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Comparison of Convective Drying and Sun Drying Methods on Moisture Content and Color Characteristic of Roselle (*Hibiscus sabdariffa L.*)

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***ABSTRACT**: Roselle (Hibiscus sabdariffa L.) calyces are widely used in herbal and functional food products but have high moisture content that accelerates spoilage, making drying an essential postharvest process to maintain quality. This study aimed to compare convective and sun drying methods on the moisture content and color characteristics of roselle calyces. Fresh calyces were dried using a food dehydrator at 60°C for 10.5 h and by traditional sun drying for 3 days until a constant weight was achieved. Moisture content was determined using the oven-drying method, while color characteristics were evaluated using the CIE Lab* color system, including total color difference (ΔE). The results showed that convective drying resulted in significantly lower moisture content (5.80 ± 1.49%) than sun drying (11.48 ± 0.10%). Convective-dried samples met the general pharmacopoeial moisture limit for dried herbal materials (≤10%), whereas sun-dried samples exceeded the acceptable limit. Color analysis indicated that sun drying produced higher redness and chroma values but also caused greater total color change (ΔE = 13.74), while convective drying showed better color stability with a lower ΔE value (10.59). Convective drying demonstrated better performance in reducing moisture content and maintaining color stability under the evaluated conditions.*

***Keywords:** color characteristics; convective drying; moisture content; roselle; sun drying*

1. INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is a tropical plant widely used in herbal beverages and functional food products due to its bright red calyces, which are rich in anthocyanins responsible for antioxidant activity and distinctive color characteristics (Juhari *et al*., 2021). Fresh roselle calyces have high moisture content, generally exceeding 90%, making them highly perishable and susceptible to microbial growth and quality deterioration (Mardiah *et al.*, 2025). Therefore, drying is a crucial postharvest process to extend shelf life and stabilize product quality (Paiva *et al*., 2021). Previous studies have demonstrated that drying plays a significant role in reducing moisture content and preserving physical quality attributes of dried plant materials, particularly color, which is closely associated with pigment stability during processing (Nguyen *et al*., 2023).

Various drying methods have been applied in roselle processing, including traditional sun drying and hot-air convective drying using a food dehydrator with controlled temperature settings. Sun drying remains widely practiced due to its simplicity

and low cost, especially among small-scale producers. Sun drying often results in longer drying times, higher residual moisture content, and greater color degradation due to uncontrolled temperature and prolonged exposure to solar radiation (Wang *et al.*, 2023). In contrast, controlled drying methods such as cabinet dryers or food dehydrators provide regulated temperature and airflow, resulting in more uniform moisture removal and improved color retention (Younis *et al*., 2023). Research on roselle and similar plant materials indicates that controlled hot-air drying generally produces lower final moisture content and smaller color changes compared to sun drying (Akther *et al.*, 2023).

Despite extensive research on roselle drying, direct comparisons between food dehydrator and sun drying methods with a specific focus on moisture content and color characteristics remain limited. Juhari *et al*. (2021) investigated several drying methods for roselle calyces, including oven-drying, freeze-drying, vacuum-drying, and sun-drying, focusing on physicochemical properties, volatile compounds, and microstructure, but did not specifically examine the comparative performance of food dehydrator and sun drying under similar operational conditions. Dried roselle intended for herbal applications must comply with pharmacopoeial quality standards, which generally require a moisture content below 10% to prevent microbial growth and ensure product stability during storage. However, information regarding the ability of these two drying methods to meet this requirement while maintaining acceptable color quality remains limited. Therefore, this study aims to compare convective and sun drying methods on the moisture content and color characteristics of roselle (*Hibiscus sabdariffa* L.) calyces.

2. MATERIALS AND METHODS

2.1. Materials

The main material used in this study was fresh roselle flowers (*Hibiscus sabdariffa* L.) obtained from a local farm at the Mandala Ecotani Garden in Jatinangor Subdistrict, Sumedang Regency, West Java, Indonesia. The roselle calyces were selected based on uniform size, maturity, and free from physical damage and visible contamination. No chemical additives were applied during processing.

