



RESEARCH ARTICLE

Evaluation of physicochemical characteristics and ultrasound-assisted extraction of *Medinilla speciosa* Blume fruit

Ratih Paramastuti, Yasmin Aulia Rachma, Surya Hilmy Ramadhan, Dina Agape Romauli Hutapea, Zefanya Avrilia Tiara Gusani & Lutfi Purwitasari*

Department of Food Technology, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Semarang 50275, Indonesia

*Correspondence email - lutfipurwitasari@live.undip.ac.id

Received: 04 March 2026; Accepted: 27 July 2026; Available online: Version 1.0: 15 September 2026

Cite this article: Ratih P, Yasmin AR, Surya HR, Dina ARH, Zefanya ATG, Lutfi P. Evaluation of physicochemical characteristics and ultrasound-assisted extraction of *Medinilla speciosa* Blume fruit. Plant Science Today. 2026; 13(sp7): 1-6. <https://doi.org/10.14719/pst.14375>

Abstract

Medinilla speciosa Blume is an underutilised tropical fruit and a promising source of bioactive compounds. However, scientific data on its physicochemical characteristics remain limited. This study characterised the physicochemical properties of fresh *M. speciosa* fruit and determined the extraction yield. Preliminary analyses were performed on fresh *M. speciosa* fruit, including colour measurement (L^* , a^* , b^* values), size assessment (horizontal and vertical diameters) and proximate composition analysis (moisture, ash, fat, protein and carbohydrate content), after which the fruit was subjected to ultrasound-assisted extraction (UAE) using methanol. The average fruit diameter ranged from 6.55–8.78 mm, while colour values indicated a reddish-purple hue. The colour development index (CDI) of *M. speciosa* fruit ranged from 0.904–0.972 and decreased as fruit size increased. Proximate analysis showed high moisture content ($90.67 \pm 0.43\%$), relatively high ash ($4.24 \pm 0.18\%$) and fat ($3.95 \pm 0.12\%$) levels, with low protein and carbohydrate contents. Ultrasound-assisted extraction (UAE) using methanol yielded an extraction efficiency of 14.95 % from *M. speciosa* fruit, which was 8–10 % higher than the average yields reported for *M. speciosa* extracted with other solvents or methods on a dry-weight basis. These findings provide essential baseline data to support future research and industrial applications of *M. speciosa* fruit extract in functional foods and nutraceuticals.

Keywords: extraction yield; *Medinilla speciosa*; physicochemical properties; ultrasound-assisted extraction

Introduction

Tropical fruits represent an important source of nutrients and bioactive compounds that contribute to human health and functional food innovation. Growing interest in natural antioxidants and antimicrobials has encouraged researchers to investigate underutilised fruits as alternative raw materials for nutraceutical and food applications. Comprehensive characterisation of fruit physicochemical properties such as colour, size and proximate composition is a crucial first step in evaluating their quality attributes, stability and industrial potential (1). The efficiency of bioactive compound recovery is strongly influenced by the extraction technique, which consequently dictates the suitability of fruit extracts for downstream applications.

Medinilla speciosa Blume, locally known as parijoto, is an underutilised tropical fruit native to Southeast Asia and widely cultivated in Central Java and Sumatra, Indonesia. Traditionally, its fruits are consumed for cultural and medicinal purposes, particularly by pregnant women and has been associated with health-promoting effects. Preliminary phytochemical screenings have shown that *M. speciosa* contains flavonoids, tannins, saponins, anthocyanins and terpenoids, which are linked to antioxidant and antimicrobial activities (2). Despite its ethnobotanical importance and functional potential, systematic data on the physicochemical properties and extraction efficiency of *M. speciosa* fruits remain limited. Such baseline information is essential for guiding further exploration of its bioactivity and possible applications in functional foods and nutraceuticals.

Colour development index (CDI) in fruits serves as a critical indicator of maturity and phytochemical composition, where the hue angle provides a quantitative measure of colour perception which correlates with pigment changes during ripening. The CDI has emerged as a valuable tool for objective maturity assessment in various fruit species, enabling standardised evaluation of harvest timing and quality parameters (3). Furthermore, these colour parameters are often linked to the fruit's bioactive compound profile, particularly its total antioxidant capacity (TAC), which represents the cumulative capacity of fruit extracts to scavenge free radicals and neutralise oxidative stress (4). Understanding the relationships between visual colour attributes, maturity indices and antioxidant potential is essential for evaluating the functional quality of underutilised fruits like *M. speciosa* and optimising their harvest for maximum bioactive compound.

