DEVELOPING TECHNOLOGY FOR PRODUCTION OF DRY FLOWERS

By
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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Developing technology for production of dry flowers"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Developing technology for production of dry flowers"** is a record of work done independently by **Sri. Priyesh, S.**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Dedicated

to

my Parents and Brother

Introduction

1. INTRODUCTION

Floriculture, consisting of cultivation and trade of cut flowers, cut foliage, potted plants, garden bedding plants, planting material, services etc., has become an important sector, experiencing rapid change the world over. It is fast emerging as a major venture on the world scene.

In India, floriculture has been associated with culture and heritage since very ancient time. India has long tradition of growing flowers. However, we have not made significant advancement in commercial floriculture in spite of our favourable and varied agroclimatic conditions. Floriculture has been identified as one of the possible areas for diversification in agri-business. Among the various segments of floriculture, dry flowers and plants have become very popular due to non-perishability of the produce leading to their longer life indoors.

Dried 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. Dry flower industry is about four decades old and was brought to India by the British. It prospered in Calcutta, because of its proximity to the north eastern region where diverse flowers and plants are naturally available. Dry flower units are now concentrated in places like Tuticorin in Tamil Nadu, Calcutta in West Bengal and Hyderabad in Andhra Pradesh.

Dry flowers and plants constitute the bulk of the export from our country accounting for 60.6 per cent of our floricultural products. India's share in the world market is less than 5.0 per cent (Singhwi, 2001). Indian dry flower export has now crossed 10,000 tonnes mark. Dried flowers are exported to USA, Israel, Hong Kong, Japan, Singapore and West European countries. The UK is the largest importer of dried flowers from India followed by Germany, Italy, the Netherlands and Spain (Raghava, 2001). In the event of competitions from other exporting countries like Columbia, Mexico and Australia, India has to sustain its volume of global trade.

Dry flower production is labour intensive, provides employment opportunities for a large number of workers and aids in the development of subsidiary industries. Eventhough the value of dry flowers has increased much in recent years, there is little reported research in this area, especially in Kerala. There is large potential to develop the dry flower industry in Kerala, a humid tropical region, in view of the plant diversity available. The situation demands development of technology for production of dry flowers and plants for commercial exploitation.

The study was thus conducted to cater the urgent need with the following objectives.

1. To assess the suitability of selected commercial flowers for dry flower production.
2. To develop technologies to dry, bleach and dye flowers for commercial exploitation.
3. To evolve techniques for storage of dehydrated flowers.
4. To work out the cost economics of dry floral crafts.

Review of Literature

2. REVIEW OF LITERATURE

Fresh flowers are beautiful and delicate but it becomes a stupenodous job to maintain their charm for a long time. In this context, dry flowers provide a better alternative or at least a supplement. Anything from flowers to petals, to buds, stem, roots, fruits and leaves in a dried form come under the domain of dry flowers. Dry flower market has grown exponentially as consumers became eco-conscious and chose dried flowers as the environment friendly alternative to fresh flowers. Different methods of drying are there, of which modern methods are faster and retain the shape, colour and artistic value. Dried flowers can be used in natural, dyed, bleached or preserved forms. The information available on dry flower technology is reviewed here.

2.1 SELECTION OF MATERIALS

Almost any plant part, flowers, leaves or stems can be dried naturally or artificially. Generally plant or plant part should contain low moisture and fibrous tissue. It should have attractive shape and pattern. Stage of the plant at the time of harvest is also very important. Fleshy and fully opened flowers are difficult to dry because the shapes are often lost during the drying process (Prasad *et al.*, 1997).

2.2 TIME AND SEASON OF HARVEST

Plant materials should be collected at the most suitable time of the year for drying and preserving. In general, all plant materials should be collected when they are in peak condition. According to Kanta and Bajpai (1978) flower should be picked at the full bloom stage for drying purpose so as to get better results.

Prasad *et al.* (1997) found that harvesting during dry or summer months gave excellent results as most of the water gets evaporated easily. Brightest colours were produced during monsoon or winter season but the plants were very much susceptable to pests and diseases.

Roberts (1997) reported that air drying of straw flowers, cockscomb, statice and baby's breath was the best when harvested in morning hours after dew has disappeared.

Rose blooms must be selected for drying a few days before their prime. Flowers should be picked on dry days, midmorning being the best time (Seaberg, 1997).

Mirunalini (1999) found that half bloom and full bloom stages of celosia, rose and chrysanthemum are best suited for drying purpose. The best time of harvest for statice as a dry flower was when 90 per cent flowers of the inflorescence were open (Sangama, 2001).

The plants and flowers free of insect damage should be harvested as damage become more obvious after drying (Rothenberger, 2000).

According to Bull (1999) the best time of the day to cut is midmorning, after the dew has dried but well before any flowers wilt.

2.3 DRYING

Since flowers and foliage contain more water, dehydration is necessary for getting dry flowers. There are several methods of drying and dehydration of flowers, which can be used without much investment.

2.3.1 Air drying (drying under shade)

This is the simplest method of drying. This method is ideal for grasses and many flowers having more of cellulose material. Main disadvantages of this method are weather dependence and shrinkage of petals.

According to Underwood (1951) zinnias are best dried in sand or borax method and *Gomphrena globosa* by hanging them upside down. Crisp textured flowers like *Helichrysum* (straw flower) and *Limonium* (statice) could be easily dried either by hanging or positioning them erect in containers for 1-2 weeks (Bhutani, 1990 and Susan, 1990). Air drying was found to be the earliest method to dry rose, larkspur, statice, straw flower (Bryan, 1992). Perry (1996) studied harvesting techniques and drying methods employed for dry flowers. He stated that flowers of good quality at slightly immature stage should be selected and stripped off the foliage from stem and weak flowers wired before drying. The bunches should be hung upside down in a warm dark area. It would take two to three weeks to dry completely.

Majority of the upright growing flowers dry their best upside down. Small bunches of a few stems are made, that provide good air circulation and stagged in a way that they do not touch each other (Thomler, 1997). According to Barton (1997) celosia, *Helichrysum* and Marigold could be dried by hanging them at fully opened stages. Evelyn (1997) carried out air drying in dusty rooms by placing the flowers inside a perforated paper bag to promote air circulation.

Stewart (1997) in his trials to dry roses, found that they shrivelled to some extent and red colour would darken to give the colour of dried blood by simple air drying. Champoux (1999) recorded that flowers hung on a dark area took 8-10 days when there was sufficient ventilation. Mac-Phail (1997) studied 30 cultivars of 16 plant species and observed that Gypsophila, *Gomphrena* and statice dried well by hang dry method in a dark dry room.

Rose bunches could be hung dried in shade within 5-10 days (Seaberg 1997). According to Prasad *et al.* (1997) materials must be dried in shade with plenty of air flow such as near a window sill or left hung on a wash rope / clothing line.

Kumar and Parmar (1998) found that air drying in shade is applicable during dry season and summer for flowers such as *Aeroclenum*, *Helichrysum* and *Limonium*.

Lourdusamy (1998) reported that gomphrena flowers from half to full maturity took 7-9 days for air drying and roses took 5-10 days.

Padmavathamma (1999) suggested that shade drying was the best method to dry statice flowers by keeping the flowers face up in the container.

Datta (1997) opined that flowers can be dried under natural conditions either by hanging them with rope/ wire or by spreading them over blotting sheets or newspapers and this process is weather dependant. Air drying requires a warm clean dark and well ventilated area with low humidity (Raghupathy *et al.*, 2000).

Rothenberger (2000) reported that in addition to garden flowers and everlastings, many seed heads of grasses and other plants can be air dried by hanging. Large flowers can be hung individually rather than in bunches.

Alpertuit (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.

Though air drying is very cheap, shrinkage of petals is considered to be a major disadvantage.

2.3.2 Sun drying

Bhutani (1990) gave a detailed account on sun drying of embedded flowers. According to Basappa *et al.* (1991) sun drying was the most suitable drying technique for straw flowers.

Silhol and Denis (1994) reported that for drying flowers and herbs, solar drier can be used.

Sun drying is a rapid method of dehydration and it is cheap and dependant on weather (Arumugan *et al.*, 1999 and Raghupathy *et al.*, 2000).

Lourdusamy *et al.* (2001) reported that 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 took 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 and it takes 4-5 days for drying (Sujatha *et al.*, 2001).

Flowers are bunched together and hung upside down to a thread in sun (Sangama, 2001). According to Ranjan and Misra (2002) a layer of desiccant (dried silver sand, borax or silica gel) at the bottom of the container is placed and flower stems and wires are pushed into it and placed in sun for drying.

2.3.3 Hot air oven drying

Electrically operated hot air oven at a controlled temperature of 40-50°C is used for drying flowers in an embedded condition. The most important advantage is that drying is faster. Standardisation of drying time and temperature were done at NBRI. According to Kher and Bhutani (1979) a temperature of 45-49°C for 48 hours was found to be ideal to dry Gerbera, Chrysanthemum, *Gomphrena, Helichrysum* and Statice. China aster, *Delphinium*, rose buds and zinnia took 48 hours, medium and large roses took 72 hrs and very large flowers took 96 hours at 40-44°C (Bhutani, 1990).

Prasad *et al.* (1997) observed that fully opened flowers are not suitable for oven drying since the petals might have already lost their elasticity and will peel off easily on drying.

Baking pan containing preheated sand at 170°C can be used for embedding the flower petals and drying is faster (Barton, 1997).

Sangama (2001) opined that drying temperature and duration varies with plant size, structure and moisture content.

According to Raju and Jayanthi (2002) oven drying of China aster flowers using white sand as the medium is the best for retention of colour, shape and texture of dried flowers. At 45-49°C, French marigold took 72 hrs and African marigold 96 hrs for drying (Ranjan and Misra, 2002).

2.3.4 Microwave oven drying

Here, drying is based on the principle of liberating moisture by agitating water molecules in the organic substances with the help of microwaves. Drying is exceptionally fast and gets completed within a few minutes and generates little heat.

Paprozzi and McCallister (1988) conducted trials on glycerol and microwave preservation of annual statice and concluded that fresh cut statice stems upto 34 cm long preserved well by soaking in a 1:2 or 1:3 glycerol:water for 48 hrs, followed by drying for 1 minute at 34°C. Based on the studies conducted at NBRI, Bhutani (1990 & 1995) has given the time taken for drying a variety of flowers and leaves in a microwave oven.

Microwave oven drying is more suited for cluster of florets such as golden rod, gyposphilia and corn flowers (Thomler, 1997). A combination of silica gel and microwave oven is the fastest and sophisticated method to obtain good colour flowers. Anemones, chrysanthemum, marigold, roses, pansies, peonies are best suited to this method (Bull, 1999).

Rose buds, spider mums, leaves and ferns can also be dried in a microwave oven (Nerius, 1997). According to Miller (1997) large roses require two and a half minutes to dry.

Datta (1997) observed that microwave oven drying as the most suitable method to dehydrate the white flowers of Jubilee cultivar of chrysanthemum.

According to Rothenberger (2000), a cup of water in the oven before starting helps to prevent excessive drying. Petals of microwave oven dried flowers should be sprayed with hair spray or lacquer to prevent the absorption of air moisture. Drying times vary from about 3 minutes for very dense flowers to 1 minute for smaller and thin petaled flowers.

White *et al.* (2002) reported that microwave oven dried flowers look fresher and more colourful than that obtained by other methods. After drying in the microwave oven, flowers must be left in the drying agent for a few hours i.e. setting time should be given for getting good appearance and colour to the flowers.

Flowers embedded in silica gel kept in earthenware are kept in microwave oven for few minutes. Gerbera, gladiolus and chrysanthemum took 3 minutes for drying and water lily took 4 minutes for drying (Ranjan and Misra, 2002).

2.3.5 Press drying

In this method, fresh flowers and leaves are placed between the folds of blotting sheets or newspaper sheets giving some space in between. The sheets are kept one above the other and then placed in the press till drying (Kher and Bhutani, 1979).

Succulents take more time for drying. Such flowers and leaves retain their colour and brightness which may either be stored in folded sheets at a dry place or in desicators for future use (Bhutani, 1995).

Microbial attack is a common feature because of the moisture and the cellulose of the paper serves as substrate for the growth of microbial organisms (Prasad *et al.*, 1997).

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 keep the colours from fading.

According to Rothenberger (2000) flowers of celosia, chrysanthemum, cosmos, daisy and candytuft can easily be press dried.

Lourdusamy *et al.* (2001) described the pressing as the easiest method of preserving flowers and suggested that flowers and foliages like candytuft, chrysanthemum, lantana, rose, verbena, euphorbia and foliages like thuja, marigold, rose, ferns, silver oaks etc. are suitable for press drying.

Quality of dried plant materials varies with plant structure, moisture content, harvest stage, drying methods and weather conditions. Dried plant parts become brittle and damaged during handling (Sangama, 2001).

2.3.6 Silica gel drying

Alleman (1994) reported that silica gel crystals could be used for drying roses. The self indicating nature of silica gel ensures the moisture content by exhibiting blue colour when dry and pink / white when it regains moisture from flowers. Heating of silica gel at 250°F in an oven for 30 minutes regain the original blue colour. Silica gel crystals after drying may be placed in an airtight container for future use. He also reported the drying time as 3 days for Baby's breath, 3-4 days for celosia and 5-7 days for rose buds.

Naeve (1996) suggested that silica gel was the best agent for drying flowers. Anemone, aster, dahlia, salvia and larkspur may be dried using silica gel at 250°-300°F.

Champoux (1999) recommended the use of silica gel to obtain dried flowers having good colour and shape.

Among the different desiccants like silica gel, borax, sand, borax + sand, silica gel was found suitable for plumeria flowers by retaining their form and colour (Rani *et al.*, 2000).

According to Prasad *et al.* (2003) rose flowers appeared almost fresh wher dried in Silica gel, although the colour darkened. Colours that came out close to the original when dried in Silica gel are white, yellow, lavender and blue (non roses) Darker colours such as Red, deep pink and orange tend to turn even darker.

2.3.7 Glycerin drying or Glycerining

Glycerinizing or glycerin drying is the term used in the ornamental cu flower and foliage industry to describe the treatment of fresh plant materials with a hygroscopic chemical with the objective of retaining the suppleness of plant materials Fresh and fairly matured foliage is ideal for glycerinizing. Eucalyptus, magnolia, oak silver oak, anthurium, periwinkle are subjected to glycerin drying.

The use of glycerin in drying is successful with most foliages. Semant *et al* (1993) observed that one part of glycerin mixed with 2 parts of hot water was the idea mixture for twigs of 26 plant species to absorb at room temperature. The materia should remain in the solution until full absorption has taken place.

Verey (1994) found that glycerinizing replaced the water content of leaves giving them a strong and pliable nature. The preserving solution consists of one par glycerin and two parts hot water along with the addition of Chlorohexidine to reduce bacterial growth. This method is found most suitable for Eucalyptus, Hydrangea, ivy and Magnolia.

Addition of few drops of vegetable dye intensified the colour anc glossiness of the stem when kept in a cool dark place (Miller, 1997).

Preservation of flowers in a fully hydrated state should be completed ir two to three weeks (Sell, 1997).

Glycerin 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).

Miller (1997) reported that addition of a few drops of vegetable dye in the preserving solutions and the dip of the smashed tips of woody stem would appear glossy and the colour also gets intensified when kept in cool dark place. Magnolia took four weeks by this method while ivy and ferns took only two weeks.

Raghupathy *et al.* (2000) reported that in glycerin drying flower is actually preserved but not dried. Quality of the flower is maintained. For glycerin drying plant materials are gathered in the fully hydrated condition. Ming tree fern and salal are suited for glycerin drying.

White *et al.* (2002) reported that average time for glycerin treatment is 2 to 3 weeks.

2.3.8 Freeze drying

Freeze dried flowers are fresh flowers that have been specially dried to preserve their natural shape, colour and beauty.

Wilkins and Des Borough (1986) reported the technique of cryopreservation of carnation by placing at -80°C for 12 hrs and then in a freeze drier for 7 days to keep the naturalistic appearance.

Shannel (1999) reported that light expression to freeze dried arrangements should be avoided to prevent colour fading.

Bridal bouquets could be preserved without any damage by the technique of freeze drying (Ruth, 2000).

Raghupathy *et al.* (2000) reported that solvent based polymers may also be applied to help hold flowers together or to help flowers to retain their colours longer. It takes 4-5 days to complete the drying cycle.

Freeze drying is removal of water in the form of vapour by heating frozen water (ice) under vacuum. High vacuum and low temperature are necessary for freeze drying. Freeze dried flowers are used in the preparation of open bouquets, open baskets open wreaths etc. (Talele, 2001).

According to Sangama (2001) freeze drying technique was not commercially used because of high cost of equipment and relatively low market value. Freeze dried roses appeared more natural in colour, size, shape and texture.

