%, a pH of 6.36, a vitamin C content of 12.44%, and an antioxidant activity of 49.25%. In contrast, red ginger emerged as the most preferred by panelists, scoring highest in terms of color, aroma, and taste, with values of 3.50, 3.97, and 3.60, respectively. The findings indicate that herbal additives can enhance the functional properties and sensory appeal of moringa instant drinks. Yellow turmeric effectively optimized physicochemical traits, making the beverage more suitable for health-conscious consumers. Meanwhile, red ginger improved sensory appeal, increasing the likelihood of consumer acceptance. Future research should optimize the concentrations of yellow turmeric and red ginger to balance their effects on physicochemical and sensory qualities, investigate advanced drying techniques to meet Indonesian National Standard 4320:1996 water content standards, and explore the bioavailability and health impacts of these products.

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Introduction

Moringa (*Moringa oleifera Lam*.) is a well-known tropical plant that grows in most parts of Indonesia, including Palu City and Central Sulawesi. Leaves are widely used because of their high nutritional content compared with other plant parts. The antioxidant content of moringa leaves, such as vitamin C, polyphenols, β-sitosterol, and flavonoids, is very useful in lowering blood cholesterol levels (Tjong *et al*., 2021). Moringa leaves can also treat hyperglycemia, asthma, flu, heart disease, malaria, diarrhea, pneumonia, and blood pressure (Daba, 2016), and have anticancer, antibacterial, anti-inflammatory, antihypertensive, antioxidant, and antidiabetic effects (Gopalakrishnan *et al*., 2016). In Indonesia, moringa leaves are widely consumed as a vegetable, whereas other processed foods are still minimal because the unpleasant and bitter taste of moringa leaves is less popular (Rohman and Rahmawaty, 2024). Technological innovation is needed to increase the economic value of moringa leaves, one way is to prepare instant moringa drinks by adding brown sugar and other spices or herbs, which can increase the benefits and public interest in moringa instant drinks.

Instant powdered drinks are powdered drinks that dissolve easily in water and are practical and durable. This instant drink is made from various simple ingredients, such as leaves, spices, fruit, water, and sugar. Fruit-based instant drinks utilize fruits as sources of vitamins, while instant drinks with leaves and spices have herbal benefits and properties, such as red ginger, lemongrass, galangal, white turmeric, and yellow turmeric.

The combination of several herbal extracts can produce a synergistic effect from the bioactive compounds present in the composition of the ingredients to improve their immunomodulatory activity (Husnani and H, 2021), as demonstrated by the research results of Widyaningsih *et al*. (2022), a combination of moringa and pandan leaf extracts. Fragrant and red ginger can reduce uric acid levels in the blood of patients with hyperuricemia (high uric acid levels) (Widyaningsih *et al.*, 2022).

Red ginger, lemongrass, galangal, white turmeric, and yellow turmeric are herbal plants that have the potential to act as immunomodulators (improving immune system function and endurance) because they are rich in antioxidant compounds. These herbal plants generally contain bioactive compounds that act as antioxidants and immune boosters (immunity-enhancing foods or drinks), such as flavonoids and curcumin. Flavonoids are present in the rhizomes of red ginger, lemongrass stems, and galanga, while curcumin is present in the rhizomes of white turmeric and yellow turmeric. Consuming foods and drinks high in flavonoids can reduce the risk of high blood pressure and cardiovascular disease (heart and blood vessel disease) through their antioxidant effects, which play a role in warding off disease-causing free radicals (Panche *et al.*, 2016). In addition to flavonoids, other compounds, such as curcuminoids found in curcumin, also have immunomodulatory properties (Yuandani *et al.*, 2021).

