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Effect of different levels of embedding media, temperature and duration on drying quality of rose cv. Mirabel in vacuum drying

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Abstract

Fresh flowers are undeniably attractive, but they are expensive, short-lived, and available only in certain seasons. In contrast, dried flowers are long-lasting, maintain their aesthetic appeal, and are available year-round. An experiment was aimed to obtain attractive dried rose flowers using vacuum drier with low temperature, various embedding media, temperature and durations. Among all the treatment combinations in the vacuum drying of roses, flowers embedded in silica gel and vacuum dried at 50 °C temperature for 4 hours (h) duration under low pressure has recorded maximum per cent weight loss, per cent moisture loss, change in diameter and also took less time for drying.

Keywords: Rose, vacuum drying, silica gel, embedding media, dry flower

Introduction

Flowers have a short shelf life, often lasting only a few days to weeks after harvest. During off-seasons or gluts, farmers may be forced to dispose of large quantities of unsold flowers, with up to 3–4 tonnes discarded daily into rivers like the Godavari, contributing significantly to water pollution. Reports suggest that floral waste accounts for 16% of river pollutants (Waghmode *et al.*, 2016) [8].

Dry flower technology offers a sustainable and artistic solution by preserving flowers for longer periods, reducing the need for fresh blooms. Dehydrated flowers hold great potential for replacing fresh flowers in home décor, as well as in artistic and industrial uses. Vacuum drying, a key method in this technology, is particularly effective for preserving delicate and high-value flowers. Unlike traditional drying methods, vacuum drying prevents colour fading, brittleness, and shrinkage by removing moisture in a low-pressure chamber at low temperatures. This allows flowers to retain their natural shape, colour, and texture. Widely adopted in the floral industry, vacuum drying is a popular method for producing long-lasting decorative flowers, floral arrangements, and eco-friendly value-added products. By extending the aesthetic and functional life of flowers, this technology minimizes environmental impact while providing high-quality, preserved blooms for use in various sectors, including interior design, fashion, and event planning.

Materials and Methods

The present investigation was carried out on “Effect of different levels of embedding media, temperature and duration on drying quality of rose cv. mirabel in vacuum drying Impact of embedding media, temperature and duration on the drying quality of Rose cv. Mirabel using vacuum drying” during 2020-21 at College of Horticulture, Venkataramannagudem, West Godavari district, Andhra Pradesh. Rose cv. Mirabel flowers collected during glut period from kadiyapulanka flower market, situated in Coastal Andhra Pradesh. Rose flowers immediately after brought to the laboratory embedded in different media (M) (sand, silica gel, sand: silica gel (50:50 v/v), dried in vacuum dryer at different temperatures (T) (40 °C, 45 °C and 50 °C) with different durations (D) (3:00h, 3:30h, 4:00h). Flowers kept in face up position and dried in vacuum dryer and after drying in vacuum dryer, flowers kept for setting. The experiment was laid out in a Factorial Completely Randomized Design (FCRD).

Treatment combinations are T₁ - M₁T₁D₁: Sand + 40 °C + 3:00 h, T₂ - M₁T₁D₂: Sand + 40 °C + 3:30 h, T₃ - M₁T₁D₃: Sand + 40 °C + 4:00 h, T₄ - M₁T₂D₁: Sand + 45 °C + 3:00 h, T₅ - M₁T₂D₂: Sand + 45 °C + 3:30 h, T₆ - M₁T₂D₃: Sand + 45 °C + 4:00 h, T₇ - M₁T₃D₁: Sand + 50 °C + 3:00 h, T₈ - M₁T₃D₂: Sand + 50 °C + 3:30 h, T₉ - M₁T₃D₃: Sand + 50 °C + 4:00 h, T₁₀ - M₂T₁D₁: Silica gel + 40 °C + 3:00 h, T₁₁ - M₂T₁D₂: Silica gel + 40 °C + 3:30 h, T₁₂ - M₂T₁D₃: Silica gel + 40 °C + 4:00 h, T₁₃ - M₂T₂D₁: Silica gel + 45 °C + 3:00 h, T₁₄ - M₂T₂D₂: Silica gel + 45 °C + 3:30 h, T₁₅ - M₂T₂D₃: Silica gel + 45 °C + 4:00 h, T₁₆ - M₂T₃D₁: Silica gel + 50 °C + 3:00 h, T₁₇ - M₂T₃D₂: Silica gel + 50 °C + 3:30 h, T₁₈ - M₂T₃D₃: Silica gel + 50 °C + 4:00 h, T₁₉ - M₃T₁D₁: Sand:silica gel (50:50 v/v) + 40 °C + 3:00 h, T₂₀ - M₃T₁D₂: Sand:silica gel (50:50 v/v) + 40 °C + 3:30 h, T₂₁ - M₃T₁D₃: Sand:silica gel (50:50 v/v) + 40 °C + 4:00 h, T₂₂ - M₃T₂D₁: Sand:silica gel (50:50 v/v) + 45 °C + 3:00 h, T₂₃ - M₃T₂D₂: Sand:silica gel (50:50 v/v) + 45 °C + 3:30 h, T₂₄ - M₃T₂D₃: Sand:silica gel (50:50 v/v) + 45 °C + 4:00 h, T₂₅ - M₃T₃D₁: Sand:silica gel (50:50 v/v) + 50 °C + 3:00 h, T₂₆ - M₃T₃D₂: Sand:silica gel (50:50 v/v) + 50 °C + 3:30 h, T₂₇ - M₃T₃D₃: Sand:silica gel (50:50 v/v) + 50 °C + 4:00 h.

