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Kinetics and Temperature Dependent Moisture Diffusivities of Pumpkin Seeds During Drying

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ABSTRACT

Pumpkin seeds were soaked in 25% w/w NaCl solution for 1 h before hot-air drying with a tray dryer or a fluidized bed dryer (FBD) at drying temperatures of 60, 70 and 80°C. The FBD was operated at an air velocity of 1.8 m/s and a bed depth of 3 cm, whereas the seeds were dried as a single layer in the tray dryer with the air velocity over the sample in the range 0.23–0.28 m/s. The experimental data was fitted into four thin-layer drying models namely the Page, Lewis, Wang and Singh, and two-compartment models. The drying rate constants and coefficients of the models tested were determined by non-linear regression analysis. Among the various models, both the Page model and two-compartment model were the best-fit models for the three drying conditions. Effective moisture diffusivities of pumpkin seeds determined by applying Fick's second law of diffusion and the method of slope ranged between 7.69×10^{-11} and 50.96×10^{-11} m^2/s. The temperature dependence of the effective moisture diffusivity followed an Arrhenius relationship with the activation energies between 15 and 62.12 kJ/mol.

Keywords: drying, effective moisture diffusivity, fluidized bed drying, pumpkin seed, tray drying

INTRODUCTION

Recently, the utilization of food-processing by-products and wastes has been in the spotlight due to increasing environmental concern. Pumpkin (*Cucurbita* spp.) seed is one of the food-processing by-products that are a good source of oils and proteins (Tu *et al*., 1978; El-Adawy and Taha, 2001; Sacilik, 2007). Sacilik (2007) claimed that pumpkin seed contains 37.8–45.4% oil and 25.2–37.0% protein. The oil extracted from the pumpkin seed is highly unsaturated (Asiegbu, 1987). Apart from edible oils and proteins, pumpkin seed has good quality minerals and valuable dietetic and medicinal advantages (Yoshida *et al*., 2004). In many countries, pumpkin seeds are consumed as snacks (Al-Khalifa, 1996; Sacilik, 2007).

In several countries, the pumpkin seeds are exposed to a salting process prior to human consumption as snacks (Yoshida *et al*., 2006). The pumpkin seeds have high moisture content, usually greater than 25% on a wet basis (w.b.), after the salting process that involves spraying the seeds with NaCl solution or soaking them in an NaCl solution. Therefore, they must be dried to reduce the moisture content to a level that allows safe storage over an extended period. Moisture removal can prevent the growth of decay-causing microorganisms and minimizes several of the moisture-mediated deteriorative reactions. Jittanit *et al*. (2010) claimed that the corn, rice and wheat

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seeds should be dried to below 14% w.b. for long-term storage. Sacilik (2007) stated that hot-air drying is the most common preservation method used for moist biological and agricultural products, such as fresh pumpkin seed. Generally, two regimes are used to dry high moisture products (Can, 2007). First, the drying takes place on the product surface at a constant rate. This process involves the evaporation of water in an open environment; thus, the amount of evaporated water depends mainly on the environmental conditions, rather than the nature of the composition of the product. In the second regime, the drying rate relies on the diffusion process inside the sample, resulting in a slow drying rate. Consequently, in this stage, the drying rate is decelerated and controlled by the internal moisture diffusion of the product (Roberts *et al.*, 2008). The effective moisture diffusivity of a product is the imperative physical property that indicates how quickly the moisture can transfer from the inside to the surface of the product.

A fluidized bed dryer (FBD) is a dryer that has been recommended by a number of researchers for drying high moisture food grain, because it provides rapid drying and high drying efficiency (Jittanit *et al.*, 2010). However, some researchers, such as Sacilik (2007), dried their hull-less pumpkin seeds at low to medium drying temperatures (less than or equal to 60°C) using hot air, a solar tunnel and open sun drying methods. To date, although several studies have reported on the drying kinetics and effective moisture diffusivities of food grain and seeds (Sogi *et al.*, 2003; Roberts *et al.*, 2008), information on the drying kinetics and effective moisture diffusivities of pumpkin seed is still limited.