Processing herbal raw materials into instant drinks enhances their usability and shelf life. The raw materials are affordable, easy to obtain, and traditionally used in various food and medicinal applications. Combined with herbal ingredients, moringa leaves can serve as a functional beverage with enhanced antioxidant properties. Despite the potential of moringa-based drinks, there is limited research on their physicochemical and sensory characteristics when combined with various herbal additives. This study aims to address this gap by evaluating the effects of different herbal combinations on the quality of instant moringa drinks. This research aimed to evaluate the impact of various herbal additions on the quality and sensory attributes of moringa (*Moringa oleifera Lam*)-based instant beverages.

Materials and Methods

The effect of treatment on the physicochemical properties of the moringa instant drink was measured using a random property design method. In contrast, the organoleptic properties of the moringa instant drink were measured using a randomized block design method. The treatments in this study included variations in the addition of herbal ingredients, with six levels of treatment: P0 (no additional herbs), P1 (red ginger), P2 (lemongrass), P3 (galangal), P4 (white turmeric), and P5 (yellow turmeric). Each treatment was repeated three times to obtain 18 experimental units, and the research was conducted from March to June 2023 at the Industry Laboratory, Faculty of Agriculture, Chemistry Laboratory, Faculty of Mathematics and Natural Sciences, Tadulako University, and UPT Goods Quality Testing and Certification (PSMB).

The raw materials used to make moringa instant drinks are fresh moringa leaves (medium-aged) obtained from residents' yards in Tondo Village, Palu City, including red ginger, lemongrass, and moringa leaves (medium-aged, approximately 3-6 months old) from residents' yards in Tondo Village, Palu City. The leaves were selected based on their maturity, ensuring they were not too young (which would have lower nutrient content) or too old (which may have a more fibrous texture and less desirable quality for processing). In addition, red ginger, lemongrass, and other herbal ingredients were also sourced from local suppliers. Galangal, white turmeric, and yellow turmeric were obtained from Sipayo Village, Parigi Moutong, as well as supporting ingredients in water and brown sugar. The analytical materials needed are iodine (I2) 0.01 N, sulfuric acid (H2SO4 2 N), starch indicator, 2.2-diphenyl-1-picrylhydrazyl (DPPH), distilled water (H2O), buffer, and 96% ethanol (C2H5OH). The tools used to make instant moringa drinks are cutting boards, baking sheets, knives, pans, spatulas, spoons, stoves, blenders, strainers, and 80 mesh sieves. Tools used for physicochemical analysis included UV-Vis spectrophotometry, filter paper, analytical balance, pH meter, porcelain cup, oven, Erlenmeyer, test tube, desiccator, hotplate, volumetric flask, volume pipette, burette, stand, stopwatch, tissue, and beaker.

Moringa leaf juice

Fresh moringa leaves were separated from the stems and weighed 150 g. Moringa leaves are washed with running water and then drained. Place it in the blender, add water with a ratio of moringa leaves and water 1:4, then blend at a low speed (number 1). The finely ground material was filtered through a sieve to separate the dregs from the juice (Kadir *et al.*, 2021).

Preparation of herbal plant extracts

The plant parts included rhizomes (red ginger, galangal, white turmeric, and yellow turmeric) and stems (lemongrass). Each material was separated from the unused parts (including the skin and damaged parts) and washed with running water to remove annoying dirt, and then drained. All ingredients were cut to 1 cm to make it easier to smooth them. Then, 135 g of each ingredient was weighed and blended with a ratio of ingredients to water of 1:2. The finely ground ingredients were filtered using a sieve to separate the dregs from the juice.

The plant parts used included rhizomes (red ginger, galangal, white turmeric, and yellow turmeric) and stems (lemongrass). The process began by separating the usable parts from unwanted parts such as skins, damaged sections, or debris. The materials were thoroughly washed under running water to remove dirt and then drained to remove excess moisture. Next, the ingredients were cut into small pieces approximately 1 cm long to facilitate blending, and 135 grams of each material were weighed. The prepared materials were blended with a water-to-material ratio of 1:2 (*e.g.*, 135 grams of material mixed with 270 mL of water) until a homogeneous mixture was obtained. The resulting mixture was filtered using a fine sieve or muslin cloth to separate the juice from the pulp, ensuring maximum extraction by pressing or squeezing the pulp. If not used immediately, the extracted liquid was transferred to clean, airtight containers and stored at 4°C.

