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RECENT ADVANCEMENTS IN DRY FLOWER TECHNOLOGY : A REVIEW

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ABSTRACT

The growing interest in floral decoration and sustainable practices has propelled dry flower technology into a significant area of research and commercial application. This review paper explores various drying methods, including traditional techniques like air drying and pressing, as well as advanced methods such as freeze drying, microwave drying and glycerinisation. Each method is evaluated for its suitability for different plant materials, preservation of colour and shape and economic feasibility. The paper highlights the importance of dry flowers in decorative arts, their role in rural entrepreneurship and their potential in domestic and export markets. Key findings reveal that while simple methods like air drying are cost-effective and eco-friendly, advanced techniques like freeze drying offer superior quality but require significant investment. The study also emphasizes the need for proper harvesting and pre-treatment to enhance the longevity and aesthetic appeal of dried flowers. By analysing practical applications and commercial opportunities, this review underscores the potential of dry flower technology to contribute to sustainable livelihoods and the floriculture industry.
***Keyword* :** Dry flower technology, Floral preservation methods, Sustainable floriculture, Commercial applications, Rural entrepreneurship and Decorative arts.

Introduction

The growing interest in floral decoration and craft has opened new doors in the field of dry flower technology. This emerging industry of dried flowers is now becoming a major area of commercial use especially in countries like India where traditional art meets modern innovation. Drying flowers is a simple yet artistic process that helps preserve their natural look, shape and colour for a long time. Usually, after harvesting flowers go through processes like drying, bleaching and dyeing. There are different ways to dry flowers some can be air-dried easily while others need special methods like glycerine treatment to maintain their softness. Advanced techniques like freeze drying are also being used now to get better results. Sulphur gas is sometimes used to fix the colour in certain flower species (Sankari *et al.*, 2013). Dry flower technology is not just eco-friendly but also economical. It offers a great solution for preserving ornamental parts of plants especially flowers throughout the year. Dried flowers are light in weight, easy to handle and cheaper to transport. They are used in making a variety of decorative items like greeting cards, wall hangings, floral frames, potpourri, calendars and many more. Even other parts of plants like leaves, pods, cones, berries and grains can be dried and used creatively. These items also have good demand in local markets and for export. The beauty of this technology is that it needs very little input and makes good use of the wide variety of vegetation found in tropical and sub-tropical areas like ours. Many Indian households especially in rural areas have started small-scale businesses using dried flowers which helps in creating self-employment opportunities for women and youth (Datta *et al.*, 2011). The quality of dried flowers mainly depends on when they are harvested. Flowers should be picked either at the bud stage or when they are partially open before their colour starts fading. A delay of even 2-3 days can lead to overlapping and folding of petals which may result in petal breakage (Bhattacharjee and De, 2003). Certain flowers like Strawflower, Globe Amaranth, Salvia and Chrysanthemum give the best results when harvested early (Smith, 1993). Similarly, roses picked at the half-bloom stage dry faster and retain better colour (Safeena *et al*., 2006). Drying also depends on the structure of the flower. For example, in the embedding method flowers at half bloom dry quicker as their petals are loosely arranged allowing the drying medium to reach between the petals more easily. It is also advised to spray flowers with neem-based pesticides or Dithane Z-78 (0.5%) before drying to protect them from pests and diseases (De *et al*., 2016). The art of drying and preserving flowers is not new. It has existed for centuries from the ancient Egyptians who used dried herbs in mummification to Europeans and Americans who decorated their homes with dried flower arrangements during long winters (Brown *et al*., 2013). What began as a traditional and artistic craft has now grown into a scientific field with wide commercial potential across the world (Verma *et al*., 2012). To review the techniques used for drying and preserving flowers and plant parts, and to assess their practical applications and commercial potential.

Objectives

1. To describe the major drying methods used for flowers and foliage.
2. To assess the quality and suitability of these methods for different plant materials.
3. To highlight the practical uses and value addition of dried floral products.
4. To identify the scope for income generation and small-scale entrepreneurship through dry flower technology.

Importance of Dry Flowers:

Dry flowers hold significant value both aesthetically and economically. Their long shelf life, low maintenance and year-round availability make them a preferred choice over fresh flowers for decoration and craft purposes. They retain their shape and to a large extent, their colour, making them ideal for creating greeting cards, wall hangings, floral arrangements, gift items and potpourri. In countries like India, dry flower technology plays an important role in rural development. It offers low-cost opportunities for self-employment, especially for women, students and small entrepreneurs. With minimal input and simple infrastructure, a wide variety of flowers and plant materials available in different regions can be transformed into beautiful and saleable products. Additionally, dried flowers have growing demand in domestic and export markets. In regions where fresh flowers are unavailable due to extreme weather, dry flowers serve as excellent alternatives. Their lightweight and durable nature also reduces transportation costs. As a result, this sector is emerging as a promising component of the floriculture industry, with potential for income generation, employment creation and value addition.

Market Trends & Outlook

The global dried flower market has witnessed steady growth in recent years due to increasing consumer interest in sustainable and decorative floral products. As of 2024, the global dried flower market is valued at approximately USD 370 million, and it is projected to reach USD 640 million by 2033, growing at a Compound Annual Growth Rate (CAGR) of 6.5% during the forecast period. This surge is attributed to the rising popularity of eco-friendly lifestyle choices, the increasing demand for low-maintenance decorative items, and the growing use of dried flowers in interior design and gifting sectors (Business Research Insights, 2024). In parallel, the preserved flower market, a related sector, is also expanding. According to Precedence Research (2024), the market for preserved flowers is expected to grow from USD 200.44 million in 2025 to USD 320.67 million by 2034, at a CAGR of 5.36%, reflecting the increasing demand for long-lasting and aesthetically pleasing floral solutions across both developed and emerging economies.

