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Mathematical Modeling and Investigation of the Effect of Power on Effective Moisture Diffusivity and Activation Energy of Turnip Slices in Microwave Drying

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ABSTRACT

Microwave (MW) drying is an energy-efficient drying method that helps maintain product longevity and quality. Microwave drying process factors are among the important issues in innovative methods of drying food and agricultural products. In this study, the effect of microwave power on moisture content, moisture ratio, drying rate, Effective Moisture Diffusivity and activation energy was investigated in the microwave drying process. For this purpose, 3 mm thick turnip slice samples were dried at different microwave power levels (550, 770 and 1100 W). To determine the kinetic parameters and mathematically model the drying process, experimental data were fitted to various models. Among the thin layer drying models, the Midili model showed a better fit for all drying conditions at different power levels. As the microwave output power increased, the Deff values increased from 3.829×10^{-9} to 8.845×10^{-9} m^2/s. During the drying process, higher moisture release rates occur at lower activation energy levels. The values of Ea and D_0 were determined as 20.869 W/g and 2.0×10^{-8} m^2/s, respectively.

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INTRODUCTION

Turnip has been used in human diets due to its high content of vitamins and minerals. Its high antioxidant content, as well as its anti-diabetic and anti-inflammatory properties, are of great interest. Turnip is recognized for its nutritional value: this vegetable contains significant amounts of carbohydrates, proteins, beta-carotene, dietary fiber, vitamin E, vitamin C, iron, calcium, and zinc (Kong et al., 2021). Considering the importance of turnip in the human diet, its high quality storage is very important. Drying is the final process of removing water or other solvents from wet solids. Drying is a method for long-term food preservation and a way to process agricultural products after harvest. In addition, the use of appropriate drying techniques is desirable for producing quality dried products (Bissaro et al., 2022). Through this process, safe food products are obtained by inactivating enzymes and destroying microbes. Of course, drying a product may result in color changes, changes in physical appearance and shape, changes in texture, and changes in its nutritional value (Ambawat et al., 2022, (Ambawat et al., 2022; Keramat Bacheh Jackie et al., 2022). To this end, the moisture content of agricultural products is reduced to a level that allows for safe long-term storage. Other advantages of dried products include less need for packaging and lower transportation costs. It is also possible to control some chemical, biological, and even physical reactions that may have a negative effect through the drying process. Microwave (MW) drying is an energy-efficient drying method that helps maintain product longevity and quality (Kong et al., 2021; Kouhila et al., 2020). In this process, materials are exposed to electromagnetic waves focused on the material. Microwaves have a high frequency and can penetrate the product's texture and vibrate polar molecules of the product, such as water and salts. Microwave drying uses microwave electromagnetic waves to heat the interior of the material, which results in rapid evaporation of water due to the rapid absorption of microwave energy by water molecules (Agbede et al., 2020). Due to the concentration of energy on the product, moisture removal occurs at higher rates. Depending on the product type and drying conditions, the use of microwaves can reduce drying time by up to 50% (Jafari et al., 2018). Microwave power and drying time are two important factors in microwave drying that can affect other drying parameters such as drying rate, drying efficiency, and final product quality (Zadhossein et al., 2021). To increase the shelf life and efficiency, as well as maintain the quality of turnips for use in non-production seasons, the drying process is essential and important in accordance with technical and scientific principles. Evaluating the drying kinetics and the required activation energy and modeling it leads to a greater understanding of how the product is dried. Such information can be used in the design and optimization of the drying process (Zadhossein et al., 2021).

