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Economically viable flower drying techniques to sustain flower industry amid COVID-19 pandemic

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Abstract

Imposing lockdown amid COVID-19 pandemic has severely affected flower cultivation and their trades. Flower plants are very sensitive to the harvesting, and any unexpected delay may cause great loss (~50–60%) to the farmers. In 2018–2019, the worth of total production of floriculture products was ~Rs 571.38 crore. During lockdown, the availability of human laborers and restricted transport has disrupted the supply of flowers to the market. Hence, some alternative options are suggested here for the farmers, for example, conversion of decorative flowers (e.g., anthurium, China aster, globe amaranthus, sweet-william, anemone, sea lavender, etc.) and inflorescence (e.g., Michaelmas daisy, zinnia, statice, ferns, aspidistra, eucalyptus, magnolia, etc.) can also be into value-added products through drying and dehydration technologies. Many dehydration methods such as hot air oven, solar drying, press drying, freeze-drying, embedded drying, glycerine drying, and microwave oven drying polyester drying can be used for flower drying at room temperature (~25 °C). These floral and foliage dehydration techniques are quite simple, which can also be operated by unskilled persons. Moreover, it will generate self-employment for the youth and women along with increased revenue than selling fresh flowers. In this review, different techniques of flower drying have been discussed in detail along with the influencing factors, efficiency, economic feasibility, flower waste management and sustainability. Further, it has also been suggested how these techniques could be useful for farmers, researchers, and traders to create value-added products? Hence, the present paper could be very interesting for the flower growers, retailers, students, as well as floricultural scientists who are involved in flower production worldwide.

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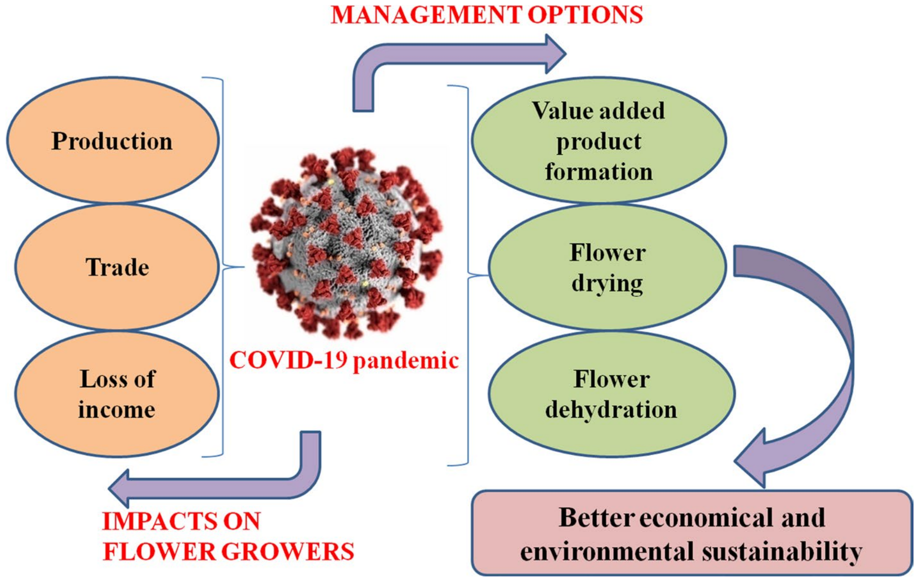
Graphical Abstract



Keywords Drying techniques of flowers · Local employment · Waste management · Value-added products · Environmental sustainability, COVID-19 triggered lockdown

1 Introduction

Flowers' longevity and their freshness are widely utilized in cultural, social activities and all functions of humans like ceremonies, birth, marriage, and death of people (Jadhav et al., 2013). In India, flowers are associated with the happiness and sorrow of the individual as man is born with flowers, lives up with flowers, and eventually dies with flowers. Worship is likewise an essential part of human life and places of worship consist of temples, mosques, churches, and gurudwaras where flowers are used all the year without difference of religion. Recently, floriculture has been proved as a profitable business as its importance, utility, and scope of ornaments have been realized (Raghava, 2001). The color and fragrance of flowers bring a sense of freshness and beauty to life and are a beautiful way of expressing one's feelings and play a vital role in making the life of a person more joyful. Flowers are one of the best gifts to offer to someone, but fresh flowers cannot be stored for long periods; however, gifts in the form of dried flowers can stay with the recipients for longer times as sweet memories (Bhalla et al., 2006).

Dried flowers can be a potential sources for replacing fresh flowers and foliage plants in the house decoration, as well as for artistic and industrial uses. In both domestic and international markets, dehydrated flower products are in high demand. There is a great demand for dried flower items in the USA, Japan, and Europe, which are marketed at higher costs due to handcraft and new valuable products. The use of dried flowers in the manufacture of various products enhances the appearance and beauty of handicrafts (Batra, 2016; Singh & Kumar, 2008). In the changing climate scenario, dehydrated flower items can be made throughout the year and are also very important sources of additional income for the farmer's family as well as the rural unemployed persons. Kant (2018) concluded that drying techniques of ornamental plants and foliage are one of the pleasant methods to maintain these in original shape, color, and year-round availability due to toughness, novelty, smooth operation, low transportation price as well as being environmentally pleasant. Dehydration technology of flowers can help to remain the shape and color of flowers as original for a longer time with little care. Dried flowers are long life span flowers and maintain their size and color for several months after harvesting (Malcolm, 1994). Dried flowers can have a longer shelf life if they are dried under proper technique (Sheela, 2008). Dried products prepared from ornamental plants have a huge range of characteristics together with unique quality, longer durability, creativity, flexibility, and all-year availability for flower lovers (Joyce, 1998). Dried flower industries can assist in the creation of jobs for other family members, rural women, physically challenged individuals, and farmers where these unemployed persons can easily generate more income. Presently, consumers are becoming more environmentally concerned, and they want to use flower products that are eco-friendly and biodegradable (Singh, 2018). A wide range of wild/unused plant species are available and can be used commercially to make various dried flower products (Bhattacharjee & De, 2003). The drying of flora and leaves can also be used for various functions to make ornamental products including floral segments, greeting cards, wall hangings, potpourris, landscapes, calendars, etc. (Bhalla & Sharma, 2002; Bhutani, 1990). Murugan et al. (2007) reported that potpourris that are the main parts of the dried flower trades earned value at Rs 55 crore in India. In the earlier period, the British established a dry flower industry in Calcutta for its proximity to the northern and eastern parts of India, where a wide range of diverse flowers as well as exotic in nature are available. In floriculture and flower-based value-added products, the business of dried flowers in India's fastest-growing industry, with more than 50 enterprises, is presently involved. Most of the companies are mainly located in Tamil Nadu, Calcutta, and Mumbai. M/s Ramesh Flower Limited, situated in Tuticorin (Tamil Nadu), exported 50% of the total dried flower shares from India (Anon, 2014). In the year 2016, total floriculture products exported amounted to Rs 450 crore, with dried flowers contributing Rs 315 crore (60%). The industry exported 500 different varieties of dehydrated flowers and foliage part to 20 countries around the world (Jawaharlal et al., 2013). The main export houses of dried flowers in India are in Tuticorin (50%) and Kolkata (40%), and remaining 10% are exported other parts of country. The major dry flower players in India are Singhvi International, Kolkata (based on Tuticorin port), M/s Minex Agencies, Kolkata (APEDA, 2017). Keeping in view the above facts about the dried flower industry, the present review focuses on the flower production scenario and how flower growers can benefit flower products during the lockdown in the country like COVID-19. These days, the ICAR, a premier research organization in India, also encouraged farmers to make dried colored plants from roses, marigolds, chrysanthemums, and China aster in preference to destroying the ornamentals. Dried flower petals may be utilized to develop gulal in various colors and different marketable commodities for further use (Anon, 2020).

2 Impact of lockdown on flowers trade

2.1 World scenario

Ornamental plants have strong socio-economic values across the world. Dried flowers and leaves can be used to derive value-added products with imposing beneficial impacts

Table 1 Top ten exporting countries for floricultural products in 2019 (Source: APEDA/COMTRADE, United Nations)

Rank	Exporting country	Quantity in MT	Value in (000USD)	Share (%)
1	Netherland	6,278,066.00	8,619,166.00	43.41
2	Colombia	191,915.00	1,434,655.00	7.23
3	Germany	467,480.00	1,040,716.00	5.24
4	Ecuador	115,705.00	930,843.00	4.69
5	Kenya	692,453.00	837,364.00	4.22
6	Italy	298,961.00	810,229.00	4.08
7	Belgium	392,992.00	597,729.00	3.01
8	Canada	128,224.00	477,260.00	2.40
9	Spain	175,940.00	472,725.00	2.38
10	China	257,528.00	444,829.00	2.24
	Total	8,999,264.00	15,665,516.00	

on the society. Flowers represent the € 15bn (£ 14bn/$ 18bn) worldwide industry, which supports financially better to the millions of human populations, which involved in their trades. A total of 169 countries are involved in exports of floriculture products. The top ten floriculture exporting countries are presented in Table 1, which show that among the floriculture trading countries, a country like the Netherlands leads the global market with 43.41%, followed by Colombia (7.23%), Germany (5.24%), and India that is ranked 27th with accounted for 0.39% of total global exports in 2019 with a total value of 78,284,000 USD. In importing of floriculture products, 127 countries were involved. The top ten flower importing countries are depicted in Table 2. Germany is the largest importer of floriculture products with a 14.73% share, USA (13.02%), and Netherlands (12.21%), and India is in 48th rank with a total value of USD 31,545,000 and share in world trade is 0.16%. Floriculture was severely altered due to the COVID-19 pandemic and the world moved to lockdown, with flowers closing their doors, resulting in the EU cut flower traders spending an amount of €1bn (£900m/$1.2bn) during the first six weeks of lockdown as reported by Union Flyers, The International Flower Trade Association (Fredenburgh, 2021). On March 13, 2020, the Dutch auction fell and Royal Flora Holland in Amsterdam stopped importing and exporting, which is responsible for 40% of the world's total cut flowers on demand. During lockdowns in various countries, the need for flowers, decorative ornamental plants, as well as bulbs of flowering plants decreased due to the COVID-19 epidemic (Van der Ploeg, 2020). This is because of the cutback on global flights and shipments, which are major logistics ways to supply the chain of flowers. Social gatherings, weddings ceremony, funerals, and other flower-based activities around the world have been banned by issuing guidelines from various countries, which has significantly reduced the demand for these products. Therefore, financial risks to florists were observed. For example, in the early stages of lockdown by April 2020, the New York Times reported that Dutch florist had destroyed nearly 400,000,000 flowers that had not been sold due to the pandemic COVID-19 or even donated to hospitals or passers (Lioutas & Charatsari, 2021). In a survey carried out via Perez-Urestraz et al. (2021), the entire variety of contributors who spoke back the questionnaire from different nations was 4205. The survey obtained general responses from forty-six international locations global. Brazil had the highest turnout (29.6%), followed by Greece (23.8%), Spain (19.6%), and Italy (9.4%). Overall results indicate that the

Table 2 Top ten importing countries for floriculture products in 2019 (Source: APEDA/COMTRADE, United Nations)

Rank	Importing country	Quantity in MT	Value in (000USD)	Share (%)
1	Germany	834,865.00	2,924,441.00	14.73
2	USA	465,736.00	2,585,840.00	13.02
3	Netherland	977,284.00	2,423,553.00	12.21
4	UK	414,087.00	1,496,696.00	7.54
5	France	374,336.00	1,274,650.00	6.42
6	Japan	106,075.00	600,736.00	3.03
7	Italy	169,723.00	581,076.00	2.93
8	Switzerland	203,585.00	570,581.00	2.87
9	Russia	242,293.00	563,451.00	2.84
10	Belgium	292,325.00	547,769.00	2.76
	Total	4,080,309.00	13,568,793.00	

need for ornaments and flowers may not decrease, but market availability was almost nil. Royal Flora Holland sales have dropped by an average of 50% each week in comparison with the earlier year due to a shortage of flowers (Craig, 2020). The European Union is a major producer, trader, as well as consumer of flowering plants (Darras, 2020). The total production of flowers in the EU is approximately about 20 billion, which is 44% of global flower and potted plant production. The main flower-producing countries under the EU are the Netherlands, Italy, Germany, France, and Spain (Darras, 2020). European Union ornamentals decorators are estimated to have misplaced almost four billion $ because of the entering of COVID-19 in nations (Button, 2020). Seventy percentage of flowers produced in Kenya are exported to Europe, primarily through the auction of the Netherlands. Most of the ornamentals are offered in early spring, but because of the epidemic starting from March 2020, the ornamentals had no longer been exported to the market. Instead, there is a shortage of requests for ornamentals, due to restrictions, declining sales, the closing of shops, and a situation where people cannot get out of their homes. Fredenburgh (2021) pointed out that Kenya is the third-largest supplier of all rose varieties and sold these flowers in the European Union, where 100,000 flower farms pay low wages to workers and in general vulnerable to sudden losses of income as told by Anna Barker, senior consultant of flowers and served at the Fairtrade Foundation. Flower exports from Kenya fell by 85% in April, "said Barker. By May 2020, 50,000 people had lost their jobs and 20 million had indirectly affected their livelihoods. From 2020, new rules were enacted in favor of the area (legislation of 22 March 2020), which allowed the production, transportation, marketing of ornamental seeds as well as plants, cut flowers, potting plants, etc.

