Value Addition: Dehydration of Flowers and Foliage and Floral Craft

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Contents

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S. K. Datta, Y. C. Gupta (eds.), *Floriculture and Ornamental Plants*, Handbooks of Crop Diversity: Conservation and Use of Plant Genetic Resources,
https://doi.org/10.1007/978-981-15-3518-5_21

Abstract

More than three fourth of the export basket of Indian floricultural products comprises of dry flowers and different handmade items made from botanical specimens, presented in a dried and colored form. With the increasing awareness for natural ecofriendly products, dried flowers have attained prime importance in the floriculture industry. It constitutes nearly 15% of the global floriculture business, and considering the present COVID-19-related pandemic situation, dry flower industry is going to become more relevant. At present, the industry relies substantially on gathering of flowers from the wild and drying those using conventional methods. However, some fresh flowers are also converted into dry flowers for better returns, including chrysanthemum, dahlias, marigold, jute flowers, wood roses, lotus pods, and lilies among others. Over 70 lakh people, mostly in rural areas, earn their livelihood from production of handicrafts and related activities through low capital investment. Dry flowers and plant materials have tremendous potential as substitute for fresh flowers and foliage for interior decoration as well as for a variety of other aesthetic and commercial uses. This chapter provides all relevant and latest information, which could be helpful in drawing the attention of the researchers and scientists to work on it. Besides the entrepreneurs would be directly benefitted by utilizing the knowledge reviewed in this chapter and expected to contribute a lot to the country's economy.

Keywords

Dry flowers · Botanicals · Drying · Preservation · Glycerinization · Skeletonization · Bleaching · Dying · Packaging · Value added products

8.1 Introduction

Holding on the piece of choice is human nature. This is very natural and this basic instinct has taught us the art and science of "preservation." The beauty of flowers and their serenity tempt us to wish that the flowers should never ever fade. In spite of using best chemicals for improvement of keeping quality and enhancement of vase life, the cut flowers cannot be stored for a long time. This greatly limits the use of flowers, to overcome which different methods for preserving flowers and other plant materials by drying and dehydrating have been tried since a very long period. History depicts that preserved garlands were placed in the tombs of ancient Egyptians. Centuries later, medieval monks harvested and dried flowers and herbs for medicinal purpose. Later an Italian Monk named Giovanni Batista Ferrari discussed about drying of flowers in his book *Flora-ouer o Cultura di Fiori*. During Victorian age, the skills in floral handicrafts and displaying dried flowers were highly esteemed.

In India, the dry flower industry took off more than 50 years back (Chakrabarty et al. 2011). India shares 10% of total global dried flower by exporting more than 10,000 tons of dried flowers, annually. India's total export of floriculture was Rs. 571.38 Crores/81.94 million USD in 2018–2019 (APEDA). The export basket of the Indian floricultural products comprises of dry flowers (77.1%), cut flowers (6.1%), bulbs and rhizomes (0.8%), cut foliage (0.02%), and others (15.9%).

There is no separate code for exporting dry flowers. Mostly all the dry flowers and handmade items fit into the HS code-06042000 (Fresh Foliage, Branches and Plants, Not Having Flowers/Buds, And Grasses, Mosses and Lichens Fresh, Dried, Dyed) and HS code-06049000 (Other (Excluding Fresh) Foliage, Branches and Plants, Without Flowers Buds And Grasses, Mosses and lichens). The major importing countries are the United States, the Netherlands, the United Kingdom, Germany, and the United Arab Emirates. At present there are more than 300 export-oriented units in India, 50% of which are based in Karnataka, Andhra Pradesh, and Tamil Nadu.

The shelf life of dehydrated floral material may be reasonably long if they are protected from moisture and dust by covering in glass or plastic jars. Dehydrated flowers and foliage can be used for designing distinctive and artistic greeting cards, sweet-smelling potpourris, collages, flower pitchers, flower balls, festive decorations, wall plates, bouquets, wreaths, landscapes, etc. Any plant part including inflorescence, pods, bract, peduncle, fruits anything over the earth, which is having moisture percentage between 15% and 20% or less (after drying) is suitable for this item. Stems, twigs, branches, bark, leaves/foliage, flowers, thorns/spines, fruits, cones, seeds, roots, lichens, fleshy fungi, mosses, selaginellas, ferns, etc. can be utilized for making various value-added floral crafts and flower arrangements which are nonperishable and have longer shelf life (Raj 2001).

The main advantage of dry flower industry is that it can be operated from a rural base, using Indian floral wealth to earn valuable foreign exchange. A number of supporting industries like terracotta, basket weaving, paper, textile, metal, glass, ribbon, and packaging have an ample scope for growth as a subsidiary to dry flower industry which as a whole can contribute immensely to the development of any area. Plants may be domesticated, semi-domesticated, or non-domesticated. We use only small number of crop plants for our basic requirements. Unutilized vegetation means whose potential has not been properly realized. There is an increasing interest in neglected and unutilized vegetation to develop new products for export and domestic markets. There are a wide range of wild/unutilized/underutilized plant species which have the potential for commercial exploitation in different forms. Road sides of rural and hilly areas are covered with different types of colorful flowers and foliage at different seasons round the year, and all these are wasted under natural process. The entire seasonal unutilized vegetations can be converted into value added products by using biotechnology-based dehydration technique.

Murugan et al. (2007) classified dry flower items (finished products) under eight categories: (1) dried flowers and plant parts in bulk, (2) potpourri, (3) arrangements, (4) floral handicrafts, (5) main blooms, (6) fillers, (7) liners, and (8) exotics.

Kamal Kant (2018) suggested drying techniques as one of the best methods to preserve ornamental parts of plant especially flowers for their year-round availability, longevity, quality, novelty, easy handling, low transportation cost, as well as eco-friendly nature. The demand of dry flower items has increased in such a way that India constitutes two thirds of dry flower export of the total floriculture exports and it offers a lot of opportunities for the floriculturist, entrepreneurs, industrialists, etc. to enter in the global floricultural trade. Moreover, preparation of dry flowers has been given top priority to cope with the pandemic situation due to COVID-19. Floriculture sector being badly affected with religious places closed, weddings postponed, major events in public sector and private sector deferred, no major social and religious functions lined up, farmers are facing hardship to market their produce, and flower consumption has come to a standstill. Many farmers started discarding the flowers not only in India but also in global auction houses located in the Netherlands. As a general advisory for all the Indian farmers, ICAR recommended that it would be a good idea to dry flowers that are colorful (rose, marigold, chrysanthemum, and China aster) instead of discarding the flowers. The dried petals could be used to make eco-friendly *gulal* and other marketable products for later use (Anon 2020).

8.2 Why Dry Flower Lasts Long?

Fresh flowers, after detaching from their mother plant, act as an individual living entity undergoing all biological processes starting from cell division to photosynthesis, respiration, etc. which strongly interpret that those are living entity. As applicable for all living entities, their senescence and death also come as a natural phenomenon; that is again triggered by microbial activity and several stress conditions like lack of water and food supply (due to clogging). On the other hand, removal of the water (75–90%) present in fresh flowers through drying and dehydration results in lesser water activity and increases resistance against most of the deteriorative agents. On the course of dehydration, moisture content of flowers is reduced to a point where growth of microorganisms is prevented and chemical changes are brought, almost, to a stand still. Reduction of moisture content in the dried flowers is the main cause of increased longevity, and it is inversely proportional to the durability. Reduced moisture content is related to uniform cell contraction in the flowers resulting in rigidity, while comparatively higher moisture content after drying leads to flaccid flowers. Thus the moisture content after drying influences flower shape, but there is a chance of rapid tissue desiccation, breakage, and petal shedding during handling in dried flowers. To obtain a good quality product with reasonable firmness and keeping quality for more than 6 months, a range of 8.0–11.5% moisture has to be maintained in dried flowers. Drying below 8.0% moisture content resulted in petal shedding which might be attributed to excessive loss in moisture that might have resulted in weakened adhesion and cohesion forces in flower tissue and might have caused softening of the middle lamella leading to abscission (Singh et al. 2004).

8.3 Collection of Materials for Drying

Almost all plant materials can be dried starting from flowers, foliage, and branches to grains, cones, nuts, berries, thorns, barks, and other fruits. Materials for drying (which may be under “flower” or “non-flower” category) are collected from nature as fresh or in semi-dried form. Collecting plants when they are wet or moist from dew should be avoided. Plant materials that are without insect or disease problems are to be avoided as any damage in the bloom will be magnified in drying process. After collection, the drying process of plant materials must be started as early as possible. Selected species are either commercially grown for obtaining good quality raw material or sometimes collected from the forests also. When the raw materials are fetched from commercially grown plants, we call it "harvesting" and otherwise termed as "collection."

8.3.1 Time and Season of Harvest

Plants for drying and preserving can be collected throughout the year. Flowers at different stages of development can be picked for drying purpose. Collecting plant materials when they are wet is always to be avoided. Stage of harvesting or collection is an important criteria for dry flower production. Harvesting prior optimum stage results in deformation upon drying. On the other hand, over-matured stage causes shattering of petals after drying. The stage of harvesting for different flowers varies according to the species and the form of flower desired. Depending upon the type of products, we can classify certain parameters of harvesting.

A) **For herbs**: Herb flowers should be picked just before they are fully open. Factors that can severely reduce the quality of herbs cause discoloration are sun rays, dew moisture, and frost.
B) **For flowers and foliages**: Datta (1999) reported that flowers and foliage should be collected from the fields, 1 or 2 days after irrigation. It is found that harvesting during dry or summer months gives excellent result as most of the water gets evaporated easily. Brightest colors are produced during winter season, but the plants are very much susceptible to pests and diseases in monsoon. Flowers should be picked on dry sunny days, mid-morning to mid-day (after the dew has dried off) being the best time. Picking in too late hours should be avoided because the strong sun can cause blooms to fade. It is best to cut the flowers in the morning hours after the dew has evaporated from the plants.

The flowers should be picked when they attain their peak bloom period. If picked past their prime, when they start turning brown, flowers will continue the browning process, and no amount of after care would prevent this. After cutting, leaves from the stem are stripped, since foliage on the stems do not dry properly. Everlasting flowers such as *Helichrysum* and *Helipterum* should be cut when they feel crisp and papery and start to dry on the plant. But flowers will disintegrate in storage if they are picked too late. *Helichrysum* harvested at fully open stage took lesser time for drying than those harvested at tight bud and half-open stage (Sangama 2004). For drying purpose, roses may be harvested when the buds are just beginning to unfurl. Mostly all flowers should be picked before they are in full bloom since they will open slightly while drying. Avoid harvesting too much matured flowers as they will generally shed upon drying and will not hold up well in arrangements. Foliage should be removed from the stem when those are fully matured. Lourduswamy et al. (2001) reported that for gomphrena full-bloom stage and for French marigold and zinnia half- and full-bloom stages are ideal for production of dry flower. Bhattacharjee and De (2003) found that half-bloom and full-bloom stages of chrysanthemum, rose, and celosia are best suited for drying purpose. Safeena et al. (2006) reported that faster dehydration of flowers harvested at half-bloom stage may be due to sensitivity of the flower tissues to ethylene or other hydrolyzing enzymes and senescence also. Hemant et al. (2016a, b) reported that harvesting at 50% open stage in microwave oven embedded with silica gel resulted best quality in terms of overall dry flower quality considering shape, color, flower diameter, intactness, pigment retention, and dry flower shelf life.

C) **For dry grasses, seeds, pine cones, and most seed heads:** Materials such as dry grasses, seeds, pine cones, and most seed heads should be harvested at the end of their growing season when they have reached the full maturity, but withering has not initiated.

The following conditions/criteria are normally followed during harvesting or collection of plant materials:

- Plant materials should be collected during dry season and on sunny days. Collecting plants when they are wet or moist (from dew/rain) must be avoided.
- Flowers are to be harvested when surface moisture (dew) is evaporated but before attaining the stage of wilting.
- Plants and flowers should be free from insect and disease damage as the damage becomes more obvious after drying.
- If the field is irrigated, then harvesting for dry flowers should be postponed for a day or two.
- Sharp knives or pruning shears must be used to cut flowers and plant materials.
- Time gap between harvesting and arranging the harvesting materials for drying should be least. Under unavoidable situation, plant materials may be placed in water to prevent wilting. Some flowers may hold color better if allowed to stand in water for a few hours.
- At least 10–15% more plant materials must be collected than needed to accommodate some unavoidable loss.
- While collecting plant materials, unlawful or endangered plants should be avoided.
- Flowers or plant parts selected at any stage for drying may be sprayed with Dithane Z-78 or neem-based pesticide (0.5%) for disinfection.

8.4 Techniques for Drying Flowers

The range of dried flowers and other attractive plant parts is quite extensive, namely, stems, roots, shoots, buds, flowers, inflorescences, fruits, fruiting shoots, cones, seeds, foliage, bracts, thorns, barks, lichens, fleshy fungi, mosses, sellaginellas, etc. A number of flowers respond well to drying such as anemone, zinnia, allium, sweet William, carnation, stock, freesia, narcissus, chrysanthemum, pansy, daffodils, marigold, rose, lilies, etc. and foliages like ferns, aspidistra, eucalyptus, ivy, laurel, magnolia and mahonia, etc.

Selection of a suitable crop for drying purpose is very important for success of the business. Some flowers loose its ornamental value after drying, like how sweet pea flowers loses their color and becomes dark brown when pressed dried which is not suitable for further use. Also, quality of dry flower may vary with cultivar of a particular crop. In *Helichrysum*, especially in yellow cultivars, in spite its inherent crisp texture, petals reflex downward, and center disc florets may shed after drying. This characteristic is encountered less with varieties of other colors (Sangama 2004).

Method of drying immensely affects the quality and appearance of dried flowers and other ornamental plant parts. Different techniques used for drying ornamental plant material include air drying, press drying, embedded drying, oven drying, freeze drying, etc. The National Botanical Research Institute (NBRI), Lucknow, India, is a pioneer institute where various dehydration techniques have been developed by which fresh look of flowers, twigs, branches, foliage, etc. can be retained for several months or years.

Commercially, flowers and other botanicals are normally processed by traditional means of sun drying. However, other drying techniques like air drying, oven drying, embedded drying with desiccants, microwave oven drying, freeze drying, press drying, and glycerinization treatment have also become useful. The dried flowers and botanicals can be used for making decorative floral crafts items like cards, floral arrangements, wall hangings, landscapes, calendars, potpourris, etc. for various purposes with potpourris being the major segment of dry flower industry (around 70% or more).

