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Temperature influence on the *Tagetes Erecta* L. Flowers dehytratation process

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Abstract

Tagetes erecta L. flowers are used in medicine with therapeutic role, in food industry as natural pigments source (carotenoids, flavones etc.) or in aviculture sector as feed pigment. The main objective of this research was to investigate the influence of different dehydration process conditions on the sensorial characteristics of yellow and orange *Tagetes erecta L.* flowers. The drying process was performed using a tray drying equipment under the following conditions: constant air velocity (0.55 m/s), 40, 50 and 60°C suited to relative humidity (RH) values of 28.0, 27.5 and 28.5% respectively. Mathematical modeling of drying process, effective moisture diffusivity and activation energy calculations were estimated using *Arrhenius* equations . The effective moisture diffusivity was between (1,3– 5,19)$\cdot 10^{-12}$ $m^2 \cdot s^{-1}$ for yellow flowers and (1.02 – 2.71)$\cdot 10^{-12}$ $m^2 \cdot s^{-1}$ for orange samples. The activation energy value was with 35.57% much higher for yellow samples comparative to the orange *Tagetes erecta* L. flowers.

Keywords: *Tagetes erecta* L. flowers, dehydration process, drying process, activation energy.

1. Introduction

Tagetes erecta, the Mexican marigold, also called Aztec marigold [1] is a species of the genus *Tagetes* native to Mexico and is spread in South and Middle America as well as Mexico. Genus *Tagetes L.* belong in the family *Asteraceae* and consists of about 30 species [2, 3]. This plant reaches heights of between 50 and 100 cm (20 and 39 in). The Aztecs used to gather this wild plant and cultivated it for medicinal, ceremonial and decorative purpose. Nowdays it is widely cultivated commercially with many cultivars in use as ornamental plants [3] and for the cut-flower trade [4, 5]. Marigold (*Tagetes erecta L.*), known as a common ornamental plant which bears bright yellow and orange flowers, is available in many parts of the world [6].

Marigold flowers are used as tea leaves, ingredient in cooking (*Imeruli shaphrani*) [7] as well as food and textiles yellow colorant. Marigold is also widely used as a medicinal herb for its anti-inflammatory [8], analgesic [9], anti-edematous properties, which are important to phytotherapy as well as to dermatology and cosmetology [10, 11]. The pharmacological activity of marigold is related to the content of several secondary metabolites, and the most important compounds are the terpene, essential oils, flavonoids, carotenoids tannins, saponins, a bitter principle, mucilage and resin [11, 12]. Commercially available additive for poultry feed was studied in order to improve the pigmentation of the bird's fat, skin and egg yolk [14, 15, 16].

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Drying is an important process for handling raw materials in order to prolong shelf life, as the drying process inhibits enzymatic degradation and limits microbial growth [17, 18]. Hot air (HA) drying is the most commonly employed commercial technique for drying vegetables and fruits [19]. The major disadvantage associated with HA drying is that the long drying time needed causes degradation of food quality [20].

The main objective of this research was to investigate the influence of different dehydration processing conditions on the sensorial characteristics of yellow (**YF**) and orange (**OF**) *Tagetes erecta L.* flowers.

2.Materials and Method

2.1.Raw material

YF and OF of *Tagetes erecta* L. were purchased from Natural Sciences Museum, Botanical Garden, in Galati, Romania. Marigold flowers were cleaned and kept one hour at room temperature to drain.

Flower petals were cut from the base of the petals and were evenly and thinly distributed on the drying trays. Marigold flowers were picked at the maximum opening stage – stage 3 (figure 1).

Figure 1. Marigold flower development stages
Stage 1 - The beginning of the bloom, Stage 2 - Half open flower, Stage 3 - Flower maximum opening, Stage 4 - The beginning of the offensive

2.2.Drying treatment

In this study a computer controlled pilot tray dryer (UOP8MKII Tray Drier, model 2014, Armfield Ltd., UK), from the Integrated Center For Research, Expertise And Technological Transfer In Food Industry (Bioaliment-Tehnia, Https://Erris.Gov.Ro/Food-Biotechnology) of Faculty of Food Science and Engineering, Dunarea de Jos University of Galati, Romania was used for plants drying. The tray drier has capacity up to 2.1 kg of wet material and it is integrated with a full data logging to control the flow rate, temperature (up to 80 °C), humidity, air velocity (from 0.4 to 3.0 $m \cdot s^{-1}$) and to determine drying rate [21]. The tray dryer is integrated with a data logging UOP8MkII-306 software with PID (Proportional Integral Derivative) controller which allows registration of the drying parameters and performs some standard calculations on the data [22]. The drying process was performed using a tray drying equipment under the following conditions: constant air velocity (0.55 m/s), 40, 50 and 60°C corresponding to relative humidity (RH) values of 28.0, 27.5 and 28.5% respectively [23].

