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Effect of different drying methods on drying characteristics of gerbera flowers

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ABSTRACT

Fresh flowers, through exquisite in their beauty, but have short life due to their highly perishable nature. The charm of flowers can be maintained and preserve for several years by employing the technology of drying. Dried flowers can be put to many beautiful and varied uses. The principle behind preservation of flowers by drying is based on quickly reducing moisture content of flowers to a point at which biochemical changes can be minimized or brought to a standstill while maintaining cell structure, petal pigment level and shape of flower. The different flowers required suitable drying method with appropriate drying parameters according to their foliage characteristics. Moreover, the dried flowers should retained their colour, shape, texture and dry matter. Gerbera (*Gerbera jamesonii Bolus ex Hook.F*) belongs to the family of Asteraceae, is most commonly used world wide as a cut flower and occupies fourth position among the top ten cut flowers. The gerbera flowers, were dried by employing different drying methods such as hot air drying at 40, 50 and 60 °C, microwave oven drying with silica gel at 50 °C, vacuum drying at 40 °C and 760 mm Hg pressure besides solar and shade drying to find out the most suitable method and drying parameters for drying. The Exponential and Page's model were tested for their validity to gerbera flowers drying. The results were drawn from drying behaviour and statistical analysis. he maximum and minimum drying time for rose flowers was observed as 5 days and 13 minutes during shade and microwave oven drying respectively. While in case of gerbera flowers the maximum and minimum drying time was found as 5 days and 25 minutes during shade and microwave oven drying respectively. The drying of both the flowers under all the treatments completely took place in the falling rate period. The drying behaviour was predicated reasonably by Exponential and Page's model. Though, from the value of coefficient of variations the Page's model was found to be best fitted. The maximum over all drying rate was found during microwave oven drying with silica gel at 50 °C which was 3.2164 %/min respectively followed by vacuum drying at 40 °C, while minimum overall drying rate was observed during shade drying. From the drying characteristics, microwave oven drying with silica gel at 50 °C followed by vacuum drying at 40 °C was found reasonably good method for quality dried produce of rose and gerbera flowers.

Keywords:Gerbare, flowers, drying method

Consumption of flowers in most countries is increasing gradually. This has resulted rapid change in floriculture sector. In India, floriculture has been associated with culture and heritage since very ancient time. Now, it is poised for a transformation owing to increase in demand for quality flowers due to urbanization, innovative technology, policy, environment etc.

Thus, there is good scope for quality cut flowers not only for local market but also for export purpose. Fresh flower is one of the main components of floriculture trade. Fresh flowers, through exquisite in their beauty, but have short life due to their highly perishable nature and available only during a particular season. Huge amount of fresh flowers is lost due to lack of proper marketing channel and some unavoidable circumstances during blooming season. The beauty and freshness of flowers can only be retained for a few days even by using suitable preservatives and chemicals. The charm of flowers can be maintained

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and preserve for several years by employing the technology of drying. Through drying, the microbial activity and aging effect come to a standstill in the absence of moisture. Therefore, such dried flowers can be stored in dry atmosphere for a very long period without loosing their appearance and decorative value.

Dried flowers are the important products of present day floriculture due to their long lasting quality, year round availability, easy handling, low transportation cost, eco friendly and suitable for subsequent flower products. The flower drying has gained scientific approach only from the last century onward. The United State of America, Japan, China and Arab countries have well organized set up for a dried floriculture product market. India is still galloping fast to compete global level in this field. With the increased popularity of plastic and fiber flowers (silk for example), many people still prefer "the real thing" preserved in a lifelike manner. Flower preservation has become a popular hobby. Flowers such as marigolds, zinnias, goldenrod, yarrow, roses and hydrangeas are readily available and the costs of additional materials needed are relatively inexpensive when compared to that of other hobbies.

Dried flower arrangements are a wonderful way to preserve flowers when fresh flowers are not available. Dried flower arrangements make memorable gifts for special friends and also a way of preserving memories of special events such as birthdays, anniversaries or weddings. Dried flowers can be put to many beautiful and varied uses such as long lasting pictures, frames, flower balls, cards, covers, pomanders, festive decoration, candles, potpourri and many other things according to one's creativity. The technique of drying the flowers has tremendous importance in social development in terms of employment generation. The principle behind preservation of flower by drying is based on quickly reducing moisture content of flowers to a point at which biochemical changes can be minimized or brought to a standstill while maintaining cell structure, petal pigment level and shape of flower. Due to this the flowers can be preserved for several seasons by retaining their colour, texture and charm. There are several methods of drying of flowers such as air drying, embedding and drying, room drying, sun drying, oven drying, vacuum drying and microwave oven drying. The different flowers required suitable drying method with appropriate drying parameters according to their foliage characteristics. Moreover, the dried flowers should retained their colour, shape, texture and dry matter.

Foliage and flowers with low moisture content, fibrous tissues, attractive shape and pattern and brightest colour are used for drying. Materials harvested during dry or summer season give excellent result (Rajeevan and Valsalakumari, 2004). Gerbera (*Gerbera jamesonii Bolus ex Hook.F*) belongs to the family of Asteraceae, is most commonly used world wide as a cut flower and occupies fourth position among the top ten cut flowers. Due to the attractive appearance, the demand of dried gerbera flowers in domestic and global market is more as compared to other flowers. Moreover, the changes occurred in quality of these flowers during drying are minimum and they retained their original bright colour for long time after drying. Organized and systematic research work on various aspects of flower dehydration technology is limited. To determine the appropriate method of drying and drying parameters for gerbera flower, a study is required to undertake. To asses the effect of various drying parameters like temperature and time of drying on the quality of dried flowers is also essential. Moreover, the efficacy of various methods of drying for commercial and domestic application is also required to study. Therefore, a study was conducted to determine appropriate method for drying for gerbera flowers

MATERIALS AND METHODS

Weighing at different time interval

Preparation of Sample

Fresh gerbera flowers, harvested at full boom stage, without any injury and compact petals were selected and procured from a nearby nursery. The new batch of freshly harvested flowers at full boom maturity was used during each drying run.