Conventional solvent extraction methods for recovering bioactive compounds from plant matrices are often limited by long processing times, high solvent consumption and low yields. In contrast, ultrasound-assisted extraction (UAE) has emerged as an efficient and environmentally friendly technique that enhances mass transfer, reduces solvent usage and preserves heat-sensitive compounds through acoustic cavitation. The UAE has been successfully applied in various fruits and medicinal plants to improve the recovery of phenolics, flavonoids and pigments (5). However, its application to *M. speciosa* fruit has not yet been systematically evaluated.

Therefore, this study was designed to characterise the physicochemical properties of fresh *M. speciosa*, including colour parameters (L^* , a^* , b^*), size and proximate composition and determine the extraction yield obtained using UAE with methanol. Findings from this study are expected to provide essential baseline data on the physicochemical profile and extraction efficiency of *M. speciosa*, addressing the limited available information and supporting its future development as a natural source of bioactive compounds for the food and nutraceutical industries.

Materials and Methods

Materials

The equipment used in this study consisted of a colour reader, a digital caliper, drying oven, muffle furnace, Soxhlet extractor, Kjeldahl apparatus, grinder, freeze dryer, bath ultrasonicator, rotary vacuum evaporator, magnetic stirrer, a set of glassware and an analytical balance. The primary material used in this study was *M. speciosa* fruit collected from Colo, Kudus Regency, Central Java, Indonesia. The fruits were selected based on their red purple colour and were authenticated at the Food Engineering and Agricultural Products Laboratory, Department of Agriculture, Universitas Diponegoro. The fruits were extracted using methanol using UAE method. Chemical reagents used in this study included distilled water, petroleum ether, concentrated sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), boric acid (H_3BO_3) solution, hydrochloric acid (0.1 N HCL), catalyst selenium and mixed indicators (methyl red and methyl blue).

Methods

Colour measurement

Fruit colour was evaluated using a colour reader (Minolta CR-400, Japan) following the CIE Lab* system, where L^* represents lightness, a^* represents the red-green coordinate and b^* represents the yellow-blue coordinate. Measurements were performed on the surface of small, medium and large fruits at three random points per fruit. Results were expressed as mean $\pm$ standard deviation (SD). Calculation of chromatic colour areas ($^{\circ}$ hue) are calculated by the following equation (6).

$$^{\circ}\text{hue} = \tan^{-1} \left(\frac{b^*}{a^*} \right) \quad (\text{Eq. 1})$$

The CDI represents the departure from skin greenness towards yellowness, blueness, or redness. The CDI was derived from hue angle using the following formula (3).

$$\text{CDI} = \left| \frac{\text{hue}^{\circ}}{180} - 1 \right| \quad (\text{Eqn. 2})$$

Fruit size determination

Thirty fruits (10 per size category: small, medium and large) were randomly selected from different *M. speciosa* plants collected from the study area. Horizontal and vertical diameters were measured using a digital caliper with 0.01 mm accuracy. The average values were calculated and compared among fruit sizes. Results were expressed as mean $\pm$ standard deviation (SD).

Proximate composition analysis

Proximate composition was determined following the method described by Eden and Rumambarsari and all analyses were

performed in triplicate (7). Moisture content was determined by oven-drying 5 g of sample at 105 °C until constant weight. Ash content was determined by incinerating 3 g of dried sample in a muffle furnace at 550 °C until a constant weight was achieved. Crude fat was determined using Soxhlet extraction with petroleum ether for 6 hr. Crude protein was determined by the Kjeldahl method ($N \times 6.25$). Carbohydrates calculated by difference from 100 - (moisture + ash + fat + protein).

Dehydration

Medinilla speciosa fruits were prepared by separating the fruits from stems and leaves. The separated fruits were then cut into four pieces each. The chopped fruits were placed into small cups and frozen in a freezer for 24 hr. The frozen fruits were subsequently dried using a freeze dryer at -40 °C under vacuum conditions for 36 hr until a completely dried. The dried *M. speciosa* fruits were finally ground into a fine powder using a grinder until a homogeneous powder was obtained (8).