Hence, the present study was carried out with the following objectives: 1) to investigate and compare the thin-layer drying kinetics of pumpkin seed using the fluidized bed and tray drying methods; and 2) to fit the experimental data to mathematical models in order to predict the drying characteristics and temperature dependent moisture diffusivities of pumpkin seed.

The outcome of this research would be useful for food industries that are involved in the production or the utilization of pumpkin seed.

MATERIALS AND METHODS

Sample preparation

The pumpkin (*Cucurbita* spp.) seeds used in this study were purchased in December 2009 from Talaad Thai, which is the largest central market for agricultural goods in Thailand. The pumpkin seeds with hulls had a moisture content lower than 14% w.b. because they had been dried by the supplier in order to extend their storage life. The samples were prepared by sorting out the fissure seeds, then salting the seeds by soaking them in 25% w/w NaCl solution for 1 h, followed by draining. The salting process improves the taste of the pumpkin seeds as a snack food. The ratio between seeds and soaking solution was 5 kg of seed per 8 L of solution. After preparation, the seed samples became moist.

Drying experiments

The pumpkin seed prepared by the method described above was exposed to drying experiments. The initial moisture content of the seed was higher than 25% w.b. The drying experiments utilized two pieces of equipment, namely a lab-scale FBD and a tray dryer. A schematic diagram of the FBD is shown in Figure 1. The FBD was tailor-made by a local machine manufacturer in Bangkok, Thailand. The tray dryer was constructed by Kluaynamthaitowop Company Limited, Bangkok, Thailand. Both dryers were operated in batch mode. The drying temperatures applied in this study were 60, 70 and 80°C. The FBD was operated at an air velocity of 1.8 m/s and a static bed depth of 3 cm, whereas the seeds were spread in a single layer on a wire-mesh tray and dried in the tray dryer with the air velocity

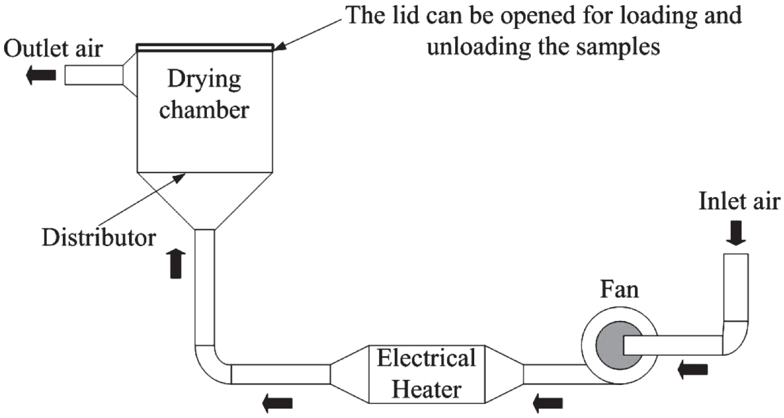

Figure 1 Schematic diagram of fluidized bed dryer.

over the sample in the range 0.23–0.28 m/s. The seeds were dried until the moisture content was below 5% w.b. in order to be comparable with the pumpkin seed snack sold in the market. During the drying process, seeds were collected at each specified time interval for moisture content determination.

Moisture content determination

The moisture content determinations were conducted in duplicate (2 g for each sample) by the oven method in accordance with AOAC (2000). The 2-g samples were ground and dried in a hot air oven at 102°C for 2 h. After that, the samples were cooled in a desiccator, weighed, redried for 30 min and the whole process was repeated until the change in weight between successive drying cycles at 30 min intervals was not more than 1 mg. The weight loss after drying in the oven was used to calculate the moisture content of the sample, expressed on a percent wet basis.

Drying model development

The data acquired from the experiments at each drying temperature were fitted to four thin-layer drying models, comprising the Page model, the two-compartment model, the Wang and Singh model and the Lewis model. Additionally, two modified models, the modified Page model and the modified two-compartment model, were used for fitting the data from all drying temperatures ranging from 60 and 80°C. The models are shown in Table 1. The moisture ratio was calculated using Equation 1:

$$MR = \frac{M_t - M_e}{M_i - M_e} \quad (1)$$

where: MR = the dimensionless moisture ratio,

M_t = the moisture on a percent dry basis (d.b.) at any time t during drying,

M_i = the initial moisture content (% d.b.),

M_e = the equilibrium moisture content (% d.b.).