Determination of initial moisture content

The moisture content of the fresh flowers was determined by vacuum oven method (AOAC, 1995). Accordingly, three samples of flowers were dried in vacuum oven at 65 °C and 300 mm Hg pressure for 24 hours. The samples were weighed initially and after the required period of time using digital electronics balance (Mettler 360) of 0.1gm accuracy and 360 gm capacity. The moisture content on weight basis was estimated using relationship,

$$\text{M.C. (\%, wb)} = \frac{W_i - W_f}{W_i} \times 100$$

Where,

W_i = Initial weight of sample, gm

W_f = Final weight of sample, gm

Drying of Flowers

The full boom gerbera flowers, without any bruising and intact petals were dried by employing different drying methods such as hot air drying at 40, 50 and 60 °C, microwave oven drying with silica gel at 50 °C, vacuum drying at 40 °C besides solar and shade drying. The drying of flowers was done with the predecided drying parameters. Before putting the samples in drying unit, the dryer was started to attain the pre set temperature. The reduction in weight was taken regularly with increase time period with the help of electronic digital weight balance (Mettler 360) of 0.1gm accuracy and 360 gm capacity. During drying, the samples of gerbera flowers were dried from initially at about 85 % (w.b.) to 3.0 % (w.b.) moisture content respectively (Bhutani and Kher, 1979).

Drying Characteristics of Flowers

The drying characteristics of gerbera flowers in terms of variation in moisture content, weight loss, drying time, drying rate and moisture ratio with respect to time was studied for different methods of drying, considered for the study. The effects of drying temperature on the drying behaviour were also studied.

Moisture content during drying

Moisture content of gerbera and rose flowers during experiment was determined on the basis of dry matter of flowers using following expression.

$$\text{Moisture content (\%, w.b.)} = \frac{W_\theta - DM}{DM} \times 100$$

Where,

W_θ = Weight of the sample at time q, gm,

DM = dry matter of the sample, gm

Dry matter

It is the matter left after complete removal of moisture from the product. The initial moisture content of gerbera and rose flowers was determined by vacuum oven method as described earlier. The percent dry matter in sample was calculated as follow (Ranganna, 2000).

$$\text{DM (\%, dry matter)} = 100.0 - [\text{MC (\% w.b.)}]$$

Drying rate

The moisture content data recorded during experiments were analysed to determine the moisture lost by gerbera and rose flowers in particular time interval. The drying rate of the samples was then calculated by weight balance equation.

$$DR = \frac{\text{Initial weight of sample, gm - Weight of sample after time } \theta\text{, gm}}{\text{Time interval (hours) x DM (gm)}}$$

Where,

DR = Drying rate at time θ, gm of water removed / gm of DM - h

Equilibrium moisture content

Equilibrium moisture content was calculated taking any two successive observations of moisture content M_n and M_{n+1} % w.b. and their corresponding drying times t_n and t_{n+1} and fitting in the following equation (Singh *et al.*, 1986)

$$M_n = z^{\cdot} M_{(n+1)} + (1-z) M_e$$

Where,

$Z = \exp(k\Delta t)$, and $\Delta t = t_n - t_{n+1}$

M_e = equilibrium moisture content, % w.b.

The equilibrium moisture content calculated using above expression was found much above than the final moisture content and therefore the final moisture content was considered as equilibrium moisture content (Prabhanjan *et al.*, 1995).

Overall drying rate

The overall drying rate was calculated as (Kar and Gupta, 2003),

$$(\delta M/\delta t)_0 = \frac{M_i - M_f}{\Delta t}$$

Where,

$(\delta M/\delta t)_0$ = overall drying rate, % min.,

M_i = initial moisture content, % w.b.

M_f = final moisture content, % w.b.,

Δt = total drying time, min.

Moisture ratio

Moisture ratio for the individual drying experiment under each drying method was estimated using equation,

$$MR = \frac{M_i - M_e}{M - M_e}$$

Where, M_i and M are the moisture content of sample at time $\theta = 0$ and at any instant time respectively.

The following commonly used grain models were tested for their validity to rose and gerbera flower drying.

(i) Exponential model (Brooker *et al.*, 1974)
$(M - M_e) / (M_0 - M_e) = \text{Exp}(-kt)$

(ii) Page's model (Brooker *et al.*, 1974)
$MR = \text{Exp}(-kt^n)$

Where,

M = Moisture content at any instant time, % w.b.,
M_e = Moisture content at equilibrium, % w.b.,
M_0 = Initial moisture content, % w.b.
t = Time, min.,
K = Drying constant

The linerized forms of these models were fitted to the experimental data using regression techniques in Microcol origin and model constants and their statistical parameters for individual drying run were determined.

RESULTS AND DISCUSSION

Initial Moisture Content

The initial moisture content of the selected flowers was determined by vacuum oven method. Accordingly, the moisture content of gerbera flowers was found 85% (w.b.), which was dried, up to about 3.00% w.b. (Bhutani and Kher, 1979) using different drying methods.

Drying behaviour of gerbera flowers under different drying methods

The full boom gerbera flowers with bright colour were dried from about 85 to 3 % (w.b.) moisture content by different methods of drying at pre-decided temperatures. The drying behaviour of gerbera flowers under different drying methods and parameters is discussed below.