Processing of moringa instant drinks

Moringa leaf juice (600 g) was obtained, and 45% (270 g) of the herbal plant juice was mixed with moringa leaf juice. Next, 20% (174 g) brown sugar was added to the total solution (moringa leaf juice + herbal plant juice). Ingredients were mixed in a pan to facilitate cooking. The proportions of ingredients in processing the instant moringa beverage were meticulously selected to achieve an optimal balance between flavor, nutritional content, and functional benefits. Moringa leaf juice (600 g) was utilized as the primary base due to its exceptional nutritional profile, rich in vitamins, minerals, antioxidants, and bioactive compounds. To enhance the flavor profile and amplify its health-promoting effects, herbal plant juice was incorporated at a proportion of 45% (270 g of the total moringa leaf juice). This addition not only complements the distinctive taste of moringa but also introduces aromatic and bioactive compounds known for their therapeutic properties. Furthermore, 20% brown sugar (174 g, calculated based on the combined weight of moringa and herbal juices) was added to counteract the natural bitterness of the moringa and herbal juices. Brown sugar was chosen for its mild sweetness and ability to harmonize flavors without overwhelming the beverage, aligning with consumer preferences for less processed sweeteners. All ingredients were thoroughly mixed in a pan before cooking, facilitating even distribution and proper flavor integration during the heat application, which is crucial for product consistency and stability. These calculated proportions ensure that the instant moringa beverage is palatable and nutritionally beneficial, making it a functional drink suitable for diverse consumers.

The solution was mixed with brown sugar, cooked at low heat for ±55 minutes, and stirred continuously. The stove heat was turned off when the solution thickened, and small bubbles appeared. The solution was stirred continuously until the thick solution formed semi-dry crystals, which were then transferred to a tray.

The ingredients were placed in the oven for ±5 hours at 50°C. Once the powder had cooled, it was blended until smooth with an 80-mesh sieve to ensure the particles were the same size. Next, instant moringa powder was packaged in plastic and stored in a tightly closed container. The final stage is the physicochemical and organoleptic analysis of the moringa instant drink.

Research variables

Dissolution time is the time required for an effervescent tablet to dissolve completely in water. To measure it, the sample is placed in a glass filled with water, and the time it takes for the tablet to dissolve is observed and the data is recorded.

Water content is the amount of water present in the effervescent powder. The sample was weighed before and after drying, and the weight difference was used to determine the moisture content.

Solution pH is the acidity of the effervescent solution after dissolution. The sample is dissolved in water, then the pH of the solution is measured using a calibrated pH meter.

Vitamin C refers to the vitamin C content in the effervescent tablet. The sample is extracted, then measured using titration or spectrophotometry methods.

Antioxidant activity is the ability of compounds in the sample to neutralize free radicals. To measure it, the sample extract was prepared, and antioxidant activity tests were performed.

The organoleptic test is a sensory evaluation of the product based on a preference scale. Samples were provided to panelists who were asked to rate them based on a scale of 1-5 (strongly dislike to strongly like) for aspects such as taste, aroma, and appearance. Sensory evaluation of the product was conducted using a preference scale to assess attributes such as taste, aroma, and appearance. The test involved 30 untrained panelists, selected based on specific criteria, including their availability, interest in participating, and familiarity with similar products. The panelists represented a diverse demographic group, ensuring a broad perspective on product acceptability. The evaluation was performed under controlled conditions to minimize external factors that could influence the sensory perception. The scores from the panelists were collected and analyzed statistically to determine the average preference level for each sensory attribute and identify significant differences among the samples.

Analysis of variance was used to analyze the data. The 5% honestly significant difference (BNJ) test tests treatments that show a real effect, and the 1% level BNJ test tests treatments that show a very real effect. The analysis was performed using statistical software (Excel, Microsoft, Redmond, WA, USA).