In the Indian context, the dried flower industry has shown notable performance, particularly in the area of exports. India exports over 500 varieties of dried flowers to more than 20 countries, with key destinations including the USA, Japan, and several European nations. In the fiscal year 2023–24, India exported 19,677.89 metric tonnes of dried flowers with a total value of INR 717.83 crore (USD 86.63 million) (ExportImportData.in, 2024). Over the period from 2011–12 to 2023–24, the total volume of dried flower exports amounted to 8,678.69 metric tonnes, with a cumulative value of USD 4,318.14 million, highlighting India's growing footprint in the global dried flower trade (IJCRT, 2024). The broader Indian floriculture market, under which dried flowers fall, is also experiencing robust expansion. The market size was valued at INR 292.0 billion in 2024 and is projected to reach approximately INR 744.0 billion by 2033, growing at a CAGR of 10.9% during the forecast period. This growth is being driven by increasing urbanization, rising disposable incomes, and the popularity of flowers in festive, decorative, and ceremonial uses (IMARC Group, 2024). Several key trends are shaping the future outlook of the dried flower sector. Firstly, there is a growing preference for eco-friendly and sustainable decorative products, making dried flowers an attractive option. Secondly, the rise of digital commerce platforms has improved market access for rural artisans and small-scale entrepreneurs, enhancing product visibility and consumer reach. The dried flower industry has demonstrated significant regional development, with several states leading in both production and export. The top five states contributing prominently to the dried flower and floriculture sector are Tamil Nadu, Karnataka, Madhya Pradesh, West Bengal and Gujarat. Among these, West Bengal has historically held a dominant position, contributing up to 70% of India's dried flower exports in earlier years (OEC, 2024). Tamil Nadu and Karnataka are notable for their large-scale floriculture cultivation, while Madhya Pradesh and Gujarat have shown consistent growth in dried flower-based rural enterprises. These states benefit from favourable agro-climatic conditions, established infrastructure, and growing entrepreneurial activity in flower drying and craft-making. The concentration of production in these regions underscores their strategic role in supporting India's export-driven growth in the dried flower sector.

Types of Drying Methods for Flowers and Foliage:

Various drying methods are used to preserve flowers and plant parts while retaining their shape, colour and structure. The choice of method depends on the flower type, desired quality, available resources and end use. Below are the commonly used methods:

- Air Drying
- Sun Drying
- Press Drying
- Hot Air Oven Drying
- Microwave Oven Drying
- Freeze Drying
- Glycerine Drying
- Solar Cooker Drying
- Embedded Drying
- Water Drying
- Skeletonisation

(A) Air Drying

Air drying is one of the oldest, simplest and most economical methods of drying flowers. It involves drying flowers in a warm, clean, dark and well-ventilated place with low humidity. This method is natural and easy to perform, even at home. Flowers are tied together using twine or ribbon and hung in a warm, dark room. Several factors influence the time it takes for flowers to dry completely, including air circulation, temperature, atmospheric humidity, moisture content of the flowers, their shape and air velocity. Most flowers can be dried on their own stems; however, some flowers such as strawflowers have weak stems and require a wire support before drying to prevent damage (Patel *et al*., 2018). With good air circulation, flowers usually take between one to three weeks to dry fully. Singh and Kumar (2008) reported that flowers like Chinese lanterns, baby's wreath, poppy seed heads and globe thistles dry well when hung upside down. Hanging flowers in this way helps them maintain their shape and dry evenly. One of the biggest advantages of air drying is that it is chemical-free and environmentally friendly, requiring no expensive equipment or machinery. However, the main limitation is that high humidity can prevent flowers from drying properly and may lead to fungal growth or mildew. Therefore, a low-humidity environment is essential for successful drying. Overall, air drying helps preserve the natural colour and shape of flowers, making them ideal for decorative purposes and crafts. This method is commonly used for cut flowers, which can later be used in long-lasting floral arrangements or potpourri.

Table 1: Flowers Recommended for Air Drying

Botanical Name	Common Name	Family
Acacia dealbata	Silver wattle	Fabaceae
Anthemis nobilis	Chamomile	Asteraceae
Bougainvillea sp.	Bougainvillea	Nyctaginaceae
Calendula officinalis	Pot Marigold	Asteraceae
Callistemon lanceolatus	Bottle brush	Myrtaceae
Celosia cristata	Cockscomb	Amaranthaceae
Delphinium ajacis	Larkspur	Ranunculaceae
Gaillardia pulchella	Blanket flower	Asteraceae
Gomphrena globosa	Globe amaranth	Amaranthaceae
Gypsophila elegans	Baby's breath	Caryophyllaceae
Helichrysum bracteatum	Strawflower	Asteraceae
Hydrangea macrophylla	Hydrangea	Saxifragaceae
Limonium latifolium	Sea lavender	Plumbaginaceae

