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Effect of embedding media, temperature and durations on hot air oven drying of Rose (Rosa hybrida L.) cv. 'First Red'

KEYWORDS

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ABSTRACT *The studies on effect of embedding media, temperature and durations on drying of cut flowers of Rose cv. 'First Red' in hot air oven were conducted in the Department of Floriculture and Landscaping, Dr YS Parmar University of Horticulture & Forestry, Nauni (Solan) HP during 2008-2009 to find out the most suitable embedding mediUM, temperature and duration for hot air oven drying of rose. The cut flowers of Rose cv. 'First Red' at half bloom stage with 10 cm long stems were embedded in five drying media namely river bed sand, silica gel, borax, mixture of river bed sand and silica gel (50:50, v/v) and mixture of river sand and borax (50:50, v/v). After embedding, the flowers were given different temperature treatments (35oC, 40oC and 45oC) and durations (36 hours, 48 hours, 60 hours and 72 hours) in hot air oven. In total, there were 60 treatment combinations replicated thrice. The data recorded on various parameters were subjected to statistical analysis with CRD (factorial).*

The results obtained show that maximum moisture loss (86.97%) was recorded in flowers embedded in silica gel and dried at 45oC for 72 hours and minimum (33.28%) in river bed sand and kept at 35oC for 36 hours. Maximum anthocynin content (1.10 mg/g) was recorded when flowers were embedded in borax and dried at 35oC for 36 hours and minimum (0.74 mg/g) in the mixture of silica gel and sand and dried at 45oC for 72 hours. The maximum total sugars (9.64%) were recorded in the flowers embedded in silica gel and dried at 45oC for 72 hours and minimum (6.27%) in river bed sand embedded flowers dried at 35oC for 36 hours. The quality evaluation of the dried cut rose flowers scored maximum points (81.99) when flowers were embedded in borax and dried at 35oC for 36 hours and minimum points (39.93) for the flowers embedded in silica gel and dried at 45oC for 72 hours.

Introduction
Flowers have always remained an integral part of mankind and love for flowers is a natural instinct. Fresh flowers, though quite attractive and beautiful, are expensive, short lived and available in a particular season only. The beauty and freshness of cut flowers and cut foliage is lost due to microbial activities and biochemical changes (oxidative reactions) and can be retained only for a few days even if the best techniques of post harvest management strategies are exploited. Therefore, to overcome this problem as well as maintaining the charm of the flowers, the application of dehydration technology can play a vital role (Bhutani, 1995). The dried flowers are near to natural, having beauty as well as an everlasting value, if preserved and processed with appropriate dehydration technology. Hence, the dried flowers are extra special as they can be kept and cherished for years together (Singhwi, 1996). Owing to the fact that drying leads to the reduced microbial activity and ageing effect due to absence of moistures. Hence, the dried flowers can be stored in any moisture free atmosphere for longer periods without losing their appearance and aesthetic value. Thus, they become free from the bondage of season. Besides, the dry flowers are a good stand by for florists, since designs can be made during the stack periods and the arrangements can be displayed accordingly, whereas the fresh flowers are unsuitable from the grower's point of view and the price is less than for equivalent fresh flowers (Salinger, 1987). Rose is one of the top ranking cut flower in the international flower trade and the dry cut flowers of roses are the most expensive and exquisite of all dried flowers traded in the international market (Barnett and Moore, 1999).

Hence, considering the premium potential of cut roses in dry flower industry, the present study was planned to find out the most effective embedding medium, temperature and duration for hot air oven drying of quality cut roses.

Materials and Methods
The present investigations were conducted in the Department of Floriculture & Landscaping, Dr YS Parmar University of Horticulture and Forestry, Nauni-Solan (HP during 2008-09 The cut flowers of rose cv. 'First Red' were produced under naturally ventilated polyhouse at the Experimental Farm of the Department. The healthy, disease free and uniform flower stems of Rose cv. 'First Red' were harvested and immediately brought to the Floral Craft Laboratory of the department. The stem length of each selected cut flower was kept at a uniform length of 10 cm. The leaves present on each cut stem were removed before using them for drying. The glass jars (17 cm height and 10 cm diameter) selected for drying were filled evenly with five different embedding media viz., M_1 (river bed sand), M_2 (silica gel), M_3 (borax), M_4 (river bed sand:silica gel 50:50, v/v) and M_5 (river bed sand:borax 50:50, v/v) upto 4 inches of height. Depressions were made to insert the selected cut flowers into the each medium. After inserting the flowers, the respective embedding media were gently poured for uniform covering of the petals without deforming the petals. The respective embedding medium was evenly distributed so as to equalize the pressure on all sides of the flowers. After that, the glass jars were kept in hot air oven at the different temperature treatments viz., T_1 (35°C), T_2 (40°C) and T_3 (45°C) for varied drying durations namely, D_1 (36 hours), D_2

(48 hours), D_3 (60 hours) and D_4 (72 hours), respectively. There were 60 treatment combinations and replicated thrice. The data were collected on per cent moisture loss (%), estimation of anthocyanin content (mg/g), total sugar content (%) and quality attributes (flower colour, flower shape, calyx colour, calyx shape, skin shape and flower brittleness). The data obtained, thus, were subjected to statistical analysis of variance using CRD (factorial).

