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Drying behaviour of French marigold *Tagetes patuala* Linn flowers

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ABSTRACT

The study was conducted to analyze the drying behaviour of French marigold flowers (variety Jafri) while drying in mechanical drier. The drying curves for moisture content of drying sample (db) vs drying time (min) and drying rate (dM/dt) vs drying time (min) at different air velocities were drawn. The experimental flowers had initial moisture content of 84 ± 1% (wb) and the samples were dried up to 19 to 20 per cent moisture content (wb). There was a non-linear decrease of moisture with drying time for all the air velocities as well as temperatures. The effect of temperature on the drying time was more significant as compared to drying air velocities. The drying time required for reaching a moisture content of 19 to 20 per cent at 45°C was more than three times the time required at 55°C. Total drying time for flowers under control conditions was also noted for air velocity of 2.5 m/s and it was higher than the drying time for pretreated flowers. The drying time did not change with increase in the level of sulphitation. The initial drying rate of flowers was very high due the presence of free moisture in the flowers particularly the ones which had been pre-treated. The EMC data were used to determine the relation between moisture ratio and drying time. The correlation coefficient revealed that the Page model better describes the drying data as compared to one term exponential model.

Keywords: Marigold flowers; drying time; moisture content

INTRODUCTION

Flowers have always remained an integral part of man's life. Fresh flowers though quite attractive are very expensive and short lived as well as available only during a particular season. Dried flower products on the other hand are long lasting and retain their aesthetic value irrespective of the season (Malcolm 1994). The art of flower drying is a very age old practice. Earlier dried flowers were in practice in the form of herbarium made by botanists for the purpose of identification of various species (Prasad et al 1997). Dried and preserved ornamental products offer a wide range of qualities like novelty, longevity, aesthetic properties, flexibility and year round availability. They make the surroundings clean, healthy, pleasant and cheerful.

Nowadays floriculture has been transformed from a hobbyist activity to a profitable commercial enterprise. The demand for dry flowers and attractive plant parts, dried floral arrangements and floral crafts has increased manifold during the last decade. In the recent floriculture trade the exports from India during 2002-2007 grew from ₹266 crore during 2002-2003 to ₹302 crore during 2003-2004 and ₹ 273 crore during 2004-2005 to achieve a growth rate of 2.66 per cent (Singh 2009). The Indian export basket comprises of 71 per cent of dry flowers which are exported to USA, Europe, Japan, Australia, Far East and Russia. Dry flowers constitute more than two-thirds of the total floriculture exports. The demand for dry flowers is increasing at an impressive rate of 8-10 per cent annually thus offering a lot of opportunities for the Indian entrepreneurs to enter in the global floricultural trade (Singh 2009). In fact during 2008-09 dried flowers constituted over 60 per cent of cut flower export and dried foliage constituted over 95 per cent of total foliage export from India (Sarkar Sumana 2010). As a matter of fact the items in dried flowers are many and varied which are eco-friendly, biodegradable and easily available at cheaper rates. The main techniques/methods used for drying of flowers are air drying, sun drying, oven and microwave oven, freeze drying and embedded drying. But the studies on mechanical drying of flowers are limited. Keeping this in view the specific objective of the study was to analyze the drying behaviour of french marigold flowers while drying in mechanical drier.

MATERIAL and METHODS

French Marigold flowers (variety Jafri) were selected as test material and purchased from local market. The flowers were sorted for nearly uniform size and colour subjectively before the experiment. The pre-treated flowers were dried at 45, 55 and 65°C drying air temperatures with air velocities as 2, 2.5 and 3 m/s in a laboratory tray drier (Satake make). In addition the untreated flowers were also dried at the selected temperatures and air velocity of 2.5 m/s. The air velocity was measured by using vane probe Anemometer.

In order to preserve the yellow colour which is due to the presence of xanthophylls (a class of carotenoids) marigold flowers were pre-treated by soaking in 0.1, 0.5 and 0.9 per cent potassium metabisulphite (KMS) solution for 15 minutes. The drying experiments were carried out according to Box and Behnken design for three variables-three levels (Table 1 and 2) with two replications.

The flowers had initial moisture content of 84±1 per cent (wb) and they were dried up to about 20 per cent moisture content (wb) in order to avoid brittleness (Armstrong et al 2000). The data for dried flowers was analysed for equilibrium

Table 1. Experimental design for three variables-three levels

X_1	X_2	X_3	Number of runs
±1	±1	0	i
±1	0	±1	3×4 (combinations) = 12
0	±1	±1	
0	0	0	
			1×3 replications = 3
			————————————
			Total runs= 15

Table 2. Process variables and their levels

Independent variable	Symbol		Level	
	Coded	Uncoded	Coded	Uncoded
Temperature (°C)	X_1	T	1	65
			0	55
			-1	45
KMS Concentration (%)	X_2	C	1	0.9
			0	0.5
			-1	0.1
Air Velocity (m/s)	X_3	V	1	3.0
			0	2.5
			-1	2.0

moisture content (EMC), drying rate and moisture ratio. EMC of the flowers was measured using Guggenheim-Anderson deBoer (GAB) equation given below:

$$EMC=\frac{A\times B\times C\times RH}{(1-B\times RH)(1-B\times RH+B\times C\times RH)}$$

The drying rate was measured as the change in moisture content (db) per unit time and moisture ratio as the ratio of available moisture to the total free moisture content present in the product and is given as:

$$Moisture-ratio(MR)=\frac{M-Me}{Mo-Me}$$

where M is the moisture content at any time, Mo is the initial moisture content and Me is the equilibrium moisture content.