Hot air oven drying

The observations on drying under hot air oven method at different drying temperatures are presented in Table 1. From the weight loss data, it was found that the time required for gerbera flowers to reduce from initial moisture content of about 85% (w.b.) to the final moisture content of about 4.00 %(w.b.) was about 52, 32 and 23 hours at 40, 50 and 60 °C, respectively. During drying, it was observed that as the drying process commenced, the initial drying rate was higher and decreased gradually with time. The initial drying rate was found to be 0.55, 1.54, 3.50 gm/gm of dry matter-h which reduced to 0.008, 0.01 and 0.02 gm/gm of dry matter-h after 52, 32 and 23 hours when the drying was carried out in hot air oven at 40, 50 and 60 °C, respectively.

The flowers dried at 60 °C took considerably lower time to reduce the moisture content initially from 85% (w.b.) to 3.09% (w.b.). Because at higher temperature the penetration of drying front was fast as compared to lower temperature that resulted into rapid evaporation of water from the vegetative parts of flowers resulted in to higher drying rate and lesser time required for drying. The similar types of results were obtained by Cheng *et al.*, (2002) for lotus flowers, Sohn *et al.* (2003) for different cultivars of rose flowers and Pandya *et al.*, (2001) for chrysanthemum flowers. The variation in moisture content and drying rate with respect to time is shown in Fig. 1 and 2. The variation in these parameters with time was observed to be curvilinear in nature, suggested that drying proceeded under falling rate.

The observations on drying were fitted to Exponential and Page model of drying, and the predicted equations were also determined (Fig. 3-5). From the coefficient of variations, both the models were found to be

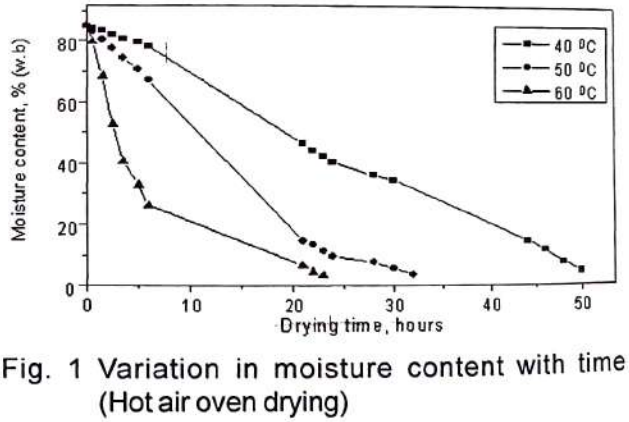

Fig. 1 Variation in moisture content with time (Hot air oven drying)

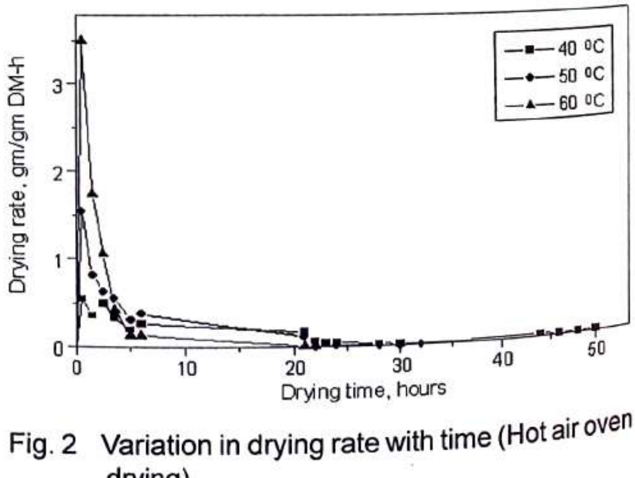

Fig. 2 Variation in drying rate with time (Hot air oven drying)

Table 1. Drying of Gerbera flowers by different methods

Sr. No.	Drying time, h	Weight of sample gm	Moisture loss gm	Cumulative weight loss,gm	M.C., % (w.b.)	Drying rate,gm/gm of dry matter-h	MR
			Hot air oven drying at 40 °C				
	0.0	10.562	0.0	0.0	85.00	0.0	1.00
1	0.5	10.131	0.431	0.431	84.38	0.550	0.99
2	1.0	9.711	0.420	0.851	83.71	0.530	0.98
3	1.5	9.402	0.309	1.160	83.17	0.390	0.98
4	2.0	9.154	0.248	1.408	82.72	0.310	0.97
5	2.5	8.764	0.390	1.798	81.95	0.490	0.96
6	3.0	8.486	0.278	2.076	81.36	0.350	0.96
7	4.0	8.221	0.265	2.341	80.76	0.340	0.95
8	5.0	7.751	0.470	2.811	79.59	0.200	0.93
9	6.0	7.328	0.423	3.234	78.41	0.270	0.92
10	8.0	6.275	1.053	4.287	74.79	0.330	0.88
11	10.0	5.182	1.093	5.380	69.47	0.350	0.81
12	12.0	4.228	0.954	6.334	62.58	0.300	0.73
13	15.0	3.527	0.701	7.035	55.15	0.150	0.64
14	18.0	3.115	0.412	7.447	49.21	0.090	0.56
15	21.0	2.949	0.166	7.613	44.35	0.110	0.53
16	24.0	2.664	0.080	7.898	39.62	0.050	0.46
17	28.0	2.483	0.181	8.079	34.29	0.030	0.41
18	32.0	2.415	0.068	8.147	28.49	0.010	0.38
19	36.0	2.179	0.236	8.383	22.40	0.040	0.30
20	40.0	2.019	0.160	8.543	17.64	0.030	0.23
21	44.0	1.851	0.168	8.711	12.53	0.020	0.14
22	48.0	1.792	0.059	8.770	07.72	0.010	0.11
23	52.0	1.741	0.051	8.821	03.93	0.008	0.09
24							
			Hot air oven drying at 50 °C				
1	0	12.646	-		85.00	0	1.00
2	0.5	11.186	1.460	1.460	83.05	1.540	0.98
3	1.0	10.422	0.764	2.224	81.81	0.800	0.96
4	1.5	9.653	0.769	2.993	80.36	0.810	0.94
5	2.0	9.125	0.528	3.521	79.22	0.560	0.93
6	2.5	8.451	0.674	4.195	77.56	0.710	0.91
7	3.0	7.958	0.493	4.688	76.17	0.520	0.89
8	4.0	7.381	0.577	5.265	74.31	0.610	0.87
9	5.0	6.488	0.893	6.158	70.78	0.310	0.83
10	6.0	5.775	0.713	6.871	67.17	0.380	0.78
11	8.0	5.012	0.763	7.634	62.17	0.200	0.72
12	10.0	4.308	0.704	8.338	55.99	0.190	0.65
13	12.0	3.655	0.653	8.991	48.13	0.170	0.55
14	15.0	2.982	0.673	9.664	36.42	0.180	0.41
15	18.0	2.415	0.567	10.231	21.49	0.100	0.23
16	21.0	2.225	0.190	10.421	14.79	0.030	0.14
17	24.0	2.101	0.044	10.545	9.76	0.025	0.08
18	28.0	2.059	0.042	10.587	7.92	0.015	0.06
19	32.0	1.969	0.042	10.677	3.71	0.010	0.01
			Hot air oven drying at 60 °C				
1	0.0	10.610	0.0	0.0	85.00	0.0	1.00
2	0.5	7.824	2.786	2.786	79.67	3.50	0.93
3	1.0	6.508	1.316	4.102	75.55	1.65	0.88