Results and Discussion

Moisture loss (%): The rose cut flowers dried in silica gel recorded highest moisture loss (77.55%) and it was minimum (48.02%) in river bed sand. The maximum moisture loss in silica gel may be due to the better hydrosorbent properties of silica gel in comparison to other desiccants used. The better hydrosorbent 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 (Safeena **et al.**, 2006a). Pertuit (2002) also reported that silica gel can absorb about 40 per cent of its weight with water. So, it is appropriate for drying flowers with closely packed petals such as rose. On contrary, the less moisture loss in river bed sand and borax may be due to the fact that sand has a larger particle size and is heavier in weight and thus, absorbs less moisture as well as it is not able to retain moisture for longer duration. Consequently, the moisture is re-absorbed by the flowers. Though, the borax is lighter than sand but is not comparatively as hygroscopic as silica gel.

As regards the effect of temperature, maximum moisture loss (64.79%) was repeated at 45°C and minimum (56.24%) at 35°C. The highest moisture loss at 45°C may be due liberation of more water at high temperature than the low temperature as there is direct relationship between temperature and moisture loss. In addition, liberation of more moisture contents at high temperature is because of the fact that there is high circulation of electric waves generated at high temperature. Dahiya **et al.** (2003) recorded significant decrease in weight and moisture content of chrysanthemum flowers with the corresponding increase in the temperature of hot air oven.

The drying of rose cut flowers for 72 hours resulted in maximum moisture loss (67.67%) whereas minimum (52.67%) was recorded in flowers dried for 36 hours. The maximum moisture loss of cut roses dried for 72 hours may be due to the prolonged duration of flowers in the hot air oven whereas circulation of hot air continued for longer duration hence resulting in maximum moisture loss. The interaction of embedding media x temperatures indicated that maximum moisture loss (81.56%) was recorded when rose cut flowers were embedded in silica gel and dried at 45°C and minimum (44.11%) in river bed sand when kept at 35°C. The higher moisture loss may be ascribed to the better hygroscopic properties of silica gel when drying of flower was carried out at high temperature in hot air oven. The interaction of embedding media and drying duration elucidates that maximum moisture loss (85.51%) was recorded in flowers embedded in silica gel and kept for 72 hours and minimum (40.71%) in flowers embedded in river bed sand and kept for 36 hours. The maximum loss of moisture contents in silica gel may be due to its better hygroscopic nature which is further catalyzed when dried for longer duration in hot air oven where the circulation of hot air continued for longer duration.

Similarly, the interaction of temperature and drying duration resulted in maximum moisture loss (71.51%) when flowers were dried at 45°C for 72 hours and minimum (48.03%) in flowers kept at 35°C for 36 hours. The high moisture loss at 45°C for 72 hours may be due to the fact that hot air circulated continuously for longer period resulting in maximum moisture loss from the cut flowers of rose cv. 'First Red' having compact petals. These results are in conformity with the findings of Safeena **et al.** (2006a) who concluded that rose cv. 'Ravel' having compact petals required more time for drying than cv. 'Lambada' having loose arrangement of petals.

The interaction of embedding media, temperatures and drying durations on dehydration of rose cut flowers indicated that maximum moisture loss (86.97%) was recorded when flowers were embedded in silica gel and dried at 45°C for 72 hours and found to be statistically at par with flowers embedded in silica gel dried at 40°C for 72 hours. However, minimum moisture loss (33.28%) was recorded in flowers embedded in river bed sand and dried at 35°C for 36 hours (Table 2).

The highest moisture loss in rose flowers embedded in silica gel and dried at 45°C for 72 hours may be ascribed to the fact that silica gel has better hygroscopic properties as well as there was circulation of hot air continuously for a long time resulting in maximum liberation of moisture content from the rose cut flowers.