RESULTS and DISCUSSION

The drying curves for moisture content of drying sample (db) vs drying time (min) and drying rate (dM/dt) vs drying time (min) at different air velocities were drawn as shown in Figs 1 to 3. The experimental flowers had initial moisture content of 84 ± 1% (wb) and the samples were dried up to 19 to 20 per cent moisture content (wb) because according to Armstrong et al (2000) the brittleness in marigold flowers increases at a moisture content of 12 per cent or less (wb). The graphs showed a non-linear decrease of moisture with drying time for all the air velocities as well as temperatures. The effect of temperature on the drying time was more significant as compared to drying air velocities.

It was found that the drying time required for reaching a moisture content of 19 to 20 per cent at 45°C was more than three times the time required at 55°C. Similar observations were also reported by Shene et al (1999) for pyrethrum flowers. Hansen et al (1993) have also indicated that the drying rate for taxus clippings increased by fifteen times for an increase in temperature from 40°C to 60°C. Total drying time for flowers under control conditions was also noted for air velocity of 2.5 m/s and it was higher than the drying time for pre-treated flowers. It was due to the fact that sulphitation increases energy absorption by the product leading to elevated product temperature and shorter drying time (Rajkumar and SreeNarayanan 2001). It was also observed that the drying time did not change with increase in the level of sulphitation.

The relation between drying rate and drying time is shown in Fig 3 for different temperatures. The curves indicated similar non-linear decrease of moisture content with time. It is evident that the entire drying of flowers took place in the falling rate period. The initial drying rate of flowers was very high due the presence of free moisture in the flowers particularly the ones which had been pre-treated. The drying rate was very slow at 45°C after sometime because initially the petals dry faster and thereafter the moisture had to be extracted from inside the thick layers of the receptacles that resulted in slow moisture transfer through diffusion from inside the flowers. The equilibrium moisture content was measured (Table 3) for all the temperatures using the GAB equation. This equation is particularly used for determining the moisture content of flowers because this equation best fitted the EMC data for the marigold flowers with correlation coefficient (R^2) of 0.96 over a range of 5-75 per cent relative humidity (RH) (Buser et al 1999).

The EMC data were used to determine the relation between moisture ratio and drying time as shown in Fig 4. The figures show almost a linear relationship between the two variables. Based on the

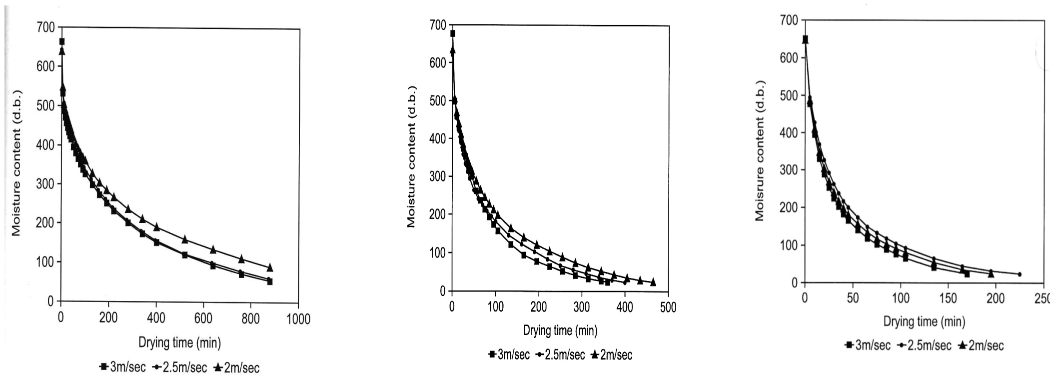

Fig 1. Effect of drying air velocity on moisture content of flowers at 45, 55 and 65°C respectively

