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Potential of Underutilized Flowers for Dried Floral Applications: A Comparative Evaluation of Different Drying Methods

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ABSTRACT

This study investigated the potential of selected underutilized ornamental flowers for dried floral applications in Sri Lanka by comparing the effects of six drying techniques on their physical and ornamental quality. Five flower species, namely, *Ixora coccinea*, *Plumeria rubra*, *Petrea volubilis*, *Bougainvillea spectabilis*, and *Holmskioldia sanguinea*, were subjected to air drying, press drying, silica gel drying, sand-borax drying, hot air oven drying, and microwave oven drying. Significant differences (P < 0.05) were observed among the techniques for moisture loss, colour retention, texture, shape, brittleness, and overall quality. Results revealed that both drying methods and flower species significantly influenced the drying time and product quality. Microwave oven drying consistently achieved superior overall quality, less drying time, and better colour preservation in most species, while silica gel and hot air oven drying showed species-specific suitability. Among the flower species, *B. spectabilis* and *H. sanguinea* demonstrated the most favourable combination of physical and ornamental attributes after drying. These findings indicate that microwave oven drying and silica gel drying are the most effective and market-preferred methods for producing high-quality dried flowers in Sri Lanka, demonstrating strong potential to enhance the country's value-added floral industry.

Keywords: Bougainvillea, Dry flowers, Drying techniques, Microwave drying, Silica gel drying

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INTRODUCTION

Floriculture is a rapidly expanding industry with significant economic potential for developing countries. Global floriculture production is growing by nearly 10% annually (Devrani *et al.*, 2023). Fresh flowers are widely valued in cultural, social, and religious activities; however, they are seasonal, costly, and highly perishable. In contrast, dried flowers retain their aesthetic appeal for longer periods and are increasingly used in decorative products such as greeting cards, floral arrangements, potpourri, baskets, and interior ornaments (Thakur *et al*., 2020). The dried flower industry contributes nearly 15% of the global floral trade and continues to expand due to rising consumer demand for eco-friendly, biodegradable, and long-lasting floral products (Kumar *et al*., 2021; Mir *et al*., 2022).

Dried flowers are produced through moisture removal while preserving their colour, shape, and texture. Common preservation methods include air drying, press drying, silica gel drying, hot air oven drying, and microwave drying, each influencing product quality differently (Kumar *et al.*, 2023). In Sri Lanka, the dried flower industry remains underdeveloped due to limited flower diversity, dependence on traditional drying methods, and lack of quality standards (Bandara *et al*., 2024). Although a few species, such as *Tagetes*, *Gomphrena*, and *Rosa,* are commonly utilized, many ornamental flowers remain underexploited for value addition (Karunananda and Peiris, 2007). Research on suitable drying techniques for these species is also limited.

Developing the dried flower industry could diversify Sri Lanka's floriculture sector while generating rural employment, export opportunities, and sustainable use of floral resources. Therefore, this study investigates the potential of selected underutilized ornamental flowers for dried floral products by comparing different drying methods and evaluating their effects on product quality.

MATERIALS AND METHODS

Selection of Flowers

Five flowering species were selected based on their availability, ornamental value, structural integrity, and potential suitability for drying. The selected species were *Ixora coccinea* (Ixora / *Gini Erabadu*), *Plumeria rubra* (Temple flower / *Araliya*), *Petrea volubilis* (Sandpaper vine / *Nil Niyagala*), *Bougainvillea spectabilis* (Bougainvillea), and *Holmskioldia sanguinea* (Chinese hat plant). Flowers were harvested when they had reached maturity but before the colour had deteriorated, and in the early morning, to maintain freshness and structural quality for drying (Mebakerlin and Chakravorty, 2015). Flowers were obtained from locations in the Kurunegala District (Low Country Intermediate Zone), Sri Lanka, and the experiments were conducted from January to June 2025.

