Original Article

Journal of Biosystems Engineering

J. Biosyst. Eng. 43(3):237-246. (2018. 9)
https://doi.org/10.5307/JBE.2018.43.3.237

eISSN : 2234-1862
pISSN : 1738-1266

Investigation of Drying Kinetics and Color Characteristics of White Radish Strips under Microwave Drying

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Received: July 31th, 2018; Revised: August 21th, 2018; Accepted: August 22th, 2018

Abstract

Purpose: This study (a) investigated the effect of microwave power intensity and sample thickness on microwave drying characteristics of radish strips, and (b) determined the best-fit drying model for describing experimental drying data, effective moisture diffusivity (D_{eff}), and activation energy (E_a) for all drying conditions. **Methods:** A domestic microwave oven was modified for microwave drying and equipped with a small fan installed on the left upper side for removing water vapor during the drying process. Radishes were cut into two fixed-size strip shapes (6 and 9 mm in thickness). For drying experiments, the applied microwave power intensities ranged from 180 to 630 W at intervals of 90 W. Six drying models were evaluated to delineate the experimental drying curves of both radish strip samples. The effective moisture diffusivity (D_{eff}) was determined from Fick's diffusion method, and the Arrhenius equation was applied to calculate the activation energy (E_a). **Results:** The drying time was profoundly decreased as the microwave power intensity was increased regardless of the thickness of the radish strips; however, the drying rate of thicker strips was faster than that of the thinner strips up to a certain moisture content of the strip samples. The majority of the applied drying models were suitable to describe the drying characteristics of the radish strips for all drying conditions. Among the drying models, based on the model indices, the best model was the Page model. The range of estimated D_{eff} for both strip samples was from 2.907×10^{-9} to 1.215×10^{-8} m^2/s. E_a for the 6- and 9-mm strips was 3.537 and 3.179 W/g, respectively. **Conclusions:** The microwave drying characteristics varied depending on the microwave power intensity and the thickness of the strips. In order to produce high-quality dried radish strips, the microwave power intensity should be lower than 180 W.

Keywords: Activation energy, Color change, Effective moisture diffusivity, Radish, Microwave drying

Introduction

Radish—a root vegetable belonging to the family Brassicaceae—is processed into a variety of products such as dried and pickled products. Among a variety of products processed using radishes, dried radish strips are widely used as a traditional Korean food ingredient because of their unique texture and flavor. As the radish is dried, the nutritional content such as calcium, phosphorus, glucose, and free amino acid contained in the radish can be increased, and physiological activity (anti-oxidation) can be also be improved (Kim et al., 2015). Sun drying and hot-air drying are frequently employed to dehydrate radish strips; however, these

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methods have inherent limitations such as long drying periods, case hardening, and interference by harmful rodents and insects (El-Beltagy et al., 2007).

In microwave drying, the volumetric heat in the product is generated by two main mechanisms: the dipolar relaxation and ionic conduction in the applied electric field. Internal heating results in rapid water evaporation, resulting in high drying rates of the products (Pu et al., 2017). Compared with hot-air drying, microwave drying offers a significantly increased drying rate and better quality of dried product (Yan et al., 2013). Energy consumption in the drying process is the important factor in the selection of suitable drying methods. The drying process using a microwave source has proven to have lower energy consumption than hot-air drying (Motevali et al., 2012). Despite the aforementioned advantages, limitations of microwave drying include a partial loss of aroma and negative sensory changes. The product texture may be affected, and a specific sample size and shape may be required for effective drying. To overcome these disadvantages, it is necessary to determine the optimum condition through the control of either the power density (watts/grams) or duty cycle (time of power on/off) (Orsat et al., 2006). The microwave drying characteristics of several fruits and vegetables have been researched in previous works, including microwave-assisted drying (Baysal et al., 2003; Soysal, 2004; Wang, 2007; Arikan et al., 2012; Darvishi, 2012; Harish et al., 2014; Paengkanya et al., 2015; Zarein et al., 2015). However, no work has been reported on the microwave drying of radish strips for designing, optimizing, and controlling the drying process.

The aim of this study was to determine the effect of microwave power intensity on the drying characteristics of radish stripes with changes in color value, to determine a suitable drying model for describing the drying process, and determining an effective moisture diffusivity (D_{eff}) and activation energy (E_a) for all drying conditions.