Vacuum Drying: Vacuum chamber is consisting of a vacuum pump and condenser that helps to maintain vacuum pressure and condensing the moisture respectively. Embedded materials are placed into this chamber and product quality is good.

Precautions during Embedded Drying

- Flowers are embedded into the desiccants after removing of all undesirable parts and embedded.
- In the desiccant, only one type of flowers is embedded at a time and two specimens of the same species should not be touch to each other or sides of the wall.
- Precaution should be taken during the cleaning of end products as dried flowers are more delicate.

Results and Discussion

The data was recorded on following quantitative parameters.

Per cent weight loss (%): The data recorded on per cent weight loss due to different levels of embedding media, temperature and duration in rose cv. Mirabel are presented in table 1(a).

The data in the table 1(a) clearly revealed that per cent weight loss differed significantly due to different levels of embedding media, temperature and duration after 12 h of setting. The per cent weight loss due to embedding media varied from 64.55% to 69.87%, temperature varied from 64.57% to 69.21% and duration varied from 65.96% to 68.18%.

After 12 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent weight loss. In two way interaction between flowers embedded in silica gel and dried at 50 °C temperature (M₂T₃) showed maximum per cent weight loss (71.60%). In interaction between flowers dried at 50 °C temperature for 4 h duration (T₃D₃) elucidated maximum per cent weight loss (70.09%). Similarly, interaction between embedding media and duration showed maximum per cent weight loss (71.12%) flowers embedded in silica gel kept for 4 h duration (M₂D₃). In three way interaction, among the treatment combinations flowers

embedded in silica gel at 50 °C temperature for 4 h (M₂T₃D₃) showed significantly maximum per cent weight loss (72.40%) followed by silica gel at 50 °C temperature for 3:30 h (M₂T₃D₂, 71.56%) and the minimum per cent weight loss (59.68%) was observed in flowers embedded in sand at 40 °C temperature for 3 h (M₁T₁D₁).

After 24 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent weight loss. Among the treatment combinations, flowers embedded in silica gel at 50 °C temperature for 3:00 h (M₂T₃D₁) showed significantly maximum per cent weight loss (72.00%) followed by sand:silica gel (50:50 v/v) at 50 °C temperature for 4:00 h (M₃T₃D₃, 71.13%) and the minimum per cent weight loss (61.25%) was observed in flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁).

After 36 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent weight loss. Among the treatment combinations, flowers embedded in sand:silica gel (50:50 v/v) at 50 °C temperature for 4:00 h (M₃T₃D₃) showed significantly maximum per cent weight loss (72.00%) followed by sand:silica gel (50:50 v/v) at 50 °C temperature for 3:30 h (M₃T₃D₂, 71.02%) and the minimum per cent weight loss (62.41%) was observed in flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁). After 48 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent weight loss. Among the treatment combinations, flowers embedded in sand:silica gel (50:50 v/v) at 50 °C temperature for 3:00 h (M₃T₃D₂) showed significantly maximum per cent weight loss (71.85%) followed by sand:silica gel (50:50 v/v) at 50 °C temperature for 3:00 h (M₃T₃D₁, 71.06%) and the minimum per cent weight loss (63.91%) was observed in flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁). From the above findings, it was observed that flowers embedded in silica gel dried at 50 °C for 4:00 h under low pressure recorded maximum per cent weight loss. This might be due to the better hydro-absorbent properties of silica gel may be ascribed to the fact that silica gel is manufactured from sodium silicate and is composed of a vast network of inter connecting microscopic pores, which attract and hold moisture by a phenomenon known as physical absorption and capillary condensation reported by Safeena *et al.* (2006) [7] in rose. Due to better hydro-absorbent properties, maximum weight loss was reported with silica gel as desiccant compared to other desiccants used. Due to lower pressure during vacuum drying at 50 °C, evaporation of moisture takes place for longer duration leading to maximum weight loss. There is a significant decrease in weight loss due to high temperature in rose cv. Mirabel. Similar results were recorded by Dahiya (2003) [2] observed in chrysanthemum.

Per cent moisture loss (%)

The data recorded on per cent moisture loss because of different levels of embedding media, temperature and duration in rose cv. Mirabel are presented in table 2(a).

The data revealed that per cent moisture loss differed significantly due to different embedding media, temperature and duration after 12 h of setting. The per cent moisture loss due to embedding media varied from 54.86% to 70.16%, due to temperature varied from 55.32% to 68.15% and due

to duration varied from 58.87% to 64.96%.

After 12 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent moisture loss. In two way interaction between, flowers embedded in silica gel and dried at 50 °C temperature (M_2T_3) showed maximum per cent weight loss (76.26%). In interaction between flowers dried at 50 °C temperature for 4:00 h duration (T_3D_3) recorded maximum per cent weight loss (70.99%). Similarly, interaction between embedding media and

duration showed maximum per cent weight loss (73.74%) flowers embedded in silica gel kept for 4:00 h duration (M_2D_3). In three way interaction, among the treatment combinations flowers embedded in silica gel at 50 °C temperature for 4:00 h ($M_2T_3D_3$) showed significantly maximum per cent moisture loss (79.28%) followed by silica gel at 50 °C temperature for 3:30 h ($M_2T_3D_2$, 76.37%) and the minimum per cent moisture loss (45.05%) was observed in flowers embedded in sand at 40 °C temperature for 3:00 h ($M_1T_1D_1$).