2.2. Equipment

The equipment used in this research included a food dehydrator (PAPALOLO, SS 10H) equipped with 10 stainless steel trays (30 × 28 cm each). The dehydrator had overall dimensions of 35 × 40 × 43 cm, a power consumption of 800 W, an adjustable temperature range of 30–90 °C, and a timer setting of 30 min to 24 h. Other equipment included stainless steel knives, an analytical balance, a digital pH meter, a chromameter based on the CIE L*a*b* color system, a thermometer, a hygrometer, glassware, beakers, measuring cylinders, and airtight containers for sample storage.

2.3 Sample Preparation

The calyces of fresh roselle flowers were separated manually from the seed pods. The calyces then were washed under running water to remove adhering dirt and foreign materials and drained with dry cloth to remove surface moisture.

2.4 Drying Methods

1. Convective Drying

Roselle calyces were arranged evenly on the trays of the food dehydrator to avoid overlapping. Drying was conducted at a constant temperature of 60 °C for 10.5 hours until a constant weight was achieved (Marak *et al*., 2021). Hasri *et al.* (2026) also reported that drying roselle at 60 °C resulted in lower moisture content, improved antioxidant retention, and acceptable sensory characteristics, compared to lower temperatures that caused higher moisture content. The temperature inside the food dehydrator was checked using type-K thermocouple to ensure the stability of the temperature during the drying process. After drying, the samples were cooled to room

temperature and stored in airtight containers for further analysis.

2. Sun Drying

For sun drying, roselle calyces were spread evenly on clean drying trays and placed under direct sunlight. Drying was performed during daytime hours under natural environmental conditions with an average ambient temperature of ±30–35 °C. The samples were covered with a thin mesh to prevent contamination from dust and insects. Drying was continued for three days until the samples reached a constant weight. Dried samples were then stored in airtight containers prior to analysis.

2.5 Analyzing Methods

1. Determination of Moisture Content

Determination of the water content analysis in the material was carried out based on the oven method (AOAC, 2005). Sample (2 g) was heated at 105°C by oven for at least 3 hrs or more and then cooled in a desiccator for 30 mins. This treatment was carried out several times until the sample weight obtained was constant until the difference in numbers is less than 0.02 g. Calculation of water content can be obtained through the following formula:

$$\text{Moisture content } (\textit{wet basis}) = \frac{(w1\text{-}w2)}{(w1\text{-}w3)} \times 100\% \quad (1)$$

Where W1 is sample weight and the cup before heating, W2 is sample weight and the cup after being heated, and W3 is the weight of the empty cup.

2. Color Analysis

Color characteristics of dried roselle samples were analyzed using a chromameter based on the CIE L*a*b* color system. The parameters measured included L* (lightness), a* (red–green coordinate), and b* (yellow–blue coordinate). Measurements were conducted at three different points on each sample, and the results were expressed as mean values.

3. RESULTS AND DISCUSSION

3.1. Color Analysis

Color is an important quality attribute in dried roselle (Hibiscus sabdariffa L.) because it reflects changes in bioactive pigments, particularly anthocyanins, during processing. Drying can cause color changes through exposure to heat, light, and humidity, which can lead to anthocyanin degradation (Rifqi et al., 2025). To objectively evaluate these changes, this study employed the CIE L*a*b* color space, which is widely used in food science to represent color differences in a uniform and perceptually meaningful manner (Pandiselvam et al., 2023).

Table 1. Means of color analysis of roselles after drying.

Treatment	L*	a*	b*	C	H	ΔE	Color Category
Fresh	26.68	20.35	8.74	22.20	23.86	–	Red
SD	21.74	31.46	13.75	34.19	21.25	13.74	Red
CD	19.34	18.14	4.91	18.82	14.93	10.59	Red Purple

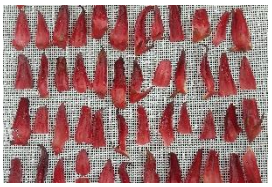
CD—convective drying, SD—sun drying.

In roselle flowers, the red coloration is mainly attributed to anthocyanin pigments, which are sensitive to heat, oxygen, and light. Drying processes can therefore alter L*, a*, and b* values through pigment degradation, oxidation, and non-enzymatic browning reactions (Rodríguez-Mena *et al*., 2023). As a result, differences in drying methods are expected to significantly influence the final color characteristics of dried roselle (Rizkiyah *et al.,* 2023).