2.2 Indian scenario

In 2018–2019, total export of floriculture products was 19,726.57 MT (worth Rs 571.38 crore), but due to COVID-19 in 2020–2021, the country is expected to export floriculture products worth Rs 575.98 crore with a total of floriculture products exported quantity being 15,695.31 MT. Indian floriculture products include dried petal flowers (77.1%), flowers under cut flower category (6.1%), bulbs of ornamentals (0.8%), foliage (0.02%), and others (15.9%). Prominent export destinations from India are the USA,

Table 3 Floriculture product exports from India in the year 2020–2021 (Source: DGCIS Annual export)

S. No.	Country	Quantity (MT)	Value (INR in Lacs) 1 million = 10 lacs
1	USA	3139.19	15,895.51
2	Netherland	1603.87	10,930.30
3	United Arab Emirates	1659.88	3443.22
4	UK	860.91	3312.10
5	Germany	1054.69	3213.11
6	Japan	114.16	2614.74
7	Canada	485.65	2301.48
8	Italy	235.31	1767.47
9	Singapore	1418.93	1119.58
10	Australia	57.71	1044.08
	Total	10,630.30	45,641.59

Netherlands, United Arab Emirates, UK, and Germany (APEDA, 2021). The top ten floriculture product importer scenarios are presented in Table 3, with the USA being the largest importer of floriculture products from India and contributed INR lakh 15,895.51, followed by the Netherlands with INR 10,930.30, Australia (INR 1044.08 lakh) and Singapore being the tenth largest importer of floriculture products (INR 1119.58 lakh) from India in the year 2020–2021. The COVID-19 advisory constituted by way of APEDA recommended that Indian exporters could take advantage of the flower by supplying gaps created from African countries to European markets. However, it is estimated that 99% of the flowers are sold in the domestic market and any loss from that market will have a greater impact on them. The effect of COVID-19 on the flower industry in India has also been observed in areas where the virus does not affect people. The market then plummeted due to lockdown in the whole country due to the spreading of the COVID-19 epidemic. The lockdown becomes introduced in two levels as level I had been started from 25 March to 14 April 2020 and II level lockdown implemented from 15 April to a few days in May 2020 and closed all social gatherings, cultural occasions, religious capabilities, motels, and hospitals wherein plants are big in call for sell. Saha and Bhattacharya (2020) reviewed reports on the influence of the COVID-19 epidemic on Indian florists and found that florists suffered losses as they could not even recoup their investment. Mitesh Patel, a florist in Badarkha village near Ahmedabad, was worried about the lockdown, fearing that his rose plants were burnt due to high temperature that caused delays in harvesting. Patel, a florist, also said that the supply of fresh roses and marigolds had not been done during the entire crop and dumped the crops in a dust bin as there was no supply of flowers. Monaz Waman from Maharashtra destroyed chrysanthemum flowers worth Rs. 1.60 lakhs, because he could not sell almost 2 tons of chrysanthemum flowers. In the city of Ahmedabad, florist Kunal Yadav expressed his opinion that he had to destroy flowers Rs. 15,000 worth of flowers due to not proper care they are rotting and stinking. Bolapalli, who is also the director of the South India Floriculture Association (CIFA), a florist and exporter's association, said flower growers were suffering because most of the flowers did not fall under the category of essential commodities. He grows cut flowers like carnations and roses from Bangalore, but due to the non-supply of flowers, all flowers were kept in a compost pit or used the stalks for cattle feed due to the lockdown. Keshav Murthy, a florist in Denkanikottai, exports an average of 1.2 lakh roses to countries like New Zealand and Malaysia but was unable to export such cut flowers due to interruption in air connectivity and lockdown. Ashok Kumar, from Solan, Himachal Pradesh, in northern India, said he had grown chrysanthemums and carnations on 3000 m^2 of land, but lost at least Rs. 15 lakhs due to COVID-19 (Vora & Kulkarni, 2020). Maitreyi (2020) opined that due to the country lockdown, people were not going to temples for religious and social gatherings, and events were postponed or canceled. Therefore, marigold, chrysanthemum, lily, jasmine, and other locally grown flowers are taken to wholesale markets in cities and dumped. According to the Financial Express Bureau (2021), due to the lockdown, floriculture farmers have been lost Rs. 100 crores, and it was very difficult to export flowers due to increasing freight charges. Protected agriculture in India is expected to comprise 2000 acres of cut flower land, with a daily yield of 30–40 lakh stems, according to the Indian Society of Floriculture Professionals (ISFP). Praveen Sharma is working in the capacity of president of the Indian Society of Floriculture Professionals (ISFP); the flower export market had completely collapsed due to the cancellation of marriages, which was causing trouble to the florist farmers. Najeeb Ahmed, president of the South Indian Floriculture Association (CIFA), said the lockdown had damaged flower cultivation and management since there was no business from March to October 2020. Although the floriculture business started after October, Indian florist was unable to export their products due to high freight prices. This occupation is highly dependent on labor and the reverse migration of labor has affected crop management. However, to address the problem of florists, the Government of India (GOI) has issued guidelines from 25 April 2020 to partially open retail outlets with limited restrictions and to restart the limited flowers supply chain management. Therefore, states such as West Bengal permitted flower markets to be sold flowers for a few hours, but some flowers were wasted due to the non-supply of flowers. COVID-19 was declared a "Notified Disaster" by the Ministry of Home Affairs (MHA), Government of India, on March 14, 2020, under the Disaster Control Act, 2005. The review report suggested that state governments can make State Disaster Response Fund (SDRF) to resolve this problem. According to the guidelines, the Government of India will allocate a fund consisting of 75% amount of the SDRF allocation to states that comes under the general category/ Union Territories as well as Northeastern (NE) States like as Sikkim and to special category states/ Union Territories such as Himachal Pradesh, Uttarakhand, and Jammu & Kashmir. The National Disaster Response Fund (NDRF), established under the same Act, makes 90% of donations to states, in the event of a serious natural disaster and, if not adequately funded, affiliates to the State SDRF. The Fifteenth Financial Commission has approved INR 28,983 crores for the provinces for the fiscal year 2020–2021, with the SDRF accounting for 80% of the total. States might allocate 40% accountability and freedom, as well as 40% recovery and reconstruction in this scenario. Such an amount can be used to help flower producers and retailers that have suffered losses as a result of COVID-19. According to a statement by the Director of the Ghazipur Flower Market Traders Association, which was published in the Hindu newsprint on April 10, 2020, flowers worth a few crores had to be dumped due to COVID-19 and the country's lockdown. The relief amount can be used to compensate floriculturists as well as retailers where they lost their flowers due to COVID-19. Many of them even have poly house bank loans. A statement was given by the President of Himachal Pradesh Fruit, Vegetables and Flowers Grower Association where he reported that floriculturists are not included to receive income support under the scheme launched by Govt. of India under the umbrella of the PM-KISAN Scheme. Bulgari et al. (2021) also reported that ornamental products are not important to the human diet; due to the emergency of COVID-19, most of the farmers as well as flower growers are not sold flowers and destroy flowers.

3 Sustainable way to protect flower crop production

3.1 Dried flowers

The export of Indian flower products includes dried flowers (77.1%) followed by cut flowers (6.1%), bulbs of flowers (0.8%), foliage plants (0.02%), and others (15.9%). As products such as fruits and vegetables, there is no separate code for the export of dried flowers, and most dried and handmade flowers are included under HS code-06039000 (APEDA, 2021), which includes bleached, dried impregnated, dyed, or other products developed from cut flowers and buds of flowers for making of bouquets or ornamental uses. Dried flowers, as well as plant parts, are also used to design different greetings and art cards as well as interior decorations. Other plant parts containing pods, bract, peduncle, fruit, or anything found in the ground, with a moisture content varied from 15 and 20% or less (after drying), are appropriate under such category (Chakrabarty & Datta, 2021). Plant parts like mosses, stems, fleshy fungi, inflorescence, twigs, branches, bark, flowers, thorns/spines, fruits, leaves/ foliage, selaginella, ferns, cones, seeds, roots and minor forest products like lichens, etc., are also appropriate for drying (Raj, 2001; Vermam et al., 2012). Murugan et al. (2007) reported that the drying of flower arrangements (final products) can be classified under eight categories including (1) liners, (2) main blooms, (3) dehydrated flowers and parts of plants in bulk, (4) floral arrangements, (5) fillers, (6) floral handicrafts, (7) potpourri, and (8) exotics. Dried flowers and their economically important products have an additional value and may be preserved for a longer period if they are kept dry and dust-free. It is well known that dried flower products can be stored for years without being disturbed by various environmental conditions. In recent days, flower drying at the commercial level has been selected as a potential source for the export destination, making up 15% of the world's flower business, while the Netherlands leads the way in dried flower exports after the USA, Mexico, India, Columbia, and Israel (Sharvani & Sree, 2018). India exports over INR 315 crores worth of dried flowers and plants each year, with the USA being the top consumer of dried and processed flowers (APEDA, 2017). Currently, over 300 export-oriented businesses exist in India, with Karnataka, Andhra Pradesh, and Tamil Nadu accounting for half of them (Chakrabarty & Datta, 2021).

3.2 Dried flower products

Various types of dried flower products such as potpourri, flower wreaths, painted cards, and greeting cards are used (Jain, 2016). Dried flower and foliage-based products are depicted in Fig. 1. Dried flower-based value-added products can be divided into the following categories. Gift packs, wall striking, flower bouquets, artistic greeting cards, table mats, mirror decoration, calendar, potpourris, pictures, hats, flower baskets, refrigerator magnets, wall plates embedding in gold/silver or resin could be utilized in jewelry, coasters, three-dimensional floral arrangements, landscape, for interior decoration and so on are all made from dried flowers. Some of the key issues were raised (Chakrabarty & Datta, 2021) and discussed below:

Fig. 1 **A** and **B** Road-side vegetation; **C** avenue tree; **D** Plant press; **E** and **F** Pressed dehydrated leaves; **G** and **H** Pressed dehydrated flowers; **I** and **J** Greeting cards; **K** Table mat and coaster; **L**–**N** Landscapes; **O** Embedding of flowers in sand; **P** Dehydrated rose; **Q** Dehydrated entire marigold plant; **R** Dehydrated dahlia; **S** Three-dimensional arrangements of dry flowers (Datta, 2016)

3.2.1 Pictures of pressed flowers, flower trays, tabletops, and shadow boxes

A bit of cardboard is protected with material or paper, and the design has painted a touch earlier in which the dried products are glued. As soon as the glue is dried, cover it with glass and apply it as soon as viable. The same for trays with vegetation or table tops may be fixed and the shadow containers can be adjusted in this manner with an honest association of intensity and skipping glass coverings.

3.2.2 Wood panels/intermediate piece/pandal decoration

Plant-based products like wood, plywood, and bamboo are polished or rubbed with an equal mixture prepared from linseed oil and turpentine in equal ratio followed by a pinnacle layout. Seeds, pods, dried branches, and other objects were then cemented and sealed with transparent shellac. The same technique can be used to make centerpieces.

3.2.3 Floral craft or arrangement

Floral crafts with floral motifs are also made with dried flowers, which include pictures of flowers, cards and cover greeting cards, flower designs, and other artistic creations that can be attached to the wall frames (Bhutani, 1990). Drying flowers and foliages have also been used to make unique gift packs, artistic floral arrangements, greeting cards, festive decorations, bouquets, floral balls, flower pitchers, pomanders, wall sceneries, wedding cards, floral designs, pictures, calendars, sweet-smelling potpourris, and landscapes, etc.

3.2.4 Corner bouquet arrangements

These floral arrangements are normally placed on a different table and are designed to be seen from the front. The decoration must be the right size for the display desk.

3.2.5 Stick materials

Various kinds of bleached and dyed leaves can be used to make stick substances of numerous sizes (10″, 12″, and 18″ rod sticks) via putting dried material near the rod in the sort of manner that they shape an amazing shape. Ribbon and peeps are examples of accessories that can be utilized to enhance the beauty of a product.

3.2.6 Carry bags

In the first-class portions of dried leaf, bags may be crafted from dehydrated foliages using sewing/stitching dried flower products. A bag manufactured from dried leaves is a historic artwork that stretches to antiquity and eternity.

3.2.7 Jewelry box

Wooden and paper box in the desired size can be polished in any color scheme, and dried leaves can be placed on top. The flowers are arranged to create a distinctive pattern, layout, or image. In the packing containers, thoughts or messages can be written with dried leaves.

3.2.8 Greeting card

Apart cutting from paper, leaves are positioned on top of it so that when forced, the flowers and leaves do not come out. Card/floral item is additionally dried for an hour on the top glass table before being stored and protected from dust and moisture. A number of the floral items may be fixed in frame or laminated. Diverse designs and styles may be used in addition to a mixture of various colors to make such types of cards.

3.2.9 Making candles

Dried flowers can also be used to produce beautiful candles. It can be made by arranging dried flowers in a vase without the need for an empty candle. If the dried flowers are no longer overwhelmed, they are put over wax, filled with lightly heated wax and rolled.

3.2.10 Potpourri

Potpourri can be prepared by a mixture of dehydrated flowers, berries, foliages, roots, stems, and seeds (De, 2011). Florists use herbs, dried flowers, seed heads, and grasses to create durable products like non-preserving decorative arrangements and potpourri blends (Bose et al., 1999). Some of the common ingredients used to prepare potpourri are orris root, benzoin, sweet flag, gum, fine-grained non-iodized salt, storax, and ambergris. In

India, main flowers such as rose, bougainvillea, and marigold can be used in combination with globe amaranthus and cockscomb. These flowers and their parts are contained in a well-designed glass bowl of various ranges in colors and stand or placed in a colored satin or muslin bag. Potpourris are not made only to provide a pleasant aroma, but also to repel moths and protect woolen garments while they are being stored. Anon (2018) suggested that the materials make potpourri, which consist of curly pod, lata ball, bowl, coco chips, and star flower (77.72 g without package material) and package (H: 13.5 cm XW: 8 cm XL: 8 cm) 34.78 g. The total cost of raw material to prepare potpourri was Rs. 4.00/-. The overall cost of production per pack, including packaging materials, labor, establishment, and other costs, was Rs. 15 per pack, and it was sold at a wholesale price of Rs.40 per pack and a retail price of Rs. 100 per pack.

3.3 Arrangements for dried flowers

Dried flowers are also termed as dried ornaments, and they offer more flexibility than new flowers. These types of flower arrangements can also be used repeatedly without the problem of fading. The stem length varied from 15 to 40 cm, and it could be lengthened by employing wire and hot glue guns. The arrangement of dried flowers is divided into 'main flowers,' 'liners,' and 'exotics':

3.3.1 Main flowers

These form a large mass and play an important role in flower arrangement because of various shapes, sizes, and colors. Flowers including statice, strawflower, nigella, larkspur, and roses are commonly used.

3.3.2 Liners

Liners are a type of decorative glass that is commonly used to draw attention to a floral arrangement. Avena, Phleum, Halaris, and Triticale are examples of such grasses. Over grass, maize, sorghum, dried sorghum, dried twigs, and branches of trees and bushes can also be used.