Application of Drying Methods

Six drying methods were applied to each flower type. For air drying (AD), flowers were tied in bundles and hung upside down in a dry, shaded, well-ventilated area at room temperature (30 ± 2°C; 72 ± 2% RH) for 5 - 8 days (Thakur *et al.*, 2020). For press drying (PD), flowers were pressed between blotting paper and corrugated boards under uniform pressure for 7 days at room temperature (Thakur *et al.*, 2020). For silica gel drying (SG), silica gel was dried at 105°C for 2 h and allowed to cool. A 1 - 2 cm silica gel layer was placed in an airtight container, flowers were arranged on it and gently covered with silica gel. The sealed containers were kept at room temperature for 16 - 24 h. Dried flowers were then carefully brushed clean (Mir *et al.*, 2020). For sand: borax drying (SB), a 1:1 mixture of fine sand and borax was layered in a container. Flowers were placed upright and fully covered with the mixture. The container was kept undisturbed at room temperature for 5–10 days before gently cleaning the dried flowers (Kumar *et al.*, 2021). For hot air oven drying (OD), flowers were arranged in a single layer on mesh trays and dried at 45 – 55°C for 4 - 8 h, depending on flower thickness. Regular checks ensured proper dryness and colour retention (Mir *et al.*, 2020). For microwave drying (MW), flowers were embedded in silica gel in a microwave-safe container and microwaved at 500–700 W until dry. A cup of water was included in a corner of the microwave oven to prevent scorching. Containers were cooled for 4 - 10 min before flowers were cleaned (Rani and Reddy, 2015).

Data Recording

Drying efficiency (time taken for drying to the expected quality) and the quality attributes of dried flowers were assessed for drying techniques and individual species. Parameters measured included drying time, percentage moisture loss (Safeena and Patil, 2013), colour retention, texture and shape retention, brittleness, and overall quality. Drying time was recorded as the time taken for flowers to become crisp and reduced moisture content, confirmed by stable weight. The post-drying colour retention was visually assessed using a 5-point quality rating scale (5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1 = Poor).

Texture, shape, brittleness, and overall quality score were evaluated through physical observation and ranked using the same scale.

Dried flower samples that resulted in the optimum drying methods were sealed in polypropylene bags and stored in air-tight plastic boxes under ambient conditions (30 ± 2°C; 72 ± 2% RH). The quality attributes were assessed for 2 months at 7-day intervals.

Experimental Design and Statistical Analysis

The experiment followed a Completely Randomized Design (CRD) with six treatments and three replicates, each replicate containing 10 flowers. Data were analyzed using the Analysis of Variance (ANOVA) procedure using R (Ver. 4.4.3) statistical software, with mean separation by Tukey's HSD test at a 5% significance level.

RESULTS AND DISCUSSION

Effect of Drying Method and Flower Type on Quality of Dry Flowers

There were significant treatment effects of the drying methods, flower type, and their interaction ($P < 0.05$) on the quality of dried products [colour retention and overall quality scores (OQS)], and the moisture loss in flowers (Table 1). This indicates that the effectiveness of drying methods varies not only with the treatment applied but also depends on the flower species, necessitating customized postharvest drying protocols for different species. Nevertheless, across the species, microwave drying (MW) has resulted in relatively higher colour retention and overall quality score. Across the drying methods, *Holmskioldia sanguinea* (HS) exhibited comparatively higher colour retention and OQS, followed by *Bougainvillea spectabilis* (BS). However, the presence of a significant interaction effect indicates that species-specific drying methods should be identified.

Mean Drying Time and Qualitative Attributes of Dried Flowers

The drying times of flower species showed significant variation ($P < 0.05$) under different drying techniques (Table 2). Microwave drying consistently achieved the shortest times across all species, ranging from 0.09 - 0.21 h (5.4 – 12.6 min), due to rapid, uniform internal heating. In contrast, AD and PD exceeded 144 h for every species. Silica gel drying (SG) and hot-air oven drying (OD) yielded intermediate drying times, with OD generally faster. For instance, in *I. coccinea*, OD took 6.33 h, while SG required 21.5 h. Overall, MW proved the most efficient method for all flower species. Microwave heating facilitates rapid removal of moisture due to volumetric heating, which prevents microbial degradation and minimizes oxidative reactions (Mebakerlin and Chakravorty, 2015).