2.3.Mathematical modeling of tray drying curves

For the mathematical modeling, we assumed the thin layer drying equations which are appropriate for drying on layer of sample particles or slices [24]. If the relative humidity of the drying air is constant during the drying process, then the moisture equilibrium is constant too [25]. The moisture ratio (*MR*) of slices of yellow and orange flowers of *Tagetes erecta* L was calculated using the following equation:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \qquad (1)$$

where:
M_t is mean moisture content at time t (% dry basis);
Me is equilibrium moisture content (% dry basis);
M0 is initial moisture content (% dry basis).

2.3.1.Effective moisture diffusivity calculation

Diffusion in solids during drying is a complex process that may involve molecular diffusion, capillary flow, Knudsen flow, hydrodynamic flow, or surface diffusion [25]. All these phenomena are combined in effective moisture diffusivity that can be calculated from linearity of MR versus time (equation 2):

$$\ln(MR) = \ln(a) - k\cdot t \qquad (2)$$

where:
a is mean the constant (dimensionless);
t is the drying time (s)
k is the drying constant (s^{-1}).

The drying constant, *k* is defined as:

$$k = -\frac{\pi^2 \cdot D_{eff}}{A_2} \qquad (3)$$

where:

$$A_2 = 4 \cdot L^2 \qquad (4)$$

In this case *Deff* can be estimated from drying constant *k* with eqn. (5):

$$D_{eff} = \frac{k \cdot A_2}{\pi^2} \qquad (5)$$

where:
A_2 is mean the geometric constant (m^2);
L is the thickness of the slice if drying occurs only from one side (m);
D_{eff} is the effective moisture diffusivity ($m^2\cdot s^{-1}$).

2.3.2.Activation energy calculation

The effect of different drying temperatures on D_{eff} is described by Arrhenius equation that indicate a linear variation of ln (D_{eff}) versus [1/(T+273.15] (equation 6).

$$\ln(D_{eff}) = \ln(D_0) - 10^3 \cdot \frac{E_a}{R} \cdot \frac{1}{(T+273.15)} \qquad (6)$$

where: D_0 is the reference diffusion coefficient at infinitely high temperature ($m^2\cdot s^{-1}$);

E_a is activation energy ($kJ\cdot mol^{-1}$);

R is the universal gas constant (8.314 $kJ\cdot mol^{-1}\cdot K^{-1}$);

T is absolute temperature (K).

The slope of equation (6) is equal to ($-10^3\cdot E_a/R$), so E_a is easily calculated with revealing the slope by deriving from linear regression of ln(D_{eff}) – [1/(T+273.15].

3.Statistics

Non-linear regression procedure (SAS software, version 9.1, Cary, NC, USA) was applied to estimate the parameters of equations (3) and (5).

4. Color measurement

Color measurements (before and after drying process) were performed using a Chroma Meter colorimeter (Konica Minolta CR-400 model, 2015) according to the methods described in literature [26,27]. The colorimeter uses three values (*L*, *a* and *b*) to describe the precise location of a color inside a three-dimensional visible color space and before each actual color measurement was calibrated against standard white plate [28]. The measuring surface included the cap, gills and stipe. The measurements were displayed in *L*, *a* and *b* values which represents light–dark spectrum with a range from 0 (black) to 100 (white), the green–red spectrum with a range from - 120 (green) to + 120 (red) and the blue-yellow spectrum with a range from –120 (blue) to + 120 (yellow) dimensions respectively. An increasing *L* value indicates a higher degree of whiteness.

Color parameters evaluation

Total color difference, ΔE was calculated using equation (7), where subscript "0" refers to the color reading of fresh flowers [29].

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b - b_0)^2} \qquad (7)$$

where:
L is mean degree of lightness to darkness;
L_0 is the initial value of L;
a is the degree of redness to greenness;
a_0 is the initial value of a;
b is the degree of yellowness to blueness;
b_0 is the initial value of b.