Anthocyanin content (mg/g): The anthocyanin content in fresh flowers was 1.57 mg/g and decreased significantly in dried flowers. It is evident from the Table 3 that anthocyanin content was maximum (1.01 mg/g) in flowers dried in borax and minimum (0.84 mg/g) in the flowers dried in the mixture of silica gel and river bed sand. The retention of minimum anthocyanin content in the mixture of silica gel and river bed sand may be ascribed to the fact that heating effect of silica gel as well as river bed sand based embedded media was far quicker as compared to other desiccants, thus resulting in more degradation of pigments (carotenoids and anthocyanins) as well as browning effect of anthocyanin. Owing to the reason that anthocyanins being water soluble and are located in vacuoles. Hence, with increase in moisture loss and release of ethylene from the flower tissues, there have been disintegration of tonoplast leading to degradation of anthocyanin pigments. These results are in conformity with the findings of Smith (1993) who reported more loss of carotene content in sand and sand based embedding media.

The rose cut flowers dried at 35°C retained highest anthocyanin content (0.96 mg/g) and it was minimum (0.89 mg/g) in flowers dried at 45°C. The loss of more anthocyanin content in the flowers dried at 45°C may be ascribed to the fact that there is degradation of carotenoids and anthocyanins as well as auto-oxidation of carotenoids and browning effect of anthocyanin at higher temperature. Similar results have also been reported by Hrazdina (1971), Minquez et al. (1994) and Sharma et al. (2000). Since anthocyanins are water soluble and located in vacuoles so at higher temperature, there is more moisture loss and release of higher amount of ethylene which might have caused disintegration of tonoplast, thus, leading to degradation of anthocyanin pigments. Similarly, Meschester (1953) has reported exponential increase in anthocyanin pigment destruction with the increase in temperature. As regards, the effect of drying durations on anthocyanin content, maximum anthocyanin content (0.98 mg/g) was found in rose flowers dried for 36 hours and minimum (0.86 mg/g) in flowers dried for 72 hours.

The maximum loss of anthocyanin content in rose flowers dried for 72 hours may be due to the reason that there was maximum moisture loss when flowers were dried continuously for a longer time which resulted in the degradation of cellular components, thus, leading to disintegration of more anthocyanin contents.

The interaction, embedding media x temperature indicates that maximum anthocyanin content (1.04 mg/g) was recorded in the flowers dried in borax at 35°C in hot air oven and minimum (0.79 mg/g) in flowers embedded in silica gel and dried at 45°C. The retention of maximum anthocyanin content in borax at 35°C may be ascribed to the reason that the heating effect of borax at low temperature is comparatively slower than the other desiccants and resulted in less degradation of pigments. However, the maximum degradation of anthocyanin in flowers dried in silica gel at 45°C may be due to the fact that the heating effect of silica gel is much quicker especially at high temperature which led to faster loss of moisture as well as release of ethylene from the flower tissues and hence resulted in disintegration of tonoplast leading to the maximum degradation of anthocyanin content. In addition, the hygroscopic properties of silica gel increased exponentially especially with increasing temperature, thus, causing the faster disintegration of cellular components and ultimately resulted in maximum degradation of anthocyanin. The interaction, embedding media x drying duration elucidated that maximum anthocyanin content (1.07 mg/g) was recorded in flowers embedded in borax and dried for 36 hours and minimum (0.78 mg/g) in flowers embedded in the mixture of silica gel and sand (50:50, v/v) and kept for 72 hours. The maximum retention of anthocyanin content in flowers embedded in borax for 36 hours may be due to the fact that the heating effect of borax for comparatively lesser duration has resulted in low degradation of pigments. The highest degradation of anthocyanin content embedded in silica gel based embedding media for 72 hours may be ascribed to the reason that silica gel might have resulted in faster heating effect particularly when kept for longer duration and so leading to quicker moisture loss besides releasing the ethylene from the flower petals and disintegrated the tonoplast that ultimately resulted in the degradation of maximum anthocyanin content.

The interaction, temperature and duration indicated that maximum anthocyanin content (1.02 mg/g) was recorded in flowers dried at 35°C for 36 hours and minimum (0.83 mg/g) in flowers kept at 45°C for 72 hours. The retention of more anthocyanin content in the flowers dried at 35°C for lesser duration might be due to the reason that there was a gradual heating effect at low temperature which resulted in less degradation of pigments. However, the anthocyanin content was degraded to the maximum when flowers were dried at 45°C for 72 hours which may be ascribed to the fact that there might have faster heating effect at high temperature which was further catalysed when dried for longer duration and disintegrated the cellular components that ultimately resulted in the maximum degradation of anthocyanin content.

The interaction of embedding media, temperature and durations on dehydration of rose cut flowers indicated that maximum anthocyanin content (1.10 mg/g) in the flowers embedded in borax when dried at 35°C for 36 hours in hot air oven and minimum (0.74 mg/g) in flowers embedded in the mixture of silica gel and sand (50:50, v/v) and kept at 45°C for 72 hours (Table 4). The retention of maximum anthocyanin content in the flowers embedded in borax and dried at 35°C for 36 hours may be due to the fact that borax exhibited slow heating effect at low temperature particularly for less duration, thereby, resulting in less disintegration of tonoplast as well as release of minimum amount of ethylene from the flower tissues, which ultimately resulted in the degradation of lesser anthocyanin content.