3.3.3 Exotics

It is evident from the name that such types of plants that come into this category are palm spears, lotus heads, and okra pods.

3.3.4 Fillers

These are a collection of things that are used to increase the number of flower arrangements (Somani, 2010).

4 Factors affecting the quality of dried flower products

Following are important factors which affect the quality of dried flower products:

4.1 Selection of suitable crop/genotype

The selection of appropriate crop/genotype for drying flowers is one of the most important aspects of drying flower products (Chakrabarty & Datta, 2021). All plant materials like flowers, foliage, branches of plants, nuts, seeds, grains, pods, cones, berries as well as fruits can also be used for drying (Musgrove, 1998). Raj (2001) suggested the materials for drying including leaves/foliage, flowers, cones, roots, thorns/ spines stems, twigs, mosses, bark, fruits, branches, seeds, lichens, ferns, fleshy fungi, etc., and all are used to create various value-added products. Floral crafts and flower-based arrangements made from fresh flowers are indestructible and long-lasting. However, the quality of dried materials is dependent on the type of variety in a particular crop. It has been observed that some flowers deteriorate their ornamental value after drying. As a result, the selection of suitable crop/genotype for drying is critical to the profitability of the dried flower sector (Mishra et al., 2003). Flowers like as sweet william, anemone, rose, narcissus, pansy, zinnia, stock, daffodil, lily, allium, carnation, freesia, chrysanthemum, marigold, etc., respond well to drying (Rogers, 1988). Similarly, foliage like ferns, eucalyptus, aspidistra, and leaves such as ivy, magnolia, mahonia, laurel are also showed suitability for dehydration (Healey, 1986; Rogers, 1967). In the case of sweet pea flowers, when the flowers are pressed, the dried flowers have lost their color and have turned dark brown, making them unfit for use (Jean & Lesley, 1982). In Helichrysum, the petals are tough but lose their shape as they dry, the petals turn downward and the center disc flowers fall off. This characteristic is more common in the yellow varieties than in the rest (Sangama, 2004). Safeena and Patil (2013) dried four different varieties of roses, and the Lambada cultivar scored the highest for retaining color, form, and texture, while the lowest scores for color, form, and texture were recorded in ’Ravel’ ’. Datillo (2001) made his opinion that the brighter the color of the flower, the longer its color lasts. The bright orange roses, impatiens, marina, tropicana, carrot tops, and holly Toledo faded to dry brilliant orange when drying the yellow flowers keep their color well after drying; however, white blooms can turn a light gray-brown tone. Flowers in dark red colors may darken as they dry. Differences in flower color can be caused by a variety of traits. This type of difference in the color of drying rose varieties was also reported by Acharyya et al. (2013), Sohn et al. (2003). Sharma et al. (2019) dried various varieties of roses such as First Red, Taj Mahal, Peach Avalanche, Gold Strike, Avalanche, Confetti, Corvette, Guana, Hollywood, Nobelsey, Sweet Avalanche, and Teineke. Taj Mahal responded best when dehydrated under a microwave oven. Somani (2010) also noted some ornamental flowering plants which are given below and suitable for drying:

- *Red*: Zinnia, cockscomb, pomegranate, sumac, peony,
- *Pink*: Peony, gladiolus, statice, larkspur, snapdragon,
- *Yellow*: Zinnia, marigold, Acacia, goldenrod, yarrow, strawflower,
- *Blue*: Larkspur, thistle, delphinium cornflower, globe amaranth, hydrangea,
- *Green*: Seedpods, foliage, grasses,
- *Orange*: Strawflower, marigold, zinnia
- *Violet*: Statice, gladiolus, stock, heather, lilac

4.2 Selection of techniques

Various workers have standardized a wide range of drying procedures for decorative leaves, flowers, ferns, grasses and other plant parts. The optimum flowering stage, harvesting time, and dehydration time differ from plants and foliage parts. Wang et al. (2019) suggested that chrysanthemum flowers drying under hot air drying showed the lowest general flavonoid levels. Microwave treatment for 30 min after that treated by hot air drying at 75 °C was found most effective method for preserving biologically active chemicals with improved antioxidant properties and further inhibition of the enzyme acetyl cholinesterase. Vacuum air oven drying has been visible as the fine technique for maintaining floral color and associated characteristics. (Pinder & Namita, 2018). Oulakh and Radha Rani (2018) advocated various display packaging materials to increase the visibility of the products and retain the whole quality of the dehydrated flowers for a longer time. Plants dehydrated in a microwave oven and stored in paper envelopes for 120 days received the highest grade (Sharma et al., 2019).

4.3 The harvesting time of flowers for drying

Early morning or late evening crop is suitable for drying of flowers. Kant (2018) reported the timing of harvesting of some important flowers as depicted in Table 4. However, harvesting of flowers during the hot months responded best because most of the water content evaporates from flowers. Adequate care is required in the selection of a method to obtain good results. Harvesting time depends on the flower to flower, and usually, flowers should be harvested when they have reached maturity but before the flower color has disappeared (Padmavathamma, 1999). Bhattacharjee and De (2003) suggested that flowers such as chrysanthemum, rose, and celosia are harvested at the semi-blooming and full-blooming stages for drying. However, pine cones, ornamental grasses, seeds, and seed heads are harvested when they reach complete maturity (Sankari & Anand, 2014). Datta (1997) made his opinion that after one or two of irrigation, flowers and leaves should be collected from the fields. The plucked flowers should be moisture and dew-free. Therefore, it is advisable fact that flowers should be plucked on a sunny day in dry weather. Norman (1998) concluded that the flowers must be harvested in the noon period and given proper ventilation for complete drying. Spielberg (2002) opined that the blooms should be picked on dry sunny days for drying. Flowers should pluck when they fully open, but special attention

Table 4 Name of some important flowers and foliage with their appropriate harvesting time (Kant, 2018)

Name of flowers	Harvesting stage	Parts of plant
Alstroemeria hybrids	4–5 florets open	Flower
Althea rosea	1/3 florets open	Flower
Anemone coronaria	Buds just start to open	Flower
Bellis perennis	Fully open	Flower
Bouvardia hybrids	Flowers just start to open	Flower
Dahlia variabilis	Fully open	Flower
Eucharis grandiflora	Before the flowers fully open	Flower
Helianthus annuus	Fully open	Flower
Papaver spp	Buds showing color	Flower
Thujaorentalis	The immature stage of foliage	Foliage

is to be taken for Helichrysum where the flowers shattered during storage if plucked very later. Sharon (2006) pointed out that drying methods do not play any role, but it should be ensured that the flowers must be plucked at an appropriate time means before reaching full maturity. The harvesting stage of the flower depends on the species and types of flowers (Paul & Shylla, 2002). Prasad et al. (1997) reported that fully open flowers should not be harvested as these are not suitable for oven drying. Safeena et al. (2006b) observed that flowers collected at the half-bloom stage took less time to dry. White et al. (2002) gave the opinion that hay, pine cones, seeds, and most seed heads are harvested at the fully mature stage, but before they become visible wither. They further suggested that the flowers are plucked before fully open and the leaves are collected at the peak of the crop growth. In Helichrysum, flowers cut at the fully open stage take less time to dry than the tight bud and half-open bud stage (Sangama, 2004). Lourdusamy et al. (2001) measured the drying pattern in three flowers. They concluded that completely opened gomphrena flowers, as well as half and full opened French marigold and zinnia flowers, are excellent for dehydration. Erv, Evans, and Miller (1998) suggested that herb flowers that are dried and harvested for crafts are plucked just after fully opened. The sun's rays, moisture in the blossoms and cold, cause the flowers to discolor and deteriorate the herb's quality. Seeds, pine cones, hay, and mostly seed heads are harvested at a fully mature stage, but before they become visible wither (Dana & Lerner, 2002). Hemant et al., (2016a, 2016b) reported that drying is done in a microwave oven embedded with silica gel for excellent dried flower quality, size, color, flower diameter, integrity, and pigment retention. Sharma et al. (2019) harvested flower varieties, namely Avalanche, Confetti, Corvette, First Red, Gawana, Gold Strike, Hollywood, Noblessie, Peach Avalanche, Sweet Avalanche, Taj Mahal, and Tinker in November 2017, April 2018, June 2018, and August 2018. The cultivation of the Taj Mahal in November and April and the harvesting of the Corvette in June and August gave the best results under microwave oven drying. Kumar et al. (2021) obtained the best results in roses when half-open stage flowers were plucked and dried in a hot air oven. Chakrabarty and Datta (2021) have given below the timing of harvesting of different types of flowers.

4.4 For herbs

The flowers of herbs must harvest before opening the flower. Dew and moisture in flowers, rays of the sun, and frost cause discoloration of flowers and deteriorate the quality of products.

4.5 For flowers and foliage

After one to two days of irrigation, flowers and leaves should be collected from the fields. Plucking of flowers during the dry season gives the best performance because water contains in flowers and foliage easily evaporates. In terms of flower quality, the winter season produces the brightest colors, but in monsoon, the plants are more susceptible to various insects, pests, and diseases. Flowers ought to be plucked on dry sunny conditions, mid-morning to mid-afternoon (after complete evaporate dew), but avoid picking too late as bright sunlight can fade the bloom. The appropriate time for plucking flowers is early morning when the sun rises because the plants' dew has evaporated due to the sun (Datta, 1999).

4.6 For dry grasses, seeds, pine cones, and most seed heads

Seeds, seed heads, dry grasses, and pine cones when reaching full maturity but have not dried are collected on the last day of their growing season (Chakrabarty & Datta, 2021).

5 Drying methods

The drying procedure has a considerable impact on product quality, clarity of dried products, and other decorative elements (Chakrabarty & Datta, 2021). Various methods for drying or dehydrating flora or foliage are used. In these techniques, moisture is eliminated artificially by the use of various techniques of dehydration and desiccants. Datta (1999, 2016) standardized various dehydration techniques including pressure drying, freeze-drying, embedded drying, air drying, press drying, oven drying, etc., for fresh forms of flowers, twigs, branches, leaves, etc., which may store for a longer period. Flowers and other plant parts are commonly dried in the sun for commercial purposes, but alternative drying strategies such as microwave oven drying, air drying, oven drying, desiccants drying, ice drying and glycerinization treatment are now also useful. Drying flowers and other plant parts like foliage may be helpful to make decorative floral craft items such as floral-based cards, flower arrangements, wall hangings, landscapes, calendars, and potpourris. Among the dried flower products, Potporis is the major segment of the dried flower industry (about 70% or more) for various purposes.

Drying of plant parts refers to the evaporating moisture artificially from any plant parts by heating under controlled humidity, temperature, and airflow. In living materials, the drying process has been used to examine any chemical alterations and microbial growth (Bhattacharjee et al., 2010). The quality of dried flowers as well as plants foliage is generally influenced by the dehydration method adopted for drying purposes. Various dehydration techniques, such as sun drying, air drying, oven drying, dryer drying, freeze-drying, press drying, and microwave oven drying, have been now in progress. Glycerinization can be used to treat flowers, twigs, and leaves for retaining their fresh appearance for several months or years (Mishra et al., 2003).

5.1 Natural drying

It is the oldest and simplest method of drying in which leaves, plants, pods, etc., can be dried in the solar. In such a method, the flower or foliage is kept to dry itself and collected when completely dry. Plants like as *Caesalpinia separi, Cassia fistula, Aegle marmelos, Pinus roxburghi, Sapindus mucrosi, Bambusa spp,* etc., responded better for natural drying (Chakrabarty & Datta, 2021).

5.2 Air drying

It is the simplest, easiest, and cheapest method of drying and is commonly used for drying of flowers and foliage. In this drying method, the plant material is attached with a rope/wire and kept in a dark or sun-hanging position for quick drying. A wide range of flowers has been demonstrated the suitability for air drying (Chakrabarty & Datta, 2021; Datta, 2015; Geetha et al., 2004; Raj, 2006; Singh et al., 2008). Collier and Jett (2002) concluded that air drying is the simplest method to preserve seed pods and flowers with little or no cost. Dana and Lerner (2002) stated that air drying is suitable for plants with semi-dry flowers and stems. It demands a warm, dark, and well-ventilated environment with a minimal humidity (Raghupathy et al., 2000). However, Champoux (1999) reported that flowers hanged under dark conditions took 8–10 days to dry if adequate ventilation is available. Raghupathy et al. (2000) mentioned that a clean dark place with a minimum of humidity in the drying area is needed to dry the air. Flowers should be picked in good quality for air drying, and then, the foliage should be removed and hung upside down in a warm dark place. Stewart (1997) noted the withering of petals in air-dried flowers, while Martha (1997) noted that air drying works best on plants, perennials, and ornamental grasses. Weak flowers if any should be discarded before they dry out (Perry, 1996). White et al. (2002) optimized longer time for dehydration in foliage and more fleshy flowers. Dana and Lerner (2002) opined that air drying is the easiest technology for semi-dried flowering plants and drying is recommended in a cool, dark place with good air circulation. The flowers are tied with twine, ribbon and hung in warm air in a dark room, a process that takes 1–2 weeks to dry completely and is determined by atmospheric humidity, temperature, humidity, flower size, air, and velocity (Datta, 2015). Sell (1993) suggested that rooms with a relative humidity of 75% or higher encourage the growth of mold that spoils flowers so humidity must be maintained. Datta (1999) concluded that flowers can spread on blotting sheets/newspapers and be saved inside the darkish or within the sun to dry plants. Sharon (2004) made his opinion that air drying is an excellent technique for plant parts drying and is of high quality suited for flowers with low humidity. Air drying technology should be accomplished in a closed cellar due to the fact that dark places assist the flowers to retain their natural shade. Dubois and Joyce (2005) discovered that raising the air temperature hastened the drying process. The ideal temperature range for drying flora is between 60 and 80 degrees celsius. Enzyme reactions are destroyed if the temperature surpasses 60 °C, which is relevant because some enzymes are necessary for chemical reactions that result in browning (for example, polyphenol oxidase). Schmutze (2007) pronounced that air drying is the greatest method for preserving color and flavor. According to Bryan (1992), air drying in roses, larkspur, statice, and strawflowers is the finest approach. Helichrysum and statice flowers have a crunchy feel that can be dehydrated by hanging them upside down or keeping them in a container until dry (Bhutani, 1995). Delphiniums, globe thistle, celosia, and hydrangeas can be easily dried by air drying (Mercer, 1996). During the dry season and summer, Kumar and Parmar (1998) discovered that air dehydration under shade is very beneficial to flowers like acroclinium, helichrysum, and limonium. Salvia, goldenrod, strawflower, celosia (crested and plumed types), hydrangeas, baby wreath, and statice were found to be suitable for air-drying (Smith & Laschkewtsch, 1998). Pavildou (1998) noted that species including*, Craspedia globosa, Delphinium consolida, Limonium suworowii, Limonium ottolepis, Helipterum manglesii, Achillea millefolium, Helichrysum bracteatum, Helipterum roseum, Limonium perezii and Limonium sinuatum* responded best under air drying. To keep their color and quality, all of the above species can do well when dried at 30 °C for the first week and 20 °C for the second and third weeks under darker conditions and well-ventilated areas. Pertuit (2002) noticed that air-dried flowers become exceedingly rigid. After drying, blue and yellow flowers retain their color but pink blooms fade. Flowers with a crisp texture, such as strawflowers, statice and others are more suited to this drying procedure (Susan, 1990). This approach is simple and inexpensive, but it takes a longer time to dry. Anopheles, Delphinium, Oregano, Rumex and Holmscoldia, among other flowers, can also be air-dried (Raj, 2006). Statice flowers, gypsophila, and gomphrena responded best in air drying when hang dry under a dark room (MacPhail, 1997). Some important flowers with a crisp texture, such as Limonium (statice), helichrysum (strawflower), and acrolinum (paper daisy), are hung upside down and placed in a pot so that they are dried easily. Keep in mind that the drying area is sufficiently ventilated to prevent the flowers from decaying before they dry out. Poppy heads, globe thistle, Chinese lanterns, and baby's wreath dry out in the air when hung upside down (Singh & Kumar, 2008). Pinder and Namita (2018) observed high acceptability of dried flower texture, minimum brittleness of dried flowers, flower damage, flower size, and maximum flower color acceptability under a vacuum air oven for 60 days. However, reduced flower weight was observed under microwave drying. Overall, drying with vacuum air oven drying performed best because it preserved floral color and associated parts.

