



RESEARCH ARTICLE

Optimising techniques for high-quality preservation of hybrid Rose cv. 'Minu Parle': Physicochemical, sensory and multivariate insights

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Abstract

Flower preservation is an important value-addition strategy in commercial floriculture, particularly for short-lived ornamentals such as roses. This study evaluated 5 chemical formulations comprising ethanol, acetone, acetic acid, citric acid and glycerine to optimise the preservation of Hybrid rose cv. 'Minu Parle'. Flowers were processed through depigmentation, re-pigmentation and silica-gel drying at 40 °C, followed by assessment of moisture content, dry weight, texture, colour absorption and overall appearance. Significant differences among treatments ($P < 0.05$) were recorded. Among the tested formulations, the multi-solvent combination of ethanol + acetone + acetic acid + glycerine (T5) consistently produced superior results. Flowers treated with T5 exhibited the lowest residual moisture (13.25 %) compared with T1 treatment having maximum moisture (18.08%), higher dry weight retention (2.99 g) and maximum textural stability (3.75 out of 5), along with the highest dye absorption (4.75 mL) and most appealing aesthetic quality (3.58 out of 5) during storage. Texture score in T5 (3.75) was nearly 2 times higher than T1(1.75). Correlation analysis identified moisture content as the primary factor negatively influencing texture and appearance, while Principal Component Analysis showed that moisture-driven variation accounted for the majority of total variance, clearly separating treatments based on quality attributes. The enhanced performance of T5 appears to result from the synergistic dehydrating ability of ethanol-acetone coupled with humectant action of glycerine. Overall, the study establishes an efficient, reproducible and commercially viable multi-solvent protocol for producing high-quality preserved roses, offering significant potential for adoption in floriculture-based value-addition and dry flower industries.

Keywords: preserved flowers; multi-solvent dehydration; hybrid rose; moisture-quality relationship; silica-gel drying

Introduction

The global demand for long-lasting ornamental products has increased steadily, creating expanded opportunities for value addition within the floriculture industry. Among ornamental crops, roses (*Rosa hybrida* L.) are one of the most commercially important cut flowers of the world with an area of 29. 41 thousand ha and production of 301.95 thousand MT in India (1). However, fresh rose has a relatively short vase life 7–8 days, depending upon the variety and other factors leading to physiological deterioration after harvest (2). This limitation has ignited interests in development of different preservation techniques that can extend the utility and market value of roses (1, 2). Dried and preserved flowers are widely used in décor, craft and boutique markets, offering farmers and entrepreneurs a profitable diversification option. Traditional preservation methods such as air-drying and press-drying are inexpensive but often result in colour fading, deformation and brittleness, limiting their suitability for premium commercial applications (3). Desiccant-based drying offers improved retention of shape and colour by rapidly reducing moisture to 12–14 %, thereby minimizing microbial and biochemical degradation during storage (4–6).

To meet commercial expectations for flexible, vibrant and durable preserved flowers, several advanced technologies have been introduced. The Vermont Process demonstrated the effectiveness of glycerine-based sap replacement in producing soft, “life-like” flowers with enhanced colour preservation, although high processing costs have restricted its large-scale adoption (7). Subsequent commercial innovations in the 1990s incorporated polyethylene glycol and multi-step treatments-including depigmentation, re-pigmentation and controlled solvent-assisted dehydration-which improved stability and colour uniformity, as documented in polymer-based floral preservation studies (8–10). Despite these developments, scientific evaluation of solvent combinations and their effects on preserved rose quality remains limited. Several studies have demonstrated that drying methods significantly influence colour retention, shrinkage and overall quality of dried roses (11, 12). Moreover, the use of suitable dehydration techniques and desiccants plays an important role in improving moisture removal and maintaining structural stability in ornamental flowers (13, 14).

However, limited information is available on the combined effects of different multi-solvent formulations on moisture reduction, colour absorption and texture stability in hybrid roses. In view of the growing market demand for premium preserved florals, there is a need for standardised, cost-effective and scalable preservation protocols. Therefore, the present study was conducted at AICRP on Floriculture, BCKV, to evaluate the influence of selected solvent combinations on moisture reduction, texture retention, colour enhancement and structural stability in Hybrid rose cv. 'Minu Parle'.