Materials and methods

Material

Fresh radishes (Korean radishes) procured from a local market were stored at room temperature before use. Each radish was thoroughly washed with tap water to remove crumbly soil on its surface. The skin of the radish was not peeled, and the radish was cut into the shape of two different thicknesses (6 and 9 mm) by using a vegetable slicer. The average weight of the radish strip samples used in this study was 100 ± 0.2 g. To determine the initial moisture content of the radishes used in this study, the radish samples were dried at 105°C for 24 h in a convection dryer (AOAC, 1990). The initial moisture content was 15.51 ± 0.01 kg of water per kg of dry matter. During the experiments, the radish strips were dried to a final moisture content of 0.004 ± 0.005 kg of water per kg of dry matter.

Microwave drying equipment and experimental procedure

A domestic microwave oven (Mwx304sl, Whirlpool Co., USA) that could deliver up to 900 W of power at 2450 MHz was employed for the drying experiments. In this oven, the microwave power could be controlled from 90 to 900 W at increments of 90 W. The volume of the microwave cavity was 240 × 354 × 358 mm. In order to ventilate water vapor from the radish samples during microwave drying, the outlet duct, which was connected to a small centrifugal fan, was equipped on the upper left side of the microwave oven. The outlet air speed measured by a hygro-anemometer (HHC261, OMEGA Engineering, Inc., USA) was 2.8 m/s.

The effect of different microwave power intensities (180 to 630 W at increments of 90 W) on the drying characteristics of the radish strip samples was investigated with changes in the thickness. The radish strips were spread in a single layer on a circular mesh tray, and then the tray was placed on a glass plate (315 mm in diameter) at the center of the microwave cavity. Moisture loss from a thin layer of radish strips during microwave drying was measured by taking out and weighing the tray on a digital balance with 0.01-g precision (PAG2102C, OHAUS Co., USA). The moisture loss was recorded at two different time intervals (an interval of 30 s until the initial stage of 2 min; afterward, an interval of 2 min). When the weight of the thin layer of radish strips reached a constant value, the drying experiment was completed. All of the drying experiments were conducted in duplicate.

Mathematical modeling of drying curves

The drying curves of the thin layers of radish strips with different thicknesses were obtained from microwave drying at different power intensities. As summarized in

Table 1, the drying curves were fitted with six different drying models that could account for the moisture ratio (MR) during the drying process. The moisture ratio (MR) and drying rate of the radish strips were estimated by the following equations:

$$\text{Moisture ratio (MR)} = \frac{M - M_e}{M_o - M_e} \tag{1}$$

$$\text{Drying rate} = \frac{M_{t+dt} - M_t}{dt} \tag{2}$$

where M, M_o, and M_e are the moisture content at any time, initial moisture content, and equilibrium moisture content, respectively. M_t and M_{t+dt} are the moisture content at t and the moisture content at $t+dt$ (kg water/kg dry matter), respectively. t is the drying time (min).

In this study, the final moisture content calculated from the final weight of the thin layer of radish strips was considered as the equilibrium moisture content (M_e).

Nonlinear regression analysis was carried out using SPSS 24.0 software (SPSS Inc, Chicago, IL, USA). By performing a nonlinear regression analysis, all parameters for the applied drying models were estimated. Comparative model indices such as the coefficient of determination (R^2), root mean square error (RMSE), and chi-square (χ^2) were determined to evaluate the fit of the experimental data to six drying models. The coefficient of determination (R^2) could be the most crucial factor used for selecting the best drying model to describe the experimental drying data of the radish strips (Shama et al., 2005). RMSE and χ^2 could be used to determine the suitability of the drying models (Meziane, 2011). The best drying model should have the highest R^2 value and the lowest RMSE and χ^2 values. The RMSE and χ^2 values were calculated by the following equations:

$$\text{RMSE} = \left[\frac{1}{\text{N}}\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2\right]^{1/2} \tag{3}$$

$$X^2 = \frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2}{N - z} \tag{4}$$

where $MR_{exp,i}$ is the i^{th} experimental moisture ratio, $MR_{pre,i}$ is the i^{th} predicted moisture ratio, N is the number of observations, and z is the number of drying constants.