Table 1. Effect of single-factors (drying method, flower species) and their interaction on drying time and the quality of dry flowers

Factor	Mean drying time (h)	Mean moisture loss at drying (%)	Mean colour retention score	Mean overall quality score
Drying method				
T1-Air drying (AD)	158.57^{e}	58.9^{a}	3.00^{b}	2.00^{b}
T2-Press drying (PD)	163.10^{f}	63.4b^{c}	3.34^{c}	3.18^{c}
T3-Silica gel drying (SG)	21.13^{c}	60.7a^{b}	3.56^{d}	3.56^{e}
T4-Sand-Borax drying (SB)	139.67^{d}	65.6^{c}	2.02^{a}	1.74^{a}
T5-Hot air oven drying (OD)	5.93^{b}	57.5^{a}	3.34^{c}	3.46^{d}
T6-Microwave drying (MW)	0.15^{a}	59.4^{a}	3.80^{e}	4.20^{f}
P value	<0.05	<0.05	<0.05	<0.05
Flower species				
PR-*Plumeria rubra*	97.35^{d}	83.33^{a}	2.78^{a}	3.00^{a}
BS-*Bougainvillea spectabilis*	67.68^{a}	74.33^{b}	3.25^{c}	3.25^{c}
HS-*Holmskioldia sanguinea*	84.72^{c}	74.53^{b}	3.92^{d}	3.24^{c}
IC-*Ixora coccinea*	84.67^{c}	74.03^{b}	3.13^{b}	3.00^{b}
PV-*Petrea volubilis*	72.69^{b}	80.86^{c}	2.80^{a}	2.63^{a}
P value	<0.05	<0.05	<0.05	<0.05
Drying method*Flower species (interaction)	<0.05	<0.05	<0.05	<0.05

Means within a column, under each factor, followed by different superscript letters are significantly different (P<0.05). [1]Score: 5=Excellent, 4=Very Good, 3=Good, 2=Fair, 1=Poor.

Table 1. Mean drying time and qualitative attributes of flower species under different drying methods.

Flower species under different treatments	Drying time (h)	Colour retention score	Shape retention score	Texture score	Overall quality score
Plumeria rubra					
AD (Air drying)	191.83^{ns}	1.0^{c}	1.0^{c}	2.0^{e}	1.0^{f}
PD (Press drying)	167.66^{a}	3.0^{a}	3.0^{a}	4.0^{a}	3.0^{a}
SG (Silica gel drying)	24.50^{b}	3.6^{b}	3.6^{b}	3.0^{b}	3.6^{b}
SB (Sand-Borax drying)	191.83^{ac}	1.0^{c}	3.0^{a}	4.0^{c}	2.0^{c}
OD (Hot air oven drying)	8.16^{c}	3.7^{b}	3.6^{b}	4.0^{d}	4.0^{d}
MW (Microwave drying)	0.12^{d}	4.4^{d}	3.6^{b}	4.0^{ad}	4.4^{e}
Bougainvillea spectabilis					
AD	120.34^{ac}	3.0^{f}	3.0^{c}	3.0^{a}	3.0^{f}
PD	144.50^{a}	3.5^{a}	4.0^{a}	3.0^{a}	3.5^{a}
SG	16.34^{b}	3.7^{b}	4.7^{b}	4.0^{b}	3.7^{b}
SB	120.67^{ac}	1.10^{c}	4.0^{a}	2.0^{c}	1.1^{c}
OD	4.16^{c}	3.2^{d}	4.7^{b}	4.0^{b}	3.2^{d}
MW	0.09^{d}	5.0^{e}	4.7^{b}	4.0^{b}	5.0^{e}
Holmskioldia sanguinea					
AD	168.50^{a}	5.0^{d}	2.0^{d}	2.0^{d}	2.0^{f}
PD	167.67^{a}	4.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}
SG	22.00^{b}	3.5^{b}	3.7^{b}	4.0^{b}	3.5^{b}
SB	144.50^{c}	4.0^{a}	2.6^{c}	3.0^{a}	2.6^{c}
OD	5.50^{c}	3.0^{c}	3.7^{b}	4.0^{b}	3.3^{d}
MW	0.17^{d}	4.0^{a}	3.7^{b}	4.0^{c}	5.0^{e}
Ixora coccinea					
AD	167.67^{ns}	3.0^{f}	1.0^{e}	2.0^{c}	2.0^{e}
PD	167.83^{a}	3.2^{a}	3.0^{a}	4.0^{a}	3.4^{a}
SG	21.50^{b}	3.6^{b}	4.6^{b}	4.0^{b}	3.6^{b}
SB	144.50^{c}	1.0^{c}	4.0^{c}	2.0^{c}	1.0^{c}
OD	6.33^{c}	3.4^{d}	3.6^{d}	4.0^{d}	3.4^{a}
MW	0.21^{d}	4.6^{e}	4.6^{b}	4.0^{d}	4.6^{d}