Whereas the anthocyanin content was degraded to the maximum amount in the flowers embedded in the mixture of silica gel and sand (50:50, v/v) when dried at 45°C for 72 hours. This may be ascribed to the fact that silica gel based embedding media might have exhibited quicker heating effect as compared to other desiccants at higher temperature which further pronounced when drying continued for a longer time resulting in the more moisture loss as well as degradation of pigments besides the browning effect of anthocyanins.

Owing to the reason that anthocyanins being water soluble and are present in the vacuoles, thus, with the increase in moisture loss and release of ethylene from the petal tissues, there have been increased disintegration of tonoplast leading to the maximum degradation of anthocyanin pigments. These results are in close proximity with the findings of Smith (1993).

Total sugars (%)

The total sugar in fresh flowers was estimated as 4.40 per cent and increased significantly in dried flowers. The sugar content was found to be maximum (9.05%) in the flowers dried in silica gel and minimum (7.16%) in flowers embedded in sand. The more concentration of sugar content in silica gel dried flowers may be due to the fact that silica gel has better hygroscopic properties leading to more moisture loss from the flowers. Hence, there is more concentration of sugars. The less sugar content in sand dried cut flowers may be due to the reason that there is less removal of moisture content as sand is composed of larger size particles and ultimately the sugar content in sand dried flowers is less. As regards the effect of temperature, the sugar content was maximum (8.48 %) in flowers dried at 45°C and minimum (7.95%) at 35°C. The more sugar content in flowers dried at 45°C may be due to the reason that there is more and faster removal of moisture content at higher temperature whereas there is slow and less moisture loss from the flowers dried at low temperature and, thus less concentration of sugar content.

Similarly, drying of flowers for 72 hours recorded maximum sugar content (8.51%) and minimum (7.74%) when dried for 36 hours. The drying of flowers for more time resulted in the removal higher amount of moisture content leading to the increased concentration of total sugars, however, drying for lesser period removed smaller amount of moisture and hence resulted in less sugar content.

The interaction, embedding media x temperature showed maximum sugars (9.17%) when flowers were embedded in silica gel and dried at 45°C. This may be due to the reason that silica gel might have removed more moisture content particularly when drying was accomplished at high temperature and resulted in more concentration of total sugars. However, minimum total sugars (6.63%) was estimated in flowers embedded in sand and dried at 35°C. The less amount of total sugars may be ascribed to the reason that sand removed less amount of moisture from flowers especially when dried at low temperature.

The interaction, embedding media x durations elucidated that maximum sugar contents (9.48%) were found in flowers embedded in silica gel and kept for 72 hours and minimum (6.67%) in flowers embedded in sand and dried for 36 hours. This may be due to the fact that silica gel might have removed larger amount of moisture especially when drying was continued for longer duration, thus, leading to more concentration of sugars which was contrary when drying was accomplished in sand for lesser duration.

Similarly, the interaction, temperatures x durations indicated maximum total sugars (8.76%) when flowers were dried at 45°C for 72 hours and minimum (7.64%) in flowers kept at 35°C for 36 hours. This may be due to the reason that drying of flowers comparatively at high temperature and longer duration might have removed sufficient amount of moisture and thus recorded maximum amount of total sugars. However, the flowers dried at low temperature particularly for less time lost lesser amount of moisture and thereby recorded less total sugars. The interaction, embedding media, temperatures and durations showed maximum sugars (9.64%) recorded in flowers embedded in silica gel and dried at 45°C for 72 hours and minimum (6.27%) when flowers were embedded in sand and kept at 35°C for 36 hours. This may be due to the fact that silica gel has better hygroscopic properties which improved categorically when drying was practiced at higher temperature for longer time. Hence, this interaction might have removed larger amount of moisture leading to more concentration of total sugars. Whereas, less sugar content in sand embedded flowers may be due to the reason that there was less removal of moisture by sand particularly at low temperature for lesser duration and recorded less total sugars.