5.3 Sun drying

The plant material is implanted in a container and dried quickly in the sun using the sun-drying process. Materials like eucalyptus, palm leaf, poppy pod, lotus pod, cornflower, etc., are commonly used for sun drying. Aside from that, flowers such as marigolds, pansies, zinnias, and pompon chrysanthemums are dried by embedding them upside down in the sand before exposing them to the sun. In India, sun-drying is the most frequent method (Anon, 1997). Bhutani (1990, 1995) briefly discussed the use of sun-drying in flowers. For most flowers and herbs, solar dryers have been employed for the same reason. In India, open sun drying is a typical method of flower drying. Bassapa et al. (1991) investigated the suitability of sun-drying strategies for strawflowers (*Helichrysum bractatum*) and concluded that drying in sun responded best for strawflowers. Flowers including poppy, zinnia, acroclinium, chrysanthemum, globe amaranth, and marigold can be easily sun-dried (Deepthi & Santhosh, 2008). Dubois (2005) suggested that solar dehydration is a low-cost method for dehydration of flowers. Rangasamy (1998) mentioned that the best solar dryer could reduce drying times and may be the best strategy for drying flowers. He also said that the sun dryer method of rapid dehydration is less expensive, although it is depending on weather conditions. Chrysanthemum, pansies, zinnias, pompon, and marigolds embedded in the sand and set in the sun will dry up within two days (Sankari & Anand, 2014).

5.4 Press drying

Flowers and foliages are kept between newspaper sheets or two blotting paper layers, and these sheets are placed on corrugated board of the same size to evaporate water to escape from the plant and also be permitted to flowers and leaves to dry without losing the products natural shape. The method of press drying is described in 1820, but this method was later adopted to prepare the herbarium (Lawrence, 1969). In this method, it must be ensured that the water vapor completely escapes from the plants otherwise there is a risk of microorganism attack, failure of drying and loss of material. Drying sheets are placed in the oven at the optimal temperature; drying time can be reduced (Datta, 1997). Prasad et al. (1997) highlighted the drawbacks of press drying and observed that the shape of the material could not be maintained as it flattened by the press. Flowers and leaves flatten after press drying; they cannot be utilized to manufacture products like floral designs, greeting cards, and other wall-mounted art (Bhutani, 1990).

A wide range of flowers and leaves as well as a big variety of unknown materials can be dried quickly by press drying (Chakrabarty & Datta, 2021; Datta, 2015; Geetha et al., 2004; Mir et al., 2009). Kher and Bhutani (1979) optimized the temperature and time of flowers under press drying in an oven at 35–39 °C for 48 h as compared to 24 h for leaves of hibiscus, haemotoxylon, calliandra, marigold, and Cassia. Flowers such as roses, carnations, and helichrysum are dried under an electric hot air oven at 40–45 °C for 120, 133, and 72 h, respectively, as compared to 24 h for leaves and flowers of adiantum, nephrolepis, and flowers of thuja, Hibiscus, marigold, and caliandra (Verma et al., 2012). The drying time can be reduced if the sheets are kept at the proper temperature in the oven. The original color of the material is preserved in this procedure, but the shape of the substance is not (Datta, 1997). Lourdusamy et al. (2002) noted that flower press drying is a quick-drying method for drying chrysanthemum, verbena, candytuft, lantana, rose, euphorbia, and leaves as fern, silver oak thuja, etc. Gill et al. (2002) optimized time for rose drying at 120 h while carnation took 132 h and helichrysum best drying and took 72 h for press-drying. They further suggested that absorbent face tissues can be kept on the pages to aid in the drying of the flowers. Kher and Bhutani (1979) optimized time for dehydration of pansy under press drying varied from 35 to 39 °C while oven took 48 h, compared to 24 h for thuja, adiantum, and silver oak leaves. According to Smith and Laschkewtsch (1998), pressing flowers is a simple method of preserving them, but the color fades and the blooms flatten out, especially asters, buttercups, zinnias, pansies and geraniums. Buttercups, daffodils, pansies, marigolds and Queen Anne lace, on the other hand, are excellent in suppressing it. Flowers can be pressed by layering them between absorbent materials such as newspapers, old books, or catalogs. Flowers like pansies, coral-bells, lilies, hardy geraniums, and vine flowers are appropriate for press drying (Sharon, 2004). Datta and Roy (2011) reported press drying for fern (9 days); caeselpinia, rorippa, (13 days); *Digera muricata, Digitaria setigera, M*imusops *elengi*, *Setaria glauca, and Echinochloa colonial* (12 days); Mussanda, *Vernonia cinerea* (18 days); *Wedelia chinensis,* Ixora and *Oplisnemus hirtellus,* (11 days); Acalypha, *Bamboo spp*, *Azadirachta indica, Sapium cebiferum* (14 days); thuja (28 days); bougainvillea (8 days), Brassica (25 days); phlox (29 days), *Oplisnemus spp., Polygonum spp., Sida acuta, Synedrella nudiflora* took (16 days) under press drying. Raghupathi and Subhendu (2020) found that wood press drying is the best technology for press drying of *Celosia argentia* flowers, while iron press drying was found to be the best technology for *Viola tricolor* and *Phlox drummondii* flowers.

5.5 Embedded drying

In embedded drying, shredded flowers are placed in desiccants such as silica gel, river sand, borax, boric acid, aluminum sulfate, sawdust, and corn granules to dry them. In this technology, the size and color of product remained. Flowers and foliage must be very fine for embedded drying. Drying of flowers can be done throughout the year by embedding methods with readily available flora and fauna by setting up small-scale industries, which can help generate employment for unemployed men and women (Batra, 2016). Flowers and foliage are gently embedded in silica gel, sand, clay, borax metal or plastic containers in a well-ventilated environment at room temperature. During hang-drying, Raj (2006) noticed changes in the shape of dehydrated ornamental products primarily owing to moisture loss from the cells. Flowers must be dried by adding desiccants such as borax mixture, fine sand, and silica gel to avoid petal shrinkage. As for embedding media, borax, sawdust, sand, perlite, silica gel, and a combination of desiccants are utilized. Sand and borax are less expensive in embedded media, but drying takes longer; therefore, desiccants including borax, sand, silica gel, and cornmeal are utilized. Silica gel responded best for delicate flowers like roses, dahlias, carnations, etc. (Prasad et al., 1997). Borax and alum are lighter in weight and can be used in dehydrating flowers (Bhattacharjee & De, 2003).

Being hygroscopic, borax can be used to bleach petals of flowers, if they are left in place for a long period (Datta, 1997). Due to its easy handle, weighty and not reacting with water vapor fine sand is the excellent embedding media (Datta, 2001). Silica gel is supported by Winter, 1998, because it is absorbed moisture more quickly from flowers than from borax and sand and the shape of the flowers is also retained (Nirmala et al., 2008). Trinklein (2000) observed that flowers treated with silica gel dried quickly, so it is an easy way to have more flowers dried in a short period. Silica gel crystals turn blue on drying and showed pink color after absorbing moisture. If reuse silica gel as embedding media, heat it in the oven until the crystals turn blue. Drying may be successful, but it is a time-consuming procedure that is completely dependent on weather conditions. The pots were kept at the proper temperature after the flowers were embedded with desiccants (Kher & Bhutani, 1979).

Various workers have reported that silica gel responded ideal media for producing high-quality dehydrated flowers (Susan, 1990; Bhutani, 1993; Champoux, 1999; Datta, 1999; Alleman, 1994;, Roberts, 1997; Thomler, 1997; Lourdusamy, 1998; Pertuit, 2002; Nirmala et al., 2008; Hemant et al., 2016a, 2016b; Jeevitha et al., 2020; Jeevitha et al., 2021). Silica gel is the fastest-acting desiccant (Neave, 1996). At all drying temperatures, silica gel embedded flowers minimized maximum moisture loss (Nair & Singh, 2011). Trinklein (2000) noted that the flowers treated with silica gel dried quickly, allowing for the movement of more dried flowers in the same season. When embedding and drying chrysanthemum and dahlia flowers, Sell (1993) found that a mixture of borax and corn flour (1:1 v/v) produced the best results. According to Smith (1993), borax is a good drying medium for carnations, roses, larkspur, asters, marigolds, geraniums, dahlias, delphiniums chrysanthemums, and zinnias. Sujatha et al. (2001) showed that a 1:1 ratio of borax crystals and sand was the optimum combination for maintaining quality and color. Of the various desiccants used fine sand gave the best results in water lily flowers (Geetha et al., 2002). Datta (2001) also pointed out that fine sand responded best as embedding media due to easy handling, being heavy, and not reacting with water vapor. Moona (2004) observed minimal changes in flower size with higher carotenoids in dried flowers when embedded in silica gel. Kumar and Jayanthi (2004) observed that silica gel as an embedding media had shown the highest score of texture and size in chrysanthemum. When zinnia flowers were dried in the sand, good quality dried flowers with magnificent bloom color and flawless petal texture were noticed (Singh et al., 2004). Silica gel is made up of a huge network of interconnected tiny pores that use physical adsorption and capillary condensation to attract and hold moisture. Mishra et al. (2009) dried zinnia flowers by embedding method using sand and silica with electric oven and microwave oven. Flower size and color remained unchanged in both media after dehydration but decreased flower weight due to water vapor from products. Swati et al. (2017) embedded flowers of African Marigold cv. Pusha Orange in four embedding media, namely dust, fine sand + silica gel in the ratio of 2:1, river sand and borax + cornmeal in the ratio 1:1 and exposed to hot air at a temperature of 45 °C drying in the oven. Sand + silica gel (2:1) took the shortest time to complete drying, while the maximum reduction in flower size, the highest percentage of moisture loss from flowers obtained in the dust-embedded treatment. However, acceptable quality was seen by dust in terms of color retention, whereas river sand produced good texture and shape. Akram and Sharma (2021) took *Cleretum bellidiforme* and *Calendula officinalis* embedded by various desiccants at room temperature and in a hot-air oven at 55 °C. Embedding drying with silica was found to be the best for flower texture after dehydration. Kumar et al. (2021) used rose flowers in the stage of half-open and processed under a hot-air oven at 50 °C for 42 h by embedded with silica gel and placed in transparent acrylic boxes for storage.

5.6 Oven drying

This is one of the most important ways to get a better-dried flower product. In this method, plant materials are dried in a microwave and hot air oven under an optimized temperature and time. Now days, ovens are so popular due to faster drying and improving the quality of dried flowers. Oven drying of flowers can be classified into two types microwave and hot air oven. Optimized drying times of some flowers in hot air ovens and microwave over ovens are presented in Tables 5, 6, and 7.