Table 1 shows the L* value decreased after drying for both drying methods compared to the fresh sample. Fresh roselle showed an L* value of 26.68, while sun-dried (SD) and convective-dried (CD) samples exhibited lower L* values of 21.74 and 19.34, respectively. The lower L* value observed in

CD samples suggests a more intense dark color, which resulted from controlled drying conditions that limited excessive pigment oxidation while concentrating anthocyanins (Enaru *et al*., 2021). The a* value, which represents red color intensity, increased significantly in sun-dried samples (31.46) compared to fresh (20.35) and food-dehydrator-dried samples (18.14). While higher a* value indicates a strong red appearance, it does not necessarily mean the overall result is better than the lower a* value. In this case, the high a* value in sun-dried roselle may also be influenced by prolonged exposure to sunlight, which initially intensify red pigmentation through moisture loss but may eventually lead to pigment degradation (Ghorbani *et al*., 2025). In contrast, CD samples exhibited a lower a* value, suggesting partial degradation or transformation of anthocyanins under constant thermal exposure. The b* value increased after sun drying (13.75) compared to fresh (8.74), indicating a shift toward yellowish tones. This change is commonly associated with non-enzymatic browning reactions and anthocyanin degradation products formed during extended drying under direct sunlight. Conversely, CD samples showed a lower b* value (4.91), indicating reduced yellow discoloration and better preservation of the original pigment profile. The appearances of roselle after the drying process can be observed in Table 2.

Table 2. The appearances of roselle with different types of drying.

Drying Methods	Before Drying	After Drying
CD		
SD		

CD—convective drying, SD—sun drying.

The chroma (C*) values indicated differences in color saturation among treatments, with sun-dried roselle showing the highest chroma (34.19), followed by fresh (22.20) and food-dehydrator-dried samples (18.82). The higher chroma observed in sun-dried samples suggests a more vivid color appearance, likely caused by pigment concentration during prolonged moisture loss (Adamu *et al*., 2021), although such intense coloration may be less stable. Hue angle (H°) values further revealed color shifts due to drying, where fresh and sun-dried roselle remained within the red color region (23.86° and 21.25°, respectively), while food-dehydrator-dried samples exhibited a lower hue angle (14.93°), indicating a shift toward a red–purple hue. This shift suggests changes in anthocyanin structure induced by controlled thermal drying (Roy & Rhim, 2021). Total color difference (ΔE) values confirmed that both drying methods caused visually perceptible color changes compared to fresh roselle, with sun drying resulting in a higher color deviation (ΔE = 13.74) than food dehydrator drying (ΔE = 10.59). These results indicate that although sun drying produces more intense coloration, food dehydrator drying provides better control

over color stability and minimizes overall color alteration (Nawawi *et al*., 2023).

3.2. Moisture Content

Moisture content is the amount of water contained in foodstuffs, expressed as a percentage (Nasution & Nuraisyah, 2023). The moisture content of rosella is measured before and after the sample is dried. Moisture content measurement aims to determine the water content in the material as a key indicator of the stability and safety of simplisia storage. (Singh *et al*., 2026). The moisture content is reduced until it reaches the simplisia standard set in the Farmakope Herbal Indonesia (2017), which is less than 10%.

Table 3. Means of moisture content (%) of fresh roselle and after drying process.

Treatment	Drying temperature (°C)	Drying time	MC (%)
Fresh	105	4 hours	90.84 ± 0.15
CD	60	10.5 hours	5.8±1.49
SD	31.75	3 days	11.48 ± 0.10

Data are mean values ± standard deviations. CD—convective drying, SD—sun drying.

Based on table 3, fresh rosella has an average moisture content of 90.84 ± 0.15%, which reflects the general characteristics of fresh plant materials with very high water content. This high water content is due to the intact tissue structure of rosella, which retains cellular fluid within the calyx cells, making it highly perishable (Juhari *et al*., 2021). The high water content in fresh materials emphasizes the importance of the drying process to prevent the growth of microorganisms and extend the shelf life of the materials.