4	1.5	5.048	1.460	5.562	68.48	1.83	0.80
5	2.0	4.25	0.798	6.360	62.56	1.00	0.73
6	2.5	3.358	0.892	7.252	52.62	1.12	0.61
7	3.0	2.975	0.383	7.635	46.52	0.48	0.53
8	4.0	2.675	0.300	7.935	40.52	0.23	0.46
9	5.0	2.369	0.306	8.241	32.84	0.19	0.36
10	6.0	2.152	0.217	8.458	26.07	0.17	0.28
11	8.0	2.058	0.094	8.552	22.69	0.15	0.24
12	10.0	1.965	0.093	8.645	19.03	0.13	0.20
13	12.0	1.87	0.095	8.740	14.92	0.11	0.15
14	14.0	1.788	0.082	8.822	11.02	0.09	0.10
15	16.0	1.748	0.040	8.862	8.98	0.06	0.07
16	18.0	1.707	0.041	8.903	6.80	0.04	0.05
17	20.0	1.668	0.039	8.942	4.62	0.03	0.02
18	23.0	1.651	0.017	8.959	3.63	0.02	0.01
Vacuum oven drying at 40 °C and 760 mm vacuum							
1	0	12.294	0.0	0.0	85.00	0.0	1.00
2	0.5	10.401	1.893	1.893	82.22	2.05	0.97
3	1.0	7.628	2.773	4.666	75.76	1.50	0.89
4	2.0	5.963	1.665	6.331	68.99	0.90	0.80
5	3.0	4.696	1.267	7.598	60.63	0.69	0.70
6	4.0	3.807	0.889	8.487	51.43	0.48	0.59
7	5.0	3.200	0.607	9.094	42.22	0.33	0.48
8	6.0	2.781	0.419	9.513	33.51	0.23	0.37
9	7.0	2.057	0.724	10.237	10.11	0.11	0.09
10	8.0	1.943	0.114	10.351	4.84	0.06	0.02
Solar drying							
1	0	12.151			85.00		1.00
2	0.5	11.638	0.513	0.513	84.34	0.56	0.99
3	1.0	11.217	0.421	0.934	83.75	0.46	0.98
4	1.5	10.816	0.401	1.335	83.15	0.44	0.98
5	3.5	9.732	1.084	2.419	81.27	0.39	0.95
6	5.5	7.41	2.322	4.741	75.40	0.34	0.88
7	7.5	5.189	2.221	6.962	64.87	0.29	0.75
8	9.5	4.805	0.384	7.346	62.06	0.26	0.72
9	11.5	3.281	1.524	8.87	44.44	0.24	0.51
10	14	2.336	0.945	9.815	21.96	0.17	0.23
11	16	2.196	0.14	9.955	16.99	0.11	0.17
12	18	2.051	0.145	10.1	11.12	0.06	0.10
13	20	1.969	0.082	10.182	7.41	0.04	0.05
14	22	1.898	0.071	10.253	3.95	0.02	0.01
Microwave oven drying at 50 °C (with silica gel)							
1	0	10.952			85.00		1.00
2	5	5.375	5.577	5.577	69.43	40.73	0.81
3	10	2.994	2.381	7.958	45.12	8.70	0.51
4	15	2.245	0.749	8.707	26.82	1.82	0.29
5	20	1.931	0.314	9.021	14.91	0.57	0.15
6	25	1.722	0.209	9.230	4.59	0.31	0.02
Shade drying							
1	0	11.758			85.00		1.00
2	1	6.197	5.561	5.561	71.53	0.13	0.84
3	2	2.246	3.951	9.512	21.46	0.09	0.23
4	3	1.98	0.266	9.778	10.91	0.04	0.10
5	4	1.910	0.07	9.848	7.64	0.02	0.06
6	5	1.850	0.06	9.908	4.65	0.01	0.02

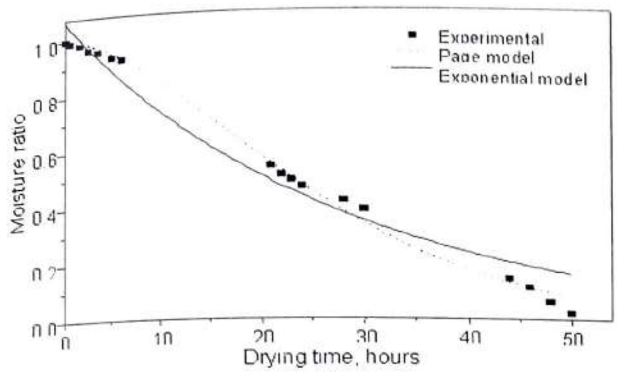

Fig. 3 Effectiveness of drying model (Hot air oven at 40 °C)