Table 5 Effect of temperature and time of drying in flowers under oven drying

Flowers	Temperature (°C)	Drying time (h)	References
French marigold	45–49	72	Ranjan and Misra (2002)
African marigold	45–49	96	Ranjan and Misra (2002)
Bougainvillea	35–39	48	Kher and Bhutani (1979)
Pompon dahlia, Narcissus/daffodil	35–39	72	Sheela (2008)
Haelipterum, Helichrysum, Candytuft, Gerbera, Gomphrena, Limnium	45–49	48	Sheela (2008)
China aster, Eurphobia, Larkspur, Rose bud, Zinnia	40–44	48	Sheela (2008)

Table 6 Optimization of time duration for different flowers in the microwave (Sharvani & Sree, 2018)

Flowers	Time (minutes)
Dahlia, Narcissus, Snap dragon, China aster, Chrysanthemum, Bougainvillea, Gerbera, Gladiolus, Pride of India	3
Delphinium, Straw flower, Phlox, Statice	2.5
Gulmohar, Helipterum, Ixora	2
Combretum comosum, Petrea volublis	1
Water lily	4
Rose	2.5

Table 7 Heating time and the standing time of few flowers in microwave oven (Brown et al., 2016)

Flower	Heating time (minutes)	Standing time (h)
Rose	2.5	Overnight
Daisy-type flowers: marigold, chrysanthemum, zinnia, daisy	1.5	10
Carnation	1.5	10
Large dahlia	3.0	36
Large chrysanthemum	3.0	36
Peony	3.0	36
Small orchid	1.5	24

5.7 Hot air oven drying

This approach involves keeping plant material at an optimized temperature for a specific period, which is determined by the size of embedding product their structure and available moisture content. This is the fastest method of dehydration but has the drawback that the plant material tends to discolor. The efficiencies of hot air oven-dried flowers were higher in the covered condition when using silica gel at 60 °C for 24 h. In that way, flowers obtained from the microwave oven were embedded in silica gel for 90 s under covered conditions achieving maximum marks (Sankari & Anand, 2014). An advantage of the hot air-drying method is that it does not affect the environment for dehydration. The process is quick, and the product quality is very good (Raval et al., 2020). After a specific drying time of products, the containers are removed from the oven and maintained at room temperature for a certain amount of time to allow the moisture to escape and the plant material dries out completely. China aster flowers dried using white sand under an oven which remained the original color, texture, and shape of dehydrated products (Raju & Jayanthi, 2002). The drying temperature and time for French and African marigolds were optimized at 45–49 °C and kept at 72 and 96 h, respectively (Ranjan & Misra, 2002). Flowers like bougainvilleas (*Bougainvillea* sp.), *Narcissus* sp, dahlia (*Dahlia variabilis*), gerbera (*Gerbera jamesonii*), chrysanthemum (*Dendranthema grandiflora*), *Gomphrena globosa,* acrolinium (*Helipterum roseum*), China aster (*Callistephus chinensis*), statice, marigold (*Tagetes* sp.), *Gladiolus* sp., larkspur, (*Delphinium ajacis*), *Ixora coccinea*, *Nymphaea* sp., *Rosa* sp., *Zinnia linearis*, silver fern, golden fern, *Adiantum*, etc. has been shown suitability for oven drying (Chakrabarty & Datta, 2021; Datta, 2015; Deepthi & Santhosh, 2008; Geetha et al., 2004). Similarly, Kher and Bhutani (1979) obtained best results at 35–39 °C temperature in bougainvillea when kept at (48 h), while pompon dahlias and narcissi do best at (72 h), but 40–44 °C temperature was standardized for rose buds, *Callistephus chinensis*, *Euphorbia leucocephala*, *Aerva javanica, Mina lobata*, *Delphinium ajacis* and *Zinnia linearis* responded best at (48 h). *Tagetes patula* in the size of medium and large flowers of rose showed suitability at 40–44 °C for (72 h) but gladiolus and very large rose flower, keeping time was (96 h). *Helipterum roseum*, perennial chrysanthemum in small flowers, candytuft, dombeya, gerbera, gomphrena, helichrysum, statice flower kept (48 h), *Tagetes erecta* (96 h), and water lily (120 h) were all best at 45–49 °C. Helichrysum flowers dried in the oven for 48 h to maintain their color and shape for a longer time (Venugopal & Patil, 2000). Datta and Roy (2011) recorded the drying time of individual flowers in a hot oven and found that flowers of aster, bougainvillea, acroclinum, candytuft, French marigold, and zinnia responded best at (48 h), ixora (36 h), small chrysanthemum flower (45–48 h) while pompon dahlia, African marigold, narcissus, zinnia type dried best at (72 h); however, nymphaea showed best when kept at (120 h) with 40–45 °C temperature. By embedding dried chrysanthemum blossoms in silica gel and preserving them in a hot air oven at 50^0 C for 48 h, the best grade dried chrysanthemum blooms were obtained (Dahiya, 2003). Singh et al. (2004) examine the impact of temperature on zinnia (*Zinnia elegans*) drying and found that a faster dehydration process can be achieved by higher temperature, but all pigments such as chlorophyll, carotene, xanthophyll and anthocyanin degraded. Chen et al. (2000) also observed similar results in roses and carnations, and Khafaga and Kock (1980) recorded higher degradation of anthocyanins at higher temperatures in *Hibiscus sabdariffa* var Sabdariffa. Pandya et al. (2001) noticed that the structure and color in dehydrated chrysanthemum flowers did not change, but the total chlorophyll concentration in the dehydrated products was much lower than the control, with no change in the flower size. Safina et al. (2006a) discovered that drying Dutch rose flowers in silica gel at 40^0 C produced the greatest results in terms of color, texture, and appearance. Dahiya (2003) obtained excellent dehydrated chrysanthemum flowers by embedded in silica gel and placing them at 50 °C for 48 h. However, when the hot-air oven temperature and drying period increased, the number of dried flowers and carotenoids reduced dramatically in terms of weight and moisture content. Singh et al. (2002) found minimal degradation in zinnia flower pigment (chlorophyll, carotene, xanthophyll, and anthocyanin) when kept in room drying, while maximum degradation in flowers was recorded at 50^0 C in a hot air oven. Cut statice stems up to 34 cm were kept alive for 48 h by soaking them in a 1:2 or 1:3 glycerol: water solution and then drying them at 34 °C for 1 min (Paparozzi & McCallister, 1988). Dehydration times optimized in hot air oven flowers such as bougainvillea, marigold (small), acroclinum, aster, candytuft, and *Zinnia linearis, the* temperature kept 48 h; ixora took 36 h; chrysanthemum (small flower) dried at 45- 48 h, while marigold (large), pompon dahlia, narcissus, zinnia lilliput responded best at 72 h and nymphia dry best at 120 hours (Datta & Roy, 2011).

5.8 Microwave oven drying

This is the fastest way of flower dehydration. It works on the idea of electronically produced microwaves stirring the molecules in organic materials to release moisture (Bhutani, 1990; Verma et al., 2012). Microwave oven drying is the best method for conserving antioxidant activity, total anthocyanin content, and total phenolic content in dried flowers, as it results in the least moisture loss, epicuticular wax, and percentage of leachates while producing the highest dry weight (Acharyya et al., 2017; Arunkumar & Mangaiyarkarasi, 2019; Biswas & Dhua, 2010; Datta, 2015; Preethi et al., 2019; Safeena & Patil, 2013; Ullas et al., 2018). It is a suitable method for the flowers like snapdragon, China aster, chrysanthemum. Microwave radiation has the unusual virtue of being preferentially absorbed by water, according to Dubois (2005), making it an extremely effective energy source for the drying process. The maximum dry weight of flowers was recorded with quartz sand for 120 s in the microwave oven drying method (Nirmala et al., 2008). White et al. (2002) concluded that flowers dried under microwave oven appear fresh with rich in colorful as compared to the flowers dried by other techniques. Bhutani (1990) discovered that using an electrical microwave oven to dry the planting material releases moisture by activating the water molecules present in the organic material. Before beginning the oven process, Rothenberger (2000) suggested putting a cup of water in it to prevent excessive drying. To avoid moisture absorption from the air, spray dried flower petals with hair spray or lacquer before placing them in the microwave oven. Flowers and greenery are embedded in a fine silica gel and encapsulated in non-metallic pottery or glassware, the drying process is hastened in a microwave oven (Bhutani, 1995; Datta, 1997). Nowadays, microwave vacuum drying (MVD) is used in some horticultural crops for better dehydration techniques because it showed high efficiency, well controllability, and cleanliness (Gong et al., 2007; Yanyang et al., 2004), but information on flowers is very scarce. Ran et al. (1995) pretreated rosehips by dipping three solutions including 0.1% hibiscetin, 0.3% $CaCl_2$, and a mixture of 0.3% $CaCl_2$ and 0.5% vitamin C, followed by drying in a microwave vacuum dryer. All pretreatments showed no significant difference in the drying time of rosehips, but there was little taste change in roses when treated with 0.1% hibiscetin compared to other pretreatments. Dried roses were less bright than fresh flowers. The samples treated with hibiscetin revealed natural color and maximum value of stable anthocyanins during processing and storage.

Smith and Laschkewtsch (1998) obtained good results in drying of flowers such as carnations, which require 2.5–3 min of heating time, roses (1.5 min), and zinnias took (2–2.5 min). During the drying of chrysanthemums, Zhang (2000) investigated the mechanisms of microwave, airflow, and microwave-air flow. Microwave airflow combination drying shortened dehydration time but improved the quality of products, resulting in a fivefold–tenfold increase in selling price over conventional drying. Kumar and Jayanthi (2004) discovered that drying chrysanthemum flowers in a microwave oven with powdered silica gel at an 80% micro power level for 120 s provided the best quality dried chrysanthemum flowers. Allow the flowers to dry in the drying agent for a few hours after drying in the microwave oven for the finest color and attractiveness. Thomler (1997) dried clusters of flowers such as goldenrod, gypsophila, and cornflower and suggested the suitability of microwave oven drying for these types of flowers. However, anemones, chrysanthemums, marigolds, roses, pansies, and peonies are best suited for this method (Bull, 1999). Dhatt et al. (2007) used a microwave oven to dry bud rose for various times as 3 min, 4 min, and 5 min and discovered that rosebuds dried in a microwave oven for 4 min resulted in the best color and shape of products.

5.9 Glycerin drying

Various workers have employed glycerin drying to preserve attractive foliage. Glycerinization treatment keeps soft leaves pliable for simple handling and it is best for visual properties in dried flowers, particularly the leaf sections (Anon, 2004; Jawaharlal et al., 2013; Singh & Kumar, 2008; Verey, 1994; White et al., 2007). Plants like *Morina longifolia, Catharanthus sp., Digitalis purpurea, Iris orientalis, Humulus lupulus, Anthurium andrianum, Grevillea, Avena, Breeza sp., Cyperus alternifolius, Citrus limon, Codiaeum variegatum, Camellia japonica, Clematis, Crotalaria selloana,* Dracaena*, Eucalyptus sp., Hordeum jubatum, Hydrangea macrophylla, Ilex sp., Juniperus communis, Magnolia longiflora, and Populus sp*. are suitable for glycerinization (Geetha et al., 2004). Harten (2002) also reported that drying by glycerin is best suited for foliar preservation due to its osmotic nature, so leaves preserved in glycerin retain flexibility, shape, and texture. Among the drying techniques, glycerin drying is the least expensive of the drying processes and has a larger water-attracting capacity. Leaves protected by a 33% glycerol solution showed soft and flexible (Dana, 1983a, 1983b). However, Dubois and Joyce (2005) reported that the effect of glycerinization depends on the type of leaf. To maintain the elasticity of the plant material, fresh and fairly mature foliage should be treated with hygroscopic chemicals. Glycerinizing chemicals are thought to be responsible for the moisture present in plants to maintain foliage shape, texture, and sometimes color. Brown et al. (2013) observed that glycerinization depends on leaf type and among the glycerinization techniques; the dip method is more suitable for short or dissected leaves such as ferns, while the uptake method is better for broadleaves such as magnolia. Texture retention under dip treatment may be due to the replacement of contain moisture present in the leaf with glycerin, which remains the shape and texture (Bale, 2006). The reduction in brittleness with glycerin can be attributed to the plasticizing and softening action of glycerin. Anon (2011) also reported that glycerin-dehydrated substances are more flexible and have a natural shape. Drying the glycerin, the product quality was good because the flower moisture restores by a mixture containing glycerin and water (Paul & Shylla, 2002). Glycerin is a proper source for microbes; hence, just a trace amount of antibiotics is required to protect microbes in dried samples. Paparozzi and McCallister (1988) reported that glycerized annual statice with microwave protection retained the flexibility of the flower without greasing. Healey (1986) examined conserved timing for different types of foliage. Maximum conserved time (12 h) taken by *Aspidistra spp*. followed by *Fatsia japonica* (7–10 weeks), *Mahonia spp*. (3–6 weeks), *Magnolia spp*. (3–4 weeks) and a minimum conserved time (2 weeks) recorded with *Eucalyptus spp*. Semant et al. (1993) discovered that one part glycerin and two parts hot water were the best combination for absorbing 26 twigs plant at room temperature. The substance can be kept in the solution until it is completely absorbed. The resulting leaves in glycerin drying were soft and flexible as reported by Dana, 1983a, 1983b. Sell (1993) preserved magnolia stems in glycerin: hot water (1:2 v/v). Mature leaves showed good results in this treatment, and the solution was easily transferred to the stems. The glycerinizing process modified the water content of the leaves and gave the plant material a strong and resilient nature (Anon, 2004). Hydrangea, ivy, and magnolia are good materials for this strategy. Westland (1995) observed that the preserving of leaves and berries in a solution of glycerin and hot water was prolonged. According to Prasad et al. (1997), glycerin is the best source of microorganisms; hence, very small dose of antibiotic is required to protect the microbial contamination in dehydrated products. Deepthi and Santhosh (2008) stated that maiden hair fern, camellia, ivy, and leaves of eucalyptus are suitable for glycerin drying. Glycerinization is excellent for conserving small leafy tree branches where glycerin can penetrate the leaves and turn brown (Dana & Lerner, 2002). The typical time to dry during the summer season is 2–3 weeks, although best results can be attained when absorption is rapid. Jawaharlal et al. (2013) observed the best performance in glycerinized leaves of thuja (*Thuja orientalis*) and camellia (*Camellia reticulata*), silver oak (*Grevillea robusta*) with softer leaves and highest overall acceptability. Jhanji et al. (2018) glycerized with 20% under a well-ventilated dark room and yielded the best results in three leaf types as *Asparagus cetaceus* (asparagus), *Nephrolepis exaltata* (ferns) and *Gravila robusta* (silver oak). Singh et al. (2018) found the glycerin most effective for leaves such as asparagus, fern, cordyline, and silver oak. Yadav et al. (2018) glycerized cut leaves of *Peltophorum ferruginum* by two methods of glycerin (uptake and full dip) with different concentrations of glycerin (10, 20, and 40%). Leaves treated with 40% glycerin solution by full dip method showed the minimum percentage of leachate with minimum change in leaf area and maximum scores on textural quality, shape retention, brittleness, and overall acceptance. Marak et al. (2016) used the glycerization approach to produce the greatest results for silver oak in the context of size as well as texture, fragile, and overall acceptability in 20% glycerin. Buxus leaves treated with the full-dip method of glycerin were better than the absorption approach (Yadav et al., 2018), and among the concentrations of the glycerin solution, 40% was the best for drying the cut leaves. According to Karmakar et al. (2020), the useful life of *Nephrolepis exaltata* may be prolonged by 40% glycerin when using the full-dip method.