Table 1(a): Effect of embedding media, temperature and duration on per cent weight loss (%) of rose cv. Mirabel in vacuum drying (Actual figures).

Temperature (T)	Duration (D)	Media (M)															
		Drying period															
		12 Hours				24 Hours				36 Hours				48 Hours			
		M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
T ₁	D ₁	59.68	66.00	63.38	63.02	61.25	67.64	64.75	64.54	62.41	69.51	64.89	65.60	63.91	70.11	66.34	66.78
	D ₂	61.98	67.41	64.21	64.53	63.08	69.49	65.94	66.17	63.99	70.28	66.99	67.08	64.27	-	67.84	-
	D ₃	63.45	69.42	65.66	66.17	64.13	70.01	66.87	67.00	64.38	-	67.81	-	65.29	-	68.86	-
	Mean	61.70	67.61	64.41	64.57	62.82	69.04	65.85	65.90	63.59	-	66.56	-	64.49	-	67.68	-
T ₂	D ₁	64.28	69.62	65.92	66.60	64.40	70.21	67.00	67.20	65.90	-	67.97	-	66.54	-	69.01	-
	D ₂	64.77	70.08	66.89	67.24	65.55	71.12	67.86	68.17	66.64	-	68.76	-	67.48	-	70.00	-
	D ₃	65.47	71.54	67.84	68.28	66.61	-	68.88	-	67.29	-	69.97	-	68.00	-	70.94	-
	Mean	64.84	70.41	66.88	67.37	65.52	-	67.91	68.18	66.61	-	68.90	-	67.34	-	69.98	-
T ₃	D ₁	66.15	70.85	67.77	68.25	66.94	72.00	69.09	69.34	67.81	-	70.19	-	68.38	-	71.06	-
	D ₂	67.27	71.56	69.06	69.29	67.79	-	70.03	-	68.34	-	71.02	-	67.99	-	71.85	-
	D ₃	67.89	72.40	70.00	70.09	68.41	-	71.13	-	69.54	-	72.00	-	70.38	-	-	-
	Mean	67.10	71.60	68.94	69.21	67.71	-	70.08	-	68.56	-	71.07	-	68.91	-	-	-
For comparing embedding media (M) and duration (D) levels																	
	D ₁	63.37	68.82	65.69	65.96	64.19	69.95	66.94	67.02	65.37	-	67.68	-	66.27	-	68.80	-
	D ₂	64.67	69.68	66.72	67.02	65.47	-	67.94	-	66.32	-	68.92	-	66.58	-	69.89	-
	D ₃	65.60	71.12	67.83	68.13	66.38	-	68.96	-	67.07	-	69.92	-	67.89	-	-	-
	Mean	64.55	69.87	66.75	67.04	65.35	-	67.95	-	66.25	-	68.84	-	66.91	-	-	-
M ₁ - Sand, M ₂ - Silica gel, M ₃ - Sand; Silica gel (50:50 v/v); T ₁ - 40 °C, T ₂ - 45 °C, T ₃ - 50 °C; D ₁ - 3 h, D ₂ - 3:30 h, D ₃ - 4 h																	

Table 1(b): Effect of embedding media, temperature and duration on per cent weight loss (%) of rose cv. Mirabel in vacuum drying.

Temperature (T)	Duration (D)	Media (M)															
		Drying period															
		12 Hours				24 Hours				36 Hours				48 Hours			
		M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
T ₁	D ₁	50.56	54.31	52.74	52.54	51.48	55.31	53.56	53.45	52.17	56.46	53.64	54.09	53.06	56.84	54.52	54.81
	D ₂	51.91	55.17	53.23	53.44	52.56	56.45	54.27	54.43	53.10	56.94	54.91	54.98	53.27	-	55.43	-
	D ₃	52.78	56.41	54.10	54.43	53.19	56.77	54.84	54.93	53.34	-	55.41	-	53.88	-	56.06	-
	Mean	51.75	55.29	53.36	53.47	52.41	56.18	54.22	54.27	52.17	-	54.65	-	53.40	-	55.33	-
T ₂	D ₁	53.28	56.53	54.26	54.69	53.35	56.90	54.92	55.06	54.25	-	55.51	-	54.64	-	56.15	-
	D ₂	53.57	56.82	54.85	55.08	54.04	57.47	55.44	55.65	54.70	-	56.00	-	55.21	-	56.77	-
	D ₃	53.99	57.74	55.43	55.72	54.68	-	56.07	56.27	55.09	-	56.75	-	55.53	-	57.36	-
	Mean	53.61	57.03	54.85	55.16	54.02	-	55.48	55.66	54.25	-	56.08	-	55.12	-	56.76	-
T ₃	D ₁	54.40	57.30	55.39	55.70	54.88	58.03	56.20	56.37	55.41	-	56.89	-	55.76	-	57.43	-
	D ₂	55.08	57.75	56.18	56.34	55.40	-	56.79	-	55.74	-	57.41	-	55.52	-	57.93	-
	D ₃	55.46	58.28	56.77	56.84	55.78	-	57.48	-	56.48	-	58.03	-	57.00	-	-	-
	Mean	54.98	57.78	56.11	56.29	55.35	-	56.82	-	55.41	-	57.44	-	56.10	-	-	-
For comparing embedding media (M) and duration (D) levels																	
	D ₁	52.75	56.05	54.13	54.31	53.24	56.74	54.89	54.96	53.94	-	55.35	-	54.48	-	56.03	-
	D ₂	53.52	56.58	54.76	54.95	56.74	-	55.50	-	54.51	-	56.10	-	54.67	-	56.71	-
	D ₃	54.08	57.48	55.43	55.66	54.55	-	56.13	-	54.97	-	56.73	-	55.47	-	-	-
	Mean	53.45	56.70	54.77	54.98	54.84	-	55.51	-	54.47	-	56.06	-	54.87	-	-	-
Factor		SE _m (±)		CD @ 5%		SE _m (±)		CD @ 5%		SE _m (±)		CD @ 5%		SE _m (±)		CD @ 5%	
Media (M)		0.02		0.06		0.02		0.05		0.04		0.10		0.02		0.05	
Microwave power (P)		0.02		0.06		0.02		0.05		0.04		0.10		0.02		0.05	
Duration (D)		0.02		0.06		0.02		0.05		0.04		0.10		0.02		0.05	
M x P		0.04		0.10		0.03		0.08		0.06		0.18		0.03		0.08	
P x D		0.04		0.10		0.03		0.08		0.06		0.18		0.03		0.08	
M x D		0.04		0.10		0.03		0.08		0.06		0.18		0.03		0.08	
M x P x D		0.06		0.18		0.05		0.13		0.11		0.31		0.05		0.15	
Figures indicate arc sign transformed values																	