Limonium sinuatum	Statice	Plumbaginaceae
Protea sp.	Protea	Proteaceae
Peltophorum ferrugineum	Copperpod	Fabaceae
Salvia splendens	Salvia	Lamiaceae
Solidago canadensis	Goldenrod	Asteraceae
Tagetes sp.	Marigold	Asteraceae
Zinnia elegans	Zinnia	Asteraceae

(Source: Geetha *et al*., 2004)

(B) Sun Drying of Flowers

In India, open sun drying is a traditional and widely followed method for drying various flowers. This method involves exposing flowers directly to sunlight, which helps in quick dehydration due to the combined effect of heat and air circulation. Flowers such as small zinnias, marigolds, pansies and pompon chrysanthemums are often embedded upside down in sand and placed under the sun for drying. This technique protects the flowers from direct harsh sunlight while allowing them to dry effectively, helping to retain their shape and prevent damage (Patel *et al*., 2018). Typically, these flowers dry within one to two days when the sunlight is strong and consistent. However, flowers like Gomphrena, Zinnia and French marigold require slightly longer drying times, usually around three to four days (Singh and Kumar, 2008). Sun drying demands careful management to avoid issues such as moisture retention, insect attacks and rain damage. It is crucial to spread the flowers adequately without overcrowding to ensure proper airflow and uniform drying. Also, the drying site should be clean and free from dust and pollutants to maintain the quality of dried flowers (Geetha *et al*., 2004). Although sun drying is an economical and simple method, it has some drawbacks. Prolonged exposure to intense sunlight can cause colour fading in delicate flowers. Additionally, unpredictable weather changes can disrupt the drying process. Despite these challenges, with proper precautions, sun drying remains an effective and popular technique for preserving flowers used in decoration, crafts and other applications in India.

Table 2: Flowers Recommended for Sun Drying

Botanical Name	Common Name	Family	Approximate Drying Time (Days)
Zinnia elegans	Zinnia	Asteraceae	1-2
Tagetes erecta	Marigold	Asteraceae	1-2
Viola tricolor	Pansy	Violaceae	1-2
Chrysanthemum morifolium	Pompon Chrysanthemum	Asteraceae	1-2
Gomphrena globosa	Globe amaranth	Amaranthaceae	3-4
Tagetes patula	French marigold	Asteraceae	3-4

(Source: Geetha *et al*., 2004)

(C) Press Drying of Flowers

Press drying is one of the most common and simplest methods used for drying flowers and foliage. This traditional method is still widely favoured because of its ease and effectiveness in preserving flowers for decorative purposes. In press drying, flowers and foliage are placed between sheets of blotting paper or other absorbent materials, then subjected to pressure. It is important to avoid excessive overlapping or folding of the plant parts, as this can damage the shape and structure of the flowers and leaves.

Pressure can be applied using different tools, with the most common being a plant press, which consists of wooden frames tightened with straps or screws. Unlike air drying, press drying does not preserve the three-dimensional shape of flowers; instead, it flattens them. However, one of the key advantages is that the original colour of the flowers is better retained compared to some other drying methods. The time required for complete drying depends largely on the moisture content of the plant tissues and the thickness of the flowers. Typically, drying may take anywhere from 3 to 4 weeks. For example, Mir *et al*. (2019) reported that ferns take about 10 days to dry, hibiscus flowers require 4 days, marigolds 8 days, Ixora 10 days, nettle leaf velvet berry 5 days, chrysanthemums and asters 7 days, pentas 6 days, bougainvillea 7 days, plumeria rubra 7 days, melia 8 days, and Caesalpinia around 11 days for complete drying in a press. Raval *et al*. (2020) found that the embedded drying technique was best for rose, while press drying and microwave drying techniques were best for gerbera. These methods helped maintain the shape, size, and colour of the flowers.

Table 3 : Flowers Recommended for Press Drying

Botanical Name	Common Name	Family
Ageratum houstonianum	Ageratum	Asteraceae
Crocus sativus	Crocus	Iridaceae
Viola tricolor	Pansy	Violaceae
Alyssum spp.	Alyssum	Brassicaceae
Narcissus spp.	Daffodil	Amaryllidaceae
Phlox spp.	Phlox	Polemoniaceae
Anemone spp.	Anemone	Ranunculaceae
Bellis perennis	Daisy	Asteraceae
Primula spp.	Primula	Primulaceae
Rhododendron spp.	Azaleas	Ericaceae
Delphinium spp.	Delphinium	Ranunculaceae
Rosa spp.	Rose	Rosaceae
Dicentra spectabilis	Bleeding heart	Papaveraceae
Various fern species	Ferns	Polypodiaceae
Pelargonium spp.	Geranium	Geraniaceae
Salvia spp.	Salvia	Lamiaceae
Limonium spp.	Statice	Plumbaginaceae
Lathyrus odoratus	Sweet pea	Fabaceae
Celosia argentea	Celosia	Amaranthaceae
Calluna vulgaris	Heather	Ericaceae
Verbena officinalis	Verbena	Verbenaceae
Chrysanthemum spp.	Chrysanthemum	Asteraceae
Hydrangea macrophylla	Hydrangea	Hydrangeaceae
Zinnia elegans	Zinnia	Asteraceae
Centaurea cyanus	Cornflower	Asteraceae
Tagetes erecta	Marigold	Asteraceae
Cosmos bipinnatus	Cosmos	Asteraceae

(Source: Geetha *et al.*, 2004)

