Optimization of convective drying process for Persian shallot using response surface method (RSM)

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Abstract: Optimization of convective drying process of Persian shallot was investigated using dependent variables of effective moisture diffusivity (D_{eff}), specific energy consumption (SEC), shrinkage and color changes. The central composite design (CCD) was selected for design and optimization of the process. The second-order polynomial models with transformed responses were developed from experimental data to generate three dimensional response surfaces and contour plots. Experiments were performed at air temperatures of 40°C, 55°C and 70°C, air velocities of 0.5, 1.5 and 2.5 m/s and slice thicknesses of 2, 4, and 6 mm in triplicate. Based on response surface and desirability functions, the optimum conditions for Persian shallot drying were: air temperature 70°C, air velocity 2.5 m/s and slice thickness 4.58 mm. At this point, D_{eff}, *SEC*, shrinkage and color changes were obtained as 1.18675×10^{-9} m^2/s, 13.83 MJ/kg, 35.04% and 42.27%, respectively.

Keywords: color, diffusivity, energy, central composite design, shrinkage

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1 Introduction

Persian shallot (*Allium hiertifolium Boiss.*) is a perennial and bulbous plant. It is from Alliaceae family and is an important medicinal plant. The shallot is native of Iran, and grows in the high pastures. It is well known in Iranian folk medicine and its bulbs have been widely used for treating rheumatic and inflammatory disorders (Ghodrati Azadi et al., 2009).

Dried bulb slices of Persian shallot used as an additive to yogurt and pickling mixtures. It is a very nutritive with special taste. In Iran powder of dried bulb used as a tasty additive or spice for foods. It has been proved that aqueous extract of the shallot has antibacterial effects (Ashrafi et al., 2004; Ebrahimi et al., 2009; Asili et al., 2010). Also, antifungal, antiviral, antiprotozoal, and antihelmintic properties of Allium genus have been reported (Taran et al., 2006).

Drying is the most common procedure of food preservation. Drying improves the product stability, since it reduces the moisture and microbiological activity of the foodstuff and minimizes physical and chemical alterations during storage (Hatamipour et al., 2007). Drying of moist products is a complicated process involving simultaneous heat and mass transfer process.

Water is transferred by diffusion phenomenon from inside the food material to the air–food interface and from the interface to the air stream by convection. Knowledge of heat and moisture transport is crucial for process design, energy savings and product quality. Developing drying models and determining moisture transport parameters are of particular interest for efficient mass transfer analysis and reproducibility of quality-controlled products (Corzo et al., 2008).

Water removal from food and agricultural materials is very energy consuming. The efficiency of drying with respect to both time and energy is an important economic consideration. Case hardening and low thermal conductivity of the material are the main factors responsible for controlling the hot air drying process

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(Umesh Hebbar et al., 2004). In most drying operations, water is the liquid evaporated and air is the drying medium (Ozgener and Ozgener, 2006).

The increasing demand for high-quality shelf-stable dried fruits and vegetables requires the design, modeling and optimizing of the drying process with the purpose of implementing not only the final quality of the dried product but also the efficiency of the process. During drying of food and agricultural products undergo physical, chemical, structural and nutritional changes that cause quality degradation (Arslan and Özcan, 2011). Optimization has been applied in food process engineering for the efficient operation of systems and unit processes yielding a high quality product (Corzo et al., 2008).

Modeling and optimizing of the process is vital important in drying technology to increase the efficiency of the drying facilities. Complex and highly nonlinear phenomena in drying process are involved (Omid et al., 2009). Hence, it is difficult to quantify the complex relationships between inputs and outputs of a drying approach based on analytical methods. Response surface method (RSM) is a powerful tool for optimizing of many engineering applications probably because of its high efficiency, simplicity and comprehensive theory. It can save a lot of time and can build models accurately and quickly in an optimization design (Nazghelichi et al., 2011).

RSM included a group of techniques used to establish the relationship between one or more measured responses and independent variables. RSM can be used in problems that have ingredients and/or processing conditions as variables (Kiat Pua et al., 2010). RSM has been frequently used in the optimization of food processes (Varnalis et al., 2004; Eren and Kaymak-Ertekin 2007; Wani et al., 2008; Erbay and Icier 2010; Nazghelichi et al., 2011).

