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Physico chemical characters of marigold flowers during drying as influenced by embedding media and drying methods

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Abstract
An experiment was conducted to study "Physico chemical characters of marigold flowers during drying as influenced by embedding media and drying methods" during the year 2022-23. The minimum time taken for drying (19 hrs.), minimum dry weight (0.540 g) and maximum loss of moisture content (87.030%) were recorded in flowers embedded in silica gel under sun drying method. Maximum time taken for drying (175.500 hrs) recorded in flowers dried under shade without embedding medium. Maximum dry weight (0.980 g) and minimum loss of moisture content (70.780%) was recorded in flowers embedded in sand under shade drying method. Maximum diameter (3.740 cm), minimum shrinkage (15.573%), maximum xanthophyll content (46.410%) and maximum score for colour (4.810) was recorded in flowers embedded in silica gel under shade conditions. Minimum diameter (3.151 cm) and maximum shrinkage (28.893%) was recorded in flowers dried under sun without embedding medium. Minimum xanthophylls (15.620%) and minimum score for colour (2.520) was recorded in flowers embedded in sand and dried under sun.

Keywords: Marigold, silica gel, sun drying, moisture content

Introduction

Flowers have become an integral part of human life in the modern era. They symbolize love, beauty, hospitality, devotion, unity, appreciation, condolence etc. India has the advantage of varied climate and vast potential for floriculture sector. In recent past, Indian floriculture has undergone a transformation from a simple garden activity into an important export-oriented business activity. In most of the states, flower cultivation is a remunerative activity particularly among the small and marginal farmers involving women in harvesting, grading and making floral ornaments and bouquets. Flower drying offers excellent prospects, particularly for Indian entrepreneurs. Dried flowers and plants are being exported from India to many countries like Germany, United states and United kingdom. Dry flower products exported from India are estimated to be 71% of total export to various countries and earned 10-15 times more returns than the domestic market (Priyaranjan Koley, 2020.) [1].
In the light of above, the present investigation was conducted with an objective of studying physic-chemical characters of marigold flowers during the process of drying under the influence of various embedding media and drying methods.

Material and Methods

The present experiment was carried out at KVK Pandirimamidi, Alluri Sitarama Raju district, Andhra Pradesh with support from Dr. YSRHU-College of Horticulture, Venkataramannagudem. It was conducted in a Factorial Completely Randomized Design. There were two factors one on embedding media and the other on drying methods. Fresh marigold flowers were embedded in different media like sand, silica gel, borax, silica gel + borax (2:1) and also dried without embedding media. Flowers were kept face up position and dried under shade, poly solar or solar tunnel and under sun.

There were fifteen treatment combinations as follows:
M0Dm1: without embedding medium + Shade drying,
M0Dm2: without embedding medium + Poly solar drying,
M0Dm3: Without embedding medium + Sun drying,

M1Dm1: Riverbed sand + Shade drying,
M1Dm2: Riverbed sand + Poly solar drying, M1Dm3: Riverbed sand + Sun drying,
M_2Dm_1: Silica gel + Shade drying,
M2Dm2: Silica gel + Poly solar drying, M2Dm3: Silica gel + Sun drying,
M3Dm1: Borax + Shade drying, M3Dm2: Borax + Poly solar drying,
M3Dm3: Borax + Sun drying,
M4Dm1: Silica gel + Borax (2:1) + Shade drying, M4Dm2: Silica gel + Borax (2:1) + Poly solar drying,
M4Dm3: Silica gel + Borax (2:1) + Sun drying.

Results and Discussion Time taken for drying (hrs.)

The data pertaining to time taken for drying of flowers (hrs.) as influenced by different embedding media and drying methods in marigold revealed significant influence of treatments (Table 1.) Among the different embedding media, flowers embedded in silica gel (M_2) recorded least time for drying (79.333 hrs.) preceded by (M_4) those embedded in silica gel + borax (2:1v/v) (91.667 hrs.), whereas maximum time was in flowers embedded in sand (M_1) as (124.167 hrs.) As regards to drying methods, sun drying (Dm_3) recorded least time for drying (53.100 hrs.) whereas flowers dried under shade (Dm_1) had maximum time for drying (150.900 hrs.). Flowers dried under sun with no embedding medium (M_0Dm_3) recorded least time for drying (13.000 hrs.) while flowers dried under shade with no embedding medium (M_0Dm_1) exhibited maximum time for drying (175.
500) with regard to interaction effects. As evident from the above results, flowers dried under sun recorded less time for drying which might be due to the reason that sun drying was perhaps at a higher temperature compared to shade drying. Therefore drying under shade was slow as compared to former method. Similar finding was also reported by Kamble (2018) [2] in gerbera.