Several methods are practiced for drying or dehydration of different flowers or its plant parts. In these methods, removal of moisture is done artificially either by using desiccants or controlled temperature, humidity, and airflow. The principle involved in all the methods or techniques is common in which the plant material is exposed to a vapor pressure deficit ($\text{v.p.d.} = \text{v.p.}_{\text{source}} - \text{v.p.}_{\text{sink}}$), which induces water vapor to move by transpiration or evaporation from the plant material (source) into the surrounding environment (sink).

The flux of water vapor (J) is proportional to the vapor pressure deficit, i.e., $J = k \times (\text{v.p.d.})$, where k is a constant that depends upon water vapor transfer properties of the particular product (Joycee 1998).

Some of the important methods are described below.

8.4.1 Air Drying

Air drying is nothing but hanging of plant materials after tying up with a rope/wire, in a warm, clean, dark, and well-ventilated area with low humidity (for quick drying). Humid rooms with more than 75% relative humidity (like basements) should be avoided for air drying because of mold growth which may spoil the flower. Also drying in direct sunlight should be avoided as it causes discoloration or bleaching. Air drying in dark places (like closed cellar) help the flowers to retain its natural color. While drying, plant materials are bunched together in groups of maximum ten stems, and each bunch should be of one plant variety. Of course, large flowers can be hung individually rather than in bunches. The flowers without strong stems should be wired before drying. The flowers can also be spread over blotting sheets or newspapers and kept in dark or in sun for drying (Datta 2015). Short stem and small leaves like thyme may be placed in trays in thin layer for better drying. Flowers hung in a dark area took 8–10 days for drying when there is sufficient ventilation (Champoux 1999).

Air drying is simple and cheap, without use of any chemicals or desiccants, shrinkage of petals being the major disadvantage. Also, drying period is more and such flowers naturally retain straight stems upon drying. It takes 1–2 weeks for drying depending upon the moisture content, temperature, and humidity. Drying time is more for fleshy flowers and foliages. The stage of harvest is also important for getting superior quality of dry flower in this method. Flowers of good quality at bud stage, slightly immature stage, or partially opened should be selected in this method as they continue to open while drying and foliages must be removed from the flowers before drying.

Flower color should also be kept in mind before selecting the flowers for air drying. Bright red roses attain darker shade (like dried blood color) after drying; white roses are converted to yellow parchment color. However, blue- and yellow-colored flowers normally retain their color after air drying, but pink color fades away (Dilta et al. 2011).

Dubois (2005) reported that one way of increasing the drying rate is to raise the air temperature. When temperature is more than 60 °C, several enzymes responsible for browning of tissues within the plant tissue are destroyed.

Thus to sum up, we can put that time required for air drying depends on (1) the type of plant material, (2) harvesting stage and time, (3) relative humidity of the drying chamber, (4) air circulation of the room, and (5) temperature of the air.

Weather dependence and low quality of the product due to shrinkage and drooping of petals are the major drawbacks.

Flowers like *Helipterum* (acroclinium), *Helichrysum* (straw flower), goldenrod (*Solidago*), *Gypsophila* (baby's breath), *Limonium* (statice), *Achillea* (yarrow), *Gomphrena* (globe amaranth), *Anaphalis* (pearly everlasting), *Celosia* (cockscomb), *Centaurea cyanus* (bachelor button), *Consolida ajacis* (larkspur), *Cassia fistula* (golden rain tree), *Nigella* (fennel), *Bougainvillea*, *Setaria verticillata* (bristly foxtail), *Miscanthus sinensis* (eulalia grass), *Pennisetum setaceum* (fountain grass), *Distichlis spicata* (spike grass), *Chasmanthium latifolium* (northern sea oats), *Callistemon lanceolatus* (bottlebrush), *Amaranthus caudatus* (love-lies-bleeding), *Jacobaea maritima* (dusty miller), *Physalis* (Chinese lantern), *Stachys* (lamb's ear) and *Alchemilla mollis* (lady's mantle), *Craspedia globosa*, *Anaphalis*, *Holmskioldia*, hydrangeas, xeranthemums, *Astilbe*, *Baptisia*, *Gaillardia*, *Larkspur*, lilac, marigold, milkweed, okra, paulownia, *Polygonum*, poppy, rose, sages, *Santolina*, *Acacia dealbata*, *Anthemis nobilis*, *Delphinium ajacis*, *Gaillardia pulchella*, *Protea* sp., *Peltophorum ferrugineum*, *Tagetes* sp., *Zinnia elegans*, *Salvia*, *Artemisia*, *Chrysanthemum*, *Delphinium*, *Oregano, Rumex* thistles, etc. could be easily dried by air drying (Datta 2015; Geetha et al. 2004, Raj 2006; Singh and Kumar 2008).

8.4.2 Press Drying

First reported in 1820, press drying is another common, easy, and inexpensive method of drying. In this method, the flowers and foliage are kept in blotting sheet/newspaper and pressed dried with the help of "plant press" or any heavy object. The plant press is made up of two wooden boards fixed with nuts and bolts at four corners. The size of plant press may vary (6 "X 12" to any desired size). Sheets could also be put one above the other, and corrugated boards of the same size are placed in between the folded sheets to allow the water vapor to escape. Collected leaves and flowers are kept between blotting sheets, and one type of leaves/flowers is always pressed in one sheet. All blotting sheets containing leaves/flowers are kept between two ply boards and tightened with nut and bolt. The materials may be kept at room temperature for dehydration. Drying room should be warm and dry. Blotting sheets are changed every third and fifth day to avoid fungal effect/contamination. This helps maintenance of original color of flowers and leaves.

After 24 h the bundle may be removed to an electric hot air oven for 24 h at 40–45 °C, for quicker drying. Press drying in oven at 35–39 °C for 48 h is optimum for pansy whereas 24 h for the leaves of silver oak, thuja, adiantum, and nephrolepis.

Placing the foliage between two pieces of wax paper and pressing medium hot iron easily preserve the flexibility and colors of foliage. New piece of wax paper must be used for each pressing.

Most flowers and leaves are suitable for pressing except those with bulky centers such as succulents and odd-shaped flowers such as daffodils. In that case it may be cut in half and opened out before pressing. Thick flowers like chrysanthemum need to have the calyx reduced in thickness; single petals can also be dried and reassembled when making craft. Time required for pressing varies with type of flowers and water content of tissue; however, it should be completed within 4 weeks, mostly requiring 1–3 weeks under ambient condition. Foliages (ivy) dry within 1 week and flowers like gerbera and chrysanthemum dry in a maximum of 2 weeks.

The drawbacks are that the finished material is rather more two dimensional than three dimensional and very brittle. The shapes of the flowers cannot be maintained as it becomes flattened, because the fresh material after pressing within the iron or wooden frame tends to stick to the paper. Pressing works best with leaves that are naturally flat. Press dried samples are used in card making, wall hangings, batches, stationary candles, etc.

Dehydration through press drying has already been standardized both for wide range of seasonal cultivated flowers/flower petals/foliages and unutilized rural, road side, and hill side flora: *Acalypha*, *Crocus*, pansy, *Alyssum*, daffodil, *Phlox*, anemone, daisy, *Primula*, azaleas, *Delphinium*, heather, bleeding heart, butterfly weed, heath, *Celosia*, *Bougainvillea*, *Ixora*, *Jarul*, *Caesalpinia*, *Lantana camara*, *Panicum*, *Mussaenda*, *Radhachura*, *Euphorbia hirta*, *Triumfetta rhomboidea*, *Polygonum*, *Oxalis*, *Cycas*, *Cleome viscose* and *Cleome rutidosperma*, *Desmodium gyrans*, *Mikania cordata*, *Atalantia* sp., *Oplismenus compositus*, *Hemigraphis hirta*, *Ipomea tridentate*, *Hemidesmus indicus*, *Vitex negundo*, *Teramnus labialis*, *Ziziphus oenoplia*, *Limonia acidissima*, *Cleome rutidosperma*, *Peperomia pellucida*, *Sida rhomboidea*, *Morus alba*, *Tephrosia purpurea*, *Scoparia dulcis*, *Phyllanthus simplex, Sapium sebiferum*, *Vitis* sp., *Merremia tridentata*, *Phoenix paludosa*, *Triumfetta rhomboidea*, *Boerhavia repens*, *Pouzolzia hirta*, *Prosopis juliflora*, *Ageratum conyzoides*, *Commelina benghalensis*, *Alysicarpus bupleurifolius*, *Urena lobata*, *Spilanthes calva*, *Cestrum fasciculatum*), *Adiantum*, *Selaginella*, *Candytuft*, *Chrysanthemum*, *Lantana*, *Rose*, *Statice*, *Zinnia*, *Verbena*, *Euphorbia*, *aster*, butter cup, geranium, marigolds, Queen Anne's lace, coral bells, lily, hardy geranium, bell flower, African violets, *larkspur*, *Hibiscus*, *Ixora*, nettle leaf, velvetberry, *Aster*, *Pentas*, *Bougainvillea*, *Plumeria rubra*, *Melia*, *Cesalpinia*; leaves like thuja, ferns, silver oak, blue gulmohar, thuja, and cockscomb; spiky leaves in iris, *Montbretia*, etc.; and a large number of unidentified materials (Geetha et al. 2004; Datta 2015; Mir et al. 2009).

8.4.3 Embedding/Drying Flowers by Using Desiccants

To maintain the three-dimensional structure, plant materials are dried in a desiccant by embedding. Embedded drying is one of the methods of flower dehydration useful for delicate flowers with high moisture content that shatter or misshapen when air dried. Also, this technique is advantageous to produce exquisite life to flowers in both form and color. But it is a costly method, and desiccated flowers are more fragile and vulnerable to atmospheric moisture.

Containers such as earthen pots, dark trays, microwave safe open containers, candy tins, plastic containers, large mouth jars, or any other with a tight-fitting lid are being used for embedding. These containers should be deep enough to accommodate the plant material without disturbing its shape and form. For embedding, the bottom of the containers is filled up to 5 cm. with the embedding materials, upon which stalks of the flowers are inserted upright. The entire material is covered with desiccants, and during the process sufficient care should be taken to protect the floral structure. After embedding the containers can be kept in room or can be exposed to sun on a regular basis or can be kept in oven (electric oven or microwave oven) for faster or rapid drying. Thus we can divide the process of "embedding" under the following categories:

1. **Sun** drying after embedding
2. **Oven/hot air oven** drying after embedding
3. Microwave drying after embedding

Desiccant is the material which removes moisture quickly from ornamental flowers or plant parts embedded without reacting with water vapor released during drying. Material which is used for embedding and drying flowers and foliage should be fine. It should not chemically react with floral parts. Sand, borax, alum, silica gel, yellow corn meal, etc., are such desiccants which may remove water from the flowers more rapidly than air drying and also retain their natural forms. Besides, borax + sand mixtures, fresh kitty litter, white cornmeal and borax mixture, silica gel + sand mixture, etc. can also be used as desiccants for drying flowers. Among these two most satisfactory desiccants used are sand-borax mixture and silica gel. Others such as kitty litter, perlite, saw dust, corn starch, and corn meal can be used but those are not reliable. This method of drying is usually preferred over air or oven drying as it reduces the problem of petal shrinkage. The desiccants can be reused provided they are free from any particle of dried flowers and thoroughly dried. The ideal size of desiccant should be 0.02–0.2 mm or 20–200 mesh (Raj 2014).

During desiccation the moisture of the plant material is absorbed by the surrounding desiccants that also support the flowers/foliage from all around and, thus, maintains original shape, color, and size of flowers for a long time. Drying with sand provides smooth petal texture, silica gel provides slight roughness, and borax causes fading of color and rough texture of petals. The flower quality is very well maintained with silica gel and sand regarding post-drying parameters and longevity (Malakar et al. 2019). Regarding pretreating the flowers with some chemicals, Sindhuja et al. (2016) reported pre-drying treatment of magnesium chloride (10%) for 5 h. could improve the quality of carnation flowers after drying by embedded in borax + silica gel (1: 1, v/v) mixture and dried in hot air oven at 55 $\pm$ 1 °C considering color, shape, texture, brittleness, overall acceptability, and total carotenoid content.

Drying of Plant Materials in Sand as Embedding Material

Drying with sand is one of the least expensive methods of dehydration of flowers. Flowers or leaves may be embedded in white silver sand in metallic, plastic, or earthen container at room temperature and allowed to dry naturally in shade and well-ventilated place. Fine white sand found on the seashore (river sand), clean, dry, and preferably salt-free, can be used for embedding because of its easy handling, availability, and no reaction with water vapor. Sand from the river or beach should be washed and dried. The fine sand does not react with the water vapor released during the process of drying like silica gel and borax. It allows the water vapor to escape into the air freely, thereby causing minimum loss in the size of flowers which is otherwise maximum in silica gel-embedded flowers. Since sand is heavier, it takes a longer time for drying than the other desiccants. It usually takes 4 days to 2 weeks for drying.

Flowers and leaves like anemone, black-eyed Susan, butterfly weed, chrysanthemum, corn flower, delphinium, gladiolus, rose, and pansy are suitable for embedded drying in sand along with asters, carnations, chrysanthemums, gladiolus, geranium, coreopsis, cosmos, tulips, and zinnias. Color retention is better in the flowers embedded in sand and dried under shade compared to oven-dried flowers of *Nerium* *oleander*. Among the various desiccants used to dry Indian blue water lily flowers, fine white sand was the best (Geetha et al. 2004). Color and structure of floral parts show no change after dehydration with sand and hot air oven but need careful handling. Total chlorophyll stability shows significant negative role. Enzyme stability examined in dehydrated floral parts was also significantly negative. But injury index shows significant positive association with per gram dry weight. Physiological parameters like diameter, length, color, and texture varied with each plant part.

Although sand is cheap and results better quality of dried flowers, it takes longer time for drying due to its heavy weight which sometimes destroy the specimens or tends to flatten flowers unless used very carefully. However, if necessary, it should be used in combination with cornmeal or borax for embedding purpose.

Drying of Plant Materials in Borax as Embedding Material

Borax is the least expensive and best-suited embedding material for drying delicate flowers which are less stiff than those preserved with air drying. Due to hygroscopic nature, borax shows slight fading of color (bleaching) and rough petal texture (brittleness) and sometimes burns the flower petals if embedded for a long time. To prevent this, washed, sifted fine sand mixed with two parts of borax can be used as desiccant to preserve flowers.