It is not information available about physical and thermal properties of Persian shallot and its optimization the drying process in the literature. The aim of this study was: (a) to determine of some physical and thermal properties of Persian shallot, (b) to study the effect of independent variable on the dependent variable and (c) optimization of the Persian shallot drying in a convective dryer.

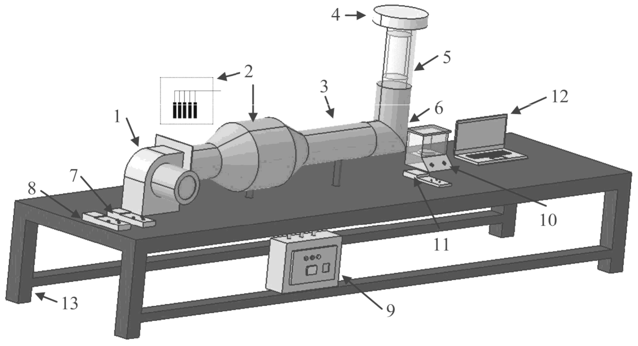
2 Materials and methods

2.1 Sample preparation

The samples of Persian shallot were collected from agricultural lands of Kermanshah province, Iran. The samples were stored in a refrigerator at 3°C±1°C until used. The samples were sliced manually by different slice thicknesses (2, 4 and 6 mm). A standard hot air oven method was used to determine the moisture content of Persian shallot in triplicate (ASAE, 1996). The average moisture content of the samples was 1.99 (d.b.).

2.2 Drying equipment

The drying of Persian shallot slices was investigated in a laboratory scale convective dryer (Figure 1). A centrifugal fan was supplied the required air flow rat. The fan speed was changed by controlling the speed of the motor which operates the fan. The Plexiglas cylindrical chamber was 15 cm in diameter and 40 cm in height. The dryer had an automatic temperature controller with an accuracy of ±1°C. Weighing was made at every five minute using a digital balance (GF-6000, Japan) with an accuracy of ±0.01 g for moisture content determination. During the experiments, ambient temperature and relative humidity were recorded.



1. Fan and electrical motor 2. Heating elements 3. Duct and tunnel 4. Chamber cap 5. Drying chamber 6. Mixing chamber 7. Temperature and moisture meter 8. Anemometer 9. Thermostat and inverter 10. Digital balance 11. Input and output air temperature recorder 12. Notebook 13. Chassis

Figure 1 Schematic diagram of convective dryer

2.3 Experimental setup

Relative humidity and temperature of ambient air during the experiments were recorded at the range of 18%-26% and 23-28°C, respectively. Three parameters of air temperature, air velocity and slice thickness were selected as input variables. Three levels of air temperature (40°C, 55°C and 70°C), air velocity (0.5, 1.5 and 2.5 m/s) and slice thickness (2, 4 and 6 mm) were applied in the drying experiments. All experiments were performed in three replications. The air flow in drying chamber was perpendicular to the sample surface.

2.4 Experimental procedure

Before starting the experiment, the shallot bulbs were sliced to the samples with diameter of 20 mm and different thickness by a special cutter. Each condition set was replicated three times. After the dryer condition was reached steady state for operation velocity and temperature, the samples were put in the drying chamber and drying process was started.

2.5 Experimental design

Response surface method was applied to study the effects of air velocity, air temperature and slice thickness on the dependent variable (effective moisture diffusivity, specific energy consumption, shrinkage and color changes). The experiments were established based on a face-centered central composite design. In this experimental design, three coded levels for each variable were selected: -1, 0 and +1 corresponded to the low level, mid-level and high level of each independent variable, respectively. The independent variables and representative coded and un-coded levels are given in Table 1.

Table 1 The independent variables and representative coded and un-coded levels

Independent variables	Symbol	Coded values		
		-1	0	1
Air temperature/°C	X1	40	55	70
Air velocity/m s^{-1}	X2	0.5	1.5	2.5
Slice thickness/mm	X3	2	4	6

The behavior of the response surface was studied for the response function (y) using the polynomial regression equation. The generalized response surface model is given as follow:

$$y=\beta_0+\sum_{j=1}^{k}\beta_j x_j \sum i<j\sum \beta_{ij}x_i x_j+\sum_{j=1}^{k}\beta_{jj}x_j^2 \qquad (1)$$

where, y is response calculated by the model; β_0 is a constant; β_j, β_{jj} and β_{ij} are linear, squared and interaction coefficient, respectively.

