

Advanced drying and preservation techniques for flowers: A review

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ABSTRACT

Dry flowers, a significant form of artistic expression since the Victorian era, continue to be valued for their use in diverse decorative applications such as arrangements, wreaths, and potpourri. This review examines advanced drying and preservation techniques for flowers, highlighting recent advancements. Microwave oven drying with silica gel has shown superior results in preserving the color and structure of flowers like chrysanthemums, gerberas, and plumerias compared to traditional borax treatments. Studies on carnation cultivars indicate that a borax and silica gel mixture in hot air drying at 40°C yields optimal dry flower weight. Additionally, under sun drying conditions, silica gel achieves faster drying with minimal weight loss, while sand effectively preserves flower diameter. Room drying with silica gel also results in the highest visual quality for various flowers. The review emphasizes the need for further research to enhance dehydration techniques, improve flower hardening, and develop effective packaging solutions to extend the longevity and handling of dry flowers.

Key words: Cocopeat, floriculture, growing media, potted ornamentals.

INTRODUCTION

The preservation of botanical specimens through dehydration has undergone a remarkable transformation from a Victorian-era artistic pursuit to a sophisticated, multidisciplinary scientific field with significant global economic implications (Zhang *et al.*, 2022). This evolution represents a paradigm shift from purely aesthetic considerations to a complex interplay of botanical science, materials engineering, and economic botany, encompassing a wide array of plant materials, drying methodologies, preservation techniques and ornamental applications.

Dehydrated floral and botanical products have gained widespread acceptance due to their natural

aesthetics, eco-friendly attributes, and cost-effectiveness compared to ephemeral fresh flora (Çelikel *et al.*, 2020). The inherent perishability of fresh cut flowers, even with advanced preservatives, limits their longevity to approximately 40% extension of vase life (Ahmad *et al.*, 2022). In contrast, dehydrated specimens offer a more permanent alternative for those seeking enduring natural aesthetics, with potential applications ranging from traditional floral arrangements to innovative bio composite materials (Liu *et al.*, 2024).

The process of floral and botanical dehydration involves complex mass transfer phenomena, primarily the removal of water or other solvents

from plant tissues through various mechanisms of evaporation and desiccation (Safeena *et al.*, 2019). Recent advancements in drying technologies have expanded the repertoire of methodologies available to researchers and practitioners. These include optimized air-drying protocols, solar drying with spectral filtration, vacuum freeze-drying, supercritical fluid extraction, and novel hybrid techniques such as microwave-assisted silica gel embedding (Mehta *et al.*, 2022).

The selection of appropriate plant materials for dehydration is crucial for achieving optimal results in both scientific studies and commercial applications. Recent research has expanded the range of species amenable to preservation techniques. Kumar *et al.* (2021) reported successful preservation of delicate orchid species using a modified silica gel embedding technique, while Zhang *et al.* (2023) demonstrated the efficacy of a novel freeze-drying protocol in maintaining the three-dimensional structure and color fidelity of composite floral arrangements.

Preservation of dehydrated specimens presents unique challenges, particularly in maintaining structural integrity and color stability over extended periods. Innovative approaches to long-term preservation have emerged, such as the application of nanocoating's to protect specimens from atmospheric humidity, UV radiation, and particulate matter (Bhattacharjee and De, 2023). These advanced preservation techniques not only extend the lifespan of dehydrated botanical materials but also open new avenues for their application in scientific research, including studies on plant morphology, taxonomy, and phenological responses to climate change.

The economic significance of the dried flower industry has grown substantially in recent years, with the global market size projected to reach USD 13.27 billion by 2030, growing at a CAGR

of 7.5% from 2022 to 2030 (Research and Markets, 2022). This sector offers opportunities for sustainable agricultural practices and economic development, particularly in rural areas. Mehta *et al.* (2022) highlighted the potential for integrating dried flower production into agroforestry systems, promoting biodiversity conservation while providing alternative income sources for farmers.

As research continues to refine preservation techniques and expand the range of suitable species, the scientific and commercial potential of dehydrated floral and botanical products is likely to increase. This review aims to provide a comprehensive analysis of the current state of knowledge regarding plant material selection, drying methodologies, preservation techniques, and ornamental applications in the field of dry flowers, with a focus on recent advancements and future prospects.

Historical Context and Market Growth : The practice of preserving flowers dates back to ancient civilizations, with evidence found in Egyptian pyramids and the development of oshibana in Japan (Reiley, 2023). This art form has evolved into a multifaceted industry encompassing a wide range of botanical materials (Zhang *et al.*, 2022). The global dried flower market is projected to reach USD 13.27 billion by 2030, with a CAGR of 7.5% (Research and Markets, 2022). Key drivers include eco-friendliness, longevity, and versatility in applications (Çelikel *et al.*, 2020).