Flower species under different treatments	Drying time (h)	Colour retention score	Shape retention score	Texture score	Overall quality score
Petrea volubilis					
AD	144.50^{ns}	3.0^{a}	3.0^{c}	2.0^{d}	2.0^{c}
PD	167.83^{a}	3.0^{a}	5.0^{a}	3.0^{a}	3.0^{a}
SG	21.33^{b}	3.4^{b}	3.6^{b}	4.0^{b}	3.4^{b}
SB	96.83^{c}	3.0^{a}	3.0^{c}	3.0^{a}	2.0^{c}
OD	5.50^{d}	3.4^{b}	4.6^{d}	4.0^{c}	3.4^{b}
MW	0.13^{e}	1.0^{c}	4.0^{e}	3.0^{a}	2.0^{c}

Means in a column, within a species sharing the same letter, are not significantly different at P=0.05. Score: 5=Excellent, 4=Very Good, 3=Good, 2=Fair, 1=Poor.

When considering overall drying performance, *P. rubra* consistently required the longest drying times, ranging from 0.12 – 192 h (Table 1). The results presented in Table 2 demonstrate significant differences in the quality attributes of dried flowers across both drying methods and flower species. Microwave drying consistently produced the highest colour retention scores for most species, particularly *B. spectabilis* (5.0/5.0), *H. sanguinea* (4.0/5.0), and *I. coccinea* (4.6/5.0), indicating superior pigment preservation. This finding aligns with previous studies, which have reported that rapid internal heating in MW reduces enzymatic oxidation and minimizes pigment degradation, thereby maintaining vibrant floral colours (Kumar *et al*., 2023).

Silica gel drying maintained colour moderately well, typically recording scores between 3.4 - 3.7, followed closely by OD with scores of 3.2 - 3.7 (Table 2). In contrast, AD, PD, and SB generally resulted in lower colour retention scores due to prolonged drying times and increased exposure to oxidative degradation. Similar results for other species have been reported by Kumar *et al.* (2023), in which prolonged air drying and press drying were associated with colour fading and textural degradation.

The higher colour retention under MW and SG observed in this study aligns with reports that found that MW preserved anthocyanins and carotenoids more effectively than traditional drying methods (Singh *et al*., 2024). Silica gel's effectiveness is attributed to its ability to provide a moisture-free microenvironment around petals, thus preventing oxidative browning. In contrast, AD and SB drying expose flowers to direct environmental conditions, which can cause pigment oxidation and photo-degradation (Singh and Laishram, 2010).

Shape retention determines the ornamental value and usability of dried flowers. Silica gel drying and PD preserved flower shape most effectively, with scores reaching 4.6 - 5.0 in some species (Table 2). Microwave drying and OD also demonstrated adequate shape retention, with values typically above 3.6. Air drying and SB often produced misshapen or distorted flowers, resulting in lower shape retention scores. In terms of texture, which reflects the brittleness and handling quality of dried flowers, MW, SG, and OD maintained desirable texture scores, often reaching 4.0 or above. These methods preserved the physical integrity of the petals while minimizing brittleness. Conversely, AD and SB typically resulted in dry, fragile flowers with poor texture, making them less suitable for commercial use. Considering the combined effect of all evaluated parameters, MW consistently produced the highest overall quality scores (4.4 - 5.0), demonstrating superior performance in preserving colour, shape, and texture while ensuring rapid drying. Silica gel drying also yielded satisfactory overall quality scores (3.4 - 3.7), particularly due to its effectiveness in maintaining flower shape and colour. Hot air oven drying produced acceptable-quality dried products in most cases, whereas AD, PD, and SB generally resulted in a comparatively lower product quality.

