International Journal of Farm Sciences **1(2)** : 1-16, 2011

Flower drying techniques - A review

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ABSTRACT

In the present era of eco-consciousness, use of natural products like dry flowers and their parts has become the premier choice of the masses in their lifestyles for interior decoration. Future prospects of the dry flower industry are expected to contribute a lot to the country's economy in comparison to the fresh cut flowers and other live plants. 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. In this review the scattered information and data on drying of flowers and other ornamental plant parts are being compiled which would be useful for further studies. This can eventually be helpful in drawing the attention of the researchers and scientists to work on it, besides the entrepreneurs who would be directly benefitted by utilizing the knowledge review in this paper.

Keywords: Dry flowers, dehydration, drying techniques

INTRODUCTION

Flowers have always remained an integral part of man's life and love for natural flowers is an inherent instinct .

Fresh flowers though quite attractive, are very expensive and short lived as well as available only during a particular season. Dried flower products on the other hand are long lasting and retain their aesthetic value irrespective of the season (Malcolm 1994).The art of flower drying is a very age old practice. Earlier dried flowers were in practice in the form of herbarium made by botanists for the purpose of identification of various species (Prasad et al 1997). In 'The Florist' published in 1860, author describes the techniques of drying red rose, pansies, stock and other single flowers in sand. Though drying of flowers was well known even in the past but for the first time the flowers were dried commercially in Germany (Jean and Lesley 1982). Dried and preserved ornamental products offer a wide range of qualities like novelty, longevity, aesthetic properties, flexibility and year round availability (Joyce 1998). Dried ornamental plant parts are generally less expensive and are sought for their

everlasting and attractive appearance (Smith 2000). Only few research and development projects have been undertaken on the dried flower industry across the globe in contrast to other areas of floriculture (Joyce 1998). Numerous workers have described varied approaches/methods to dehydrate or dry flowers and other ornamental plant parts (Bhutani 1995, Dubois and Joyce1989, Westland1995). Drying of flowers and foliage by various methods like air drying, sun drying, oven and microwave oven drying, freeze drying and embedded drying can be used for making decorative floral crafts items like cards, floral segments, wall hangings, landscapes, calendars, potpourris etc for various purposes (Bhutani 1990, Bhalla and Sharma 2002) with potpourris being the major segment of drying flower industry valuing at Rs 55 crore in India alone (Murugan et al 2007). Dried flowers are a good standby for the florist's, since designs can be made up during the slack periods and arrangements can be displayed where fresh flowers are unsuitable from the growers point of view and the price is less than for equivalent fresh flowers (Salinger 1987).The demand for dry flowers and attractive plant parts, dried floral arrangements and floral crafts has increased manifold during the last decade. In the recent floriculture trade, the exports from India during 2002-2007 grew from Rs 266 crore during 2002-2003 to Rs 302 crore during 2003-2004 and Rs 273 crore during 2004-2005 to achieve a growth rate of 2.66 per cent (Singh 2009).The Indian export basket comprises of 71 per cent of dry flowers which are exported to USA, Europe, Japan, Australia, far East and Russia. Dry flowers constitute more than two-thirds of the total floriculture exports. The demand for dry flowers is increasing at an impressive rate of 8-10 per cent annually thus offering a lot of opportunities for the Indian entrepreneurs to enter in the global floricultural trade (Singh 2009).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 (Desh Raj 2001). A number of flowers respond well to drying techniques such as anemone, zinnia, allium, sweetwilliam, carnation, stock, freesia, narcissus, chrysanthemum, pansy, daffodils, marigold, rose, lilies etc (Rogers 1988) and foliage like ferns, aspidistra, eucalyptus, ivy, laurel, magnolia and mahonia etc (Rogers 1967, Healy1986). Kashyap et al (2007) have enlisted many wild as well as cultivated flowers and foliage which can be used for dry flower making. Dehydrated plant parts may be arranged aesthetically and covered with plastic or transparent glass to protect them from atmospheric humidity, wind and dust. (Datta 1997, Bhattacharjee and De 2003). Saleable articles like paper weights, pendants and table pieces can be made by embedding the dry flowers in transparent blocks or sheets (Kher and Bhutani 1979).