Estimation of moisture diffusivity and activation energy

The effective moisture diffusivity (D_{eff}), which is influenced by the constituents and moisture content of the material and temperature, is practical for understanding the moisture transfer during the drying process (Sharma and Prasad, 2004). D_{eff} at a given moisture content can be estimated by Fick's second law. D_{eff} for agricultural products of an infinite slab shape can be calculated as follows:

$$\text{MR} = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\exp\left[-\frac{(2n-1)^2 \cdot D_{eff} \cdot \pi^2 \cdot t}{4l^2}\right] \tag{5}$$

where D_{eff} is the effective moisture diffusivity (m^2/s), l is the half-thickness of the samples (m), n is the number (1, 2, 3, ⋯) of terms taken into consideration, and t is the drying time (s).

When the drying time is quite long, only the first term in Eq. (5) is considered, and Eq. (5) can be simply expressed in a logarithmic form (Wang et al., 2007):

$$\text{In(MR)} = \text{In}\left(\frac{8}{\pi^2}\right) - \left(\frac{D_{eff} \cdot \pi^2 \cdot t}{4l^2}\right) \tag{6}$$

After plotting the experimental drying data in terms of ln(MR) vs. the drying time, D_{eff} can be estimated by the linear slope from the plot.

Table 1. Drying models applied to fit with drying curves of radish strips

Model name	Drying model	Reference
Newton	$\text{MR} = \exp(-kt)$	O'Callaghan et al. (1971)
Page	$\text{MR} = \exp(-kt^n)$	Page (1949)
Henderson and Pabis	$\text{MR} = \alpha\exp(-kt)$	Henderson and Pabis (1961)
Logarithmic	$\text{MR} = \alpha\exp(-kt) + c$	Yagcioglu et al. (1999)
Modified Henderson and Pabis	$\text{MR} = \alpha\exp(-kt) + b\exp(-gt) + c\exp(-ht)$	Karathanos (1999)
Two-Term	$\text{MR} = \alpha\exp(-kt) + b\exp(-k_0 t)$	Madamba et al. (1996)

Since the effective moisture diffusivity of agricultural products during microwave drying can be significantly affected by the microwave power intensity, it is necessary to determine the relationship between the ratio of the microwave power intensity to the weight of the sample and D_{eff} (Alibas, 2014). The relationship, especially the dependence of D_{eff} on the ratio of the microwave power intensity to the weight of a thin layer of radish strips can be determined by the Arrhenius equation (Dadali et al., 2007):

$$D_{eff} = D_0 \exp\left(-\frac{m}{p} \cdot E_a\right) \tag{7}$$

where P is the microwave power intensity (W), m is the weight of the sample (g), D_{eff} is the effective moisture diffusivity (m^2/s), D_0 is a pre-exponential diffusivity (m^2/s), and E_a is the activation energy (W/g).

Activation energy and pre-exponential diffusivity can be obtained by plotting D_{eff} versus m/P. Or after taking logarithm in Eq. (7) activation energy and pre-exponential diffusivity can be obtained by straight slope from the plot of ln(D_{eff}) versus m/P (Motevali et al., 2012).

Determination of color parameters

The color values of radish strips were determined before and after drying by using a TES-135 colorimeter (TES Electrical Electronic co., Taiwan) calibrated with a white standard paper. Before the drying process, the chromaticity of the fresh radish sample surface was measured and set as a standard value. The samples were shrunk after the drying; the surfaces of the samples were uneven. Due to aforementioned reason, one strip sample was judged to be difficult to represent the overall chromaticity of the sample after drying. Therefore, the dried samples were ground by a blender to precisely measure the color values of dried samples. The total color difference (ΔE), which was color change index from fresh radish, was calculated by the following equation:

$$\Delta E = \sqrt{(L^*_o - L^*)^2 + (a^*_o - a^*)^2 + (b^*_o - b^*)^2} \tag{8}$$

where L^*, a^*, and b^* express whiteness/darkness, redness/greenness, and yellowness/blueness, respectively. The subscript "o" indicates the color values of fresh radish.