5.9.1 Desiccant drying

Some wild flowers such as blanket flower (*Gaillardiax grandiflora*), maximilian sunflower (*Helianthus maximiliani*), and black-eyed susan, desiccant are suitable for desiccant drying (Frogge, 2000). Dana and Lerner (2002) found the most satisfactory results in two desiccants, namely silica gel and sand-borax combination. Other desiccants like perlite, sawdust, kitty litter, corn starch, and maize are also being used, but they are not as efficient. Westland (1992) reported that the application of borax showed a slight discoloration of the color and a rough petal texture. Silica gel is suggested as the best media as compared to sand or borax for faster dehydration of flowers (Anon, 1997) and also retains flower color (Champoux, 1999). When flowers are dried in silica gel, the color of the flowers resembles the original in white, yellow, lavender and blue (non-rose). Colors that are already dark, such as crimson, dark pink and orange grow considerably darker (Datta, 2015; Dilta et al., 2011; Safeena, 2005; Sankari & Anand, 2014; Shailza et al., 2018). Dried flowers acquire moisture from the air quickly, so put them in a sealed container containing silica gel to avoid this. With silica gel and sand, flower quality is preserved very well in terms of post-drying properties and lifespan (Malakar et al., 2019). Evelyn (1997) employed fine grains like sand to drying of flowers. Fresh kitten litter can also be used to dry flowers (Barnett, 1996). According to Gupta and Prashant (2005), out of four embedding agents (river sand boric acid, sawdust, and silica gel), silica gel showed the most effective for removing moisture from leaves and flowers. After conventional air drying, many delicate flowers lose their structure irrevocably. The petals can be held in the desired form by placing the flower in fine-grained sand that has been entirely dried in the oven (Dubois, 2005). Cornmeal, borax, silica gel, and kitty litter are also be utilized and their desiccating activity draws water out of the air, allowing for speedier drying with the original color of products. According to Dhatt et al. (2007), silica gel showed the best embedding technique of dehydration for preserving color and shape in rose cvs. Kristen Dyer and Gold Medal, Carnations, marigolds, lilies, and dahlias are stored for extended times in a dry state for drying (Deepthi & Santhosh, 2008). Flowers with numerous petals such as zinnias, dahlias, and daisies are dried with silica gel. Drying of different types of roses using silica gel yielded good results (Safeena et al., 2006b). Flowers that have been pre-treated with particular chemicals have also been proven to be appropriate for drying. Sindhuja et al., 2016 pretreated the flowers with magnesium chloride (10%) for 5 h. It is then dried by embedding in media containing silica gel + borax (1:1, v/v) followed by dehydration under a hot air oven at 55 ± 1 °C produced the best shape, texture, color, fragile and overall acceptability with total carotenoid pigment in the carnation.

5.9.2 Sand drying

Tulips, snapdragons, marigolds, roses, and dahlias are among the flowers that can be dried with sand drying (Anon, 2014). Daisy flowers can be dried with the petals facing down. Blooming branches in the sand should be planted horizontally with elongated snapdragons, lilacs, blossoms, and flowering branches. Sand can be used to dry small and hard flowers (Martha, 1997). Flowers such as zinnias, marigolds, pansies, and pompon chrysanthemums do best in sand drying. Roses and cup-shaped flowers were dried upside-down, daisies were dried downward, and snapdragons and other elongated flowers were arranged horizontally in the sand (Anon, 2001).

An application of two desiccants, such as borax, with a mixture of sand, when applied in a ratio of 1: 0.5 to 1:1 can change the color of the flowers. Sea sand with a smaller concentration of borax in flowers like roses, carnations, and gerberas dried well for 10–15 days. Flowers kept in a 1:1 combination of dry sand and borax have been shown to keep their natural shape with minimal shrinking and color retention. Flowers kept using a combination of sand and borax in the ratio of (2:1) took 10–12 days to become scaly and dry, but they are less rigid as compared to the flowers treated with the "hang and dry" method (Chakrabarty & Datta, 2021). In some cases, sand can cause small holes in the petals because of its rough edges (Pertuit, 2002). For foliage such as *Juniperus chinensis*, *Araucaria cunninghamii and Thuja orientalis,* the combination of silica gel and white sand under a microwave oven for 30 and 20 s worked perfectly (Malakar et al., 2016). After being immersed in sterilized sand, drying in a solar dryer is found to be superior to other drying methods such as mechanical drying, air drying, and sun-drying (Willson et al., 2015). Padmapani et al. (2019) discovered a hybrid solar that efficiently dehydrated marigold and rose flowers which maintained carotenoid content, anthocyanin, size as well as texture, fragile, integrity, color, and diameter of dried flowers. Helipterum gulabum, chrysanthemum, small flowering perennials, candytuft, zinnia, gomphrena globosa, China aster *Dombeia spp*., gerbera, dahlia, strawflower, *Limonium spp*., larkspur, rose, linearis, bougainvillea, gladiolus and large-flowered roses cultivars, marigolds, Nympha and leafy plants, etc., responded best this dehydration technology (Datta, 2015).

5.9.3 Freeze drying

The flowers are dried in unique freeze-drying equipment for 12 h, usually at a temperature of – 10 °C. Although William Hyde Wollaston affiliated with the Royal Society in London in 1813 presented the technology which discover the attractiveness and lifespan of freeze-dried flowers. The freeze-drying technology of flowers is an advanced technology and completely new to India. The main merit of freeze-drying is that the products produced by freeze-dryers look almost like fresh ones (Nilsback & Zisserman, 2006). Freeze drying is the most effective way of flower preservation. Freeze drying is based on the sublimation concept, which involves holding ice at a low temperature (less than 0 °C) in a partial vacuum (less than 4.58 torr) and then evaporates by heating without passing through the liquid phase. The vacuum drying temperature is low resulting in a flower color similar to that of fresh flowers (Chen et al., 2000).

Wilkins and Desborough (1986) investigated the efficacy of various pretreatments (Glycerine (G), clove oil (CO), ethylene glycol (EG), G + dimethylsulfoxide (DMSO), CO + DMSO, and EG + DMSO when carnation flowers are kept at a cryo-drying temperature of – 80 °C for 12 h. Flowers that had not been treated retained their natural appearance, but flowers that had been treated had less aesthetic value. Brown (1999) observed drying in various cultivars of rose and carnation and discovered that the temperature and freezing time of flowers play an important role in maintaining the bloom quality of dehydrated flowers. Behera (2009) reported that freeze dryer treated dried flowers were found to have maximum moisture loss and maximum total sugar content. Bhattacharjee and De (2003) cryodried several varieties of carnation flowers and found them to be natural in color after being placed under a freeze dryer (−20 °C) for seven days. The impact of two methods of drying as microwave and freeze-drying on China rose flowers was investigated by Liang et al. (2005) and observed that freeze-dried again treated with a tartaric acid solution gave good color and appearance before being microwave dried. Sohn et al. (2003) also examine the impact of freeze-drying on the color and form of different *Rosa hybrid* cultivars like Tineke, Golden Gate, Safir, and Rote Rose. Freeze drying caused shrinkage, but the color of the roses remained the same as when they were fresh. The hue of the straws and the Golden Gate stayed the same as new roses. Fernandes et al. (2018) dried good-quality herb flowers by freeze-drying. Bindu et al. (2021) treated statice flowers with various flower preservatives followed by kept in the freeze dryer. A chemical compound containing an exchange medium color preservative, color fixative, buffer, modifier, pH regulator, and shatter-resistant substance (ethyl vinyl acetate) when treated with flowers resulted in flowers obtained as close to natural color.

5.9.4 Water drying

Flowers are kept in water; some flowers will dry out. The cut flowers are first submerged in two inches of water and then allowed to dry before being moved up. Flowers and containers are placed in a dry, warm and dark environment. Flowers like ageratum, allium, acacia, celosia, hydrangeas, gypsophila, bells of Ireland and yarrow are dried well (Singh & Kumar, 2008). *Alchemilla mollis,* hydrangea and gypsophila are chosen and set upright in a vase with an inch of water until the flowers have used up all of the water and are completely dry. (Anon, 2001).

5.9.5 Molecular sieve drying

Molecular sieve is a synthetic crystalline alumino-silicate with a regular micropore structure and is now used for the dehydration of flowers. Molecular sieves exhibited high water adsorption capacity when maintained at low partial pressures with temperatures up to 100 °C. The hole in the flower dehydrator is filled with a mixture of organic solvents until the level is roughly 2 cm higher than the flowering level. Water molecules are gradually absorbed into the molecular sieve's microscopic cells or pores in this approach. However, dried flowers reabsorb some of the moisture from the environment, so dried flowers have increased softness and plasticity. This method is appropriate for drying of peonies, marigolds, orchids, dahlias, phloxes, summer chrysanthemums, roses, globe flowers, hollyhocks, carnations, camellias and some other species having a large number of petals or a tough structure (De et al., 2016).

5.9.6 Cryo drying

Flowers are cut into consistent (15 cm) lengths and maintained in vials, with the bottom 5 cm soaked in glycerin, ethylene glycol, clove oil, dimethyl sulfoxide and wetting agent solution. The stems of the flower are then recut to 5 cm in length and frozen at – 80 °C for 12 h, after which the flowers are kept under freeze dryer at 20 °C for 7 days under a vacuum of fewer than 100 microns. The flowers and stems have to be completely dry for at least 7 days in this approach. Wilkins and Desborough (1986) dried several varieties of carnation (*Dianthus caryophilus* L.) in a cryo-dried method and found that flowers were placed in – 80 °C for 12 h and subsequently freeze-dried for 7 days; the flowers remained natural in appearance.

Dry sawdust, perlite, clay, rice bran, corn starch, and kitty litter have also been used as desiccants. Perlite, perlite + borax, and perlite + silica gel have also been efficient for dehydration of various orchid blossoms under room circumstances (25–28 °C and 60% R. H (De & Thapa, 2017).

5.9.7 Polyset drying

About 45 min before drying, the polymer-based approach is applied to flowers and foliage. This approach reduces drying time and increases floral color intensity. This approach also prevents petal breakage and wrinkling from occurring during the drying process (Katagi et al., 2014). The beauty of native flowers can be appreciated forever (Thakur et al., 2019) since they are elegantly embedded into the resin, warding off dust.

6 Comparative analysis of different drying techniques

Paul and Shylla (2002) reviewed the efficiency of various desiccants and found that silica gel was the best but an expensive desiccant. In some elegant flowers such as anemone, larkspur, cosmos, and ornithogalum, borax and alum were best suited for drying. Silica gel and borax were found to be a highly quick method for drying zinnia flowers (Singh et al., 2003). Orduno and Baltazar (1995) investigated the drying efficiency of roses, carnations, and gerberas using river or sea sand with borax. Roses and carnations are dehydrated excellent in river sand with a higher proportion of borax in 15–20 days, while gerbera with a lower quantity of borax took 10–15 days to dry well in sea sand. Westland (1995) reported that media contains a mixture of silica gel crystals and dry river sand with 2–3 parts of alum or borax to overcome media sticking problems when either of them was used alone. Bull (1999) reported that flowers such as chrysanthemums, marigolds, roses are best suited for hot air drying and microwave drying. For some important flowers like dahlia, roses, carnations, etc., silica gel is an excellent drying treatment (Prasad et al., 1997). Rar and Gupta (2003) found that excellent dehydrated flowers and foliage when silica gel (60–120 mesh) was used as adsorbent followed by boric acid (granules). Gill et al. (2002) found best-dried roses, carnations, ferns and silver-oak when treated with silica gel while helichrysum gave satisfactory results when silica gel was used in a combination of sand. Flowers were faster dried when borax with silica gel was employed in combination as compared to sand (Singh et al., 2003). According to Singh (2004), sand drying gives a smooth petal texture, whereas drying with silica gel produces a minor roughness and drying with borax produces a higher roughness. Sujatha et al. (2001) found in the brighter color of flowers when employed borax crystals with sand in a combination of 1:1 ratio. Among the various desiccants, fine sand was the best for drying the flowers of the Indian blue water lily (Geetha et al., 2002). Rose flowers were embedded in five different drying mediums including sand and silica gel. Hot air ovens and microwave ovens were used to treat the flowers at various temperatures. When the flowers were immersed in borax and then micro-waved for 3.30 min, the anthocyanin content was highest (Behera, 2009). Singh (2004) noticed that the drying speed of silica gel was faster without harming the quality of zinnia flowers; however, the petal texture had a minor acceptable roughness. Dhatt et al. (2007) discovered that the silica gel treated rose buds embedded best in terms of color, size as well as the quality of products. Singh and Dhaduk (2005) observed that the drying process at high temperature in the oven showed faster results than river sand and borax. Kumar and Jayanti (2004) applied various dehydration technologies like sun drying, oven drying and microwave drying to the flowers of chrysanthemum (button local type). Microwave-based drying with silica gel ensures that the color and shape of flowers are maintained. Flowers were submerged in silica gel and dried in a hot air oven at 30 °C for 24 h and then micro-waved for 35 s showing the greatest carotene and the least size reduction in product (Bhalla et al., 2006). According to Gupta and Prashant (2005), silica gel outperformed the other four desiccants (boric acid, silica gel, river sand and sawdust) in eliminating moisture from flowers. Nirmala et al. (2008) noted maximum score when dried carnation flower with silica gel followed by treated in quartz sand and least score produced by borax treated flowers. Fully open flowers from button-type chrysanthemums, gerbera, and plumeria were dried by