Materials and Methods

Hybrid rose cv. 'Minu Parle', cultivated at AICRP on Floriculture, BCKV (2021), was used for the experiment. Flowers were harvested at the fully opened stage, trimmed to a uniform stalk length of 5 cm, and subjected to 5 chemical formulations, each previously reported as an effective dehydration agent for roses and other ornamentals (13):

T1: 70 % ethyl alcohol + 20 % acetic acid+ glycerine 20 % +dye (Control as per previous studies)

T2: 70 % acetone+ 20 % acetic acid+ glycerine 20 % +dye

T3: 70 % acetone+ citric acid (10 %) + glycerine 20 % +dye

T4: 70 % acetone+ citric acid (20 %) + glycerine 20 % +dye

T5: 70 % ethyl alcohol + 70 % Acetone + 20 % acetic acid+ glycerine 20 % +dye

Depigmentation was carried out using graded ethanol solutions, following standard rose pigment extraction protocols (15–17). Re-pigmentation was performed by immersing the flowers in a 4 % food-grade dye solution for 24 hr, using established procedures for uniform colour infusion in dehydrated ornamentals (18,19). The dye used was a commercial food-grade red dye (Allura Red AC (Red 40/INS 129), commonly used for beverages, candy and sweets.

Treated flowers (each treatment consisted of 4 replications with 10 flowers per replication) were then embedded in silica gel and dried in a hot-air oven at 40 °C and weight was measured at 6 hr interval, till a constant weight was observed. The difference between the fresh weight and dry weight gives the actual moisture content of flowers or loss of moisture.

Observations recorded

Quantitative parameters

a. Flower dry weight (g)

b. % moisture content- calculated following standard methodology (20).

Moisture content (%) was calculated using the formula =

$$\frac{\text{Fresh weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

c. Flower diameter (cm)

Qualitative parameters

a. Flower shape integrity

b. Colour absorption

c. Petal texture - following standard scale of (21)

d. Brittleness (1-5 scale)

Brittleness of dried petals was evaluated visually and manually using a five-point hedonic scale where 1 = very brittle and 5 = highly flexible (8).

e. Brightness (1-5 scale)

Brightness of the flower colour was assessed visually using a five-point rating scale (1 = very dull, 5 = very bright) (8).

f. Overall appearance (1–5 scale)

Overall appearance of dried flowers was evaluated based on colour, texture and shape retention using a 5-point visual scoring scale (1 = poor, 5 = excellent) following standard methods used in dried flower evaluation (19–21).

A Completely Randomised Design (CRD) was adopted for the experiment with four replications per treatment. Data were analysed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) for mean separation using SPSS statistical software (version 22.0, IBM Corp., USA) in accordance with standard procedures used in floriculture research (22).

Results and Discussion

Moisture content dynamics

Significant variation in moisture loss was observed across treatments (Table 1), confirming that solvent composition strongly influences dehydration behaviour, as reported previously for roses and other ornamentals (23, 24). Treatment T5 recorded the lowest residual moisture (12.25–14.00 %), attributable to the synergistic water-extracting efficiency of ethanol-acetone mixtures (25, 26). Conversely, T1 exhibited the highest moisture content (17.00-19.00 %), indicating slow solvent penetration and inadequate dehydration. The overall trend (T5 < T2 < T4 < T3 < T1) clearly established T5 as the most efficient dehydration system. Fig. 1 illustrates the moisture variation pattern across treatments. The superior performance of treatment T5 might be attributed to the synergistic physicochemical effects of the ethanol-acetone solvent system, which is are highly polar and water-miscible, allowing rapid

Table 1. Changes in moisture content (%) of dried rose flowers under different preservation treatments