All these parameters are dimensionless. All color measurements were performed in triplicate at different positions of samples.

Chroma (C^*) value describes the brightness colour (colour saturation starting from a value of 0).

$$C^* = (a^{*2} + b^{*2})^0 \qquad (8)$$

Hue angle (H^o) value describes the hue or colour angle (colour of sample as defined by its location in a 360° axis; 0 or 360^0 = red, 90° = yellow, 180° = green and 270° = blue).

$H^o = \text{arctg } b^*/a^*$ (9)

E value represents enhancement of the fraction of redness relative to those of yellowness and lightness; this parameter was calculated using an equation rewritten according to reported authors [30, 31]

$E = a^*/b^* + a^*/L^*$ (10)

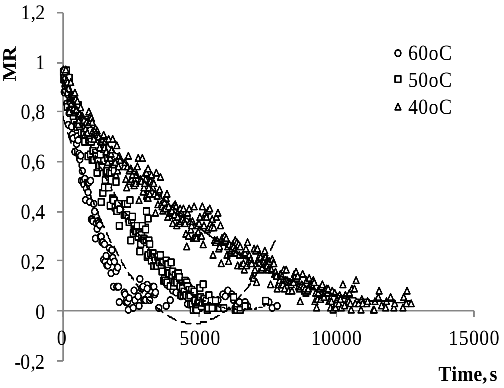
5.Results and Discussion

5.1.Drying kinetics

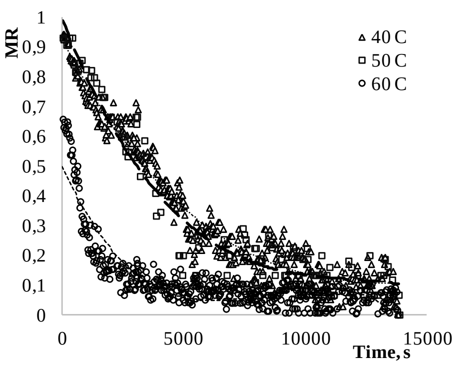
The experiments were performed at the equilibrium moisture content 4.0837 ± 0.46 % at 20°C and RH 75%.

Figure 1 presents how the moisture ratio depending on temperature varies in time, at constant air velocity (0.55 $m\cdot s^{-1}$) in the tray drier for both marigold flower types.

Increasing the air temperature from 40ºC to 60 °C, the drying rate increased and the drying time decreased (from 170 min at 40 °C up to 70 min at 60°C for YF, and from 160 min at 40 °C up to 80 min at 60 °C for OF).



a.YF



b. OF

Figure 2. Effect of drying parameters on MR values

The initial moisture content of the flower petals of YF was 15.36 %, respectively 15.15% for OF. Most part of the moisture was lost during the first period of time where sensible heat is transferred to the product directly influencing the moisture content and increasing the rate of water evaporation. Drying curves of flower petals exhibited a fast-drying rate at the beginning, followed by a period of reduced drying rate.

5.2.Effective moisture diffusivity and activation energy calculations

The increased temperature determines decreasing of moisture content and the moisture ratio decreases proportionally with drying rate.

These results were in accordance with those of others authors that reported that drying rates increased with the increase in temperature and decreased in time for different systems such as ginger [32] and tomatoes [33].

Effective moisture diffusivity values (Table 1) were calculated according to eqn. (3) described in the Materials and methods section.

Effective moisture diffusivity values increased directly proportional with drying temperature for both colour flower species. The minimum value of effective moisture diffusivity was 1.02 10^{-12} $m^2\cdot s^{-1}$ for OF at 40 °C, while the maximum value was 5.19 10^{-12} $m^2\cdot s^{-1}$ for YF at 60 °C.

The R^2 values were obtained by applying non-linear regression model, ln (*MR*) versus time plots.

Table 1. Effective moisture diffusivity values of yellow and orange flowers *Tagetes erecta L.*

Sample	Temperature [°C]	R^2	$D_{eff}\cdot 10^{12}$ [$m^2\cdot s^{-1}$]
YF	40	0.9756	1.30
	50	0.9764	2.62
	60	0.8825	5.19
OF	40	0.9502	1.02
	50	0.9459	1.11
	60	0.8038	2.51

The variation of ln (D_{eff})-[1/(T + 273.15] is presented in Figure 3 and the activation energy (E_a) values were estimated according equation (6).