2.3.9 Skeletonising

Leathery and fibrous textured leaves are skeletonised by treating in soda or acetic acid for a few days. Leaves become slimy and the lamina portions can be removed leaving the vein skeleton (Prasad *et al.*, 1997).

Skeletonising is a difficult and tedious process which requires great patience and care (White *et al.*, 2002). Skeletonised leaves are used to increase the appearance of dried arrangements. Heavy textured leaves are more suited to this technique. Fully matured, healthy leaves of *Ficus religiosa* immersed in NaOH 40 per cent solution could be skeltonised after two days (Geetha *et al.*, 2002a). Skeltonised leaves lend an interesting, lacy appearance to dried arrangements.

2.3.10 Desiccants (Drying agents)

Flowers that wilt must be dried in a supportive substance to preserve their form and shape. The method of embedding, choice of the container and the embedding medium are to be taken into consideration during drying flowers. Sand, borax, silica gel, sawdust, perlite and combination of these are used as media for embedding (Prasad *et al.*, 1997).

Roberts (1997) had recorded that asters, carnations, chrysanthemums, gladiolus, geranium, coreopsis, cosmos, tulips and zinnias dried well in desiccants like sand and borax.

Evelyn (1997) suggested the use of fine grained builders sand as drying medium.

Thomler (1997) recommended desiccant method as the useful method for delicate flowers that may fall apart when air dried. Desiccants are suited for roses, marigolds, zinnias, tulips and lilies. Among the desiccants like sand, cornmeal and borax and silica gel used, silica gel was the best.

Fresh kitty litter can also be used as desiccant (Barnett, 1999). According to Lourdusamy *et al.* (2001) sand, borax, kitty's litter, silica gel, sawdust, perlite and combination of these can be used as desiccants. Among these, silica gel is an ideal drying agent for delicate flowers such as roses, carnation, dahlia, etc. and can be reused.

Material which is used for embedding and drying flowers and foliage should be fine. It should not chemically react with floral parts. 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).

Sujatha *et al.* (2001) reported that borax crystals and sand in the ratio (1:1) was the best combination as it helps to retain brightness and colour.

Among the various desiccants used to dry Indian blue water lily flowers fine white sand was the best (Geetha *et al.*, 2002b).

2.4 BLEACHING

Bleaching is an important step in the processing of plant material to be marketed. This process allows the use of dyes for colouring. The process of bleaching of any plant material was the chemical modification of coloured compounds within the plant tissues (Robson, 1967). He also reported that the plant material treated with both oxidative and reductive bleaches lead to multistage bleaching leaving the plant material in permanent white.

Schumacher and Stewart (1967) reported that hypochlorites undergo bleaching by chlorhydrinating the double bonds in the plant material.

Chichester (1972) observed that plant tissues contained a variety of coloured organic pigments (chlorophylls), carotenoid pigments (xanthophylls), anthocyanins and lignin.

Roymoulik (1972) reported the action of peroxidase on cellulose and prolonged exposure resulted in the shortening of cellulose chain or peeling due to the loss of polysaccharide terminal sugars. Sodium chlorite is considered to be the best bleaching agent for plant foliage due to its selective mode of action (Dena *et al.*, 1980). Chlorite removes the cellulose with minimal damage even under prolonged contact.

According to Sjostrom (1981), the efficiency of bleaching is based on the accessibility of the bleach to the lignin. He found that hydrogen peroxide cause less damage to cellulose than hypochlorite.

Gulrajani and Sukumar (1985) suggested low temperature, low concentration and pH of 10.5 as the optimum conditions for hypochlorite bleaching. Chlorite can be used on delicate leaf tissues without causing excessive physical damage.

Dubois and Joycee (1992) reported that the two classes of bleaches (oxidative and reductive) have different modes of action. The hypochlorite, chlorite and peroxidases (oxidative) destroyed the chromophore by cleaving the double bonds and brought about bleaching. The reductive bleaches eliminated the double bond by facilitating formulation of covalent bonds at the double bond site. They concluded that peroxidase poses no pollution hazard. They also reported that the plant foliage to be bleached is soaked in alkali to activate the peroxidase before placing it in bleach solution.

Studies conducted at Tamil Nadu Agricultural University revealed sodium chlorite 10 per cent as the best bleaching agent for complete colour removal of *Gomphrena* (Lourdusamy, 1998) and celosia flowers (Mirunalini, 1999). This was followed by hydrogen peroxide 30 per cent solution.

Sodium chlorite 15 per cent or hydrogen peroxide 30 per cent in 60°C water recorded complete whitening in rose flowers cv. First Red (Yogitachari, 2000).

According to Sujatha *et al.* (2001) hydrogen peroxide was the best bleach at room temperature and the damage caused to the cell tissues is minimum. Hydrogen peroxide is decomposed to form hydroxyl radical which then decomposes to water. Peroxide and hydroxyl radical form the active bleaching agents.

Sangama (2001) reported bleaching as an oxidative process of breaking down colour compounds of dried products. Hypochlorite, chlorite and peroxide are most commonly used either individually or in multistep bleaching process.

2.5 'EING

The decorative value of dried flowers can be increased by dyeing. Squires (1971) suggested the use of different paints like enamel paint, interior paint, poster paint and tube paint for painting the dried flowers and foliage. Tampion and Reynolds (1971) have described the common method of absorption for dyeing fresh flowers. The cut stems are placed in the dye solution to which a few drops of washing up liquid is added to increase the spreading of the dye.

According to Westland (1992) hydrangeas and gypsophila may be best dyed by this method. For colouring seed heads and pods, dip dyeing and spraying may be done. Booth (1997) suggested a list of dyes from strong tea, mushrooms, rit dyes, flowers of marigold, zinnia, iris, onion skin and also from hibiscus leaves. Commercial dyes also can be used for colouring bleached dry flowers.

Among the different colour groups in the dye industry, vat colours are found ideal for *Gomphrena* flowers at 0.25 per cent concentration and 10 minutes immersion in cold water (Lourdusamy, 1998). Celosia flowers also took bright colour when immersed in vat dyes (Mirunalini (1999). Vat dyes performed better as there was minimum colour fading on storage (Sujatha *et al.*, 2001).

For bleached *Aerva* flowers and roses, Basic colours are ideal at 0.3 per cent concentration and 15 minutes dipping at 75° water (Lourdusamy *et al.*, 2001).

2.6 FLORAL CRAFTS

Dehydrated flowers and foliage can be used for designing distinctive and artistic decorative items. Rob and Wood (1991) described the method of collecting flowers and preserving them. They also reported on the arrangements suited for special occasions and the basic guidelines for making floral crafts.

Bryan (1992) explained the various methods of making different crafts. Westland (1992) also described various dried designs including garlands, swags, wreaths, pot pourri and pressed floral crafts.

Hatala (1994) had explained different methods to make effective arrangements suited to spring, autumn and winter seasons.

Hammond (1994) had described the topics like wiring the dry flowers, preparing gifts for various occasions like wreath, wall, vase and Christmas arrangements with various dry flowers.

Pressed flowers can be limited in their use in that they can only be used on flat surfaces. It can, however, be used as craft decoration between panes of glass (Raghupathy *et al.*, 2000).

Press dried materials can be arranged in framed displays (Alpertuit, 2002).

All kinds of plants and flowers are dried and used in value added products - collages and flower pictures, flower balls, cards and covers, pomanders, festive decorations, sweet smelling pot pourri, etc. (Raghava, 2001). Raj (2001) had given a list of plants native and naturalized in Himalayas having ornamental parts for developing value added products.

2.6.1 *Pot pourri*

One of the most important uses of dry flowers is in the preparation of *pot pourri*. It is usually a mixture of dried, sweet scented plant parts including flowers, leaves, seeds, stem and roots. Westland (1992) had given the various steps for the preparation of dry and moist *pot pourri.*

Wood (1997) also described the methods of making dry and moist *pot pourri.* Finely ground non iodised salt, orris root, sweet flag, gum benzoin and amber gris could be used as fixatives. Addition of essential oils along with fixatives would improve the fragrance. Pot pourri is designed in a glass bowl or a ceramic jar or in muslin or satin sachets. It is used as a decorative piece and room freshner.

2.7 STORAGE AND PACKING

Dry flowers are fragile and require careful handling. Champoux (1999) recommended storage of dry flowers in boxes after covering with loose tissue paper. Silica gel crystals should be sprinkled at the bottom to avoid moisture build up.

The fragile material is wrapped with tissue paper and kept in cardboard boxes and placed in a cool dry place. Glycerined material should be packed in a different box (Thömler, 1997).

Rothenberger (2000) 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.

Dried flowers should be treated with a suitable biocide (insecticide and fungicide) and packed in water proof containers. Since dry flowers are hygroscopic in nature, it absorbs moisture resulting in mould infection (Lourdusamy *et al.*, 2001). According to Datta (2001) the shelf life of dehydrated floral material may be long if they are protected from moisture and dust by covering in glass or plastic jars in which blue silica gel crystals are kept at the bottom. This is done to prevent them from spoilage and for their future utilization.

Materials and Methods

3. MATERIALS AND METHODS

The present investigations on developing technology for production of dry flowers were carried out during 2001-2003 at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara. The investigations reported herein consists of five main parts.

1. Standardisation of drying
2. Standardisation of bleaching
3. Standardisation of dyeing
4. Standardisation of packing and storage
5. Development of floral crafts

3.1 STANDARDISATION OF DRYING METHODS

Treatment details

Number of plant species: Three

1. Celosia (*Celosia cristata*)
2. China aster (*Callistephus chinensis*)
3. Gerbera (*Gerbera jamesonii*)

Harvest stages : Four

1. Tight bud stage
2. Half bloom stage
3. Full bloom stage
4. Over bloom stage

Drying methods: Five

1. Sun drying
2. Shade drying
3. Hot air oven drying
4. Microwave oven drying
5. Silica gel drying

Design: CRD

3.1.1 Material / flowers

Celosia

Celosia also known as cocks comb is an erect, annual herb belonging to the family Amaranthaceae. It has a branching growth habit and produces large flower heads which are crested and resemble cockscomb.It grows to a height of 40-100cm, depending upon the season. The cockscomb is useful as a bedding plant or for borders and pots. Both dried and fresh flowers are used for table decorations.

China aster/Aster

China aster is a half hardy erect annual belonging to the family Asteraceae. It is excellent as a cut flower. It has got hispid hairy branches bearing alternate, broadly ovate or triangular ovate deeply and irregularly toothed leaves. Flowers are solitary and the colour change is so great that today China aster is one of the most valuable garden flowers.

Gerbera

Gerbera, commonly known as Transvaal daisy, Barberton daisy or African daisy, belongs to the family Asteraceae. It is commonly used worldwide as a cut flower. The plants are stemless, dwarf, 30-45cm tall, and are hairy throughout with petioled, lanceolate and deeply lobed leaves. The foliage is arranged in the form of a rosette at the base. The flowers are daisy like, may be single or double and are available in various colours. The flowers are borne in long and slender stalks and are long lasting with both in field conditions and in vase.

3.1.1.1 Crop culture

Celosia

Seeds were sown in nursery beds of size 2.0 m x 1.0 m and covered with fine sand. Watering was done regularly and seedlings were transplanted to the main field in raised beds of size 3 m x 1 m. The spacing adopted was 20 cm x 30 cm.

China aster/Aster

Aster seeds were sown in mud pots and covered with fine sand. Watering was done regularly till the seedlings attained transplanting size (3-4 leaf stage). They were transplanted in mud pots filled with potting mixture containing sand, soil and cowdung in the ratio 1:1:1.

Gerbera

Gerbera germplasm maintained in the department was utilized for collecting flowers for performing the experiment.

The crops were maintained as per the Package of Practices (KAU, 2002).

3.1.2 Stages of harvest

The stages of harvest were fixed based on the nature of crop growth and flower development. Four stages of harvest, namely, tight bud, half bloom, full bloom and over bloom stages were assessed under each flower to standardise the optimum stage at which drying is perfect to retain colour, shape and the visual quality at its best.

3.1.2.1 Celosia

Tight bud stage

The buds are compact, yet to open to reveal colour. The buds take 9-10 days from bud appearance to reach this stage.

Half bloom stage

Fifty per cent of the petals are open. Buds take 14-16 days from bud appearance to this stage.

Full bloom stage

Florets are fully open, but no seedset. It needs around 18-21 days from bud appearance to reach this stage.

Over bloom stage

It takes 25-27 days from bud emergence to attain this stage. The original colour is lost and the dull colour is seen due to fading of the petals. Seed set is also noticed.

3.1.2.2 China aster/Aster

Tight bud stage

The stage at which the buds remain tight and compact with only the outer ray florets starting to unfurl. It takes eight days from bud appearance to attain this stage.

Half bloom stage

This is the stage when around 50 per cent of ray florets are open and the buds take about 10 days from bud appearance to reach this stage.

Full bloom stage

All the florets have unfurled and the flowers attain the full size. It needs 12 days from bud appearance to full bloom.

Over bloom stage

Flowers are fully opened and the ray florets start curling from the disc with fading of colours. It takes 17 days to attain this stage from bud appearance.

3.1.2.3 Gerbera

Tight bud stage

The stage at which onl

tight and compact and it takes nearly 9 days to attain this stage from bud appearance.

Half bloom stage

The stage at which around 50 per cent of ray florets are open and the remaining to be opened. It takes about 15 days to reach this stage from bud appearance.

Full bloom stage

All the florets have unfurled and the flowers display the full size. It takes nearly 21 days from bud appearance to reach this stage.

Over bloom stage

This is the stage at which ray florets start curling from the disc with fadir of colours. It takes 26 days to attain this stage from bud appearance.

3.1.3 Drying methods

Drying methods like sun drying, shade drying, hot air oven drying, mic wave oven drying and silica gel drying were dried. For drying flowers IFB Microw oven (Model Neutron with grill), YORCO hot air oven (ISI marked model YS1-4 silica gel for column chromatography, glass containers, clean fine white sand plastic trays were used.

3.1.3.1 Sun drying

Flowers of aster and gerbera were embedded in clean fine white sand the method suggested by Bhutani (1995) and were daily exposed to sun and v loss was noted. Celosia flowers were dried under direct sun light without embe The containers were kept in the room during the night to reduce the adverse ef night temperature.

3.1.3.2 Shade drying

Flowers of aster and gerbera were embedded in clean fine white sar kept in a well ventilated, dry room and weight loss was noted at daily intervals.

Celosia flowers were kept directly in the room in trays.

3.1.3.3 Hot air oven drying

Flowers of aster and gerbera were embedded in clean fine white sa kept in a hot air oven at a temperature of 50-55°C for drying and weight los noted at two hours interval (Kher and Bhutani, 1979).

Celosia flowers were directly kept in the oven at 50-55°C.

3.1.3.4 Microwave oven drying

Aster and gerbera flowers were dried in micro-wave oven by embedding in clean fine white sand in a microwave oven safe container as suggested by Bhutani (1995) and kept in the oven for a few minutes for drying. Observations were taken at one minute interval.

Celosia flowers were dried without embedding. Weight loss was recorded at regular interval.

3.1.3.5 Silica gel drying

Flowers of celosia, China aster and gerbera were embedded in silica gel and kept in a well ventilated room for drying. Observations on weight loss was taken at daily interval.

3.1.4 Effect of desiccants on drying

Attempts were also made to standardise the drying method that recorded high cumulative score for visual and aesthetic qualities on drying, using different desiccants. For this experiment, flowers of aster and gerbera were taken at the stage that retained aesthetic qualities on drying.

3.1.4.1 Desiccants

Silica gel powder
Silica gel crystals
Borax
Clean fine white sand
Borax : sand in 1:1 combination

3.1.4.2 Drying methods

China aster : shade drying, microwave oven drying
Gerbera : microwave oven drying

The desiccants were placed in about 2 cm thick layer in the container and flowers with 2-5 cm stem were inserted with face up. The desiccant was then placed over and around the flower using a spoon to cover the flowers and was left for drying.

3.2 STANDARDISATION OF BLEACHING TECHNOLOGY

For bleaching experiments, flowers were taken at the stage that retained the aesthetic qualities on drying.

Number of chemicals : Three

1. Hydrogen peroxide : 10, 20 and 30 per cent
2. Sodium hypochlorite : 5, 10 and 15 per cent
3. Calcium hypochlorite : 3, 4 and 5 per cent

Flowers were immersed in the bleaching solution at room temperature and bleaching of colour was observed at hourly interval. Bleached flowers were washed with clean water and dried in shade.

3.3 STANDARDISATION OF DYEING TECHNOLOGY

Flowers that bleached well in the above experiment was taken for dyeing. Textile dyes used in commercial industries were used for colouring.

Primary group of dyes : five

Acid, Base, Direct, Procion, vat.

The selected dyes under the five groups are given below.