After 24 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent moisture loss. Among the treatment combinations flowers embedded in silica gel at 50 °C temperature for 3:00 h (M₂T₃D₁) showed significantly maximum per cent moisture loss (77.28%) followed by silica gel at 45 °C temperature for 3:30 h (M₂T₂D₂, 74.19%) and the minimum per cent moisture loss (47.27%) was observed in flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁). After 36 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent moisture loss in vacuum drier. Among the treatment combinations flowers embedded in sand:silica gel (50:50 v/v) at 50 °C temperature for 4:00 h (M₃T₃D₃) showed significantly maximum per cent moisture loss (77.12%) followed by sand:silica gel (50:50 v/v) at 50 °C temperature for 3:30 h (M₃T₃D₂, 73.55%) and the minimum per cent moisture loss (49.24%) was observed in flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁).

After 48 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on per cent moisture loss. Among the treatment combinations flowers embedded in sand:silica gel (50:50 v/v), silica gel at 50 °C temperature for 3:30 h (M₂T₃D₂) showed significantly maximum per cent moisture loss (76.38%) followed by sand:silica gel (50:50 v/v) at 50 °C temperature for 3:00 h (M₂T₃D₁, 73.59%) and the minimum per cent moisture loss (51.37%) was observed in flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁).

The results illustrate that, the flowers embedded in silica gel at 50 °C temperature for 4:00 h under low pressure recorded maximum per cent moisture loss. This may be due to lower pressure, high temperature in vacuum dryer and hydro-absorbent nature of silica gel used during drying leading to rapid evaporation of moisture and increase in per cent moisture loss. Similar results were found by Kumpavat *et al.* (2015) [3] in gerbera.

Table 2(a): Effect of embedding media, temperature and duration on per cent moisture loss (%) of rose cv. Mirabel in vacuum drying (Actual figures).

Temperature (T)	Duration (D)	Media (M)															
		Drying period															
		12 Hours				24 Hours				36 Hours				48 Hours			
		M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
T ₁	D ₁	45.05	59.12	51.29	51.82	47.27	63.27	53.86	54.80	49.24	67.28	56.57	57.69	51.37	70.11	59.29	60.25
	D ₂	48.58	63.15	54.12	55.28	50.29	67.29	57.06	58.21	52.36	70.85	60.47	61.22	54.29	-	63.29	-
	D ₃	51.79	67.21	57.63	58.87	52.67	71.49	60.28	61.14	54.49	-	63.24	-	56.79	-	66.34	-
	Mean	48.47	63.16	54.34	55.32	50.07	68.01	57.06	59.05	52.03	-	60.09	-	54.15	-	62.97	-
T ₂	D ₁	52.92	67.89	57.99	59.60	54.59	71.26	60.58	62.14	57.00	-	63.86	-	59.16	-	66.69	-
	D ₂	55.10	70.57	60.34	62.00	57.29	74.19	63.25	64.91	59.16	-	66.29	-	62.01	-	69.38	-
	D ₃	57.11	74.73	63.24	65.02	59.16	-	66.55	65.01	61.49	-	69.28	-	63.87	-	72.71	-
	Mean	55.04	71.06	60.52	62.20	57.01	-	63.46	65.02	59.21	-	66.47	-	61.68	-	69.59	-
T ₃	D ₁	58.44	73.15	64.00	65.19	61.00	77.28	67.29	68.52	62.99	-	70.58	-	65.34	-	73.59	-
	D ₂	61.25	76.37	67.24	68.28	63.21	-	70.19	-	65.26	-	73.55	-	67.28	-	76.38	-
	D ₃	63.57	79.28	70.13	70.99	65.37	-	73.66	-	67.28	-	77.12	-	69.54	-	-	-
	Mean	61.08	76.26	67.12	68.15	63.19	-	70.38	-	65.17	-	73.75	-	67.38	-	-	-
For comparing embedding media (M) and duration (D) levels																	
	D ₁	52.13	66.72	57.76	58.87	54.28	70.60	60.57	61.82	56.41	-	63.67	-	58.62	-	66.52	-
	D ₂	54.97	70.03	60.56	61.85	56.86	-	63.50	-	58.92	-	66.77	-	61.19	-	69.68	-
	D ₃	57.49	73.74	63.66	64.96	59.06	-	66.83	-	61.08	-	69.88	-	63.40	-	-	-
	Mean	54.86	70.16	60.66	61.90	56.73	-	63.63	-	58.80	-	66.77	-	61.07	-	-	-
M ₁ - Sand, M ₂ - Silica gel, M ₃ - Sand: Silica gel (50:50 v/v); T ₁ - 40 °C, T ₂ - 45 °C, T ₃ - 50 °C; D ₁ - 3 h, D ₂ - 3:30 h, D ₃ - 4 h																	