The data from the drying experiments were fitted into the six mathematical models by a non-linear regression procedure using the computer package Statistica 5.5 (StatSoft, Inc. Tulsa, OK 74104 USA). The drying rate constants and coefficients of the models were determined by regression. In developing the thin-layer drying models, the required data consisted of the initial moisture content, moisture content of samples during the drying process, equilibrium moisture content, drying air temperature and drying time. All of these required data were measured in the experiments, except for the equilibrium moisture content. Several researchers, including Doymaz and Pala (2003), McMinn (2006) and Sacilik

Table 1 Summary of thin-layer drying models.

Model	Equation	Reference
Page model	$MR = \exp(-kt^{N})$	Kumar *et al.* (2006)
Two-compartment model	$MR = A\exp(-k_1 t) + B\exp(-k_2 t)$	Henderson (1974) and Sharaf-Elden *et al.* (1980)
Wang and Singh model	$MR = A\exp(-kt)$	Wang and Singh (1978)
Lewis model (exponential model)	$MR = \exp(-kt)$	Lewis (1921)
Modified Page model	$MR = \exp\left(-kt^{N}\exp\left(-\frac{A}{T_K}\right)\right)$	Jittanit (2007)
Modified two-compartment model	$MR = A_1\exp\left(-k_1 t\exp\left(-\frac{B}{T_K}\right)\right) + A_2\exp\left(-k_2 t\exp\left(-\frac{B}{T_K}\right)\right)$	Jittanit (2007)

MR = the dimensionless moisture ratio,
M_t = the moisture on a percent dry basis (d.b.) at any time t during drying,
M_i = the initial moisture content (% d.b.),
M_e = the equilibrium moisture content (% d.b.),
T_K = the drying temperature (°K),
k, k_1 and k_2 are the drying rate constants and N, A, A_1, A_2 and B are constants

(2007), have suggested that when developing thin-layer drying models, the equilibrium moisture content of food can be assumed to be zero, since: 1) it is substantially less than the initial moisture content or 2) the relative humidity of the drying air fluctuates during drying. This assumption would always be correct if the drying temperature is not lower than 100°C (Taechapairoj *et al.*, 2003). However, if the drying temperature is below 100° C, this assumption will be valid solely at the beginning of drying process, because the moisture content of the sample is much higher than the equilibrium moisture content ($M_t >> M_e$). However, when the sample is dried to a moisture content level that is close to its equilibrium moisture content, this assumption would lead to a significant deviation of the slope and linearity of the normalized drying curve (Roberts *et al.*, 2008). The drying temperatures in the present study were in the range 60–80°C; thus, the equilibrium moisture contents were determined by drying a single layer of pumpkin seeds in a tray dryer at each temperature until the weights were constant. For model fitting, the moisture ratio was considered as the dependent variable. The statistical validity of the models was evaluated and compared using the coefficient of determination (R^2) and root mean square error (RMSE), using Equations 2 and 3, respectively:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(\text{Measured } MR \text{ value} - \text{Predicted } MR \text{ value})^2}{\sum_{i=1}^{n}(\text{Measured } MR \text{ value} - \text{Average } MR \text{ value})^2} \tag{2}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\text{Measured } M_t \text{ value} - \text{Predicted } M_t \text{ value})^2}{n}} \tag{3}$$

Determination of effective moisture diffusivity

Wang and Brennan (1992) affirmed that drying of most food materials regularly took place in the falling rate period, which meant that the moisture transfer during drying was controlled by internal diffusion. The internal diffusion occurring during the falling rate period for most food materials is described by Fick's second law of diffusion (Crank, 1975). For the determination of moisture diffusivity, the pumpkin seeds were considered as having slab geometry, due to their very small relative thickness when compared to other dimensions (Sacilik, 2007). The analytical solution of Fick's second law of diffusion for slab-shaped material, with the assumptions of moisture transfer by diffusion, negligible shrinkage, and constant diffusion coefficients and temperature is provided by Equation 4 (Crank, 1975):

$$MR = \left[\frac{8}{\pi^2}\right]\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left[-\frac{\pi^2(2n+1)^2 D_{eff}t}{4H^2}\right] \tag{4}$$

where: D_{eff} = the effective moisture diffusion (m^2/s),

t = the drying time (s),

H = half-thickness of the slab (pumpkin seed), 9.99×10^{-4} m.