In borax mixtures flowers take longer time to dry than in silica gel, and it is difficult to dry delicate flowers with high water content such as rose buds. The use of borax for preserving flowers has an advantage in that the flowers hold their shape with minimum shrinkage, well-acceptable color, smooth petal texture, and less mechanical damage during handling. Generally, color of the flowers is assured except pinks and reds which may vary. But if the flowers remain in borax too long, they become brittle and may lose their petals. Rose, aster, carnation, marigold, dahlia, larkspur, geranium, zinnia, chrysanthemum, and delphinium are considered suitable for drying in borax.

Drying of Plant Materials in Silica Gel as Embedding Material

Among the different embedding materials tried, silica gel (60–120 mesh) is the best absorbent for removing moisture from flowers, and it prevents shrinkage of flowers and degradation of coloring pigments that could take place when petal tissues are exposed to high temperature. It is reported as the best desiccant for getting excellent quality of dry flowers that retain color and shape as it does not cause bleaching or brittleness to flower petals even if embedded for a long time. It can be used with all sizes of flowers; crystals can be ground down in a liquidizer or coffee grinder to a very fine powder and will dry even the smallest flower, enabling to keep their shape. The crystals leave less residue on the flowers and produce less air contamination. Self-indicating silica gel is blue in color when dry and becomes pink/white after absorbing moisture. It can be reused by warming up in oven (for 30 min at 250 °F) till the crystals turn blue in color again.

Silica gel, a xerogel of silicic acid, granular in shape, is composed of a network of interconnecting microscopic pores which attract and hold moisture by physical adsorption and capillary condensation, thus, acting as a dehydrating agent. It is suggested that silica gel can absorb large quantities of moisture (up to 40%).

Most flowers kept in silica gel dry within 36 to 72 h at 250°-300 °F (baby's breath, celosia, rose buds, rose, anemone, aster, dahlia, salvia and larkspur, aster, balsam, carnation, chrysanthemum, gladiolus, geranium, coreopsis, cosmos, tulip, and zinnia). Generally thin-textured flower or leaf takes 2 days, medium-textured takes 3–4 days, heavy-textured type takes 5–7 days, whereas in other desiccants thin-textured flower or leaf takes 4–5 days, medium-textured type takes 6–9 days, and heavy-textured varieties take 10–14 days.

Most of the flowers appeared almost fresh when dried in silica gel, although the color may be darkened to some extend. Colors that come out close to the original when dried in silica gel are white, yellow, lavender, and blue (non-roses). Darker colors such as red, deep pink, and orange tend to turn even darker (Safeena 2005; Dilta et al. 2011; Shankari and Anand 2014; Datta 2015; Shailza et al. 2018). Dried flowers readily absorb moisture from the air which can be avoided by placing in a closed container with the silica gel.

Mixture of More than One Embedding Materials

The proportion of the borax with sand mixture can vary with the color of flowers, ranging from a ratio of 1:50 to 1:1. For drying of rose, carnation, and gerbera, it is found that sea sand with a low proportion of borax for 10–15 days resulted in better drying. It is reported that flowers preserved in a mixture of borax and dry sand in the ratio of 1:1 hold their natural shapes better, shrinkage is minimal, and color retention is generally better. It is suggested that a mixture of borax and sand (2:1) will take 10–12 days to make the flowers papery and dry but less stiff than those preserved with "hang and dry" method, but the particles tend to cling to some flowers. In some cases, the sand because of its rough edges may produce small holes in the petals (Pertuit 2002a).

Borax and alum being light in weight could also be used for dehydration of flowers in combination with sand or corn meal for embedding, and borax combinations can be placed directly in a warm dry place without covering. Trinklein (2006) suggested that mixture of borax and cornmeal is better than mixture with sand as cornmeal is lightweight that makes flower boxes easier to handle and has less tendency to flatten flowers. Flowers that dry well in sand and borax include asters, cornflower, cosmos, liatris, daffodils, lupine, dahlias, daisy, delphinium, pansies, candytuft, dandelion, peony, rose, carnations, geranium, chrysanthemum, gladiolus, stock, coleus leaves, gloriosa, snap dragons, tulip, zinnias, etc. Drying will normally take 2–3 weeks. Malakar et al. (2016) reported that for foliages like *Araucaria cunninghamii*, *Thuja orientalis*, and *Juniperus chinensis*, silica gel and white sand+ microwave oven combination for 30 and 20 seconds was the best.

8.4.3.1 Sun Drying After Embedding

Sun drying is the most common method practiced in India. Flowers like small zinnias, marigold, pansies, and chrysanthemum embedded in sand in an upside down fashion and kept in the sun dry in 2 days. *Gomphrena*, zinnia, and French marigold take 3–4 days for sun drying. Flowers like gerbera, zinnia, and chrysanthemum dried well with minimum shrinkage when sun dried after placing them in a box containing sand which takes 4–5 days. A layer of desiccant (dried silver sand) at the bottom of the container is placed, and flower stems and wires are pushed into it and placed in sun for drying. Marigold, poppy, zinnia, chrysanthemum, acroclinium, and globe amaranths can be sun dried easily (Lourduswamy et al. 2001; Sujatha et al. 2001; Ranjan and Misra 2002).

The greatest advantage of solar drying is that it is cheap. All that is needed is a black painted tin shed or a black plastic tunnel. An efficient solar dryer can reduce drying time to less than 3 weeks. Even drying in solar dryer may be at par with hot air oven at 45 °C or microwave oven (450 Wt), thus an economically cheaper method of dehydration. In this context solar cooker and solar dryer have become very effective. Flowers can be directly embedded in the container of solar cooker and dried under the sun. The time of exposure varies according to day temperature. The solar cooker can also be operated by using electricity, and it could be the most suitable technique for rural women as they can cook food in a solar cooker and utilize it for dehydration for rest of the time. Drying in a solar dryer after being embedded in sterilized sand is found better as compared to other methods of drying like air drying, sun drying, and mechanical dehydration (Wilson et al. 2015). A hybrid solar dryer is developed by Padmapani et al. (2019) which successfully dried rose and marigold flowers in terms of anthocyanin and carotenoid content, shape, texture, brittleness, intactness, color, and percent reduction in diameter.

8.4.3.2 Oven/Hot Air Oven Drying After Embedding

Oven drying or hot air oven drying is also an important method of drying flowers and foliages. Drying is faster and quality of product is superior in oven drying. NBRI standardized the method of oven drying on *Helipterum roseum*, chrysanthemums, small flowered perennial, candytuft, *Dombeya* spp., gerbera, *Gomphrena globosa*, strawflower, *Limonium* spp. China aster, larkspur, rose, *Zinnia linearis*, bougainvillea, narcissus and dahlia, Gladiolus and large-flowered rose cvs, marigold and *Nymphaea* spp. (water lily), and foliage plants (Datta 2015).

From the reports of different scientists, some basic facts can be jotted:

- It takes lesser time for drying in oven as compared to shade drying for the same flower because at higher temperature the rate of transpiration is comparatively much higher. Diffusion pressure deficit of air increases with increase in temperature that stimulates diffusion and vaporization of internal moisture leading to high moisture loss (Mayak and Halevy 1980).
- The best temperature range is 45–50 °C for 24–72 h in oven depending upon the type of flower. The drying temperature varies from species to species and plant to plant.
- Drying temperature and duration vary with plant size, structure, and moisture content and stage of harvesting of the material.

- Half-opened flowers or flowers at bud stage are suitable for drying in hot air oven, while fully opened flowers are not suitable as their petals lose elasticity and peel off easily on drying.
- After dehydration, yellow flowers retain their color properly, but white becomes off-white, and red, blue, and other bright ones become considerably dark. The higher the temperature, the faster is the dehydration as well as degradation of pigments, viz., chlorophylls, carotenes, and xanthophylls. The anthocyanin content of flowers increases with increase in temperature which results in darkening of flower petals.
- The best advantage of oven drying method is that the process of drying is comparatively faster than air, water, and embedded drying, but if the temperature of hot air oven is more than 50 °C, the flowers will shrink.

Geetha et al. (2004), Deepthi and Kumar (2008), and Datta (2015) listed the flowers suitable for oven drying technique among which gerbera (*Gerbera jamesonii*), dahlia (*Dahlia variabilis*), chrysanthemum (*Dendranthema grandiflora*), China aster (*Callistephus chinensis*), statice, bougainvilleas (*Bougainvillea* sp.), marigold (*Tagetes* sp.), *Larkspur* (*Delphinium ajacis*), acrolinium (*Helipterum roseum*), *Gladiolus* sp., *Gomphrena globosa*, *Ixora coccinea*, *Narcissus* sp., *Nymphaea* sp., *Rosa* sp., *Zinnia linearis*, silver fern, golden fern, *Adiantum*, etc. are most prominent.

8.4.3.3 Microwave Drying After Embedding

Microwave drying takes only a few minutes and provides material that looks fresher and more colorful than that obtained by other methods. In microwave oven, the water molecules present in the sample are agitated by electronically produced microwaves which help in liberation of moisture, finally leading to drying. Microwave energy has the peculiar attribute of being preferentially absorbed by water and hence is a particularly efficient energy source for the process of drying. Drying is exceptionally fast in microwave oven, as it gets completed within a few minutes and generates little heat.

Only glass, paper, or special microwave containers should be used to hold the flowers and desiccants. Also placing cardboard box on an upturned saucer is recommended to raise the height so that the moisture can escape from its base. It is better if only one flower is dried at a time because the less heat the flower subjected to, the better color retention will result. Flowers can be kept into a plastic container filled with silica or just lay in between sheets of paper towel.

A cup of water in the microwave before drying is useful to prevent excessive drying which is a major threat in this case. After drying in the microwave oven, flowers must be left in the drying agent for a few hours for getting good appearance and color to the flowers. Thus, containers with flowers after taking out from microwave should be kept for a particular period of time at room temperature so that the moisture evaporates and the plant material is fully dried. This is called as "setting time" or "standing period" which varies from species to species. Also petals of dried flowers in microwave oven may be sprayed with hair spray or lacquer to prevent the absorption of air moisture. If the microwave oven has about 10 settings, using the setting of 4 (that's about 300 watts) is suggested. If the microwave oven has a defrost setting, we may use that (about 200 watts). It takes about two and a half minutes to dry flowers in a half pound of silica gel. The best way to determine the length of time required to dry flowers is to use a microwavable thermometer that is placed into the silica gel about a half inch from the covered plant material. When the temperature of silica gel reaches about 160 °F, the drying process is completed (Pertuit 2002a, b).

Microwave oven drying is not suitable for all flowers as some dried flowers are susceptible to breakage. It is the best for flowers with many petals such as marigold, rose, carnation, China aster, chrysanthemum, and zinnia and flowers with cluster of florets such as goldenrod, gypsophila, corn flower snapdragon, larkspur, acroclinium, ixora, candytuft, etc. Among nontraditional flowers, *Wedelia trilobata*, *Mussaenda luteola*, and *Cassia glauca* dried by microwave were also successful. Flowers with thin, delicate petals or those with hairy and sticky surfaces are not much suitable for drying in microwave. Also flowers with thick petals or high water content such as magnolia, hyacinth, and orchids do not dry well in microwave. Based on the studies conducted at NBRI, Lucknow, the time taken for drying a variety of flowers and leaves in a microwave oven ranges within 30 seconds to 10 min. Heating time in microwave oven for carnation is 2.5–3 min, for daffodil and violet 1.5–2 min, for pansy and rose 1.5 min, for sunflower 1.75 min, and for zinnia 2–2.5 min. Drying in microwave oven depends on the thickness of the flower. Roses take 2.5 min heating time and overnight standing time; zinnia, chrysanthemum, and marigold take 1.5 min heating time and 10 hrs standing time; large chrysanthemum takes 3 min heating time and 36 h standing time; and orchids take 1.5 min heating time and 24 h standing time. For *Hibiscus* and *Bougainvillea*, embedding in borax is suitable for drying at 2.5 min with flexibility and without brittleness. On an average, time required for dehydration in microwave oven varies from 1 min to 4 min and setting time from 24 h to 36 h. Among different combinations of embedding materials and drying methods, flowers dried in microwave oven embedded with silica gel scored highest for retention of color, shape, texture, and overall appearance. Microwave oven drying of rose flowers at 50 °C with silica gel was found the best from the reduction in size point of view. Microwave oven drying is the best method for attaining highest dry weight, lowest moisture loss, and least change in pigment levels, enzyme levels, epicuticular wax, and percentage of leachates retaining its total anthocyanin content, total phenolic content, and antioxidant activities (Biswas and Dhua 2010; Safeena and Patil 2013; Datta 2015; Acharyya et al. 2017; Arunkumar and Mangaiyarkarasi 2019; Ullas et al. 2018 and Preethi et al. 2019).

8.4.4 Freeze Drying

Freeze drying is the most advanced and effective method of flower preservation. The technique was originally introduced in 1813 by William Hyde Wollaston to the Royal Society in London. Procedures for freeze drying have been standardized for very few flowers till date. It relies on the principle of sublimation, where ice held under conditions of partial vacuum (less than 4.58 torr) and low temperature (less than 0 °C) evaporates on heating without going through a liquid phase. Absence of liquid water during the dehydration process discards many undesirable chemical reactions and helps in better retention of shape, natural color, and even fragrance (Dubois and Joyce 1989). It requires a special freeze drying machine where flowers are first frozen at −10 °C by placing in a refrigerated chamber for at least 12 h. Then vacuum is created in the chamber, leading to sublimation (transformation of solid to gaseous state bypassing the liquid phase) of moisture in the flowers. A vacuum pump slowly pulls the water out of the flowers as a vapor in one chamber which condenses as ice in another chamber. Freeze-dried flowers are allowed to warm up slowly to room temperature. The full drying cycle takes 5–9 days.

Chen et al. (2000) reported that vacuum-drying temperatures had more effect on the flowers than freezing time. Lower vacuum-drying temperatures resulted in flowers with color closer to fresh and control flowers, while higher vacuum-drying temperatures resulted in lower moisture contents and stronger/stiffer petals but more changes in color.

Major flowers dried by this method are roses, carnation, bridal bouquets, etc. For carnation freeze drying at (−)20 °C for 7 days (Bhattacharjee and De 2003) and for rose (cvs. Tineke, Golden Gate, Saphir, and Rote Rose) freeze drying for 14 days (Sohn et al. 2003; Behera 2009) are recommended. Shrinkage was observed in some cases, but the color remained similar to fresh rose. Freeze drying was standardized in China rose flowers (Liang et al. 2005) and pansy also (Deepthi and Kumar 2008).

Sireesha and Reddy (2016) reported that for freeze drying technique in orchid, application of preservative (a blend of Sprite and bleach) in lukewarm water (43–45 °C) during hydration process followed by pretreatment with base composition III and posttreatment by application of dried material preservative (DMP) as sealant was found to be effective for retaining inherent qualities of the flowers.