Treatments	Moisture content (%)			
	1 st Month	3 rd Month	5 th Month	Mean
T1: 70 % ethyl alcohol + 20 % acetic acid+ glycerine 20 % +dye	17.00 ± 0.27 ^c	18.25 ± 0.29 ^b	19.00 ± 0.22 ^a	18.08 ± 0.89^a
T2: 70 % acetone+ 20 % acetic acid+ glycerine 20 % +dye	14.00 ± 0.19 ^g	15.00 ± 0.24 ^f	16.00 ± 0.29 ^d	15.00 ± 0.88^d
T3: 70 % acetone+ citric acid (10 %) + glycerine 20 % +dye	15.00 ± 0.32 ^f	16.00 ± 0.33 ^d	17.25 ± 0.31 ^c	16.08 ± 1.00^b
T4: 70 % acetone+ citric acid (20 %) + glycerine 20 % +dye	14.75 ± 0.27 ^f	15.50 ± 0.25 ^e	17.00 ± 0.20 ^c	15.75 ± 1.00^c
T5: 70 % ethyl alcohol + 70 % Acetone + 20 % acetic acid+ glycerine 20 % +dye	12.25 ± 0.25 ⁱ	13.50 ± 0.28 ^h	14.00 ± 0.22 ^g	13.25 ± 0.80^e
Mean	14.60 ± 1.59^c	15.65 ± 1.61^b	16.65 ± 1.70^a	

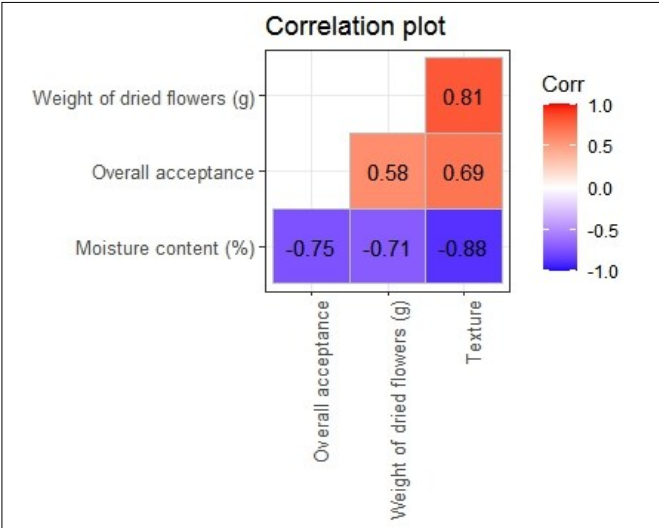


Fig. 1. Correlation matrix illustrating relationships among major quality attributes of preserved rose flowers.

penetration through petal cell membranes and facilitating efficient intracellular water displacement. The mixed ethanol-acetone system likely formed a quasi-azeotropic environment that enhanced dehydration efficiency by reducing surface tension and accelerating solvent diffusion within petal tissues. This rapid solvent exchange promoted removal of bound water molecules from cellular matrices while minimising structural collapse, which explained the significantly lower moisture content recorded in T5 (13.25 %) compared with other treatments. Similar solvent-assisted dehydration effects have been reported in roses and other ornamental flowers (15, 16).

Dry weight retention

Dry weight differed significantly among treatments (Table 2), reflecting the close relationship between solvent-induced dehydration and structural mass stability (27). T4 showed the highest dry weight retention (3.37–2.59 g), followed closely by T5 (3.34–2.47 g), suggesting

effective cytoplasmic water replacement by acetone and improved structural stabilization (28, 29). T1 had the lowest dry weight values, consistent with its high residual moisture and greater tissue collapse. A graphical comparison is provided in Fig. 2.

Texture quality (sensory evaluation)

Texture scores varied markedly (Table 3), with T5 maintaining the highest flexibility and lowest brittleness throughout storage, aligning with earlier glycerine-solvent preservation findings (30–32). Texture deterioration was most pronounced in T1 (2.75→1.25), indicating the brittle nature of inadequately dehydrated petals. Although texture declined across all treatments over time, the slowest rate of decline occurred in T5, demonstrating its superior structural stability. A visual summary is shown in Fig. 3. Glycerine present in the formulation acted as a humectant and plasticizing agent that partially replaced cellular water, maintaining petal flexibility and preventing brittleness during storage (8).

Colour absorption efficiency

Colour absorption differed significantly among treatments (Table 4). T5 exhibited the highest dye uptake (4.75), consistent with enhanced pigment extraction in acetone-rich systems documented earlier (33, 34). Limited dye penetration in T1 may have resulted from incomplete depigmentation, like earlier observations in alcohol-only systems (35). Fig. 4 presents the absorption pattern. Enhanced dye absorption during re-pigmentation was carried out using a 4 % aqueous solution of food-grade synthetic dye (Allura Red AC; INS 129), a water-soluble azo dye commonly used in food and beverage products. The higher colour uptake recorded in T5 (4.75 mL) indicates that solvent-assisted depigmentation improved cell membrane permeability and pigment diffusion pathways within petal tissues.