Expansion of the first three terms (n = 0, 1 and 2) of Equation 4 produces Equation 5:

$$MR = 0.81057e^{-2.4674N_{Fo}} + 0.09006e^{-22.2066N_{Fo}} + 0.0324e^{-61.685N_{Fo}} \tag{5}$$

where: N_{F0} is a Fourier number $((D_{eff}t)/H^2)$.

As supported by the observations of Sacilik (2007) and Saykova *et al.* (2009), it is noticeable that the first term of the series solution in Equation 5 will dominate the other terms. Consequently, the natural logarithm of Equation 5 is expressed as Equation 6:

$$\ln(MR) = \ln(0.81057) - 2.4674\left[\frac{D_{eff}t}{H^2}\right] \tag{6}$$

Typically, the effective moisture diffusivity has been calculated using the method of slope (Sacilik, 2007; Roberts *et al.*, 2008). In the present study, it was determined by plotting experimental data in terms of In (MR) versus drying time, and then using Equation 7:

$$D_{eff} = \frac{-slope}{\left[\frac{2.4674}{H^2}\right]} \tag{7}$$

Sensory evaluation

The pumpkin seed samples dried in the present study and the pumpkin seed of a well-known brand purchased from a supermarket were assessed for their sensory attributes using a 9-point Hedonic scale test with 25 panelists who were students in the Department of Food Science and Technology, Kasetsart University. The sensory attributes that were considered in this study were: appearance, color, aroma, taste, texture and overall liking. The samples used in the sensory tests were dried to moisture content levels close to those in similar products bought from the supermarket.

RESULTS AND DISCUSSION

Drying characteristics and thin-layer drying models

The drying characteristics of pumpkin seed during drying in the FBD and the tray dryer are shown in Figures 2 and 3, respectively. It is noticeable that drying occurred during the falling rate period from the beginning of the drying process. Therefore, the drying rate of the samples was controlled by internal diffusion. With increasing drying temperatures, the samples dehydrated more rapidly because the pressure of moisture inside the samples at higher temperatures was substantially raised, whereas the equilibrium moisture contents of samples diminished; as a result, the driving force or the moisture gradient between the center and the surface of samples was elevated. Furthermore, at the same drying temperature, the drying rates of pumpkin seed samples in the FBD were visibly faster than those from tray drying. This could be explained by the increased convective heat and moisture transfer

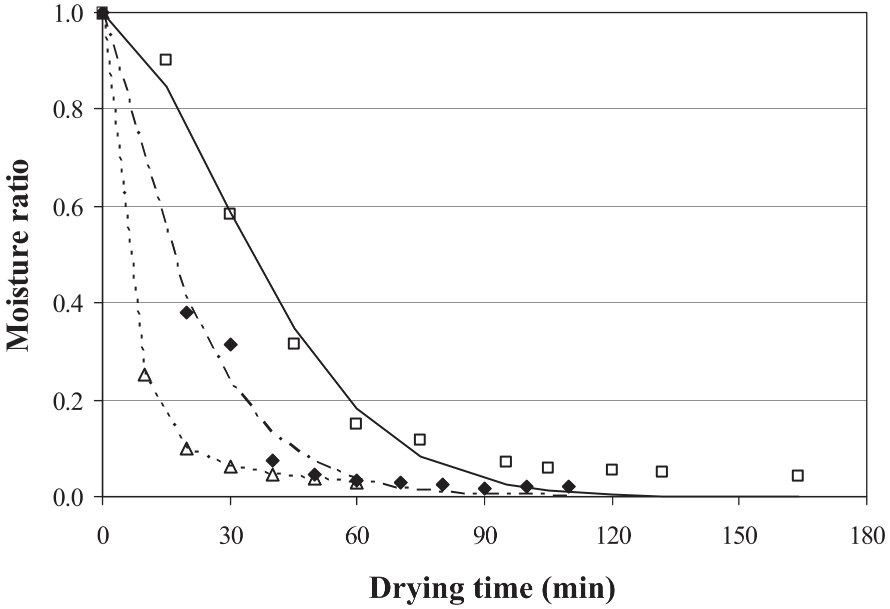

Figure 2 Drying characteristics of pumpkin seeds in FBD at different temperatures (□ = experimental 60°C; ♦ = experimental 70°C; Δ = experimental 80°C; —— = predicted 60°C; —— - —— = predicted 70°C; – – – = predicted 80°C); prediction using Page model for 60 and 70°C and two-compartment model for 80°C.