Results and discussion

Microwave drying characteristics of radish strips

Figure 1 shows the change in moisture ratio of different thickness radish strips vs. the drying time under different microwave power intensities. It was clearly observed that the drying time was profoundly decreased as the microwave power intensity was increased regardless of the thickness of the radish strips. When microwave intensities below 540 W were applied for drying, the drying time was increased with an increase in the thickness of the strips; however, the drying times for both samples were similar at intensities over 540 W because some radish strips were charred and boiled.

Maskan (2001) reported that the charring and boiling

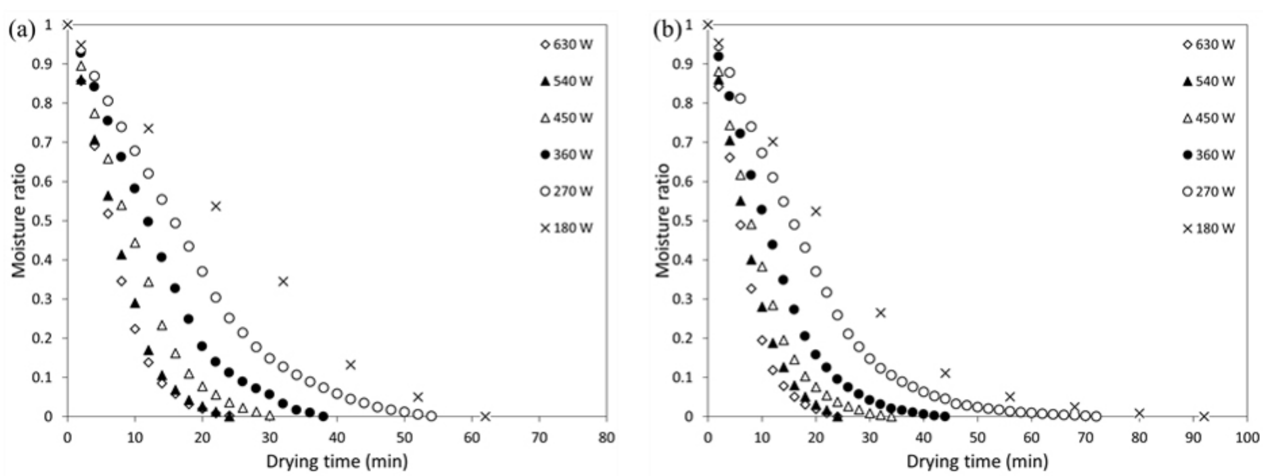

Figure 1. Moisture ratio of different thicknesses of radish strips vs. drying time: (a) 6-mm and (b) 9-mm.

of kiwi fruit samples occurred when a microwave intensity of 490 W was applied for drying. Thus, when a higher microwave power was applied, the effect of the microwave power on the drying time was more dominant than the thickness of the sample at the same weight of the samples. Even though the drying time of the 6-mm thickness radish strips was faster than that of the 9-mm strips, the slope of the plot for the 9-mm strips was steeper than that of the 6-mm strips until the MR reached around 0.1 regardless of the microwave power intensities. Thus, thicker strips with high moisture content could absorb more microwave power than thinner strips. In addition, a small strip number at the same total weight could result in a reduced drying time until a certain moisture ration. This finding was similar to research done by Wang et al. (2004). Although not mentioned in this paper, hot-air drying experiments were performed for the same sample conditions with microwave drying.

The drying curves of both radish strips are illustrated in Figure 2. At the beginning of drying, the highest drying rates were estimated regardless of the microwave power and thickness of the radish strips because the samples with high moisture content at the beginning could absorb more microwave power. Although the shape of the drying curves for both strip samples at the same microwave power seemed to be similar, the drying rate of thicker strips was slightly higher than that of thinner ones up to around a moisture ratio of 0.1. However, the slope of the drying rates of the thinner sample in a range of moisture ratio between 0 and 0.1 (distinct falling rate) was steeper than that of the thicker sample. Therefore, the drying time of the thicker strip samples was longer than that of the thinner samples in order to remove moisture at the end of the drying process.