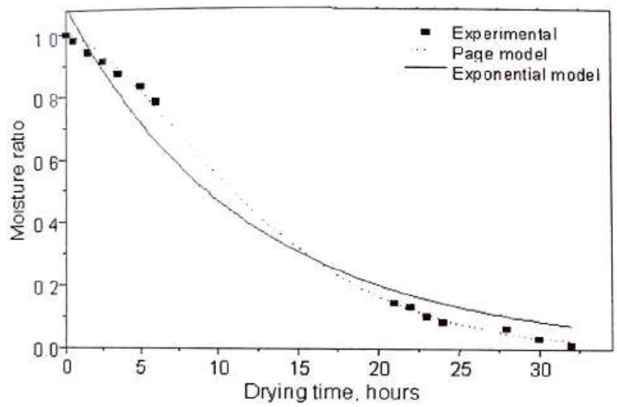

Fig. 4 Effectiveness of drying model (Hot air oven at 50 °C)

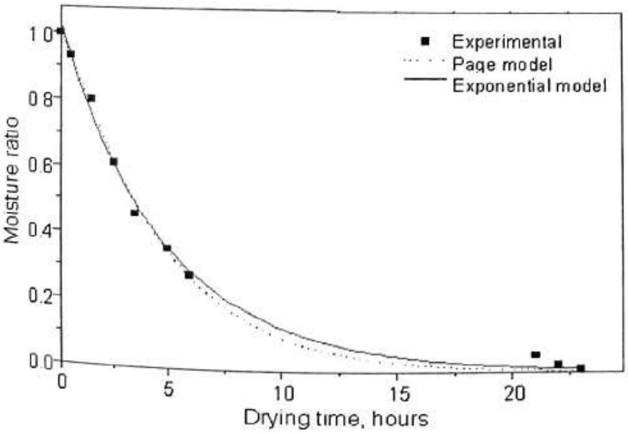

Fig. 5 Effectiveness of drying model (Hot air oven at 60 °C)

reasonably fitted, though, the Page model was observed to be more precise than Exponential model. The values of constants of Exponential as well as Page model are given in Table 2.

Vacuum oven drying

The observations on drying under vacuum oven at different drying temperatures are presented in table-1. From the weight loss data, it was found that the time required for gerbera flowers to reduce from initial moisture content to the predecided final moisture content was about eight hours at 40 °C and 760 mm Hg vacuum. The drying process was faster at the commencement of drying and decreased thereafter gradually with time. The initial drying rate was found to be 2.05 gm/gm of dry matter-h, which reduced to 0.06 gm/gm of dry matter-h at the completion of drying after eight hours.

Due to lower pressure during drying, the evaporation of moisture was rapid even at low temperature, resulting in to the fast vaporization of moisture. Therefore, during vacuum drying the time required for reducing the moisture content by the same level was much less than that of hot air oven drying. Chen *et al.* (2000) also suggested four hours vacuum drying for red rose flowers initially at 45.52 % (w.b.) moisture content, which was in line with the results obtained during experiment. The variation in moisture content and drying rate with respect to time is shown in figure 6 and 7. The variation in these parameters with time was observed to be of curvilinear pattern suggesting that drying proceeded under falling rate.

The observations on drying were fitted to Exponential and Page model of drying, and the predicted equations

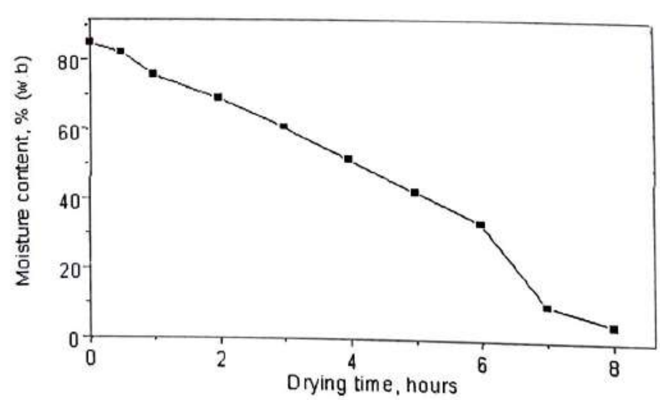

Fig. 6 Variation in moisture content with time (Vacuum oven at 40 °C)

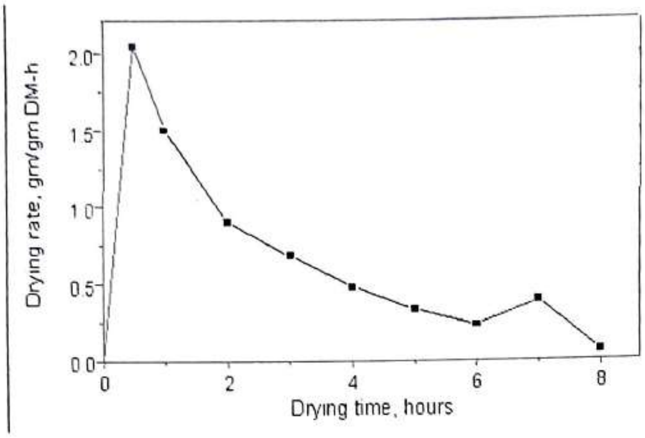

Fig. 7 : Variation in drying rate with time(Vacuum oven at 40 °C)