Fernandes et al. (2018) reported that freeze drying may be applied to produce dried borage flowers for infusions, while alginate coating is a promising treatment to increase shelf-life subject to further development.

Freeze-dried flowers are used to make open baskets, open wreaths, open bouquets, etc. Bridal bouquets could be preserved by this technique of drying without any damage. High cost involvement and lack of precise processing techniques are the major disadvantages of freeze drying. The initial costs of equipment investment, electrical energy consumption, and maintenance are relatively higher than those for other drying techniques; however, the quality of the finished floral product is almost doubled. Freeze-dried flowers are fragile, and care should be taken while handling and in their storage. The cartons containing dry flowers should be strong enough to protect them during transportation.

8.5 Factors Affecting the Rate of Moisture Loss During Drying

The rate of moisture loss during drying is primarily dependent upon the following factors:

- **Type of plant materials**: Selection of plant materials is the most important point for production of successful dried flowers to be kept for long duration, because the basic botany of the plant material, whether flower or foliage or any other plant parts, and the type of flower, its color, volume, petal types, thickness, moisture content, type of tissue (the more lignified is the tissue, the lesser is the distortion after drying), and finally stage of maturity – everything – matter. Scientists have worked on many items and standardized the protocol, but there are lots to be covered. Degradation of pigments as well as loss of water from the cells during drying results in change of color of flowers into brown which is not suitable for future use. It is reported that the red flowers turned to dark purple or bluish, pure blue acquired lavender or purplish color, pink color changed to red while magenta turned to lavender, but yellow and orange colors were usually well preserved and also intensified well after drying. Usually, the fading flower color was less in embedding method. Flower color after dehydration not only depends on category of pigment but also on internal or ultrastructural factors. Therefore, flower color as well as method of drying should be taken into consideration for getting excellent quality of dry flowers.
- **Temperature for drying**: According to thermodynamics, amount of heat transferred (H) from any surface is directly proportional to the temperature ($H \alpha t$). It indicates that the higher the temperature, the more rapid is the moisture loss. However, for living materials, though time taken for drying is definitely less in higher temperature, there is often a chance of charring of cells in high temperature which invariably reduces the quality of finished product. Therefore, it is advised that plant materials must be dried in a temperature range of 40–50 °C for obtaining a quality product.
- **Humidity**: Increased humidity in the air surrounding the item placed for drying always hinders the drying process. Wet air or the air containing higher moisture definitely has less power to absorb further moisture from the product. Besides, humidity affects the drying process by reducing the air temperature and preventing crispness of the surface of the product.
- **Airflow**: Absorbance of moisture from a product is primarily an evaporation process, which is directly proportional to the velocity of surrounding air. Actually it is not the air itself responsible for drying but the heat conducted by the air which helps in evaporation. That is why circulation of air is an absolute need for ready transmission of heat during dehydration. Hot air heats up the embedding material which in turn conducts the heat to the flower or foliage, liberating moisture in the form of vapor to be carried away by air again to the outside atmosphere.
- **Embedding material**: Embedding materials can be defined as the substances having a higher capacity of moisture absorbance which can act as a desiccant and is used for drying flowers and foliages in a better way. It can also be termed as drying material or desiccant. In general the embedding material should possess certain characteristic features like:

  Fineness – The finer the particles of embedding materials, the easier is to fill the crevices and cavities of flowers and foliages so that those are completely covered leaving no gaps. In this way the flowers and foliages are in closest contact with the desiccants, which ensures uniform escape of water from their surface and ensures preservation of the shape after drying. The ideal size of desiccant should be 0.02–0.2 mm or 20–200 mesh.

Reactivity – As a part of the process, it is obvious that water vapor will be liberated from the materials undergoing drying and get transferred to the embedding materials. It is very important that the embedding materials should never react either chemically or physically (lump formation) to this excreted water. Otherwise the entire drying process will be hampered. Besides the embedding material should inevitably be free from any salt or chemicals which can, by any chance, react with the petals and foliages and discolor them.

Heaviness – If the embedding material is too lightweight, it becomes difficult to envelop the plant material properly and leaves gap during embedding. To avoid certain circumstances, heavier materials are to be used. Again, if it is too heavy (like red sand), shape of the dried flowers may not be maintained and those may be disfigured.

8.6 Precautions for Drying

The following precautions may be followed at different steps of dry flower production to obtain quality products:

- All the materials should be collected after dew and surface moisture is evaporated.
- Harvesting of flowers and foliage should be done 1 or 2 days after irrigation, in case of cultivated crops.
- Dry seasons and sunny days are preferred for collecting plant materials.
- Faded or disease-/pest-infected materials should be discarded.
- Materials should be dried as early as possible after plucking.
- Soft brush should be used to clean any unwanted material sticking to the dry flowers.
- Dried flowers and foliage should be handled very carefully after dehydration.
- Dry flowers absorb moisture from the atmospheric very easily and tend to lose their shape. Therefore, they should be stored in moisture-proof containers immediately after drying. Different containers, like glass desiccators, tin boxes, and carton, wrapped with plastic sheet or wax paper, are used for storage.
- Small quality of silica gel should be placed inside the container to absorb the moisture if any.
- Dried items should be protected from light and direct sun light to preserve color.
- These should be handled very gently and carefully as these are very brittle and fragile.
- Dust particles not only spoil the beauty of flowers but also reduce storage longevity period. Hence storage containers used for dry flowers should always be free from dust particles.

8.7 Suitability of Technique

Dehydration technique has been standardized for a wide range of cultivated flowers, grasses, ferns, ornamental foliage, etc. The optimum stage, time of harvesting, and time required for dehydration vary from material to material. The technique has been extensively used for dehydration of several popular and common flowers, and several examples are given in Table 1. Wang (2019) reported that hot air drying (HD) of chrysanthemum flowers resulted in lowest total flavonoid values due to reaction between flavonoids and oxidase during drying. Microwave treatment for 30s combined with 75 °C hot air drying was the most effective treatment in preserving biologically active compounds, resulting in higher antioxidant capacity and greater inhibition of the enzyme acetylcholinesterase (AChE). FT-IR showed that the blanching-hot air drying, microwave treatment for 90s, and vacuum-hot air drying led to loss of more compounds than freeze drying. This study also found that 3,5-di-caffeoylquinic acid (3,5-DCQA), luteolin-7-O-glucoside (LuG), luteolin, and kaempferol were the key bioactive substances inhibiting AChE. Furthermore, molecular docking studies showed that a high inhibition of AChE by 3,5-DCQA and LuG could be attributed to the formation of strong hydrogen bonds. The study may be beneficial for understanding *C. morifolium*'s nutritional value and the effects of drying methods on the quality of the final product. On the other hand, vacuum air oven drying method was observed to be the best technique for retention of flower color and related traits (Pinder and Namita 2018) (Tables 1 and 2).

8.8 Post-dehydration Care

Drying is complete when the petals are completely dry and crispness can be felt. Flowers may be removed from the embedding materials by gently pouring off the desiccant particles and air dried to complete the process. Any remaining drying medium is whisked away with a soft brush. The thickest parts are slowest to dry in all types of drying. After drying, white or clear glue may be placed at the base of some flower petals to prevent shattering. Post-drying longevity studies revealed that the microwave-dried buds embedded in silica gel exhibited a longer shelf life than buds treated with the other treatments.

Flower shape after drying is influenced by its moisture content. Lower moisture content provides rigidity, and higher moisture content results flaccid flowers. Chen et al. (2000) reported low moisture content resulted in stronger and stiffer petals in dried flowers. Mechanical support provided by embedding media, throughout the drying process, ensured well-maintained flower shape when moisture content remains below 11.55%. The moisture content of dried flowers is inversely proportional to their longevity (Pandey 2001). A range of 8.0–11.5% moisture content in the dried flowers ensures good quality, firmness, along with keeping quality of more than 6 months. Drying below 8% moisture content showed shedding effect. Excessive moisture loss might be the cause of weakened adhesion and cohesion forces in

Table 1 Suitability of plant materials for different types of drying

Method of drying	Suitability of plant materials
Air drying	*Helipterum* (acroclinium), *Helichrysum* (straw flower), goldenrod (*Solidago*), *Gypsophila* (baby's breath), *Limonium* (statice), *Achillea* (yarrow), *Gomphrena* (globe amaranth), *Anaphalis* (pearly everlasting), *Celosia* (cockscomb), *Centaurea cyanus* (bachelor button), *Consolida ajacis* (larkspur), *Cassia fistula* (golden rain tree), *Nigella* (fennel), *Bougainvillea*, *Setaria verticillata* (bristly foxtail), *Miscanthus sinensis* (eulalia grass), *Pennisetum setaceum* (fountain grass), *Distichlis spicata* (spike grass), *Chasmanthium latifolium* (northern sea oats), *Callistemon lanceolatus* (bottlebrush), *Amaranthus caudatus* (love-lies-bleeding), *Jacobaea maritima* (dusty miller), *Physalis* (Chinese lantern), *Stachys* (lamb's ear) and *Alchemilla mollis* (lady's mantle), *Craspedia globosa*, *Anaphalis*, *Holmskioldia*, hydrangeas, xeranthemums, *Astilbe*, *Baptisia*, *Gaillardia*, larkspur, lilac, marigold, milkweed, okra, *Paulownia*, *Polygonum*, poppy, rose, sages, *Santolina*, *Acacia dealbata*, *Anthemis nobilis*, *Delphinium ajacis*, *Gaillardia pulchella*, *Protea* sp., *Peltophorum ferrugineum*, *Tagetes* sp., *Zinnia elegans*, *Salvia*, *Artemisia*, *Chrysanthemum*, *Delphinium*, oregano, *Rumex*, and thistles
Press drying	*Acalypha*, *Crocus*, pansy, *Alyssum*, daffodil, *Phlox*, *Anemone*, daisy, *Primula*, azaleas, *Delphinium,* heather, bleeding heart, butterfly weed, heath, *Celosia*, *Bougainvillea*, *Ixora*, *Jarul*, *Caesalpinia*, *Lantana camara*, *Panicum*, *Mussaenda*, *Radhachura*, *Euphorbia hirta*, *Triumfetta rhomboidea*, *Polygonum*, *Oxalis*, *Cycas*, *Cleome viscose* and *Cleome rutidosperma*, *Desmodium gyrans*, *Mikania cordata*, *Atalantia* sp., *Oplismenus compositus*, *Hemigraphis hirta*, *Ipomea tridentate*, *Hemidesmus indicus*, *Vitex negundo*, *Teramnus labialis*, *Ziziphus oenoplia*, *Limonia acidissima*, *Cleome rutidosperma*, *Peperomia pellucida*, *Sida rhomboidea*, *Morus alba*, *Tephrosia purpurea*, *Scoparia dulcis*, *Phyllanthus simplex*, *Sapium sebiferum*, *Vitis* sp., *Merremia tridentata*, *Phoenix paludosa*, *Triumfetta rhomboidea*, *Boerhavia repens*, *Pouzolzia hirta*, *Prosopis juliflora*, *Ageratum conyzoides*, *Commelina benghalensis*, *Alysicarpus bupleurifolius*, *Urena lobata*, *Spilanthes calva*, *Cestrum fasciculatum*), *Adiantum*, *Selaginella***,** candytuft, *Chrysanthemum*, *Lantana*, rose, statice, *Zinnia*, *Verbena*, *Euphorbia*, *aster*, butter cup, geranium, marigolds, Queen Anne's lace, coral bells, lily, hardy geranium, bell flower, African violets, larkspur, *Hibiscus*, *Ixora*, nettle leaf, velvetberry, *Pentas*, *Plumeria rubra*, and *Melia*; leaves like thuja, ferns, silver oak, blue gulmohar, thuja, and cockscomb; and spiky leaves in iris and *Montbretia*
Embedding/drying flowers by using desiccants	*Ageratum*, dahlia, lily of the valley, anemone, daisy, magnolia, bells of Ireland, *Delphinium*, marigold, black-eyed Susan, dogwood, pansy, butterfly weed, false dragon head, passion flower, carnation, fever few, peony, *Chrysanthemum*, *Gladiolus*, rose, *Coleus*, hollyhock, *Salvia*, cone flower,

(continued)

Table 1 (continued)

Method of drying	Suitability of plant materials
	Lantana, snapdragon, coral bells, larkspur, stock, daffodils, lilac, *Verbena*, water lily, yarrow, *Zinnia*
Oven drying	*Bougainvillea* sp., *Callistephus chinensis*, *Dahlia variabilis*, *Delphinium ajacis*, *Dendranthema grandiflora*, *Helipterum roseum*, *Gerbera jamesonii*, *Gladiolus* sp., *Gomphrena globosa*, *Ixora coccinea*, *Narcissus* sp., *Nymphaea* sp., *Rosa* sp., *Tagetes* sp., *Zinnia linearis*
Drying in microwave oven	African daisy, *Aster*, *Calendula*, carnations, *Chrysanthemum*, *Clematis*, daffodil, dahlia, *Dianthus*, dogwood, marigold, orchids, pansy, peony, poppy, rose, salvia, Mexican sunflower, tulip, *Zinnia*

Table 2 Drying period of flowers and foliage (Geetha et al. 2004)

Flower and foliage plants	Hot air oven drying (in hours)		Press drying (in days)
	35–40 °C	45–50 °C	
Acroclinium	–	48	–
Acalypha	–	–	14
Aster	–	48	–
Antigonal	–	48	–
Bamboo	–	–	14
Bougainvillea	48	–	8
Caesalpinia	–	–	13
Chrysanthemum	–	45–48	–
Dahlia (pompon)	72	–	–
Digera muricata	–	–	12
Digitaria setigera	–	–	12
Echinochloa colona L	–	–	12
Fern	–	–	9
Ixora	–	36	11
Marigold small	–	48	–
Marigold large	–	72	–
Mimusops	–	–	12
Mussaenda	–	–	18
Narcissus	75	–	–
Nymphaea	–	120	–
Pansy	60	–	–
Zinnia linearis	–	48	–
Zinnia lilliput	–	72	–

flower tissue and softening of the middle lamella, which ultimately resulted into abscission (Singh et al. 2004).

Packaging is a very important aspect regarding post-dehydration care. Quality reliability and continuity are major considerations when purchasing dried flower products because dried flowers and foliages are fragile and require careful handling. Before using dried materials for making decorative items, it is necessary to protect them from all possible hazards.