Drying time was found to be more under shade drying which might be due to low ambient temperature causing very small rate of evaporation to vaporize free water from floral parts. Shade under a roof may also have more moisture content slowing down drying process through removal of moisture. Similar results were reported by Kumpavat *et al*. (2015) [3] in gerbera.

Table 1: Effect of drying method, embedding medium and their interaction on time taken for drying (hrs.) of marigold flower

Embedding medium	**Time taken for drying (hrs.)**			
	Drying method			
	Dm_1	**Dm_2**	**Dm_3**	**Mean of M**
M_0	175.500	91.000	13.000	93.167
M_1	161.000	85.500	126.000	124.167
M_2	143.500	75.500	19.000	79.333
M_3	119.000	88.500	80.500	96.000
M_4	155.500	92.500	27.000	91.667
Mean of Dm	150.900	86.600	53.100	96.867
	SEm±		CD at 5%	
Embedding medium (M)	0.627		1.907	
Drying method (Dm)	0.486		1.477	
M x Dm	1.086		3.304	

M0: Without embedding media, M1: Riverbed sand, M2: Silica gel, M3: Borax, M4: Silica gel + borax, Dm1: shade drying, Dm2: poly solar drying, Dm3: sun drying

Dry flower diameter (cm)

There were significant differences in the treatment means pertaining to dry flower diameter due to influence of embedding media and drying methods in marigold (Table 2). The mean diameter of fresh flowers was 4.474 cm and it decreased to 3.552 cm after drying. Among the different embedding media, maximum diameter has recorded in (M_1) flowers embedded in sand (3.642 cm) followed by (M_4) silica gel + borax (2:1) (3.633 cm) whereas minimum diameter was recorded by (M0) flowers dried without embedding medium (3.324 cm). Regarding drying methods, minimum diameter of flower was recorded in (Dm3) sun drying (3.441 cm) and maximum diameter was recorded in (Dm1) flowers dried under shade drying (3.632 cm). The interaction between embedding media and drying methods was found significant. The minimum diameter was recorded in (M0Dm3) flowers dried under sun with no embedding medium (3.151 cm) followed (M0Dm2) by those dried through solar tunnel drying without embedding medium (3.351 cm) whereas, maximum diameter was recorded in flowers dried through silica gel embedding under shade (M2Dm1) (3.740 cm).

As noted from the above, maximum diameter of flowers embedded in silica gel under shade might be due to removal of moisture in a steady rate without affecting structural integrity of flowers. Present results are also in conformity with those reported by Akram *et al.* (2021) [4] in *Centaurea cyanus* and *Chrysanthemum coronarium*.

Shrinkage (%)

Influence of embedding media and drying methods and their interaction resulted in significant differences in respect of per cent shrinkage of flowers in marigold (Table 4.2). Among the different embedding media, maximum per cent of shrinkage was recorded (M0) in flowers dried with no embedding media (25.323%) whereas, minimum per cent shrinkage was recorded (M_1) by flowers embedded in sand (19.239%). As regards to drying methods, maximum shrinkage was noticed in (Dm_3) flowers dried through sun drying (23.316%). Minimum per cent shrinkage was recorded under shade drying (Dm_1) (18.141%). The maximum percentage of shrinkage was recorded in (M0Dm3) flowers dried by using without any embedding medium through sun drying (28.893%) followed by (M0Dm2) those dried under solar tunnel drying with no embedding medium (25.055%). Flowers embedded in silica gel under shade drying (M2Dm1) recorded the minimum per cent of shrinkage (15.575%).

The above results indicated minimum shrinkage (%) of flower in silica gel embedding medium and shade drying method. This could be due to removal of moisture from flower tissue in a steady state without effecting the structural integrity of the flower. The present results are in conformity with those reported by Kamble (2018) [2] in gerbera.