Table 2(b): Effect of embedding media, temperature and duration on per cent moisture loss (%) of rose cv. Mirabel in vacuum drying.

Temperature (T)	Duration (D)	Media (M)															
		Drying period															
		12 Hours				24 Hours				36 Hours				48 Hours			
		M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
T ₁	D ₁	42.14	50.24	45.72	46.03	43.42	52.67	47.20	47.76	44.55	55.09	48.76	49.47	45.77	56.84	50.33	50.98
	D ₂	44.17	52.60	47.34	48.04	45.15	55.09	49.04	49.76	46.33	57.30	51.02	51.55	47.44	-	52.69	-
	D ₃	46.01	55.04	49.37	50.14	46.51	57.07	50.91	51.50	47.56	-	52.66	-	48.88	-	54.52	-
	Mean	44.11	52.63	47.48	48.07	45.03	54.95	49.05	49.68	46.15	-	50.81	-	47.36	-	52.51	-
T ₂	D ₁	46.66	55.46	49.58	50.57	47.61	57.56	51.09	52.09	49.00	-	53.03	-	50.26	-	54.73	-
	D ₂	47.91	57.12	50.95	51.99	49.17	59.44	52.66	53.76	50.26	-	54.49	-	51.93	-	56.38	-
	D ₃	49.07	59.80	52.66	53.84	50.26	-	54.64	55.71	51.62	-	56.32	-	53.03	-	58.48	-
	Mean	47.88	57.46	51.06	52.13	49.01	-	52.80	53.85	50.29	-	54.61	-	51.74	-	56.53	-
T ₃	D ₁	49.84	58.77	53.11	53.91	51.33	61.51	55.09	55.98	52.51	-	57.13	-	53.91	-	59.05	-
	D ₂	51.48	60.89	55.06	55.81	52.64	-	56.89	57.77	53.86	-	59.03	-	55.09	-	60.90	-
	D ₃	52.85	62.90	56.85	57.53	53.93	-	59.10	59.40	55.09	-	61.40	-	56.48	-	-	-
	Mean	51.39	60.85	55.01	55.75	52.63	-	57.03	57.71	53.82	-	59.19	-	55.16	-	-	-
For comparing embedding media (M) and duration (D) levels																	
	D ₁	46.21	54.82	49.47	50.17	47.46	57.25	51.13	51.95	48.68	-	52.97	53.78	49.98	-	54.70	-
	D ₂	47.85	56.87	51.12	51.95	48.99	-	52.86	-	50.15	-	54.84	55.71	51.49	-	56.65	-

	D ₃	49.31	59.25	52.96	53.84	50.23	-	54.88	-	51.42	-	56.79	57.59	52.80	-	-	-
	Mean	47.79	56.98	51.18	51.98	48.89	-	52.96	-	50.08	-	54.87	55.69	51.42	-	56.75	-
Factor		SE _m (±)	CD @ 5%	SE _m (±)	CD @ 5%	SE _m (±)	CD @ 5%	SE _m (±)	CD @ 5%	SE _m (±)	CD @ 5%	SE _m (±)	CD @ 5%	SE _m (±)	CD @ 5%	SE _m (±)	CD @ 5%
Media (M)		0.04	0.12	0.02	0.06	0.04	0.10	0.02	0.05	0.04	0.10	0.02	0.05	0.04	0.10	0.02	0.05
Microwave power (P)		0.04	0.12	0.02	0.06	0.04	0.10	0.02	0.05	0.04	0.10	0.02	0.05	0.04	0.10	0.02	0.05
Duration (D)		0.04	0.12	0.02	0.06	0.04	0.10	0.02	0.05	0.04	0.10	0.02	0.05	0.04	0.10	0.02	0.05
M x P		0.07	0.20	0.03	0.10	0.06	0.17	0.03	0.08	0.07	0.20	0.03	0.08	0.07	0.20	0.03	0.08
P x D		0.07	0.20	0.03	0.10	0.06	0.17	0.03	0.08	0.07	0.20	0.03	0.08	0.07	0.20	0.03	0.08
M x D		0.07	0.20	0.03	0.10	0.06	0.17	0.03	0.08	0.07	0.20	0.03	0.08	0.07	0.20	0.03	0.08
M x P x D		0.12	0.35	0.06	0.17	0.10	0.30	0.05	0.14	0.12	0.35	0.06	0.17	0.10	0.30	0.05	0.14

Figures indicate arc sign transformed values

Time taken for drying (h)

The data recorded on time taken for drying due to different levels of embedding media, temperature and duration in rose cv. Mirabel are presented in table 3.