Therefore, dry flowers score over the cut flowers that often decorate homes and offices because of their ability to remain decorative for longer periods almost definitely with less care (Zizzo and Foscella 1999).

Type of crop and variety

Selection of a suitable crop for drying purpose is very important for the success of the industry (Mishra et al 2003). Some of the flowers lose their ornamental value after drying. Sweet pea flowers when pressed dry lose their colour and become dark brown which is not suitable for further use (Jean and Lesley 1982). The quality of dry flowers also varies with cultivar of a particular crop. In helichrysum, although its petals are hard but lose its shape after drying, petals reflex downward and centre disc florets shed. This characterstic is encountered with yellow cultivars than the rest (Sangama 2004).

Stage of harvesting

The stage of harvesting for different flowers varies according to the species and the form of flower desired (Paul and Shylla 2002). However, usually flowers are harvested just before they are fully open and the colour has not faded (Padmavathamma 1999). Flowers harvested at fully open stage took lesser time for drying than those harvested at tight bud and half open stage of helichrysum (Sangama 2004). Safeena et al (2006a) reported that flowers harvested at half bloom stage took minimum time for drying. Faster dehydration may be due to the reason that flowers lose moisture as harvesting time is delayed due to sensitivity of the flower tissues to ethylene, or other hydrolyzing enzymes and senescence also (Kofranek and Halevy 1972). Lourduswamy et al (2003) reported that full bloom of gomphrena and both, half as well as full bloom of French marigold and zinnia are the ideal harvest stages for dry flower production.

Moisture content after drying

Moisture content in the flowers after drying influences flower shape. The lower moisture content provides rigidity and results in uniform cell contraction in the flowers while the higher moisture content in dried flowers lead to flaccid flowers. Chen et al (2000) reported stronger and stiffer petal in dried flowers having low moisture content. Mechanical support provided by the media throughout the drying process ensures well maintained flower shape provided the moisture content remains below11.55 per cent. In addition, the moisture content in the dried flowers also influences longevity and is inversely proportional to longevity (Pandey 2001). A range of 8-11.5 per cent moisture content in the dried flowers will ensure good quality and firmness and maintains keeping quality for more than six months. Excessive drying

of flowers resulted into petal shedding during handling (Singh 2004). Drying below 8 per cent moisture content showed shedding effect which might be attributed to excessive loss in moisture, that might have resulted into weakened adhesion and cohesion forces in flower tissue and might have caused softening of the middle lamella leading to abscission. Paparozzi and McCallister (1988) observed rapid tissue desiccation in microwave dried statice flowers. Similarly Wilkins and Desborough (1986) observed vulnerability of flowers to breakage in vacuum dried flowers.

Techniques of flower drying

The quality and appearance of dried flowers and other ornamental plant parts is greatly influenced by the method of drying or the drying technique being followed. Various techniques involved for the production of dried ornamental plant material includes air drying, press drying, embedded drying, oven drying and freeze drying etc. The NBRI, Lucknow is a pioneer institute in India which works on the dehydration of flowers, foliage and floral crafts. Various dehydration techniques have been developed by which flowers, twigs, branches, foliage etc retain their fresh look for several months or years (Mishra et al 2003).

Air drying

The air drying is a very common method of drying where plant materials are attached to rope/wire and are kept in hanging position either in dark or in the sun for quick drying. Air drying requires a warm clean dark and well ventilated area with low humidity (Raghupathy et al 2000). Flowers may also be spread over blotting sheets/ news papers and kept in dark or in the sun (Datta 1997). Bryan (1992) reported air drying as the earliest method to dry rose, larkspur, statice and straw flower. For air drying flowers of good quality, a slightly immature stage should be selected and thereafter stripped off the foliage and hung upside down in a warm dark area. The weak flowers, if any, are to be wired before drying (Perry 1996). Evelyn (1997) carried out air drying in dusty rooms by placing the flowers inside a perforated paper bag to promote air circulation. Crisp textured flowers of helichrysum and statice can be easily dried either by hanging them in an inverted position or by keeping them in a container positioned erect till they get desiccated (Bhutani 1995, Susan 1990). Kumar and Parmar (1998) found that air drying in shade is applicable during dry season and summer particularly for flowers such as acroclinum, helichrysum and limonium. Other crisp textured flowers like anaphilis, delphinium, oregano, rumex and holmskioldia etc can also be dried by air drying (Deshraj 2006) Flowers hung in a dark area took 8-10 days for drying when there is sufficient ventilation (Champoux 1999). Only gypsophilla, gomphrena and statice flowers dried well by hang dry method in a dark room out of the 30 cultivars of 16 plant species tested in drying