Earlier research supports these observations. Singh *et al*. (2024) reported that SG drying was particularly effective in maintaining the natural shape of delicate flowers due to its cushioning effect. Similarly, they noted that MW drying prevented shriveling by allowing uniform moisture removal. In contrast, SB drying, although economical, often exerts mechanical stress on petals, leading to deformation (Singh *et al*., 2024). These results collectively reinforce those methods combining rapid drying with structural support yield better ornamental quality.

Based on overall performance, MW proved the most effective drying method, ensuring rapid drying with superior colour, texture, and quality. Silica gel drying performed moderately well, especially for delicate flowers. Hot air oven drying, PD, and SB produced lower-quality dried products. Based on overall quality, *B. spectabilis* and *H. sanguinea* emerged as the most promising species for dried flower production (Table 2). They consistently maintained vibrant colour, good texture, and structural integrity. Their resilience during drying makes them ideal for commercial and decorative use. *Ixora coccinea* also showed potential, achieving satisfactory scores across most quality traits. In contrast, *P. rubra* and *P. volubilis* recorded lower overall quality, especially in shape retention and acceptability (Figure 1).

These species-specific results agree with earlier findings. *Bougainvillea* is widely reported as a suitable ornamental species for drying due to its papery bracts and pigment stability (Kumar *et al*., 2023). Similarly, *H. sanguinea* has been noted to retain vibrant colour and shape when dried under controlled conditions. Conversely, *P. rubra* and *P. volubilis* possess fleshy petals with high moisture, making them more prone to shrinkage and discoloration, as also reported by Mir *et al*. (2020). These findings underline the importance of selecting flower species with inherent structural and pigment resilience for dried flower production.

Quality of Dried Flowers During Storage

The evaluation of colour changes during storage revealed clear differences in the stability of colour retention among flower species and between the two drying methods (SG and MW drying; Figure 2A). Under MW, *B. spectabilis*, *H. sanguinea,* and *I. coccinea* retained high colour scores (4.0 – 5.0) with minimal decline throughout the storage duration, suggesting superior pigment preservation and resistance to post-drying discolouration. *P. rubra* and *P. volubilis*, however, exhibited comparatively lower colour scores under MW, although their values remained relatively consistent over time.