Table 2: Effect of drying method, embedding medium and their interaction on dry flower diameter (cm) and shrinkage (%) of marigold flowers

Embedding medium	Drying method											
	Fresh flower diameter(cm)				Dry flower diameter (cm)				Shrinkage (%)			
	Dm_1	Dm_2	Dm_3	Mean of M	Dm_1	Dm_2	Dm_3	Mean of M	Dm_1	Dm_2	Dm_3	Mean of M
M_0	4.450	4.470	4.430	4.450	3.470	3.351	3.151	3.324	22.022 (4.798)	25.055 (5.104)	28.893 (5.467)	25.323 (5.123)
M_1	4.450	4.530	4.550	4.510	3.680	3.645	3.600	3.642	17.303 (4.278)	19.536 (4.532)	20.879 (4.677)	19.239 (4.496)
M_2	4.430	4.435	4.440	4.435	3.740	3.710	3.400	3.617	15.575 (4.071)	21.170 (4.708)	23.423 (4.942)	20.056 (4.574)
M_3	4.420	4.435	4.470	4.442	3.551	3.542	3.535	3.543	19.683 (4.548)	20.081 (4.591)	20.917 (4.682)	20.227 (4.607)
M_4	4.435	4.620	4.540	4.532	3.720	3.658	3.520	3.633	16.121 (4.138)	20.908 (4.681)	22.466 (4.844)	19.832 (4.554)
Mean of Dm	4.437	4.498	4.486	4.474	3.632	3.581	3.441	3.552	18.141 (4.367)	21.350 (4.723)	23.316 (4.922)	20.935
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
Embedding medium (M)	-		NS		0.020		0.062		0.013		0.039	
Drying method (Dm)	-		NS		0.016		0.048		0.010		0.030	
M x Dm	-		NS		0.035		0.108		0.022		0.068	

Figures in parenthesis ( ) are square root transformed values

M0: Without embedding media, M1: Riverbed sand, M2: Silica gel, M3: Borax, M4: Silica gel + borax, Dm1: shade drying, Dm2: poly solar drying, Dm3: sun drying

Dry weight of flowers (g)

The data pertaining to dry weight of flowers (g) revealed significant differences due to embedding media and drying methods in marigold as presented in Table 3. and Figure 1. The mean fresh weight of flowers was 4.331 g which decreased to 0.764 g after drying. At the end of drying, the minimum dry weight of flowers was observed in flowers embedded in (M_2) silica gel (0.573) whereas maximum dry weight was in (M_1) river sand (1.465 g). Among the drying methods, dry weight of flowers was minimum (0.740 g) in sun drying at the end of drying. Maximum dry weight (0.794 g) was recorded under shade drying (Dm_1). As per the interaction effects, the minimum dry weight of flowers after drying was recorded in the treatment combination of (M_2Dm_3) silica gel + sun drying (0.540 g). However, the maximum dry weight of flowers after drying was in the combination of (M_1Dm_1) river sand + shade drying (0.980 g). As evident from these results, dry weight was at the minimum in flowers embedded in silica gel under sun drying (M_2Dm_3). Such less dry weight after drying indicates physical properties of silica gel having quick dehydration ability. Rapid drying under sun might be due to higher temperature. Similar outcome was also reported in calendula, coreopsis and cosmos by Parmar *et al.* (2018) [5] and chrysanthemum var. marigold by Chithira (2017) [6].

Loss of moisture content (%)

The data pertaining to loss of moisture content of flowers (%) revealed significant differences due to media and drying methods in marigold are presented in Table 3. Figure 2. The mean loss of moisture content in flowers after drying was 82.264%. At the end of drying, the maximum loss of moisture content was observed (M_2) in flowers embedded in silica gel (87.293%) whereas minimum loss of moisture content (77.850%) was recorded in flowers embedded in sand as embedding medium. Among the drying methods, loss of moisture content was maximum (83.284%) in sun drying (Dm_3). Minimum loss of moisture after drying (81.166%) was recorded in flowers dried under shade (Dm_2). As per the interaction effects, the Maximum loss of moisture content of flowers after drying was recorded in treatment combination of (M_2Dm_3) silica gel + sun drying %) followed by (M_2Dm_2) flowers embedded in silica gel under solar tunnel drying (87.550%). However, minimum loss of moisture content of flowers after drying was in combination of (M_1Dm_1) river sand + shade drying (76.720%). From the above results, it is concluded that flowers embedded in silica gel dried under sun drying (M_2Dm_3) recorded maximum percentage of loss of moisture content. From the findings, it was evident that loss of moisture content causes the weight loss during drying. At higher temperatue, the rate of moisture loss or liberation of moisture from flower tissue (transpiration) was increased due to increased conduction and convection of heat to the flower tissue, and its evaporation from surface was also accelerated due to an increase in DPD (Diffusion Pressure Deficit) and a decrease in relative humidity in the outside conditions, which causes drying. Similar results were recoreded by Singh *et al.* (2004) [7] in zinnia and Varu (2014) [8] in rose, gerbera and gomphrena.

