International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(2): 697-701
www.biochemjournal.com
Received: 18-11-2023
Accepted: 21-12-2023

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Examining the influence of drying methods and desiccants on the physical attributes of dried roses

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DOI: https://doi.org/10.33545/26174693.2024.v8.i2i.660

Abstract
Roses the reigning champions of the global cut flowers trade and India's leading floral export, boast numerous distinguishing features. In today's market augmenting value holds paramount importance. To delve deeper into this realm a comprehensive experiment was conducted between 2019 and 2020. Employing a fully randomized design with a factorial approach the study with two critical factors: drying methods and desiccants with three replications. Among the examined physical parameters the combination of sun drying with silica gel desiccant stood out. It yielded remarkable results including the highest weight loss percentages (1st day: 57.03%, 2nd day: 65.21% and 3rd day: 71.34%), the lowest moisture content percentages (1st day: 52.73% and 2nd day: 44.59%) and the most substantial moisture loss percentages (2nd day: 58.64%) during the drying process. Nevertheless when contemplating the reduction in flower diameter the shade drying method complemented by sea sand as a desiccant emerged as supremely effective displaying minimal diameter reduction (1st day: 0.56, 2nd day: 0.60, 3rd day: 0.63 and 4th day: 0.66). In summary, it can be concluded that sun drying with silica gel proves optimal for achieving desired physical parameters in rose flowers with the exception of flower diameter reduction, where shade drying with sea sand demonstrates superior suitability.

Keywords: Rose, desiccants, drying methods, physical parameters

Introduction
Flowers play a significant role in our nation's social and cultural traditions, being an essential part of celebrations. The dry flower industry in India is witnessing remarkable annual growth, ranging from 10-20 percent. India produces a wide variety of floriculture products, including fresh and dried flowers like roses, carnations, chrysanthemums, gladiolus, gerbera, anthurium and orchids. In the 2019-20 period, India successfully exported 16,949.37 metric tons of floriculture goods worth Rs. 541.61 crores. This success was attributed to extreme weather conditions in Europe and the scorching heat in Gulf countries. Key export destinations for Indian dried flowers include the United States, Israel, Hong Kong, Japan, Singapore and various West European nations. Dried flowers are favored for their enduring beauty, cost-effectiveness and reduced microbial aging due to moisture removal. They possess qualities like novelty, longevity, aesthetics, flexibility and year-round availability. This study delves into the impact of different drying methods and desiccants on the physical attributes of dried roses providing insights into their effects on the drying process and resulting characteristics.

Materials and Methods
Selection of flowers for drying
Flowers selected for drying were chosen for uniformity in size, shape, color and maturity. Only open, turgid and freshly harvested roses in the tight bud stage were used. Harvested in the early morning cut ends were immediately placed in water. In the laboratory, damaged or pest-infested flowers were discarded and uniform stem lengths were ensured before embedding with flower weight and diameter recorded.

Selection of desiccants for drying
1. **Red river sand:** Ranging from 0.2 to 2.0 mm in diameter.
2. **Black river sand:** Varied in size from 0.6 to 2.0 mm.

3. **Sea sand**: Particle size between 0.02 to 0.2 mm. It underwent thorough washing with tap water, sun drying to remove moisture and sieving for impurity removal.
4. **Silica gel**: Mesh size 9-12 with a diameter range of 2.68-1.19 mm.
5. **Borax powder**: High-quality analytical grade.

Results and Discussion

Weight loss (%)

Different drying methods significantly influenced weight loss percentages. Sun drying exhibited the highest percentages (1st day: 50.83%, 2nd day: 58.29%, 3rd day: 64.64%, 4th day: 70.68% and 5th day: 74.88%) while shade drying had the lowest. Silica gel embedding resulted in the highest weight loss percentage (1st day: 54.55%, 2nd day: 62.00%, 3rd day: 68.59%, 4th day: 73.75% and 5th day: 77.39%) comparable to drying without desiccant. Borax powder embedding had the lowest weight loss percentages (1st day: 41.85%, 2nd day: 49.96%, 3rd day: 56.75%, 4th day: 60.95% and 5th day: 66.74%). Interaction effects were significant with sun drying combined with silica gel resulting in the highest weight loss percentages (1st day: 57.03%, 2nd day: 65.21% and 3rd day: 71.34%) comparable to sun drying without desiccant (Table 1). This can be attributed to the synergy of elevated temperatures and reduced humidity during sun drying coupled with the exceptional moisture-absorbing properties of silica gel desiccant which hastens moisture removal and results in the highest weight loss percentages. Conversely, shade drying combined with borax powder had the lowest percentages (1st day: 41.51%, 2nd day: 49.49% and 3rd day: 55.78%) because shade drying requires more time for drying and the formation of lumps by borax desiccant slows down moisture loss reducing the weight loss percentage. These findings align with previous studies on China aster (Meman, 2006) [9] and various flowers (Khyati, 2015) [8] (Table 2).