Overall appearance

Table 2. Changes in dry weight (g) of dried rose flowers under different preservation treatments

Treatments	Weight of dried flowers (g)			
	1 st Month	3 rd Month	5 th Month	Mean
T1: 70 % ethyl alcohol + 20 % acetic acid+ glycerine 20% +dye	2.82 ± 0.09 ^{de}	2.33 ± 0.10 ^{hi}	2.08 ± 0.13 ^j	2.41 ± 0.33^c
T2: 70 % acetone+ 20 % acetic acid+ glycerine 20 % +dye	3.18 ± 0.11 ^b	2.65 ± 0.10 ^f	2.23 ± 0.09 ⁱ	2.69 ± 0.42^b
T3: 70 % acetone+ citric acid (10 %) + glycerine 20 % +dye	2.97 ± 0.11 ^{cd}	2.73 ± 0.09 ^{ef}	2.44 ± 0.08 ^{gh}	2.71 ± 0.24^b
T4: 70 % acetone+ citric acid (20 %) + glycerine 20 % +dye	3.37 ± 0.09 ^a	3.00 ± 0.13 ^c	2.59 ± 0.13 ^{fg}	2.99 ± 0.35^a
T5: 70 % ethyl alcohol + 70 % acetone + 20 % acetic acid+ glycerine 20 % +dye	3.34 ± 0.11 ^a	2.93 ± 0.10 ^{cd}	2.47 ± 0.09 ^{gh}	2.91 ± 0.38^a
Mean	3.14 ± 0.24^a	2.73 ± 0.26^b	2.36 ± 0.21^c	

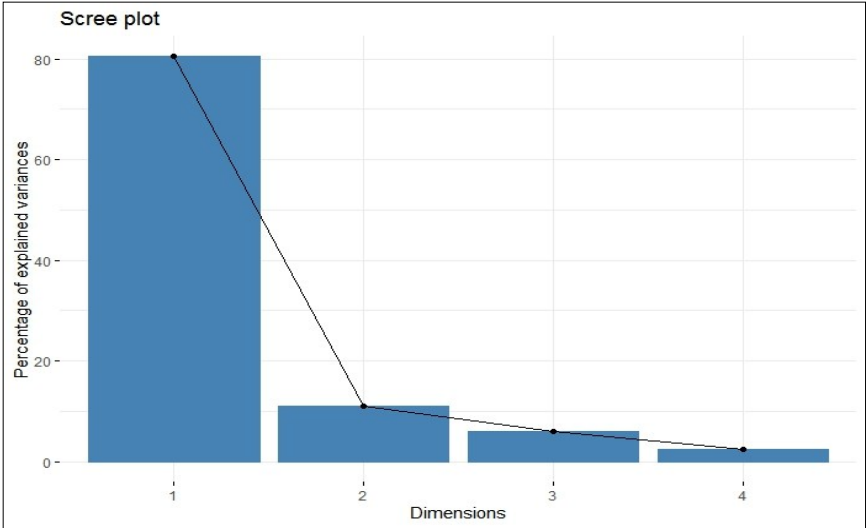


Fig. 2. Scree plot illustrating the proportion of total variance contributed by each principal component.