When hot-air temperatures (50 and 70°C) and velocities (5 and 7 m/s) were applied for the hot-air drying of both radish strip samples, the hot drying times took 7 to 14 times longer than microwave drying at a microwave power of 180 W. The drying rate of the radish strips under microwave drying at 180 W was slightly faster than that under hot-air drying. In addition, the temperature values measured in the microwave during the drying of both samples at 180 W by an optical temperature sensor was in a range between approximately 36 and 39°C.

Drying models

It was attempted in this study to develop empirical modeling that could describe the experimental drying data of white radish strips; however, the form of the established empirical modeling was more complicated than those of well-known drying models. Moreover, the parameter numbers of empirical modeling were much greater than those of well-known drying models. Therefore, several well-known drying models were inevitably applied to describe the microwave drying kinetics of white radish strips in this study. The fit of the experimental drying data of radish strips treated by different microwave power intensities to the applied drying models was evaluated based on comparative model indices (statistical indices; R^2, RMSE, and χ^2) that are summarized in Table 2. All R^2 values from six drying models were above 0.967, and the RMSE and χ^2 values were below 0.067 and 0.0044, respectively.

According to statistical indices resulting from a

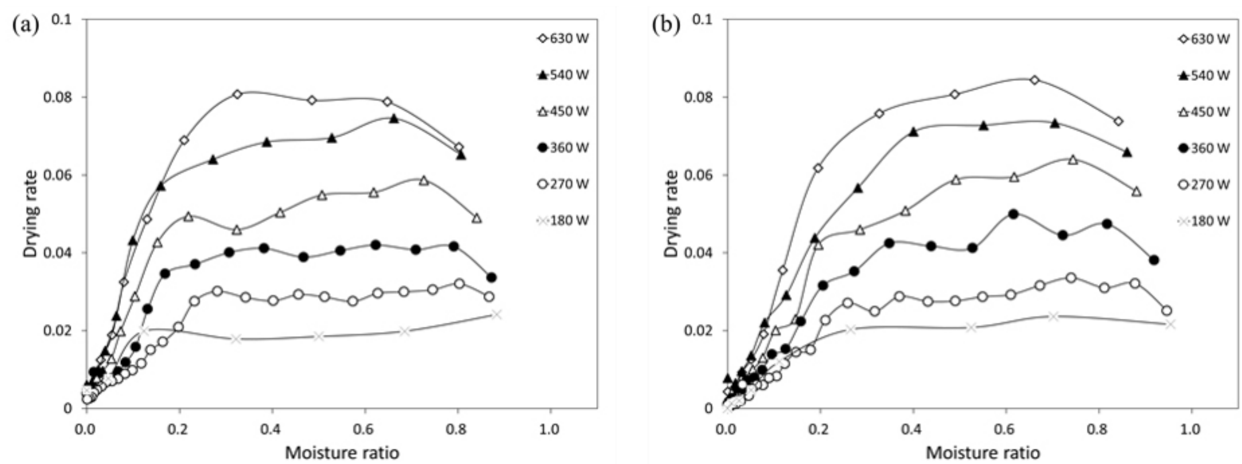

Figure 2. Drying rate of different thicknesses of radish strips: (a) 6-mm and (b) 9-mm.

Table 2. Statistical analysis of applied models at different thicknesses and microwave power