Jawaharlal et al. (2013) and discovered that a combination of sand and silica gel followed by a microwave-oven embedded technique was suitable for drying with a high overall acceptance. Radha Rani and Reddy (2015) noted that carnations took 12 days to air-dry, while borax mixtures take 7–8 days, although dried in 4 days in silica gel, and microwave ovens take only 4 min. Sindhuja et al. (2015) observed that carnation dried flower color varies greatly depending on the varieties and types of desiccants. Among the varieties cv. With Yellow, Harvey Kept exhibited good color and got the maximum score. Wilson et al. (2015) used four alternative methods to dry chrysanthemum flowers: mechanical dehydration, sun drying, air drying, and low-cost solar drying with variable times. Solar drying, when compared to other drying processes, resulted in the most moisture loss. Air drying resulted in the greatest reduction in blossom diameter when compared to other approaches, although low-cost solar drying produced a higher color preservation score than other methods. After being immersed in sterilized sand, solar dryers were indicated to be good performance than other drying technologies. Renuka et al. (2017) investigated the impact of dehydration methods with embedding media on the quality of dried flowers of roses (*Rosa chinensis* Jac.) and water lilies (*Nymphaea alba* L.). Minimal pigment loss (20.27%) was noted in silica gel treated with dried roses. Microwave oven at 350 Hz for 2 min lost maximum pigment (63.14%) without embedding flowers. Roses and water lilies dried in silica gel at 350 Hz for 3 min in a microwave oven showed the highest sensory scores (8.57 and 7.87), while the lowest scores for size (5.04 and 4.93) were recorded under untreated. Jhanji et al. (2018) dried three types of leaves under different drying techniques *Asparagus cetaceus* (asparagus), *Nephrolepis exaltata* (ferns) and *Gravilea robusta* (silver oak). 20% glycerinization under a well-ventilated darkroom was the best method for drying leaves and higher acceptability as compared to other drying methods. Jadhav and Joshi (2021) investigated the efficacy of various drying methods in carnations including air drying, desiccant dryings like silica gel, and a 1:1 ratio of borax and sand and microwave oven drying (flowers prior treated in silica gel). Microwave drying technology takes less time than other drying methods. The hues of the blossoms have a big impact on the fresh and dry weight of the carnation flower. Bassapa et al. (1991) observed that helichrysum flowers dried in a room retain their color intensity for a longer period in open sunlight than 40 °C and 50 °C oven-dried flowers. Venugopal and Patil (2000) also noticed similar results when flowers of helichrysum were dehydrated at room temperature in the shade and then oven-dried at 50 °C for 150–180 days, retaining their original color intensity. Kumar and Jayanti (2004) studied the efficacy of several drying processes for chrysanthemum (button type) flowers including oven drying, sun drying, and microwave drying. Microwave drying with silica gel produced excellent outcomes, whereas white sand with oven drying produced the greatest color and acceptability of flowers. Liu et al. (2017) employed principal component analysis (PCA) and Flow-Injection Mass Spectrometric Fingerprinting (FIMS) to analyze the applicability of drying materials using two daylily flowers (Mengzhi and Chongli) with three drying technologies (solar dehydrator, vacuum freeze dehydrator and hot-air technique). The straightforward FIMS approach is capable of distinguishing between species (raw materials) and treatments within each species. After being processed in the hot air-drying method, two species could not be distinguished very effectively. Shisa Ullas et al. (2018), Ullas et al. (2018) employed different drying procedures to dry the ray florets of five anthocyanin-rich chrysanthemum (*Chrysanthemum morifolium* Ramat.) cultivars. A microwave oven was an excellent method for maintaining anthocyanin content in by-products, antioxidant activities and total phenolic content. The microwave oven drying method retained the highest total phenolic content with antioxidant activities and total anthocyanin pigment. Microwave dried ray floret-based antioxidant activity assays revealed a positive and substantial association between varieties. Barani et al. (2019) dried flowers with various concentrations, viz. 0.1%, 1% and 2% w/v) like as chemicals (citric acid, CA; ascorbic acid, AA; tartaric acid, TTA; and sucrose, Suc) after that fresh roses were dried at 50 °C in hot air. Flowers pretreated with 2% TTA resulted in the greatest amount of anthocyanin, the dry masscyaniding 3-glucoside equivalent equated to a 3.2% loss in comparison with the fresh sample. Flowers color-treated with 2%-TTA were not so better as products generated by the treatment of 0.1% TTA, 0.1% Suc, and 1% Suc. As per the literatures, silica gel method of flower drying has been considered as the best method. However, solar drying is the cheapest method for flower drying and environment friendly in nature. Moreover, for the countries like India, it is quite suitable because of having a greater number of sunny days in one calendar year.

7 Factors affected dried flower and foliage products

7.1 Pre drying treatment

The speed with which dried flowers dehydrate determines their texture, size, and general desirability. Citric acid is a common flower preservative that can help improve the form and color of flowers. It functions as an acidifying agent, reducing the pH of the fluid and preventing xylem vessel obstructions. It also aids in the improvement of size, shape, and color.

7.2 Moisture content after drying

The drying flower moisture content has an impact on their quality. Low moisture content in flowers provides hardiness, while high moisture content in dried flowers causes flowers to wither. Therefore, the percentage of moisture content should be determined before ensuring the drying of various flowers. Chen et al. (2000) discovered that dried flowers with robust and rigid petals had low moisture content. The mechanical help furnished by using the media at some point of the drying manner ensures preserved flower form and moisture content less than 11.55%. Dried flowers containing moisture also affect the longevity of dried flowers. Pandey (2001) also reported a moisture content of 8–11.5% in dried flowers, which ensures the finest quality, strength and remains products quality for a longer time. The drying period of the flowers in excess resulted in the petals falling off during storage (Singh, 2004). Less than 8% moisture content in dried flowers showed a shedding effect, which can be related to excess moisture loss in flowers. In addition, Wilkins and Desborough (1986) found the amenability of flowers to breakage under vacuum-dried flowers.

7.3 Packaging, storage, and care of dried plant products

Packaging material plays a crucial role to maintain the quality of dried flowers. Therefore, display packaging of dried flower products is the major requirement in the current competitive market. The packaging material must be stable and firm to hold the dried flowers well without any damage during storage. A wide variety of materials are available in the market for the packing of dried flowers and leaves, including wood, bamboo, rigid and foam plastics, solid cardboard and corrugated fiberboard. Dehydrated flowers and foliage are arranged properly with covered with transparent glass as well as plastic sheets to protect products from wind, dust, and humidity. Flowers and leaves are stored in appropriate size cardboard boxes without any lining performed better in terms of color preservation than those stored in polythene covers. Cardboard boxes have seen more flower damage than polythene covers (Shital, 2017). Acrylic is more suitable as compared to glass, plastic, and thermocol for glass table mounts and potpourri. This is owing to the material's transparency, which allows customers to appreciate the beauty of the dried flower arrangements inside the container while still being stronger than glass. Flowers that are kept open for storage show good self-life as compared to dried flowers that were kept in opaque containers. This may be due to the direct interaction of dried flowers with environmental factors (Radha Rani, 2011). Bhupender (2012) pointed out that dried flower products are stored in dry cardboard boxes with silica gel pouches, which help to avoid moisture. Dried flower-based flower crafts require a polyethylene lining to protect them from pests and outside moisture. It should also be ensured that dry material should be dust-free and can be cleaned with a brush or dry cloth while plant parts such as cones, seed pods, berries, and large leaves are given a protective coating with varnish or shellac, which can improve their quality. In some cases, a dry part can be separated and fixed by applying transparent glue. Better results can be obtained when glue apply before drying (Sheela, 2008). Smith and Laschkewitsch (1992) opined that dried flowers should be stored in river sand with strong cartons to prevent the flower petals from breaking. Shirin (2011) also reported that air-tight plastic containers for color, texture, and appearance upon storage performed better in dried flowers than in polythene covers dried flowers. Safeena et al., (2006b) observed maximum moisture loss when the half-open flower is dried by silica gel-based embedding for 49 h under a hot air oven with a temperature at 40 °C. Misra et al. (2009) dried zinnia flowers and preserved them in glass plastic or acrylic containers by keeping a small amount of silica gel on the bottom of the container which preserves color and shapes for a longer period making it more durable and moisture resistant. Datta (1999) advocated that dried flowers should be kept in moisture barrier containers like moisture-resistant receptacles such as glass vials, acrylic boxes, and cardboard boxes coated with plastic film or wax paper. Because dried flowers are highly hygroscopic, they absorb atmospheric humidity and do not maintain their shape. He also suggests that the containers should be free from dust and protected from direct sunlight to retain their color. Shirin (2011) recommended flower storage for color retention, texture, and size as compared to airtight plastic containers kept in polythene covers. Plomaritis (2004) dried flowers stored in flakes with some naphthalene flakes to protect against the growth of pests and molds. Dried flowers should be sealed in containers such as airtight tins or plastic boxes, adhesive tape or airtight boxes and plastic bags for extended use. Trinklein (2006) recommended various control measures against domestic insects that enter boxes during storage. It is suggested to occasionally check the box for insects and use naphthalene flakes.

8 Special operations used for drying of flowers

8.1 Processing

In this method, the internal moisture of the flowers is replaced with 2-propyl alcohol or t-butyl alcohol (Romero-Sierra & Webb 1982), where these solvents destabilize the moisture from the flowers, so that flower size is lost. As a result, an epoxy resin replacement procedure using an ascending chain of acetone (Von Hagens, 1981) has been created, resulting in full tissue discoloration. The colors precipitate out of the petals during drying because of the availability of water in the solvent in this process, which uses an ascending chain of ethyl alcohol. Markham et al. (2000) used a moisture replacement procedure without using water-based solvents and found that the pigment diffused but stayed in dried flower petals. Dehydrated flowers with natural hues and textures can be created by utilizing simple mono-hydroxy alcohols and lateral chain diols according to Ito et al., 2010. They devised a technique in which the primary and secondary soaking solvents like ethyl alcohol and polypropylene glycol were used, respectively. Petal shrinking is prevented by using a primary soaking solvent with low viscosity, such as ethyl alcohol. Petal depletion generated by secondary soaking solvents (polypropylene glycol) was considerably reduced after petals were first soaked in several primary soaking solvents such as ethyl alcohol. This appears to be a good alternative in texture and pigmentation almost as good as natural.

Plant species such as *Dianthus caryophyllus*, *Papaver nudicaule, Centaurea cyanus*, *Delphinium grandiflorum*, *Commelina communis*, *Antirrhinum majus*, *Dendrobium phalaenopsis, Viola wittrockiana*, *Eustoma grandiflorum*, *Celosia cristata*, *Bougainvillea spectabilis*, *Mirabilis jalapa*, *Rosa hybrida*, *Hydrangea macrophylla*, *Saintpaulia ionantha*, *Salvia guaranitica*, *Pelargonium incrassatum*, *Rhipsalidopsis gaertneri*, *Portulaca grandiflora*, *Tulipa gesneriana*, *Narcissus pseudonarcissus, Tradescantia ohiensi*s, *Iris hollandica*, *Camellia japonica*, *Helianthus annuus*, and *Dianthus barbatus* have been successfully dehydrated by processing technology.

8.2 Bleaching

Bleaching is one of the most important processes related to the production of commercial dried flowers (Somani, 2010). In the flowering plant materials that are sold in the market, bleaching is very significant. Bleaching is used to eliminate all or almost all of the colors that develop during the dehydration phase of the preservation process. There are two types of bleaching: oxidative and reductive, but the level of efficiency is determined by the measurement of the bleach's access to lignin. Sodium chloride, hypochlorite and peroxide are examples of oxidative bleaches, while sodium sulphide, hydrosulfite and dioxide are examples of reductive bleaches. According to Lourdusamy, 1998, sodium chlorite (10%) performed better than hydrogen peroxide (30%) as a bleaching agent for flowers like gomphrena. Bleached ornamental plant material shows contrasting attractiveness when kept with dried or dyed ornamental plants. Bleaching also makes it possible to utilize dyes for coloring. Because it is relatively selective for lignin and causes minimal harm to the fiber, sodium chlorite is an effective bleaching agent. Hydrosulfites (sodium or zinc hydrosulfite) are less expensive than other bleaching chemicals. Many workers advocated the superiority of hydrogen peroxide because peroxides are responsible for degrading of cellulose, as well as discolor of products and stain removal is less expensive (Dubois & Joyce, 2005; Zeronian & Inglesby, 1995) and also found to be the best bleaching agent (Lourdusamy, 1998). The main concern after bleaching with oxidative or reductive chemicals is plant material yellowing. To avoid yellowing, an alternative with multistep bleaching such as reductive bleach should be done. A final wash with a 2% solution such as calcium hydroxide, aluminum sulfate, barium hydroxide, and sodium bicarbonate can prevent yellowing. Because of its selective action, sodium chlorite is commonly used to bleach for plant foliage (Masschelein, 1979). Even after longer contact, this bleach eliminated the full color from cellulose-based materials while causing no harm to the cellulose. Mazamder et al. (1994) investigated the efficiency of para-acetic acid-like as jute fabric bleaching agent and found it better than peroxide bleaching with non-silicate stabilizers. Dana and Lerner, (2002) & White et al. (2002) discovered that boiling leaves in a solution of 1 tsp. lye or baking soda per quart of water for 40 min has a skeletal impact. Jawaharlal et al. (2013) bleached dried pods of *Jacaranda mimosifolia* and *Castanospermum australe* with 10% sodium hydroxide, then treated them overnight with 2% sodium hydroxide + 2.5% sodium silicate + 35% hydrogen peroxide. The dyeing consistency was light fastness, wash fastness and rubbing fastness with acrylic dyes. Mir and Jana (2015) found that a mixture of 20% hydrogen peroxide and 15% "Ala" can be used to bleach venation skeletons for up to 2 h. Preethi et al. (2019) advocated the 100% bleaching efficiency with sodium chlorite for dried plant material such as *Wedelia trilobata, Clitoria ternetia, Musenda luteola, 'Flava', Musenda luteola, Hamelia petens, Thrylis glauca, Ixora coccrellia. 'Rossia', Circa indica, Cordia Sebestena, and Cassia Glauca.*

8.3 Skeletonizing

It means the removal of all plant tissue from the plant, leaving just the veins of the leaves intact. Skeleton leaves give an interesting glossy look to dried arrangements. Skeletal leaf preparations can be utilized for interior decorating and attractiveness. Skeletal leaves, sometimes known as fossil leaves, are semi-transparent leaves (Ranjan & Misra, 2002). Verma et al. (2012) discovered that peepal leaves that were completely formed and healthy could be skeletonized for more than two days when soaked in NaOH (40%) solution. They advocated heavily textured leaves that are more suitable for this method. According to Marak and Chakrabarty (2015), NaOH (40%) is the skeletonization (removal of mesophyll layers) process for 2 days with maximum vein visibility. The heavy texture leaves responded best for skeletonizing. Ivy leaves, stink pods of Stramonium (now found ripe enough to stand), oak leaf, ficus, bauhinia, *Michelia champaca* and other skeletonized plants have sown more beauty than actual plants. Gift tags, greeting cards, scrapbooks, collages, papermaking, stamping and wedding card decoration are all examples of its uses. Mir and Jana (2015) induced skeletons in leaves that were previously prepared by fermentation (Ranjan & Misra, 2002). Hydrogen peroxide and a cloth whitener named Ala were utilized as bleaching chemicals. Ala's overall bleaching outcomes were found to be better at lower concentrations.