Dry flowers are fragile and require careful handling. Flowers dried using silica gel will sometimes reabsorb moisture and wilt; therefore it is recommended that the flowers should be stored and displayed in a closed container to keep out moisture and dust. Since dry flowers absorb atmospheric moisture and lose their shape, they should be stored in moisture-proof containers like glass desiccators, tin boxes, and cartons wrapped with plastic sheet or wax paper wherein silica gel crystals are kept at the bottom. Storage containers should be dust-free, and it should be protected from light and direct sunlight to preserve color. Also flowers dried with sand can be stored in a strong carton to protect the petals from breaking.

Placing a layer of tissue paper in flowers may reduce breakage. Spraying the dried flowers with a clear plastic spray prevents them from absorbing water during humid periods and also keeps away dust from sticking and discoloring the petals. Silica gel crystals should be kept at the bottom of the storage containers like desiccators, glass jars, or plastic jars. It helps to prevent spoilage and maintenance of better quality for their future utilization. The flowers such as larkspur, hydrangea, or sweet Annie could be made durable by using a hair spray over them and wrapped loosely with tissue paper or newspaper and laid flat in the container kept in a cool dry place. Selection of proper packaging, giving proper cushioning, and use of moisture barrier packaging materials are major factors for successful marketing in dry flower industry. Boxes should be free from insects since they chew the soft tissue and flower petals shatter making the material unsuitable. Wrapping of dried flowers in newspaper and placing them in a cardboard box also work. The box should not be stored in an unusually damp or very dry place. A few moth balls can be kept to protect from small rodents and insects. Trinklein (2006) recommended various control measures against the household insects which move into the boxes during storage. Occasional checking of the box for insects and using naphthalene flakes are suggested.

Packaging for delicate dried plant materials should be done manually during transportation and distribution. It is always advisable to purchase a superior-grade or standard cartons or boxes for packaging. Dried plant parts should be stored in dust-free area, and cartons or boxes used for storage should be cleaned from time to time.

Insect pests can afflict all types of dehydrated plant parts. Book lice, silver fish, and mice are the common pests infesting dried plant material. These could be controlled by insecticides applied in the solid pest strips (dichlorvos), liquid (synthetic pyrethroids, ethyl parathion 0.01%), or gas (methyl bromide, phenyl tablets). The most common genera of fungi, namely, *Aspergillus*, *Penicillium*, and *Rhizopus* infest dried plant material. To prevent this plant material before collection may be treated with Dithane M-45 (0.2%). Sulfur burning or sulfur dioxide fumigation also reduced these fungi during storage. Oulakh and Radha Rani (2018) reported that different display packaging materials can be used to enhance the appearance of the products and also to retain the overall quality of the dried flowers for longer period. Sharma et al. (2019) reported that maximum score was allotted to flowers which were dried in microwave oven and kept covered in paper envelopes up to 120 days in

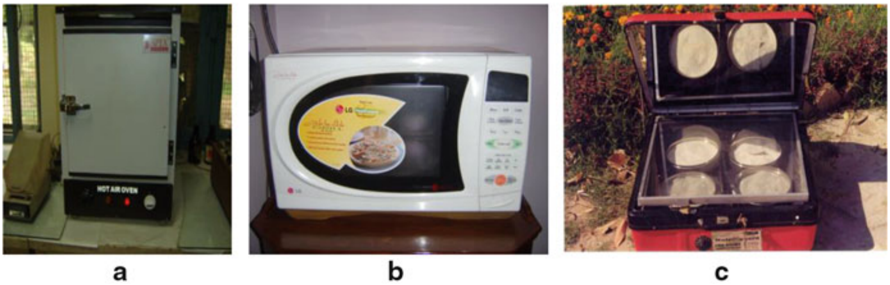

Fig. 1 Photographs of (**a**) cabinet dryer, (**b**) microwave oven dryer, (**c**) solar dryer

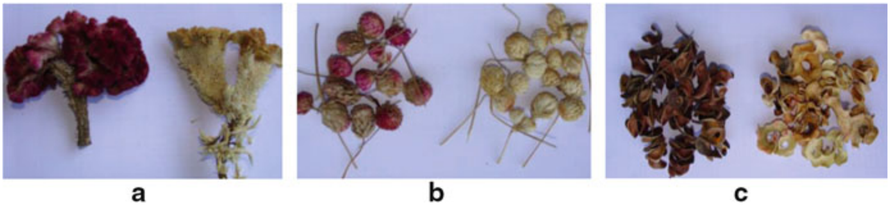

Fig. 2 Photographs of plant materials before and after bleaching: (**a**) *Celosia* sp., (**b**) *Gomphrena* sp., (C) *Inga dulcis*

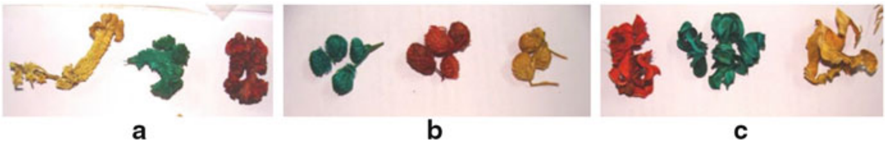

Fig. 3 Photographs of plant materials after dying: (**a**) *Celosia* sp., (**b**) *Gomphrena* sp., (**c**) *Inga dulcis*

storage. In case of dyed flowers, maximum presentability was found in flowers dyed with yellow fabric dye and stored in paper envelopes (Figs. 1, 2, and 3).

8.9 Utilization/Uses with Examples and Photographs

Both press-dried and embedded dry materials may be used for preparation of diversified value added products like bouquets, gift boxes, wall hanging, potpourris, artistic greeting cards, get well cards, wall plates, calendar, pictures, flower baskets, refrigerator magnets, mirror decoration, hats, embedding in gold/silver or resin to use as jewelry, landscape, table mats, coasters, three-dimensional arrangements of flowers for interior decoration, etc. Floral album may be prepared for identification of plants for taxonomic studies. Dehydrated flowers may be used as botanical specimens for demonstration and for teaching students. Pictures given Figs. 4 and 8.

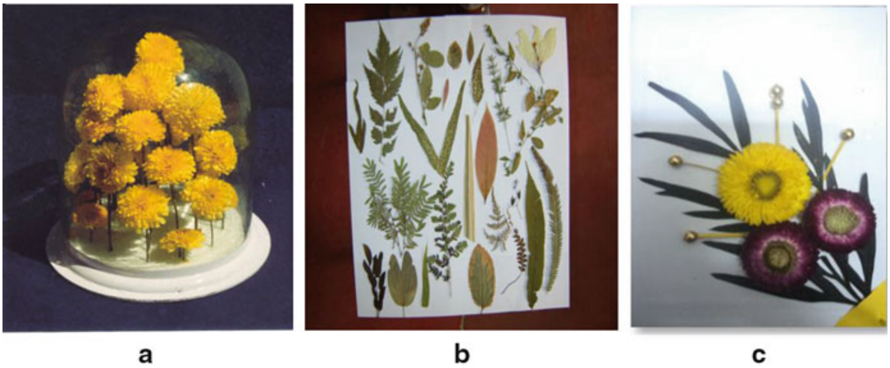

Fig. 4 Photographs of plant materials after dying: (**a**) *Chrysanthemums* kept in glass vial after embedded drying. (**b**) Foliages pasted after press drying. (**c**) Bouquet with dried *Helichrysum* flowers and glycerinized leaves of *Grevillea robusta*

8.10 Combination of Other Botanicals with Dried Flowers and Its Potentiality

The dry flower industry deals with hundreds of plant materials for making different products like potpourri, arrangements, floral handicrafts, main blooms, fillers, liners, exotics, etc. for which other than natural flowers, lots of other botanicals are also used. Some techniques to produce those items are discussed below.

8.10.1 Preservation with Glycerine (Glycerinization)

Most of the plant materials contain more than 50% of their fresh weight as water. Upon drying, when the water content falls below 10%, brittleness becomes an issue for both handling and appearance. Glycerine drying has been used by several workers to preserve plant materials, especially foliage (whole bunches or single leaves) and retain their natural shape and flexibility. They lasted indefinitely and could be dusted or even wiped with damp cloth without risk owing to the leathery texture of leaves. Glycerine is reported as one of the best osmotic reagents, effective for dehydrating foliages as well as maintaining flexibility, shape, and texture. Thus, the preserved plant material is less brittle than dried material, making it less prone to shattering and mechanical damage (White 2007).

Many types of foliage have been successfully preserved by immersing leaves in diluted glycerol solution or placing crushed stems into it. Fresh and fairly matured foliage is ideal for glycerinizing. The resultant leaves are soft and flexible. Freshly cut statice stems may be preserved by soaking in 1:2 or 1:3 glycerol-water solution for 48 h followed by microwave drying for 1 min at medium high temperature (34 °C). A solution of 10–30% glycerol in water was found to be satisfactory for preserving most of the foliage by Dubois (2005). However, amount of glycerol accumulated by plant tissue increased with increasing concentration (from 10% to 30% v/v). Addition of 10 or 100 mM NaCI or KCI to the glycerol solution increased glycerol uptake by about 10%. Varying pH (2–8) of the glycerol solution had no differential effect on uptake. Glycerol uptake was not affected by soluble biocides like sodium dichloroisocyanurate, copper sulfate, and benzalkonium chloride. But poorly soluble fungicide mixtures like benomyl + iprodione + furalaxyl and propiconazole + propamocarb + procymidone may block the stems. Maintenance of a large vapor pressure deficit (vpo) greatly enhanced glycerol solution uptake. Thus pre-wilting the foliage for 12 h increased the initial rate of solution uptake. Fraying stem did not influence uptake of glycerol solution.

Also temperature of the solution had an impact on uptake. One part of glycerine mixed with two parts of hot water was the ideal mixture for twigs of a number of plant species like eucalyptus, hollyhock, hydrangea, etc. Addition of few drops of vegetable oil in the said solution intensified the color of immersed stems. Also mature leaves responded well to glycerine treatment as they translocated the solution readily to stems. Branches are allowed to absorb glycerine for 2–6 weeks depending on the texture and size of the leaves and branches.

Glycerine serves as a good source for microorganisms, so a pinch of antibiotic is necessary to prevent microbial growth in the dried specimens. Glycerine drying is actually replacement of cell moisture by glycerine which keeps the leaves soft and pliable for easier handling and less shedding. Thickness of the leaf is an influencing factor in glycerinization as it was found that thick magnolia leaves take longer time than a soft thin maple leaf. Though this method is most suitable for foliage than flowers, certain flowers like bells of Ireland, statice, hydrangeas, lady’s mantle, narcissus, and rose hips can be used. Some plants take 30 h, while others may take 2–3 months. Actually glycerinization is the best for preserving small leafy tree branches where glycerin enters the leaves easily. Average time taken for drying is 2–3 weeks, and best results were reported during summer season when absorption is rapid and drying is completed within 2–6 days of immersion. In glycerine drying moisture in plant materials is replaced by a mixture of water and glycerine (Paul and Shylla 2002). Actively growing foliage gives the best results. Species which normally undergo cyclic growth patterns (like *Leucodendron*) may take up the glycerol solution better when picked during a growth “flush” (usually mid-summer). At other times soaking technique is better as slower rate of absorption takes place in soaking.

Also glycerinization can be effective to increase flexibility when flowers are placed in hot air oven with sand-embedded technique after pretreatment with glycerol and water mixed in the ratio of 1:5. This technique was effective in improving color, size, and flexibility in dry flowers of rose var. noblesse and *Chrysanthemum* var. yellow double. Similarly, air-dried helichrysum pretreated with ratio 1:4 glycerol was the best.

After glycerinization, though stem and leaves may turn brown in this process, they remain flexible and pliable almost indefinitely. There are two methods: glycerin uptake with the average time taken is 2–3 weeks for this treatment, and next is full-dip method, in which the plant material absorbs glycerin through the leaf surface and can be submerged in the solution done with ferns and single leaves of poplar and palmetto. The plant materials are not allowed to stand in the glycerine solution for a longer time as it results in glycerine bleeding. Sweating also occurs when there is a sudden drop in the humidity from a high level. Thus, there is drastic reduction in the water-holding capacity of dehydrating agent which then releases free water. This water cannot evaporate quickly enough and collects as droplets on the surface of the plant material where it provides an ideal environment for bacterial or fungal growth. Keeping the level of humectants in the plant tissues as low as practicable and by storing glycerine foliage at low humidity, sweating can be minimized. Marak et al. (2016) suggested that ideal concentration of glycerine best suited for preservation varied from species to species and method of treatment; however, best results were obtained in terms of texture, shape, brittleness, and overall acceptability for silver oak in 20% glycerine by uptake method. Yadav et al. (2018) reported that in *Buxus* leaves full-dip method of glycerine application was better as compared to uptake method and the best concentration of glycerine solution was 40% for drying of cut foliage. Karmakar et al. (2020) suggested that usable shelf life of *Nephrolepis exaltata* could be enhanced by processing with glycerin (40%) up to 87.33 days by full-dip method (Fig. 5).

The process of glycerinization as a whole can be jotted as:

- Normally the glycerine-water mixture is used to preserve foliage.
- This is done by placing the base of branches in a bucket or some other container of the glycerine-water mixture (normally containing one part glycerine to two parts water).
- The lower 2 inches of the branch may be crushed and placed in the jar for better absorption.
- The glycerine is drawn up the stem and moves into the leaves where it absorbs moisture.
- The process is complete when beads of glycerine begin to form on the edges of the leaves.
- Meanwhile, if the glycerine solution is depleted, supplementation with a solution of one part glycerine to four parts water is ideal.
- If the flowers seem to wilt after removing them from the solution, they need to be hung upside down to allow the glycerine to migrate to the leaf tips.
- Usually the process takes a couple of weeks. Excess glycerine is then washed off with soapy water. When dry, the leaves will be gray and pliable and can be sprayed with green floral paint.
- For best results, this method is used during the summer months when absorption is most rapid. Leaves that are thick and waxy will be dried with a soft and pliable texture, when immersed in glycerine solution for 2–6 days.