Flowers embedded in silica gel at 45 °C temperature for 4:00 h, 50 °C temperature for 3:30 and 4:00 h duration of vacuum dried flowers took 12 h of setting for drying.

Table 3. Effect of embedding media, temperature and duration on time taken for drying in rose cv. Mirabel.

Treatment combinations	Time taken for drying
M ₁ T ₁ D ₁	48 h of setting
M ₁ T ₁ D ₂	48 h of setting
M ₁ T ₁ D ₃	48 h of setting
M ₁ T ₂ D ₁	48 h of setting
M ₁ T ₂ D ₂	48 h of setting
M ₁ T ₂ D ₃	48 h of setting
M ₁ T ₃ D ₁	48 h of setting
M ₁ T ₃ D ₂	36 h of setting
M ₁ T ₃ D ₃	36 h of setting
M ₂ T ₁ D ₁	48 h of setting
M ₂ T ₁ D ₂	36 h of setting
M ₂ T ₁ D ₃	24 h of setting
M ₂ T ₂ D ₁	24 h of setting
M ₂ T ₂ D ₂	24 h of setting
M ₂ T ₂ D ₃	12 h of setting
M ₂ T ₃ D ₁	24 h of setting
M ₂ T ₃ D ₂	12 h of setting
M ₂ T ₃ D ₃	12 h of setting
M ₃ T ₁ D ₁	48 h of setting
M ₃ T ₁ D ₂	48 h of setting
M ₃ T ₁ D ₃	48 h of setting
M ₃ T ₂ D ₁	48 h of setting
M ₃ T ₂ D ₂	48 h of setting
M ₃ T ₂ D ₃	48 h of setting
M ₃ T ₃ D ₁	48 h of setting
M ₃ T ₃ D ₂	36 h of setting
M ₃ T ₃ D ₃	36 h of setting

M₁ - Sand, M₂ - Silica gel, M₃ - Sand:silicagel (50:50 v/v); T₁ - 40 °C, T₂ - 45 °C, T₃ - 50 °C;

D₁ - 3 h, D₂ - 3:30 h, D₃ - 4 h

Flowers embedded in silica gel at 40 °C temperature for 4:00 h, 45 °C temperature for 3:00 and 3:30 h, 50 °C temperature for 3:00 h duration of vacuum dried flowers took 24 h of setting for drying.

Flowers embedded in sand at 50 °C temperature for 3:30 and 4:00 h, silica gel embedded flowers at 40 °C temperature for 3:30 h, sand:silica gel (50:50 v/v) embedded flowers at 50 °C temperature for 3:30 and 4:00 h duration of vacuum dried flowers took 36 h of setting for drying.

Flowers embedded in sand at 40 °C and 45 °C temperature for 3:00 to 4:00 h and at 50 °C temperature for 3:00 h, silica gel embedded flowers at 40 °C temperature for 3:00 h, sand:silica gel (50:50 v/v) embedded flowers at 40 °C to 45 °C temperature for 3:00 to 4:00 h and at 50 °C temperature

for 3:00 and 3:30 h duration of vacuum dried flowers took 48 h of setting for drying.

From the above findings time required for complete drying of rose is less when flowers embedded in silica gel at 45 °C temperature for 4:00 h, 50 °C temperature for 3:30 and 4:00 h duration of vacuum dried flowers. This might be due to embedding media silica gel and also due to low pressure drying results in fast vaporisation of moisture. Therefore, time taken for drying was less compared to other drying methods. The results are in accordance with findings of Kumpavat *et al.* (2015) ^[3] in gerbera.

Change in diameter (cm)

The data recorded on effect of different levels of embedding media, temperature and duration in rose cv. Mirabel on change in diameter are presented in table 4 and graphically depicted in figure 1.

The data revealed that change in diameter differed significantly due to different embedding media, temperature and duration after 12 h of setting. The change in diameter due to embedding media varies from 0.729 cm to 0.905 cm, temperature varies from 0.739 cm to 0.870 cm and duration varies from 0.783 cm to 0.836 cm.

After 12 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on the change in diameter. In two way interactions, embedding media and temperature showed minimum change in diameter (0.665 cm) when flowers embedded in sand and dried at 40 °C temperature (M₁T₁). Similarly, interaction between temperature and duration registered minimum change in diameter (0.709 cm) when flowers dried at 40 °C temperature for 3:00 h duration (T₁D₁). In interaction between embedding media and duration exhibited non-significant difference. In three way interactions, among the treatment combinations flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁) showed significantly minimum change in diameter (0.642 cm) followed by sand embedded flowers at 40 °C temperature for 3:30 h (M₁T₁D₂, 0.660 cm) and significantly maximum change in diameter (1.010 cm) was observed in silica gel embedding flowers at 50 °C temperature for 4:00 h (M₂T₃D₃).

After 24 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on the change in diameter. Among the treatment combinations, flowers embedded in sand at 40 °C temperature for 3:00 h (M₁T₁D₁) showed significantly minimum change in diameter (0.652 cm) followed by sand embedded flowers at 40 °C temperature for 3:30 h (M₁T₁D₂, 0.681 cm) and significantly maximum change in diameter (0.972 cm) was observed in silica gel embedded flowers at 50 °C temperature for 3:00 h (M₂T₃D₁).