(MacPhail 1997). Rose bunches could be hung dried in shade within 5-10 days (Seaberg 1997). Smith (1993) reported that flowers like strawflower, globe amaranth, salvia, chrysanthemum and many other of the everlastings can be picked up for air drying in the bud stage or partially opened, as they continue to open while drying and some other are picked when they are fully mature. Sell (1993) suggested various rooms/areas for drying the flowers and reported that rooms with 75 per cent or more relative humidity should be avoided as they encourage the mould growth which spoils the flowers. Flower heads of hydrangea and gypsophilla can be dried by putting their stems in a little water (Westland 1995). Water drying, which usually seems like a contradiction in terms, gives fairly good results with flowers, eg hydrangeas, cornflower, gypsophilla and a few others (Desh Raj 2006). Pertuit (2002) observed that flowers dried by air drying are extremely stiff once dried. Blue and yellow flowers retain their colour when air dried but pink flowers fade. According to White et al (2002) more fleshy flowers and foliage took more time for drying.

Press drying

Press drying is thought to have been first reported in 1820. Later it was used by the herbalists or botanists for the preparation of herbarium (Lawrence 1969). In press drying, the flowers and foliage are placed between the folds of newspaper sheets or blotting papers giving some space among flowers. These sheets are kept one above the other and corrugated boards of the same size are placed in between the folded sheets so as to allow the water vapour to escape (Bhutani 1990). The drying time can be reduced if the sheets are kept in oven at an appropriate temperature (Datta 1997). However, Prasad et al (1997) added that shapes of the material 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 used. Further, the microbial attack is a common feature because the moisture and cellulose of the paper serve as the potential substrate for the sporulation and growth of these organisms. Though the flowers and foliages become flat after press drying, yet this material can be used for composing floral-craft items like greeting cards, floral designs and other art creations which may be framed for wall pin-ups (Bhutani 1990). Gill et al (2002) reported the time required for press drying of different flower crops and they concluded that rose, carnation and helichrysum required 120, 132 and 72 hours, respectively, for press drying. Kher and Bhutani (1979) found that press drying in oven at 35-39ºC for 48 hours was optimum for pansy, whereas, 24 hours for the leaves of silver oak, thuja, adiantum, nephrolepis and flowers of hibiscus, haemotoxylon, calliandra, marigold and *Cassia biflora.* A temperature of 40-44ºC for 24 hours was optimum for *Euphorbia*

leucocephala, Galphimia nitida, Lantana camara, Lantana depressa and Lantana montevidensis while it was 45-49ºC for flowers of *Ixora* sp and *Mussaenda* sp. Lourdusamy et al (2001) described press drying as the earliest method of preserving flowers and suggested that flowers like candytuft, chrysanthemum, lantana, rose, verbena, euphorbia and leaves like thuja, ferns, silver-oaks, etc are suitable for press drying. Datta (1997) reported that original shape of the material cannot be maintained by this method but the original colour is maintained. Lissy (1999) suggested the application of water based varnish over the entire pressed picture to avoid fading of original colour.