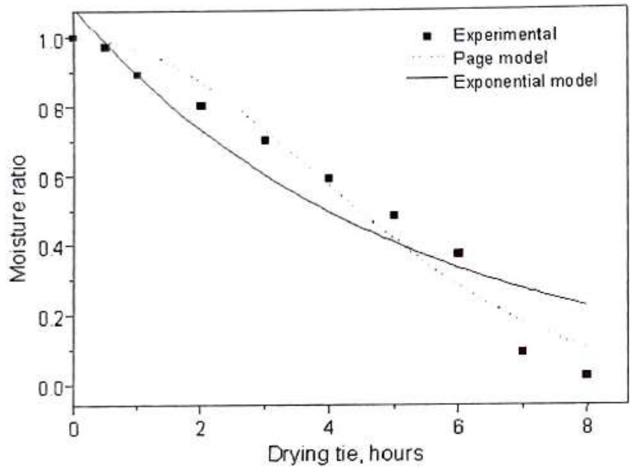

Fig. 8 Effectiveness of drying model (Vacuum oven at 40 °C)

were also determined (Fig. 8). From the value of coefficient of variations (R^2), the Page model was found to be best fitted. The values of constants of Exponential as well as Page model are given in Table 2.

Solar drying

The observations on weight loss during solar drying of gerbera flowers are presented in Table 1. From the observations, it was found that solar drying took nearly 22 hours to reduce the moisture content of gerbera flowers from about 85 to 4.00 % w.b. Drying during the initial period was faster and subsequently the rate of drying was decreasing with time. The initial drying rate was found as 0.56 gm/gm of dry matter-h, which was reduced to 0.02 gm/gm of dry matter-h after 22 hours of drying.

The drying of gerbera in solar dryer was slower as the condensation effect was observed during drying. Due to the moderate temperature inside the dryer, the rate of evaporation was slow. Moreover, the lower rate of evaporation was further diminishing due to the condensation of vapour accumulated in the free space in side the dryer. Simalemga *et al.,* (1990) reported 8 - 10 hours duration for drying of 50 kg tanacetum cinerarifolum flowers (generally harvested at lower moisture than gerbera) in solar dryer.

The variation of moisture content and drying rate with respect to time are shown in figure 9 and 10. The variation in these parameters with time was observed that drying was carried out under falling rate. The observations on drying were fitted to Exponential and Page model of drying, and the predicted equations were also determined (Fig. 11). From the coefficient of variations, both the models were found to be fitted satisfactory to the observed values. Though, from the R^2 value the Page model was found more accurate as compared to Exponential model. The values of constants of Exponential as well as Page model are given in Table 2.

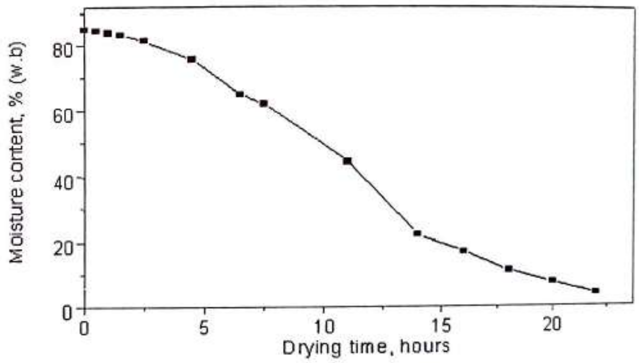

Fig. 9 Variation in moisture content with time (Solar drying)

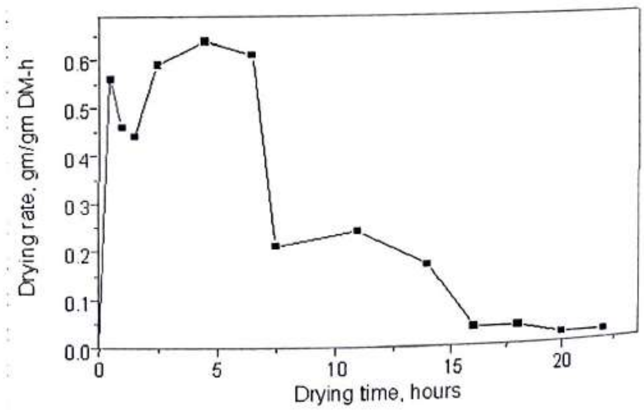

Fig. 10 Variation in drying rate with time (Solar drying)

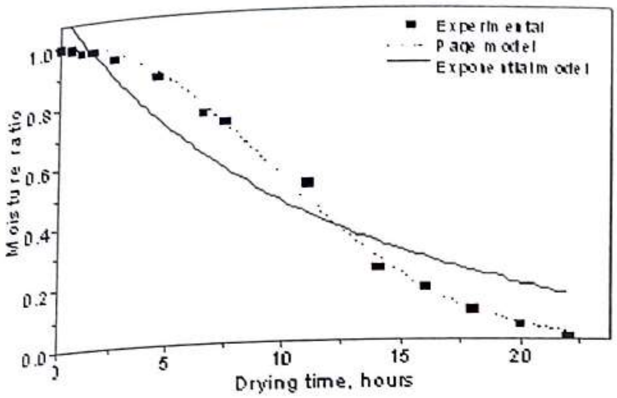

Fig. 11 Effectiveness of drying model (Solar drying)

Microwave oven drying

The observations on drying under microwave oven are presented in table 1. From the weight loss data, it was found that the time required for gerbera flowers to reduce from initial moisture content to the predecided level was about 25 minutes under microwave oven drying at 50°C. During drying, it was also observed that as the drying process commenced, the initial drying rate, which was very high during beginning was decreasing gradually with time. The initial drying rate was found to be 40.73 gm/gm of dry matter-h, which reduced to 0.31 gm/gm of dry matter-h, after 25 minutes.

During microwave drying the free water situated in the cells of floral parts of the flowers got evaporated due to heating, which resulted in to dried flowers. The flowers produced without any treatment under microwave drying were more prone to breakage due to rapid evaporation and structural collapse. Therefore, the drying under microwave was carried out with silica gel.