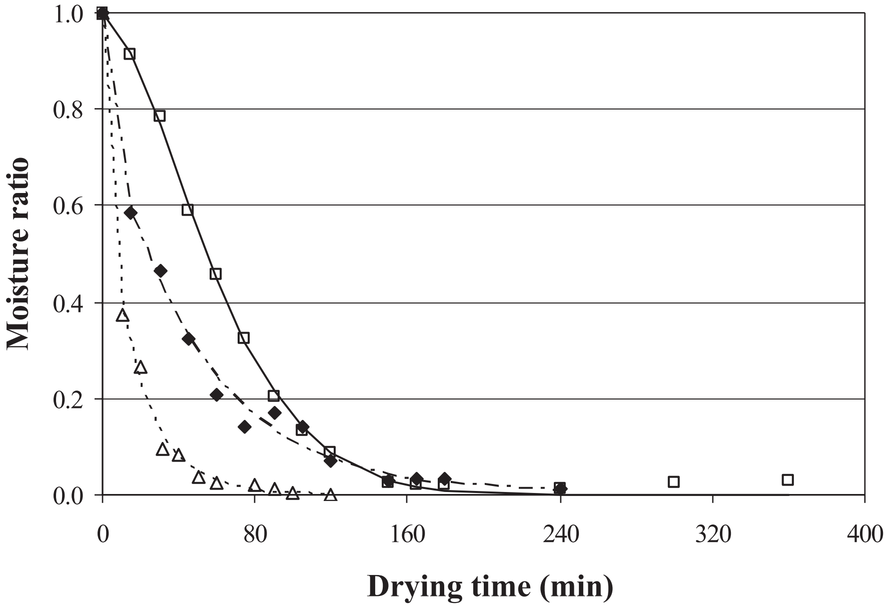

Figure 3 Drying characteristics of pumpkin seeds in tray dryer at different temperatures (□ = experimental 60°C; ♦ = experimental 70°C; Δ = experimental 80°C; —— = predicted 60°C; —— - —— = predicted 70°C; – – – = predicted 80°C); prediction using Page model for 60°C and two-compartment model for 70 and 80°C.

coefficients for drying in the FBD due to the high drying air velocity and good mixing in its drying chamber.

The results of experimental data fitting in the four thin-layer drying models are illustrated in Table 2. The R^2 value was used as the primary comparison criterion for evaluating and comparing the best-fit empirical models. Models with lower RMSE values were considered to be better than those with higher values. As shown in Table 2, either the Page model or the two-compartment model had the highest R^2 values for the three drying conditions. The Page model produced the best fit for drying in the FBD at 60 and 70°C and the tray dryer at 60°C, while the two-compartment model was excellent for the remaining drying runs. All the best fitting models had R^2 values higher than 0.9868 and the RMSE values were not over 3.2% d.b. Jittanit (2007) indicated that drying experimental data from corn, rice and wheat seeds were well fitted by the Page model and the two compartment model. In addition, Sacilik (2007) pointed out that the two-compartment model was the best-fit model for the experimental data from thin-layer drying of hull-less pumpkin seeds in a hot air dryer at 40-60°C, while the other models provided a good fit with a value of R^2 greater than 0.9931. Furthermore, Robert *et al.* (2008) found that the Page model was a better fit model for thin-layer drying of grape seeds (Concord variety). The comparisons between the experimental data and the prediction of the best-fit, thin-layer drying models are depicted in Figures 2 and 3, which demonstrate that the models can precisely represent the drying kinetics of pumpkin seeds for both dryers.