After 36 h of setting in the media, different levels of embedding media, temperature and duration showed

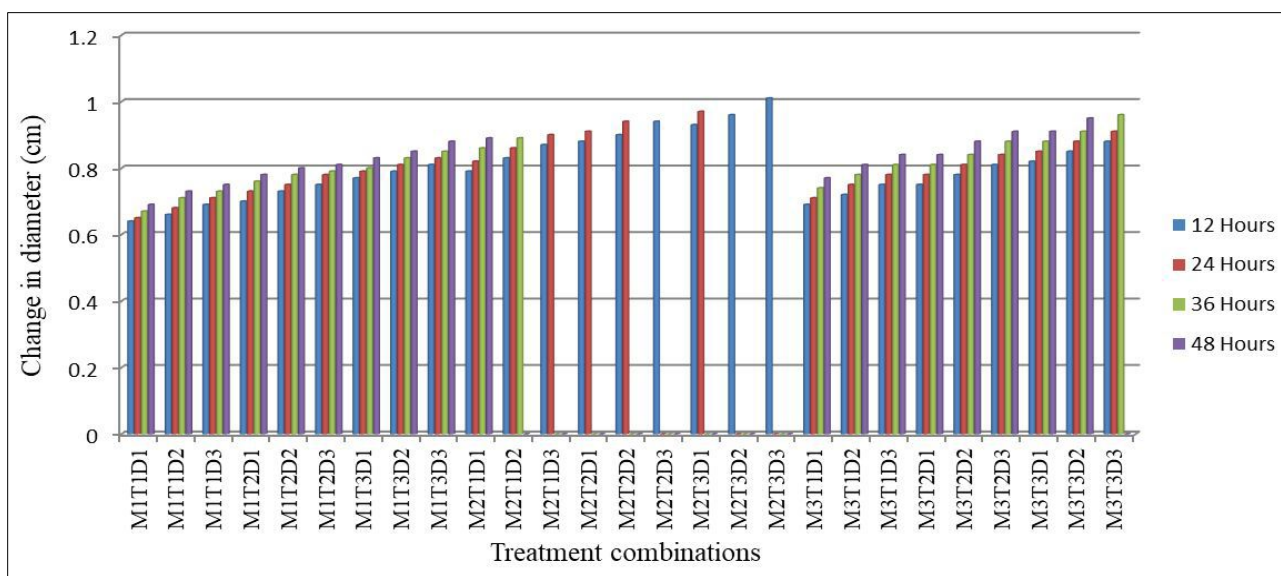
significant effect on change in diameter. Among the treatment combinations, flowers embedded in sand at 40 °C temperature for 3:00 h ($M_1T_1D_1$) showed significantly minimum change in diameter (0.673 cm) followed by sand embedded flowers at 40 °C temperature for 3:30 h ($M_1T_1D_2$,

0.712 cm) and significantly maximum change in diameter (0.963 cm) was observed in sand:silica gel (50:50 v/v) embedding flowers at 50 °C temperature for 4:00 h ($M_3T_3D_3$).

Table 4: Effect embedding media, temperature and duration on change in diameter (cm) of rose cv. Mirabel in vacuum drying.

Temperature (T)	Duration (D)	Media (M)															
		Drying period															
		12 Hours				24 Hours				36 Hours				48 Hours			
		M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
T_1	D_1	0.642	0.793	0.691	0.709	0.652	0.822	0.712	0.729	0.673	0.862	0.740	0.758	0.693	0.892	0.773	0.78
	D_2	0.660	0.831	0.722	0.738	0.681	0.861	0.753	0.765	0.712	0.891	0.782	0.795	0.732	-	0.812	-
	D_3	0.692	0.870	0.753	0.772	0.711	0.902	0.781	0.898	0.731	-	0.811	-	0.752	-	0.841	-
	Mean	0.665	0.831	0.722	0.739	0.681	0.862	0.749	0.764	0.705	-	0.778	-	0.726	-	0.809	-
T_2	D_1	0.701	0.881	0.753	0.778	0.733	0.913	0.781	0.809	0.761	-	0.811	-	0.781	-	0.842	-
	D_2	0.731	0.902	0.782	0.805	0.752	0.941	0.812	0.835	0.782	-	0.842	-	0.801	-	0.881	-
	D_3	0.752	0.941	0.811	0.835	0.782	-	0.841	-	0.792	-	0.881	-	0.813	-	0.911	-
	Mean	0.728	0.908	0.782	0.806	0.756	-	0.811	-	0.778	-	0.845	-	0.798	-	0.878	-
T_3	D_1	0.773	0.931	0.820	0.841	0.791	0.972	0.851	0.871	0.801	-	0.882	-	0.832	-	0.911	-
	D_2	0.792	0.961	0.851	0.868	0.811	-	0.881	-	0.831	-	0.912	-	0.853	-	-	-
	D_3	0.813	1.010	0.882	0.902	0.833	-	0.911	-	0.852	-	0.963	-	0.881	-	-	-
	Mean	0.793	0.967	0.851	0.870	0.812	-	0.881	-	0.828	-	0.919	-	0.855	-	-	-
For comparing embedding media (M) and duration (D) levels																	
	D_1	0.707	0.877	0.764	0.783	0.725	0.902	0.791	0.806	0.747	-	0.823	-	0.768	-	0.845	-
	D_2	0.728	0.898	0.785	0.804	0.748	-	0.815	-	0.775	-	0.845	-	0.795	-	-	-
	D_3	0.752	0.940	0.815	0.836	0.775	-	0.844	-	0.792	-	0.885	-	0.815	-	-	-
	Mean	0.729	0.905	0.788	0.807	0.749	-	0.817	-	0.771	-	0.851	-	0.793	-	-	-
Factor		$SE_m(\pm)$				CD @ 5%				$SE_m(\pm)$				CD @ 5%			
Media (M)		0.001				0.003				0.001				0.002			
Microwave power (P)		0.001				0.003				0.001				0.002			
Duration (D)		0.001				0.003				0.001				0.002			
M x P		0.002				0.005				0.001				0.004			
P x D		0.002				0.005				0.001				0.004			
M x D		0.002				NS				0.001				0.004			
M x P x D		0.003				0.009				0.002				0.007			