(D) Hot air drying

Hot air drying is a widely adopted technique for rapid and effective dehydration of flowers and plant materials, employing warm air circulation within a controlled environment such as a convection chamber or hot air oven (Raval *et al.*, 2020). This method significantly accelerates moisture removal compared to traditional air or sun drying, minimizing microbial growth and enzymatic activity that can degrade flower quality (Mir *et al.*, 2019). The temperature range is critical; it is typically maintained between 30°C and 60°C to balance drying efficiency and preservation of flower attributes. Delicate flowers require gentler drying at around 30°C to 35°C, while more robust species can withstand temperatures up to 60°C without quality loss (Patel *et al.*, 2018). Adequate airflow and humidity control ensure uniform moisture evaporation, preventing uneven drying and Mold formation (Singh and Kumar, 2008). Drying duration varies by species and moisture content, generally spanning from several hours to three days (Raval *et al.*, 2020). Hot air drying provides consistent year-round operation independent of external weather conditions, making it highly suitable for commercial flower processing where quality and efficiency are paramount (Mir *et al.*, 2019). This technique has also been found to better preserve flower colour, shape, and fragrance compared to sun drying, which often causes photodegradation due to UV exposure (Geetha *et al.*, 2004). Advances in hot air-drying technologies have improved energy efficiency, rendering it a cost-effective alternative in floriculture industries (Gupta *et al.*, 2021). Malakar *et al.* (2016) found that in both *Araucaria* and *Thuja orientalis*, the combination of silica gel and microwave oven for 30 and 20 seconds respectively gave the best results in terms of moisture loss (49.23% and 58.33%) and quality. White sand at room temperature caused 61.41% moisture loss in *Thuja orientalis* when treated for 16 days. In *Juniperus chinensis*, white sand plus microwave oven and silica gel plus room condition treatments for 20 seconds and 16 days respectively showed moisture loss of 44.26% and 50.16%. Boric acid as an embedding material was also effective for dehydration in these species. All three species were treated with glycerin: water solutions of 1:1 and 1:3 (volume/volume) for 24, 48, and 96 hours, followed by drying using a hot air oven at 70-80°C for 5 hours and air drying at room temperature for 24 hours. Significant moisture loss of 60.56% to 62.56% was recorded in *Thuja orientalis* after hot-air-oven dehydration for 96 hours.

Table 4 : Flowers Recommended for Hot Air Drying with Recommended Drying Time and Temperature

Botanical Name	Common Name	Family	Recommended Drying Time	Recommended Temperature
Helichrysum bracteatum	Strawflower	Asteraceae	12–24 hours	30–35°C
Gomphrena globosa	Globe amaranth	Amaranthaceae	1–2 days	30–35°C
Tagetes erecta	Marigold	Asteraceae	1–2 days	35–45°C
Zinnia elegans	Zinnia	Asteraceae	1–2 days	35–45°C
Calendula officinalis	Pot Marigold	Asteraceae	12–24 hours	30–35°C
Gypsophila elegans	Baby's breath	Caryophyllaceae	24–48 hours	30–35°C
Chrysanthemum spp.	Chrysanthemum	Asteraceae	1–3 days	35–45°C
Limonium sinuatum	Statice	Plumbaginaceae	1–2 days	30–35°C
Salvia splendens	Salvia	Lamiaceae	12–24 hours	30–35°C
Celosia argentea	Cockscomb	Amaranthaceae	1–2 days	30–35°C

(Source: Mir *et al*., 2019)

(E) Microwave drying

Microwave drying is a modern and highly efficient method for dehydrating flowers that significantly reduces the drying time compared to conventional methods. This technique typically requires only 5 to 10 minutes of microwave heating, making it one of the fastest drying methods available (Rani *et al*., 2015). In this process, flowers are often embedded in an inert medium such as sand or silica gel, which helps in absorbing moisture evenly and protects delicate flower tissues from direct microwave radiation, thus preventing damage. After microwave treatment, the flowers are allowed to stand at room temperature for some time, usually ranging from 10 minutes to over half an hour depending on the flower species, to allow residual moisture to stabilize and complete the drying process (Geetha *et al*., 2004). Microwave-dried flowers generally retain their original colour, shape, and freshness much better than those dried using air or sun drying methods, primarily due to the rapid dehydration which limits enzymatic browning and pigment degradation (Rani *et al*., 2015). The quick dehydration also inhibits microbial growth and reduces the chance of Mold or decay, resulting in a product that is visually more appealing and commercially valuable. Microwave drying is especially useful for flowers with high moisture content and delicate structures that are prone to wilting or discoloration when dried slowly (Gupta *et al*., 2021). Moreover, microwave drying is energy-efficient and can be easily standardized for large-scale floriculture industries to ensure consistent quality and productivity. Acharya *et al*. (2013) found that the rose cultivar 'Gold Medal' is more suitable for drying than the cultivar 'Minu Parle'. In both cultivars, buds embedded in silica gel showed the best results for early drying, retention of colour, shape, and texture when dried in a microwave oven, followed by hot air oven drying. 'Gold Medal' had better colour retention and overall acceptability. The maximum size reduction occurred with sawdust treatment alone. Post-drying longevity studies showed that microwave-dried buds embedded in silica gel had a longer shelf life compared to other treatments. Jeevitha and Jadhav (2020) reported that orchids took 5 days to dry completely using silica gel drying technique. Maximum moisture loss was 81–83%. The colour of the orchid faded, and its appearance became dull. Therefore, colour enhancement was needed for these flowers. The most suitable methods for colour enhancement were fabric paints, oil paints, and spray paints. Sharma *et al*. (2019) found that the cultivar *Mahal* is suitable for drying in a microwave oven during November (Flush I) and April (Flush II), while *Corvette* is better during June (Flush III) and August (Flush IV). The dehydrated flowers retained their original shape, size, and colour, making them good for value-added products. Renuka *et al*. (2016) reported that silica gel combined with microwave drying is the most suitable method for dehydration of rose and water lily, giving maximum weight loss, minimum pigment loss, and good colour, shape, and overall acceptability. Sudeep *et al*. (2018). found that fresh and dry weight of spikes was highest in silica gel drying, while percentage of moisture loss was maximum in borax. Among different drying temperatures, maximum fresh and dry weight of spikes was recorded at 48°C for 48 hours. Maximum moisture loss of 89.20% was observed at 54°C for 48 hours. Colour retention, shape, texture, and overall acceptability after drying were highest in silica gel dried flowers. Flowers dried in a hot air oven also showed maximum sensory scores for colour retention, shape retention, texture, and overall acceptability when dried at 50°C for 48 hours. Shade drying by embedding in silica gel gives the best quality dried rose flowers (Swamy *et al.*, 2009). For chrysanthemum, embedded drying is the best method as it maintains flower shape, size, structure, and colour. For marigold, microwave and air-drying techniques are best for maintaining size, colour, and shape.