Ultrasound-assisted extraction (UAE)

The extraction of *M. speciosa* fruits was performed using UAE method, following a previously established protocol. The powdered fruit samples were mixed with methanol at a sample-to-solvent ratio of 1 : 20 (w/v). The mixture was then subjected to extraction using an ultrasonicator operating at a frequency of 40 kHz for 60 min at room temperature. After extraction, the sample was filtered through fine filter paper and collected in a beaker. The resulting filtrate was concentrated using a rotary vacuum evaporator for 1 hr to obtain a thick crude extract.

Statistical analysis

Colour characteristics and diameter measurements were conducted in triplicate and results were expressed as mean $\pm$ SD. Statistical analysis were performed using SPSS v.26 (IBM, USA). One-way analysis of variance (ANOVA) followed by Tukey's post hoc test was applied to assess significant differences ($p < 0.05$).

Results and Discussion

Medinilla speciosa fruit, commonly known as parijoto, is native to Indonesia (Fig. 1). The fruit has vibrant red stems and a round shape. The fruit colour ranged from bright magenta and reddish tones to deep purple and bluish hues. The berries exhibited different stages of ripeness, some fully matured with a darker shade, while others are still transitioning to their mature form, showing a greenish-yellow core at the center.

The external colour of *M. speciosa* varied significantly across fruit sizes (Table 1). The colour parameters (L , a , b) describe the colour changes of *M. speciosa* fruit based on size. Small fruits exhibited higher lightness ($L = 30.12$), redness ($a^* = 19.31$) and yellowness ($b^* = -1.73$). In medium sized fruits, the L , a and b^* values decrease (26.53; 16.01; -1.54), whereas large fruits exhibited very dark colours ($L^* = 24.17$), greenish ($a^* = 12.71$) and bluish ($b^* = -3.95$). These results indicate that larger fruits exhibited darker colouration, reduced redness, enhanced blue tones and lower colour saturation. Such instrumental colour evaluation is vital for objective and precise assessment of quality attributes, as colour influences consumer perception and can serve as a non-destructive proxy for underlying biochemical changes during fruit development or maturation (9).



Fig. 1. *Medinilla speciosa*.

Table 1. Colour characteristics (L^* , a^* , b^*) of *Medinilla speciosa* (parijoto) in various sizes

Colour	Various size		
	Small	Medium	Large
L^*	30.12 ± 0.89^a	26.53 ± 0.96^b	24.17 ± 1.37^c
a^*	19.31 ± 1.64^a	16.01 ± 1.11^b	12.71 ± 2.10^c
b^*	-1.73 ± 1.37^a	-1.54 ± 1.13^a	-3.95 ± 0.74^b

Different superscript letters within the same row indicate significant differences at $p < 0.05$ (Tukey's test).

Hue angle (h°) ranging from 0° (or 360°) denotes maximum redness, 90° maximum yellowness, 180° maximum greenness and 270° maximum blueness (3). The hue angle of *M. speciosa* fruits ranged from 342.7 – 354.9° (Table 2), indicating that fruits of all sizes remained within the red-magenta region of the CIELAB colour space (Fig. 2). The colour characteristics of *M. speciosa* were relatively stable within the red-magenta region. The results showed that the hue angle of *M. speciosa* decreased with increasing fruit size. This trend implies that as *M. speciosa* fruits mature and increase in size, their external colour becomes more intense, moving from a near-red tone toward a deeper red-purple colouration. Previous studies have reported that similar colour changes during fruit ripening are often associated with anthocyanin accumulation (10). These results indicate that lower hue values were associated with fruit maturation.

Table 2. Hue angle (h°) and colour development index (CDI) of *Medinilla speciosa* (Parijoto) in various sizes

Parameter	Various size		
	Small	Medium	Large
Hue angle (h°)	354.9	354.5	342.7
CDI	0.972	0.969	0.904

However, anthocyanin content was not determined in the present study. The CDI is strongly related to fruit maturity and postharvest time. The CDI values range from 0–1, with higher values indicating redder colouration. Higher CDI values indicate redder colouration (3). The CDI of *M. speciosa* fruit varied from 0.904–0.972, decreasing with increasing fruit size. Although larger fruits exhibited lower hue angles, the reduction in CDI suggests that their surface colour became less purely red because of the increasing contribution of blue tones (more negative b^* values), resulting in a deeper red-purple appearance rather than a brighter red colour. The positions of hue angle and CDI values for different sizes of *M. speciosa* are presented in Fig. 2.