All experiments were conducted in a random order. To calculate the sum of square error and the lack of fitness for the developed regression equation between the dependent and independent variables, six replications performed at the central points of the coded variables. The Design Expert software (Version 7) was used for experimental design matrix, data analysis and optimization procedure. First step in RSM is to find a suitable approximation for the true functional relationship between response and the set of independent variables (Montgomery 2001).

2.6 Effective moisture diffusivity

It has been accepted that the mass transfer of biological products in the falling rate period can be described by using second law of Fick in diffusion mode. Simplified equation of moisture diffusivity provides an approximate method to present a common quantitative comparison between different products in the aspect of moisture transfer. Because it can provides a description analysis for mean diffusion coefficient in the entire drying process (Arslan and Özcan, 2011).

For determination of effective moisture diffusivity (D_{eff}) the Equation (2) (for an infinite slab) can be defined as follows (Ponkham et al., 2011):

$$MR=\frac{M-M_e}{M_0-M_e}=\frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n+1)^2}\exp\left(-\frac{(2n+1)^2\pi^2D_{eff}t}{4h^2}\right) \qquad (2)$$

where, MR is the dimensionless moisture ratio; M is the moisture content at any time (d.b.), %; M_e is the equilibrium moisture content (d.b.), %; M_0 is the initial moisture content (d.b.), %; h is the half thickness of the slab in sample, m; t is the drying time, s; D_{eff} is the effective moisture diffusivity, m^2/s. Moisture ratio (MR) can be simplified to M/M_0 because M_e was relatively small compared to M and M_0. Equation (2) can be written as logarithmic form:

$$\ln(MR)=\ln\left(\frac{8}{\pi^2}\right)-\left(\frac{\pi^2D_{eff}t}{4h^2}\right) \qquad (3)$$

The slope (K_0) is calculated by plotting t against ln(MR) as follows:

$$K_0=\frac{\pi^2D_{eff}}{4h^2} \qquad (4)$$

2.7 Specific energy consumption

Specific energy consumption (SEC) for eliminating of one kilogram of moisture from the Persian shallot samples were calculated using follow thermodynamic equation (Amiri Chayjan et al., 2011):

$$SEC=\left(\frac{t}{m_v}\right)\left[\frac{Q(C_{pa}+C_{pv}h_a}{V_h}\right](T_{in}-T_{am}) \tag{5}$$

where, SEC is specific energy consumption, kJ/kg; C_{pv} is specific heat capacity of vapor (1,004.16 J kg^{-1} $°C^{-1}$); C_{pa} is specific heat capacity of air (1,828.8 J kg^{-1} $°C^{-1}$); Q is the flow rate of input air to drying chamber, m^3/s; t is the total drying time, min; h_a is absolute air humidity ($kg_{vapor}/kg_{dry\ air}$); T_{in} and T_{am} are inlet air to drying chamber and ambient air temperature, respectively, °C; m_v is mass of removal water (kg) and V_h is specific air volume (m^3/kg). It was expressed in terms of MJ/kg of water removed and used as one of the factors in the optimization of process parameters.

2.8 Shrinkage

Shrinkage value is usually defined as the ratio of the final to initial volume of a dried product (Hashemi et al., 2009). In this study the volume of sample was measured by digital caliper with accuracy of 0.01 mm. Shrinkage of the samples is calculated using the following equation (Mayor and Sereno, 2004):

$$S_b=\frac{(V_0-V)}{V_0}\times 100\ \% \tag{6}$$

where, S_b is shrinkage, %; and V_0 and V is the volume of sample before and after drying, m^3, respectively.