Table 1: Impact of different drying methods and desiccants on weight loss percentage

	Weight loss %				
Treatments	**1st day**	**2nd day**	**3rd day**	**4th day**	**5th day**
Factor A: Drying methods (S)					
S_1=Sun drying	50.83	58.29	64.64	70.68	74.88
S_2=Shade drying	47.98	55.02	61.04	66.87	72.01
S.Em±	0.25	0.35	0.28	0.50	0.46
C.D. at 5%	0.74	1.03	0.83	1.45	1.35
Factor B: Desiccants (M)					
M_1=Without media	53.35	60.26	67.28	72.68	76.62
M_2=River sand (pinkish red)	46.82	53.82	59.30	66.12	71.28
M_3=River sand (black)	47.92	54.95	60.22	67.69	72.67
M_4=Sea sand	51.94	58.93	64.91	71.49	75.97
M_5=Silica gel	54.55	62.00	68.59	73.75	77.39
M_6=Borax powder	41.85	49.96	56.75	60.95	66.74
S.Em±	0.44	0.61	0.49	0.86	0.80
C.D. at 5%	1.29	1.78	1.44	2.52	2.34
Interaction (S × M)					
S.Em±	0.62	0.86	0.70	1.22	1.13
C.D. at 5%	1.82	2.51	2.03	NS	NS
C.V.%	2.19	2.63	1.92	3.07	2.68

Table 2: Interaction impact of different drying methods and desiccants on weight loss percentage

	Weight loss %		
Treatments	**1st day**	**2nd day**	**3rd day**
S_1M_1	55.39	62.81	70.59
S_1M_2	47.76	55.16	60.19
S_1M_3	49.08	56.34	61.11
S_1M_4	53.52	59.78	66.88
S_1M_5	57.03	65.21	71.34
S_1M_6	42.19	50.42	57.73
S_2M_1	51.30	57.71	63.96
S_2M_2	45.87	52.47	58.40
S_2M_3	46.75	53.55	59.33
S_2M_4	50.35	58.09	62.94
S_2M_5	52.07	58.78	65.85
S_2M_6	41.51	49.49	55.78
S.Em±	0.62	0.86	0.70
C.D. at 5%	1.82	2.51	2.03
C.V. %	2.19	2.63	1.92

Moisture content (%)

Diverse drying methods significantly affected moisture content. Sun drying yielded the lowest moisture content percentages (1st day: 57.70%, 2nd day: 50.23%, 3rd day: 43.26%, 4th day: 36.00% and 5th day: 30.19%) while shade drying retained higher moisture levels. Silica gel embedding resulted in minimal moisture content (1st day: 53.96%, 2nd day: 46.73%, 3rd day: 38.82%, 4th day: 31.26% and 5th day: 24.93%) comparable to drying without a desiccant. On the 4th day, silica embedding matched results with sea sand. In contrast, borax powder embedding had the highest moisture content (1st day: 68.03%, 2nd day: 60.08%, 3rd day: 54.13%, 4th day: 47.80% and 5th day: 41.05%) (Table 3). Interaction effects were significant on the 1st and 2nd day with sun drying combined with silica gel resulting in the lowest moisture content (1st day: 52.73% and 2nd day: 44.59%) comparable to sun drying without desiccant due to higher temperatures and the hygroscopic nature of silica gel. Conversely, shade drying combined with borax powder had the highest moisture content (1st day: 68.95% and 2nd day: 60.87%) attributed to the longer drying time required in shade drying and borax's slower moisture removal. These findings align with previous studies on various flowers (Sell, 1993, Roberts, 1997, Dahiya *et al.*, 2003, Desh Raj and Gupta, 2003, Aravinda and Jayanthi, 2004, Bhalla *et al.*, 2006 and Meman *et al.*, 2006) [14, 10, 13, 4, 5, 1, 2] (Table 4).

Table 3: Impact of different drying methods and desiccants on moisture content percentage

Treatments	Moisture content %				
	1st day	2nd day	3rd day	4th day	5th day
Factor A: Drying methods (S)					
S_1=Sun drying	57.70	50.23	43.26	36.00	30.19
S_2=Shade drying	61.27	53.58	46.26	38.97	32.78
S.Em±	0.29	0.25	0.34	0.33	0.38
C.D. at 5%	0.84	0.72	0.99	0.96	1.11
Factor B: Desiccants (M)					
M_1=Without media	55.23	47.68	39.99	32.01	26.34
M_2=River sand (pinkish red)	62.33	54.66	47.61	41.11	35.11
M_3=River sand (black)	61.22	53.24	46.72	39.82	33.62
M_4=Sea sand	56.13	49.05	41.29	32.87	27.84
M_5=Silica gel	53.98	46.73	38.82	31.26	24.93
M_6=Borax powder	68.03	60.08	54.13	47.83	41.05
S.Em±	0.50	0.43	0.59	0.57	0.66
C.D. at 5%	1.45	1.26	1.71	1.67	1.93
Interaction (S × M)					
S.Em±	0.70	0.61	0.83	0.81	0.93
C.D. at 5%	2.05	1.78	NS	NS	NS
C.V.%	2.04	2.03	3.21	3.74	5.14