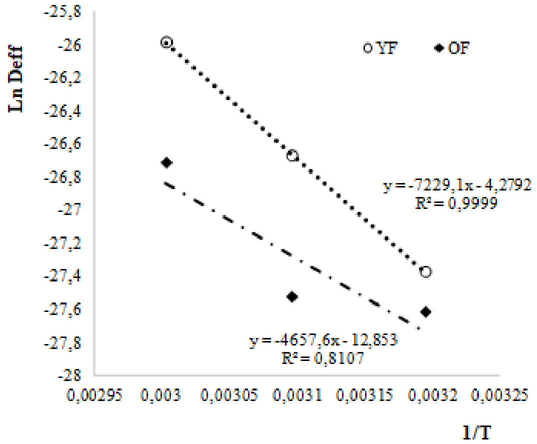


Figure 3. Effective moisture diffusivity versus absolute temperature for yellow and orange flowers *Tagetes erecta L*

In our study, for the tray drying of flowers, the activation energy for moisture diffusion, E_a, was calculated in range 60.103 kJ·mol^{-1} for YF and 38.723 kJ·mol^{-1} for OF. These results indicate that YF need more energy input for tray drying process. Considering the literature reports, the activation energy values are from 12.7 to 110 kJ·mol^{-1} for food products in general, our values are in line with other results reported [20].

6.Color measurement

One of the most important sensorial attribute is color of food products. Table 2.1 and table 2.2. presents the *L, a, b* and total color change *(ΔE)* for fresh and tray dried flowers at 40, 50 and 60°C. The color measurements indicated that the *L* values decreased with increased drying temperatures for both types of flowers, so the browning is more pronounced at higher temperatures. Also the total color change (*ΔE)* was greater in the samples dried at 60 °C.

Table 2.1. *L, a, b and calculated color parameters values for YF at different tray drying temperatures*

Samples / Temp.	YF						
	a*	b*	L*	C*	H°	ΔE	E
YF fresh	16.99±2.05	87.23±9.42	69.66±8.53	88.88±8.80	1.38±0.03	nd	0.44±0.08
40	12.52±0.30	38.48±1.16	43.98±0.93	40.47±1.10	1.26±0.02	55.28	0.61±0.02
50	13.80±0.81	49.66±0.99	49.98±0.57	51.55±1.08	1.30±0.01	42.53	0.56±0.03
60	15.96±0.38	51.55±1.36	50.91±0.95	54,00±1.27	1.27±0.01	40.33	0.62±0.02

Table 2.2. *L, a, b and calculated color parameters values for OF for different tray drying temperatures*

Samples / Temp.	OF						
	a*	b*	L*	C*	H°	ΔE	E
OF fresh	31.26±4.78	78.65±12.13	65.30±1.30	84.65±12.62	1.19±0.04	nd	0.88±0.11
40	16.82±0.66	34.18±0.94	42.04±1.21	38.10±0.99	1.13±0.01	52.22	0.92±0.03
50	19.24±1.21	37.97±2.26	43.84±1.08	42.57±2.52	1.11±0.01	47.53	0.94±0.04
60	21.01±1.57	38.06±1.80	43.59±1.09	43.48±2.26	1.07±0.02	47.16	1.03±0.054

a*: redness; b*: yellowness; L*: lightness; C*: Chroma; H°: hue angle; ΔE: total colour difference; E: fraction of redness relative to those of yellowness and lightness; nd – not determined.

This implies that with increase in air temperature, the degradation rate of color becomes faster as a result of high energy transferred to the inside of food material. For fresh flowers, typical *L* values for the caps and stipes were 80.6 for YF and with 1.61 % higher for OF.

7. Conclusion

This study aim was to evaluate the influence of different temperature hot air on the sensorial characteristics of two types of marigold flowers. Drying kinetics allowed estimation of the diffusion coefficients for marigold YF and OF drying at temperature between 40°C and 60°C.

The mathematical model of drying process allows the calculation of the activation energy and the values indicate the necessity of more energy input for YF tray drying process. Our study underlined the changes in color that were produced during drying.

Our study provides information for food industry applications that considers the use of marigold flowers as a valuable resource for producing natural pigments.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards

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