Apart from the four common drying models, the entire drying experimental data from all drying temperatures were fitted into the modified Page model and the modified two-compartment model (Table 3), with both models providing comparable values of R^2 and RMSE. Although the modified models provided lower R^2

Table 2 Empirical constants of the Page, Lewis, Wang and Singh and two-compartment models and the statistical parameters used for evaluation of the different drying models.

Dryer	Temp	Page model				Lewis model			Wang and Singh model				Two-compartment model					
	(°C)	k(min^{-1})	N	R^2	RMSE (% d.b.)	k(min^{-1})	R^2	RMSE (% d.b.)	k(min^{-1})	A	R^2	RMSE (% d.b.)	k_1(min^{-1})	K_2(min^{-1})	A	B	R^2	RMSE (% d.b.)
FBD	60	0.0018	1.6763	0.9870	2.2	0.0233	0.9516	4.3	0.0253	1.0944	0.9609	3.8	0.0253	0.0253	0.5472	0.5472	0.9609	3.8
	70	0.0242	1.2037	0.9868	3.2	0.0487	0.9844	3.5	0.0430	1.0065	0.9844	3.5	0.0490	0.0490	0.5033	0.5033	0.9844	3.5
	80	0.3619	0.5916	0.9989	0.5	0.1277	0.9913	1.4	0.1273	0.9955	0.9913	1.4	0.0202	0.1668	0.1015	0.8985	1.00	0.03
Tray	60	0.0011	1.6005	0.9985	0.4	0.0150	0.9585	2.3	0.0165	1.1093	0.9700	1.9	0.0165	0.0165	0.5547	0.5547	0.9700	1.9
dryer	70	0.0606	0.7761	0.9928	2.2	0.0252	0.9784	3.8	0.0238	0.9489	0.9817	3.5	1.2482	0.0197	0.2094	0.7906	0.9932	2.1
	80	0.1760	0.7220	0.9962	0.8	0.0786	0.9861	1.6	0.0770	0.9785	0.9866	1.6	2.8812	0.0524	0.3474	0.6526	0.9974	0.7

RMSE = root mean square error.

Table 3 Empirical constants of the modified Page and modified two-compartment models and the statistical parameters used for evaluation of the different drying models.

Dryer	Temp	Modified Page model					Modified Two-compartment model						
	(°C)	k (min^{-1})	N	A	R^2	RMSE (% d.b.)	k_1 (min^{-1})	k_2 (min^{-1})	A_1	A_2	B	R^2	RMSE (% d.b.)
FBD	60-80	18.925	1.3048	475.36	0.9755	3.6	-7.945	12.662	0.0005	1.0349	377.4	0.9710	3.8
Tray dryer	60-80	5.865	1.0936	385.28	0.9577	4.5	551.60	6.140	-0.1288	1.1288	356.6	0.9599	4.6

RMSE = root mean square error.

and higher RMSE values than the common models such as the Page and the two-compartment models, the modified models are useful and appealing because they have wide applicable temperature ranges.

Effective moisture diffusivity

The drying experimental data were also used to determine the effective moisture diffusivities of pumpkin seeds during drying in the FBD and the tray dryer following the method of slope, as described previously. The calculated effective moisture diffusivities are shown in Table 4. It appeared that the effective moisture diffusivities of pumpkin seeds with hulls during drying in the FBD and the tray dryer were in the range 37.62 × 10^{-11} to 50.96 × 10^{-11} m^2/s and 7.69 × 10^{-11} to 36.40 × 10^{-11} m^2/s, respectively. They increased with increasing drying temperature. The effective moisture diffusivities were higher for drying in the FBD because the drying air velocity in the FBD (1.8 m/s) was much higher than that in the tray dryer (0.23–0.28 m/s). The faster drying air velocity could improve the convective heat transfer leading to the elevated vapor pressure inside the seed. The increased vapor pressure within the seed resulted in faster moisture diffusion. The effective moisture diffusivities of pumpkin seeds with hulls in the present study were not much different from those of the hull-less pumpkin seeds determined by Sacilik (2007). Sacilik (2007) indicated that the effective moisture diffusivities of hull-less pumpkin seeds ranged between 8.53 × 10^{-11} and 17.52 × 10^{11} m^2/s for hot-air drying at 40–60°C. In addition, the effective moisture diffusivities were 1.94 × 10^{-11} m^2/s and 1.66 × 10^{-11} m^2/s for solar tunnel drying and open sun drying, respectively. Sacilik (2007) considered that the higher drying temperature and air velocity caused the greater values of effective moisture diffusivities in the product. In comparison with the other food grains, the effective moisture diffusivities of pumpkin seeds were comparable with those of rough rice (between 2.56 × 10^{-11} and 7.92 × 10^{-11} m^2/s) and brown rice (between 3.89 × 10^{-11} and 14.6 × 10^{-11} m^2/s) calculated by Thakur and Gupta (2006).