Acid	:	Orange GC, Acid violet
Base	:	Fast orange, Fast yellow
Direct	:	Swiss pink, Brown MR, Direct Green
Procion	:	Red H 8 B, Blue H 2 R
Vat	:	Methylene Blue, Basic Rhodamine, Auromine Yellow

The desiccants were placed in about 2 cm thick layer in the container and flowers with 2-5 cm stem were inserted with face up. The desiccant was then placed over and around the flower using a spoon to cover the flowers and was left for drying.

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The selected dyes under the five groups are given below.

Acid	:	Orange GC, Acid violet
Base	:	Fast orange, Fast yellow
Direct	:	Swiss pink, Brown MR, Direct Green
Procion	:	Red H 8 B, Blue H 2 R
Vat	:	Methylene Blue, Basic Rhodamine, Auromine Yellow

Concentration of the dye solution : Three

0.1, 0.2 and 0.3 per cent.

Duration of treatment : Three

5, 10 and 15 minutes.

The flowers were kept immersed in the solutions for specified time and dried in well ventilated shaded place.

3.4 STANDARDISATION OF PACKING TECHNIQUES

The dried flowers were packed in corrugated cardboard boxes after covering with a lining material.

Pretreatments :

1. Wrapping by newspaper
2. Wrapping by tissue paper
3. Inserting in polythene covers
4. Wrapping by cellophane sheets
5. Control (No lining)

Silica gel crystals/naphthalene flakes were sprinkled at the bottom of the cardboard boxes. The boxes were stored at ambient temperature. Flow diagram for pre treatment and packaging of dry flowers is given in Fig.1.

6. The embedded flowers namely, aster and gerbera were also stored in air tight containers after sprinkling silica gel crystals at the bottom.

3.5 DEVELOPMENT OF FLORAL CRAFTS

For preparation of floral crafts, flowers, foliage, seeds and other plant materials that have already been assessed were collected and used as fillers. The

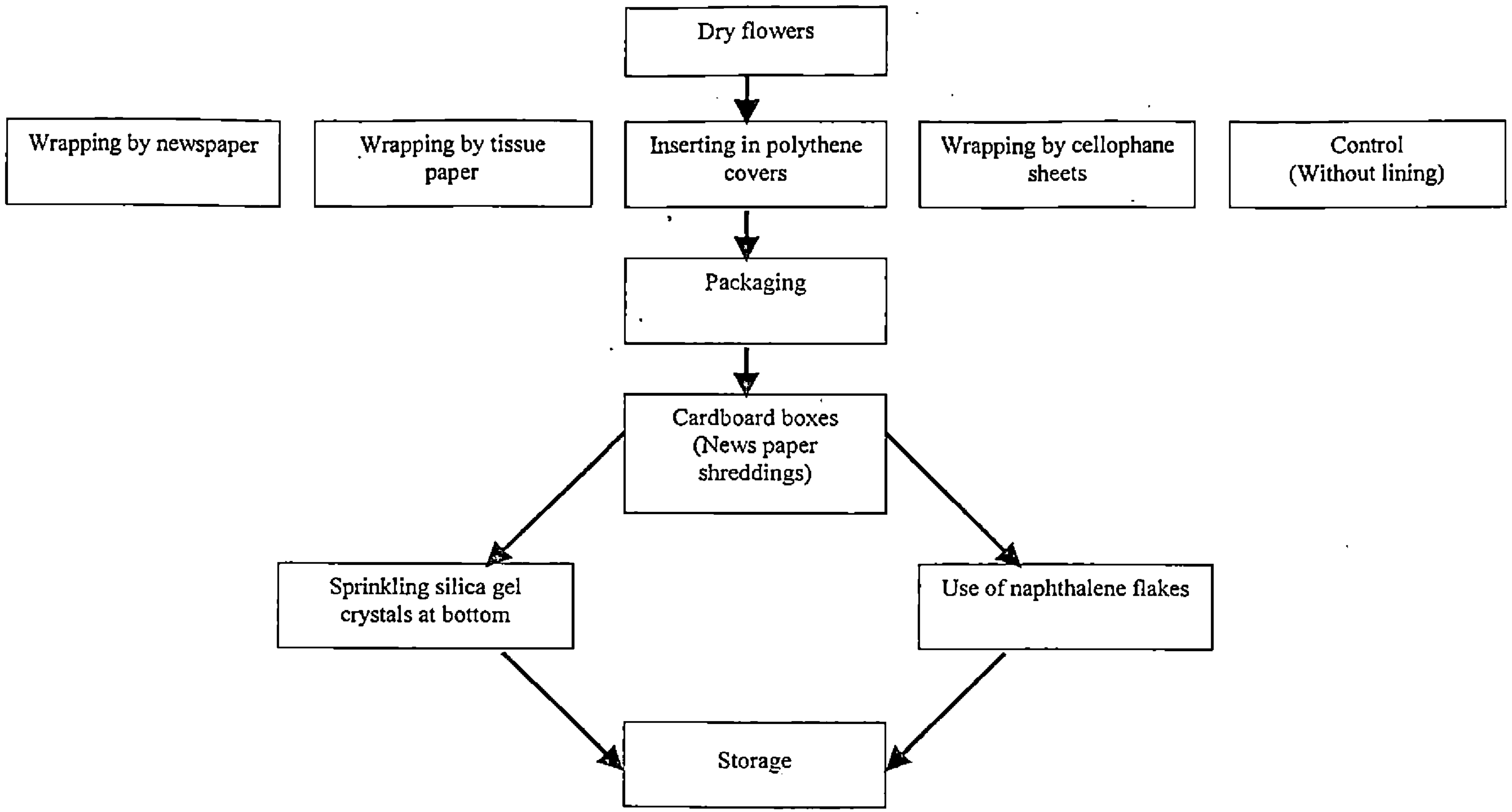

Fig. 1. Flow diagram for pretreatment and packaging of dry flowers

material were preserved by drying, bleaching and dyeing. The following crafts were made:

1. Bouquets
2. Table arrangements
3. Pressed flower cards
4. Potpourri
5. Mirror frame
6. Christmas wreath

Cost of production was also estimated.

3.6 OBSERVATIONS

3.6.1 Drying studies

3.6.1.1 Time taken for perfect drying

Drying time was observed. Observations were taken daily for shade, sun and silica gel drying methods and every minute when dried in a microwave oven and every two hours when dried using a hot air oven.

Drying time was found by noting the weight loss of the flowers in different stages at various intervals until the drying is completed.

3.6.1.2 Weight loss

Weight loss due to drying was found out using the formula given below and expressed as percentage.

$$\text{Weight loss (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

3.6.1.3 Brittleness of the plant part

It is scored by the feel method and the score card technique and the scoring was done based on scores ranging from 0 to 4 denoting 0 as very low and 4 as very high (Table 1).

3.6.1.4 Brightness of the plant part

The brightness was found out by visual method and score card technique. Scores were given from 0 to 4 denoting zero as very poor and 4 as excellent (Table 1).

3.6.1.5 Changes in colour intensity

The change in colour of the flowers after drying was observed by visual method and the score card technique. Scores were allotted from zero to four denoting zero as complete colour change to 4 as no colour change (Table 1).

3.6.2 Bleaching experiments

3.6.2.1 Colour removal level

The extent of colour removal at periodical intervals of the flowers was done by visual method. The flowers were compared with unbleached flowers and extent of colour removal was found out in percentage.

3.6.2.2 Time taken for drying

Bleached flowers were washed in water and dried in shade. The time required for the bleached flowers to attain the original moisture content was noted and expressed as hours.

3.6.2.3 Best bleaching chemical

The best bleaching chemical for the particular flower was selected based on the condition of the flower after bleaching, time taken for colour removal, brittleness after bleaching and damage to the plant part were assessed using a score card method with scores from 0 to 4 (Table 1).

3.6.2.4 Brittleness of plant part

The brittleness of the bleached flowers was observed by feel method and scores were allotted from 0 to 4 (Table 1).

Table 1. Scoring for aesthetic parameters

Experiment	Character	Scores				
		0.0 - 0.4	0.5 - 1.4	1.5 - 2.4	2.5 - 3.4	3.5 - 4.0
Drying	Brightness	Very poor	Poor	Moderate	Good	Excellent
	Brittleness	Very low	Low	Moderate	High	Very high
	Colour change	Complete	High	Medium	Little	No change
Bleaching	Brittleness	Very low	Low	Medium	High	Very high
	Quality	Very poor	Poor	Moderate	Good	Excellent
	Damage to plant part	Very high	High	Moderate	Slight	No damage
Dyeing	Colour take	Very low	Low	Moderate	High	Very high
	Colour fading on storage	Very high	High	Medium	Low	Very low

3.6.2.5 Damage to plant part

The possibility of damage to plant part was mainly due to the concentration of the bleaching chemical or prolonged immersion. The damage was assessed by scoring technique with 0 to 4 scores (Table 1).

3.6.3 Dyeing experiments

For dyeing experiments, the flowers that bleached well from the above experiment were taken.

3.6.3.1 Best dye for flowers

The best dye for the selected flowers was found out based on aesthetic parameters by observing the colour intensity, time of colouring, the extent of colour fading on storage and brightness of the coloured flowers after drying. Method of scoring followed to evaluate the aesthetic parameters is given in Table 1.

3.6.3.2 Time taken for colour take

Bleached flowers were immersed in dye solutions (0.1, 0.2 and 0.3%) for 5, 10, 15 minutes and dried to find out the exact time required for best colour take.

3.6.3.3 Colour intensity

Colour intensity was noted based on visual method in comparison with the particular dye solution. The colour take was assessed adopting score card method with 0 to 4 scores.

3.6.3.4 Time taken for drying

Dyed flowers were dried in a well shaded ventilated place. The time required for dyed flowers to attain the original moisture content was noted and expressed in hours.

3.6.3.5 Level of colour fading on storage

The flowers were stored in card board boxes for one month and the extent of colour fading was observed by scoring technique. The colour take was assessed ıdopting a score card method with scores ranging from 0 to 4.

3.6.4 Packing and storage studies

The well dried, bleached and dyed flowers were packed in card board boxes using different lining materials and stored at ambient temperature. Aster and gerbera were also stored in air tight containers. The best condition was found out by observing the extent of colour fading on storage, damage to plant part due to incidence of pests / diseases etc. after one month.

3.6.5 Making floral crafts

Floral crafts were made and estimated the cost of production.

3.6.6 Scoring technique

Scoring method was followed to evaluate the aesthetic parameters. Score was recorded from ten adult individuals and average was taken.

3.6.7 Statistical analysis

The data recorded for drying studies were statistically analysed following the method suggested by Pansy and Sukhatme (1985).

Results

4. RESULTS

The results of the studies conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara on developing technology for dry flower production are presented in this chapter.

4.1 STANDARDISATION OF DRYING METHODS

Data on the trials conducted to standardise the drying method and the optimum stage at which drying was perfect to retain colour, shape and visual quality at its best in selected commercial flowers, viz., celosia, china aster and gerbera are presented in Tables 2 to 9 and Figures 2 to 4.

4.1.1 Celosia

Data pertaining to the effect of different drying methods and stage of harvest on celosia are given in Tables 2 and 3 and Fig.2.

4.1.1.1 Weight loss

The weight loss during drying of celosia flowers at various intervals of time is furnished in Table 2.

Microwave oven drying

Maximum weight loss was observed for three and four minutes drying which were on par.

Hot air oven drying

Drying of flowers for 8 hours in a hot air oven recorded the highest water loss at all the stages and was on par with that for 6 hours.

Shade drying

All the stages recorded maximum weight loss on the 3rd day of drying and was on par with the weight loss on the 2nd day of drying.

Table 2. Weight loss during drying of celosia

Drying method	Stage of harvest	Weight loss (%) after drying				
		1 min	2 min	3 min	4 min	Mean
Microwave Oven drying	Tight bud	30.55^{c}	46.84^{b}	58.59^{a}	60.60^{a}	42.13
	Half bloom	28.53^{c}	44.72^{b}	68.07^{a}	69.51^{a}	52.71
	Full bloom	28.51^{c}	44.69^{b}	70.24^{a}	72.48^{a}	53.98
	Over bloom	26.58^{c}	43.28^{b}	68.79^{a}	70.28^{a}	52.23
		2 hrs	4 hrs	6 hrs	8 hrs	Mean
Hot air Oven drying	Tight bud	58.34^{c}	67.56^{b}	76.41^{a}	77.97^{a}	70.07
	Half bloom	42.39^{c}	62.17^{b}	74.06^{a}	75.36^{a}	63.50
	Full bloom	46.98^{c}	63.01^{b}	73.14^{a}	74.83^{a}	64.49
	Over bloom	46.22^{c}	57.89^{b}	68.88^{ab}	71.31^{a}	61.08
		1 day	2 days	3 days	Mean	
Shade drying	Tight bud	62.38^{b}	72.42^{a}	74.01^{a}	69.60	
	Half bloom	68.47^{b}	78.29^{a}	79.32^{a}	75.36	
	Full bloom	61.69^{b}	76.10^{a}	76.85^{a}	71.55	
	Over bloom	62.91^{b}	72.97^{a}	74.26^{a}	70.05	
		1 day	2 days	3 days	Mean	
Silica gel drying	Tight bud	64.19^{b}	73.05^{a}	74.40^{a}	70.55	
	Half bloom	63.08^{b}	73.60^{a}	74.83^{a}	70.50	
	Full bloom	70.99^{b}	78.14^{a}	79.43^{a}	76.19	
	Over bloom	61.65^{b}	75.97^{a}	77.53^{a}	71.72	
		1 day	2 days	Mean		
Sun drying	Tight bud	75.13^{a}	76.61^{a}	75.87		
	Half bloom	77.58^{a}	78.79^{a}	78.19		
	Full bloom	73.81^{a}	75.04^{a}	74.43		
	Over bloom	77.38^{a}	77.81^{a}	77.60		

Silica gel drying

Data on the maximum loss of moisture was recorded on the 3rd day of drying in all the stages and were on par with results obtained on the 2nd day of drying.

Sun drying

The weight loss recorded on the 1st day and 2nd day of drying were statistically on par.

4.1.1.2 Time taken for perfect drying

Time taken for perfect drying of celosia flowers varied with the method of drying (Table 2). Celosia took three minutes for perfect drying in a microwave oven and 8 hours in a hot air oven. It took two days for shade drying and silica gel drying whereas one day for sun drying.

4.1.1.3 Aesthetic and visual scores after drying

The scores for the aesthetic and visual qualities, namely brightness, brittleness and colour change of celosia flowers under different methods of drying and stages of harvest are presented in Table 3 and Fig.2.

Shade drying

The scores for brightness due to shade drying ranged from 2.3 (over bloom stage) to 2.7 (full bloom stage).

Full bloom flowers also scored high (2.3) for brittleness, whereas the score was less (2.1) in tight bud and over bloom stages. Half bloom stage recorded a score of 2.2.

The colour change was rated as lower to no colour change in all the stages. There was no colour change at full bloom stage (3.5). The half bloom stage was rated for lower colour change with a score of 3.2. Tight bud and over bloom stages were rated for medium colour change (2.0 and 2.2, respectively).

Sun drying

The score for brightness due to sun drying ranged from 1.6 (tight bud and over bloom stage) to 1.9 (full bloom stage).

Full bloom stage also scored high for brittleness (2.2). This was closely followed by half bloom flowers (2.1), while it was less in tight bud stage (1.9).

The flowers after sun drying were rated to have medium to high colour change. The scores for colour change for full bloom, half bloom, over bloom and tight bud stages were 1.5, 1.4, 1.4 and 1.2, respectively.

Silica gel drying

The scores for brightness was rated as medium in all stages and ranged from 1.8 to 2.2. The full bloom (2.2), half bloom (2.1), over bloom (1.9) and tight bud stages (1.8) accounted for moderate brightness.

Brittleness due to silica gel drying of celosia was rated as moderate in all stages. A score of 1.7 was observed in full bloom stage followed by half bloom stage (1.6) and over bloom and tight bud stage (1.5).

The colour change was rated as medium to high in all stages. The scores ranged from 1.0 (half bloom stage) to 2.3 (full bloom stage). The rating for tight bud and over bloom stages were 1.5, each.

Hot air oven drying

Brightness due to hot air oven drying was rated as moderate to good with scores ranging from 2.2 (tight bud stage) to 2.4 (half bloom stage). The score was 2.3, each, for full bloom and half bloom stages.

Brittleness was rated as moderate with a score of 2.2 in full bloom stage, while it was 2.1 in over bloom stage, 2.0 in half bloom stage and 1.8 in tight bud stage.

Celosia flowers at full bloom stage after hot air oven drying showed only slight colour change with a score of 2.5. All the other stages scored for moderate colour change and the scores ranged from 1.9 (tight bud stage) to 2.1 (half bloom stage).