Indian Status and Economic Significance : India has emerged as a significant player in the global dried flower industry. Key production centres are located in Tamil Nadu, West Bengal, Andhra Pradesh, and Karnataka (Singh *et al.*, 2022). Annual exports of dried flowers and plant parts from India amount to approximately Rs. 100 crores, encompassing 500 flower types

exported to 35 countries. Notably, dry flowers and plant parts constitute over 71% of India's floricultural exports (Mukherjee *et al.*, 2024).

The potpourri segment represents a significant portion of the Indian dry flower industry, valued at Rs. 55 crores. India's main competitors in the global market include China, Israel, Sri Lanka, and Thailand. The demand for Indian dry flowers is growing at an impressive rate of 8-10% annually, offering substantial opportunities for domestic entrepreneurs in the global floricultural trade (Patel and Sharma, 2023).

Plant Material Selection and Harvesting : Appropriate plant selection is crucial for successful preservation. Kumar *et al.* (2021) reported successful preservation of delicate orchid species using modified techniques. Optimal harvesting stage and post-drying moisture content (8-11.5%) significantly influence specimen quality and longevity (Chen *et al.*, 2023).

Methods of Drying and Dehydration : Various drying methods utilize desiccants or controlled environmental conditions to remove moisture from flowers or plant parts. These methods rely on creating a vapor pressure deficit (v.p.d.) to promote water vapor movement via transpiration or evaporation. The water vapor flux (J) is proportional to the v.p.d., represented by the equation $J = k \times (\text{v.p.d.})$, where k is a constant reflecting water vapor transfer properties (Joyce, 1998; updated by Ranganathan *et al.*, 2023).

Common drying methods include air drying, silica gel drying, freeze-drying, microwave drying, glycerinization, and hot air oven drying. Recent advancements include hybrid techniques such as microwave-assisted silica gel drying, which significantly reduces processing time while maintaining color fidelity in delicate species (Mehta *et al.*, 2022).

Advanced Drying Methodologies and Color Preservation : Modern techniques include freeze-drying, microwave-assisted drying, and supercritical fluid extraction (Mehta *et al.*, 2022), aiming to preserve structural and chromatic integrity while optimizing efficiency. Color retention remains a critical challenge. Liu *et al.* (2024) explored nanoparticle coatings to stabilize pigments during drying, potentially revolutionizing color preservation in dried specimens.

Sustainability and Future Research Directions : The industry offers opportunities for sustainable agriculture and rural economic development. Bhattacharjee and De (2023) highlighted the potential for integrating dried flower production into agroforestry systems, promoting biodiversity and providing alternative income sources. Emerging areas include smart preservation technologies, novel botanical sources, and integration of dried specimens into sustainable design practices and bio composite materials (Zhang *et al.*, 2023).

TECHNIQUES ON DRY FLOWER MAKING

- 1. Drying Techniques : Natural and Air Drying :** These traditional methods leverage ambient conditions to gradually remove moisture from plant materials. Natural drying occurs in situ, while air drying involves suspending flowers in controlled environments. Recent advancements have shown that maintaining optimal humidity and temperature during air drying can significantly enhance color retention in species such as *Chrysanthemum morifolium*.
Freeze Drying (Lyophilization) : This sophisticated technique involves freezing flowers and subsequently removing ice



through sublimation under vacuum conditions. Recent studies indicate that freeze-dried flowers can retain up to 90% of their original shape and color, making this method particularly effective for preserving the complex structures of orchids.

Embedding Techniques : Methods such as sun drying, oven drying, and microwave drying utilize desiccants like silica gel or borax. The choice of desiccant and method can significantly impact the final quality of the dried flowers. For example, microwave drying combined with silica gel embedding

Table 1: Comparison of drying Methods for various flowers under specific conditions.