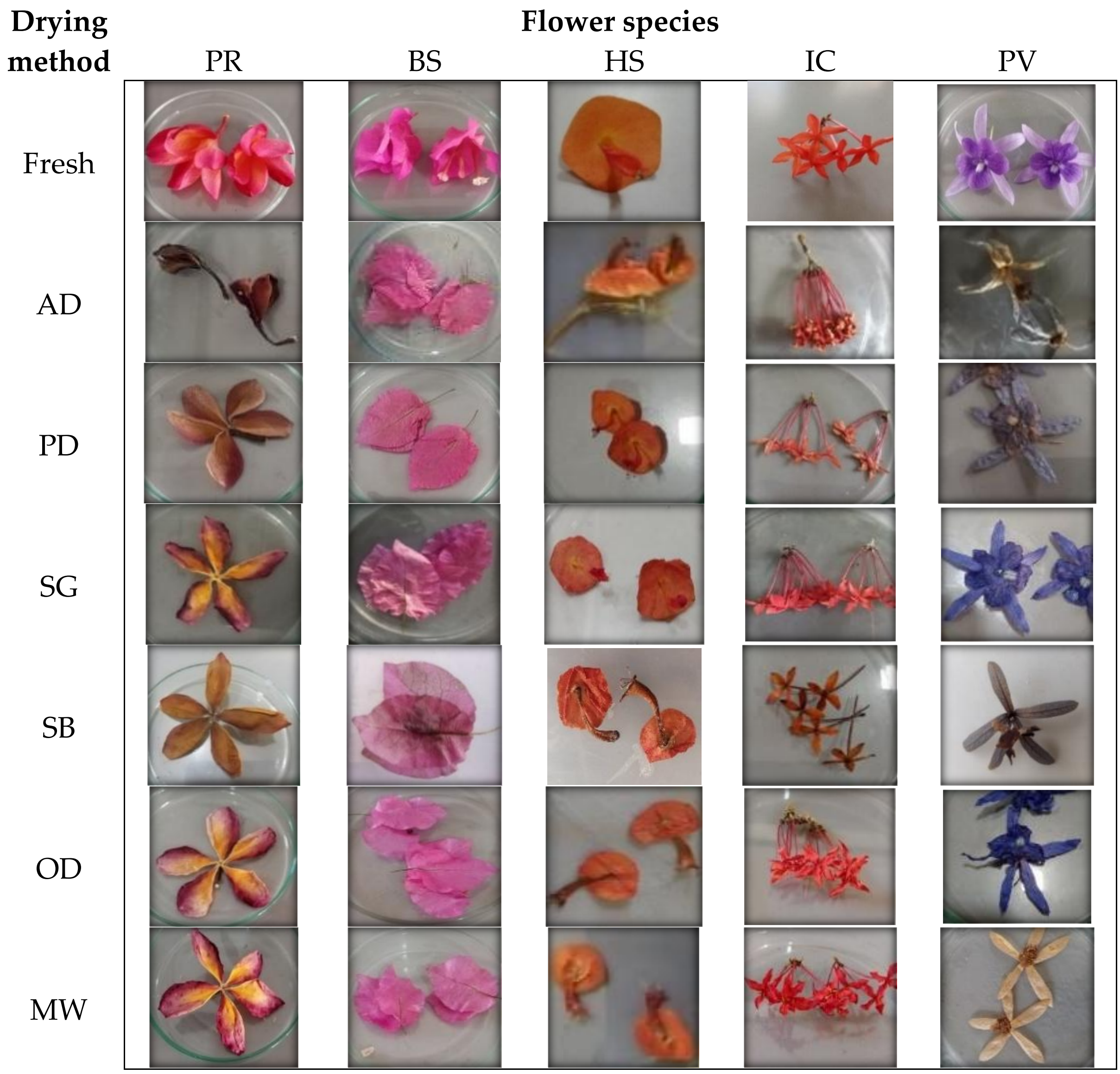

Figure 1. The appearance of five flower species after application of different drying treatments. *PR = Plumeria rubra, BS = Bougainvillea spectabilis, HS = Holmskioldia sanguinea, IC = Ixora coccinea, PV = Petrea volubilis. AD = Air drying, PD = Press drying, SG = Silica gel drying, SB = Sand-Borax drying, OD = Oven drying, MW = Microwave drying.*

In contrast, under SG, noticeable declines in colour scores were observed in *H. sanguinea*, *I. coccinea*, and *P. rubra* after approximately 28 – 35 days of storage (Figure 2A). This suggests that while SG is effective in immediate post-drying colour preservation, slower moisture diffusion during storage may facilitate gradual pigment degradation. *Bougainvillea spectabilis* showed moderate colour stability under SG but still exhibited a gradual decline towards the latter stages of storage. *P. volubilis* consistently recorded the lowest colour retention scores under both drying methods, reflecting its inherent sensitivity to pigment degradation during storage (Kumar *et al*., 2023). These findings indicate that MW not only provides superior initial colour retention but also ensures greater long-term stability of dried flower colour during storage. Silica gel drying while effective initially, showed more noticeable colour fading in certain species as storage duration extended (Figure 2A).

The evaluation of overall quality changes during storage revealed clear differences in the stability of flower quality retention among the flower species and between the two drying methods (Figure 2B). Microwave drying consistently maintained higher and more stable overall quality scores across the 63-day storage period for most flower species compared to SG. This indicated that MW was superior in preserving the physical and aesthetic characteristics of flowers during storage.