Microwave oven drying

Brightness due to microwave oven drying was rated as medium to high in all the stages. The scores ranged from 1.9 (tight bud stage) to 2.5 (half bloom and full bloom stages). High brightness (2.5, each) was recorded in full bloom and half bloom stages, followed by over bloom stage (2.1).

Brittleness was rated as moderate in all stages with a score of 2.2 in over bloom stage, 2.0 in full bloom stage, 1.9 in half bloom stage and 1.6 in tight bud stage.

The full bloom stage was rated to have lower colour change with a score of 3.2, followed by half bloom stage (2.8). The tight bud stage and over bloom stages had medium scores of 2.4 and 2.1, respectively.

4.1.1.4 Comparison of cumulative, aesthetic and visual quality scores after drying

Data on the cumulative score for aesthetic and visual quality under different methods of drying and stages of harvest on celosia are presented in Table 3 and Fig.2.

Full bloom stage recorded the highest cumulative score (5.6 to 8.5) for all aesthetic and visual qualities under all methods of drying, compared to all other stages of harvest. This was followed by half bloom stage (4.7 to 7.9).

Among the drying methods, maximum cumulative score was recorded in shade drying (8.5), followed by microwave oven drying (7.7) and hot air oven drying (7.0).

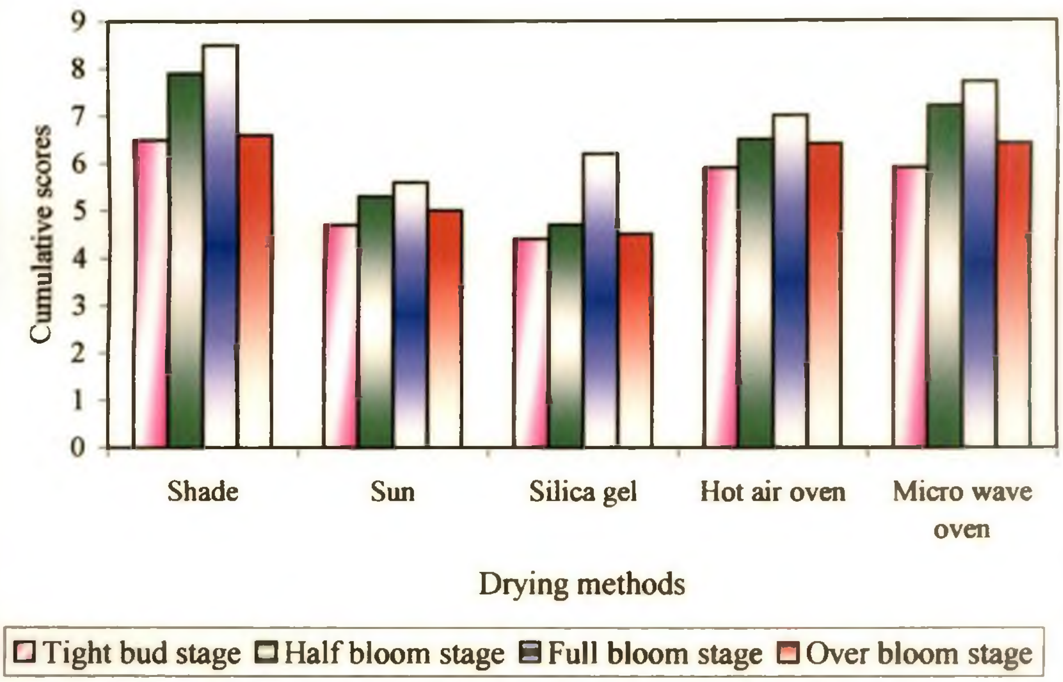

Fig. 2. Cumulative aesthetic and visual quality scores of celosia under different methods of drying and stages of harvest

4.1.2 China aster / Aster

Data on the effect of different drying methods on aster flowers are furnished in Tables 4 to 7 and Fig.3 and 4.

4.1.2.1 Weight loss

The moisture loss expressed as percentage during drying of aster flowers as influenced by stage of harvest at regular intervals of time are given in Table 4.

Shade drying

The percentage water loss on the 5th and 6th day of shade drying of aster flowers were on par in all stages of harvest.

Microwave oven drying

In microwave oven drying, the percentage weight loss on the 4th and 5th minute after drying were statistically on par in all the stages of harvest of aster flowers.

Hot air oven drying

All the stages recorded maximum weight loss after 10 hours of drying and was on par with weight loss after 8 hours.

Silica gel drying

Silica gel dried flowers recorded maximum weight loss (76.92%) in full bloom stage when compared to other stages. Data on the moisture loss recorded on the 3rd and 4th day of drying were statistically similar at all the stages of harvest.

Sun drying

When the days taken for sun drying was taken into consideration, the weight loss recorded on the 3rd and 4th day of drying under sun at all the stages of harvest were statistically on par.

Table 4. Weight loss during drying of aster

Drying method	Stage of harvest	Percentage weight loss after drying						Mean
		1 day	2 days	3 days	4 days	5 days	6 days	
Shade drying	Tight bud	33.48^{d}	36.52^{d}	57.98^{c}	64.39^{b}	69.34^{ab}	72.68^{a}	55.73
	Half bloom	41.23^{e}	45.00^{d}	51.81^{c}	63.02^{b}	68.69^{a}	70.69^{a}	56.74
	Full bloom	44.73^{d}	47.75^{d}	52.48^{c}	61.65^{b}	67.53^{a}	69.56^{a}	57.28
	Over bloom	41.06^{c}	50.75^{b}	54.66^{b}	68.50^{a}	71.91^{a}	72.92^{a}	59.97
		1 min	2 min	3 min	4 min	5 min	Mean	
Micro-wave oven drying	Tight bud	27.48^{d}	54.34^{c}	63.80^{b}	73.22^{a}	74.41^{a}	58.65	
	Half bloom	41.23^{d}	45.00^{c}	51.81^{b}	63.02^{ab}	68.69^{a}	70.69	
	Full bloom	44.73^{c}	47.75^{b}	52.48^{b}	61.65^{a}	67.53^{a}	69.56	
	Over bloom	41.06^{d}	50.75^{c}	54.66^{b}	68.50^{a}	71.91^{a}	72.92	
		2 hrs	4 hrs	6 hrs	8 hrs	10 hrs	Mean	
Hot air oven drying	Tight bud	34.40^{d}	44.73^{c}	53.20^{b}	63.87^{a}	65.44^{a}	52.33	
	Half bloom	32.73^{d}	43.33^{c}	57.97^{b}	66.11^{a}	66.75^{a}	53.38	
	Full bloom	24.81^{c}	44.33^{b}	67.49^{a}	71.02^{a}	72.17^{a}	55.96	
	Over bloom	25.35^{d}	42.64^{c}	60.01^{b}	66.63^{a}	67.70^{a}	52.47	
		1 day	2 days	3 days	4 days	Mean		
Silica gel drying	Tight bud	55.47^{a}	62.75^{a}	72.93^{a}	73.90^{a}	66.26		
	Half bloom	62.38^{b}	66.82^{b}	75.70^{a}	76.69^{a}	70.39		
	Full bloom	59.89^{a}	67.19^{a}	75.82^{a}	76.92^{a}	69.96		
	Over bloom	59.27^{c}	64.92^{b}	74.08^{a}	75.94^{a}	68.55		
		1 day	2 days	3 days	4 days	Mean		
Sun drying	Tight bud	41.43^{c}	58.82^{b}	71.43^{a}	72.64^{a}	61.08		
	Half bloom	56.99^{c}	64.52^{b}	75.78^{a}	77.43^{a}	68.68		
	Full bloom	63.35^{b}	70.65^{a}	76.65^{a}	77.40^{a}	72.01		
	Over bloom	66.20^{c}	70.76^{bc}	77.61^{ab}	79.12^{a}	73.42		

4.1.2.2 Time taken for perfect drying

The drying methods differed in the time taken for perfect drying of aster flowers. It ranged from 4 minutes (microwave oven drying) to 5 days (shade drying). It took 8 hours in a hot air oven and 3 days each, for silica gel drying and sun drying.

4.1.2.3 Aesthetic and visual scores after drying

The scores for aesthetic and visual quality parameters, viz., brightness, brittleness and colour change under different methods of drying and stages of harvest of aster flowers are shown in Table 5 and Fig.3.

Shade drying

The brightness of aster flowers was rated good (3.1) when dried at full bloom stage and as medium (1.8) when dried at half bloom stage. Over bloom (2.4) and tight bud (2.1) stages were also rated as moderate.

The score for brittleness of aster flowers ranged from 1.5 (over bloom stage) to 2.0 (half bloom stage). All the stages showed moderate brittleness, of which, half bloom stage possessed the maximum (2.0) score for brittleness.

The scores for colour change under shade drying was rated as medium to little in all the four stages of harvest in aster flowers. The colour change was rated as low (3.4) when dried at full bloom stage and medium (2.1) when dried at tight bud and over bloom stages.

Sun drying

The score for brightness under sun drying ranged from 1.1 to 1.8. Brightness was rated as medium (1.8) when dried at full bloom stage and low (1.1, each) when dried at tight bud and over bloom stage. The score at half bloom stage (1.3) was also rated as low.

Brittleness was rated as moderate (2.2) when dried at full bloom stage and low (1.0) when dried at tight bud stage. However, half bloom and over bloom stages were rated as medium with scores 1.9 and 1.7, respectively.

Colour change was rated as high (1.2) when dried at tight bud stage, medium when dried at over bloom (2.1), half bloom (1.5) and full bloom (2.0) stages.

Silica gel drying

The scores for brightness due to silica gel drying ranged from 1.1 to 1.9. The brightness was rated as moderate (1.9) at full bloom and over bloom (1.6) stages and low for tight bud (1.2) and half bloom (1.1) stages.

Brittleness was rated as moderate when dried at all stages of harvest with scores ranging from 1.7 to 2.2.

The scores for colour change under silica gel drying ranged from 1.4 to 2.2. Among the different harvest stages, colour change was rated as high at over bloom stage whereas it was rated as medium at full bloom (2.2), tight bud 1.7) and half bloom (1.6) stages.

Hot air oven drying

The scores for brightness under hot air oven drying was rated as moderate to good with scores ranging from 1.6 (tight bud stage) to 2.8 (full bloom stage). Over bloom (2.1) and half bloom (1.7) stages were also rated as moderate as full bloom stage.

The score for brittleness under oven drying ranged from 1.8 to 2.5. The rating was high (2.5) for full bloom stage and moderate (2.2) for half bloom, tight bud and over bloom (1.8, each) stages.

Table 5. Aesthetic and visual quality of aster flowers under different methods of drying and stages of harvest

Drying methods	Drying time	Stage of harvest	Scores for aesthetic parameters			Cumulative score
			Brightness	Brittleness	Colour change	
Shade drying	5 days	Tight bud	2.1	1.6	2.1	5.8
		Half bloom	1.8	2.0	2.7	6.5
		Full bloom	3.1	1.8	3.4	8.3
		Over bloom	2.4	1.5	2.1	6.0
Sun drying	3 days	Tight bud	1.1	1.0	1.2	3.3
		Half bloom	1.3	1.8	1.5	4.6
		Full bloom	1.8	2.2	2.0	6.0
		Over bloom	1.1	1.9	2.1	4.1
Silica gel drying	3 days	Tight bud	1.2	1.7	1.7	4.6
		Half bloom	1.1	1.9	1.6	4.6
		Full bloom	1.9	2.2	2.2	6.3
		Over bloom	1.6	2.2	1.4	4.9
Hot air oven drying	8 hours	Tight bud	1.6	1.8	1.8	5.2
		Half bloom	1.7	2.2	1.7	5.6
		Full bloom	2.8	2.5	2.7	8.0
		Over bloom	2.1	1.8	1.7	5.6
Microwave oven drying	4 min	Tight bud	1.5	2.0	2.0	5.5
		Half bloom	1.6	2.5	2.0	6.1
		Full bloom	2.8	2.4	3.0	8.2
		Over bloom	2.2	2.1	1.9	6.2

Scores:				
	0.0-0.4	Very poor	Very low	Complete
	0.5-1.4	Poor	Low	High
	1.5-2.4	Moderate	Moderate	Medium
	2.5-3.4	Good	High	Little
	3.5-4.0	Excellent	Very high	No change

The score for colour change under hot air oven drying ranged from 1.7 to 2.7. The colour change was rated as lower (2.7) when dried at full bloom stage and as medium when dried at tight bud (1.8), half bloom and over bloom (1.7) stages.

Microwave oven drying

Scores for brightness ranged from 1.5 to 2.8 under microwave oven drying. Brightness was scored as good (2.8) when dried at full bloom stage and as medium when dried at tight bud (1.5), half bloom (1.6) and over bloom (2.2) stages.

The score for brittleness was rated as high (2.5) when dried at half bloom stage and as moderate when dried at all other stages. Moderate rating was recorded by tight bud, full bloom and over bloom stages with scores 2.0, 2.4 and 2.1, respectively.

The score for colour change ranged from 1.9 to 3.0 under microwave oven drying. The colour change was rated as little (3.0) when dried at full bloom stage and as medium when dried at tight bud and half bloom (2.0, each) and over bloom (1.9) stages.

4.1.2.4 Comparison of cumulative, aesthetic and visual quality scores after drying

Data on the cumulative score for aesthetic and visual quality under different methods of drying and stages of harvest of aster flowers are given in Table 5 and Fig.3.

In aster, among all the four harvest stages, full bloom stage registered the highest cumulative score (6.0 to 8.2) for all aesthetic and quality parameters under all methods of drying, compared to the rest of the stages of harvest. This was followed by half bloom stage (4.6 to 6.5).

Among the drying methods, cumulative score was the highest (8.3) under shade drying, followed by microwave oven drying (8.2) and hot air oven drying (8.0), at full bloom stage.

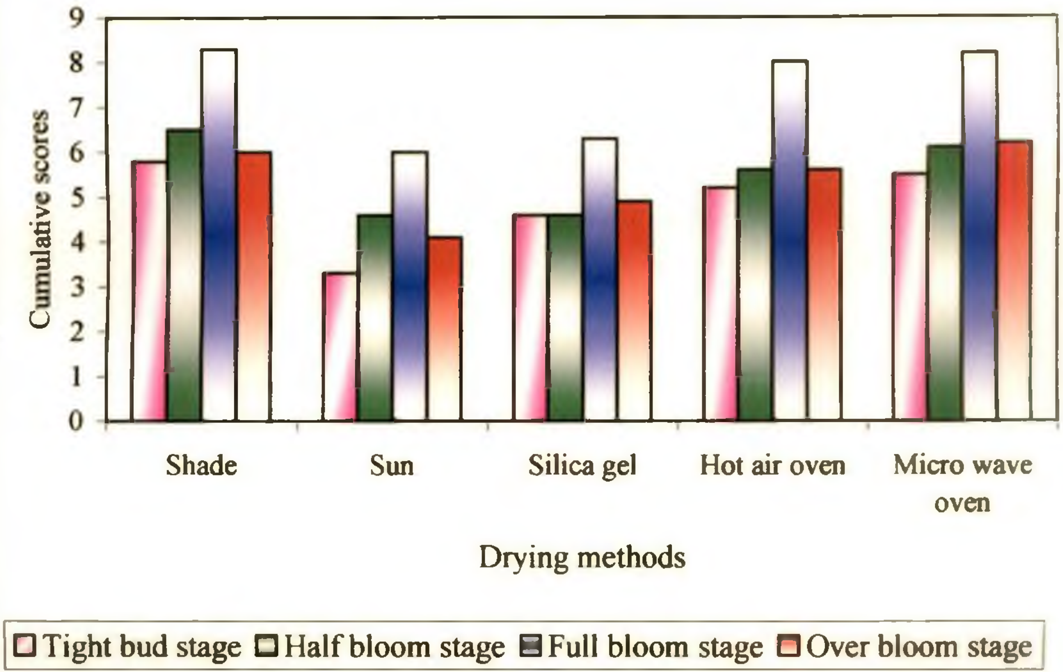

Fig. 3. Cumulative aesthetic and visual quality scores of aster under different methods of drying and stages of harvest

4.1.2.5 Effect of desiccants

Data on the effect of various desiccants on the quality of aster flowers after drying are given in Tables 6 and 7 and Fig. 4.

4.1.2.5.1 Shade drying

Data on the effect of various desiccants on the aesthetic and visual quality of aster flowers under shade drying are given in Table 6 and Fig.4.

The flowers embedded in fine clean white sand (Plate 1) recorded maximum cumulative score (8.6) for all aesthetic and visual quality parameters, viz., brightness (3.1), brittleness (2.1) and colour fading (3.4). The score for brightness was rated as good and for brittleness and colour change as medium. The flowers retained shape and colour and the quality was good. This was followed by the desiccant sand + borax in the ratio 1:1 with a cumulative score of 7.3. The scores for brightness was rated as good (2.6), brittleness as medium (1.6) and colour change as low (3.1). Appearance of the flowers was good, but slight colour change was noticed.