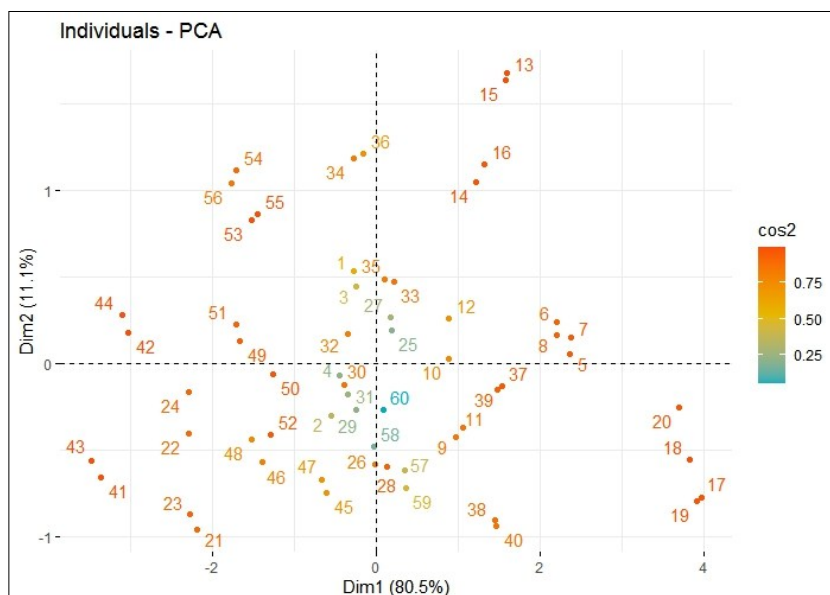


Fig. 3. Principal Component Analysis (PCA) of individual samples showing variation in quality traits of preserved rose flowers.

Table 3. Influence of processing methods on the texture of dried roses as assessed through sensory evaluation

Treatments	Texture			
	1 st Month	3 rd Month	5 th Month	Mean
T1: 70 % ethyl alcohol + 20 % acetic acid+ glycerine 20 % +dye	2.75 ± 0.22 ^{ef}	1.25 ± 0.16 ^h	1.25 ± 0.27 ^h	1.75 ± 0.76^e
T2: 70 % acetone+ 20 % acetic acid+ glycerine 20 % +dye	4.50 ± 0.21 ^b	3.00 ± 0.16 ^{de}	2.60 ± 0.21 ^{fg}	3.37 ± 0.87^b
T3: 70 % acetone+ citric acid (10 %) + glycerine 20 % +dye	3.25 ± 0.29 ^d	2.50 ± 0.22 ^{fg}	2.25 ± 0.21 ^g	2.67 ± 0.50^d
T4: 70 % acetone+ citric acid (20 %) + glycerine 20%+dye	4.00 ± 0.21 ^c	2.75 ± 0.27 ^{ef}	2.40 ± 0.25 ^{fg}	3.05 ± 0.75^c
T5: 70 % ethyl alcohol + 70 % acetone + 20 % acetic acid+ glycerine 20 % +dye	5.00 ± 0.31 ^a	3.25 ± 0.25 ^d	3.00 ± 0.27 ^{de}	3.75 ± 0.96^a
Mean	3.90 ± 0.87^a	2.55 ± 0.74^b	2.30 ± 0.64^c	

Table 4. Influence of processing methods on colour absorption in roses assessed through sensory evaluation during 24 hr of dyeing

Treatments	Colour absorption (ml)
T1: 70 % ethyl alcohol + 20 % acetic acid+ glycerine 20 % +dye	3.00 ± 0.73
T2: 70 % acetone+ 20 % acetic acid+ glycerine 20 % +dye	4.00 ± 0.82
T3: 70 % acetone+ citric acid (10 %) + glycerine 20 % +dye	3.75 ± 0.69
T4: 70 % acetone+ citric acid (20 %) + glycerine 20%+dye	4.50 ± 0.66
T5: 70 % ethyl alcohol + 70 %Acetone + 20 % acetic acid+ glycerine 20 % +dye	4.75 ± 0.74