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Keeping quality of dried flowers

The keeping quality of dried flowers was assessed on the basis of flower colour, flower shape, calyx colour, calyx shape, stem shape and flower brittleness for different storage intervals i.e. 0 days to 120 days under covered conditions. The data presented in Table 7 elucidated that maximum points (81.99) were scored by the flowers embedded in borax and dried at 35°C for 36 hours while minimum (39.93) in flowers embedded in silica gel and kept at 45°C for 72 hours. The better keeping quality of the flowers embedded in borax and dried at 35°C for 36 hours may be ascribed to the reason that drying of flowers in borax at low temperature for lesser duration might have helped in retaining the original flower colour, shape, calyx colour, calyx shape as well as exhibited minimum flower brittleness mainly due to the slow heating effect of borax which is otherwise contrary when flowers were dried in silica gel at comparatively higher temperatures for longer durations resulting in excessive drying due to maximum loss of moisture that resulted into weakening of adhesion and cohesion forces in flower tissues and ultimately causing abscission by softening of middle lamella.

A perusal of Table 7 also indicated the interaction among embedding media, temperature, durations and storage intervals on keeping quality of dried flowers. The maximum points (85.00) were scored by the flowers embedded in borax and dried at 35°C for 36 hours when observed on zero (0) day and was found to be at par with the flowers dried under the same conditions and observed after 30 days and 60 days, respectively. This may be due to the reason that these interactions of embedding media, temperature, durations and storage intervals might have proved beneficial for the drying of cut roses which exhibited better keeping quality even upto 60 days, however, the minimum score (39.00) was obtained by the flowers embedded in silica gel and kept at 45°C for 72 hours and observe after 120 days of drying and was found to be at par with the flowers dried under the same conditions and observed after 90 days of dehydration. The lesser keeping quality of the flowers embedded in silica gel and dried at 45°C for 72 hours and particularly when observed for 120 days may be ascribed to the reason that the interactive effects of silica gel, higher temperatures and durations as well as storage intervals have contributed for the poor quality drying of cut roses which further deteriorated when they were stored for longer time i.e. 90 to 120 days after drying.

Conclusion

From the above studies, it was concluded that dried rose cut flowers exhibited better keeping quality when embedded in borax at low temperature (35°C) for comparatively lesser time (36 hours).

Table 1. Effect of embedding media (M), temperatures (T) and durations (D) on moisture loss (%) of flowers of rose cv. 'First Red' dried in hot air oven

	M_1	M_2	M_3	M_4	M_5	Mean	D_1	D_2	D_3	D_4
T_1	44.11 (41.57)	72.79 (58.74)	65.10 (53.87)	52.23 (46.29)	46.95 (43.25)	56.24 (48.74)	48.03 (43.85)	54.19 (47.50)	58.81 (50.26)	63.90 (53.37)
T_2	48.75 (44.28)	78.30 (62.55)	65.17 (53.90)	56.26 (48.64)	50.47 (45.27)	59.79 (50.93)	52.33 (46.39)	58.48 (50.10)	60.76 (51.44)	67.59 (55.79)
T_3	51.19 (45.68)	81.56 (64.77)	69.39 (56.48)	60.55 (51.15)	61.25 (51.54)	64.79 (53.93)	57.64 (49.54)	62.53 (52.49)	67.48 (55.51)	71.51 (58.17)
Mean	48.02 (43.84)	77.55 (62.02)	66.55 (54.74)	56.35 (48.69)	52.89 (46.69)		52.67 (46.59)	58.40 (50.03)	62.35 (52.40)	67.67 (55.78)
D_1	40.71 (39.60)	69.15 (56.34)	59.58 (50.54)	47.67 (43.67)	46.19 (42.81)					
D_2	46.00 (42.70)	76.23 (60.92)	65.30 (53.92)	52.85 (46.64)	51.63 (45.95)					
D_3	49.99 (44.99)	79.31 (63.03)	67.84 (55.52)	59.12 (50.28)	55.50 (48.19)					
D_4	55.37 (48.09)	85.51 (67.79)	73.49 (59.03)	65.73 (54.19)	58.25 (49.79)					

CD0.05					
	M=0.62	M × T=1.07	M1= Sand	T1=35°C	D1=36 Hours
	T=0.48	M × D=1.25	M2= Silica gel	T2=40°C	D2=48 Hours
	D=0.55	T ×D = 0.96	M3= Borax	T3=45°C	D3=60 Hours
			M4= Sand: Silica gel		D4= 72 Hours
			M5= Sand: Borax		

Figures in parentheses are arc sine transformed value

Table 2. Interaction effects of embedding media (M), temperatures (T) and durations (D) on moisture loss (%) of flowers of rose cv. 'First Red' dried in hot air oven