Geetha et al. (2004) suggested following plants for glycerinization:

Anthurium andraeanum, *Avena*, *Briza* sp., *Camellia japonica*, *Catharanthus* sp., *Citrus limon*, *Clematis*, *Codiaeum variegatum*, *Crotalaria selloana*, *Cyperus*

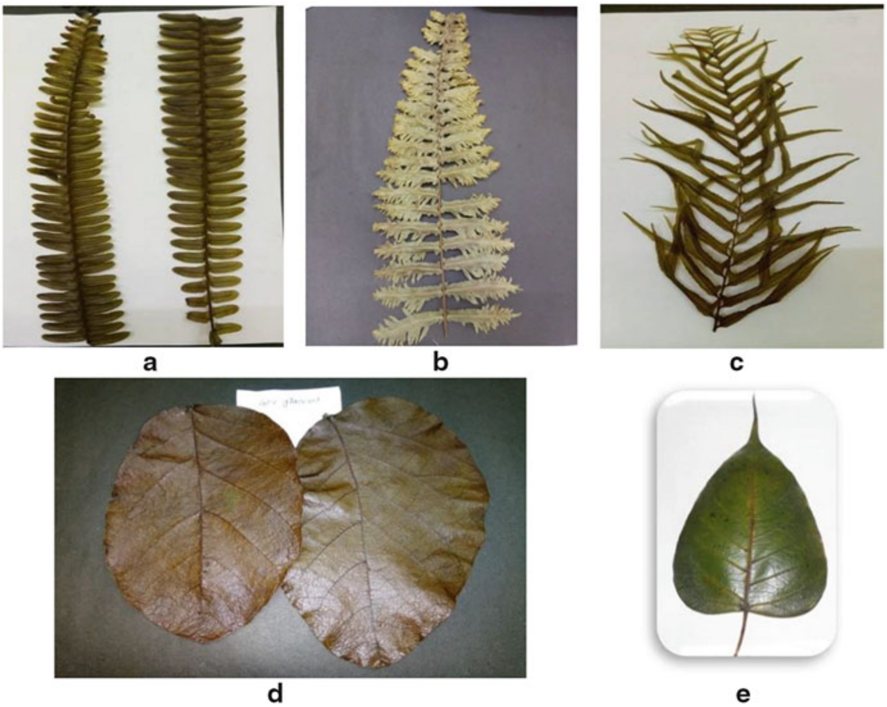

Fig. 5 Photographs of leaves preserved by glycerinization after 6 months (**a**) just after drying and (**b**) after 1 year of storage

alternifolius, *Digitalis purpurea*, *Dracaena*, *Eucalyptus* sp., *Fagus sylvatica*, *Grevillea robusta*, *Gypsophila elegans*, *Hordeum jubatum*, *Humulus lupulus*, *Hydrangea macrophylla*, *Ilex* sp., *Iris orientalis*, *Juniperus communis*, *Magnolia longiflora*, *Morina longifolia*, *Populus* sp. (Fig. 6).

8.10.2 Drying of Other Botanicals

Natural drying: The easiest and oldest method of drying used for leaves, flowers, pods, etc. is natural drying, drying in the sun. In this method, the flowers or plant parts are allowed to dry on the plant itself and collected when they are completely dried. Some of the important naturally dried plant parts are beautiful fruiting shoots of *Aegle marmelos*, *Bambusa* spp., *Cassia fistula*, *Caesalpinia sepiaria*, *Pinus roxburghii*, *Sapindus mukrossii*, etc. and seeds of *Abrus precatorius/Aesculus indica*, *Sapium sebiferum*, etc. were identified in the outer Himalayan regions. A number of botanicals (Table 3 and Fig. 7) were collected and dried by different drying methods by Anon (2018). The dried materials were tested for bleaching and dying, and several value added products were prepared from the said items like corner bouquet

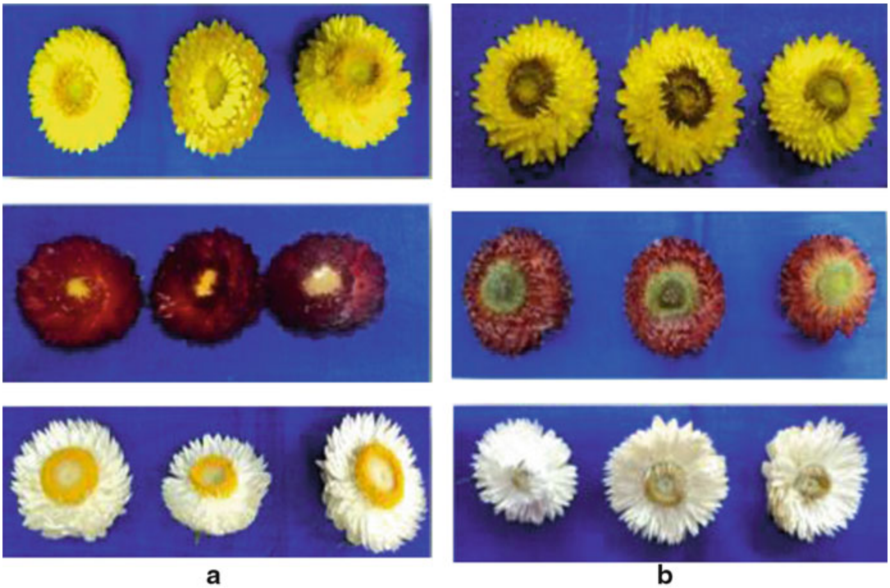

Fig. 6 Photographs of *Helichrysum* after embedded dying in silica gel at 50 °C (**a**) just after drying and (**b**) after 1 year of storage

arrangement, stick materials, carry bags, jewelry box, greeting card, rakhi, etc. Products gave a profit margin around minimum 25–30%.

8.10.3 Skeletonization

When leaves or any other green tissues are left in the same water for quite some time (3–4 months), all their soft tissues decay, and the residual structure of leaf venation containing more lignified tissues may be recovered which is known as leaf skeleton. The network or skeleton of the original object can be bleached with a little lime and may form a nice decorative item. The home-scale process of skeletonization is:

- Leaves may be boiled for 40 min in a solution of 1 teaspoonful of baking soda or lye per quart of water.
- Then the boiled leaves are rinsed in cold water and spread on newspaper.
- The fleshy green pulps on both sides are carefully scraped off with a dull knife.
- If a lighter color is desired, the skeleton is immersed in 1 quart of water with 2 tablespoons of household bleach for 2 h.
- The venations are rinsed thoroughly and gently wiped with a clean cloth.
- Finally, those are placed between sheets of absorbent paper and pressed for minimum 2 h.

Table 3 Drying of different ornamental species and plant parts (Anon 2018)

Sl. no	Common name	Botanical name	Botanical parts being used	Method of drying	Bleaching	Coloring/ painting
1.	Date palm	*Phoenix dactylifera*	Leaf and fruit bunches	Sun drying	Yes	Optional
2.	Atta fruit	*Annona squamosa*	Immature fruit	Sun drying	No	Painting
3.	Bakuli	*Lagerstroemia thorelli*	Fruit	Sun drying	Optional	Optional
4.	Broom grass	*Thysanolaena maxima*	Inflorescence	Air drying	Yes	Yes
5.	Tamarind hair	*Tamarindus indica*	Fruit hair	Sun drying	Yes	Optional
6.	Shola	*Aeschynomene aspera*	Plant stem	Sun drying	No	Optional
7.	Base of palmyra palm fruit	*Borassus flabellifer*	Fruit calyx	Sun drying	No	Painting
8.	Base of cauliflower	*Brassica oleracea* var. botrytis	Stem of cauliflower	Sun drying	Yes	Yes
9.	Siris	*Albizia lebbeck*	Pod	Sun drying	No	Optional
10.	Straw flower	*Helichrysum* sp.	Flowers	Embedding	No	No
11.	Marigold	*Tagetes* sp.	Flowers	Embedding	No	No
12.	Chrysanthemum	*Chrysanthemum*	Flowers	Embedding	No	No
13.	Bougainvillea	*Bougainvillea* sp.	Bracts	Embedding	No	No
14.	Boat fruit	*Delonix regia*	Mature fruit	Sun drying	No	Painting
15.	Small boat	*Peltophorum pterocarpum*	Mature fruit	Sun drying	No	Painting
16.	Amra pods	*Spondias pinnata*	Seed	Sun drying	Yes	Yes
17.	Arjun	*Terminalia arjuna*	Fruit	Sun drying	Yes	Yes
18.	Buddha nut	*Terminalia catappa*	Fruit coat	Sun drying	No	Painting
19.	Jarul	*Lagerstroemia indica*	Fruit	Sun drying	Yes	Yes
20.	Bel cup	*Aegle marmelos*	Fruit coat	Sun drying	Yes	Yes

21.	Casuarina	*Casuarina equisetifolia*	Cone	Sun drying	Yes	Yes
22.	Celosia	*Celosia* sp.	Flower	Silica embedded drying	No	No
23.	Coco petals	*Cocos nucifera*	Calyx	Sun drying	Yes	Yes
24.	Curly pods	*Inga dulcis*	Pod	Sun drying	Yes	Yes
25.	Curly tingting	*Cocos nucifera*	Mid-rib of leaf	Sun drying	Yes	Yes
26.	Eucalyptus pods	*Eucalyptus* sp.	Pod	Sun drying	Yes	Yes
27.	Grevillea	*Grevillea robusta*	Leaf	Press drying	Glycerine	Optional
28.	Hogla pencil	*Cyperus corymbosus*	Stem	Sun drying	Yes	Yes
29.	Jackfruit	*Artocarpus heterophyllus*	Immature fruit	Sun drying	No	Paint
30.	Cane	*Calamus* sp.	Stem	Sun drying	No	Painting
31.	BhuttaPata	*Zea mays*	Cover of the cob	Sun drying	Yes	Yes
32.	Pepal net	*Ficus religiosa*	Leaf skeleton	Press drying	Yes	Yes
33.	Mehogini spoon	*Swietenia mahagoni*	Petals	Sun drying	No	Painting
34.	Champa net	*Michelia champaca*	Leaf Skeleton	Press drying	Yes	Yes
35.	Mehogini center	*Swietenia mahagoni*	Flower Centre	Sun drying	Yes	Yes
36.	Garagara	*Coix lacryma-jobi L*	Fruit	Sun drying	No	Painting
37.	Cobra leaf	*Butea frondosa*	Leaf	Press drying	Yes	Yes
38.	Sun center	*Helianthus* sp.	Flower head	Silica embedded drying	No	No
39.	Jute stick	*Corchorus* sp.	Pith	Sun drying	Yes	Yes
40.	Coco coir/coco hair	*Cocos nucifera*	Fine coir	Sun drying	Yes	Yes
41.	Luffa	*Luffa acutangula*	Fully developed fruit, after removing the mesophyll tissue	Sun drying	Yes	Yes
42.	Nataraja	*Achras zapota*	Bark	Sun drying	No	Painting

(continued)

Table 3 (continued)

Sl. no	Common name	Botanical name	Botanical parts being used	Method of drying	Bleaching	Coloring/ painting
43.	Baramoti	*Litchi chinensis*	Immature fruits	Sun drying	No	Painting
44.	Supari	*Areca catechu*	Leaf base	Sun drying	Yes	Yes
45.	Shyama grass	*Echinochloa colona*	Inflorescence	Sun drying	Yes	Yes
46.	Lotus pod	*Nelumbo* sp.	Thalamus	Sun drying	Yes	Painting
47.	Moss	*Sphagnum moss*	Total plant body	Sun drying	Yes	Optional
48.	Banyan	*Ficus benghalensis*	Leaf	Press drying	No	No
49.	Base of palmyra palm fruit	*Borassus flabellifer*	Fruit calyx	Sun drying	No	No
50.	Base of cauliflower	*Brassica oleracea* var. botrytis	Stem of cauliflower	Sun drying	Yes	Yes
51.	Male inflorescence of Palmyra palm	*Borassus flabellifer*	Male inflorescence	Sun drying	No	No

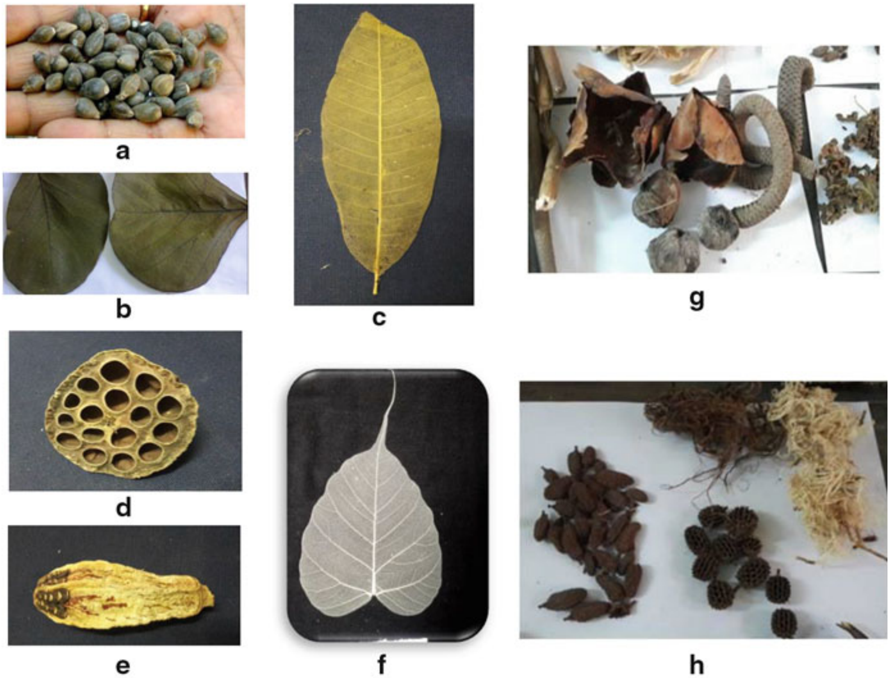

Fig. 7 Photographs of different natural items: (**a**) *Coix*, (**b**) *Bauhinia*, (**c**) skeleton of *Michelia* leaf after dying, (**d**) lotus pod, (**e**) mehogini center, (**f**) skeleton of *Ficus* leaf after bleaching, (**g**) & (**h**) mixed items

Verma et al. (2012) reported that fully matured, healthy leaves of pipal immersed in NaOH (40%) solution could be skeletonized after 2 days. He also found out that heavy textured leaves are more suitable for this method. Also use of KOH (10%) in half a liter of water helps in removing the leaf tissues when immersed for 60–70 min. Marak and Chakrabarty (2014) reported that NaOH (40%) accelerated the process of skeletonization (removal of mesophyll layers) within 2 days with maximum visibility of veins. Heavy-textured leaves are the best choices for this method of preservation. The leaves of the ivy, the stink pod of the stramonium (which is now to be found exactly ripe for steeping), the oak leaf, *Ficus*, *Bauhinia*, *Michelia champaca*, etc. express greater beauty when skeletonized than when perfect (Fig. 8).