Table 5: Suggested Drying and Standing Time for Flowers in Microwave Oven

Sr. No.	Flower	Heating Time (minutes)	Standing Time (minutes)
1	African daisy	3	10
2	Aster	2.5	10
3	Calendula	2.5	10
4	Carnations	1	10
5	Chrysanthemum	3	10
6	Clematis	3	10
7	Daffodil	1.5	10
8	Dahlia	5–7	36
9	Dianthus	3	10
10	Dogwood	1.5	24
11	Marigold	3	10
12	Orchids	1.5–2.5	24
13	Pansy	2.5–3	24
14	Peony	3–4	36
15	Poppy	2.5–3	24
16	Rose	1.5	10
17	Salvia	3	10
18	Mexican sunflower	5–6	10
19	Tulip	3	24
20	Zinnia	4–5	10

(Source: Gupta *et al.*, 2021)

(F) Solar Cooker Drying

Solar cooker drying is an innovative and eco-friendly method used for drying flowers by utilizing solar energy. In this method, flowers are directly embedded in the container or tray of the solar cooker and dried under sunlight. The drying time depends largely on the intensity of solar radiation and ambient temperature during the day (Patel *et al.*, 2018). An important advantage of this technique is that the solar cooker can also be electrically operated when sunlight is insufficient, allowing for flexible drying conditions. This method is particularly suitable for rural women who can multitask using the solar cooker for preparing meals and simultaneously drying flowers during the remaining time, making it a practical and energy-saving solution (Patel *et al.*, 2018). The solar cooker drying process preserves the colour and texture of flowers effectively while being environmentally sustainable. This method can take from several hours to a couple of days depending on flower type, moisture content, and solar intensity. Wilson *et al.* (2013) studied fully opened chrysanthemum flowers (*Dendranthema grandiflorum* Tzevlev) dried by four methods: air drying, sun drying, mechanical dehydration, and low-cost solar drying for different durations. Solar drying showed the highest moisture loss after 15 days and scored better for colour retention. Therefore, solar drying with flowers embedded in sterilized sand was found to be better than the other drying methods.

(G) Freeze Drying

Freeze drying is a highly advanced method of flower preservation that maintains the natural freshness, colour, and structure of flowers better than most other drying techniques. In this process, flowers are first carefully arranged inside a specimen chamber and then rapidly frozen to a temperature of around -35°C or lower. Once frozen, the water within the flower tissues is removed through sublimation, a process where ice transitions directly into vapor without passing through the liquid phase. This dehydration under low temperature helps preserve the flowers' cellular integrity, vibrant colours, and delicate shapes, resulting in a product that looks almost like fresh flowers but with greatly extended durability

(Patel *et al*., 2018). Freeze-dried flowers are highly valued in the floral industry, especially for premium arrangements and crafts, because they resist shrinkage, browning, and brittleness. However, this method requires expensive equipment and energy, making it less accessible for small-scale or rural flower processors.