Models	Thickness (mm)	Microwave power (W)	R^2	RMSE	χ^2
Newton	6	180	0.978	0.062	0.0038
		270	0.968	0.059	0.0035
		360	0.969	0.067	0.0044
		450	0.967	0.064	0.0041
		540	0.968	0.065	0.0042
		630	0.971	0.061	0.0038
	9	180	0.981	0.052	0.0027
		270	0.978	0.054	0.0030
		360	0.980	0.055	0.0030
		450	0.980	0.048	0.0023
		540	0.988	0.036	0.0013
		630	0.975	0.057	0.0032
Page	6	180	0.996	0.027	0.0007
		270	0.998	0.014	0.0002
		360	0.999	0.014	0.0002
		450	0.998	0.015	0.0002
		540	0.999	0.014	0.0002
		630	0.999	0.008	0.0001
	9	180	0.998	0.018	0.0003
		270	0.999	0.010	0.0001
		360	0.999	0.009	0.0001
		450	0.999	0.007	0.0001
		540	0.998	0.016	0.0003
		630	0.999	0.009	0.0001
Henderson	6	180	0.980	0.063	0.0039
		270	0.978	0.050	0.0025
		360	0.978	0.057	0.0033
		450	0.978	0.053	0.0028
		540	0.979	0.054	0.0029
		630	0.982	0.049	0.0024
	9	180	0.987	0.045	0.0020
		270	0.986	0.044	0.0019
		360	0.987	0.045	0.0020
		450	0.988	0.038	0.0014
		540	0.993	0.028	0.0008
		630	0.985	0.045	0.0020
Logarithmic	6	180	0.995	0.033	0.0011
		270	0.993	0.029	0.0008
		360	0.994	0.032	0.0010
		450	0.992	0.032	0.0010
		540	0.992	0.034	0.0012
		630	0.991	0.036	0.0013
	9	180	0.991	0.038	0.0015
		270	0.992	0.033	0.0011
		360	0.994	0.032	0.0010
		450	0.994	0.027	0.0007
		540	0.993	0.027	0.0007
		630	0.991	0.035	0.0012
Two-Term	6	180	0.995	0.034	0.0011
		270	0.994	0.027	0.0007
		360	0.994	0.031	0.0009
		450	0.994	0.030	0.0009
		540	0.993	0.032	0.0010
		630	0.992	0.034	0.0011
	9	180	0.994	0.032	0.0010
		270	0.994	0.030	0.0009
		360	0.995	0.029	0.0009
		450	0.995	0.024	0.0006
		540	0.993	0.029	0.0008
		630	0.993	0.033	0.0011
Modified Henderson and Pabis	6	180	0.995	0.039	0.0015
		270	0.998	0.017	0.0003
		360	0.994	0.032	0.0011
		450	0.998	0.017	0.0003
		540	0.998	0.020	0.0004
		630	0.992	0.035	0.0012
	9	180	0.995	0.029	0.0009
		270	0.997	0.021	0.0004
		360	0.998	0.020	0.0004
		450	0.995	0.025	0.0006
		540	0.994	0.026	0.0007
		630	0.993	0.034	0.0012

Table 3. Estimated parameters of Page model at different thicknesses and microwave power

Thickness (mm)	Microwave power (W)	*k*	*n*
6	180	0.0058	1.5197
	270	0.0142	1.4331
	360	0.0176	1.5086
	450	0.0295	1.4722
	540	0.0432	1.4745
	630	0.0496	1.4723
9	180	0.0129	1.3339
	270	0.0161	1.3912
	360	0.0263	1.4064
	450	0.0428	1.3637
	540	0.0860	1.2746
	630	0.0572	1.4332

non-regression analysis, all of the applied drying models were suitable to delineate the drying characteristics of radish strips regardless of microwave power intensity and thickness of the strips. However, the Page model was determined as the best drying model for describing all of the drying curves of the radish strips. The Page model was also comparable to other drying models in the estimation of drying curves because of its simple form. The highest R^2 value and the lowest RMSE and χ^2 values were obtained from the Page model, which could precisely describe the drying curve of 9-mm-thick radish strips treated at a microwave power of 450 W. The coefficients (k and n) of the Page model depending on the microwave power intensities and thicknesses of the radish strips are listed in Table 3.

Effective moisture diffusivity and activation energy

By plotting the logarithm of the experimentally obtained moisture ratio (MR) vs. the drying time, the linear trend was obtained, as shown in Figure 3. Based on this linear trend, the effective moisture diffusivity (D_{eff}), which could represent the tendency of the overall moisture (mass) transfer of the radish strips during microwave drying, were estimated depending on the microwave power intensities and thicknesses of the samples (Table 4). At all applied microwave power intensities, there was no significant difference of D_{eff} depending on the thickness of the radish strips; however, at the same thickness of samples, the D_{eff} values increased with an increase in the microwave power intensity. A higher microwave power intensity could induce more mass transfers of radish strips during drying. The range of estimated D_{eff} was from 2.907×10^{-9} to 1.215×10^{-8} m^2/s, which was similar to the range of 6-mm radish slices treated under vacuum drying (Lee and Kim, 2009).