The score for brightness was rated as moderate (1.8) and brittleness as high (2.5) for flowers embedded in silica gel crystals. The rating for colour change was low (2.8) and cumulative score was 7.1. The petals of the flowers shrivelled on drying.

The quality parameters such as brightness and brittleness were rated as moderate with scores 2.3 and 2.0, respectively, and colour change as low (2.6) when borax was used as desiccant. The cumulative score was 6.9 for flowers when embedded in borax. The quality of the dried flower was not good, as it retained only the colour.

All the quality parameters were rated as moderate for flowers when embedded in silica gel powder and the cumulative score was 6.2. The dried flowers had a dull appearance.

Table 6. Effect of desiccants on drying of aster

Method of drying : Shade
Stage of harvest : Full bloom

Desiccants	Scores for aesthetic parameters			Cumulative score	Appearance of flowers
	Brightness	Brittleness	Colour change		
Silica gel crystals	1.8	2.5	2.8	7.1	Colour change low, petals shrivelled
Borax	2.3	2.0	2.6	6.9	Quality not good, retained colour
Silica gel powder	1.9	2.1	2.2	6.2	Dull appearance, quality moderate
Fine clean white sand	3.1	2.1	3.4	8.6	Retained colour and shape, quality good
Sand + borax (1:1)	2.6	1.6	3.1	7.3	Appearance good, slight colour change

Scores:			
0.0-0.4	Very poor	Very low	Complete
0.5-1.4	Poor	Low	High
1.5-2.4	Moderate	Moderate	Medium
2.5-3.4	Good	High	Little
3.5-4.0	Excellent	Very high	No change

4.1.2.5.2 Microwave oven drying

Data on the aesthetic and visual quality scores of aster flowers under microwave oven drying as influenced by the embedding media are given in Table 7 and Fig.4.

Maximum cumulative score (8.3) was recorded for flowers embedded in fine clean white sand when dried in a microwave oven. The scores for brightness was rated as good (2.9), brittleness as moderate (2.4) and colour change as low (3.0). The quality of dried flowers was good, as it retained the shape and colour.

The embedding medium sand + borax in the ratio 1:1 recorded a cumulative score of 7.4. Brightness was rated as good (2.6), brittleness as moderate (2.2) and colour change as low (2.6). The quality of the dried flower was satisfactory with slight colour change.

Among the quality parameters, brightness and brittleness were rated as moderate with scores 2.4 and 2.2, respectively, for flowers embedded in borax. The rating for colour change was low (2.5). The dried flowers retained only the colour and the appearance was not good.

The scores for brightness and brittleness were rated as moderate (2.0 and 2.3, respectively) and colour change as low (2.5) for flowers embedded in silica gel crystals with a cumulative score of 6.8. Though the dried flowers retained the colour, the petals shrivelled.

The flowers embedded in silica gel powder had a dull appearance with a cumulative score of 6.3. All the quality parameters were rated as moderate.

4.1.2.5.3 Comparison of cumulative, aesthetic and visual quality scores

Among the desiccants, flowers embedded in fine clean white sand recorded exceptionally high cumulative scores under shade and microwave oven drying (8.6 and 8.3, respectively). The quality of the dried flower was also good. This was

Table 7. Effect of desiccants on drying of aster flowers

Method of drying : Microwave oven drying
Stage of harvest : Full bloom
Cooking time : 4 minutes
Setting time : 15 minutes

Desiccants	Scores for aesthetic parameters			Cumulative score	Appearance of flowers
	Brightness	Brittleness	Colour change		
Silica gel crystals	2.0	2.3	2.5	6.8	Colour change low, petals shrivelled
Borax	2.4	2.2	2.5	7.1	Appearance not good, retained colour
Silica gel powder	1.9	2.2	2.2	6.3	Quality moderate, dull appearance
Fine clean white sand	2.9	2.4	3.0	8.3	Appearance good, retained colour and shape
Sand + borax (1:1)	2.6	2.2	2.6	7.4	Quality satisfactory, slight colour change

Scores:			
0.0-0.4	Very poor	Very low	Complete
0.5-1.4	Poor	Low	High
1.5-2.4	Moderate	Moderate	Medium
2.5-3.4	Good	High	Little
3.5-4.0	Excellent	Very high	No change

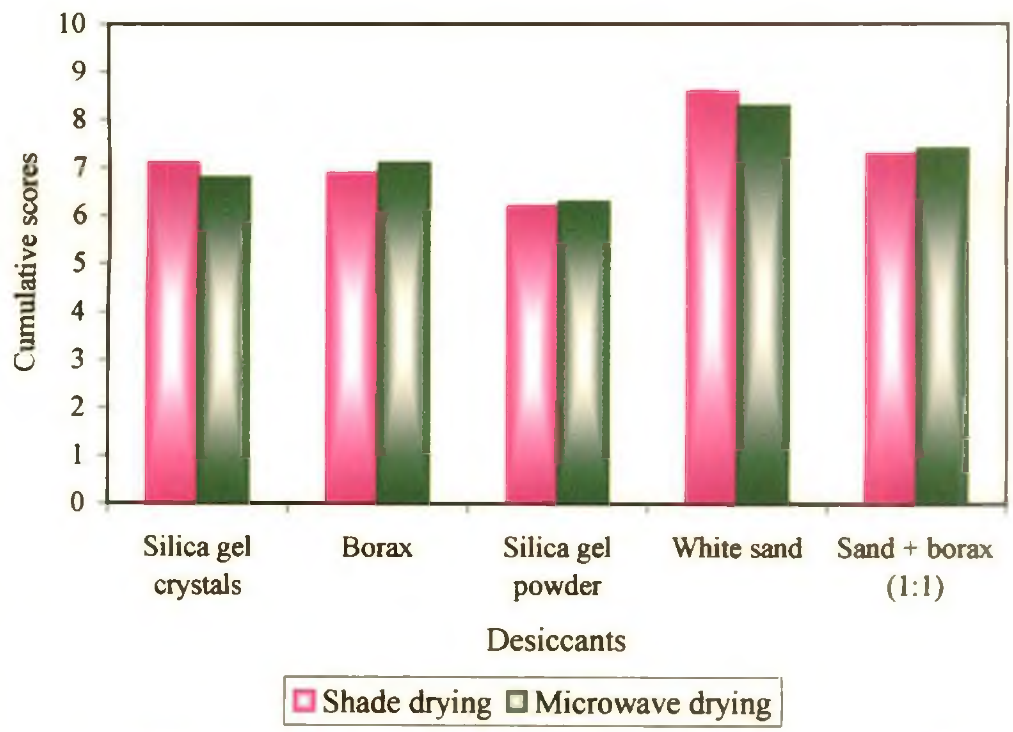

Fig. 4. Effect of desiccants on cumulative aesthetic and visual quality scores of aster after drying

followed by sand + borax in the ratio 1:1 with a cumulative score of 7.3 to 7.4. Lowest cumulative score (6.2 to 6.3) was recorded for flowers embedded in silica gel powder (Fig.4). Dried flowers had a dull appearance.

4.1.3 Gerbera

Data on the effect of different drying methods and stage of harvest on gerbera are given in Tables 8 and 9.

4.1.3.1 Percentage weight loss

Water loss expressed as percentage during drying of gerbera flowers at various intervals of time are given Table 8.

Shade drying

The weight loss of gerbera flowers at various stages of harvest was statistically on par for 4^{th} and 5^{th} day of drying under shade conditions.

Microwave oven drying

Data on the water loss recorded at all the four stages of harvest on 6^{th} and 7^{th} minute of drying in a microwave oven were statistically on par.

Hot air oven drying

Gerbera flowers dried in a hot air oven for 8 hours and 10 hours recorded almost same weight loss and were on par.

Silica gel drying

Maximum reduction in the moisture content was noticed on the 4^{th} day of drying at all the stages of harvest and this was on par with the third day of drying.

Sun drying

The amount of moisture loss recorded on the 2^{nd} day of drying was on par with that on the 3^{rd} day of drying.

Table 8. Weight loss during drying of gerbera

Drying method	Stage of harvest	Percentage weight loss after drying					Mean
		1 day	2 days	3 days	4 days	5 days	
Shade drying	Tight bud	27.43 ^{d}	46.76 ^{c}	59.59 ^{b}	70.83 ^{a}	72.15 ^{a}	55.35
	Half bloom	32.63 ^{d}	53.75 ^{c}	62.97 ^{b}	73.38 ^{a}	74.72 ^{a}	59.49
	Full bloom	30.77 ^{c}	61.53 ^{b}	66.35 ^{b}	75.74 ^{a}	77.35 ^{a}	62.35
	Over bloom	34.65 ^{b}	61.38 ^{a}	66.12 ^{a}	75.65 ^{a}	78.54 ^{a}	63.27
		1 min	2 min	3 min	4 min	5 min	Mean
Micro-wave oven drying	Tight bud	61.56 ^{d}	68.24 ^{c}	76.87 ^{b}	83.17 ^{a}	84.29 ^{a}	74.83
	Half bloom	60.28 ^{d}	63.35 ^{c}	76.85 ^{b}	81.06 ^{a}	82.14 ^{a}	72.74
	Full bloom	60.12 ^{d}	70.30 ^{c}	78.07 ^{b}	82.63 ^{a}	83.00 ^{a}	74.82
	Over bloom	62.39 ^{c}	71.03 ^{b}	79.17 ^{a}	82.30 ^{a}	82.89 ^{a}	75.56
		2 hrs	4 hrs	6 hrs	8 hrs	10 hrs	Mean
Hot air oven drying	Tight bud	36.59 ^{d}	48.52 ^{c}	61.35 ^{b}	69.81 ^{a}	71.32 ^{a}	57.52
	Half bloom	27.77 ^{d}	45.10 ^{c}	58.69 ^{b}	70.71 ^{a}	72.14 ^{a}	54.88
	Full bloom	32.79 ^{d}	50.78 ^{c}	65.84 ^{b}	72.52 ^{a}	73.69 ^{a}	59.12
	Over bloom	36.25 ^{d}	53.72 ^{c}	66.41 ^{b}	74.82 ^{a}	75.64 ^{a}	61.37
		1 day	2 days	3 days	4 days	Mean	
Silica gel drying	Tight bud	55.47 ^{c}	62.75 ^{b}	72.93 ^{a}	73.90 ^{a}	66.26	
	Half bloom	62.38 ^{b}	66.82 ^{b}	75.70 ^{a}	76.69 ^{a}	70.40	
	Full bloom	59.89 ^{c}	67.19 ^{b}	75.82 ^{a}	76.92 ^{a}	69.96	
	Over bloom	59.27 ^{b}	64.92 ^{b}	74.08 ^{a}	75.94 ^{a}	68.55	
		1 day	2 days	3 days	Mean		
Sun drying	Tight bud	65.48 ^{b}	68.99 ^{a}	70.31 ^{a}	68.26		
	Half bloom	68.66 ^{b}	72.73 ^{a}	73.97 ^{a}	71.79		
	Full bloom	69.83 ^{b}	76.20 ^{a}	77.69 ^{a}	74.57		
	Over bloom	71.78 ^{b}	77.66 ^{a}	78.44 ^{a}	75.96		

4.1.3.2 *Time taken for perfect drying*

The time taken for drying varied from 6 minutes (microwave oven drying) to 4 days (shade drying). The flowers took 2 days in sun and 3 days under silica gel drying while 8 hours in a hot air oven for perfect drying.

4.1.3.3 *Aesthetic and visual scores after drying*

The scores for aesthetic and visual quality characters, namely, brightness, brittleness and colour change of gerbera flowers under different methods of drying and stages of harvest are presented in Table 9 and Fig.5.

Shade drying

The scores for brightness due to shade drying ranged from 1.4 (tight bud stage) to 2.0 (full bloom stage). Over bloom stage and half bloom were rated to have moderate brightness with scores 1.8 and 1.5, respectively.

Scores for brittleness of gerbera flowers ranged from 1.1 to 1.5. Full bloom flowers scored the maximum (1.5) for brittleness whereas tight bud stage the minimum (1.1).

Gerbera flowers after shade drying were rated to have lower colour change (2.9) in the full bloom stage and medium colour change (2.6) at half bloom stage. Colour change (1.3) was rated as high at tight bud stage and as medium (1.6) when dried at over bloom stage and as low (2.9) when dried at full bloom stage.

Sun drying

Brightness was rated as poor in sun drying of gerbera with scores from 0.8 to 1.3 at on all the four stages. The brightness for tight bud, half bloom, full bloom and over bloom stages were rated as 0.8, 1.2, 1.3 and 1.1, respectively.

Brittleness was rated as low to little in gerbera flowers harvested at different stages. Among the four stages, brittleness was maximum (1.4) at full bloom stage and minimum (0.9%) at tight bud stage.

The scores for colour change due to sun drying ranged between 1.0 and 1.7. Full bloom flowers were rated for medium colour change (.17) while half bloom, over bloom and tight bud stages also were rated for lower colour change with scores 1.5, 1.1 and 1.0, respectively.

Silica gel drying

The brightness of flowers due to silica gel drying had scores from 1.1 to 1.6 and was rated as poor to medium. The rating was medium at full bloom and half bloom (1.6, each) stages. It was poor at tight bud stage (1.1) and moderate at over bloom stage (1.5).

The brittleness of gerbera flowers due to silica gel drying was rated low at all the four stages of harvest. Full bloom flowers recorded the maximum score (1.4) followed by half bloom and overbloom stages (1.3). Brittleness was rated as minimum (0.9) at tight bud stage.

Colour change was rated as medium to high with scores ranging from 1.0 (tight bud stage) to 1.9 (full bloom stage). The colour change was rated as medium at half bloom and over bloom stages with scores 1.6 and 1.7, respectively.

Hot air oven drying

Brightness of gerbera flowers was rated as good (full bloom stage) to medium (tight bud, half bloom and over bloom stages). The rating for brightness at full bloom stage was 2.6 and at tight bud, half bloom, over bloom stages as 1.7, 2.3 and 2.2, respectively.

The scores for brittleness was moderate in all the four stages and ranged from 1.6 to 2.4. Maximum score (2.4) was observed at full bloom stage, followed by half bloom stage (2.2).

The colour change due to hot air oven drying was rated as moderate to high. It was moderate at full bloom and over bloom stages with scores 1.9 and 1.6, respectively. Tight bud stage was rated to have high colour change (1.3).

Table 9. Aesthetic and visual quality of gerbera flowers under different methods of drying and stages of harvest

Drying methods	Drying time	Stage of harvest	Scores for aesthetic parameters			Cumulative score
			Brightness	Brittleness	Colour change	
Shade drying	4 days	Tight bud	1.4	1.1	1.3	2.8
		Half bloom	1.5	1.2	2.6	5.3
		Full bloom	2.0	1.5	2.9	6.4
		Over bloom	1.8	1.2	1.6	4.6
Sun drying	2 days	Tight bud	0.8	0.9	1.0	2.7
		Half bloom	1.2	1.3	1.5	4.0
		Full bloom	1.3	1.4	1.7	4.4
		Over bloom	1.1	1.2	1.1	3.4
Silica gel drying	3 days	Tight bud	1.1	0.9	1.0	3.0
		Half bloom	1.6	1.3	1.6	4.5
		Full bloom	1.6	1.4	1.9	4.9
		Over bloom	1.5	1.3	1.7	4.5
Hot air oven drying	8 hours	Tight bud	1.7	1.6	1.3	4.6
		Half bloom	2.3	2.2	1.7	6.2
		Full bloom	2.6	2.4	1.9	6.9
		Over bloom	2.2	2.1	1.6	5.9
Microwave oven drying	6 min	Tight bud	1.5	1.3	1.1	3.9
		Half bloom	2.4	2.0	2.6	7.0
		Full bloom	3.0	2.2	3.3	8.5
		Over bloom	2.2	2.2	2.1	6.5

Scores:			
0.0-0.4	Very poor	Very low	Complete
0.5-1.4	Poor	Low	High
1.5-2.4	Moderate	Moderate	Medium
2.5-3.4	Good	High	Little
3.5-4.0	Excellent	Very high	No change

Microwave oven drying

Among the different stages of harvest of gerbera flowers subjected to microwave oven drying rating was good at full bloom stage (3.0) while it was moderate for brightness at half bloom, over bloom and tight bud stages with scores of 2.4, 2.2 and 1.5, respectively.

The scores for brittleness varied from 1.3 to 2.2. Brittleness was rated as moderate at half bloom (2.0), full bloom and over bloom (2.2) stages. The score for brittleness was rated as low (1.3) at tight bud stage.