(H) Embedded Drying

Embedded drying is a vital and widely used technique for removing moisture from flowers while retaining the natural colour and shape of delicate petals. This method involves placing flowers in containers filled with absorbent drying materials, commonly known as desiccants, such as silica gel, borax, cornmeal, sand, alum powder, sawdust, or white river sand (Patel *et al*., 2018; Jain *et al*., 2016). Among these, silica gel, particularly the 60–20 mesh variety, is considered the most effective desiccant due to its superior moisture absorption capacity and ability to preserve colour and form (Jain *et al*., 2016). The drying containers used may be desks, trays, earthen pots, or boxes, and their size depends on the size and quantity of flowers to be dried. Flowers are gently embedded in the desiccant up to approximately 2.5 cm from the base to avoid damaging their structure. The moisture present in the flowers is absorbed gradually by the surrounding material, resulting in flowers that feel dry to the touch but are not brittle (Patel *et al*., 2018). The embedded drying method is widely appreciated for its ability to maintain floral integrity better than many other drying methods. In some cases, drying is also done in ovens using a mixture of borax and silica gel, especially for sensitive flowers like orchids, where temperature and time are carefully controlled to prevent damage and optimise drying (Geetha *et al*., 2004). This method combines the benefits of embedding with controlled heating for faster and efficient drying. Akram *et al*. (2021) reported that embedded drying of *Centaurea cyanus* and *Chrysanthemum coronarium* using silica gel showed the best results in terms of drying time, texture, and appearance of the flowers after drying. Jawaharlal *et al*. (2013) reported that the foliage of silver oak (*Grevillea robusta*), thuja (*Thuja orientalis*), and camellia (*Camellia reticulata*) was best preserved by glycerinization. The leaves remained soft and pliable, with low moisture content and high overall acceptability. For fully opened flowers of button-type chrysanthemum (*Chrysanthemum grandiflorum*), gerbera (*Gerbera jamesonii*), and plumeria (*Plumeria alba*), a combination of sand and silica gel along with microwave-oven embedded drying was found suitable, resulting in high acceptability. Dried pods of jacaranda (*Jacaranda mimosifolia*) and Castanospermum (*Castanospermum australe*) were fully bleached by soaking overnight in 10% sodium hydroxide, followed by treatment with 2% sodium hydroxide + 2.5% sodium silicate + 35% hydrogen peroxide. These bleached pods were then dyed using acrylic dyes, which showed good dyeing consistency, light fastness, wash fastness, and rubbing fastness. Patel *et al*. (2018). studied the standardization of drying methods for various winter annual flowers such as dianthus, annual chrysanthemum, and China aster. Drying at room temperature showed the highest loss in fresh weight percentage and moisture percentage, and took the least number of days to dry when silica gel was used as the embedding material. However, the least reduction in dried flower diameter was recorded when sea sand was used as the embedding medium for dianthus, annual chrysanthemum, and China aster. Silica gel embedding also gave the highest scores in terms of colour, texture, and appearance of the dried flowers on a visual scale. Rani *et al*. (2015) selected eight flowers carnation, chrysanthemum, daisy, gerbera, gladioli, marigold, orchid, and rose and tested different drying techniques like air drying, water drying, embedding methods (sand, borax, silica gel), microwave oven drying, hot air oven drying, pressing, and glycerinizing. It was concluded that while different methods can be used for drying flowers, certain techniques are suitable only for specific flowers. Among all methods tested, the most suitable and economically viable techniques for most flowers were embedding in sand, silica gel, and borax. Flowers dried by these methods were used for three-dimensional floral arrangements. Pressing was found to be suitable for making greeting cards, bookmarks, and other creative art purposes. L C De and D R Singh (2015) found that embedded drying with borax at 50°C was successful for *Arundina graminifolia*, *Dendrobium moschatum*, Den. 'Madam Pink', Den. 'Lervia', Den. 'Abraham', Phalaenopsis 'Casa Blanca', Phal. 'Detroit', Oncidium 'Sweet Sugar' and Vanda teres. Embedded drying with borax at 60°C was successful for Cattleya bowringiana, cattleya hybrids, Den. 'Big White', *Epidendrum* spp. and Phal. 'Ox Plum Rose x Black Jack'. Embedded drying with borax at 55°C was successful for *Coelogyne cristata, C. flaccida, Cymbidium 'Sungold', Dendrobium aphyllum, D. nobile, D. williamsonii*, Den. 'Bangkok Blue' and Paphiopedilum 'Nagasaki'. Under room conditions, perlite can be used to dry spikes and florets of orchids within 15 to 20 days.

Table 6 : Flowers Recommended for Desiccant Drying

Flower Name	Flower Name	Flower Name
Ageratum	Dahlia	Lily of the valley
Anemone	Daisy	Magnolia
Bells of Ireland	Delphinium	Marigold
Black-eyed Susan	Dogwood	Pansy
Butterfly Weed	False Dragonhead	Passion Flower
Carnation	Feverfew	Peony
Chrysanthemum	Gladiolus	Rose
Coleus	Hollyhock	Salvia
Coneflower	Lantana	Snapdragon
Coralbells	Larkspur	Stock
Daffodils	Lilac	Verbena
Water Lily	Yarrow	Zinnia

(Source: Geetha *et al*., 2004)

Table 7: Embedded Drying of Orchids in Oven with Borax

Name	Temperature (°C)	Duration (Hours)
Vanda teres	50	36
Den. ‘Madam Pink’	50	60
Phal. ‘Casa Blanca’	50	180
Phal. ‘Detroit’	50	180
Den. ‘Lervia’	50	60
Den. Moschatum	50	60
Den. ‘A. Abraham’	50	60
Onc. ‘Sweet Sugar’	50	60
Arundina graminifolia	50	60
Epidendrum spp.	60	27
Blc ‘Guanmiau City’, Cattleyabowringeana	60	21
Den. ‘Big White’	60	21
Phal. Ox Plum Rose × Black Jack	60	9

(Source: Patel *et al* ,2018)

Table 8: Embedded Drying of Orchids in Oven with Borax and Silica Gel (1:1)