Paparozzi and McCallster (1988) also suggested the treatment to prevent breakage of flowers during drying under microwave drying. The similar results were also obtained by Geetha *et al.* (2003) for drying of gerbera flowers under microwave oven with silica gel.

The variation in moisture content and drying rate with respect to time is shown in figure 12 and 13. The variations in these parameters with time were observed to be curvilinear suggesting that drying proceeded under falling rate. As in case of rose, here also during the initial phase of drying, the drying rate was rapid and thereafter decreased with time.

The observations on drying were fitted to Exponential and Page model of drying, and the predicted equations were also determined (Fig. 14). From the value of coefficient of variations, both the models were satisfactorily fitted. But as the value of R^2 for Page model was 0.998 as compared to 0.954 for Exponential model, the Page model was found more effective.

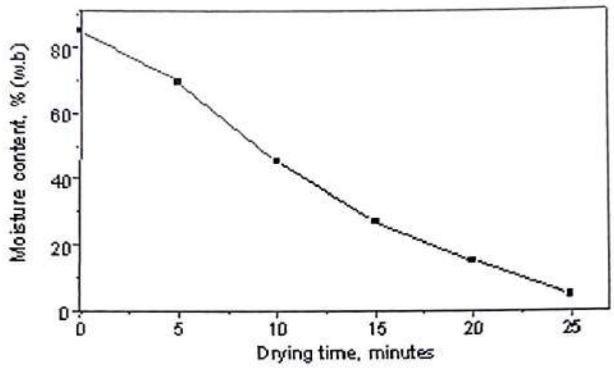

Fig. 12 Variation in moisture content with time (Microwave oven drying)

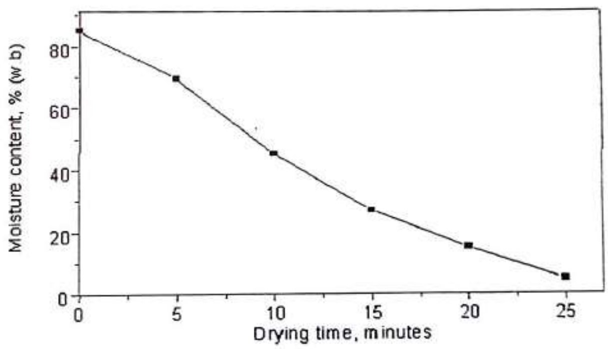

Fig. 12 Variation in moisture content with time (Microwave oven drying)

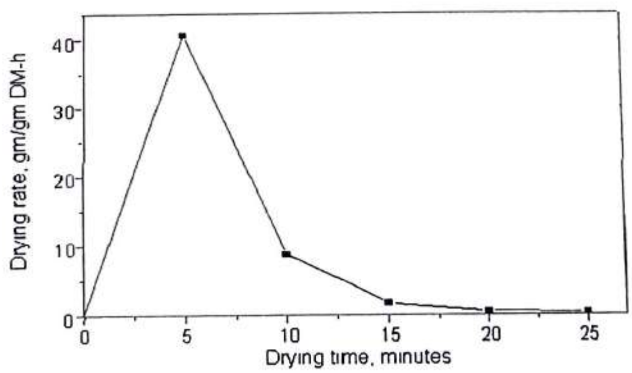

Fig. 13 Variation in drying rate with time (Microwave oven drying)

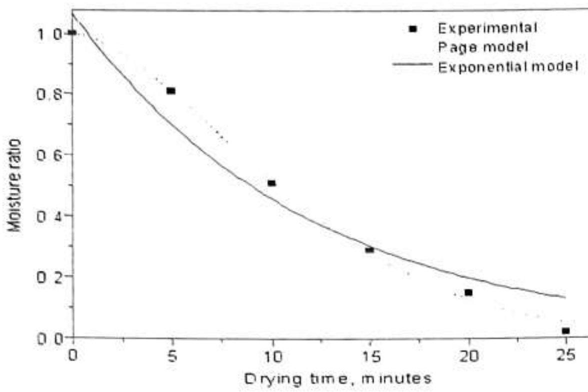

Fig. 14 Effectiveness of drying model (Microwave oven drying)

Shade drying

The data on weight loss during shade drying are presented in Table 1. From these data it was found that shade drying took about 5 days to reduce the moisture content of gerbera flowers from 85% (w.b.) to about 4.65 % (w.b.) The initial drying rate was found to be 0.13 gm/gm of dry matter-h, that was reduced to 0.01 gm/gm of dry matter-h after five days during drying under shade.

The time taken under shade drying method for drying of gerbera flowers was more as compared to other methods, as addition of supplemented heat to vapourize the free water presented in the floral parts was very small. Moreover, the rate of evaporation was also controlled by the saturation prevailed in the room. The results obtained under shade drying treatment were more or less similar to the results reported by Simalemga *et al.*, (1990) for tanacetum cineariifolum. The variation of moisture content and drying rate with respect to time are shown in figure 15 and 16. The variation in these parameters with time was observed to be curvilinear indicating that drying was carried out under falling rate. The observations on drying were fitted to Exponential and Page model of drying, and the predicted equations were also determined (Fig. 17). From the model parameters, the Page model (R^2 = 0.987) was found as best fitted for observed data. The values of constants of Exponential as well as Page model are given in Table 2.

Overall drying rate

The over all drying rate for gerbera flowers under different drying methods was found as 0.0260, 0.0423, 0.0590, 0.1670, 3.2164, 0.0614 and 0.0112 %/min during hot air oven drying at 40, 50 and 60 °C, vacuum drying at 40 °C and 760 mm Hg vacuum, microwave oven drying with silica gel at 50 °C, solar drying and shade drying respectively (Table 2). The maximum over all drying rate in case of gerbera flowers was also found during microwave oven drying with silica gel at 50 °C which was of the order of 3.2164 %/min followed by vacuum drying at 40 °C, while minimum overall drying rate as 0.0112 %/min, observed during shade drying The results of drying characteristics (time and rate of drying) of gerbera flowers revealed that the microwave oven drying with silica gel at 50 °C followed by vacuum drying at 40 °C and 760 mm Hg vacuum was better amongst all the drying treatments studied.