Table 3: Effect of drying method, embedding medium and their interaction on dry weight (g) and loss of moisture content (%) of marigold flowers

Embedding medium	Drying method											
	Fresh weight (g)				Dry weight (g)				Loss of moisture content (%)			
	Dm_1	Dm_2	Dm_3	Mean of M	Dm_1	Dm_2	Dm_3	Mean of M	Dm_1	Dm_2	Dm_3	Mean of M
M_0	4.200	4.220	4.390	4.270	0.890	0.850	0.820	0.853	78.800 (8.933)	79.850 (8.992)	81.320 (9.073)	79.990 (8.999)
M_1	4.210	4.180	4.490	4.293	0.980	0.910	0.960	0.950	76.720 (8.816)	78.220 (8.900)	78.610 (8.922)	77.850 (8.880)
M_2	4.350	4.660	4.550	4.520	0.600	0.580	0.540	0.573	86.200 (9.338)	87.550 (9.410)	88.130 (9.170)	87.293 (9.396)
M_3	4.080	4.370	4.320	4.257	0.790	0.770	0.730	0.763	80.630 (9.035)	82.370 (9.131)	83.100 (9.170)	82.033 (9.112)
M_4	4.300	4.240	4.410	4.317	0.710	0.690	0.650	0.683	83.480 (9.191)	83.720 (9.204)	85.260 (9.288)	84.153 (9.228)
Mean of Dm	4.228	4.334	4.432	4.331	0.794	0.760	0.740	0.764	81.166 (9.063)	82.342 (9.127)	83.284 (9.179)	82.264
	SEm±		CD at 5%		SEm±		CD at 5%		SEm±		CD at 5%	
Embedding medium (M)	0.024		0.073		0.006		0.018		0.108		0.324	
Drying method (Dm)	0.019		0.056		0.004		0.014		0.081		0.243	
M x Dm	0.041		0.126		0.010		0.030		0.193		0.580	

Figures in parenthesis ( ) are square root transformed values M0: Without embedding media, M1: Riverbed sand, M2: Silica gel, M3: Borax, M4: Silica gel + borax, Dm1: shade drying, Dm2: poly solar drying, Dm3: sun drying

Xanthophyll content (%)

The data pertaining to Xanthophyll content (%) due to influence of embedding media and drying methods in marigold are presented in Table 4. and depicted graphically in Figure 3. It clearly revealed that mean xanthophylls content was influenced by different embedding media and drying methods. The mean xanthophyll content in fresh flowers was estimated to (58.74%) and decreased significantly after drying of flowers (30.544%). Among the different embedding media, maximum xanthophyll content was recorded in (M_2) flowers embedded in silica gel (43.000%) whereas minimum xanthophyll content was recorded in (M_0) flowers dried without embedding medium (20.690%). As regards to the drying methods, the maximum xanthophyll content was recorded under (Dm_1) shade drying (36.084%) and the minimum xanthophyll content was recorded under (Dm_3) sun drying (26.178%). Among interaction effect between different embedding media and drying methods on xanthophylls, the maximum xanthophyll content was noticed in flowers (M_2Dm_1) embedded in silica gel dried under shade (46.410%) followed by (M_2Dm_3) silica gel under sun drying (44.410%) whereas the minimum xanthophyll content was observed in (M_1Dm_3) flowers embedded in sand dried under sun(15.620%).

The above data revealed that the flowers embedded in silica gel under shade drying exhibited maximum xanthophyll content. It could be due to high hygroscopic nature of silica gel and also less temperature effect in shade drying conditions compared to sun drying. Similar results were observed by Chithira (2017) [6] in chrysanthemum var. marigold.