2.9 Color changes

Color is one of the most important quality indices of foods and agricultural products. Color change (ΔRGB) of the shallot samples was measured by color analyzer RGB-1002 (made in Taiwan) before and after drying. Firstly, the color analyzer was calibrated using a standard calibration plate with a white surface for R (red), G (green) and B (blue). The percent of the color change was determined using gray level at the end of the process. Color change in ΔRGB is achieved using the following equations:

$$\Delta R=\frac{R_1-R_2}{R_1}\times 100\ \% \tag{7}$$

$$\Delta G=\frac{G_1-G_2}{G_1}\times 100\ \% \tag{8}$$

$$\Delta B=\frac{B_1-B_2}{B_1}\times 100\ \% \tag{9}$$

$$GL=\frac{\Delta R+\Delta G+\Delta B}{3} \tag{10}$$

where, ΔR is the percentage of change in red; R_1 and R_2 the red color before and after drying, respectively; ΔG is the percentage of change in green; G_1 and G_2 are the green color before and after drying, respectively; ΔB is percent of change in blue, B_1 and B_2 are the blue color before and after drying, respectively; GL is gray level of the sample and defined as average changes were occurred in colors of red, blue and green.

3 Results and discussion

3.1 Response surface analysis

The experimental data describe the effects of air temperature and velocity and slice thickness on the effective moisture diffusivity, specific energy consumption, shrinkage and color changes of the dried Persian shallot. Results of different runs of drying experiments are shown in Table 2. The independent and dependent variables were fitted by the second order polynomial equation to the experimental data.

3.2 Effective moisture diffusivity

Moisture diffusion coefficient of the food and agricultural products depends upon the conditions within the material. Effective moisture diffusivity describes all possible mechanisms of moisture movement within the foods, such as liquid diffusion, vapor diffusion, surface diffusion, capillary flow and hydrodynamic flow (Hashemi et al., 2009). Persian shallot drying experiments were continued until moisture content of samples reached about 0.08 (d.b.).

Table 2 shows that D_{eff} of Persian shallot as most of other agricultural crops was obtained in range of 10^{-8} to 10^{-12} m^2/s. Also Table 3 showed that all three independent variables and their interaction effects were significant on D_{eff} at level of 1%. Figures 2, 3 and 4 show these effects. Results indicated that the effect of slice thickness was more than the other independent variables. Also the effect of air temperature was more than air velocity. Results revealed that with increasing the air temperature and velocity and slice thickness, D_{eff} was increased.

Table 2 Central composite design and experimental data obtained for the response variables

Number	Air temperature/°C	Air velocity/m s^{-1}	Slice thickness/mm	D_{eff}/m^2 s^{-1}	SEC/MJ kg^{-1}	Shrinkage/%	Color change/%
1	55	1.5	4	5.62×10^{-10}	9.84	35.82	35.82
2	55	1.5	4	5.67×10^{-10}	9.82	36.99	34.72
3	40	2.5	2	7.08×10^{-11}	19.38	22.07	42.77
4	70	1.5	4	9.67×10^{-10}	8.55	40.19	63.19
5	70	2.5	6	1.65×10^{-9}	15.37	37.25	35.01
6	40	1.5	4	2.19×10^{-10}	9.9	36.03	18.41
7	70	0.5	6	7.47×10^{-10}	6.41	43.15	59.55
8	55	1.5	4	5.01×10^{-10}	10.25	31.72	35.44
9	55	1.5	4	5.27×10^{-10}	10.53	34.53	34.72
10	55	1.5	4	5.94×10^{-10}	10.26	35.87	33.94
11	70	0.5	2	3.09×10^{-10}	3.12	32.95	51.09
12	40	2.5	6	4.26×10^{-10}	20.53	42.54	19.21
13	55	0.5	4	2.93×10^{-10}	5.82	35.55	39.38
14	55	1.5	2	2.06×10^{-10}	10.35	20.71	32.73
15	55	2.5	4	4.84×10^{-10}	17.06	35.11	34.86
16	70	2.5	2	3.77×10^{-10}	12.9	21.91	56.22
17	40	0.5	2	8.41×10^{-11}	3.21	20.81	35.12
18	40	0.5	6	3.37×10^{-10}	4.57	44.76	29.62
19	55	1.5	4	5.15×10^{-10}	11.24	32.1	36.15
20	55	1.5	6	7.95×10^{-10}	12.21	46.85	56.67