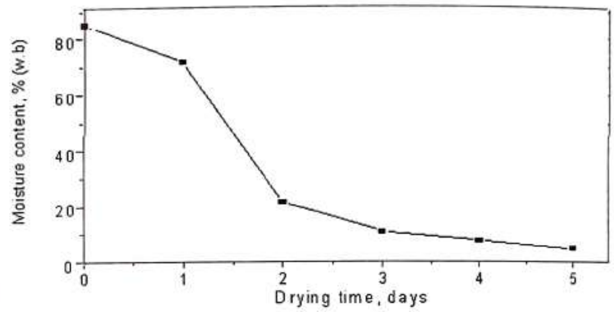

Fig. 15 Variation in moisture content with time (shade drying)

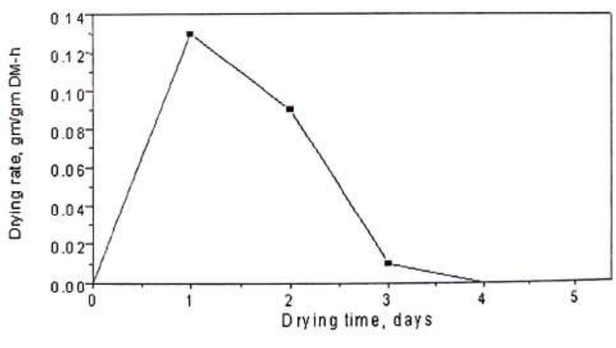

Fig. 16 Variation in drying rate with time (Shade drying)

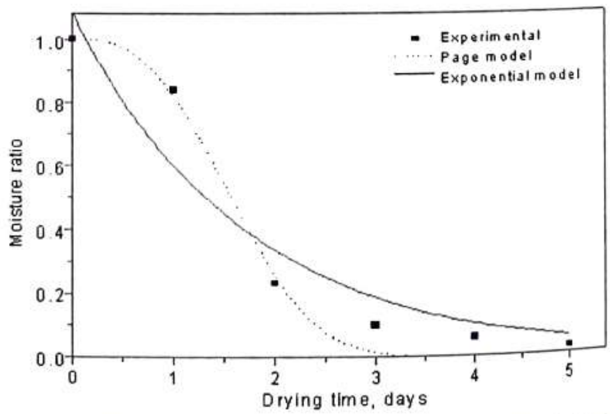

Fig 17 Effectiveness of drying model (Shade drying)

Table 2 Comparison of Drying Models and Overall Drying Rate of Gerbera flowers

Drying Methods	Drying temperature °C	Exponential model MR = c * exp (-kt)			Page modelMR = exp ($-kt^n$)			Initial moisture content, % w.b.	Final moisture content, % w.b.	Drying time, min	Overall drying rate, %/min
		c	k	R^2	k	n	R^2				
Hot air oven	40	1.0557	0.0496	0.978	0.009	1.535	0.995	85.00	3.93	3120	0.0260
	50	1.0070	0.0850	0.988	0.071	1.071	0.989	85.00	3.71	1920	0.0423
	60	1.0200	0.1990	0.996	0.156	1.158	0.999	85.00	3.63	1380	0.0590
Vacuum drying at 40 °C and 760 mm Hg vacuum	40	1.086	0.198	0.896	0.035	1.999	0.964	85.00	4.84	480	0.1670
Microwave oven drying with silica gel at 50 °C	50	1.066	0.084	0.954	0.015	1.639	0.998	85.00	4.59	25	3.2164
Solar drying	23.00 to 46.50	1.115	0.090	0.922	0.004	2.196	0.997	85.00	3.95	1320	0.0614
Shade drying	17.0 to 27.5	1.081	0.588	0.908	0.197	2.802	0.987	85.00	4.65	7200	0.0112

CONCLUSION

The drying time for gerbera flowers to reduce from initial moisture content of about 85% w.b. to the final of about 4.00% w.b. under different drying methods was found as 52, 32 and 23, 8 and 22 hours during hot air oven drying at 40, 50 and 60 °C, vacuum drying at 40 °C and 760 mm Hg vacuum and solar drying. While in case of microwave oven drying with silica gel at 50 °C and shade drying it was 25 minutes and 5 days respectively. Shade drying was taking maximum drying time while microwave oven drying with silica gel at 50 °C the minimum time. Maximum and minimum drying time was found as 5 days and 25 minutes during shade and microwave oven drying respectively. During drying, for all the drying run, initial drying rate was higher and decreased gradually with time. The drying of the flowers under all the treatments completely took place in the falling rate period. The drying behaviour of the flowers was reasonably predicated by Exponential and Page's model. Though, from the value of coefficient of variations the Page's model was found to be best fitted. The over all drying rate for gerbera flowers under different drying methods was found as 0.0260, 0.0423, 0.0590, 0.1670, 3.2164, 0.0614 and 0.0112 %/min during hot air oven drying at 40, 50 and 60 °C, vacuum drying at 40 °C and 760 mm Hg vacuum, microwave oven drying with silica gel at 50 °C,solar drying and shade drying respectively. The maximum over all drying rate in case of gerbera flowers was found during microwave oven drying with silica gel at 50 °C which was of the order of 3.2164 %/min followed by vacuum drying at 40 °C, while minimum overall drying rate as 0.0112 %/min, observed during shade drying. The results of drying characteristics (time and rate of drying) of gerbera flowers under different drying methods revealed that the microwave oven drying with silica gel at 50 °C followed by vacuum drying at 40 °C and 760 mm Hg vacuum was better amongst all the drying treatments studied.

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