After estimating the D_{eff} values, the logarithm of D_{eff} vs. the ratio of the microwave power intensity to the weight of the radish strips was plotted as shown in Figure 4. The pre-exponential factor (D_0) and activation energy (E_a) from Eq. (7) were estimated based on this linearity. The estimated pre-exponential factor (D_0) and activation energy (E_a) for the 6-mm-thick radish strips during microwave drying were 1.913×10^{-8} m^2/s and 3.537 W/g, respectively. For the 9-mm radish strips, the estimated pre-exponential factor (D_0) and activation energy (E_a) were 1.749×10^{-8}

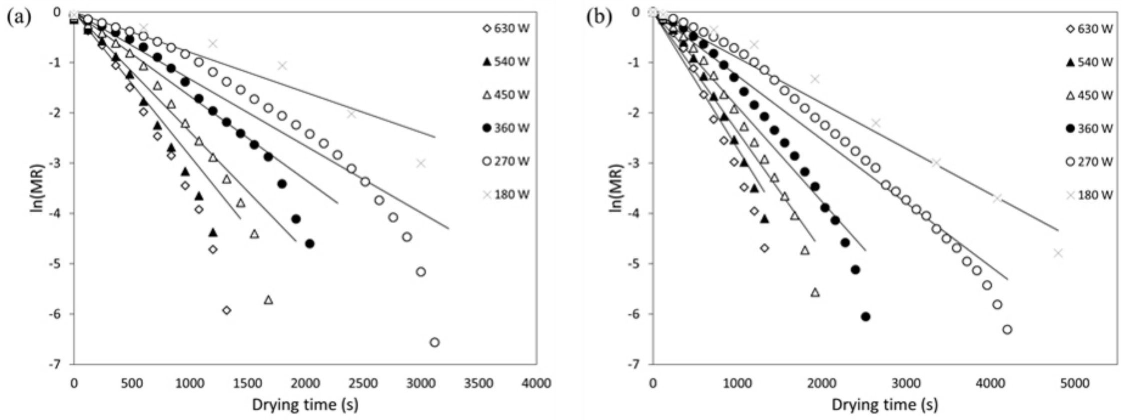

Figure 3. ln (MR) against drying time for (a) 6 mm and (b) 9 mm radish strips.

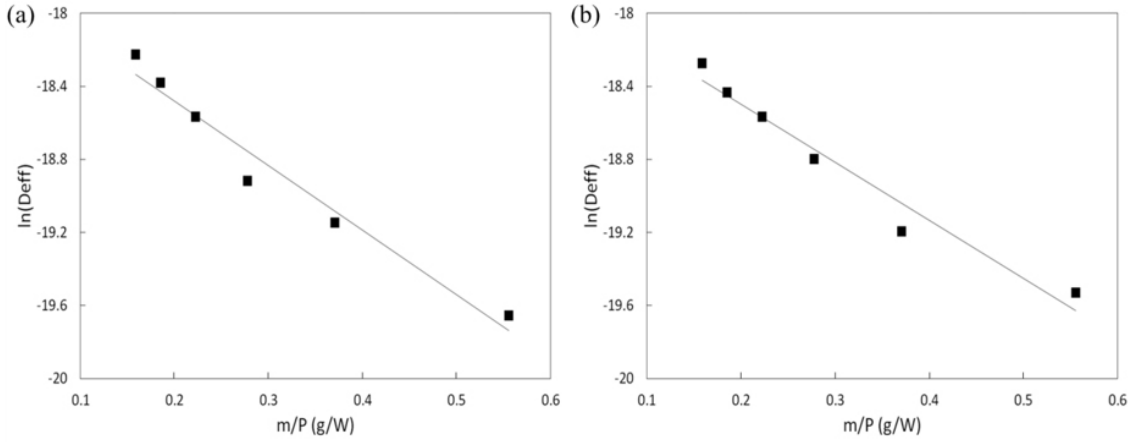

Figure 4. Effect of ratio of microwave power intensity to amounts of radish strips on effective moisture diffusivity: (a) 6-mm and (b) 9-mm.