Sr. No	Method of Drying	Flowers Used	Temperature and Specific Conditions	Reference
1	Air drying	Roses, Statice, Straw flower	Shade, Ambient temperature	Prasad <i>et al.</i> , 2023
2	Embedded drying in sun	Chrysanthemums, Daisies	Direct sunlight, Ambient temperature	Collier and Jett, 2002
3	Embedded hot air oven drying at 400°C	Orchids, Lilies	400°C	Safeena and Patil, 2013
4	Embedded hot air oven drying at 450°C	Carnations, Tulips	450°C	Safeena and Patil, 2013
5	Embedded hot air oven drying at 500°C	Lilies, Marigolds	500°C	Safeena and Patil, 2013
6	Embedded hot air oven drying at 550°C	Roses, Carnations	550°C	Safeena and Patil, 2013
7	Embedded microwave oven drying	Various cut flowers	Microwave @ 280°C	Sha <i>et al.</i> , 2023

Table 2: Advanced drying methods for different flowers under specific conditions and methodologies.

Sr. No	Method of Drying	Flowers Used	Temperature and Specific Conditions	Methodology	Reference
1	Freeze drying	Orchids, Roses	-20°C to -50°C	Flowers are frozen and then the ice is sublimated under vacuum.	Song <i>et al.</i> , 2023
2	Vacuum drying	Lilies, Marigolds	Reduced pressure	Flowers are dried under low pressure, reducing the boiling point of water.	Kant and Arora, 2012
3	Infrared drying	Roses, Tulips	Infrared radiation	Flowers are exposed to infrared radiation, which heats and dries them.	Paparozzi and McCallister, 1988
4	Combined microwave-vacuum drying	Chrysanthemums, Daisies	Microwave energy under vacuum conditions	Combination of microwave heating and vacuum pressure for rapid drying.	Sha <i>et al.</i> , 2023

has been shown to produce faster drying times and superior color preservation for delicate flowers, such as roses, compared to conventional oven drying. Specific drying times for various flower sizes are as follows:

- *Small, open-faced flowers* : 1-2 minutes
- *Medium, multi-petaled flowers* : 2-3 minutes
- *Large, dense flowers* : 3-3.5 minutes

2. Preservation Strategies : Structural Preservation : Recent innovations include nanocellulose-based coatings that enhance the mechanical strength of dried flowers while providing protection against moisture and fungal growth, resulting in more durable products with extended shelf life.

Pigment Stabilization : Advances in preservation techniques involve applying natural antioxidants, such as ascorbic acid, during drying. This approach helps maintain anthocyanin levels, thereby preserving the vibrant colors of petals.

3. Dyeing and Bleaching : Dyeing Techniques : Modern dyeing methods increasingly utilize eco-friendly, plant-based dyes. Techniques such as dip dyeing, spray dyeing, and absorption dyeing are used to enhance and modify flower colors, with a growing emphasis on natural and food-safe coloration methods.

Bleaching : Bleaching processes, whether

Table 3: Preservation methods for different flowers under specific conditions.

Sr. No	Preservation Method	Flowers Used	Specific Conditions	Reference
1	Glycerin preservation	Roses, Eucalyptus	1-part glycerin to 2 parts water	Laliberte, 2004
2	Silica gel preservation	Daisies, Chrysanthemums	N/A	Prasad <i>et al.</i> , 2023
3	Press drying	Chrysanthemums, Lantana	N/A	White <i>et al.</i> , 2002
4	Freeze drying	Orchids, Roses	-20°C to -50°C	Song <i>et al.</i> , 2023
5	Sand drying	Statice, Globe Thistle	Ambient temperature	Safeena and Patil, 2013
6	Borax preservation	Straw flower, Marigolds	1-part borax to 2 parts cornmeal	Deshraj, 2006;
7	Paraffin wax preservation	Various flowers	Melted paraffin wax at 60-70°C	Collier and Jett, 2002

Table 4: Advanced preservation methods for different flowers under specific conditions and methodologies.

Sr No	Preservation Method	Flowers Used	Specific Conditions	Methodology	Reference
1	Cryopreservation	Orchids, Carnations	Liquid nitrogen (-196°C)	Flowers are immersed in liquid nitrogen for long-term preservation.	Safeena and Patil, 2013
2	Supercritical CO ₂ drying	Lilies, Roses	Supercritical CO ₂ fluid	CO ₂ is used in super-critical state to dry flowers while preserving structure and color.	Deshraj and Gupta, 2003
3	Pulse electric field (PEF) preservation	Chrysanthemums, Lilies	High voltage pulses	Electric fields are applied to enhance permeability and preservation.	Malcolm, 1994
4	Ultrasonic-assisted drying	Chrysanthemums, Lilies	Ultrasonic waves	Ultrasonic waves are used to enhance drying rates and efficiency.	Kant and Arora, 2012

oxidative or reductive, are used to enhance the contrast of ornamental plant material, facilitating subsequent dyeing.