The colour characteristics of *M. speciosa* fruit at different ripening stages are presented in Fig. 3. Fruit colour is often associated with antioxidant capacity of the fruit. Total antioxidant capacity (TAC) represents the overall concentration of bioactive compounds, including ascorbic acid, carotenoids, phenolic compounds and tocopherols. Some of these antioxidant compounds have a characteristic colour and are pigmented. For instance, anthocyanins are major phenolic pigments found in vegetables and fruits, which is responsible for red, blue and purple colours. Most fruits and vegetables that have a hue angle below 20° and above 180° have high antioxidant capacity (>10 mmol TE/kg fresh weight) (4). The hue angle of *M. speciosa* fruit ranged from 342.7 – 354.9° , indicating a predominance of red-purple colouration. Previous studies have reported that fruits with similar colouration may contain antioxidant pigments such as anthocyanins. However, antioxidant capacity was not directly measured in the present study.

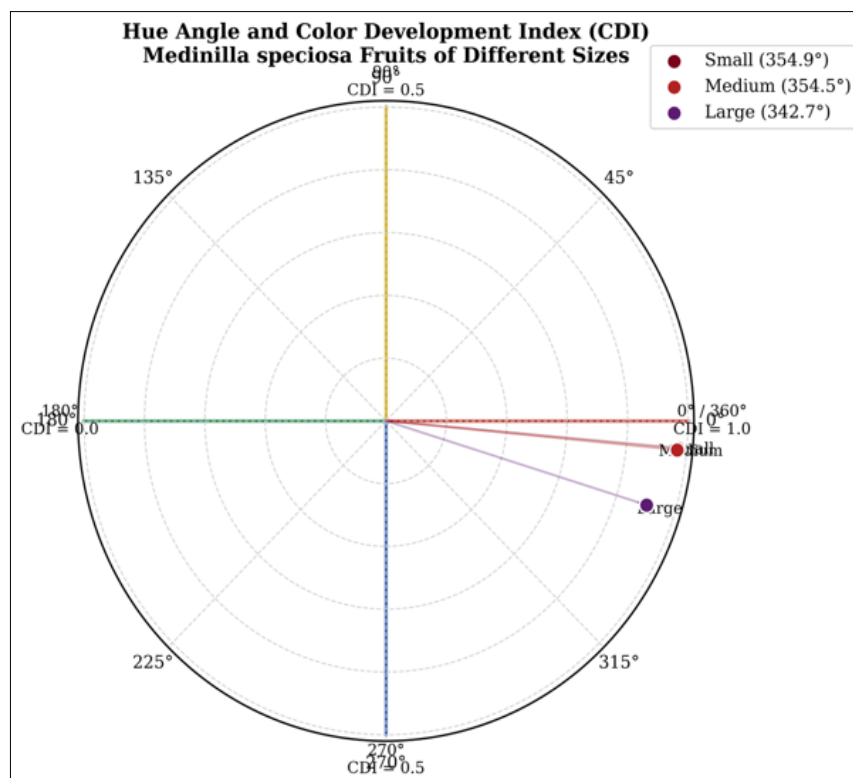


Fig. 2. Hue angle and colour development index (CDI) position of various size *Medinilla speciosa* in colour wheel.



Fig. 3. Stages of *Medinilla speciosa* fruit ripeness.

The horizontal diameter of small fruits (6.29 mm) was smaller than the vertical diameter (6.81 mm), indicating that small *M. speciosa* fruits tend to be elongated oval in shape. The overall diameter of small to large fruits shown in Table 3. Medium-sized fruits had more balanced diameters (7.45 mm and 7.72 mm), indicating a near-spherical shape with low variation. Large fruits also showed nearly identical diameters (8.72 ± 0.78 mm and 8.85), but higher vertical deviations reflect greater shape variability, likely due to non-uniform growth. Overall, the average diameter increased significantly from small (6.55 mm) to large (8.78 mm) fruits.

Table 3. The diameter of *Medinilla speciosa* (parijoto) in various sizes

Diameter (mm)	Various size		
	Small	Medium	Large
Horizontal	6.29±0.42 ^a	7.45±0.50 ^b	8.72±0.78 ^c
Vertical	6.81±0.53 ^a	7.72±0.37 ^b	8.845±1.18 ^c
Average	6.55±0.40 ^a	7.58±0.35 ^b	8.78±0.57 ^c

Different superscript letters within the same row indicate significant differences at $p < 0.05$ (Tukey's test).