	T1				T2				T3			
	D1	D2	D3	D4	D1	D2	D3	D4	D1	D2	D3	D4
M1	33.28 (35.22)	43.35 (41.18)	47.13 (43.35)	52.67 (46.53)	43.34 (41.17)	46.29 (42.87)	49.26 (44.57)	56.11 (48.51)	45.50 (42.42)	48.35 (44.06)	53.57 (47.05)	57.33 (49.22)
M2	63.30 (52.71)	71.07 (57.46)	74.75 (59.85)	82.04 (64.95)	68.55 (55.90)	78.06 (62.07)	80.07 (63.51)	85.53 (68.71)	75.61 (60.42)	79.56 (63.23)	83.09 (65.74)	86.97 (69.71)
M3	56.48 (48.72)	62.73 (52.39)	70.42 (57.08)	70.76 (57.37)	59.07 (50.23)	61.67 (54.74)	66.67 (51.50)	73.69 (59.15)	63.21 (52.66)	66.49 (54.63)	71.87 (57.97)	76.01 (60.67)

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M4	44.55 (41.86)	49.07 (44.47)	53.04 (46.74)	62.25 (52.09)	46.95 (43.25)	52.80 (46.60)	59.67 (50.58)	65.61 (54.11)	51.56 (45.89)	56.67 (48.83)	64.65 (53.52)	69.31 (56.36)
M5	42.57 (40.72)	44.75 (41.98)	48.73 (44.27)	51.78 (46.02)	43.71 (41.38)	48.59 (44.19)	53.57 (47.05)	56.02 (48.46)	52.30 (46.32)	61.57 (51.69)	64.20 (53.25)	66.95 (54.91)

CD0.05							
	M×T×D=2.14	M1= Sand	T1=35°C	D1=36 Hours			
		M2= Silica gel	T2=40°C	D2=48 Hours			
		M3= Borax	T3=45°C	D3=60 Hours			
		M4= Sand: Silica gel		D4= 72 Hours			
		M5= Sand: Borax					

Figures in parentheses arc sine transformed value

Table 3. Effect of embedding media (M), temperatures (T) and durations (D) on anthocyanin content (mg/g) of flowers of rose cv. 'First Red' dried in hot air oven

	M1	M2	M3	M4	M5	Mean	D1	D2	D3	D4
T1	0.96	0.91	1.04	0.88	1.00	0.96	1.02	0.98	0.93	0.89
T2	0.93	0.88	1.01	0.85	0.93	0.92	0.97	0.94	0.90	0.86
T3	0.90	0.84	0.99	0.79	0.91	0.89	0.94	0.90	0.87	0.83
Mean	0.93	0.88	1.01	0.84	0.95		0.98	0.94	0.90	0.86
D1	0.99	0.94	1.07	0.90	1.01					
D2	0.94	0.90	1.03	0.86	0.97					
D3	0.90	0.86	0.99	0.82	0.93					
D4	0.87	0/82	0.96	0.78	0.89					

CD0.05					
	M=0.008	M × T=0.014	M1= Sand	T1=35°C	D1=36 Hours
	T= 0.006	M × D=0.016	M2= Silica gel	T2=40°C	D2=48 Hours
	D=0.007	T ×D = 0.013	M3= Borax	T3=45°C	D3=60 Hours
			M4= Sand: Silica gel		D4= 72 Hours
			M5= Sand: Borax		

Table 4. Interaction effects of embedding media (M), temperatures (T) and durations (D) on anthocyanin content (mg/g) of flowers of rose cv. 'First Red' dried in hot air oven

	T_1				T_2				T_3			
	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
M_1	1.02	0.97	0.94	0.91	1.00	0.95	0.90	0.87	0.97	0.92	0.88	0.83
M_2	0.98	0.93	0.89	0.84	0.94	0.92	0.86	0.82	0.90	0.86	0.83	0.80
M_3	1.10	1.06	1.01	0.99	1.07	1.03	1.00	0.96	1.04	1.01	0.98	0.93
M_4	0.95	0.91	0.87	0.81	0.90	0.87	0.84	0.79	0.86	0.82	0.77	0.74
M_5	1.08	1.03	0.98	0.92	0.98	0.95	0.91	0.89	0.97	0.93	0.90	0.86

$CD_{0.05}$				
	M×T×D=0.02	M_1= Sand	T_1=35°C	D_1=36 Hours
		M_2= Silica gel	T_2=40°C	D_2=48 Hours
		M_3= Borax	T_3=45°C	D_3=60 Hours
		M_4= Sand: Silica gel		D_4= 72 Hours
		M_5= Sand: Borax		

Table 5. Effect of embedding media (M), temperatures (T) and durations (D) on total sugars content (%) of flowers of rose cv. 'First Red' dried in hot air oven