Table 1. Physicochemical characteristics of moringa instant drink.

Parameter	Addition of herbal types					
	Control	Red ginger	Lemongrass	Galangal	Turmeric white	Turmeric yellow
Physical components						
Late time (seconds)	62^{a}	66^{ab}	63^{ab}	67^{ab}	68^{ab}	83^{b}
Chemical components						
Water content (%)	5.11	5.66	5.86	5.47	5.64	5.27
pH of solution	6.50^{b}	6.35^{ab}	6.20^{a}	6.36^{ab}	6.28^{ab}	6.36^{ab}
Vitamin C (%)	8.90^{ab}	9.39^{ab}	9.03^{ab}	10.98^{ab}	8.75^{a}	12.44^{b}
Antioxidants (%)	45.02^{bc}	43.22^{a}	44.44^{ab}	44.94^{b}	46.20^{bc}	49.25^{c}
IC_{50} (ppm)	126.69^{f}	104.37^{e}	98.58^{d}	86.16^{c}	80.17^{b}	64.68^{a}

IC_{50}, half maximal inhibitory concentration. Numbers followed by the same letter are not significantly different based on the honestly significant difference test at the 1% or 5% level.

Table 2. Organoleptic characteristics of moringa instant drink.

Parameter	Addition of herbal types					
	Control	Red ginger	Lemongrass	Galangal	Turmeric white	Turmeric yellow
Color	3.20	3.50	3.30	3.27	3.40	3.57
Aroma	3.03^{a}	3.97^{b}	3.17^{ab}	3.40^{ab}	3.07^{ab}	3.17^{ab}
Flavor	3.13^{ab}	3.60^{b}	3.50^{ab}	3.20^{ab}	2.87^{a}	3.17^{ab}

Numbers followed by the same letter are not significantly different based on the honestly significant difference test at the 1% or 5% level.

Results

Table 1 shows the physicochemical properties of moringa instant drinks fortified with various herbal additions. The results indicate that the addition of different herbs significantly affected the water content, pH, vitamin C content, antioxidant activity, and half maximal inhibitory concentration (IC50) value of the drinks. Specifically, the turmeric yellow-fortified drink exhibited the highest vitamin C content and antioxidant activity, suggesting its potential as a rich source of these nutrients. Additionally, the IC50 value, which represents the sample concentration required for 50% inhibition of a specific biological activity, was lowest in the turmeric yellow-fortified drink, indicating its potent antioxidant capacity. These findings suggest that adding different herbs can significantly modify the nutritional profile of moringa instant drinks, offering opportunities for the development of functional beverages with enhanced health benefits.

Table 2 and Figure 1 present the organoleptic characteristics of moringa instant drinks fortified with various herbal additions. The results indicate that adding different herbs significantly affected the sensory attributes of the drinks, including color, aroma, and flavor. Specifically, the red ginger-fortified drink received the highest ratings for aroma, suggesting a more appealing scent than the other formulations. However, the flavor of the turmeric yellow-fortified drink was rated the highest, indicating that it was perceived as the most pleasant to taste. These findings suggest that adding different herbs can significantly modify the sensory profile of moringa instant drinks, offering opportunities for developing products with improved consumer acceptance.

Discussion

Physical and chemical characteristics

Physical and chemical tests were performed to determine the specific physicochemical composition of the moringa instant drinks. Table 1 shows the results of the tests on the physical and chemical properties of moringa instant drinks with the addition of various herbal ingredients. The time required for an instant powder drink to dissolve completely in a certain volume of water is called dissolution time. A faster dissolving time indicates good product quality because it is easier to serve (Pentury *et al.*, 2013).