8.10.4 Bleaching and Coloring of Dehydrated/Skeletonized Botanicals

- **Bleaching**

Almost all the natural botanicals attain a darker shade during drying. Bleaching involves chemical process that makes the product to attain a visibly lighter shade and

Fig. 8 Plates containing different finished products prepared from dried botanicals. (**a**) Corner bouquet arrangement, (**b**) carry bag, (**c**) stick material, (**d**) pen stand, (**e**) jewelry box, (**f**) potpourri, (**g**) greeting cards, (**h**) greeting cards

can increase its ability to absorb light. Bleaching agents are chemicals that lighten or whiten a substrate through chemical action. The attractive plant material which is inherently colored by unwanted pigments or discolored due to oxidative browning can be bleached either by oxidative bleach or by reductive bleach or sulfured also. Both oxidative and reductive bleaches can be used for bleaching plant materials. Oxidative bleaches such as chlorites, hypochlorites, and peroxides or peroxy compounds tend to break down the colored compounds, while reductive bleaches such as borohydrides and sodium sulfide tend to modify them into colorless compounds. Sodium chlorite is relatively selective for lignin without damaging fiber, hence considered as an excellent bleaching agent. Among reductive bleaches, hydrosulfites (sodium or zinc hydrosulfite) are cheap and have maximum bleaching capacity. The bleached items can directly be used in various floral arrangements, or those can be dyed with different colors. Bleaching or discoloration allows the use of dyes for coloring of plant material. Without bleaching, the dying process cannot give the desired color and leads to uneven shades.

Sulfuring is also done to prevent enzymatic color change. Sulfur dioxide acts as bleaching material for colored plant material and, when used below a certain concentration, can help in fixing colors in some flowers also. Color fixation is related to acidification of the tissues. Sulfuring is produced by burning sublimed sulfur powder or by injecting sulfur dioxide gas (1–3%) into a sealed chamber. The plant materials are usually treated with sulfur dioxide overnight prior to ventilation of the chamber and subsequent completion of the drying process (Verma et al. 2012).

After bleaching with oxidative or reductive chemicals, often yellowing of the plant material may happen, which is the major problem. To avoid yellowing, multistep bleaching technique alternating with a reductive bleach results into less yellowing. A final wash in a 2% solution of barium hydroxide, calcium hydroxide, sodium bicarbonate, or aluminum sulfate may also prevent yellowing.

A number of preserved ornamental plant materials are bleached during preservation. Bleached plant materials may be recolored with dyes. Petal shades require almost total removal of color from the dried plant materials to avoid uneven dyeing. Profitability of bleaching depends upon attainment of bright white color and the efficient utilization of expensive bleaching chemicals. Bleached ornamental plant materials help in creating "contrast" effect when arranged with naturally dried or dyed items.

For bleaching dried flowers of celosia, rose, chrysanthemum, and *Plumeria alba* (small and large flowered types), 10–30% sodium chloride was very effective. Also sodium hypochlorite was the best chemical to bleach pink, globe amaranth, French marigold, and multicolored zinnia. Sujatha et al. (2001) reported that hydrogen peroxide was the best bleach at room temperature, caused the least damage to cell tissues, and was ideal for the bleaching. Dried pods of *Acacia auriculiformis*, *Sesamum indicum*, *Gossypium hirsutum*, and *Pongamia glabra* and cones of *Pinus* spp. exhibited minimum bleaching time of 6 h and lowest rate of damage with highest whiteness index and maximum score for shape retention when treated with 20% sodium chlorite +5% hydrochloric acid (cold water). Marak and Chakrabarty (2013) reported that bleaching with sodium hydroxide (10%) + sodium silicate (10%) + hydrogen peroxide-at 70 °C (hot) gave superior results for both pipal and champa with maximum sensory attributes. Mir and Jana (2015) reported effectivity of 20% hydrogen peroxide and "Ala"(15%) on bleaching of venation skeletons used for maximum of 2 h. Preethi et al. (2019) recommended 100% sodium chlorite for bleaching of dried plant materials like *Wedelia trilobata*, *Clitoria ternatea*, *Mussaenda luteola*, *Caesalpinia pulcherrima*, *Caesalpinia pulcherrima* 'flava', *Mussaenda luteola*, *Hamelia patens*, *Thryallis glauca*, *Ixora duffii*, *Ixora coccinea*, *Caesalpinia pulcherrima* 'rosea', *Saraca indica*, *Cordia sebestena*, and *Cassia glauca.*

- **Coloring**

The decorative value of dry flowers may be increased by external color, which may be in the form of dyes (water based) or paint (oil based). Coloring of dried flowers helps to retain their naturalness and adds more value to the product. Oil-based paints, being primarily a physical process, can be applied by aerosol spray or dipping. Dried foliage and flowers are painted by using brushes or dipping and spraying. Enamel paints used for interior decoration, poster paints, and tube paints can be employed for this purpose.

Lexically dyes are organic compounds which absorb light of 205–900 in ultra-frequencies, thus only reflecting a portion of the visible spectrum with the result that the eye sees color. Each pure dye compound has a unique color. A vast number of different colors may be developed by blending pure dye stuffs. The method of dying is actually a chemical process, and dyes are usually applied by immersion of ornamental plant parts which may be fresh, dried, or bleached. Resistance of a dye or pigment to chemical or phytochemical attack is an inherent property.

There has been significant development in organic color chemistry during the last few decades. The first ever dye (discovered in 1856) was named as Perkin's mauve, and following this, many color named indigosol, fire red, Hansa yellow color, sulfur black, etc. became popular. Basic dyes were the first of the synthetic color made out of coal tar derivatives. Although basic dyes produce brilliant colors, they have poor fastness Normally acid dyes are water solution anionic dyes, while the vat dyes are water-insoluble dyes. Acid dyes are effective for protein fibers such as silk, wool, nylon, etc. and fix to the fibers by hydrogen bonding, Van der Waals forces, and ionic linkages. In this case dyeing is generally carried out at boiling temperature for 30–60 min depending upon the depth of the shade and dyestuffs used. The wet and light fastness properties of acid dyes vary from poor to excellent, depending upon the molecular structure of the dyes. These dyes have very good leveling and migration properties along with low affinity for the fiber ultimately leading to poor fastness property, in general.

Tampion and Reynold (1971) explained three ways of dying flowers, viz., (i) by absorption (the cut stems are placed in a dye solution), (ii) by dusting the cut blooms (with powdered dye), and (iii) by dipping the cut blooms into a solute of dye. In case of dipping method, few drops of washing up liquid or surfactants may be added to the dye solution which can improve contact between dye bath solution and plant material and can increase the spread of dye molecules. Dyeing of carnation, *Chrysanthemum maximum*, star flowers, gypsophila, and hydrangea can be done by absorption method. Use of vat dyes is the best to dye celosia flowers at 0.2% concentration by cold method. To dye the dried plant parts, they also suggested the use of culinary dyes which are available in wide range of colors and nontoxic in nature. Dip dyeing and spraying are normally recommended to color the seeds and pods.

Sangama (2004) reported that by varying the dye concentration and combinations (food color and feulgen reagent), different shades of colors could be obtained in tuberose cultivars single and double. Yogita (2000) found that the basic group of dyes was the best at 3% and 0.3% for bleached roses and *Aerva* flowers, respectively. Among different dyes used, vat group was superior followed by direct and acid dyes which had low level of color fading on storage.

Dana and Lerner (2002) and White (2007) reported that fragile flowers should be dyed before drying especially when dried with a desiccant. They suggested three types of dyeing, viz., dip dyeing (grasses), spray dyeing (heavy-textured materials like pods, cone seeds), and absorption dyeing (fresh leaves with glycerine medium). In general, for good adsorption of a dye by the fiber, the later must contain acidic groups. The fastness of basic dyes after washing and rubbing is less than that for direct dyes. The products dyed with direct dyes are considered to be dull and less attractive to some extent. Preethi (2019) reported that *Clitoria ternatea* could be dyed with natural yellow dyes; *Mussaenda luteola* dyed with red, blue, and yellow natural dyes; and *Cassia glauca* dyed with natural yellow dyes where the color uptake was high and color fading low.

8.11 Making Different Products with Dried Flowers and Other Botanicals

All press-dried and embedded dried materials can be used for preparation of diversified value added products like bouquets, gift boxes, wall hanging, potpourris, artistic greeting cards, get well cards, wall plates, calendar, pictures, flower baskets, refrigerator magnets, mirror decoration, hats, embedding in gold/silver or resin to be used as jewelry, landscape, table mats, coasters, three-dimensional arrangements of flowers for interior decoration, etc. Preparation of some items are discussed below:

- **Pressed flower pictures, flowered trays, table top, and shadow boxes**: A piece of cardboard is covered with fabric or paper, and a design is sketched lightly on the front on which the pressed flowers are glued. When the glue is dried, it is covered with glass and framed as early as possible. The same for flowered trays or table tops can be prepared. Also shadow boxes can be prepared in this way with a specific planning for depth and skip covering with glass.
- **Wood panels/center piece/*pandal* decoration**: Plywood, wood, or bamboo structures can either be painted or rubbed with equal parts of turpentine and linseed oil followed by sketching a design on the surface. Then seeds, pods, dried branches, etc. are cemented upon which is finally covered with a coating of clear shellac. Centerpieces can be made in the same way.
- **Floral craft or arrangements**: Dehydrated flowers and foliage can be used for designing distinctive, fascinating, and artistic floral arrangements, bouquets, gift pack, festive decorations, collages, flower pitchers, floral balls, pomanders, wall sceneries, greeting cards, wedding cards, and sweet-smelling potpourris followed by items required for preparation of greeting cards, floral designs, pictures, landscapes, calendars, etc.
- **Corner bouquet arrangement**: These are front-facing arrangement, usually kept on side table. Size of decoration should be proportionate with the display table.
- **Stick materials**: Bleached and dyed foliages of different types may be used for making stick materials (normally made of bamboo stick of 10″, 12″, and 18″) by positioning the dried items around the stick in such a way that they form a beautiful shape. Accessories like ribbon and peeps can also be used to add beauty to the product.
- **Carry bags**: Elegant pieces of dried foliage bags can be made from dried foliages by stitching/adhering dry flower items of normal carry bags made up of jute, cloth, nylon, etc. Carry bag made with dried foliage is an art that stretches to antiquity and eternity.
- **Jewelry box**: Any leftover wooden or paper box can be painted with desirable colors, and then dried foliages were placed on them. The flowers are placed forming an exclusive design or pattern or some symbol. Writing names or messages with dried foliages can also be customized on these boxes.
- **Greeting card**: A piece of paper is cut and foliages/botanicals are arranged over the paper after applying adhesive so that when pressed, it does not come out of

flowers and leaves. This card/floral item is again placed under the glass table top for about an hour to dry, and these are kept away from moisture and dust. Some of the floral items can be framed or laminated. Various designs and patterns can be used along with different color combinations for making cards.

- **Potpourris**: Annon (2018) gave details about preparing **potpourri** containing lata ball, curly pod, coco chips, bakuli, and star flower (77.72 gram excluding package materials) with a **package (**H:13.5 cm X W:8 cm X L: 8 cm) **of** 34.78 gram. The total raw material cost for potpourri (in the year 2016) was Rs. 4.00/−. The total input cost per pack including packaging materials, labor, establishment, and others is Rs.15 per pack and sold at Rs. 40 per pack at wholesale price and with a retail price of Rs.s100/−.

Items	Quantity (pcs)	Total weight (gm)	Cost (Rs.) per pc/wt	Cost (Rs.) for measured volume in potpourri	Description	Collected from (places)
Lata ball	1	2.6	0.70/pc	0.70	Natural (size: 4 cm)	Baita, Midnapore
Curly pod	26	16.2	12.00 /kg	0.19	Natural (size: mix)	S.24 pgs., Midnapore
Coco chips	99	34.32	40.00/kg	1.37	Yellow colored	Bihar
Bakuli	2	4.03	15.00/kg	0.06	Natural, varnished	Midnapore
Star flower	59	20.57	60.00/kg	1.23	Natural	S.24 pgs., Midnapore

8.11.1 Some Novel Techniques

Processing

The principle of processing flowers is based upon replacement of internal moisture with 2-propyl alcohol or t-butyl alcohol (Romero-Sierra and Webb 1982). When these solvents are volatilized from the petals, the fresh texture of flowers is lost. Thus, a replacement technique has been developed with epoxy resin using an ascending series of acetone (von Hagens 1981), which results in complete discoloration of tissues. In “replacement technique” an ascending series of ethyl alcohol is used which causes pigments to leach out of petals during dehydration due to presence of water in the solvent. Markham et al. (2000) adopted a moisture replacement technique without using water-containing solvents. In this technique, pigments diffused but remained in the petals of dehydrated flowers. Ito et al. (2010) reported that processed flowers with natural pigments and texture can be made using normal monohydroxy alcohols and lateral chain diols. They developed a protocol where ethyl alcohol and polypropylene glycol were used as the primary and secondary soaking solvents, respectively. Primary soaking solvent like ethyl alcohol, which has a low viscosity, prevents petal shrinkage. When the petals were soaked preliminarily in some primary soaking solvents like ethyl alcohol, petal shrinkage induced by the secondary soaking solvents (polypropylene glycol) was greatly reduced. Polypropylene glycol was selected as the most appropriate secondary soaking solvent because it retained the petal shape and color of carnations (var. 'moondust velvet blue') for a long time. Such processed flowers retain natural pigmentation and textures almost similar to the fresh flowers. Considering cost, safety, and waste disposal issues, production of "processed flowers" almost similar to the natural one in texture and pigmentation seems to be a good choice.

Plant species where this protocol was successful are corn flower (*Centaurea cyanus*), dwarf delphinium (*Delphinium grandiflorum*), spiderwort (*Tradescantia ohiensis*), Asiatic dayflower (*Commelina communis*), pansy (*Viola wittrockiana*), lisianthus (*Eustoma grandiflorum*), Dutch iris (*Iris hollandica*), cockscomb (*Celosia cristata*), bougainvillea (*Bougainvillea spectabilis*), Easter cactus (*Rhipsalidopsis gaertneri*), portulaca (*Portulaca grandiflora*), four o'clock (*Mirabilis jalapa*), snapdragon (*Antirrhinum majus*), cooktown orchid (*Dendrobium phalaenopsis*), rose (*Rosa hybrida*), bigleaf hydrangea (*Hydrangea macrophylla*), daffodil (*Narcissus pseudonarcissus*), carnation (*Dianthus caryophyllus*), Iceland poppy (*Papaver nudicaule*), African violet (*Saintpaulia ionantha*), salvia (*Salvia guaranitica*), camellia (*Camellia japonica*), geranium (*Pelargonium incrassatum*), tulip (*Tulipa gesneriana*), sunflower (*Helianthus annuus*), pansy (*V. wittrockiana*), oilseed rape (*Brassica napus*), watermelon (*Citrullus lanatus*), and sweet William (*Dianthus barbatus*).