According to Suarez *et al.* (1980) and Roberts *et al.* (2008), temperature dependence of the effective moisture diffusivity can be presented by an Arrhenius relationship (Equation 8):

$$D_{eff} = D_0 \exp\left(-\frac{E_a}{RT}\right) \tag{8}$$

where: D_0 = the pre-exponential factor of the Arrhenius equation in m^2/s,

Ea = the activation energy in kJ/mol,

R = the universal gas constant (8.314 × 10^{-3} kJ/mol K),

T = the absolute air temperature (°K).

The pre-exponential factors of the Arrhenius equation and the corresponding activation energies were determined by using the data of effective moisture diffusivities and absolute air temperature in the equation.

The plots between -ln (D_{eff}) versus 1/T appeared to be straight lines in the range of air temperatures studied in both the FBD and the tray dryer (Figure 4), thus, showing Arrhenius dependence. The estimated pre-exponential factors of the Arrhenius equation, the corresponding activation energies and the R^2 values achieved from using the experimental data in Equation 8 are presented in Table 4. The activation energies of pumpkin seeds were 15 and 62.12 kJ/mol for the FBD and the tray dryer, respectively, indicating that the minimum energy required to start moisture diffusion during drying in the FBD was lower than that for tray drying. The values corresponded to the activation energies of some food materials reported by Saravacos and Maroulis (2001), Thakur and Gupta (2006) and Roberts *et al.* (2008).

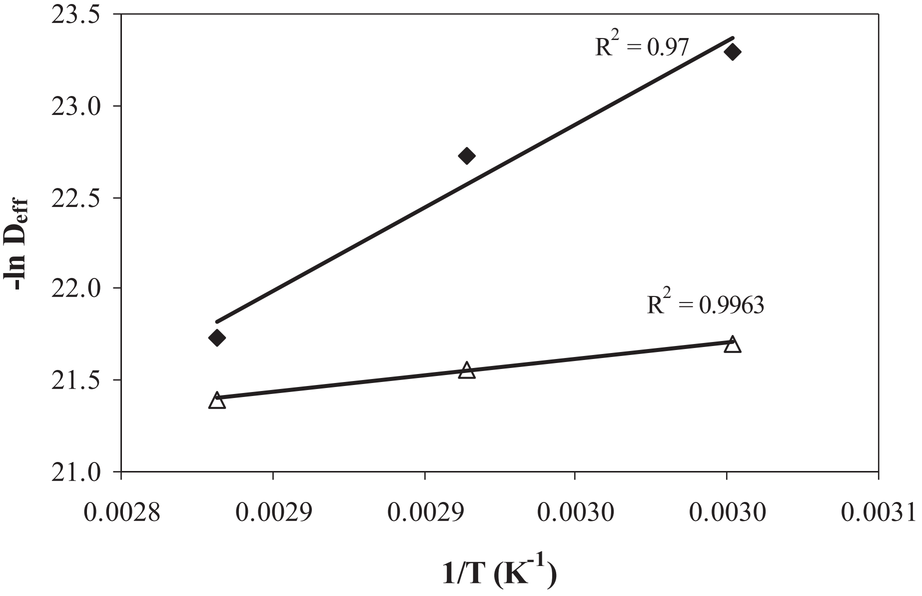

Figure 4 Arrhenius-type relationship between the effective moisture diffusivities of pumpkin seeds and absolute drying air temperature (Δ = FBD; ◆ = tray dryer).

Table 4 Estimated effective moisture diffusivities, pre-exponential factor of the Arrhenius equation and corresponding activation energies for pumpkin seeds.