Embedded drying

Sand , borax, silica gel, sawdust, perlite and combination of these are used as media for embedding. Among these , sand and borax are cheaper but they take more time for drying. For delicate flowers like roses, dahlia, carnation etc, silica gel is the ideal drying agent (Prasad et al 1997). Desiccant method is the useful method for delicate flowers that may fall apart when air dried as recommended by Thomler (1997). Among the desiccants like sand, cornmeal, borax and silica gel used, silica gel has been found to be the best. Champoux (1999) reported silica gel as the best medium for getting excellent dried flowers that retain colour and shape. Desh Raj (2006) found that it is difficult to avoid shrinkage and changes in morphology of the dehydrated ornamental plant material during hang-drying mainly due to loss of moisture from the cells . The flowers and foliage are to be embedded very carefully in various desiccants such as sand or silica gel in a suitable container during air drying to avoid shrinkage and other morphological changes (Datta 1997). Embedding in deep containers can accommodate the plant material without disturbing its shape and form in plant materials like bougainvillea, candytuft, chrysanthemum, dahlia (pompon), gerbera, marigold and roses etc (Bhutani1990, Bhutani 1995). Singh et al (2004) found that drying of zinnia flowers in sand resulted in good quality of dried flowers with attractive flower colour and smooth petal texture. Orduno and Baltazar (1995) mentioned that silica gel was not actually a gel but granular in shape like sugar. It is called gel only because it is a xerogel of silicic acid. Bhutani (1993) reported that embedding in silica gel was perhaps the easiest and the best method of embedded drying of flowers. Silica gel is composed of a vast network of interconnecting microscopic pores, which attract and hold moisture by a phenomenon known as physical adsorption and capillary condensation. Through by this phenomenon, it acted as a dehydrating agent (Safeena et al 2006b). Silica gel has been reported to be the fastest acting desiccant (Neave 1996). Trinklein (2000) reported that since silica gel dried flowers quickly, so more flowers could be moved in and out of the

mixture during a single season. Paul and Shylla (2002) while reviewing the efficacy of different desiccants for flower drying concluded that though silica gel was an expensive desiccant but could be recycled for reuse. The crystals were blue when dry and turned pink after absorbing moisture. If silica gel was to be reused again, it should be warmed up in an oven till the crystals turned blue. Desh Raj and Gupta (2003) reported that silica gel (60-120 mesh) was the best absorbent for removing moisture from flowers and foliage followed by boric acid (granules). Pertuit (2002) reported that silica gel is appropriate for drying flowers with closely packed petals such as rose. Sandhu (2002) described and recommended silica gel embedding as the more appropriate method for proper colour retention of helichrysum and statice. Gill et al (2002) found that embedding of rose, carnation, fern and silver-oak in silica gel produced good results, while, embedding helichrysum in silica gel and sand combination was also satisfactory. Drying was found much faster with silica gel and borax in comparison to sand due to the strong hygroscopic nature of silica gel and borax which lead to rapid removal of moisture from flowers (Singh et al 2003). Sell (1993) reported that a mixture of borax and corn meal (1:1 v/v) for embedding and drying of chrysanthemum and dahlia flowers produced good results. Effect of different media on dehydration of zinnia was studied by Singh et al (2004) who reported that drying in silica gel was faster without any deterioration in quality; however, there was slight roughness in petal texture which was aesthetically accepted. Bhalla et al (2006) studied the different methods of drying of chrysanthemum (*Dendranthema grandiflorum* Tzvelev) and reported that flowers dried in microwave oven after embedding in silica gel gave the best results in terms of retention of colour and shape. Dhatt et al (2007) studied the methods of drying of rose buds and found that silica gel embedding of rose buds had the best quality with respect to colour and shape. Bhattacharjee and De (2003) suggested that borax and alum being light in weight could be used for dehydration of flowers. Borax being hygroscopic in nature might bleach flower petals if embedded for a long time (Datta 1997). Smith (1993) reported that flowers like rose, aster, carnation, marigold, dahlia, larkspur, geranium, zinnia, chrysanthemum and delphinium could be dried well in borax. Orduno and Baltazar (1995) studied the effects of river or sea sand in combination with borax on drying of rose, carnation and gerbera and reported that rose and carnation dried well in river sand containing a high proportion of borax within 15-20 days period, while sea sand with a low proportion of borax for 10-15 days resulted in better dried gerberas. Mixing of silica gel crystals or dry river sand to 2 or 3 parts alum or borax to overcome the problems of sticking of the media, when either of them was used alone (Westland 1995). Singh et al (2003) found that drying of zinnia flowers was much faster with silica