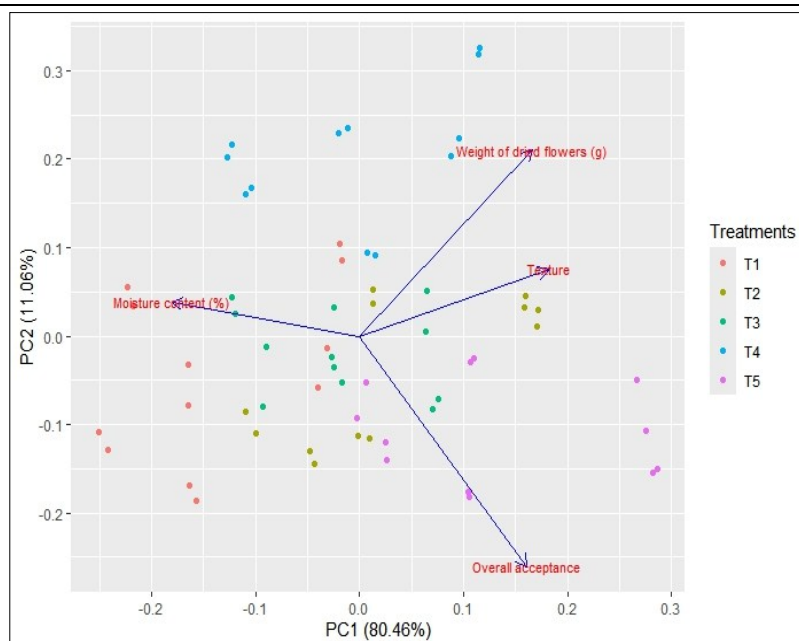


Fig. 4. Principal Component Analysis (PCA) biplot showing the distribution of preserved rose flowers across different treatments.

Overall appearance scores (Table 5) indicated that T5 produced visually superior flowers throughout storage, corroborating previous evidence that multi-solvent systems enhance aesthetic stability (36). T2 and T3 performed moderately well, while T4 and T1 showed duller colour and textural collapse toward Month 5. See Fig. 5 for comparative visual ratings. Compared with single-solvent systems, the combined ethanol-acetone-acid-glycerine formulation used in T5 appeared to create a balanced dehydration environment in which rapid water removal, improved pigment diffusion and structural stabilisation occurred simultaneously. This multi-functional mechanism likely explained the superior texture retention, higher dye absorption and better overall appearance observed in T5 during storage. Similar improvements have been reported earlier (18, 34). Furthermore, it was reported that improved quality attributes in dried roses when efficient dehydration methods were employed (12), while, another work observed similar improvements in colour retention and texture stability in gerbera flowers subjected to optimised drying treatments (13).

Correlation and multivariate analysis

Correlation analysis showed a strong negative association between moisture content and both texture (-0.88) and overall acceptance (-0.75), supporting earlier work emphasizing residual moisture as the primary driver of quality deterioration (37). PCA results indicated that PC1 explained more than 80 % of total variance, confirming moisture-related effects as the dominant quality dimension (38). T5 clustered closely with texture and dry weight vectors in the PCA biplot, while T1 aligned with high moisture loadings, mirroring patterns reported in multivariate studies on dried chrysanthemum,

statice and zinnia (39–41). Confidence ellipses further showed tight clustering for T5, reflecting its uniform performance, whereas T1 exhibited wide dispersion, like earlier rose and gerbera dehydration analyses (42–44) (Fig. 6, Fig. 7).

Implications for the dry flower industry

The growing global demand for value-added ornamental products has increased the need for high-quality, long-lasting preserved flowers, particularly for décor, craft, gifting and export markets (45). The present study provides a scientifically validated preservation protocol capable of producing uniform, structurally stable and aesthetically appealing dried roses through a multi-solvent system.

Similar findings have been reported in previous studies where solvent-assisted dehydration improved the quality of dried ornamental flowers. Ethanol and acetone-based treatments enhanced moisture removal and structural stability in roses (9), while optimised dehydration methods improved colour retention and reduced shrinkage (10). Similar effects on colour brightness and texture stability were also reported in gerbera (11), supporting the present results. Among the tested treatments, the T5 formulation comprising ethanol, acetone, acetic acid and glycerine demonstrated clear advantages by offering (i) the most efficient dehydration, (ii) superior texture and structural integrity, (iii) maximum colour retention and dye absorption, and (iv) consistently attractive appearance during storage. These attributes align with earlier reports identifying multi-solvent and glycerine-assisted dehydration as promising directions for commercial dry flower technology (46–47). The reproducibility and high performance of T5 indicate strong potential for its adoption in floriculture-based value-

Table 5. Sensory evaluation of overall appearance in dried roses under different processing methods