Name	Temperature (°C)	Duration (Hours)
Dendrobium nobile	55	10
Dendrobium williamsonii	55	10
Dendrobium aphyllum	55	10
Den. ‘Erika’	55	12
Den. ‘Big White 4N’	55	12
Den. ‘Bangkok Blue’	55	7
Coelogyne cristata	55	10
Coelogyne flaccida	50	7
Paph. ‘Nagasaki’	55	10
Paph. ‘Sun Gold’	55	14

(Source: Patel *et al.*, 2018)

(I) Glycerinisation

Glycerinisation is a widely used technique for preserving the natural texture and flexibility of foliage by replacing the water content within the plant tissues with glycerin. In this process, fresh and semi-mature leaves or seed heads are selected, preferably when they are neither too tender nor too tough. The plant parts are typically submerged in a solution of glycerin and water, allowing the glycerin to be gradually absorbed and substitute the natural moisture in the foliage. Unlike other drying methods, glycerinisation does not preserve the original green colour of the foliage. Instead, the plant material often turns into shades of brown, bronze, or olive green. However, the preserved material maintains a soft, pliable texture, making it highly suitable for dried floral arrangements, craft items, and decorative installations. The final preserved foliage can also be painted or dyed as per aesthetic requirement. Glycerine-treated foliage has a longer shelf life and is less brittle compared to air- or oven-dried foliage (Patel *et al*., 2018). The ideal glycerin-to-water ratio depends on the texture of the plant material. Thick-textured foliage like magnolia or rubber plant leaves requires a stronger glycerin solution, while fine-textured leaves like ferns need a more diluted mixture. Heating the solution slightly can improve absorption. On average, it takes a few days to weeks for complete absorption depending on plant type, temperature, and solution strength. Commonly used plant parts include leaves, seed heads, and flowers.

Table 9 : Flowers Recommended for Preserving in Glycerin

Botanical Name	Common Name	Part to Glycerinise	Botanical Name	Common Name	Part to Glycerinise
Anthurium andreanum	Anthurium	Leaves	*Eucalyptus sp.*	Gum tree	Leaves
Avena	Oats	Seed heads	*Fagus sylvatica*	Beech	Leaves
Briza sp.	Quaking grass	Seed heads	*Grevilea robusta*	Silver oak	Leaves
Camellia japonica	Camellia	Leaves	*Gypsophila elegans*	Baby's breath	Flowers
Catharanthus sp.	Periwinkle	Leaves	*Hordeum jubatum*	Squirrel tail grass	Seed heads
Citrus limon	Lemon	Leaves	*Humulus lupulus*	Hop	Flower
Clematis	Clematis	Seed heads	*Hydrangea macrophylla*	Hydrangea	Flowers
Codieaum variegatum	Croton	Leaves	*Ilex sp.*	Holly	Leaves
Crotalaria selloana	Smoke bush	Seed heads	*Iris orientalis*	Iris	Seed pods
Cyperus alternifolius	Umbrella plant	Leaves	*Juniperus communis*	Juniper	Leaves
Digitalis purpurea	Foxglove	Seed heads	*Magnolia longiflora*	Magnolia	Seed heads
Draceana	Dracaena	Leaves	*Morina longiflora*	Whorl flower	Seed heads
Populus sp.	Poplar	Leaves			

(Source: Patel *et al*., 2018)

Table 10: Recommended Glycerin-Water Ratio Based on Foliage Texture

Sr. No.	Foliage Type	Glycerin: Water Ratio
1	Thick-textured foliage	1: 2
2	Medium-textured foliage	1: 2.5
3	Fine-textured foliage	1: 3

(Source: Patel *et al*., 2018)

(J) Water Drying

Water drying is a traditional yet effective method used for drying certain types of flowers that retain their form and colour well during gradual dehydration. In this technique, the stems of freshly cut flowers are placed in a container filled with approximately 1–2 inches of water. The flowers are then allowed to absorb the water slowly while the remaining moisture evaporates naturally over time. This slow drying process enables the flowers to retain their shape, structure, and in some cases, their natural coloration, as the gradual withdrawal of moisture helps minimize petal shrinkage and distortion. It is crucial to place the container in a dry, warm, and dark area during this process to avoid discoloration caused by light exposure and to promote uniform drying. This method is best suited for flowers with strong stems and papery petals such as hydrangea (*Hydrangea macrophylla*), statice (*Limonium sinuatum*), and baby's breath (*Gypsophila paniculata*). The complete drying process typically takes 1 to 2 weeks, depending on the flower species, ambient temperature, and humidity. Water drying is particularly popular among amateur florists and rural artisans due to its low cost, simplicity, and minimal equipment requirement. Though the colour retention may not be as vivid as in advanced methods like silica gel or freeze drying, the flowers obtained through this method are suitable for dried floral arrangements, potpourri and home décor.