Table 3 Analysis of variance (ANOVA) for dried Persian shallot using quadratic model

Source of variation	*df*	D_{eff}	*SEC*	Shrinkage	Color changes
Model	9	25.11**	163.69**	14.31**	2.77ns
X_1	1	86.58**	42.34**	1.02ns	17.56**
X_2	1	15.72**	1294.81**	4.04ns	0.87ns
X_3	1	86.36**	34.36**	110.81**	0.39ns
X_1X_2	1	10.3**	75.24**	3.83ns	0.42ns
X_1X_3	1	15.56**	4.42ns	5.34*	041ns
X_2X_3	1	11.32**	0.43ns	0.041ns	3.48ns
X_1^2	1	2.17ns	16.07**	1.04ns	0.09ns
X_2^2	1	3.81ns	7.34*	0.33ns	0.15ns
X_3^2	1	6.63×10^{-3}ns	4.99*	2.15ns	1ns
Residual	10				
Lack of Fit	5	14.54**	1.17 ns	2.58 ns	241.20**
Pure error	5				
Cor total	19				

Note: ns = non significant, * = significant at 5%, ** = significant at 1%.

Increase in air temperature led to increase drying rate. Also at the initial stage of drying process when the water vapor at the surface of the sample concentrated, with increasing the air velocity, the mass transfer increased and subsequently D_{eff} increased. The increase in the effective moisture diffusivity was apparently due to the increased heat transfer potential between the surrounding air and the shallot samples as well as the higher moisture diffusivity, thus enhancing the evaporation of water from shallot samples. Figure 2 shows the interaction effects of air temperature and air velocity on D_{eff}.

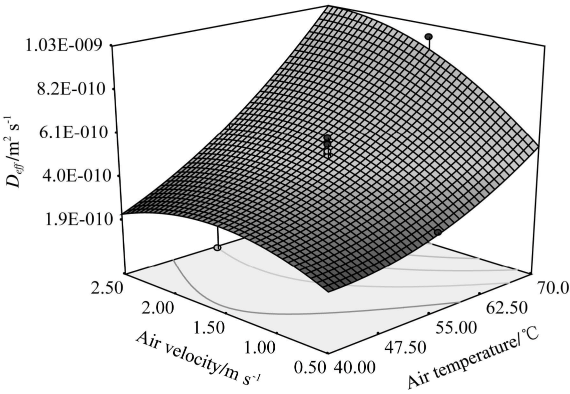


Figure 2 Interaction effect of air temperature and velocity on effective moisture diffusivity of the Persian shallot samples

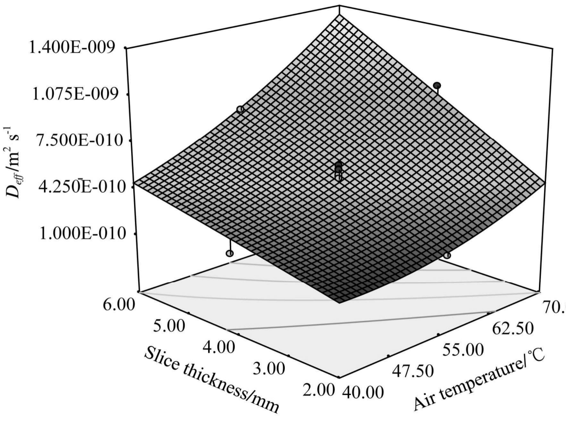


Figure 3 Interaction effect of air temperature and slice thickness on effective moisture diffusivity of Persian shallot samples

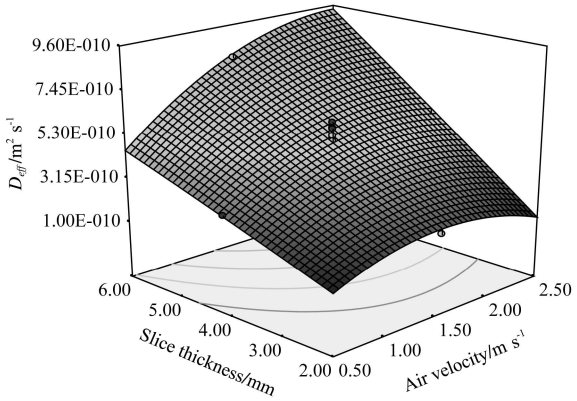


Figure 4 Interaction effect of slice thickness and air velocity on effective moisture diffusivity of the Persian shallot samples