Dryer	Temp(°C)	D_{eff} (m^2/s)	D_0 (m^2/s)	E_a (kJ/mol)	R^2
FBD	60	37.62×10^{-11}	8.393×10^{-8}	15.00	0.9964
	70	43.28×10^{-11}			
	80	50.96×10^{-11}			
Tray dryer	60	7.69×10^{-11}	0.5148	62.12	0.9299
	70	13.51×10^{-11}			
	80	36.40×10^{-11}			

Note: $$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(\text{Measured } D_{eff} \text{ value} - \text{Predicted } D_{eff} \text{ value}\right)^2}{\sum_{i=1}^{n}\left(\text{Measured } D_{eff} \text{ value} - \text{Average } D_{eff} \text{ value}\right)^2}$$

Sacilik (2007) showed that the activation energy of hull-less pumpkin seeds for hot air drying was 33.15 kJ/mol.

Sensory test

The pumpkin seed samples dried in the FBD and the tray dryer at 80°C and those of a renowned brand purchased from a supermarket were subjected to sensory evaluation using a Hedonic scale test (maximum score = 9). The samples from these two drying runs were chosen due to their fast drying rates. The results of sensory evaluation are shown in Figure 5.

The pumpkin seeds dried by FBD and tray dryer in the present study achieved comparable scores to those of the commercial product. The scores for appearance, color, aroma and taste of dried samples in the present study were slightly lower than those of samples bought from the supermarket. On the other hand, the texture and the overall liking scores of the dried samples in the present study were a little higher than those of samples bought from the supermarket. Comparing seeds dried by FBD with those dried in the tray dryer, the seeds dried in the tray dryer were generally preferred, perhaps because drying in the FBD was more severe than in-tray drying due to the higher heat and moisture transfer rate during the FBD drying process that resulted in more negative effects on the product quality, especially in appearance, color and texture.

CONCLUSION

In the present study, the Page model and the two-compartment model were the best-fit models for pumpkin seed dried in the FBD and the tray dryer. Even though the modified models provided lower R^2 and higher RMSE values than the simplified Page and two-compartment models, the benefit of the former models is that they both cover a wider applicable temperature range. The pumpkin seed dried during the falling rate period, indicating that the moisture removal was controlled by diffusion. The temperature dependence of the effective moisture diffusivity of pumpkin seed followed an Arrhenius relationship. The effective moisture diffusivities and activation energies of pumpkin seed determined in this work were within the ranges of other foods reported by various studies. According to the sensory test results, the pumpkin seed samples dried in the present study were acceptable to the consumers to a comparable level with products sold in the supermarket.

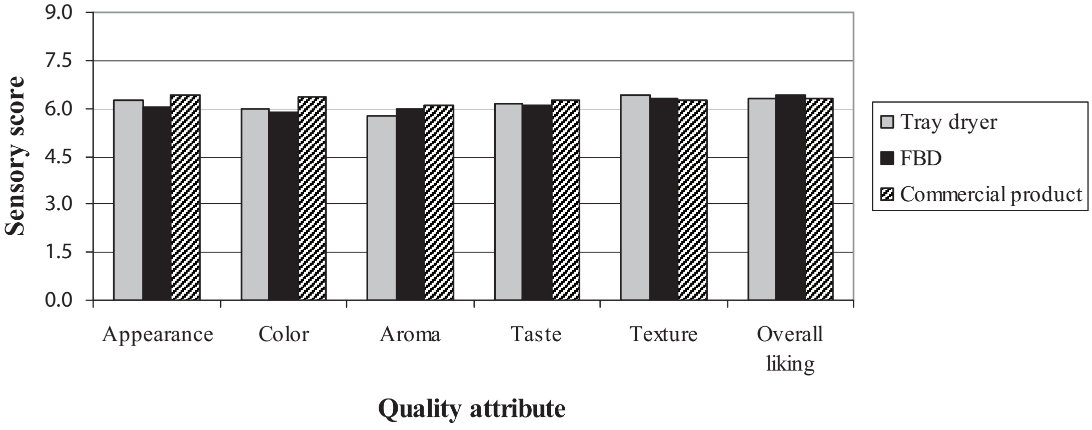

Figure 5 Sensory test results of the pumpkin seeds.

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