8.4 Coloring of flowers

8.4.1 Tinting

Artificial coloring of flowers with food dyes and stains such as food colors, bromocresol blue, eosin yellow, ammonium purpurate, feulgen stain, phenol, and bromocresol green can produce an improved quality of products in circumstances where when the floral pigment is lacking, light or dull. Tuberose, spider lilies, candytuft, and white Ixora have white blossoms with red, blue, green and yellow flowers. White gladiolus, numerous orchid species, loose jasmine, crossandra, moonshine, and other flowers are among the others (De, 2011).

8.4.2 Sulfuring

At low concentrations, sulfur dioxide is used in sulfuring to bleach-colored plant material and to keep some flowers' red color. Acidification of tissues is linked to color determination.

8.4.3 Dyeing

Colors can be applied in decorative plant parts to enhance the visual values of any ornamental plant, depending on the seasons and fashions. Plant material immersed in a suitable dye is the most extensively used dyeing procedure. Using NaOH to remove the waxy cuticle, the interaction between the dye bath solution and the dried plant material is improved, and adding surfactant improves the contact between the dye bath solution and the plant product. Plant material can be painted in addition to dyeing (staining) with silver or gold paint being the most common (Bhattacharjee, 2006). Tampion and Reynolds (1971) proposed three methods for dyeing flowers: I absorption (cut stems are dipped in dye solution), (ii) dusting cut flowers (with powdered dye), and (iii) dipping cut flowers in the dye solution. In dye solution, a few drops of washing liquid surfactant can be mixed in the dipping procedure, which increases the connection in dye bath solution and the plant product can promote dye molecule diffusion. The absorption method is best-suited for dehydration of carnation, *Chrysanthemum maximum*, starflower, gypsophila and hydrangea. Vat dye is best for celosia flowers by cold method at 0.2% concentration. Dead and dried plant parts, culinary dyes are best due to being nontoxic and are easily available in a wide range of colors. Coloring seeds and pods should be done by dip-dyeing and spraying. Preethi et al. (2019) observed that *Clitoria ternetia* can be colored with natural yellow dyes, while *Musenda luteola* can be colored with natural yellow, blue and red dyes and *Cassia glauca* can do best with yellow dyes.

9 Techno-economic analysis

9.1 Techno-economics of dried flowers

Fresh flowers in the quantity of 8000 acroclinum flowers, 2600 helichrysum flowers, 2700 asters, 350 roses, 800 marigolds, 550 dahlias, 117,500 flowers of ixora, and 16,000 annual chrysanthemum flowers are utilized to prepare 1.0 kg of dried flowers (Datta & Roy, 2011).

Datta and Roy (2011) concluded that plant presses cost varied from Rs. 100–200 per piece. Hot air ovens are widely found on the market or can be custom-made to fit any shape. The price of a hot air oven ranges from Rs. 5000 to Rs. 40,000, while a microwave oven costs between Rs. 6000 and Rs. 20,000 and a solar cooker cost between Rs. 2500 and Rs. 3,500. As a result, the initial investment required to establish a dry flower business is cheap. The cost of press drying flowers was Rs. 2000/-, whereas the cost of hot air oven drying was Rs. 10,000/- (plus additional raw materials) as an initial investment. Singh (2018) designed various value-added dried flower products such as vases, landscapes, simple or laminated greeting cards, dry flower arrangements, photo frames, sceneries of various sizes, decorative pieces, figures and pictures, birthday caps, pen stand, bookmark, wall quilt, coaster set, paperweight and table mat, etc. It took a minimum of 10 min to make a piece of a bookmark or birthday cap or vase, while it took a maximum of 180 min to create $8'' \times 10''$ scenes with the fine work of pasting dried flower petals. Making a bookmark and a birthday cap had the lowest material consumption cost, while maximum cost was involved in making $8'' \times 10''$ scenery with fine work. Instead of flowers, a number of studies have been carried out on the techno-economic analysis of value-added products, including biomass, which showed more revenue-generating products as compared to raw materials. For example, Thomassen et al. (2016) conducted a techno-economic evaluation of a biorefinery of algae and found very economic and innovative regarding its market value and revenue generation. Consequently, it will enhance the quality of human lives via generating better employment opportunities. Similarly, Somavat et al. (2018) done techno-economic analysis of extraction of anthocyanin for ethanol production using corn. Thomassen et al. (2018) assessed the combative potentials of India and Belgium with respect to the algal biorefineries in terms of environmental soundness along with social and economical feasibilities. Researchers concluded that in India profit was better than Belgium. However, environment of Belgium was better than India. Therefore, it can be referred that biomass treatment is better in terms of environmental soundness and profit to the farmers. Similar, outcomes can be expected in the flower drying techniques as well, especially with respect to India and other developing countries.

9.2 Production cost and profit margin

In India, the cost of manufacturing 1600 greeting cards (9 × 25 cm) was Rs. 4250/-, while the net profit was Rs. 3744/- (Datta & Roy, 2011). Similarly, it cost Rs. 3515/- to make 100 three-dimensional floral arrangements in sealed glass containers, while the profit was Rs. 2485/-. Singh (2018) developed various dried flower products and reported the rate of various dried flower products to vary from Rs. 20 to 2500 in the national and international market. The B: C ratio varies from 1.75 to 6.23. The ratio for making the B: C paper weight was 1.75, while for bookmarks, coaster sets, birthday caps, table mats, wall quilts, pictures and greeting cards the B: C ratio was 2.0, for photo frames the B: C ratio was 2.22, for vases the B: C ratio was 2.50, dried flower arrangements B: C ratio exhibited 2.63, for landscape or ornamental pieces the B: C ratio was 2.70, for creating simply designed scenes of 8 × 10″ size it was 3.64 and for making finely designed scenery of 8 × 10″ size was 6.23. Jeevita and Jadhav (2021) estimated the cost and profit ratio of production in rose potpourris. Estimation includes containers, cost of electricity (10%), labor cost (15%), and miscellaneous cost. They get a profit of Rs. 19.27 from potpourri which involved a total cost of Rs. 83.52. Similar trends have been recorded in potpourri made from orchid flowers, which include a total cost of Rs. 83.52 per potpourri and net profit was Rs. 19.27 through the selling of per piece of potpourri (Jeevitha & Jadhav, 2020).

10 Flower waste management and environmental sustainability

Floriculture in agriculture has become the main source of employment generation among farmers around the world including India (Bhattacharyya, 2013; Bijalwan et al., 2017). However, as a result of the COVID-19 pandemic-related lockdowns implemented in many nations, this sector has been severely harmed. Furthermore, it is expected that large quantities of flowers may become waste and cause many environmental as well as human health problems (Srivastav & Kumar, 2021). Adnan and Nordin (2021) reported that in Malaysia, the impact of COVID-19 was also very significant especially on the agricultural crops especially paddy crop. Habanyati et al. (2022) also reported similar findings on the severe impacts of COVID-19 pandemic on the agriculture sector of Tamil Nadu, India. Further, Mitra et al. (2022) assessed the effects of pandemic on the farmers of Bangladesh involved in flower cultivation. Sridhar et al. (2022) highlighted the points, which are important for the agricultural sustainability through adopting recent computational tools. Wang et al.

(2022) analyzed some influencing factors on the flower farmers of China and found that agricultural products can be protected by live streaming and ultimately it will decrease the market-related risks of the farmers. These flowers can be turned into high-value items like composts, biogas, natural dyes, etc. India is a developing country, and the problem of energy is increasing day by day. According to an estimate, 20–30% energy consumption will also increase across the world in coming decades (Singh & Tirkey, 2022a). Currently, most of the energy demand is being full filled by low-quality coal reservoirs (Raj et al., 2022). Hence, generation of biogas at village level can be an alternative of generating energy using flower wastes or other waste biomass along with compost production (Singh & Tirkey, 2022b; Tirkey et al., 2022). Dutta et al. (2022) identified the various sustainability aspects for the better cultivation of medicinal plants near Kolkata, India. These plants are capable to give immunity against hypertension, constipation, and urinary disorders. In addition, such activities can also contribute to the achievement of environmental sustainability or sustainable development goals because alternative sources of energy are being explored at world level (Singh & Tirkey, 2021). Organic farming can be done using compost, which can be grown using flower waste (Sailaja et al., 2013). Yadav et al. (2015) reported that there are many temples located in India and they can waste huge amounts of flowers after offering them to the deities. Seventeen sustainable development goals (SDGs) are specified by the United Nations in 2015 (UNSDG, 2015), and it has been observed that a country city or region can fulfill the partial objectives of around 10 SDGs after implementing successful waste management practices (Pujara et al., 2019). Therefore, it will certainly have a considerable impact on human health and environmental betterment. India is a developing country and facing a lot of environmental problems. Therefore, the Government of India is pushing every city to adopt "Swachh Bharat Abhiyan" (Clean India Campaign) sanitation practices as per the objectives of the SDGs (Srivastav & Kumar, 2021). Therefore, it can be expected that after adopting proper waste management practices, environmental sustainability can be achieved to a remarkable level as shown in Fig. 2.

Based on the above figure, it can be inferred that environmental sustainability can provide many benefits to the natural world and biodiversity. For example, several researchers from around the world have found some correlation between waste management and environmental sustainability in the form of municipal solid waste management of Nigeria (Okwesili & Iroko, 2016), the economical and environmental importance of waste management (Rigamonti et al., 2016; Sahar, 2019), improving environmental sustainability in developing countries through improvements in waste management (Vaccari et al., 2012) and various construction companies (Kurdve et al., 2015). Therefore, in the future, such practices should be encouraged in society as well as at the governance level.

11 Future perspectives

The future of the dried flower trade is predicted to contribute lots to the country's economic system versus in fresh flowers and other foliage plants. The demand for dried plants and flower crafts is increasing continuously within the local and global markets. The dried flower-based retail has grown rapidly as customers decide to prefer the biodegradable alternative of flowers. Presently, with annual exports of nearly Rs 500 crore, India is the world's top supplier of dried plant parts (Chakrabarty & Datta, 2021). There is huge potential in India for the establishment of the dried flower sector. Dried flower industries can generate employment apart from self-employment as the industry needs a lot of people to do the

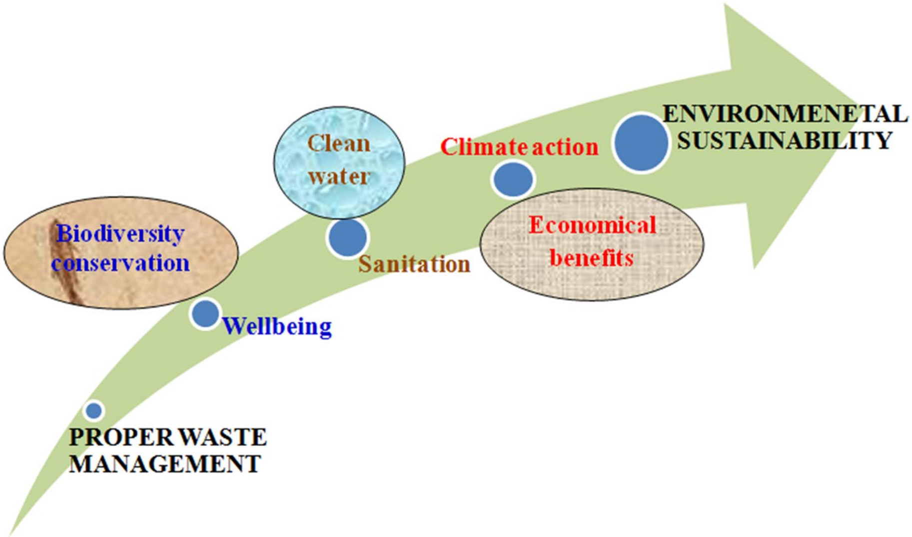


Fig. 2 Achievement of environmental sustainability through proper waste management

work. Therefore, innovative training programs and awareness campaigns should be started for rural unemployed by government agencies to promote the export of dried flowers. As per the data given in Horticulture Statistics in 2018, the total number of flower growers in India is 897,077, out of which 799,709 were marginal flower growers (0.5–1 ha) and 58,196 were small flower growers (1–2 ha) in shape. Therefore, flower growers' relief is critically needed for marginalized flower growers, who are particularly vulnerable to financial risk. Bulgari et al. (2021) suggested the increase online home delivery of flowers, which may be helpful to flower producers to greater income. The distribution chain should be improved by optimized transportation to minimize the loss of quality.

12 Conclusion

India has a rich source of flower cultivation because of its diverse geographical locations and weather conditions. Large volumes of the various types of flowers are destroyed every year because of wastage, mishandling, extreme weather conditions, etc. Flowers are very perishable, and any delay in their supply in the market may convert them into wastes. However, > 80% of such types of can be valued through the process of dehydration. These flowers can be used to develop value-added products by employing drying technologies. Moreover, heavy infrastructure is also not required for the operation of such types of technologies. These techniques are very simple and can be handled by unskilled persons, and also promotion of self-employment especially for the women is also possible in rural areas. Hence, flower drying techniques can be a better alternative to procure the value-added products. Further, dried flower may have long-lasting lives, which can be used later as per the requirements. Such types of initiatives are very useful in COVID-19 like pandemic situations. Dried flowers can also be used as flower vases or bouquet decorations, making floral handicrafts, floral based greetings, wedding cards, segments, wall hangings, attractive calendars, colorful candles, picture frames, flower ornaments, mirror ornaments, glass jar arrangement, etc. Some developers and exporters in India are already earning ~10–15 times higher income from the local as well as world trade by exporting such types of the dried flower products. Therefore, dehydration techniques of flowers can help in raising the economic condition of many residents of the rural areas like farmers, along with their traders.

Data availability Not applicable.

Declarations

Conflict of interest The authors declare no competing interests.

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