Treatments	Overall appearance			
	1 st Month	3 rd Month	5 th Month	Mean
T1: 70 % ethyl alcohol + 20 % acetic acid+ glycerine 20 % +dye	2.75 ± 0.24 ^b	2.50 ± 0.28 ^c	1.75 ± 0.25 ^d	2.33 ± 0.50^c
T2: 70 % acetone+ 20 % acetic acid+ glycerine 20 % +dye	3.50 ± 0.20 ^{cd}	2.75 ± 0.31 ^d	2.50 ± 0.29 ^e	2.92 ± 0.51^b
T3: 70 % acetone+ citric acid (10 %) + glycerine 20 % +dye	3.25 ± 0.24 ^a	2.75 ± 0.25 ^b	2.25 ± 0.30 ^c	2.75 ± 0.49^b
T4: 70 % acetone+ citric acid (20 %) + glycerine 20 % +dye	2.50 ± 0.17 ^{cd}	2.25 ± 0.27 ^e	1.50 ± 0.29 ^{fg}	2.08 ± 0.50^d
T5: 70 % ethyl alcohol + 70 %Acetone + 20 % acetic acid+ glycerine 20 %	4.50 ± 0.36 ^c	3.50 ± 0.23 ^{cd}	2.75 ± 0.25 ^{de}	3.58 ± 0.79^a
Mean	3.30 ± 0.75^a	2.75 ± 0.49^b	2.15 ± 0.54^c	

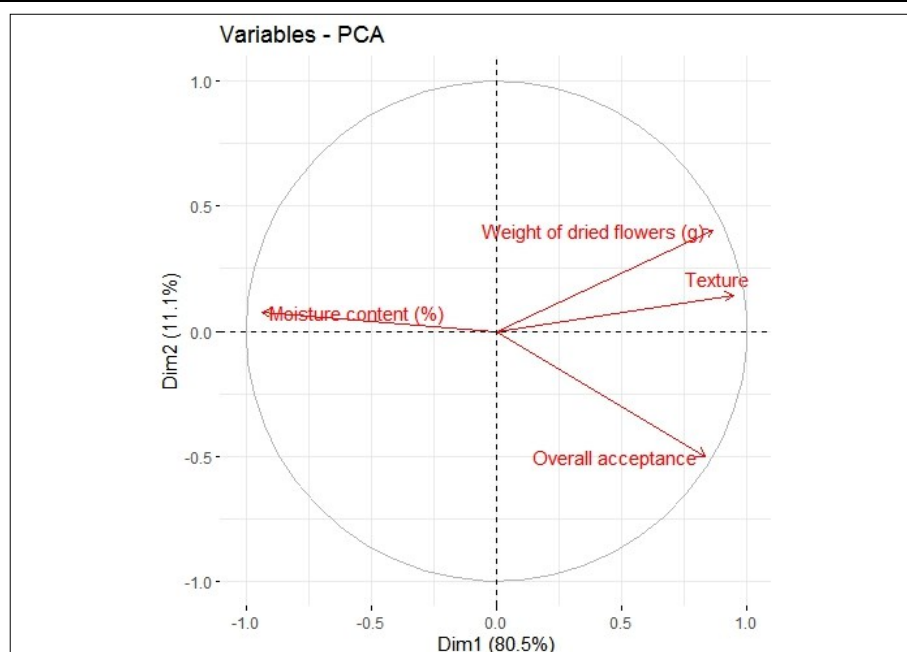


Fig. 5. Principal Component Analysis loading plot (Variables-PCA) illustrating the contribution of individual quality traits to principal components.

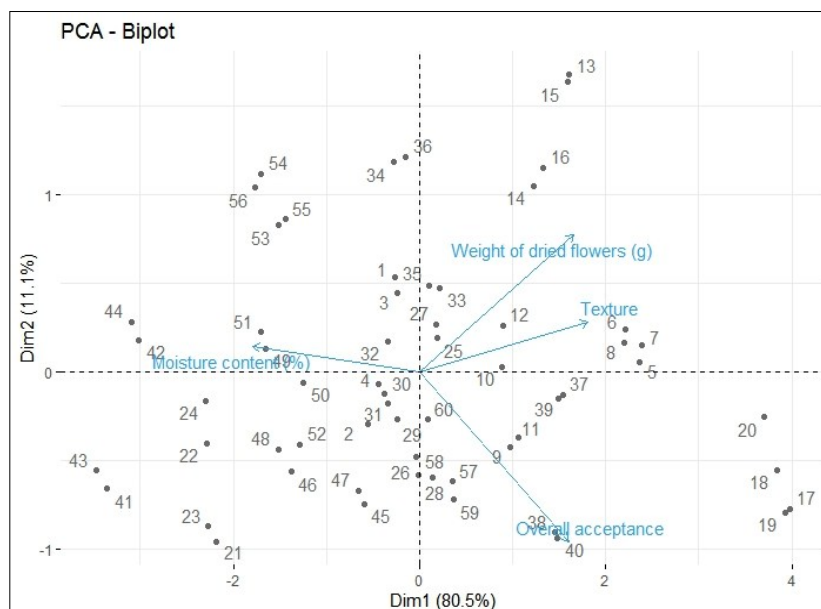


Fig. 6. Principal Component Analysis (PCA) biplot illustrating both variable loadings and the distribution of individual samples across treatments.