gel and borax. Paul and Shylla (2002) reviewed that both borax and alum were best suited for delicate flowers such as anemones, cosmos, larkspur and ornithogalum, etc. Singh et al (2004) reported that media influenced both flower colour as well as texture. Drying with sand provided smooth petal texture while with silica gel, a slight roughness and with borax more roughness were recorded. Alleman (1994) reported that silica gel crystals could be used for drying roses. The self indicating nature of silica gel ensured the moisture content by exhibiting blue colour when dry and pink/white, when it regains moisture from flowers. Sujatha et al (2001) reported that borax crystals and sand in the ratio of 1:1 volume by volume basis was the best combination as it helped to regain brightness and colour. Among the various dessicants used to dry Indian blue water lily flowers, fine sand was the best (Geetha et al 2002). Fine sand has been found to be the best material for embedding because it is easy to handle, heavy and doesn't react with water vapour (Datta 2001). Behera (2009) conducted an experiment to find out suitable drying technique, media, temperature and duration for rose cv First Red. Cut flowers at half bloom stage with 10 cm long stem were embedded in five drying media namely sand, silica gel, borax, mixture of sand and silica gel (50:50 v/v) and mixture of sand and borax (50:50 v/v). After embedding, flowers were given different temperature and exposure duration treatments in hot air oven and microwave oven. The anthocyanin content was maximum when flowers were embedded in borax and were dried for 3.30 minutes in microwave oven. The maximum presentibility till 120 days was observed in flowers embedded in the mixture of sand and borax and kept in microwave oven for 3.30 minutes compared to other treatments.

Oven drying

Now a days hot air and microwave ovens are also being used for faster drying and to improve the quality of dry flowers. In these methods, plant material is kept at controlled temperature for a specified time typical of the plant species.Temperature plays an important role in the drying of flowers and other ornamental plant parts by influencing both qualitative and quantitative parameters. At higher temperature, as proposed by Mayak and Halevy (1980), the rate of transpiration was comparatively much higher. With the increase in temperature, diffusion pressure deficit of air increases which stimulates diffusion of internal moisture surface and further increases its vaporization rate, thus leading to high moisture loss at higher temperature. Singh et al (2004) studied the effects of different temperature treatments on drying of zinnia (*Zinnia elegans*) and reported that higher the temperature, more faster would be the dehydration process owing to the fact that drying of flowers at higher temperature would accelerate degradation of all pigments viz chlorophylls, carotenes, xanthophylls and anthocyanins. Similar reports of rapid drying at higher

temperature have been documented by Chen et al (2000). Khafaga and Kock (1980) in *Hibiscus sabdariffa* var *sabdariffa* recorded higher degradation of anthocyanins at higher temperature. Prasad et al (1997) observed that fully opened flowers were not suitable for oven drying. Oven drying of china aster flowers using white sand as the medium was the best for retention of original colour, shape and texture of dried flowers (Raju and Jayanthi 2002). At 45-49^{0}C, French marigold took 72 hours and African marigold 96 hours for drying (Ranjan and Misra 2002). Kher and Bhutani (1979) advocated 35-39°C temperature as optimum for bougainvillea (48 hours) and pompon dahlias and narcissi (72 hours). Temperature of 40-44°C for *Aerva javanica*, *Callistephus chinensi*s, *Euphorbia leucocephala*, *Delphinium ajacis, Mina lobata*, rose buds and *Zinnia linearis* (48 hours), *Tagetes patula* and medium and large rose flowers (72 hours), gladiolus and very large rose flower (96 hours) and 45-49°C for *Helipterum roseum*, small flowered perennial chrysanthemum, candytuft, dombeya, gerbera, gomphrena, helichrysum and statice (48 hours), *Tagetes erecta* (96 hours) and for water lily (120 hours). Pandya et al (2001) studied the effects of drying on chrysanthemum flowers in a hot air oven at 40°C for 35-50 hours in sand as an embedding medium. They reported that the colour and structure of the floral parts showed no change, whereas, total chlorophyll content was significantly reduced in the dehydrated parts as compared to control without any change in length and diameter of floral parts. Safeena et al (2006b) studied the response of drying in hot air oven at different temperatures (30ºC, 40ºC and 50ºC) on the quality of rose (Skyline, Lambada, Ravel and First Red) and found that drying of dutch rose flowers at 40ºC by embedding in silica gel gave the best results for colour, texture and appearance. Dahiya (2003) reported that the best quality dried flowers of chrysanthemum could be obtained by embedding them in silica gel and keeping them at 50ºC for 48 hours in the hot air oven. Bassapa et al (1991) found that helichrysum flowers dried in a room and in open sun retained their colour intensity for longer duration as compared to 40°C and 50°C oven dried flowers. Venugopal and Patil (2000) observed that helichrysum flowers when dried at room temperature under shade and subsequently oven dried at 50°C retained the colour intensity for 150-180 days. Dahiya (2003) found that the weight and moisture content of dried flowers decreased significantly with an increase in the temperature of the hot air oven and duration of drying. He also reported that the carotenoids content of chrysanthemum decreased with the increase in the temperature and duration in the hot air oven. Singh et al (2002) reported minimum degradation of zinnia flower pigments (chlorophyll, carotenes, xanthophylls and anthocyanins) in room dried flowers, whereas, it was maximum