M_1 - Sand, M_2 - Silica gel, M_3 - Sand: Silica gel (50:50 v/v); T_1 - 40 °C, T_2 - 45 °C, T_3 - 50 °C; D_1 - 3 h, D_2 - 3:30 h, D_3 - 4 h



$M_1T_1D_1$: Sand + 40 °C + 3:00 h
 $M_1T_1D_2$: Sand + 40 °C + 3:30 h
 $M_1T_1D_3$: Sand + 40 °C + 4:00 h
 $M_1T_2D_1$: Sand + 45 °C + 3:00 h
 $M_1T_2D_2$: Sand + 45 °C + 3:30 h
 $M_1T_2D_3$: Sand + 45 °C + 4:00 h
 $M_1T_3D_1$: Sand + 50 °C + 3:00 h
 $M_1T_3D_2$: Sand + 50 °C + 3:30 h
 $M_1T_3D_3$: Sand + 50 °C + 4:00 h

$M_2T_1D_1$: Silica gel + 40 °C + 3:00 h
 $M_2T_1D_2$: Silica gel + 40 °C + 3:30 h
 $M_2T_1D_3$: Silica gel + 40 °C + 4:00 h
 $M_2T_2D_1$: Silica gel + 45 °C + 3:00 h
 $M_2T_2D_2$: Silica gel + 45 °C + 3:30 h
 $M_2T_2D_3$: Silica gel + 45 °C + 4:00 h
 $M_2T_3D_1$: Silica gel + 50 °C + 3:00 h
 $M_2T_3D_2$: Silica gel + 50 °C + 3:30 h
 $M_2T_3D_3$: Silica gel + 50 °C + 4:00 h

$M_3T_1D_1$: sand:silicagel (50:50 v/v) + 40 °C + 3:00 h
 $M_3T_1D_2$: sand:silicagel (50:50 v/v) + 40 °C + 3:30 h
 $M_3T_1D_3$: sand:silicagel (50:50 v/v) + 40 °C + 4:00 h
 $M_3T_2D_1$: sand:silicagel (50:50 v/v) + 45 °C + 3:00 h
 $M_3T_2D_2$: sand:silicagel (50:50 v/v) + 45 °C + 3:30 h
 $M_3T_2D_3$: sand:silicagel (50:50 v/v) + 45 °C + 4:00 h
 $M_3T_3D_1$: sand:silicagel (50:50 v/v) + 50 °C + 3:00 h
 $M_3T_3D_2$: sand:silicagel (50:50 v/v) + 50 °C + 3:30 h
 $M_3T_3D_3$: sand:silicagel (50:50 v/v) + 50 °C + 4:00 h

Fig 1: Effect of embedding media, temperature and duration on change in diameter (cm) of rose cv. Mirabel in vacuum drier



Plate 1: View of rose cv. Mirabel embedded in silica gel dried at 50 °C for 4 h after drying

After 48 h of setting in the media, different levels of embedding media, temperature and duration showed significant effect on change in diameter. Among the treatment combinations flowers embedded in sand at 40 °C temperature for 3:00 h ($M_1T_1D_1$) showed significantly minimum change in diameter (0.693 cm) followed by sand embedded flowers at 40 °C temperature for 3:30 h ($M_1T_1D_2$, 0.732 cm) and significantly maximum change in diameter (0.911 cm) was observed in sand:silica gel (50:50 v/v) embedding flowers at 50 °C temperature for 4:00 h ($M_3T_3D_3$). The perusal of data reveals that flowers embedded in sand at 40 °C temperature in vacuum drier for 3:00 h recorded minimum change in diameter this may be due to low temperature and low pressure in vacuum drier, since the chamber was evaluated high vacuum under low pressure were employed even temperature of 40 °C was sufficient for liberation of moisture from flower tissues was more due to higher transfer of heat by conduction and convection therefore resulted in flower size reduction. The results are in confirmation with the findings of Bhalla *et al.* (2006) ^[1] in chrysanthemum and Namita *et al.* (2018) ^[5] in gerbera.

Conclusion

The results of the present study concluded that, vacuum drying of rose, flowers embedded in silica gel and vacuum dried at 50 °C temperature for 4 h duration under low pressure has recorded maximum per cent weight loss, per cent moisture loss, change in diameter, and also took less time for drying. The dehydrated products obtained by using this technology can be utilized in making of various dry flower arrangements and other profitable craft items etc.

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