The colour change was rated as low to high. The full bloom stage and half bloom stage were rated for low colour change (3.3 and 2.6, respectively). Medium colour change (2.1) was observed when the flowers were dried at full bloom stage and high (1.1) when dried at tight bud stage.

4.1.3.4 Comparison of cumulative, aesthetic scores

Data pertaining to cumulative, aesthetic and visual quality scores under different methods of drying and the stages of harvest in gerbera are given in Table 9 and Fig.5.

Full bloom flowers recorded exceptionally high cumulative scores (4.4 to 8.5) in all methods of drying, compared to other stages of harvest. This stage was followed by half bloom stage (4.0 to 7.0). The lowest cumulative score was recorded at tight bud stage.

Among the drying methods, highest cumulative score (8.5) was recorded in microwave oven drying followed by hot air oven drying (6.9) and shade drying (6.4).

4.1.3.5 Effect of desiccants

Data on the effect of various desiccants on the aesthetic quality of gerbera flowers after microwave oven drying are given in Table 10 and Fig.6.

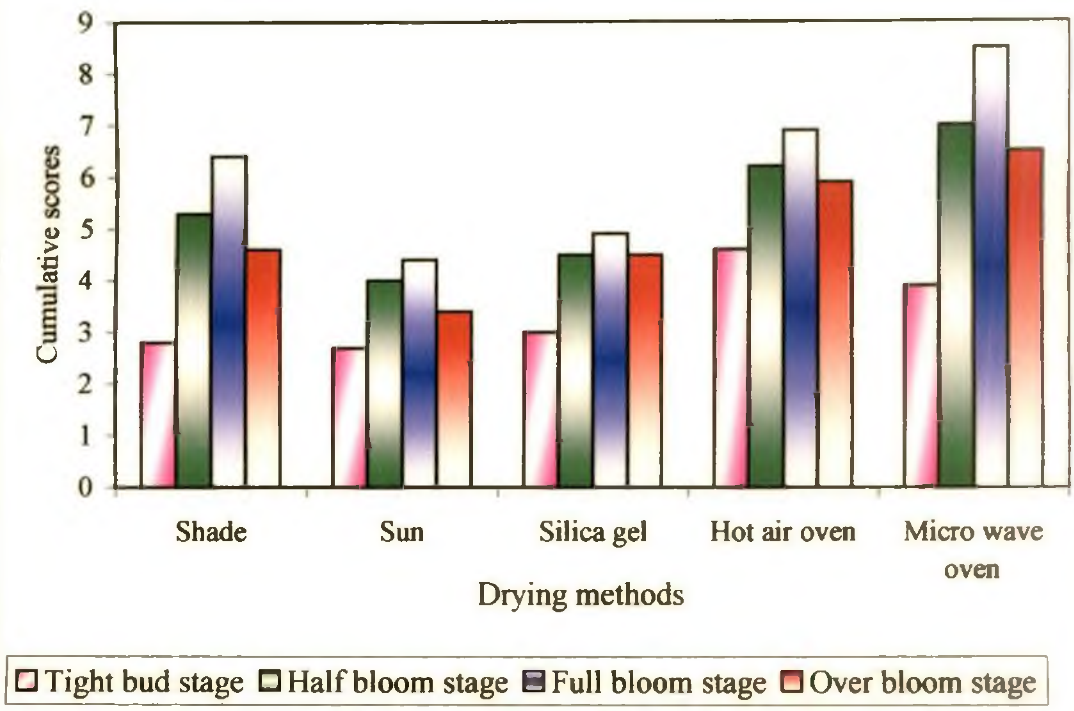

Fig. 5. Cumulative aesthetic and visual quality scores of gerbera under different methods of drying and stages of harvest

Among the desiccants, fine clean white sand (Plate 1) recorded the highest cumulative score (8.5) for all visual and aesthetic qualities, viz., brightness (3.0), brittleness (2.2) and colour fading (3.3) characters for embedding flowers. The flowers retained colour and shape on drying and quality of the product was excellent. This was followed by the desiccant, sand + borax in the ratio 1:1 with a cumulative score of 6.8. All the quality parameters were rated as medium. Appearance of the flowers was good, but colour change could be noticed.

The quality parameters such as brightness, brittleness and colour change were rated as moderate for flowers embedded in silica gel crystals with scores of 1.8, 1.8 and 2.0, respectively. The petals shrivelled on drying and the appearance was not appealing.

The brightness due to borax was rated as moderate with a score of 2.1, while brittleness was rated as low (1.2). The flowers were rated to have lower colour change with a score of 3.4 and cumulative score on aesthetic parameters was 6.7. Though the flowers retained colour, shape was not good.

Gerbera flowers embedded in silica gel powder were rated to have medium brightness (1.6), low brittleness (1.4) and medium colour change (1.9). The cumulative score was less (4.9) when compared to other desiccants. The dried flowers had a dull appearance.

4.2 STANDARDISATION OF BLEACHING TECHNOLOGY

Bleaching agents, viz., hydrogen peroxide, sodium hypochlorite and calcium hypochlorite were tried at different concentrations and observations recorded on colour removal level, brittleness of flower, damage to plant part, etc. are presented in Table 11 and 12.

4.2.1 Effect of bleaching chemicals on celosia

4.2.1.1 Extent of colour removal over time

Data on the extent of colour removal by different chemicals during bleaching taken at one hour interval are presented in Table 11.

Table 10. Effect of desiccants on drying of gerbera

Method of drying : Microwave oven
Stage of harvest : Full bloom
Drying time : 6 minutes
Setting time : 15 minutes

Desiccants	Scores for aesthetic parameters			Cumulative score	Appearance of flowers
	Brightness	Brittleness	Colour change		
Silica gel crystals	1.8	1.8	2.0	5.6	Quality moderate, petals shrivelled
Borax	2.1	1.2	3.4	6.7	Low colour change, quality not good
Silica gel powder	1.6	1.4	1.9	4.9	Dull appearance
Fine clean white sand	3.0	2.2	3.3	8.5	Retained colour and shape, quality excellent
Sand + borax (1:1)	2.4	2.0	2.4	6.8	Quality good, slight colour change

Scores:			
0.0-0.4	Very poor	Very low	Complete
0.5-1.4	Poor	Low	High
1.5-2.4	Moderate	Moderate	Medium
2.5-3.4	Good	High	Little
3.5-4.0	Excellent	Very high	No change

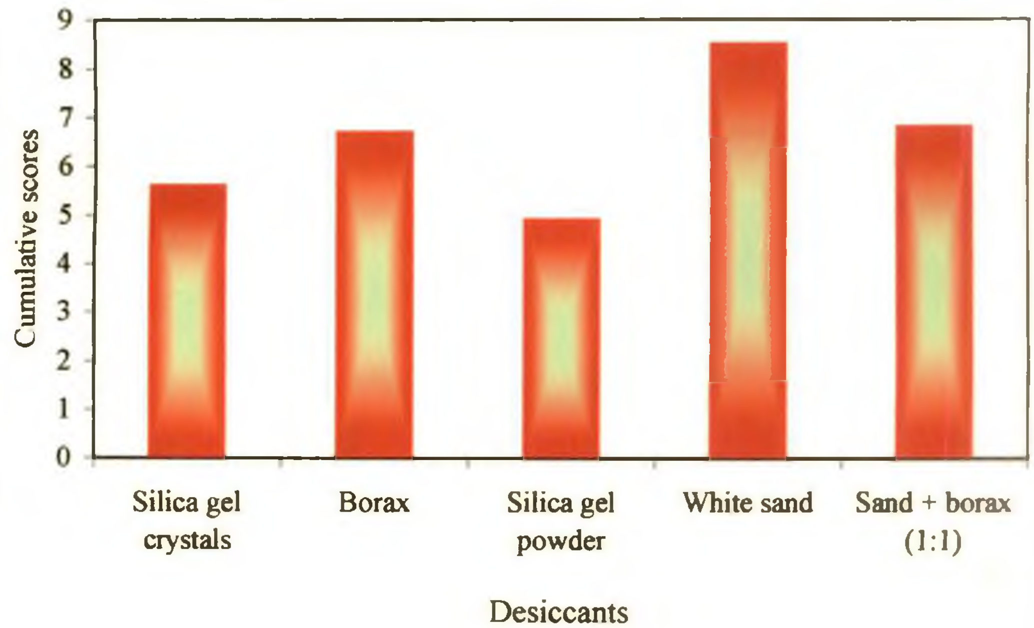

Fig. 6. Effect of desiccants on cumulative aesthetic and visual quality scores of gerbera after microwave oven drying

Shortest bleaching time (6 hrs) was observed in hydrogen peroxide 30 per cent solution and longest time (17 hrs) in calcium hypochlorite 3 per cent solution. Flowers immersed in hydrogen peroxide 10 and 20 per cent solutions took 8 and 7 hours, respectively, for effective bleaching. Among the different concentration of sodium hypochlorite tried, flowers immersed in 15 per cent solution took the shortest time (14 hrs) and in 5 per cent solution the longest time (16 hrs) for bleaching.

4.2.1.2 Brittleness of plant part

All the three concentrations of hydrogen peroxide recorded moderate scores for brittleness (1.7 for 10%, 1.9 for 20% and 2.2 for 30%).

The scores for brittleness of celosia flowers ranged from 1.6 to 1.7 in different concentrations of sodium hypochlorite. All the three concentrations recorded moderate brittleness (1.6, each, for 5% and 10% and 1.7 for 15%).

Calcium hypochlorite bleaching gave low brittleness to celosia flowers with scores ranging from 1.1 to 1.3. Among the 3 concentrations, bleaching at 5 per cent concentration gave the maximum score (1.3) for brittleness (Table 12).

4.2.1.3 Bleaching quality of plant part

The scores for the bleaching quality of celosia flowers ranged from 2.4 to 3.2 when hydrogen peroxide was used as bleaching agent. Bleaching quality was rated as high when hydrogen peroxide was used at 20 and 30 per cent concentrations (2.7 and 3.2, respectively) and as moderate (2.4) when used at 10 per cent concentration.

All the three concentrations of sodium hypochlorite recorded moderate scores (1.8 for 5%, 1.9 for 10% and 2.1 for 15%).

Bleaching quality was poor at all the concentrations of calcium hypochlorite with scores ranging from 1.0 to 1.3 (Table 12).

Table 11. Percentage of colour removal level by different chemicals over time (hrs) on celosia flowers

Bleaching agent	Concent-ration (%)	Percentage colour removal by chemicals over time (hrs)																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Hydrogen peroxide	10	5	15	40	55	80	95	98	100									
	20	5	30	50	70	85	95	100										
	30	15	40	60	90	95	100											
Calcium hypochlorite	3	5	15	20	35	40	50	55	65	70	75	85	87	91	92	94	96	100
	4	5	10	25	30	30	40	60	60	65	65	70	72	80	86	95	100	
	5	10	10	30	40	45	65	70	75	85	88	90	92	94	98	100		
Sodium hypochlorite	5	-	5	5	10	25	35	45	50	54	60	62	75	80	85	90	100	
	10	-	5	5	10	20	35	45	60	75	80	85	88	95	98	100		
	15	5	5	10	15	30	40	50	70	85	88	90	95	98	100			

Table 12. Effect of bleaching agents on celosia

Name of chemical	Concent-ration (%)	Time for bleaching (hrs)	Time for drying (hrs)	Scores for aesthetic parameters			Cumulative score
				Brittleness	Quality	Damage	
Hydrogen peroxide	10 20 30	8 7 6	11 12 12	1.7 1.9 2.2	2.4 2.7 3.2	2.5 3.0 3.1	6.6 7.6 8.5
Sodium hypochlorite	5 10 15	16 15 14	10 11 11	1.6 1.6 1.7	1.8 1.9 2.1	1.5 1.6 2.0	4.9 5.1 5.8
Calcium hypochlorite	3 4 5	17 16 15	11 11 12	1.2 1.1 1.3	1.0 1.1 1.3	1.2 1.2 1.4	3.4 3.4 4.0

Scores:				
	0.0-0.4	Very poor	Very low	Complete
	0.5-1.4	Poor	Low	High
	1.5-2.4	Moderate	Moderate	Medium
	2.5-3.4	Good	High	Little
	3.5-4.0	Excellent	Very high	No change

4.2.1.4 Damage to plant part

All the three concentrations recorded slight damage scores when hydrogen peroxide was used as the bleaching agent (2.5 for 10%, 3.0 for 20% and 3.1 for 30%).

Damage to plant part was rated as moderate (1.5 to 2.0) at all concentrations of sodium hypochlorite.

High damage to plant part was rated under all the concentrations of calcium hypochlorite and the scores ranged from 1.2 to 1.4 (Table 12).

4.2.1.5 Comparison of cumulative quality scores after bleaching

Data on the cumulative quality scores of flowers after bleaching using different chemicals are presented in Table 12 and Fig.6.

Among the bleaching chemicals, highest cumulative score (8.5) was recorded in hydrogen peroxide 30 per cent solution (Plate 2). This was followed by 20 per cent (7.6) and 10 per cent (6.6) hydrogen peroxide solution. Sodium hypochlorite 15 per cent solution came next which bleached the flower with a cumulative score of 5.8.

4.3 DYEING

The results of the studies on the standardisation of dyeing technology in celosia are given in Table 13 and Plate 3.

4.3.1 Colour take

Data on the effect of concentration and time of immersion in different dyes on colour take by bleached celosia are given in Table 13.

Among the different colour groups, Vat colour group of dyes were found superior as the ratings for different concentrations and timings were high. This was followed by Procion and Direct colour groups.

Plate 1. Drying

Plate 2. Bleaching

Plate 3. Dyeing

Table 13. Colour take of bleached celosia flowers as influenced by concentration and time of immersion in different dyes

Colour group	Name of the dye	Colour take due to concentration and time of immersion (scores)								
		0.1%			0.2%			0.3%		
		5 min	10 min	15 min	5 min	10 min	15 min	5 min	10 min	15 min
Acid	Acid Violet	1.3	1.4	1.6	1.6	2.1	2.2	1.7	2.1	2.3
	Acid Orange	1.7	1.8	2.1	2.1	2.2	2.5	2.4	2.5	2.5
Base	Fast Orange	1.1	1.3	1.4	1.3	1.9	2.0	1.9	2.1	2.2
	Fast Yellow	1.7	1.9	2.0	2.0	2.2	2.4	2.4	2.6	2.7
Direct	Green	1.6	1.7	1.8	1.8	2.0	2.3	1.8	2.4	2.3
	Brown MR	1.5	1.5	1.6	1.8	1.9	2.1	2.3	2.5	2.6
	Swiss Pink	1.8	1.9	2.1	1.9	2.3	2.4	2.2	2.5	2.5
Procion	Red H8B	1.4	1.6	1.7	1.9	2.1	2.2	2.0	2.2	2.8
	Blue H2R	1.3	1.5	1.7	1.5	2.0	2.3	2.2	2.4	2.6
Vat	Methylene Blue	2.3	2.5	2.5	2.2	2.7	2.8	2.9	3.2	3.4
	Auromine Yellow	2.3	2.4	2.7	2.2	2.4	2.7	2.7	3.0	3.3
	Basic Rhodamine	3.0	3.1	3.1	3.1	3.3	3.4	3.5	3.6	3.7

Scores:

Very low	:	0.0-0.4
Low	:	0.5-1.4
Moderate	:	1.5-2.4
High	:	2.5-3.4
Very high	:	3.5-4.0

The scores for 10 and 15 minutes under 0.2 per cent and 5, 10 and 15 minutes under 0.3 per cent were almost equal in all groups of dyes evaluated, except Basic Rhodamine under Vat group and Red H8B and Blue H2R under Procion group.

Under Vat group, colour take by celosia in Basic Rhodamine was rated as high at 10 and 15 minutes immersion (3.6 and 3.7, respectively) with 0.3 per cent concentration, followed by Methylene Blue (3.2 and 3.4, respectively) and Auromine Yellow (3.0 and 3.3, respectively). The colour take was rated as moderate to high under 10 and 15 minutes immersion with 0.3 per cent solution of Red H_8B and Blue H_2R under Procion group and Brown MR and Swiss Pink under Direct group. The colour uptake was rated as low in Base and Acid group of dyes.

4.3.2 Colour fading

Data on the level of colour fading on storage of dyed celosia is presented in Table 14.

Among the different colour groups, Vat group dyes recorded low colour fading on storage. This was followed by Procion and Direct group dyes.

The level of colour fading on storage was low to very low with all the dyes under Vat group. Under the Vat group colour fading was rated as very low for Basic Rhodamine with scores ranging from 3.0 to 3.6. Methylene Blue and Auromine Yellow were also rated as low colour fading on storage. Procion dyes (Red H_8B and Blue H_2R) also recorded moderate to low scores on colour fading on storage. The colour fading was fast in Fast Orange and Fast Yellow under Base group.