	M_1	M_2	M_3	M_4	M_5	Mean	D_1	D_2	D_3	D_4
T_1	6.63 (2.57)	8.90 (2.98)	8.50 (2.91)	8.18 (2.85)	7.38 (2.71)	7.95 (2.81)	7.54 (2.74)	7.80 (2.78)	8.03 (2.83)	8.33 (2.88)
T_2	6.97 (2.64)	9.07 (3.01)	8.62 (2.93)	8.07 (2.84)	7.37 (2.71)	7.99 (2.82)	7.64 (2.75)	7.87 (2.80)	8.11 (2.84)	8.44 (2.90)
T_3	7.88 (2.80)	9.17 (3.02)	8.67 (2.94)	8.37 (2.89)	8.33 (2.88)	8.48 (2.91)	8.05 (2.83)	8.45 (2.90)	8.67 (2.94)	8.76 (2.95)
Mean	7.16 (2.67)	9.05 (3.00)	8.59 (2.93)	8.20 (2.86)	7.69 (2.77)		7.74 (2.78)	8.04 (2.83)	8.27 (2.87)	8.51 (2.91)
D_1	6.67 (2.58)	8.67 (2.94)	8.20 (2.86)	7.88 (2.80)	7.31 (2.70)					
D_2	6.93 (2.63)	8.91 (2.98)	8.47 (2.91)	8.07 (2.84)	7.81 (2.79)					
D_3	7.54 (2.74)	9.14 (3.02)	8.74 (2.95)	8.29 (2.87)	7.66 (2.76)					
D_4	7.51 (2.74)	9.48 (3.08)	8.97 (2.99)	8.59 (2.93)	8.00 (2.82)					

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$CD_{0.05}$					
	M=0.005	M × T=0.009	M_1= Sand	T_1=35°C	D_1=36 Hours
	T= 0.004	M × D=0.010	M_2= Silica gel	T_2=40°C	D_2=48 Hours
	D=0.005	T × D = 0.008	M_3= Borax	T_3=45°C	D_3=60 Hours
			M_4= Sand: Silica gel		D_4= 72 Hours
			M_5= Sand: Borax		

Figures in parentheses are square root transformed value

Table 6. The interaction effects of embedding media (M), temperatures (T) and durations (D) on total sugars content (%) of flowers of rose cv. 'First Red' dried in hot air oven

	T1				T2				T3			
	D1	D2	D3	D4	D1	D2	D3	D4	D1	D2	D3	D4
M1	6.27 (2.50)	6.48 (2.54)	6.67 (2.58)	7.12 (2.66)	6.52 (2.55)	6.83 (2.61)	7.15 (2.67)	7.41 (2.72)	7.23 (2.68)	7.50 (2.73)	8.80 (2.96)	8.02 (2.83)
M2	8.80 (2.96)	8.98 (2.99)	9.13 (3.02)	9.40 (3.06)	8.38 (2.89)	8.74 (2.95)	9.10 (3.01)	9.41 (3.06)	8.83 (2.97)	9.01 (3.00)	9.20 (3.03)	9.64 (3.10)
M3	8.17 (2.85)	8.33 (2.88)	8.64 (2.93)	8.87 (2.97)	8.12 (2.84)	8.57 (2.92)	8.79 (2.96)	9.00 (3.00)	8.31 (2.88)	8.52 (2.91)	8.80 (2.96)	9.05 (3.00)
M4	7.88 (2.80)	8.00 (2.82)	8.26 (2.87)	8.58 (2.92)	7.70 (2.77)	8.00 (2.82)	8.18 (2.86)	8.43 (2.90)	8.07 (2.84)	8.22 (2.86)	8.43 (2.90)	8.76 (2.95)
M5	7.09 (2.66)	7.23 (2.68)	7.49 (2.73)	7.72 (2.77)	6.99 (2.64)	7.21 (2.68)	7.35 (2.71)	7.96 (2.82)	7.85 (2.80)	9.00 (3.00)	8.16 (2.85)	8.34 (2.88)

CD0.05				
	M×T×D=0.018	M1= Sand	T1=35°C	D1=36 Hours
		M2= Silica gel	T2=40°C	D2=48 Hours
		M3= Borax	T3=45°C	D3=60 Hours
		M4= Sand: Silica gel		D4= 72 Hours
		M5= Sand: Borax		

Figures in parentheses are square root transformed value

Table 7. Effect of embedding media (M), temperatures (T), durations (D) and storage intervals (I) on keeping quality of hot air oven dried flowers of rose cv. 'First Red' up to 120 days of storage under covered conditions