Table 4: Interaction impact of different drying methods and desiccants on moisture content percentage

Treatments	Moisture content %	
	1st day	2nd day
S_1M_1	53.56	46.59
S_1M_2	59.62	51.98
S_1M_3	58.32	51.02
S_1M_4	54.87	47.93
S_1M_5	52.73	44.59
S_1M_6	67.10	59.29
S_2M_1	56.89	48.76
S_2M_2	65.03	57.34
S_2M_3	64.12	55.45
S_2M_4	57.39	50.17
S_2M_5	55.23	48.87
S_2M_6	68.95	60.87
S.Em±	0.70	0.61
C.D. at 5%	2.05	1.78
C.V. %	2.04	2.03

Moisture loss (%)

Diverse drying methods exhibited significant variations in moisture loss percentages. Sun drying recorded the highest moisture loss percentages (1st day: 35.39%, 2nd day: 43.69%, 3rd day: 51.60%, 4th day: 59.73% and 5th day: 66.19%) while shade drying had the lowest. Silica gel embedding resulted in the maximum moisture loss percentages (1st day: 39.10%, 2nd day: 47.56%, 3rd day: 56.61%, 4th day: 65.43% and 5th day: 72.04%) comparable to drying without a desiccant. On the 5th day silica embedding matched results with sea sand. Conversely, borax powder embedding had the minimum moisture loss percentages (1st day: 26.16%, 2nd day: 32.22%, 3rd day: 38.91%, 4th day: 45.62% and 5th day: 54.05%) (Table 5). Interaction effects showed significant differences on the 2nd and 3rd day. The highest moisture loss percentages (2nd day: 50.01% and 3rd day: 58.64%) occurred with the combination of sun drying and silica gel comparable to sun drying without desiccant and sun drying with sea sand on these days. This can be attributed to silica gel's high moisture absorption capacity and the influence of high temperatures during sun drying. In contrast, the lowest moisture loss percentages (2nd day: 31.81% and 3rd day: 38.81%) were observed in the interaction of shade drying with borax powder due to lower room temperature during shade drying and the slower moisture absorption rate of borax powder. These findings align with previous research in various flowers (Gangadharswamy, 2003, Dubois and Joyce, 2005, Nair and Singh, 2011, Wilson *et al.*, 2013, Chithira, 2017) [7, 6, 11, 16] (Table 6).

Table 5: Impact of different drying methods and desiccants on moisture loss percentage

Treatments	Moisture loss %				
	1st day	2nd day	3rd day	4th day	5th day
Factor A: Drying methods (S)					
S_1=Sun drying	35.39	43.69	51.60	59.73	66.19
S_2=Shade drying	32.07	39.73	47.40	55.54	63.07
S.Em±	0.40	0.31	0.36	0.36	0.43
C.D. at 5%	1.18	0.91	1.04	1.04	1.27
Factor B: Desiccants (M)					
M_1=Without media	38.10	46.69	55.31	64.23	71.05
M_2=River sand (pinkish red)	30.43	38.78	45.19	52.80	59.54
M_3=River sand (black)	31.56	40.02	46.58	54.74	61.20
M_4=Sea sand	37.03	44.99	54.38	63.00	69.92
M_5=Silica gel	39.10	47.56	56.61	65.43	72.04
M_6=Borax powder	26.16	32.22	38.91	45.62	54.05
S.Em±	0.70	0.54	0.62	0.62	0.75
C.D. at 5%	2.04	1.58	1.81	1.80	2.19
Interaction (S × M)					
S.Em±	0.99	0.77	0.88	0.87	1.06
C.D. at 5%	NS	2.24	2.56	NS	NS
C.V.%	5.07	3.19	3.07	2.62	2.85

Table 6: Interaction impact of different drying methods and desiccants on moisture loss percentage

Treatments	Moisture loss %	
	2nd day	3rd day
S_1M_1	49.17	57.73
S_1M_2	40.45	48.25
S_1M_3	41.95	49.09
S_1M_4	47.92	56.87
S_1M_5	50.01	58.64
S_1M_6	32.62	39.00
S_2M_1	44.21	52.89
S_2M_2	37.11	42.13
S_2M_3	38.08	44.08
S_2M_4	42.06	51.89
S_2M_5	45.11	54.59
S_2M_6	31.81	38.81
S.Em±	0.77	0.88
C.D. at 5%	2.24	2.56
C.V. %	3.19	3.07