at 50°C in hot air oven. Bhutani (1990) advocated the use of microwave oven for drying of plant material. The principle of drying is based on liberation of moisture by agitating water molecules present in organic substances with the help of electronically produced microwaves. Drying is unbelievably fast in microwave oven, when flowers and foliage are embedded in fine silica gel contained in non-metallic earthenware or glassware (Bhutani 1995). Datta (1997) observed microwave oven drying was the most suitable method to dehydrate the white flowers of 'Jubilee' cultivar of chrysanthemum. Paparozzi and McCallister (1988) concluded that fresh cut statice stems up to 34 cm long preserved well by soaking in a 1:2 or 1:3 glycerol: water for 48 hours, followed by drying for 1 minutes at 34^{0}C. Zhang (2000) while comparing the mechanism of microwave, airflow and microwave-air flow mechanism on drying of chrysanthemum, found that microwave airflow combined drying was effective in reducing the drying time and improving the quality of the dried flowers, thereby, enhancing the selling price by 5-10 times higher as compared to traditional drying. Aravinda and Jayanthi (2004) standardized the drying techniques like microwave drying, oven drying and sun drying for chrysanthemum (Button type local) flowers. Microwave drying with silica gel gave the best results for shape while oven drying with white sand was found best for colour and overall acceptability. Thomler (1997) reported that microwave oven drying was more suited for cluster of florets such as golden rod, gypsophilla and corn flower. Anemones, chrysanthemum, marigold, roses, pansies, paeonis are best suited to this method (Bull 1999). According to Miller (1997), large roses required two and a half minutes to dry. Dhatt et al (2007) dried rose buds in microwave oven for 3 minutes, 4 minutes and 5 minutes, and found that microwave drying of rose buds for 4 minutes exhibited good colour and good shape retention. Rothenberger (2000) advocated a cup of water in the oven before starting helps to prevent excessive drying. Microwave oven dried flower petals should be sprayed with hair spray or lacquer to prevent absorption of air moisture. White et al (2002) reported that microvwave oven dried flowers looked fresh and more colourful than obtained by other methods.

Glycerine drying

Glycerine drying has been used by several workers especially to preserve foliage. It was comparatively less expensive and has a high water attracting capacity (Joyce 1998). Many types of foliage have been successfully preserved by either immersing leaves or placing crushed stems in a 33 per cent glycerol solution. The resultant leaves are soft and flexible (Dana 1983).Westland (1995) reported that preserving foliage and berries in glycerine and hot water solution brought them into almost everlasting category. In glycerine