4.4 PACKING AND STORAGE

Data on the results of the studies on the standardization of packing techniques in dried flowers namely, celosia, aster and gerbera, are given in Tables 15 to 17.

Table 14. Level of colour fading on storage of dyed celosia flowers

Colour group	Name of the dye	Level of colour fading on storage due to concentration and time of immersion (scores)								
		0.1%			0.2%			0.3%		
		5 min	10 min	15 min	5 min	10 min	15 min	5 min	10 min	15 min
Acid	Acid Violet	1.3	1.4	1.5	1.8	2.0	2.1	1.6	2.1	2.4
	Acid Orange	1.9	1.8	2.0	2.2	2.3	2.8	2.9	2.9	3.0
Base	Fast Orange	1.2	1.3	1.3	1.2	1.3	1.4	1.4	1.8	2.1
	Fast Yellow	1.1	1.4	1.4	1.4	1.6	1.8	1.8	1.9	1.9
Direct	Green	1.3	1.4	1.4	1.5	1.8	2.0	1.5	1.9	2.0
	Brown MR	1.3	1.4	1.6	1.6	1.9	2.0	2.3	2.4	2.7
	Swiss Pink	1.6	1.6	1.7	1.9	2.1	2.3	2.0	2.3	2.4
Procion	Red H8B	1.8	1.9	2.0	2.0	2.1	2.5	2.5	2.7	3.3
	Blue H2R	1.2	1.4	1.6	1.5	2.0	2.2	2.1	2.4	2.5
Vat	Methylene Blue	2.3	2.6	2.6	2.4	2.8	2.9	2.8	3.0	3.4
	Auromine Yellow	2.3	2.4	2.8	2.4	2.5	2.7	2.6	3.0	3.3
	Basic Rhodamine	3.0	3.2	3.2	3.3	3.3	3.5	3.4	3.6	3.6

Scores:
Very high : 0.0-0.4
High : 0.5-1.4
Moderate : 1.5-2.4
Low : 2.5-3.4
Very low : 3.5-4.0

4.4.1 Celosia

The dyed celosia flowers were packed in corrugated boxes after covering with different lining materials and the observations recorded are presented in Table 15.

Effect of lining materials on the level of colour fading on storage of dyed celosia flowers was evident in flowers dyed with Procion group dyes. The colour fading on storage was rated as medium for flowers packed in cardboard boxes without lining.

The level of colour fading on storage was low for flowers dyed with Vat colours, when packed in cardboard boxes. The lining materials did not influence the colour fading character during storage.

4.4.2 China aster / aster

Data on the effect of storage conditions on the aesthetic quality of dehydrated aster flowers are given in Table 16.

The level of colour fading was rated as low to medium under all storage conditions, 10 days after storage. Colour fading was rated as medium for flowers wrapped by newspaper (2.2), tissue paper (2.4) and control (2.0). Flowers packed in air tight containers, wrapped by newspaper and inserted in polythene covers were also rated as low colour fading (2.8, 2.7 and 2.9, respectively) on storage.

After 20 days of storage, colour fading was rated as high under all the storage conditions. Dropping of petals was also noticed.

4.4.3 Gerbera

Data on the effect of storage conditions on the quality of dehydrated gerbera flowers are given in Table 17.

Table 15. Effect of lining materials on colour fading of dyed celosia flowers during storage

Lining material	Colour group	Name of the dye	Level of colour fading on storage due to concentration and time of immersion (scores)					
			0.2%			0.3%		
			5 mts	10 mts	15 mts	5 mts	10 mts	15 mts
Inserting in polythene covers	Vat	Methylene Blue	2.6	2.6	2.8	2.9	3.1	3.2
		Basic Rhodamine	3.0	3.2	3.3	2.6	2.9	3.1
		Auromine Yellow	2.5	2.6	2.7	3.5	3.5	3.6
	Procion	Red H_8B	1.8	2.0	2.1	1.9	2.1	2.6
		Blue H_2R	1.6	2.0	2.2	2.1	2.2	2.4
Wrapping with news paper	Vat	Methylene Blue	1.8	2.3	2.4	2.6	2.8	2.9
		Basic Rhodamine	2.8	3.0	3.0	2.4	2.6	2.8
		Auromine Yellow	2.5	2.5	2.5	3.1	3.2	3.3
	Procion	Red H_8B	1.5	1.6	1.8	1.7	1.9	2.4
		Blue H_2R	1.2	1.7	1.8	1.9	1.8	2.1
Wrapping with tissue paper	Vat	Methylene Blue	2.0	2.4	2.6	2.7	3.0	3.0
		Basic Rhodamine	2.9	3.1	3.1	2.5	2.7	2.9
		Auromine Yellow	2.5	2.6	2.5	3.4	3.3	3.4
	Procion	Red H_8B	1.6	1.8	1.9	1.8	2.0	2.5
		Blue H_2R	1.5	1.8	1.9	2.0	2.1	2.5
Wrapping with cellophane sheet	Vat	Methylene Blue	2.1	2.5	2.7	2.8	3.0	3.1
		Basic Rhodamine	2.9	3.1	3.2	2.5	2.8	3.0
		Auromine Yellow	2.5	2.5	2.6	3.4	3.4	3.5
	Procion	Red H_8B	1.7	1.9	2.0	1.9	2.1	2.5
		Blue H_2R	1.5	1.8	2.1	2.1	2.2	2.6
Control (No lining)	Vat	Methylene Blue	1.6	1.9	2.2	2.5	2.6	2.8
		Basic Rhodamine	2.6	2.8	3.1	2.3	2.5	2.7
		Auromine Yellow	1.8	2.0	2.2	2.6	2.9	2.9
	Procion	Red H_8B	1.3	1.4	1.5	1.6	1.8	2.3
		Blue H_2R	1.1	1.6	1.6	1.7	1.7	2.0

* Scoring was done 30 days after storage

Table 16. Effect of storage condition on the quality of dehydrated aster flowers

Storage condition/ Lining material	Scores			Appearance of flowers
	Colour at the time of storage	Colour fading/ days after storage		
		10	20	
Cardboard boxes 1. Wrapping with news paper	3.4	2.2	0.7	Colour fading was noticed
2. Inserting in polythene covers	3.4	2.9	1.2	Colour fading was comparatively less
3. Wrapping with cellophane paper	3.4	2.7	0.8	Colour fading with dropping of petals
4. Wrapping with tissue paper	3.4	2.4	0.8	Colour fading with crinkling of petals
5. Control (without lining material)	3.4	2.0	0.4	Colour fading was maximum. Dropping of petals noticed
6. Air tight containers (without lining)	3.4	2.8	1.2	Colour retention was maximum but petals dropped

Scores:			
	0.0-0.4	Complete	Very high
	0.5-1.4	High	High
	1.5-2.4	Medium	Medium
	2.5-3.4	Little	Low
	3.5-4.0	No change	Very low

The level of colour fading 15 days after storage was rated as low under all the storage conditions. Maximum score (3.0) was observed in flowers stored in airtight containers. This was followed by flowers stored in cardboard boxes after wrapping with newspaper (2.9).

After 30 days of storage, the level of colour fading was rated as medium (2.4) in flowers packed in cardboard boxes with and without wrapping by cellophane paper. Flowers stored under all other conditions were rated to have low colour fading. Flowers stored in air tight containers retained colour and shape and the quality was excellent.

4.5 FLORAL CRAFTS

For making various floral crafts flowers, foliage, seeds and other planting material that have already been assessed were used as fillers. Eight floral crafts were made (Plate 4). The materials used in craft making is given in Appendix-I. The cost economics of 100 crafts in each category is presented in Appendix-II.

The floral crafts can be made cost effective using the locally available materials as fillers and increasing the volume of production. Silica gel crystals in small pouches may be kept, while storing the floral crafts to avoid dampness.

Table 17. Effect of storage condition on the quality of dehydrated gerbera flowers

Storage condition/ Lining material	Scores			Appearance of flowers
	Colour at the time of storage	Colour fading/ days after storage		
		15	30	
Cardboard boxes 1. Wrapping with news paper	3.3	2.9	2.6	Good with little colour change
2. Inserting in polythene covers	3.3	2.8	2.8	Good
3. Wrapping with cellophane paper	3.3	2.7	2.4	Good
4. Wrapping with tissue paper	3.3	2.8	2.7	Good
5. Control (without lining material)	3.3	2.5	2.4	Satisfactory with slight colour change
6. Air tight containers (without lining)	3.3	3.0	2.8	Retained colour and shape, quality excellent.

Scores:		
0.0-0.4	Complete	Very high
0.5-1.4	High	High
1.5-2.4	Medium	Medium
2.5-3.4	Little	Low
3.5-4.0	No change	Very low


a. Bouquet


b. Table centre


c. Basket arrangement


d. Christmas wreath

Plate 4. Floral crafts

Contd.

Plate 4. continued

e. Mirror frame

f. Greeting cards

g. Sealed container

h. *Pot pourri*

Discussion

5. DISCUSSION

Dry flower products are fast catching up as an avenue for self employment, as hobby and on a commercial scale as an industry in developed as well as developing countries. Earlier dry flowers were produced from selected plant species but now lot of forest species were used for commercial production of dry flowers. This industry has got a wide export potential and can fetch lot of foreign exchange.

Dry flower industry was brought to India by British and the trade prospered in Kolkatta because of its proximity to North Eastern and Eastern regions of Himalayas, where diverse flowers and plants are naturally available. In Kerala, the potential of dry flower industry has not been exploited so far. Hence, the present study was undertaken to develop technologies to dry, bleach and dye selected commercial flowers, namely, celosia, china aster and gerbera for commercial exploitation. The results generated are critically discussed here under five broad heads, namely, drying, bleaching, dyeing, storage and preparation of floral crafts.

5.1 DRYING

Drying is the first step in the dry flower production followed by bleaching and dyeing. Different types of drying techniques were employed like shade drying, sun drying, microwave oven drying, hot air oven drying and silica gel drying. The method of drying exerts tremendous influence on the composition of the plant tissues both at the exterior and interior. In the present investigation, flowers were harvested at various stages of maturity, viz., tight bud, half bloom, full bloom and over bloom stages and dried. The full bloom stage recorded maximum cumulative score for all visual and aesthetic qualities, namely, brightness, brittleness and colour fading characters in all the three flowers. This was followed by half bloom stage. According to Kanta and Bajpai (1978) flowers should be harvested at full bloom stage for drying. Rothenberger (2000) and Barton (1997) reported that slightly immature and full bloom stage were more amenable for processing since the cellular maturity is almost similar.

The over bloom stage lacks lustre due to seed set and on drying the brightness is reduced. Flowers at the tight bud stage shrivel on drying.

5.1.1 Shade drying

In celosia, shade drying was scoring high ratings for all the visual and aesthetic qualities. Colour retension was also good. This is in line with the findings of Roberts (1997) in cocks comb, statice, straw flowers and baby's breath and Lourdusamy (1998) in *Gomphrena*. As in *Gomphrena*, in celosia also the flower bracts are scaly and moisture content is naturally less.

Shade drying of aster took 5 days for full bloom stage. Further shade drying preserved the natural shape and colour of flowers with maximum cumulative score for visual and aesthetic quality, when embedded in fine clean white sand and hence proves to be cost effective. Fine sand has been found to be the best material for embedding because it is easy to handle, heavy and does not react with water vapour (Datta, 2001).

Gerbera flowers took 4 days for shade drying when harvested at full bloom stage, whereas celosia took only 2 days. Similar reports have been made by White *et al.* (2002). According to them fleshy flowers and foliage took more time for drying.

5.1.2 Sun drying

Sun drying is a rapid method of dehydration and it is cheap and dependant on weather (Arumugan *et al.*, 1999 and Raghupathy *et al.*, 2000). In the present study, flowers of celosia were subjected to sun drying without embedding. Hence shrinkage of petals and colour fading were high.

Flowers of aster and gerbera were sun dried after embedding in white sand. Colour fading was noticed in flowers and brightness was less. Similar reports have been made by Kher and Bhutani (1979) in marigold and Sujatha *et al.* (2001) in gerbera, zinnia and chrysanthemum.

5.1.3 Silica gel drying

Silica gel drying is unique in that when moisture is removed, the temperature factor is not involved because moisture is removed mechanically by absorption. In the present study, silica gel drying method ranked high for all cumulative aesthetic and visual quality scores, except brightness in all the flowers. Natural colour was preserved in the flowers after drying with silica gel. But a thin coating of silica gel powder noticed on the petals resulted in the reduction of brightness. The overall behaviour of flowers dried by this method was more or less similar as reported by George (1996) in sun flower, Thomler (1997) in marigold and zinnia and Alleman (1994) in celosia.

Celosia and aster flowers took 2 days and gerbera 3 days for effective drying by silica gel method. Alleman (1994) reported drying time of 3-4 days for celosia and Daffodil by this method. According to Lourdusamy *et al.* (2001) silica gel is the ideal drying agent for delicate flowers such as roses, carnation, dahlia, etc. Though the cost of silica gel is moderate, it can be reused for infinite number of times and thus renders cost effective.

5.1.4 Hot air oven drying

Embedded flowers of aster and gerbera took 6 and 8 hours, respectively, in a hot air oven at 55-60°C. Celosia also took 6 hours for drying at 55-60°C without embedding. Kher and Bhutani (1979) reported a drying time of 48 hours for gerbera and chrysanthemum at 45-49°C.

The most important advantage of this method is that drying is faster. The oven dried flowers also retained colour and shape. This is in conformity with the findings of Raju and Jayanthi (2002). According to them oven drying of aster flowers using white sand as the medium is the best for the retention of colour, shape and texture of dried flowers.

5.1.5 Microwave oven drying

In gerbera, microwave oven drying was scoring high for all visual quality scores, namely brightness, brittleness and colour fading, when dried at full bloom stage after embedding in white sand. In aster, cumulative score was the highest under shade drying, and was followed by microwave oven drying when dried at full bloom stage. Aster flowers took 4 minutes, while gerbera took 6 minutes for perfect drying. Drying time varies with the number of petals in flowers (Rothenberger, 2000). Celosia showed slight colour fading after drying in a microwave oven.

In this method, drying is exceptionally fast and gets completed within a few minutes and the quality of the product is superior. This is in line with the findings of White *et al.* (2002). They reported that microwave oven dried flowers appeared fresher and more colourful than those obtained by other methods.

The flowers have to be embedded in medium in a microwave oven safe container. The containers after taking out of the oven should be left at room temperature for a particular period so as to evaporate the moisture of the container. This is called 'setting time'. For aster and gerbera, the setting time is 15 minutes. Setting time is given for getting good appearance and colour to the flowers.

5.1.6 Effect of desiccants

In the present study, among the various desiccants used to dry aster and gerbera flowers, fine clean white sand was the best material for embedding. Flowers embedded in fine clean white sand recorded exceptionally high cumulative quality scores, namely, brightness, brittleness and colour fading characters. The dried flowers also retained colour and appearance and the quality was excellent. Fine sand has been found to be the best material for embedding because it is easy to handle, heavy and does not react with water vapour (Datta, 2001). Sand is cheap and can be reused for infinite number of times and is cost effective. Similar reports have been made by Geetha *et al.* (2001) for Indian blue water lily and Raju and Jayanthi (2002) for china aster.

According to Sujatha *et al.* (2001) sand + borax in the ratio of 1:1 was the best combination to retain brightness and colour of flowers. In the present study, aster and gerbera flowers embedded in sand + borax in the ratio 1:1 retained the appearance, but slight colour fading was noticed. When embedded in silica gel crystals, the petals shriveled on drying and all the quality parameters were rated as moderate. Contrary to this Champoux (1999) reported that silica gel is the best drying agent that dehydrates quickly the cut blooms in a week and heating the silica gel in a hot air oven ensure the reuse of it. He also recommended the use of silica gel to obtain excellent dried flowers that retain the colour and shape.

The use of borax as a desiccant for embedding delicate flowers has been reported (Prasad *et al.*, 1997; Thomler, 1997; Lourdusamy *et al.*, 2001; Sujatha *et al.*, 2001 and White *et al.*, 2002). In the present investigation, gerbera flowers embedded in borax were rated to have lower colour change (3.4), while brightness was rated as moderate (2.1) and brittleness low (1.2). The flowers retained only the colour, not the appearance. Although borax is relatively inexpensive, it should be used with caution because prolonged use of it may cause eye or skin irritation (White *et al.*, 2002).

5.2 BLEACHING

Some flower species lose their original colour after drying and become unattractive. By bleaching, the discolouration occurring during the dehydration can be removed. There are two classes of bleaches, i.e., oxidative and reductive, each with different mode of action. Oxidative bleaches (hypochlorites, chlorites and peroxides) are more successful to bleach plant tissues, since they cleave the double bonds of the coloured molecules, unlike the reductive bleaches (sulphites), thus enabling physical destruction of chromophores (Sjostrom, 1981).