Reduction in flower diameter (cm)

Different drying methods and desiccants significantly influenced flower diameter reduction. Notably, over the 1st to 5th day, shade drying exhibited the lowest reduction (1st day: 0.71, 2nd day: 0.76, 3rd day: 0.80, 4th day: 0.83 and 5th day: 0.85) while sun drying resulted in the largest reduction. The least diameter reduction (1st day: 0.63, 2nd day: 0.68, 3rd day: 0.72, 4th day: 0.75 and 5th day: 0.76) occurred in embedded drying with sea sand followed by river sand (red). In contrast, the greatest reduction (1st day: 0.92, 2nd day: 0.98, 3rd day: 1.02, 4th day: 1.05 and 5th day: 1.07) was observed without desiccant. Interaction effects between drying methods and desiccants were significant over the 1st to 4th day. The smallest diameter reduction (1st day: 0.56, 2nd day: 0.60, 3rd day: 0.63, 4th day: 0.66) was in the interaction of shade drying with sea sand followed by shade drying with red river sand. Lower room temperatures during shade drying contributed to less moisture loss and sea sand's non-reactive nature with water vapor minimized diameter reduction. Conversely, the largest reduction (1st day: 0.98, 2nd day: 1.06, 3rd day: 1.10 and 4th day: 1.13) was observed in the interaction of sun drying without desiccant where direct exposure to high temperatures caused uneven petal shrinkage and larger diameter reduction. These findings align with previous research in gerbera (Sujatha *et al.*, 2001) [15], carnation (Nirmala *et al.*, 2008) [12] and various flowers (Khyati, 2015) [8].

Table 7: Impact of different drying methods and desiccants on reduction in flower diameter

	Reduction in flower diameter (cm)				
Treatments	**1st day**	**2nd day**	**3rd day**	**4th day**	**5th day**
Factor A: Drying methods (S)					
S_1=Sun drying	0.80	0.87	0.90	0.94	0.96
S_2=Shade drying	0.71	0.76	0.80	0.83	0.85
S.Em±	0.01	0.01	0.01	0.01	0.01
C.D. at 5%	0.02	0.02	0.02	0.02	0.02
Factor B: Desiccants (M)					
M_1=Without media	0.92	0.98	1.02	1.05	1.07
M_2=River sand (pinkish red)	0.68	0.74	0.77	0.80	0.82
M_3=River sand (black)	0.70	0.77	0.81	0.84	0.86
M_4=Sea sand	0.63	0.68	0.72	0.75	0.76
M_5=Silica gel	0.85	0.91	0.94	0.97	1.00
M_6=Borax powder	0.75	0.81	0.85	0.88	0.90
S.Em±	0.01	0.01	0.01	0.01	0.01
C.D. at 5%	0.03	0.04	0.04	0.03	0.04
Interaction (SXM)					
S.Em±	0.01	0.02	0.02	0.02	0.02
C.D. at 5%	0.04	0.06	0.05	0.05	NS
C.V.%	3.34	4.04	3.77	3.30	3.34

Table 8: Interaction impact of different drying methods and desiccants on reduction in flower diameter

	Reduction in flower diameter (cm)			
Treatments	**1st day**	**2nd day**	**3rd day**	**4th day**
S_1M_1	0.98	1.06	1.10	1.13
S_1M_2	0.71	0.78	0.81	0.85
S_1M_3	0.72	0.81	0.85	0.89
S_1M_4	0.70	0.76	0.80	0.83
S_1M_5	0.89	0.93	0.96	1.00
S_1M_6	0.79	0.86	0.90	0.93
S_2M_1	0.86	0.90	0.94	0.98
S_2M_2	0.65	0.69	0.73	0.75
S_2M_3	0.68	0.73	0.76	0.80
S_2M_4	0.56	0.60	0.63	0.66
S_2M_5	0.82	0.88	0.92	0.94
S_2M_6	0.70	0.75	0.79	0.83
S.Em±	0.01	0.02	0.02	0.02
C.D. at 5%	0.04	0.06	0.05	0.05
C.V. %	3.34	4.04	3.77	3.30

Conclusion

The results of this study revealed that sun drying with silica gel as a desiccant yielded the best outcomes for most physical parameters including weight loss percentage, moisture content percentage and moisture loss percentage. However, when it came to the reduction in flower diameter shade drying with sea sand was found to be the most effective.

Acknowledgment

The first author expresses gratitude to the Department of Horticulture, College of Agriculture in Junagadh, Gujarat.

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