Polyset Drying It is a polymer preservation method, which is applied to the flowers and foliage about 45 min before drying. This method lessens the drying time and improves the intensity of flower color. It also minimizes shattering and wrinkling of the petals which may occur during drying. Drying of native flowering plants and their different parts with epoxy resin encapsulation is a novel approach. These are attractively embedded inside resin, avoiding dust, and beauty of native flowers can be cherished forever (Thakur et al. 2019).

8.12 Conclusion

Demand of dry flowers and floral craft is increasing day by day both in domestic and international market. Dry flower market has grown exponentially as consumers prefer it as the environmental-friendly and biodegradable alternative to fresh flowers. At present, India is a leading exporter of dried flowers with yearly exports averaging in excess of Rs.500 crores. India has rich source of plant materials year-round because of its diversity of topography and climate. Highly diversified agro-climatic conditions of India undoubtedly offer virtually countless varieties of wild flowers. Every state is very rich in natural resources of vegetations. A good amount of natural vegetations are wasted every year due to natural process. In spite of aesthetic beauty, all these natural resources are totally unutilized/wasted due to unawareness of their use. These entire seasonal colorful vegetations can be converted into value added products by using simple dehydration technique. Collection of these vegetations will not create any imbalance in nature. The technology will help proper judicial utilization of natural resources to prepare value added products. The technique has been simplified in such a way that one can learn it within 2 days. No sophisticated infrastructure is required. A cottage scale industry based on dehydrated floral craft can come up for self-employment. Such a creative occupation will help rural women to come out from their drudgery of daily life. There is large potential to develop the dry flower industry in India and to provide employment generation besides self-employment as the industry is labor-intensive. This is indeed what rural India needs. Lack of basic infrastructure and information is a stumbling block for this industry. With innovative training programs and awareness campaign, there is a lot which could be done for promotion of dry flowers' export.

References

Acharyya P, Majumder A, Malakar A, Biswas S (2017) Standardization of dehydration techniques of some selected flowers. Acta Hortic 1181:85–92. https://doi.org/10.17660/ActaHortic.2017.1181.11

Agricultural & Processed Food Products Export Development Authority (APEDA) Annual report (2018–19). In: http://apeda.gov.in

Anonymous (2018) Identification of ornamental species for preparation of value added dried products. In: Annual report of all India coordinated research project on floriculture. ICAR-Directorate of Floricultural Research, Shivajinagar, Pune, India

Anonymous (2020) Advisory to flower growers in the light of COVID 19 pandemic. In: National advisory floriculture. ICAR-Directorate of Floricultural Research, Shivajinagar, Pune, India

Arunkumar P, Mangaiyarkarasi R (2019) Microwave method for drying hibiscus and bougainvillea. Pharma Innov J 8(7):147–148

Behera TB (2009) Standardization of drying techniques of rose (Rosa hybrida L). (M.Sc.) Thesis, University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Bhattacharjee SK, De LC (2003) Advanced commercial floriculture. Avishkar Publishers, Jaipur

Biswas C, Dhua RS (2010) Microwave oven drying of cut carnation. J Ornam Hortic 13(1):45–49

Chakrabarty S, Roy S, Roy A (2011) An Entrepreneur's guide to dry flower: process and techniques in dry flower. Lambert Academic Publishing GmbH & Co. KG, Saarbrucken

Champoux J (1999) Tips and home remedies. http://www.kaepsmlin.com/tips. Accessed on 19 July 2020

Chen W, Gast KLB, Smithey S (2000) The effects of different freeze-drying processes on the moisture content, colour and physical strength of roses and carnations. Sci Hortic 84(3/4):321–332

Dana M, Lerner BR (2002) Preserving plant materials. http://www.agcom.purdue.edu/agcom/pubs/menu.htm. Accessed on 19 July 2020

Datta SK (1999) Dehydrated flowers and foliage and floral crafts. In: Bose TK, Maitti RG, Dhua RS, Das P (eds) Floriculture and landscaping. Naya Prokash, Kolkata, pp 696–703

Datta SK (2015) Dry flowers technology. Pointer Publishers, Jaipur

Deepthi S, Kumar S (2008) Dry flowers and natural splendor indoors. Floricul Today:42–48

Dilta BS, Sharma BP, Baweja HS, Kashyap B (2011) Flower drying techniques – a review. Int J Farm Sci 1(2):1–16

Dubois P (2005) Farnote 10/89: drying cut flowers and foliage. Website: www.agrc.wa.gov

Dubois P, Joyce D (1989) Drying cut flowers and foliage. Farm note No. 10/89, Western Australian Department of Agriculture, 3 pp

Fernandes L, Ramalhosa E, Casal S, José Pereira A (2018) The effect of different post-harvest treatments on the quality of borage (Borago Officinalis) petals. Acta Sci Pol Technol Aliment 17(1):5–10
Geetha CK, Rajeevan PK, Valsalakumari PK (2004) Technical bulletin on dry flowers. Kerala Agricultural University, Thrissur
Hemant U, Singh A, Ahlawat T (2016a) Standardization of dehydration technique for greenhouse cut rose var. Shakira. Indian J Hortic 73(1):99–103
Hemant U, Singh A, Ahlawat T, Palagani N (2016b) Influence of harvest stage and varieties on dry flower quality rose (Rosa & Times; hybrida). J Ornam Hortic 19(1–2):34–38
Ito H, Hayashi T, Hashimoto M, Miyagawa K, Nakamura S, Mizuta Y, Yazawa S (2010) A protocol for preparing preserved flowers with natural color and texture. HortTechnology 20(2):445–448
Joycee DC (1998) Dried and preserved ornamental plant material not new, but often overlooked and underrated. Acta Hortic 454:133–145
Kant K (2018) Drying techniques for preservation of ornamental parts of plant. Int J Sci Technol 7(5):1650–1654
Karmakar B, Chakrabarty S, Hayat A, Bagchi S (2020) Processing of Nephrolepis exaltata with glycerine to enhance shelf life by drying. Int J Curr Microbiol App Sci 9(3):348–356
Liang LY, Lai CY, Qing ZB (2005) Study on the application of freeze drying and microwave drying to cut flowers. Trans Chin Soc Agric Mach 36(1):71–74
Lourduswamy DK, Vadivel E, Azhakiamanavalan RS (2001) Research and development in dry flower technology. Floric Today 5(46):8–13
Malakar M, Acharya P, Biswas S (2016) Standardization of dehydration techniques of some Ornamental Foliages. Int J Agric Environ Biotechnol 9(4):555–562
Malakar M, Acharya P, Biswas S (2019) Effect of different Media for Dehydration of some ornamental flowers. Acta Hortic 1255:157–165. https://doi.org/10.17660/ActaHortic.2019.1255.25
Marak DW, Chakrabarty S (2013) Standardization of drying techniques for leaves of pipal (Ficus religiosa), Banyan (Ficus bengalensis) and silver oak (Grevillea robusta). Green Farming 6(6): 1388–1391
Marak DW, Chakrabarty S (2014) Value addition of Foliages for decoration. LAP Lambert Academic Publishing, Saarbrücken, Germany
Marak DW, Chakrabarty S, Singh B, Deepika (2016) Standardization of Glycerinisation for Leaves of Silver Oak (Grevillea robusta), Kanchan (Bauhinia purpurea) and Pipal (Ficus religiosa). Int J Agri Environ Biotechnol 9(5):815–820
Markham KR, Ryan KG, Gould KS, Rickards GK (2000) Cell wall sited flavonoids in lisianthus flower petals. Phytochemistry 54:681–687
Mayak S, Halevy AH (1980) Flower senescence. In: Thimann KV (ed) Senescence in plants. CRC Press, Boca Raton, p 132
Mir S, Jana MM (2015) Preparation of leaf venation skeletons of leaves for dry flower arrangement. Curr Hortic 3(1):53–56
Mir RS, Shinde BM, Chaskar MG, Jana MM (2009) Review of literature on dry flowers. Res Rev J Life Sci 9(2):52–55
Murugan PA, Thiyagarajan G, Ramesh K (2007) Dry flower technology. http://www.technopreneur.net/information-desk/sciencetech-magazine/2007/Dec07/Dry-flower.pdf. Accessed on 19 July 2020
Oulakh B, Radha Rani P (2018) Quality characteristics of dried flowers as influenced by packaging materials. Indian J Hortic 75(3):498–499. https://doi.org/10.5958/0974-0112.2018.00084.1
Padmapani P, Sharma PK, Indra M (2019) Hybrid solar dryer for drying of high-value flowers. Curr Sci 116(9):1463–1466
Pandey PH (2001) Principles and practices of post harvest technology. Kalyani Publishers, Ludhiana
Paul D, Shylla B (2002) The art of flower drying. In: Mishra RL, Mishra S (eds) Floriculture research trends in India. Indian Society of Ornamental Horticulture, New Delhi, pp 41–46

Pertuit A (2002a) Drying flowers. http://hgic.clemson.edu/factsheets/hgic1151.html. Accessed on 19 July 2020

Pertuit A (2002b) Preserve flowers using the microwave. http://hgic/clemson.edu. Accessed on 19 July 2019. https://hgic.clemson.edu/factsheet/drying-flowers/

Pinder R, Namita (2018) Influence of dehydration techniques on colour retention and related traits of gerbera (Gerbera Hybrida) flowers. Indian J Agric Sci 88(5)

Preethi TL, Thangaselvabai T, Sankaranarayanan R (2019) Standardization of drying, bleaching and dyeing techniques for non-traditional flowers. Acta Hortic 1241:627–632. https://doi.org/10.17660/ActaHortic.2019.1241.92

Raj D (2001) Making floral crafts from forest product of the Himalayas. Indian Hortic 46(3):26–27

Raj D (2006) Advances in ornamental horticulture. Pointer Publishers, Jaipur

Raj D (2014) Floriculture at a glance. Kalyani publishers, Jaipur

Ranjan JK, Misra S (2002) Dried flowers: a way to enjoy their beauty for long period. Indian Hortic 47(2):32–33

Romero-Sierra C, Webb JC (1982) Flower preservation. United States Patent 4,349,459. U.S. Patent and Trademark Office, Washington, DC

Safeena SA (2005) Standardization of drying technology for Dutch roses. M.Sc Thesis University of Agricultural Sciences, Dharwad, Karnataka, India

Safeena SA, Patil VS (2013) Effect of hot air oven and microwave oven drying on production of quality dry flowers of Dutch roses. J Agric Sci 5:179–189

Safeena SA, Patil VS, Naik BH (2006) Standardization of stage of harvest for better quality of dry flowers of rose. J Ornam Hortic 9(3):224–226

Sangama (2004) Dehydration and product diversification of Helichrysum flowers. J Ornam Hortic 7(3–4):376–380

Shailza, Shalini J, Grewal HS (2018) Emerging prospective of floriculture industry: drying of ornamental plants and their parts. Int J Curr Microbiol Appl Sci 7(7):1619–1633. https://doi.org/10.20546/ijcmas.2018.707.190

Shankari A, Anand M (2014) Process of making waste into wealth – dry flower technology. Asian J Hortic 9(2):466–483

Sharma G, Kashyap B, Gupta YC, Sharma BP (2019) Studies on keeping quality of dried and dyed chincherinchee flowers. Indian J Hortic 76(3):552. https://doi.org/10.5958/0974-0112.2019.00089.6

Sindhuja S, Padmalatha T, Padmavathamma PS, Prasad ALN (2016) Effect of chemicals as pre-drying treatments on production of quality dry flowers in carnation. Progress Hortic 48(2):231–235

Singh D, Kumar S (2008) Dry flowers and natural splendor indoors. Floric Today 13(1):42–48

Singh A, Dhaduk BK, Shah RR (2004) Effect of different temperature and embedding media on flower dehydration of zinnia (Zinnia linearis Benth.). Indian J Hortic 61(3):249–252

Sireesha M, Reddy MV (2016) Effect of freeze drying process for retaining physical characteristics of orchid flower. J Res ANGRAU 44(1):44–52

Sohn K, Hwa J, Kwon H, Young KE (2003) Effects of drying methods on shape and colour of Rosa hybrida. Korean J Hortic Sci Technol 21(2):136–140

Sujatha AN, Damodaran T, Shiva KN (2001) Dry flower industry in Andamans. Kissan World 28:28

Tampion J, Reynolds J (1971) Botany of flower arrangers. Petham Books Ltd., London

Thakur P, Joshi AK, Chandra A (2019) Epoxy resin encapsulation: a novel drying technique for native flowers. Indian Hortic 64(4):40

Trinklein D (2006) Drying flowers and foliage for arrangements. http://extension.missouri.edu/publications/DisplayPub.aspx?P=G6540. Accessed on 19 July 2025

Ullas SP, Namita N, Singh KP, Panwar S, Kundu A, Krishanan GS, Kumar G (2018) Influence of drying techniques on retention of anthocyanin and their antioxidant activities in chrysanthemum (Chrysanthemum × Morifolium) flowers. Indian J Agric Sci 88(2):228–233

Verma AK, Dhiman MR, Kumar D, Gupta A (2012) Preserving flowers and plant parts. In: Post harvest technology for commercial floriculture. New India Publishing Agency, New Delhi, pp 143–171

von Hagens G (1981) Animal and vegetal tissues permanently preserved by synthetic resin impregnation. United States Patent 4,278,701. U.S. Patent and Trade- mark Office, Washington, DC

Wang Y, Sun J, Ma D, Li X, Gao X, Miao J, Gao W (2019) Improving the contents of the active components and bioactivities of Chrysanthemum Morifolium Ramat.: the effects of drying methods. Food Biosci 29:9–16. https://doi.org/10.1016/j.fbio.2019.03.003

White P (2007) Drying and preserving plant materials. Website: www.edis.ifas.ulf.edu/pdffles/ep/ep00400.pdf

Wilson D, Attri B, Sharma SK (2015) Evaluation of different methods for drying of chrysanthemum flowers. Prog Hortic 47(1):167–169. https://doi.org/10.5958/2249-5258.2015.00030.5

Yadav P, Kashyap B, Dhiman SR, Gupta YC, Sharma P (2018) Effect of glycerine on drying of cut foliage of *Buxus sempervirens*. J Ornam Hortic 21(1–2):17–23. https://doi.org/10.5958/2249-880X.2018.00004.X

Yogita C (2000) Studies on the standardization of bleaching and dyeing technology of flowers. M. Sc. thesis., Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.