Table 4. Effective moisture diffusivity (D_{eff}) estimated from different drying conditions of radish strips

Microwave Power (w)	Thickness (mm)	Slope	D_{eff} (m^2/s)	R^2
630	6	0.0033	1.215×10^{-8}	0.931
	9	0.0032	1.158×10^{-8}	0.967
540	6	0.0029	1.041×10^{-8}	0.943
	9	0.0027	9.878×10^{-9}	0.951
450	6	0.0024	8.652×10^{-9}	0.898
	9	0.0024	8.652×10^{-9}	0.944
360	6	0.0017	6.077×10^{-9}	0.908
	9	0.0019	6.861×10^{-9}	0.931
270	6	0.0013	4.844×10^{-9}	0.862
	9	0.0013	4.614×10^{-9}	0.960
180	6	0.0008	2.907×10^{-9}	0.902
	9	0.0009	3.297×10^{-9}	0.971

m^2/s and 3.179 W/g, respectively.

Changes in color parameter

The color parameters (L^*, a^*, and b^* values and ΔE) of fresh radish and dried radish strip flour samples are presented in Table 5. As the applied microwave power intensity was increased, the L^* value decreased and the a^* and b^* values increased. When a higher microwave intensity was applied to dry both samples, the drying time to reach the target moisture content was shortened; however, both samples dried by a microwave power intensity higher than 450 W were charred. During microwave drying, the intensive microwave power could cause the internal carbonization of the radish strip samples because of excessive heat accumulation. A microwave power intensity below 360 W caused little total color change (ΔE) in the dried radish strip samples. Even though the lowest microwave power intensity (180 W) led to the longest drying time and the lowest drying rate for both radish samples, a microwave intensity below 180 W could be suggested to dry radish samples in terms of the total color change.

Conclusions

The drying characteristics of radish strips with different thicknesses under different microwave power intensities were determined in this study. It was clearly observed that the drying time decreased significantly with an increase in microwave power intensity regardless of the thickness of the radish strips. The drying times of thinner radish strips were shorter than those of thicker strips; however, the drying times of thicker strips were slightly faster than those of thinner strips up to a certain moisture content (≈ moisture ratio of 0.2). In addition, the drying rates of thicker samples was slightly higher than those of thinner samples until a certain moisture ratio was reached.

This is because of close interaction between the microwave power intensity and samples having high moisture content. The experimental drying data were fitted to six drying models, and the results from a non-regression analysis showed that all of the applied drying models were suitable for describing the drying curves of the radish strips regardless of the microwave power intensity and thickness of the strips. The Page model was the best model with the highest R^2 values and the lowest RMSE and χ^2 values for all drying conditions.

The effective moisture diffusivity (D_{eff}) for the radish strip samples under different microwave intensities was estimated based on the experimental moisture ratio data, and the range of the estimated D_{eff} was from 2.907×10^{-9} to 1.215×10^{-8} m^2/s. Furthermore, after calculating D_{eff}, the activation energy (E_a) was determined by using the Arrhenius equation, which could describe the relationship between the logarithm of D_{eff} and the ratio of the microwave power intensity to the weight of the samples. The activation energy of the thicker samples was slightly

Table 5. Change in color parameters of dried radish strips by different microwave power intensities

Microwave Power (W)	Thickness (mm)	Color parameters			Total color change (ΔE)
		L^*	a^*	b^*	
Fresh	6	68.39	−5.01	5.68	-
	9	67.34	−4.50	5.84	-
630	6	53.29	5.22	14.90	20.44
	9	44.05	9.26	13.51	28.75
540	6	52.23	6.24	14.14	21.44
	9	45.16	5.62	14.43	25.45
450	6	49.06	−1.30	14.49	21.57
	9	53.68	2.55	17.57	23.94
360	6	63.43	1.58	12.85	10.93
	9	52.12	9.65	19.16	21.18
270	6	69.00	−2.84	9.00	4.02
	9	56.03	1.75	12.96	12.91
180	6	68.95	−6.85	4.25	2.39
	9	61.79	1.53	8.77	8.75

lower than that of the thinner samples. In terms of the total color change (ΔE) of the dried radish strips, a lower microwave power intensity than 180 W could be suggested for producing high-quality dried radish strips.

Conflict of Interest

The authors have no conflicting financial or other interests.

Acknowledgement

This work was carried out with the support of "Cooperative Research Program for Agriculture Science and Technology Development (Project No. PJ01224701)" Rural Development Administration, Republic of Korea.

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