3.3 Specific energy consumption

Specific energy requirements for drying Persian shallot slices were determined using Equation (4). Table 2 shows that maximum value of SEC (20.53 MJ/kg) was calculated at air temperature of 40°C, air velocity of 2.5 m/s and slice thickness of 6 mm. Also, minimum value of SEC (3.12 MJ/kg) were calculated at temperature of 70°C, air velocity of 0.5 m/s and slice thickness of 2 mm. Also according to Table 3, the air temperature and velocity, slice thickness, interaction effect of air temperature and velocity, quadratic value of air temperature (at level of 1%) and quadratic values of air velocity and slice thickness (at level of 5%) had significant effect on SEC. Figure 5 indicates that with increasing air velocity, SEC increased. Due to the reduction of water vapor in surface of the samples, increase in drying rate and subsequently decrease in drying time, the lowest energy consumption was obtained at lowest air velocities. Similar results have been reported in drying of paddy (Khoshtaghaza et al., 2007), berberis fruit (Aghbashlo et al., 2010) and grape (Amiri Chayjan et al., 2011). With increasing the slice thickness, SEC slightly increased. In order to reduce moisture content for the maintenance of the samples, in high slice thickness more energy is required than lower slice thickness.

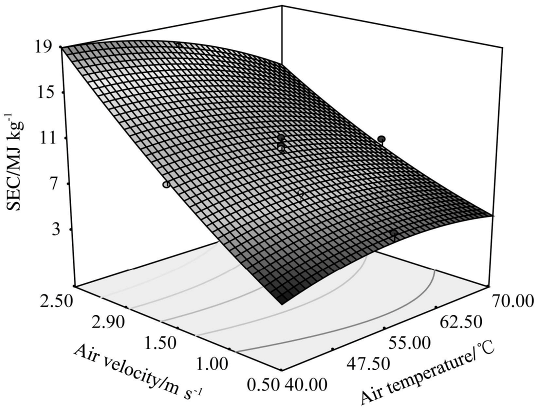


Figure 5 Interaction effect of air temperature and velocity on SEC for drying of Persian shallot samples

3.4 Shrinkage

Shrinkage of foodstuffs is a negative index in the quality of the dried products. Changes in shape, loss of volume and increased hardness cause in most cases a negative impression in the consumer (Mayor and Sereno, 2004). The slice thickness and interaction effect of air temperature with slice thickness had significant effect (at level of 1%) on shrinkage of Persian shallot samples. But, air temperature and velocity had no significant effect on shrinkage (Table 3). In shrinkage study, potato was found that the air velocity had no significant effect on shrinkage (Yadollahinia and Jahangiri, 2009). Also in shrinkage study, carrot slices was reported that air temperature and velocity had no significant effect on shrinkage (Hatamipour and Mowla, 2002). The interaction effect of air temperature and slice thickness on shrinkage is shown in Figure 6. With increasing the slice thickness, the shrinkage increased. In the higher slice thickness, as the temperature increases, a greater volume of water in samples will transferred. Also in this case, the drying rate of the sample increased and consequently shrinkage increased. Due to at the higher moisture content of Persian shallot, in higher volume, more water transferred than lower volume. There is an obvious increasing trend in the shrinkage value, while time and slice thickness increased. Actually, the increase in time and slice thickness increased the amount of heat given to Persian shallot slices which results in decreasing moisture content of the sample. Therefore, contractile stresses occur in the cellular structure of the shallot samples which intensify shrinkage. However, the shrinkage value becomes relatively constant at the end of the drying process, which is the result of the sample structure stabilization made by a firm layer formed on its surface. Similar results were achieved in optimization of a drying process of Cavendish banana slices (Swasdisevi et al., 2007) and sliced banana (Ebrahimi et al., 2012). Shrinkage value slightly increased with increasing air temperature. Similar result was reported in investigation of carrot shrinkage (Hatamipour and Mowla, 2002). The maximum value of shrinkage (46.8%) was obtained at air temperature of 55°C, air velocity of 1.5 m/s and slice thickness of 6 mm. Also minimum value of shrinkage (20.7%) was obtained at the same temperature and air velocity and thickness of 2 mm (Table 2).