When compared with other tropical berry fruits, such as blueberries (size range 5–13 mm) and mulberries (7–10 mm), *M. speciosa* fruits are consistent with the size range of small berry-type fruits that are typically spherical to slightly ovoid in shape (11). Furthermore, studies in berry crops have showed that smaller fruit size often correlates with higher concentrations of anthocyanins and phenolic compounds. For instance, smaller Cabernet Sauvignon berries have been reported to contain elevated levels of anthocyanins and total phenolics, despite not always translating directly to improved wine quality (12). Previous studies in berry fruits have reported associations between fruit size and phenolic compound concentrations. However, anthocyanin and phenolic contents were not determined in the present study, therefore, whether similar relationships exist in *M. speciosa* requires further investigation.

The proximate composition of *M. speciosa* is presented in Table 4. The result showed a high moisture content indicating that *M. speciosa* is a moisture-rich fruit, consistent with the characteristics of tropical berries. Recent studies indicate that high moisture content contributes to crisp texture and sensory freshness in various tropical fruits (13). This high moisture content suggests the fruit is highly perishable and may require immediate postharvest handling to prevent spoilage. Similar moisture levels have been reported in

Table 4. Proximate composition of *Medinilla speciosa* (Parijoto)

Parameter	Result (%± SD)
Moisture content	90.67 ± 0.43
Ash content	4.24 ± 0.18
Crude fat	3.95 ± 0.12
Crude protein	0.72 ± 0.06
Carbohydrates	0.42 ± 0.33

other tropical fruits with soft texture and high respiration rates, such as strawberries and mulberries, which generally contain 85–92 % water content.

The ash content (4.24 %) indicates a relatively high mineral content, which may contribute to the fruit's nutritional value and potential bioactivity. This value is higher than that reported for many common fruits, suggesting that *M. speciosa* could be a significant source of dietary minerals and trace elements. Current research reports that 3–6 % ash content is common in seasonal tropical fruits, reflecting the presence of essential minerals such as calcium (Ca), potassium (K) and phosphorus (P) (14).

The relatively high ash content may reflect the accumulation of mineral constituents within the fruit tissues. Since ash content is commonly used as an indicator of total mineral composition, these findings suggest that *M. speciosa* fruit may contribute nutritionally important minerals. Such minerals play important roles in physiological functions, including electrolyte balance, enzyme activation and metabolic regulation. However, individual mineral components were not analysed in the present study.

The crude fat content (3.95 %) is considered high for fruit, as most fruits typically contain less than 1 % fat. This suggests the presence of bioactive lipophilic compounds, which may include essential fatty acids or lipid-soluble antioxidants. Such compounds could contribute to the antimicrobial and antioxidant potential of the fruit extract. A previous study reported that high-fat content in indigenous fruits correlates with higher bioactivity in functional food applications (15). Consequently, the high fat content of *M. speciosa* highlights its potential as a valuable source for extracting lipophilic bioactives, distinguishing it from many other fruits that are primarily sources of hydrophilic compounds like flavonoids and polyphenols.

The relatively high fat content may also enhance the potential of *M. speciosa* fruit as a source of lipid soluble bioactive compounds. Such compounds may contribute to functional properties related to antioxidant protection and bioactive delivery systems. Therefore, the elevated fat content distinguishes *M. speciosa* from many conventional fruits that are predominantly characterised by water-soluble phytochemicals.

The crude protein content (0.72 %) and carbohydrate content (0.42 %) of *M. speciosa* were relatively low, which is consistent with typical values reported for most tropical fruits. Although these macronutrients do not contribute substantially to the fruit's caloric value, their presence may still play a functional role. Proteins, even in small amounts, can interact with polysaccharides and other structural components, potentially influencing texture and the ability of the fruit matrix to form stable systems in food applications. The low carbohydrate content further indicates that *M. speciosa* is not primarily an energy-dense fruit but rather a source of water, minerals and lipophilic compounds. Taken together, the proximate profile of *M. speciosa* suggests that its primary significance lies not in macronutrient contribution but in its potential as a

reservoir of bioactive components with nutritional and functional value. The low protein and carbohydrate levels suggest that *M. speciosa* is not an energy-dense fruit but may be more suitable for specialised applications, such as serving as a component in edible protective coatings, rather than as a significant source of calories (16).