Table 4: Effect of drying method, embedding medium and their interaction on xanthophyll content (%) of marigold flowers

Embedding medium	Xanthophyll content (%)			
	Drying method			
	Dm_1	Dm_2	Dm_3	Mean of M
M_0	23.200 (28.782)	21.390 (27.537)	17.480 (26.180)	20.690 (27.500)
M_1	25.110 (30.060)	22.540 (28.332)	15.620 (24.809)	21.090 (27.734)
M_2	46.410 (42.924)	38.180 (35.157)	44.410 (41.774)	43.000 (39.951)
M_3	42.330 (40.572)	28.430 (31.570)	22.860 (30.553)	31.206 (34.232)
M_4	43.370 (41.173)	35.310 (34.626)	30.520 (36.568)	36.400 (37.456)
Mean of Dm	36.084 (36.702)	29.370 (1.444)	26.178 (31.977)	30.544
	SEm±		CD at 5%	
Embedding medium (M)	0.113		0.344	
Drying method (Dm)	0.088		0.266	
M x Dm	0.196		0.595	

Mean xanthphyll content of fresh flowers was recorded as (58.74%) Figures in parenthesis ( ) are angular transformed values M0: Without embedding media, M1: Riverbed sand, M2: Silica gel, M3: Borax, M4: Silica gel + borax, Dm1: shade drying, Dm2: poly solar drying, Dm3: sun drying

Colour

The data pertaining to change in flower colour due to embedding media and drying methods in marigold revealed significant influence of treatments Table 5. flowers embedded in silica gel (M2) scored maximum after drying (4.747). Followed by flowers dried in silica gel + borax (M4) as embedding medium (4.293) whereas minimum scores were observed in (M2) flowers dried in sand (3.250). As regards to drying methods, flowers dried under the shade has recorded maximum scores after drying (4.354). While minimum scores (3.648) were obtained by those which are dried through sun drying (Dm3). Among the interactions flowers embedded in silica gel under shade drying (M2Dm1) recorded maximum scores (4.810). Followed by (M2Dm3) flowers embedded in silica gel under sun drying (4.730). Whereas least scores were observed in combination of (M1Dm3) sand + sun drying (2.520). The above results illustrate that flowers under shade drying with silica gel as embedding media displayed maximum colour retention. This might be due to higher retention of colour in the flowers under ambient temperature. As a result of the rapid absorption of moisture by silica gel at low temperatures, pigments get accumulated without loss of colour. Similar results were also reported by Karunananda and Peiris (2007) [9] who studied on plumeria, found that desiccant drying rapidly eliminates water and causes cell death due to scarcity of water. The high water potential within the cell arrests the biological processes preceding cell death and retains the components in their dried form. Pigments were gradually degraded as drying time increased due to the activity of senescing enzymes and colour retention after drying was reduced. Similar findings with regard to better colour maintenance by sand embedding were confirmed by Basappa *et al*. (1991) [10] and Nataraj *et al*. (2004) [11] in Nerium.

Table 5: Effect of drying method, embedding medium and their interaction on colour of marigold flowers

Embedding medium	Colour			
	Drying method			
	Dm_1	Dm_2	Dm_3	Mean of M
M_0	3.610	3.320	3.230	3.387
M_1	4.210	3.020	2.520	3.250
M_2	4.810	4.700	4.730	4.747
M_3	4.520	4.010	3.810	4.113
M_4	4.620	4.310	3.950	4.293
Mean of Dm	4.354	3.872	3.648	3.958
	SEm±		CD at 5%	
Embedding medium (M)	0.023		0.071	
Drying method (Dm)	0.018		0.055	
M x Dm	0.040		0.122	

Colour of fresh flower was taken as 5.000 M0: Without embedding media, M1: Riverbed sand, M2: Silica gel, M3: Borax, M4: Silica gel + borax, Dm1: shade drying, Dm2: poly solar drying, Dm3: sun drying

Conclusions

The present study confirms that marigold flowers embedded in silica gel and dried under sun took minimum time for drying. The flowers dried through the said combination were found to possess minimum dry weight and maximum loss of moisture content. Whereas maximum dry weight and minimum loss of moisture content was recorded in flowers embedded in sand and dried under shade. Maximum diameter, minimum shrinkage, maximum xanthophyll and colour score were recorded in the combination of silica gel embedding + shade drying.

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