Table 1 shows that the instant moringa drink with the addition of yellow turmeric juice had the longest dissolving time (83 seconds), which was significantly different from the control (without additional herbs), but no difference from the addition of red ginger juice, lemongrass, galangal, and white turmeric. This is thought to be because the added yellow turmeric juice contains curcumin with a high molecular weight and is hydrophobic (Malahayati *et al.*, 2021), thus affecting its solubility in water. In line with the statement by Goff and Guo (2019), the difference in dissolution time was influenced by the molecular weight of the material; the higher the molecular weight of a material, the longer its solubility (Goff and Guo, 2019).

On the other hand, instant moringa drinks with control treatment (without added herbs) had the fastest dissolution time (62 s), and the effect significantly differed from the treatment with yellow turmeric juice. This is caused by the lack of additional ingredients, which can increase the chemical composition of the material, resulting in a powder with a low molecular weight, which causes the powder to dissolve quickly in water. Increasing solubility is positively correlated with decreasing molecular weight; the lower the molecular weight of a material, the more soluble it is in water.

Water content

Water content is the amount of water in food ingredients or products, both bound water and free water, which influences food's acceptability, freshness, and preservation. Higher water content during storage can increase the possibility of microbes attacking the food (Savini *et al*., 2024). Table 1 shows that the water content of the moringa instant drink was relatively the same in each treatment, that is, in the range of 5%. This is thought to occur because the herbal juice added to the moringa instant drink is already in liquid form and the same amount, so the water content produced is not different. distance between the treatments. In line with the research by Edam *et al*. (2016), the water content was not significantly different in powdered drinks because the water content tends to be the same in additional ingredients, which are liquids and mainly composed of water components (Edam *et al.*, 2019).

The water content of moringa instant drinks is also influenced by the added solid ingredients, namely, palm sugar, which helps crystallize. Using large quantities of palm sugar and not adding maltodextrin and granulated sugar results in instant powdered spice drinks having a high water content (Assalam, 2022). In line with the research conducted by Firdausni *et al*. (2017), palm sugar had larger grains and more water content during crystallization.

Solution pH

The degree of acidity or pH is the material's acidity level, which determines the quality of the powder after dissolution in water. Powdered drinks must have an acidic pH of 6-6.8, because it can affect the taste and shelf life of food products(Ningrum *et al.*, 2021). Table 1 shows that the instant moringa drink without adding herbal ingredients has a solution pH value of 6.50 and adding herbal ingredients into moringa instant drinks can reduce the pH value to a range of between 6.28-6.36%. The highest contribution to reducing the pH value is found in the addition of lemongrass, this is because lemongrass has a pH value that is more acidic than other types of herbs, namely 4.34 (Deoranto *et al.*, 2021), followed by the pH of galangal juice in the range of 3.94-4.36 (Marwati *et al*., 2021), the pH of moringa leaves is 5.91 (Aliyu *et al.*, 2018), the pH of turmeric juice is 6.64, and the pH of red ginger juice is 6.76

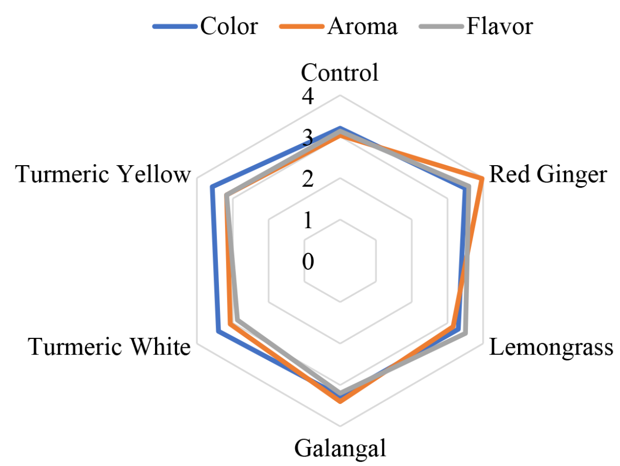

Figure 1. Organoleptic characteristics of moringa instant drink.