The results in Table 5 show that the wet weight (19.39 ± 1.25 g) and frozen weight (19.26 ± 1.21 g) of *M. speciosa* fruit samples are nearly identical, indicating minimal frozen loss (0.006 ± 0.008 g). This small loss is attributed to the freezing step prior to freeze-drying, which limits ice crystal growth and reduces cell rupture, thereby minimising drip loss during thawing (17). Such findings are consistent with previous studies reporting that controlled rate freezing preserves cellular integrity and prevents significant mass loss in plant matrices. The use of a freeze dryer in the present study is critical to maintain the integrity of heat-sensitive bioactive compounds such as phenolics and flavonoids, as sublimation under low temperature and pressure prevents degradation compared to conventional drying methods. Following freeze-drying, the dry weight obtained was 1.69 ± 0.22 g. The relatively low dry weight compared to the wet weight is primarily due to the high moisture content typical of fresh *M. speciosa*. Preservation of bioactive compounds during drying is essential for subsequent extraction efficiency.

Table 5. Weight measurements of *Medinilla speciosa* (Parijoto)

Measurement	Result
Wet weight (g)	19.39 ± 1.25
Frozen weight (g)	19.26 ± 1.21
Frozen loss (g)	0.006 ± 0.008
Dry weight (g)	1.69 ± 0.22

In this study, the extraction was performed using methanol as the solvent with the UAE method. The UAE has been widely reported to enhance extraction yields by disrupting plant cell walls through acoustic cavitation, facilitating the release of intracellular compounds without significant thermal degradation (18). Methanol is often selected for polyphenol extraction due to its high polarity and efficiency in solubilising a broad spectrum of antioxidant compounds. The extraction yield of *M. speciosa* using UAE method can be seen in Table 6. The extraction yield (14.95 %) obtained in this study indicates that UAE combined with methanol was effective in recovering extractable compounds from *M. speciosa* fruit. The UAE has been reported have a higher extraction yield compared with conventional extraction methods, as seen from previous research the UAE method yielded 5 % higher than conventional solvent extraction (19). The observed yield may have been influenced by solvent polarity, extraction conditions and the physicochemical characteristics of the fruit matrix. However, direct comparisons with conventional extraction techniques were not performed in the present study; therefore, the relative efficiency of UAE compared with other extraction methods requires further investigation.

Table 6. Yield measurements of *Medinilla speciosa* extract (Parijoto)

Measurement	Result
Sample weight (g)	20,0117
Extract weight (g)	2,9901
Yield (%)	14.95

Conclusion

This study provides the first comprehensive physicochemical characterisation of *Medinilla speciosa* and evaluates its extraction yield using ultrasound-assisted extraction (UAE). The fruit exhibited distinct physicochemical characteristics, including high moisture content and notable ash and fat levels, indicating its potential nutritional and functional value. The fruit also exhibited characteristic colour properties associated with different fruit sizes and maturity stages. The UAE method using methanol yielded 14.95 % extract on a dry-weight basis, demonstrating its suitability for recovering extractable compounds from *M. speciosa* fruit. However, this study was limited to physicochemical characterisation and extraction yield evaluation, without identification of specific bioactive compounds or assessment of their biological activities. Further studies are therefore needed to investigate these aspects. Collectively, these findings establish essential baseline data for *M. speciosa*, underscoring its potential as a novel source of bioactive compounds for functional foods, nutraceuticals and specialised applications such as edible coatings. Further studies should focus on the characterisation of bioactive compounds, antioxidant activity and the development of value-added products derived from *M. speciosa* extracts.

Acknowledgements

This research was funded by LPPM Universitas Diponegoro through International Scientific Publication Year 2025, under Contract Number: 222-474/UN7.D2/PP/IV/2025.

Authors' contributions

RP, YAR and LP conceived and designed the research. SHR, DARH, and ZATG conducted the experiments and collected the experimental data. RP, YAR, SHR, DARH, ZATG and LP performed data analysis and interpreted the results. RP prepared the first draft of the manuscript. YAR and LP reviewed and revised the manuscript critically for important intellectual content. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (OpenAI) to assist in drafting the graphical abstract, cover image and illustrating the hue angle and Colour Difference Index (CDI) position of various sizes of *Medinilla speciosa* in the colour wheel and improve readability and grammar. The authors reviewed, edited and finalised all generated content and take full responsibility for the content of the publication.

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