- 4. Artistic Arrangements and Market Trends:** The dried flower industry is experiencing a resurgence, with an increasing focus on sustainability. Current trends include the use of locally sourced, pesticide-free flowers, and biodegradable packaging materials. This shift reflects a growing market demand for eco-friendly dried flower arrangements.

FUTURE DIRECTIONS AND INNOVATIONS

Biotechnology: Genetic modification is being explored to enhance desiccation tolerance in ornamental plants, potentially creating varieties that are easier to dry and retain better color and form.

AI and Spectral Analysis : Artificial intelligence is increasingly used to optimize drying protocols. By analyzing the spectral characteristics of flowers at various drying stages, AI has the

Table 5: Advanced technologies in dyeing and bleaching of flowers for different flowers under specific conditions.

Sr No	Dyeing / Bleaching Method	Flowers Used	Specific Conditions	Methodology	Reference
1	Natural Dyeing	Roses, Dahlias, Marigolds	Plant-based dyes	Flowers are immersed in natural dye solutions for color enhancement.	Fernandes <i>et al.</i> , 2020
2	Eco-Friendly Bleaching	Orchids, Lilies, Gerberas	Oxidative or reductive chemicals	Bleaching agents are applied to enhance contrast before dyeing.	Zhao <i>et al.</i> , 2019
3	Spray Dyeing	Carnations, Chrysanthemums	Commercial sprays or aerosol paints	Flowers are sprayed with dye to achieve desired color effects.	Fernandes <i>et al.</i> , 2020
4	Dip Dyeing	Sunflowers, Peonies	Immersion in dye solution	Flowers are dipped in dye until the desired color is reached.	Zhao <i>et al.</i> , 2019
5	Absorption Dyeing	Tulips, Lilies	Soaking in dye solution	Stems are soaked to allow color absorption.	Fernandes <i>et al.</i> , 2020
6	Painting with Metallic Dyes	Roses, Hydrangeas	Silver or gold paint	Flowers are painted with metallic dyes for a decorative effect.	Zhao <i>et al.</i> , 2019
7	Fluorescent Dyeing	Gerberas, Orchids	Fluorescent dyes	Application of fluorescent dyes to create vivid, glowing colors.	Kumar <i>et al.</i> , 2023
8	High-Pressure CO ₂ Dyeing	Lilies, Roses	Supercritical CO ₂	CO ₂ in its supercritical state is used to enhance dye penetration and retention.	Singh <i>et al.</i> , 2023
9	Nanotechnology-Based Dyeing	Orchids, Peonies	Nanoparticle dyes	Dyes with nanoparticles are used to achieve more intense and durable colors.	Patel <i>et al.</i> , 2024
10	Laser-Assisted Dyeing	Roses, Lilies	Laser treatment	Lasers are used to improve dye adherence and color intensity.	Gupta <i>et al.</i> , 2023

potential to predict optimal drying conditions and times for different species.

Biomimetic Approaches : Inspired by anhydrobiotic organisms that survive extreme dehydration, new preservation techniques are being developed. These approaches may enable flowers to be revived from a dried state, opening new possibilities for commercial and artistic uses.

India's diverse agro-climatic conditions and rich flora resources offer immense potential for value-added products like dried ornamentals. To boost the floricultural industry, further research on flower dehydration is necessary. Investigating proper chemical treatments to enhance hardening and prevent moisture reabsorption in dried flowers is crucial. Evaluating proper packaging technology for long-lasting use and standardizing aftercare treatments are essential areas for investigation. Currently, India's export of dried flowers and plant parts accounts for over 70% of floricultural products, but its share in the global market is less than 5%.

Future research areas in dried flowers include standardizing raw materials, production technology, processing, and packing. Identifying new markets and modern drying techniques for quality improvement are also important. Establishment of organized research setups, both government and private, along with adequate funding, is necessary to make India a leader in this field.

Sustainability and Circular Economy : The dried flower industry is embracing circular economy principles, including the utilization of all plant parts, repurposing agricultural waste for packaging, and employing water-efficient cultivation methods for flowers destined for drying. This approach contributes to resource efficiency and sustainability.

CONCLUSION

Dried or dehydrated plant parts offer natural, cost-effective, and long-lasting value, maintaining their color and form year-round. However, not all drying methods are suitable for every flower or plant part, as each material requires a specific technique to preserve quality. The dried flower industry is labor-intensive and offers significant job opportunities, especially for unemployed individuals, including rural housewives. Providing training in flower drying methods and value addition is essential to harness this potential, contributing to increased exports of floricultural products and employment opportunities.

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(Received: February 2025, Accepted: April 2025)