(Nisfiyah *et al.*, 2022). The acidity (pH) of moringa instant drinks is influenced by the acidity level of the ingredients. The higher the acidity level of a material, the higher the H+ ions that will be released in the solution, and the concentration of H+ ions in the water increases, causing the pH to decrease (Prabowo and Saraswati, 2021).

Vitamin C

Ascorbic acid, an antioxidant, is another term used for vitamin C. In the dry state, vitamin C is soluble and easily damaged by oxidation, especially when exposed to heat (Yin *et al*., 2022). Table 1 shows that the moringa instant drink without adding herbal ingredients contains 8.90% vitamin C and adding herbal ingredients to the moringa instant drink can increase the vitamin C levels in the range by 9.03-12.44%. The highest contribution to increasing vitamin C was found in the addition of yellow turmeric herbal extract, this is because fresh yellow turmeric contains higher vitamin C than other types of herbs, namely 19.47 mg/100 g (Enemor *et al*., 2020), followed by red ginger vitamin C is 9.33 mg/100 g (Simarmata, 2022), galangal vitamin C is 5.7 mg/100 g (Saras, 2022), lemongrass vitamin C is 2.6 mg/100 g (Hakim, 2015), and the lowest vitamin C is found in white turmeric at 0.440 mg/100 g (Sujana, 2020).

The vitamin C content of fresh raw materials is different from the vitamin C of the products produced. This was due to the heating process of obtaining the instant drink powder. Cooking and drying the raw materials for moringa instant drinks causes oxidation of vitamin C by heat, so heating or drying can damage the vitamin C produced if the extracted vitamin C is not properly protected. Damage occurs due to the oxidation of vitamin C to dehydroascorbic acid. This oxidation produces diketogulonic acid, which cannot function as vitamin C. Light, heat, alkaline pH, and metal-ion catalysts can accelerate the oxidation of vitamin C (Yin *et al*., 2022). Increasing the temperature during the cooking of moringa instant drinks accelerates the oxidation reaction process, which can disrupt the stability of a substance. Prolonged heating causes vitamin C to oxidize, and the decomposition process reduces the remaining levels of vitamin C (Damayanti and Prasetia, 2021). Vitamin C is easily oxidized to form a carbonyl group because it contains a hydroxy functional group (OH) that is highly reactive with the oxidizing hydroxy group. The oxidation process is hampered under very acidic conditions or at low temperatures (Apul and Sisilia, 2018).

Antioxidant activity

Antioxidants can capture free radicals by providing one electron to free radicals that are not present to stabilize and neutralize them, thereby preventing them from disrupting the body's metabolic processes (Lobo *et al.*, 2010). The highest antioxidant activity was obtained in the treatment with yellow turmeric juice, with an average of 49.25%, which was significantly different from the addition of red ginger, lemongrass, and galangal juice. However, the lowest antioxidant activity was obtained in the treatment with the addition of red ginger juice (an average of 43.22%), which was significantly different from the control treatment (without additional herbs), the addition of lemongrass juice, galangal, white turmeric, and yellow turmeric. However, to determine the strength of the antioxidant activity of the moringa instant drink, we examined the IC50 values obtained in each treatment (Table 1).

The compound concentration required to inhibit 50% of DPPH free radicals was indicated by the IC50 (inhibition concentration) value. The level of antioxidant activity increased as the IC50 value decreased (Budaraga and Putra, 2021). In particular, an antioxidant compound is classified as very strong if its IC50 value is less than 50 ppm, strong if it is between 50 and 100 ppm, moderate if its IC50 value is between 100 and 150 ppm, weak if it is between 150 and 200 ppm, and very weak if it is above 200 ppm (Purwanto *et al.*, 2017). Table 1 shows the strength of the antioxidant activity of moringa instant drink, which was different for each treatment, including 126.69 ppm (control/without added herbs), 104.37 ppm (added red ginger juice), 98.58 ppm (added lemongrass juice), 86.16 ppm (added galangal juice), 80.17 ppm (added white turmeric juice), and 64.68 ppm (addition of yellow turmeric juice). A high value indicates a low IC50 antioxidant ability, while a low IC50 value indicates a high antioxidant ability (Hussen and Endalew, 2023). Instant drinks with the addition of yellow turmeric juice have stronger antioxidant activity (IC50=64.68 ppm) than instant moringa drinks without herbs as a control (IC50=126.69 ppm), which have moderate antioxidant activity. This means that adding herbal juice can increase the strength of the antioxidant activity of the moringa instant drink by inhibiting 50% of free radicals.