drying, the quality of the product was good as moisture in flower was replaced by a mixture of water and glycerine (Paul and Shylla 2002). The use of glycerine in drying is reported to be successful with most foliages. Semant et al (1993) observed that one part of glycerine mixed with 2 parts of hot water was the ideal mixture for twigs of 26 plant species to absorb at room temperature. The material should remain in soloution until full absorption has taken place. Glycerine serves as a good source for micro-organisms, so a pinch of antibiotic is necessary to prevent microbial growth in the dried specimens (Prasad et al 1997). Sell (1993) used glycerine : hot water (1:2 v/v) to preserve magnolia stems. He reported that mature leaves responded well to this treatment as they translocated the solution readily to stems. Verey (1994) found that glycerinizing replaced the water content of leaves giving them a strong and pliable nature. This method is found more suitable for eucalyptus, hydrangea, ivy and magnolia. Paparozzi and McCallister (1988) reported that glycerol and microwave preservation of annual statice maintained flexibility of the flower without the greasy feeling which was generally observed in glycerol preservation. Healey (1986) preserved the foliage of different ornamental plants for different intervals and reported that *Aspidistra* spp took 12 weeks followed by *Fatsia japonica* (7-10 weeks), *Mahonia* spp (3-6 weeks), *Magnolia* spp (3-4 weeks) and minimum 2-weeks by *Eucalyptus* spp.

Freeze drying

The most effective method of flower preservation is freeze drying. Freeze drying relies on the principle of sublimation, whereby ice held under conditions of partial vacuum (less than 4.58 torr) and low temperature (less than 0°C) will evaporate on heating without going through a liquid phase. The absence of liquid water during the dehydration process means that undesirable chemical reactions will not occur. Hence, colour and even fragrance are retained in the dried article (Dubois and Joyce 1989). In this process, the flowers are placed into a refrigerated chamber and the temperature of the chamber is lowered below freezing. A vacuum is then created in the chamber, causing the moisture in the flowers to sublimate, or change from solid to gaseous form. The water vapor is then collected in a separate chamber and the dried flowers are allowed to slowly warm to room temperature. This process takes several days (Trinklein 2006). Brown (1999) has conducted freeze drying with different varieties of roses and carnation and determined the freezing time and temperature at which drying was perfect to keep the quality of flowers. Bridal bouquets could be preserved without any damage by the technique of flower drying (Ruth 2000). Chen et al (2000) evaluated the effect of different freezing time (2 and 4 hours), freezing temperature (-35ºC) and vacuum drying temperature (27ºC, 37ºC, 47ºC) on colour, moisture content, stem and petal

strength of roses and carnations. Lower vacuum drying temperatures resulted in flowers with colour closer to fresh flowers. Bhattacharjee and De (2003) reported that several cultivars of carnation flowers were successfully cryo dried and remained naturalistic in appearance after being placed in freeze drier (-20ºC) for 7 days. Liang et al (2005) studied the application of freeze drying and microwave drying to China rose flowers. The flowers dried by freeze drying and pre-treated with tartaric acid solution before microwave drying had a good colour and appearance. Wilkins and Desborough (1986) compared the effect of different pre-treatments (glycerine, clove oil, ethylene glycol, glycerine + dimethylsulfoxide, clove oil + dimethylsulfoxside, ethylene glycol + dimethylsulfoxside) on carnation flowers at a cryo drying temperature of -80ºC for 12 hours duration. After that the flowers were kept in freeze drier for 7 days. It was found that untreated flowers remained naturalistic in appearance while the pre-treated ones had lower aesthetic value. Sohn et al (2003) studied the effect of freeze drying for 14 days on the shape and colour of *Rosa hybrida* (cvs Tineke, Golden Gate, Saphir, Roulette, Rote Rose). Shrinkage was observed in freeze drying but the colour remained similar to a fresh rose. The colour of Tineke and Golden Gate remained closest to fresh rose whereas dried Rote Rose was the farthest. In another experiment, flowers were dried in a lyophilizer (freeze drier) in a temperature sequence where the temperature of the flower chamber of freeze drier was increased from -5°F to 25°F with an interval of 5°F each. Maximum moisture loss and maximum total sugars content was obtained in the flowers which were dried in freeze drier (Behera 2009).

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Received : 9.2.2011 *Accepted: 18.4.2011*