Rosella drying using the sun drying method is carried out for 3 days. Drying at the right time can reduce the water content to 11%. However, if drying is carried out too quickly, the water content will only decrease slightly (Mita & Rahmatiyah, 2025). The sun drying method produces a final moisture content with an average of 11.48 ± 0.10%. This value indicates that drying with sunlight can reduce moisture content, but has not yet reached the target moisture content. The relatively higher moisture content in this method is due to limited control of temperature and humidity during the drying process, resulting in a slower and uneven rate of water evaporation. This finding is in line with the report by Lema *et al*. (2022), which states that sun drying tends to produce a higher final moisture content compared to controlled drying methods. Higher residual moisture in dried plant materials may promote the growth of molds, yeasts, and certain bacteria, particularly under uncontrolled storage conditions. Wang *et al.* (2023) reported that insufficient drying and prolonged drying under natural environmental conditions can increase the risk of microbial contamination due to extended exposure to ambient air, dust, and fluctuating humidity. In addition, Singh *et al*. (2026) stated that moisture content is an important quality parameter in dried flower products because excessive moisture can accelerate deterioration, reduce storage stability, and negatively affect overall product quality during storage. These conditions may also enhance enzymatic activity and pigment degradation, ultimately affecting the safety, color, aroma, and overall quality of dried roselle during storage.

The convective drying method showed a greater reduction in water content compared to the sun drying method, with an average value of 5.8±1.49. This indicates that drying using a food dehydrator is more effective in removing water from rosella tissue. Food dehydrators can transfer heat to ingredients through convection. Convection is the process of heat transfer from the heat source to each rack inside the dryer with the help of air flow. The hot air moves towards areas

with lower temperatures, so that over time the temperature of the flowing air will decrease (Soekarno *et al*., 2023). In addition, the effectiveness of moisture removal is also related to the use of constant temperatures and controlled hot air circulation, so that the process of water vapor diffusion from inside the material to the environment occurs more quickly and evenly. This is in line with the research by Marak *et al.* (2021), which reported that mechanical drying with temperature control produces a lower and more stable final water content compared to natural drying methods.

4. CONCLUSIONS AND RECOMMENDATIONS

The drying method significantly influenced the moisture content and color characteristics of roselle (Hibiscus sabdariffa L.) calyces. Convective drying at 60 °C for 10.5 hours produced a lower final moisture content of 5.80 ± 1.49%, meeting general pharmacopoeial requirements for dried herbal materials, while sun drying resulted in a higher moisture content of 11.48 ± 0.10%. This is because convective drying occurs at a constant and controlled temperature, allowing for faster and more uniform heat transfer and water evaporation compared to sun drying, which is highly influenced by environmental conditions such as light intensity, temperature, humidity, and air circulation. In addition to affecting moisture content, drying temperature also influences the retention of bioactive compounds such as anthocyanins, flavonoids, vitamin C, and phenolic compounds.

Different drying temperatures may influence the stability of heat-sensitive compounds in roselle, particularly anthocyanins, which contribute to the characteristic red color of the calyces. Excessively high temperatures can accelerate pigment degradation, oxidation, and non-enzymatic browning reactions. In contrast, excessively low temperatures may prolong drying time and increase exposure to oxygen and light, which may negatively affect color quality and the stability of bioactive compounds in dried roselle.

Sun drying resulted in higher moisture content because the environmental conditions during the drying process, such as light intensity, temperature, relative humidity, and air circulation, remained uncontrolled. These fluctuating environmental factors reduced the efficiency and uniformity of moisture evaporation from the roselle calyces, resulting in slower drying rates and higher residual moisture content compared to convective drying. To optimize the sun drying process, environmental conditions should be controlled more effectively to improve drying efficiency and product stability. This can be achieved by incorporating supporting systems such as dehumidifiers, air conditioners, or forced-air circulation systems to regulate humidity, temperature, and airflow during drying.

In terms of color characteristics, sun-dried roselle showed higher redness and chroma values but experienced a greater total color change (ΔE=13.74), whereas convective-dried samples exhibited better color stability with a lower ΔE value (10.59). The higher ΔE value observed in sun-dried roselle was mainly influenced by the substantial increase in a* and b* values relative to fresh roselle. Convective drying produced smaller changes in a* and b* values, resulting in a lower ΔE value and better overall color stability relative to the fresh sample.

Therefore, convective drying is recommended as a more effective method to achieve safe moisture levels and stable color quality in dried roselle calyces. Although convective drying requires higher energy input and equipment costs than sun drying, its shorter drying time, controlled conditions, and ability to achieve safer moisture levels indicate potential applicability for industrial-scale roselle processing. Further studies are suggested to evaluate the effects of different drying temperatures and operating conditions on the retention of bioactive compounds and overall product quality.

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