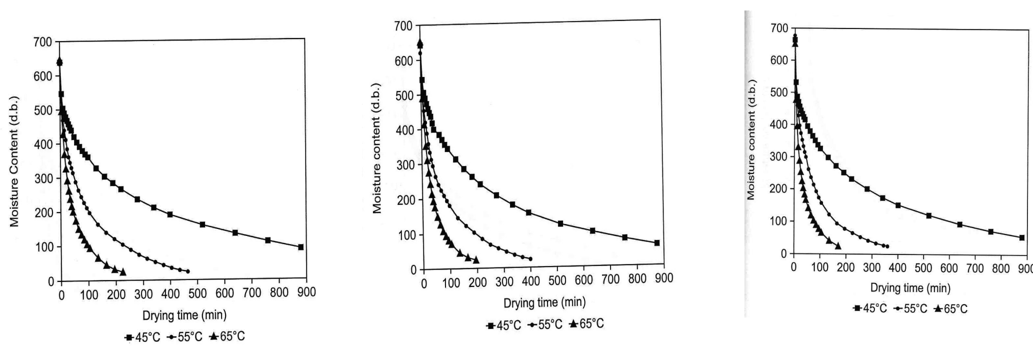

Fig 2. Effect of temperature on moisture content of flowers at 2.0, 2.5 and 3.0 m/s respectively

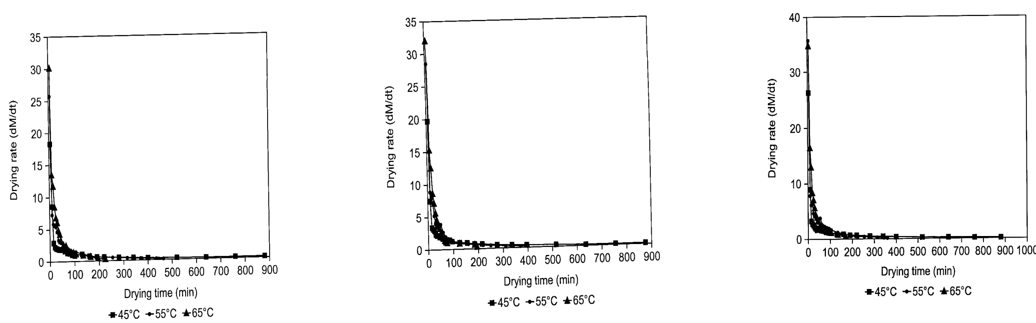

Fig 3. Effect of temperature on drying rate of flowers at 2.0, 2.5 and 3.0 m/s respectively

Table 3. EMC (% dry basis) at different temperatures for given RH range of drying air

Temperature (°C) and RH (%)	Average EMC (% db)
45 and 20-22	9.05
55 and 13-15	8.0
65 and 8-10	6.6

moisture ratio the one term exponential and Page model given below were fitted at the higher drying parameter conditions. The correlation coefficient revealed that the Page model better describes the drying data as compared to one term exponential model as was also found by many research workers for different agricultural products (Sokhansanj and Patil 1996, Afzal and Abe 1999, Hossain and Bala 2002).

$$\frac{M-Me}{Mo-Me}=e^{-kt} \quad \text{(One term exponential model);} \qquad (R^2=0.938)$$

$$\frac{M-Me}{Mo-Me}=e^{-\mathrm{k}t^{\mathrm{n}}} \quad \text{(Page Model);} \qquad MR=e^{-0.095t^{0.66}} \qquad (R^2=0.999)$$

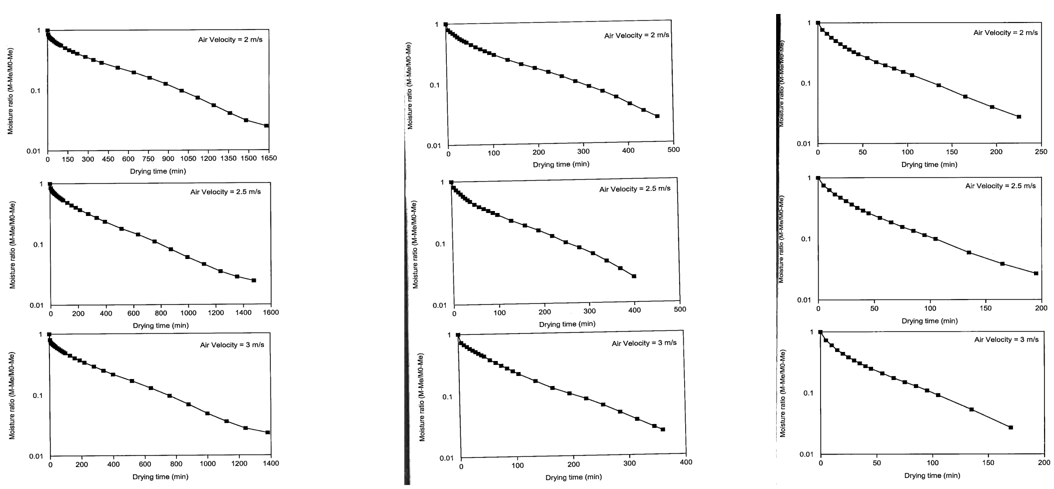

Fig 4. Relation between moisture ratio and drying time for marigold flowers at 45, 55 and 65°c for different air velocities respectively

where k is the drying rate constant and depends upon the drying air temperature and n is the reaction/drying rate order.

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