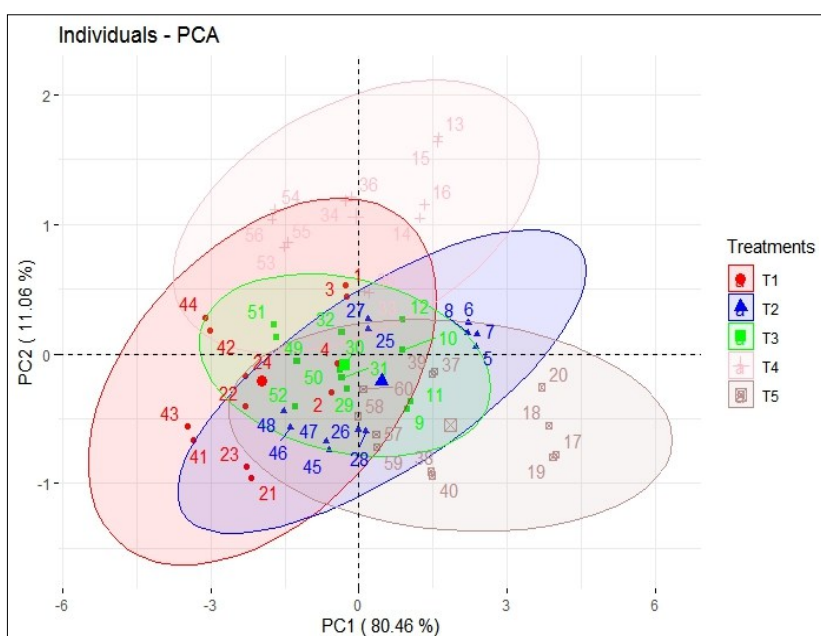


Fig. 7. Principal Component Analysis (PCA) confidence ellipses showing treatment-wise clustering of samples.

addition units, including home-based enterprises, small craft studios and commercial dry flower industries. By improving product quality and reducing post-processing losses, this protocol can enhance market competitiveness and support the expanding sector of preserved floral products (Fig. 8).

Conclusion

The study demonstrated that solvent composition plays a decisive role in determining the quality of preserved rose flowers. T1 was used as a reference formulation based on previously reported preservation protocols for roses. Therefore, the conclusion has been revised to clarify that T5 produced the best results among the tested treatments, rather than implying superiority over an untreated control. Correlation and PCA analyses further confirmed moisture content as the primary factor influencing structural and aesthetic stability. The findings highlight T5 as a reliable, reproducible and commercially viable preservation protocol. This approach holds

strong potential for adoption by floriculture enterprises seeking to produce premium value-added dry flower products.

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Authors' contributions

SCD conceived of the study and participated in its design layout, overall coordination and drafted the manuscript. VCN performed the experiments under the guidance of SCD and collected data. KB participated in the botanical studies. All authors read and approved the final manuscript.



Flowers dipped in alcohol for depigmentation



Depigmented flowers



Dyeing

Plate 1-4. Pre-treatment of rose flowers for preservation



Dyed flower



Plate 5. Embedding of flowers in silica gel for dehydration



Treatments	Dried flowers
T1: 70 % ethyl alcohol + 20 % acetic acid + glycerine 20 % + Dye	
T2: 70 % acetone + 20 % acetic acid + glycerine 20 % + Dye	
T3: 70 % acetone + citric acid (10 %) + glycerine 20 % + Dye	
T4: 70 % acetone + citric acid (20 %) + glycerine 20 % + Dye	
T5: 70 % ethyl alcohol + 70 % Acetone + 20 % acetic acid + glycerine 20 % + dye	

Plate 6. Display of dried rose flowers dried in hot air oven embedded with silica gel after pre-treated with different chemicals

Fig. 8. Dry flower technology pathway.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflict of interest to declare.

Ethical issues: None

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