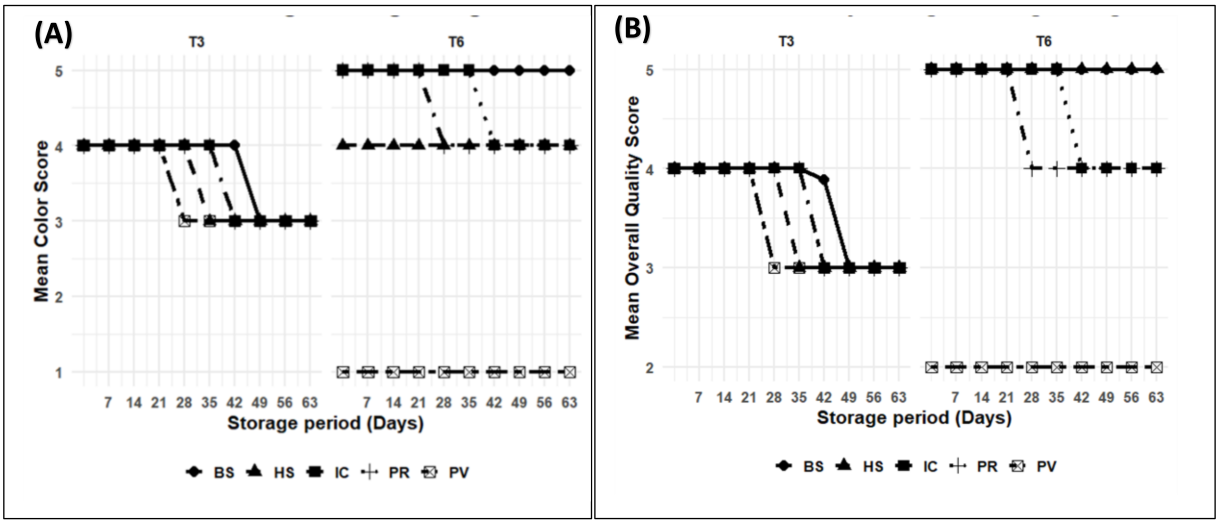

Figure 2. Changes in colour retention (A) and overall quality (B) of dried flowers during storage under silica gel (T3) and microwave (T6) drying methods.

Score: 5 = Excellent, 4 = Very good, 3 = Good, 2 = Fair, 1 = Poor. PR = Plumeria rubra, BS = Bougainvillea spectabilis, HS = Holmskioldia sanguinea, IC = Ixora coccinea, PV = Petrea volubilis

In contrast, SG exhibited moderate declines in overall quality, particularly for *P. volubilis* and *P. rubra*, highlighting that certain species with high moisture or delicate structures are more prone to deterioration over time. These findings support the conclusion that species-specific characteristics, such as petal thickness and moisture content, significantly affect storage stability and should guide the selection of drying methods (Gupta *et al*., 2019).

The study clearly indicates that MW is superior to SG in preserving both initial quality and long-term stability of dried flowers. Rapid moisture removal during microwave drying reduces the exposure of pigments and tissues to oxidative stress, whereas SG, while effective in initial shape and colour retention, allows gradual moisture diffusion that can lead to colour fading and reduced overall quality over time.

The species-specific response observed, particularly the lower performance of PV and PR, suggests that even highly effective methods like MW may require adaptation for sensitive species. These results align with previous findings that demonstrated the flower morphology and moisture content are key determinants of drying and storage outcomes (Shahin *et al.,* 2025).

CONCLUSION

This study demonstrated that both flower species and the drying techniques significantly influenced the physical, ornamental, and sensory qualities of dried flowers. Among the six methods tested, microwave oven drying (MW) proved most effective, offering superior drying time, colour retention, texture, and overall quality. Silica gel (SG) and hot air oven drying (OD) also performed well, though their effectiveness varied among species. *Bougainvillea spectabilis* and *Holmskioldia sanguinea* showed the highest potential for dried flower production. Microwave drying and SG drying resulted in a higher overall quality of these flowers during a 2-month storage. These findings highlight opportunities to diversify Sri Lanka's floriculture sector by introducing underutilized flowers and adopting efficient drying techniques.

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