The different antioxidant activities in moringa instant drinks are caused by the accumulation of other antioxidant compounds in the added herbal ingredients, thus affecting the antioxidant activity of the entire moringa instant drink produced. In line with research by Ndomou *et al.* (2021), total antioxidants are related to the food ingredients' phytochemical content. An increasing number of phytochemicals have the potential to act as antioxidants in the products produced (Ndomou *et al*., 2021).

Organoleptic characteristics

Organoleptic tests were carried out to determine consumer preference for moringa instant drinks through sensory organs. Taste stimuli, including color, aroma, and taste, can influence consumer acceptance (Trigo *et al.*, 2023). Therefore, they can be considered when developing food products. Table 2 shows the organoleptic test results of the instant moringa drink with the addition of various herbal ingredients.

Different ingredients and processing methods can significantly affect the sensory attributes of food and beverages. For instance, in the case of Yanggaeng, a traditional dessert, adding Corni fructus powder (CF) altered its color, scent, flavor, and texture (Jang *et al.*, 2023). The CF-treated Yanggaeng showed decreased lightness and yellowness, increased redness, and changes in browning index. Similarly, adding CF affected the taste, with changes in pH and °Brix levels. In the context of teas, different processing methods and tea varieties lead to distinct sensory profiles. For example, black tea's aroma is influenced by various volatile compounds produced during processing, resulting in fruity, floral, woody, malty, spicy, and smoky flavors (Parveen *et al*., 2023). Similarly, green tea processed by Echa 10 was noted for its fresh and mellow taste, clean aroma, and distinctive honeysuckle fragrance (Li *et al*., 2022).

Understanding the interaction between sensory and physicochemical properties is crucial for optimizing food product formulations. For example, the antioxidant activity of the moringa instant drink not only contributes to its health benefits but may also influence its flavor profile by reducing bitterness. This interplay aligns with research on black tea, where volatile compounds produced during processing significantly affect aroma and taste (Parveen *et al*., 2023). Therefore, future product development should consider balancing physicochemical properties to enhance sensory appeal while maintaining functional benefits.

This study was conducted on a laboratory scale, and the physicochemical interactions observed may differ in large-scale commercial processing. Additionally, the stability of vitamin C and antioxidant compounds over extended storage periods was not evaluated, which may impact the long-term nutritional quality of the product. Future research should explore alternative drying techniques and packaging methods to optimize the retention of bioactive compounds.

Conclusions

Adding herbal ingredients significantly affects the physicochemical and organoleptic qualities of moringa instant drinks. Yellow turmeric juice demonstrated the best physicochemical properties, including a dissolution time of 83 seconds, 5.27% water content, 6.36 pH, 12.44% vitamin C, and 49.25% antioxidant activity, while red ginger juice was most preferred by panelists for its color, aroma, and taste, scoring 3.50, 3.97, and 3.60, respectively, on a 5-point scale. These results highlight the practical potential of yellow turmeric and red ginger as functional additives in instant beverage development, offering both health benefits and sensory appeal.

Future research should optimize the concentrations of yellow turmeric and red ginger to balance their effects on physicochemical and sensory qualities, investigate advanced drying techniques to meet SNI 4320:1996 water content standards, and explore these products' bioavailability and health impacts. Additionally, studies on shelf life, storage stability, and broader consumer testing are recommended to enhance the product's market potential.

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