Table 11: for plant species suitable for foliage preservation with the methods listed:

Botanical Name	Common Name	Air Drying	Microwave Oven Drying	Glycerine Drying	Press Drying	Skeletonising
Adiantum assimile	Maiden hair fern	X	X			
Agave Americana	Century plant	X		X	X	X
Alpinia sp	Shell ginger	X				
Anthurium andreanum	Anthurium	X				
Aralia filcifolia	Aralia		X	X	X	
Araucaria excels	Monkey puzzle tree	X				
Artemisia martini	Dhavana	X		X	X	
Asclepias	Milk weed	X	X			
Aspidistra	Cast iron plant	X		X		
Bambusa	Bamboo	X		X		
Berberis	Barbery	X		X		
Butea monosperma	Flame of forest	X				
Buxus sempervirens	Box foliage	X	X	X		
Caladium	Caladium			X		
Casuarina	Australian pine	X				
Callistemon lanceolatus	Bottlebrush		X	X		
Centella asiatica	Asiatic pennywort			X		
Cyperus	Papyrus	X	X			
Cycas revoluta	Sago palm	X		X		
Draceana sanderiana	Draceana	X				
Ficus religiosa	Peepul				X	
Grevilea robusta	Silver oak				X	
Hedera helix	English ivy		X	X	X	
Monstera deliciosa	Monstera	X				
Nephrolepis sp	Ferns	X				
Nerium oleander	Oleander		X	X		
Philodendron bipennifolium	Philodendron	X				
Scindapsus aureus	Money plant	X				
Selasingella sp	Club moss	X				
Scheflera arboricola	Umbrella tree		X	X		
Thuja orientalis	Thuja		X	X	X	

(K) Skeletonisation

Skeletonisation is a specialized technique used to preserve the intricate venation of leaves by removing the fleshy tissues while retaining the delicate vein network, making it suitable for dry flower arrangements and decorative purposes. Mir Saima and Jana (2016) studied the preparation of leaf venation skeletons using baker's yeast (*Saccharomyces cerevisiae*) fermentation to optimize the process. Their research demonstrated that a 2.0% aqueous yeast solution concentration was most effective in producing undamaged vein networks. The study also emphasized that only mature leaves, approximately 4–5 months old, were suitable for fermentation to achieve optimal skeletonisation. Different species, including *Ficus religiosa*, *Bauhinia purpurea*, *Tectona grandis*, *Ficus benjamina*, and *Hiptage bengalensis*, showed variation in the fermentation duration needed for complete venation skeleton formation. This biological method offers a controlled and efficient alternative to traditional chemical or mechanical leaf skeletonisation, maintaining leaf structure integrity and enhancing suitability for ornamental use. Additionally, in an earlier study, Mir Saima and Jana (2015) explored chemical bleaching techniques for prepared leaf skeletons to remove unwanted colours and improve aesthetics. They highlighted that dried leaf skeletons, which are mainly cellulose, resemble fine fabric or lace and can add significant value to the dry flower industry. Proper bleaching improves their appearance and durability, making them ideal for crafting decorative floral arrangements and other art forms. Both studies together provide a comprehensive approach for producing and enhancing leaf skeletons for long-lasting ornamental use.

Conclusion

Dry flower technology represents a harmonious blend of tradition and innovation, offering sustainable solutions for floral preservation and decoration. This review highlights the diversity of drying methods, from simple air drying to sophisticated freeze drying, each catering to specific floral types and end uses. While traditional methods remain popular for their simplicity and low cost, advanced techniques provide superior quality, making them ideal for high-value markets. The commercial potential of dried flowers is vast, with applications in crafts, home décor, and festive arrangements, particularly in regions where fresh flowers are scarce. Additionally, this technology fosters rural entrepreneurship, especially among women and small-scale artisans, by creating income-generating opportunities with minimal infrastructure. However, challenges such as colour retention, pest control, and scalability need addressing to maximize industry growth. Future research should focus on optimizing drying techniques, exploring eco-friendly alternatives, and expanding market reach. By leveraging the versatility and economic benefits of dry flower technology, stakeholders can unlock new avenues for sustainable development in the floriculture sector.

Future Scope

The field of dry flower technology holds immense potential for future advancements, both in terms of scientific development and commercial expansion. Research can be directed towards optimizing drying techniques for a wider range of plant species, especially indigenous and ornamental plants. Innovations in energy-efficient and eco-friendly drying technologies, such as solar-assisted microwave or hybrid drying systems, can reduce costs and enhance sustainability. There is also scope for the development of natural and non-toxic preservatives and dyes to improve colour retention and shelf life of dried products. Integration of Artificial Intelligence (AI) and IoT (Internet of Things) in drying chambers may allow for real-time monitoring and precision control of temperature, humidity, and air circulation, thereby standardizing product quality.

From an economic perspective, future efforts should focus on establishing training centres and rural incubators to empower local artisans, especially women, in dry flower-based entrepreneurship. Additionally, branding and export strategies for dried floral crafts can open up international markets, promoting India as a global hub for sustainable decorative products. Collaboration between floriculture industries, research institutions, and policy-makers will be crucial in realizing the full potential of this growing sector.

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Author Contributions

Dr. Manish Kumar conceptualized the review, conducted the literature survey and was primarily responsible for writing the manuscript. He also served as the corresponding author, overseeing all stages of the preparation and submission process. Dr. Ragini Bhardwaj provided significant support in organizing the content, refining the structure of the manuscript and performing thorough proofreading. Her critical feedback and suggestions greatly enhanced the overall quality and clarity of the paper. Both authors have read and approved the final manuscript.

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Use of Artificial Intelligence in Enhancing Scientific Writing

Artificial Intelligence (AI): In this review paper, AI tools have been utilized to enhance grammar, refine sentence structure and ensure clarity of expression. These improvements make the manuscript more professional and accessible to scientists and research scholars. By minimizing linguistic errors and enhancing readability, AI supports the effective communication of complex scientific ideas, thereby increasing the impact and acceptance of the paper in the academic community.

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