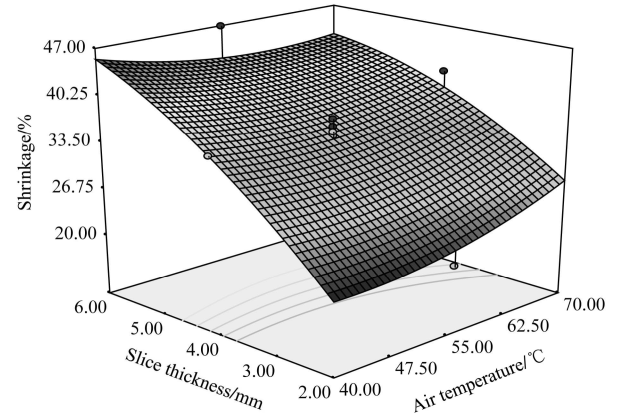


Figure 6 Interaction effect of air temperature and slice thickness on shrinkage of Persian shallot samples

3.5 Color changes

The first judgment of a foods quality is more often dependent on its various appearance characteristics, such as its color, surface structure and shape. Color, in particular, is an important sensory attribute (Varnalis et al., 2004). Table 2 shows the value of color changes in different experiments. Maximum (63.19%) and minimum (18.41%) value of color changes were obtained at temperature of 70°C and 40°C, respectively. Air temperature had significant effect on color changes, so that the color change was increased with increasing air temperature. Air velocity and slice thickness had not significant effect on color changes. Color changes may be due to browning reactions which happen during drying process (Arslan and Özcan, 2011). At high temperatures the enzymatic and non-enzymatic reaction, superficial burns and blacking of the samples increases. So in this condition, the color change increased. In most cases, at high temperatures the pigment degradation is higher. Similar results have been reported in dehydration characteristics of garlic (Sacilik and Unal, 2005), tarragon (Arabhosseini et al., 2007) and stone apple slices (Rayaguru and Routray, 2012). Figure 7 shows the percent of color changes (gray level) in the slice thicknesses of 2, 4 and 6 mm.

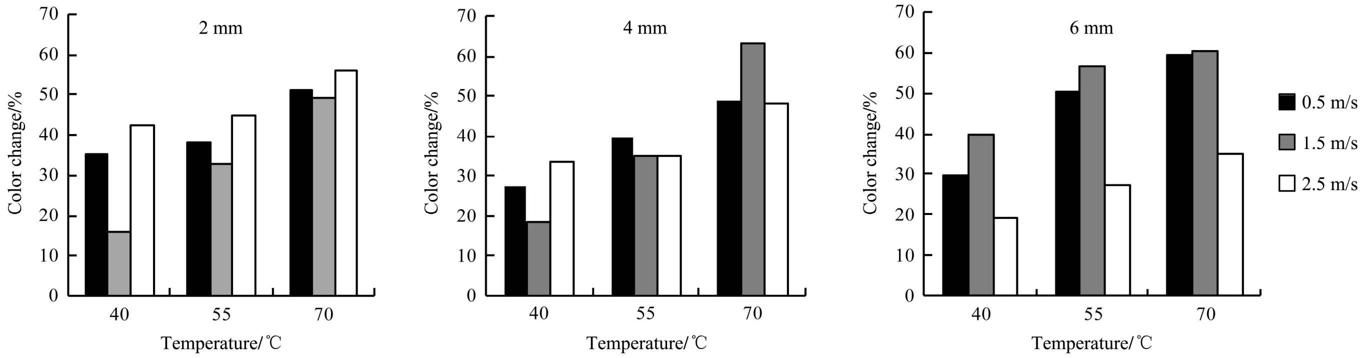


Figure 7 Color changes in dried Persian shallot samples at difference drying condition

3.6 Process optimization

A relatively straightforward approach to optimize several responses that work well when only a few process variables are is to overlay the contour plots for each response (graphic method). Often a lot of trial and error is needed to specify which parameters to hold constant and what levels to select to achieve the best view of the surface. A popular procedure is to formulate and solve the problem as a constrained optimization problem (nonlinear programming methods). Mathematical techniques are used in this method (Corzo et al., 2008).