In the present study, celosia alone withstood bleaching, while the flowers of aster and gerbera got damaged on soaking in bleaching agents. Hence, celosia alone was considered for bleaching and dyeing studies.

Among the three bleaches of oxidative group (hydrogen peroxide, sodium hypochlorite and calcium hypochlorite) studied on celosia, hydrogen peroxide scored high cumulative ratings in terms of brightness, brittleness and low damage to plant part. This was followed by sodium hypochlorite.

In the present study, 30 per cent hydrogen peroxide recorded highest cumulative score for brightness, brittleness and low damage to plant cells compared to 10 and 20 per cent. This is in confirmity with the findings of Lourdusamy (1998) in gomphrena.

Shortest bleaching time (6 hrs) was observed in hydrogen peroxide 30 per cent solution and longest time (17 hrs) in calcium hypochlorite 3 per cent solution. Hydrogen peroxide is less damaging to cellulose than hypochlorite. However, prolonged exposure of cellulose to peroxidase will cause cellulose chain shortening as 'peeling' (The loss of polysaccharide terminal sugar). The addition to the bleach liquor of either $Na_2S_2O_4$ or Na_2SO_3 is claimed to inhibit this reaction (Roymoulik, 1972). Hydrogen peroxide decomposes in the presence of reducing material to form a hydroxyl radical, which then decomposes to water (Sjostrom, 1981). Both peroxidases and hydroxyl radical are involved in active bleaching. They form oxiranes across double bonds, which are then further oxidised to vicinal diols and finally carboxylic acids (Edwards, 1967). Yellowing is not noticed in materials bleached with peroxidases (Gulrajani and Sukumar, 1985). In the present study also celosia flowers did not yellow with age after bleaching with hydrogen peroxide. This chemical can efficiently remove 50 per cent lignin without damaging the cellulose (Sjostrom, 1981).

Hypochlorite (sodium hypochlorite and calcium hypochlorite) bleaching resulted in yellowing and cell damage of flowers. Hence the cumulative score rating was low.

The results obtained from the present study indicate a good bleaching quality by peroxide bleaching. The flowers bleached with peroxide did not yellow with age. Hence, peroxides may be more practical because it is less expensive and readily available.

5.3 DYEING

The decorative value of the dried flower can be increased by dyeing. It also serves as a preservative and even enhances the natural look and texture of the product. Because the natural look is important to the consumer, dye colour should be kept in more natural tones and in line with seasonal consumer trends. Synthetic and natural dyes are available for dyeing. Though natural dyes are non toxic to plant cells the availability is limited. Hence, synthetic dyes are used commercially. In the study, commercial dyes used in the textile industry have been considered. There are twelve synthetic colour groups and many coloured dyes under each group. Among these, the dyes belonging to five colour groups, viz., Acid, Base, Direct, Procion, and Vat were used for the study.

Among the colour groups, Vat colour group recorded highest score for best visual and aesthetic quality in celosia when dyed after bleaching. This was followed by Procion and Direct colour groups. Dyeing using Vat and Procion dyes were brighter than those using Direct dyes owing to its simpler chemical structure and narrow absorption bands (Yogitachari, 2000).

The scores for 10 and 15 minutes under 0.2 per cent and 5, 10 and 15 minutes under 0.3 per cent were almost equal in all groups of dyes evaluated except Basic Rhodamine under Vat group and Blue H2R and Red H8B under Procion group. The Vat group of dyes might be having specific influence to interact with plant materials faster than the other colour groups.

For all the dyes, on increasing the dye concentration and the duration of soaking of the material in the dye solution, there was a substantial increase on the scores for various qualities. In most of the cases, the ratings for 10 and 15 minutes immersion were on par for colour take for dyeing. So ten minutes soaking may be followed for cost effective dyeing. Whenever score is low, the intensity of colour may be increased by increasing the concentration of the dye beyond 0.3 per cent.

The colour fastness of Vat, Procion and Direct dyes were found to be good upon storage. The level of colour fading on storage was low to very low with all dyes under Vat group, while Base colour recorded maximum colour fading.

5.4 STORAGE

Since dry flowers are made of cellulose materials of plant origin, it invites lot of pests. They are hygroscopic in nature, if allowed to absorb moisture, problem of mould infection will occur. Dry flowers are fragile and require careful handling. Selection of proper packing materials and giving proper cushioning are of prime consideration.

In the present study, the colour fading on storage was minimum in celosia flowers dyed with Vat colours, when stored in cardboard boxes sprinkled with Silica gel crystals at the bottom. The planting materials did not influence the level of colour fading on storage.

Level of colour fading on storage was high in dehydrated Aster flowers. Dropping of petals was also noticed in storage. Gerbera recorded low colour fading on storage when packed in air tight containers after sprinkling Silica gel crystals at the bottom. This is in confirmation with the findings of Champoux (1997) and Datta (2001). They could prolong the shelf life of dehydrated floral materials by storing in air tight glass /plastic jars.

5.5 FLORAL CRAFTS

Dry flowers and floral crafts have an everlasting value that can be cherished for longer periods. Apart from bouquets and flower arrangements, their flexibility enables them to make into long lasting flower pictures, flower balls, cards, festive decoration, *pot pourri*, etc. Now a days, the dry flower products are a replacement of various artificial and unnatural ways of decoration. The floral crafts given in Plate 4 can be made cost effective using the locally available materials as fillers and increasing the volume of production. Bleaching chemicals can be repeatedly reused and the dye solution can be fully utilized. From the benefit cost analysis, it has been observed that there is quite high margin of profit in this venture. The products of dry flowers is fast catching up as an avenue for self employment, as hobby and on a commercial scale as an industry in developed as well as in developing countries.

Silica gel crystals in small pouches may be kept while storing the floral crafts to avoid dampness. Floral crafts require polythene lining to protect from humidity and insect pests.

The foregoing discussion on the results generated from the present studies indicated the suitability of celosia, aster and gerbera in dry flower industry. Dry flower industry shows great opportunity to rural areas and cottage industries.

In Kerala the potential of dry flower industry has not been exploited so far. Kerala being a humid tropical high rainfall zone, diversity in plant species is quite high. Thus, there is an imperative need to identify tropical plant species/materials suitable for dry flower production and to develop techniques to dry, bleach and dye flowers and other plant materials for commercial exploitation. Along with dry flower industry, there is ample scope for development of a number of subsidiary industries like preparation of baskets, paper, ribbon, metal and packaging for dry flowers and floral crafts. Thus this industry as a whole can contribute immensely to area development which in turn lead to the overall development of the nation.

Summary

6. SUMMARY

Investigations on developing technology for production of dry flowers were carried out during 2001-2003 at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara. The objectives were to assess the suitability of selected commercial flowers, namely, celosia, china aster and gerbera for dry flower production and to develop technologies to dry, bleach and dye flowers for commercial exploitation. Four stages of harvest, namely, tight bud, half bloom, full bloom and over bloom stages were assessed under each flower to standardise the optimum stage at which drying is perfect to retain, colour, shape and visual quality at its best. The salient findings of the study are summarised below:

The highest cumulative score for all visual and aesthetic qualities, viz., brightness, brittleness and colour fading characters, were recorded in full bloom stage, closely followed by half bloom stage in all the three flowers. Half bloom stage (14-16 days from bud appearance) and full bloom stage (18-21 days from bud appearance) were ideal for drying, bleaching and dyeing in celosia. In china aster and gerbera also, half bloom stage (10 and 15 days, respectively from bud appearance) and full bloom stage (12 and 21 days, respectively from bud appearance) were found to be ideal for drying.

Celosia flowers took three minutes for perfect drying in a microwave oven and 8 hours in a hot air oven. It took two days for shade drying and silica gel drying whereas one day for sun drying. Shade drying of celosia proved to be cost effective with maximum cumulative visual and aesthetic qualities (8.5). This was followed by microwave oven drying (7.7) and hot air oven drying (7.0).

Aster flowers took five days for effective drying under shade and it recorded high cumulative score (8.3) for all visual and aesthetic quality parameters. This was followed by microwave oven drying (8.2) and hot air oven drying (8.0) at full bloom stage. It took four minutes in a microwave oven, eight hours in a hot air oven and three days for silica gel and sun drying.

Maximum cumulative score for all quality parameters, viz., brightness, brittleness and colour fading was recorded in aster flowers embedded in clean white sand when subjected to shade and microwave drying. The appearance of the flowers was also good. The flowers embedded in sand + borax in the ratio 1:1, showed slight colour change. When silica gel crystals were used as the embedding medium, the petals shrivelled on drying and the flowers retained only the colour in borax. The dried flowers had a dull appearance when silica gel powder was used as the drying agent and all the quality parameters are rated as moderate.

The time taken for perfect drying of gerbera flowers varied from 6 minutes (microwave oven drying) to 4 days (shade drying). The flowers took 2 days in sun and 3 days under silica gel drying while 8 hours in a hot air oven for perfect drying.

Among the drying methods, highest cumulative score (8.5) was recorded in microwave oven drying, followed by hot air oven drying (6.9) and shade drying (6.7).

Among the desiccants, gerbera flowers embedded in fine clean white sand recorded highest cumulative score for all quality parameters when dried in a microwave oven. The flowers retained colour and shape on drying.

Celosia flowers were subjected to bleaching with different bleaching agents like hydrogen peroxide, sodium hypochlorite, calcium hypochlorite. Aster and gerbera flowers gave unsatisfactory results on bleaching.

Celosia flowers immersed in hydrogen peroxide 30 per cent solution for 6 hours was found to be the best bleaching chemical and recorded maximum aesthetic and visual quality scores. Hydrogen peroxide solution at 10 and 20 per cent concentration bleached the flowers in 8 and 7 hours, respectively.

Sodium hypochlorite (15%) was recorded as the second best chemical. Here, yellowing of the flowers was noticed due to cellulose damage. It took 14 hours for bleaching at 15 per cent concentration and 13 and 12 hours, respectively, for 10 per cent solutions.

Calcium hypochlorite recorded low visual and aesthetic qualities for bleached celosia flowers. High damage to plant part was rated under all the concentrations of calcium hydrochlorite and the scores ranged from 1.2 to 1.4.

Among the different colour groups, Vat colour group of dyes was found superior as the rating for different concentrations and timings were high. This was followed by Procion and Direct colour group. Under the Vat group, Basic Rhodamine, Methylene Blue and Auromine Yellow were suitable dyes for celosia.

Dyes at 0.2 and 0.3 per cent concentrations gave high score for visual aesthetic qualities. There is no difference between immersing bleached celosia flowers in dye solution for 10 minutes and 15 minutes.

Under Procion group, Red H8B and Blue H2R and under Direct group, Brown MR and Swiss Pink recorded high score for dyeing.

Colour fading on storage was minimum in Vat colour group and fast among Base group.

The dried flowers had to be stored in dry cardboard boxes sprinkled with silica gel crystals at the bottom. The colour fading on storage was minimum in celosia flowers dyed with Vat colours and the lining did not influence the level of colour fading on storage. Effect of lining materials was evident only in flowers dyed with Procion colours.

Level of colour fading on storage was high in dehydrated aster flowers. Dropping of petals was also noticed.

Gerbera recorded low colour fading on storage when packed in air tight containers after sprinkling silica gel crystals at the bottom.

The floral crafts prepared can be made cost effective by using locally available materials and increasing the volume of production. They require polythene lining to protect from humidity and insect pest. Naphthalene balls and Silica gel pouches should be kept inside the packing to avoid insect and moisture damage.

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* Originals not seen

Appendices

APPENDIX-I

Materials used for making floral crafts

A. Plant materials

Botanical name	Common name	Part used
Acacia auriculiformis	Australian wattle	Pods
Acorus calamus	Sweet flag	Root
Artemesia sp.	Artemesia	Foliage
Asparagus plumosus	Fern asparagus	Foliage
Aster amellus	Star daisy	Flower
Bixa orellana	Anatto tree	Fruit
Caesalpinia coriaria	Divi divi	Pods
Callistemon lanceolatus	Bottle brush	Foliage
Callistephus chinensis	China aster	Flowers
Casuarina equisetifolia	Sheoah	Pods
Celosia argentia	Safed morghe	Flowers
Celosia cristata	Cocks comb	Flowers
Citrus reticulata	Orange	Peel
Cuprus sp.	Cypress	Foliage
Gerbera jamesonii	Gerbera	Flowers
Gypsophilla elegans	Baby's breath	Flowers
Helichrysum bracteatum	Straw flower	Flowers
Lagerstroemia flos-reginae	Pride of India	Pods
Limonium latifolium	Statice	Inflorescence
Limonium sinuatum	Statice	Inflorescence
Pennisetum purpureum	Napier grass	Plumes
Solidago canadensis	Golden rod	Inflorescence
Stenotaphrum secundatum	St.Augustine grass	Foliage
Thuja orientalis	Thuja	Foliage

B. Others

Mirror, plates, frame for wreath, floral blocks, satin ribbon, plastic coated ribbon, brass container, closed container, cane basket, glass paper, containers for *pot pouri*, net cloth, non iodised salt, aromatic oils, star anise, cloves

APPENDIX-II

ost of economics of floral crafts

Sl. No.	Floral crafts	Cost of production (Rs.)	Net profit (Rs.)	B/C rates
1	Basket arrangement	12500	7500	1.6
2	Table centre arrangement	20000	5000	1.3
3	Christmas wreath	6000	4000	1.7
4	Bouquet	10000	5000	1.5
5	Arrangement in sealed container	7500	5000	1.7
6	Mirror frame	7500	5000	1.7
7	Greeting cards	2000	1500	1.8
8	Pot pourri a) Glass container b) Satin sachet	 15000 4000	 7500 3000	 1.5 1.8

* Cost economics of 100 floral crafts were worked out.

DEVELOPING TECHNOLOGY FOR PRODUCTION OF DRY FLOWERS

By

PRIYESH, S.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

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Kerala Agricultural University

Department of Pomology and Floriculture

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2003

ABSTRACT

Investigations on developing technology for production of dry flowers were carried out during 2001-2003 at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara. The objectives were to assess the suitability of selected commercial flowers, namely, celosia, china aster and gerbera for dry flower production and to develop techniques to dry, bleach and dye flowers for commercial exploitation.

Four stages of harvest, namely, tight bud, half bloom, full bloom and over bloom stage were assessed under each flower to standardise the optimum stage at which drying was perfect to retain, colour, shape and visual quality at its best. Full bloom stage recorded highest cumulative score for all visual and aesthetic qualities, closely followed by half bloom stage in all the three flowers.

Celosia and aster flowers took 2 days and 5 days, respectively, for shade drying and proved to be cost effective with maximum cumulative score for visual and aesthetic qualities. This was followed by microwave oven drying and hot air oven drying.

The time taken for perfect drying of gerbera varied from 6 minutes (microwave oven drying) to 4 days (shade drying). Among the drying methods, highest cumulative score was recorded in microwave oven drying, followed by hot air oven drying and shade drying.

Among the desiccants, aster and gerbera flowers embedded in fine clean white sand recorded maximum cumulative score for all quality parameters, viz., brightness, brittleness and colour fading when dried in shade/microwave oven. The flowers retained colour and shape on drying. The dried flowers retained only the colour in borax and had a dull appearance when silica gel powder was used.

Celosia flowers immersed in hydrogen peroxide 30 per cent solution for 6 hours was found to be the best bleaching chemical and recorded maximum score for aesthetic and visual qualities. Sodium hypochlorite (15 %) took 14 hours for effective bleaching and recorded as the second best bleaching agent. Calcium hypochlorite recorded low visual and aesthetic qualities for bleached celosia flowers. Hypochlorite bleaching resulted in cellulose damage and yellowing.

Vat colour group of dyes was found good for celosia. Under the Vat group, Basic Rhodamine, Methylene Blue and Auromine Yellow were suitable. Dyes at 0.2 and 0.3 per cent concentration gave high score for visual aesthetic qualities. Immersion of celosia flowers in dye solution for 10 and 15 minutes recorded similar visual qualities.

Colour fading on storage was minimum in Vat colour group and fast among Base group. The dyed celosia flowers had to be stored in dry cardboard boxes sprinkled with silica gel crystals at the bottom. Lining materials reduced the level of colour fading on storage in celosia flowers dyed with procion colours. Level of colour fading on storage was high in dehydrated aster flowers. Gerbera recorded low colour fading on storage when packed in air tight containers after sprinkling silica gel crystals at the bottom.

The floral crafts prepared can be made cost effective by using locally available materials and increasing the volume of production. Along with dry flower industry, there is ample scope for development of a number of subsidiary industries like preparation of baskets, paper, ribbon, metal and packaging for dry flowers and floral crafts. Thus this industry as a whole can contribute immensely to area development which in turn lead to the overall development of the nation.