			I_1	I_2	I_3	I_4	I_5	Mean
M_1	T_1	D_1	81.00	80.00	78.66	78.00	75.66	78.66
		D_2	75.00	74.00	74.00	72.00	70.00	73.00
		D_3	70.00	70.00	69.00	69.00	67.00	69.00
		D_4	65.00	66.00	64.00	62.33	62.66	63.99
	T_2	D_1	76.00	74.000	74.00	72.33	73.33	73.93
		D_2	71.00	70.00	70.00	70.00	68.00	69.80
		D_3	65.00	65.00	64.00	62.33	62.00	63.66
		D_4	61.00	61.33	60.00	59.00	58.00	59.86
	T_3	D_1	66.00	65.00	65.00	63.33	62.66	64.39
		D_2	58.00	59.00	58.00	56.66	57.66	57.86
		D_3	55.00	54.00	55.33	54.00	54.66	54.59
		D_4	50.00	49.00	49.00	47.00	47.00	48.40
M_2	T_1	D_1	65.00	65.00	65.00	62.00	61.00	63.60
		D_2	60.00	58.00	57.00	57.33	58.00	58.06
		D_3	55.00	56.00	54.00	52.33	50.00	53.46
		D_4	51.00	49.00	47.00	46.00	46.00	47.80
	T_2	D_1	60.00	58.00	56.00	57.00	55.00	57.20
		D_2	55.00	53.00	54.00	50.66	50.33	52.59
		D_3	51.00	50.00	50.00	47.00	47.00	49.00
		D_4	45.00	44.00	44.00	43.00	41.00	43.40
	T_3	D_1	54.33	54.00	54.00	52.33	52.00	53.33
		D_2	51.00	49.33	49.00	47.00	47.66	48.79

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		D_3	45.33	46.00	44.00	45.00	42.00	44.46
		D_4	41.00	40.00	40.00	39.66	39.00	39.93
M_3	T_1	D_1	83.00	82.00	82.00	81.66	81.33	81.99
		D_2	78.00	79.00	77.00	77.33	77.00	77.66
		D_3	76.00	75.66	75.00	73.66	69.66	73.99
		D_4	71.00	69.00	67.00	68.00	66.00	68.20
	T_2	D_1	81.00	81.00	78.00	79.00	77.00	79.20
		D_2	74.66	74.00	74.00	74.00	72.00	73.73
		D_3	70.00	70.00	68.00	68.00	66.00	68.40
		D_4	66.00	65.00	65.00	63.33	64.00	64.66
	T_3	D_1	71.00	71.00	69.00	68.00	67.00	69.20
		D_2	65.00	65.00	65.00	64.00	62.33	64.26
		D_3	59.66	58.66	59.00	59.00	58.00	58.86
		D_4	55.00	54.66	54.00	52.00	52.00	53.53
M_4	T_1	D_1	75.00	73.00	72.33	72.00	71.00	72.66
		D_2	71.00	71.00	69.00	68.66	67.66	69.46
		D_3	65.00	64.00	64.00	62.33	60.00	63.06
		D_4	60.00	61.00	57.00	58.00	56.66	58.53
	T_2	D_1	69.00	69.00	69.00	68.00	66.00	68.20
		D_2	66.00	66.00	63.33	62.00	62.33	63.93
		D_3	60.00	60.00	59.00	58.33	58.66	59.19
		D_4	55.00	55.00	53.00	50.00	50.00	52.60
	T_3	D_1	66.00	65.00	62.00	63.00	61.00	63.40
		D_2	61.00	60.00	60.00	58.00	58.00	59.40
		D_3	55.33	55.00	54.33	54.00	52.33	54.19
		D_4	50.00	50.00	49.66	49.00	48.00	49.33
M_5	T_1	D_1	83.00	84.00	82.33	81.66	80.00	82.19
		D_2	78.00	80.00	78.33	78.00	77.00	78.26
		D_3	75.00	75.00	75.00	74.00	71.66	74.13
		D_4	72.66	72.00	73.66	72.00	70.00	72.06
	T_2	D_1	80.00	80.00	77.66	79.00	76.33	78.59
		D_2	75.00	75.00	74.00	73.00	73.33	74.06
		D_3	65.00	65.00	65.66	63.33	63.66	64.53
		D_4	62.66	62.00	62.00	62.00	62.33	62.19
	T_3	D_1	66.00	65.00	65.00	64.00	64.00	64.80
		D_2	55.00	54.00	55.00	55.00	54.00	54.60
		D_3	54.00	52.33	52.00	52.00	50.66	52.19
		D_4	54.00	52.66	51.00	50.66	50.66	51.79
$CD_{0.05}$								
	$M \times T \times D = 0.75$		I_1= 0 days	M_1= Sand		T_1=35°C	D_1=36 Hours	
	$M \times T \times D \times I = 1.68$		I_2= 30 days	M_2= Silica gel		T_2=40°C	D_2=48 Hours	
			I_3= 60 days	M_3= Borax		T_3=45°C	D_3=60 Hours	
			I_4= 90 days	M_4= Sand: Silica gel			D_4= 72 Hours	
			I_5= 120 days	M_5= Sand: Borax				

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