Optimum conditions for convective drying of Persian shallot were determined to obtain maximum D_{eff} and minimum SEC, shrinkage and color changes. Second order polynomial models achieved in this study were utilized for each response in order to determine the specified optimum conditions. These regression models for each response are valid only in the selected experimental domain. In other word, the operating region was determined considering some economical and product quality related constraints.

In this research, air temperature, air velocity and slice thickness were selected in the range of 40-70°C, 0.5-2.5 m/s and 2-6 mm, respectively. Among all treatments that selected by the software, the lowest optimal shrinkage, discoloration and specific energy consumption and the highest effective moisture diffusivity approach to high product quality and increase economic efficiency drying process were selected. By applying desirability function method, the solutions were proposed for the optimum covering the criteria. It was 70°C for air temperature, 2.5 m/s for air velocity and 4.58 mm for slice thickness. At this point, D_{eff}, SEC, shrinkage and color changes were obtained as 1.18675×10^{-9} m^2/s, 13.83 MJ/kg, 35.04% and 42.27%, respectively. The reason of proposing of high is the positive effect of temperature on the effective diffusivity and its negative impact on the shrinkage and specific energy consumption. The study proposed the maximum air temperature (70°C) for the optimization of microwave drying process of garlic (Sharma and Prasad, 2006). Also the maximum air temperature was selected for optimization of processing parameters of horse mackerel (Shi et al., 2008). By applying desirability function method, six solutions were obtained for the optimum covering criteria with desirability value of 0.525 (Table 4).

Table 4 Optimal conditions applying desirability functions methodology

Solution number	Air temperature/°C	Slice thickness/mm	Air velocity/m s^{-1}	Color changes/%	Shrinkage/%	SEC/MJ kg^{-1}	D_{eff}/m^2 s^{-1}
1	70	4.58	2.5	42.27	35.04	13.83	1.19×10-9
2	70	4.61	2.5	42.23	35.14	13.86	1.20×10-9
3	69.58	4.64	2.5	41.81	35.18	14.03	1.19×10-9
4	40	3.32	0.62	25.38	30.88	3.82	2.08×10-10
5	40	3.17	0.68	25.88	29.93	4.15	2.12×10-10
6	40	3.68	0.74	25.61	33.34	4.67	2.40×10-10

The optimal values for considered factors can be one of six solutions since the value of the desired function is unit. The final decision of the optimal conditions depends on considerations of costs and effects in the sensory characteristics of the product.

4 Conclusions

In this study, some physical and thermal properties of Persian shallot were investigated in a laboratory convective dryer to determine the effective moisture diffusivity, specific energy consumption, shrinkage and color changes, at air temperature levels of 40°C, 55°C and 70°C, air velocity levels of 0.5, 1.5 and 2.5 m/s and slice thicknesses of 2, 4, and 6mm. The effect of slice thickness on effective moisture diffusivity was more than other independent variables. With increasing air temperature and slice thickness, D_{eff} was increased (from 7.08×10^{-11} to 9.67×10^{-10} m^2/s). Increasing air velocity led to the increase specific energy consumption. The specific energy consumption varied from 3.12 to 20.53 MJ/kg. Air temperature and velocity of inlet air had no significant effect on shrinkage. Shrinkage increased with increasing slice thickness. The highest (46.85%) and lowest (20.71%) values of shrinkage were obtained at thicknesses of 6 and 2mm, respectively. The air temperature had significant effect on color changes. The highest (63.19%) and lowest (18.41%) values of color changes were obtained at air temperatures of 70°C and 40°C, respectively. The central composite design (CCD) was applied for optimization the process. The air temperature of 70°C, air velocity of 2.5 m/s and slice thickness of 4.58 mm was proposed as the optimum independent variable. The optimum value of D_{eff}, SEC, shrinkage and color changes for the drying process was obtained as 1.19×10^{-9} m^2/s, 13.83 MJ/kg, 35.04% and 42.27%, respectively. The desirability value of 0.525 was obtained for the drying process.

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