Gharehbeglou et al. investigated drying kinetics and mathematical modeling of turnip (Gharehbeglou et al., 2014). kaveh and Amiri Chayjan modeled the thin layer drying of turnip slices under a semi-industrial continuous belt dryer (Kaveh & Amiri Chayjan, 2017). Biswas et al. investigated thin-layer modeling of the drying kinetics of pineapple slices during drying (Biswas et al., 2022). In a research, Kong et al. (Kong et al., 2021) analyzed the drying kinetics, energy and microstructural properties of turnips using a solar drying system. Taghinezhad et al. predicted the drying process of turnip slices with convective-infrared dryer under different pretreatments (Taghinezhad et al., 2021). Wang et al. also investigated the control of microwave power in drying turnip greens (Wang et al., 2022). Abbaspour-Gilandeh et al. evaluated the changes in thermal (Effective Moisture Diffusivity, Specific Energy Consumption, Energy Efficiency) and qualitative properties of terbinth fruit under different drying methods (hot air, infrared, microwave, hot air–infrared and hot air–microwave drying) (Abbaspour-Gilandeh et al., 2020). Mokhtarian et al., (2021) used thin layer drying models to mathematically model pistachio kernel solar drying curves in different drying conditions. (Cavalcanti-Mata et al. fitted mathematical models (Fick, modified Henderson & Pabis, modified Page) to experimental data from chickpeas; then, using the effective diffusion coefficient calculated from each model, they determined the activation energy as well as the thermodynamic properties of the process (Cavalcanti-Mata et al., 2020). In a study, mathematical modeling of thin-layer dried potatoes and investigation of the effect of various variables on drying behavior were conducted. Four mathematical models were fitted to the experimental data. A logarithmic model was found to be the best for all the samples (Türkmen Erol, 2022). In other studies, drying kinetics of Products such as Maize Cob (Özkan et al., 2007), mint leaves (Moradi et al., 2020) were investigated. Recently, microwave drying is considered as an alternative method for drying agricultural products such as fruits and vegetables. Research has been done on microwave drying, which is generally combined. Such as pistachio kernel drying process in microwave drying with ultrasonic pretreatment (Jahanbakhshi et al., 2020), combined microwave and hot-air drying technology for purple cabbage (Liu et al., 2021), Hybrid (Microwave-Conventional) Drying of Sweet Potato (Tüfekçi & Özkal, 2023) and microwave drying conditions of two banana varieties (Omolola et al., 2015). In this study, microwave drying was used. The effect of MW power on drying kinetics of turnip slices, effective moisture diffusion coefficient and activation energy were investigated. Mathematical models were also used to model the drying behavior of turnip slices under different powers. Fick's second law of diffusion has been widely used to explain the drying process of most biological materials (Doymaz & İsmail, 2011). The effective moisture diffusivity (D_{eff}) is an important and key parameter in the drying process, which represents the conductance term of all moisture transport mechanisms. This parameter is determined using curves obtained from experimental drying data. The activation energy is another key drying parameter, which indicates the energy level of water molecules in the process of moisture diffusion and evaporation. The Arrhenius equation shows the temperature dependence of the effective moisture diffusivity hence, the activation energy can be determined using the slope of the Arrhenius plot (Kumar et al., 2021). Since direct temperature measurement is not possible in a microwave oven, a modified Arrhenius equation can be used to show the relationship between the activation energy and the microwave output power density (Kaveh & Amiri Chayjan, 2017).

MATERIALS AND METHODS

Sampling

Fresh turnips were provided from Kerman City (Iran). The samples were stored in a refrigerator with a temperature of +4 ◦C. Before testing, turnip samples were placed at room temperature for 1 hour. They were sliced into circular chips with a thickness of 3 mm. The initial moisture of the samples was determined at 9.89% (d.b.)[1] using an oven (RADLAB, SL-908F) at 70 ◦C for 24 h (Taghinezhad et al., 2021).

Drying procedure

A microwave oven (Gplus, GMW-M452s) with a maximum power of 1100 W at 2450 MHz was used to perform the drying experiments. In the microwave drying process, the samples were uniformly and homogeneously separated. 3 power levels (550, 770 and 1100 W) were used for drying. The mass of the samples (initial mass approximately 40 ± 0.2 g) was read at 30-second intervals with a digital scale (TASH Balance, TD4001) with an accuracy of 0.1 g. Drying was finishd when the moisture content of the samples reached approximately 0.2 (d.b) (Hashemi et al., 2022). The experiments were repeated three times and the average moisture values were used to plot the drying curves.

Mathematical modelling:

Various thin layer drying kinetic models have been used to analyze and describe experimental data from the drying process of food and

1 . Dry Basis Moisture Content

agricultural products. The most common models are Page, Midili, Lewis, logarithmic, Henderson-Pabis, Wang and Singh. The model coefficients are a, b, c and n, while k represents the drying constant (min^{-1}) and t the drying time. This technique has been used in many studies (Agbede et al., 2020; Ambawat et al., 2022; Bissaro et al., 2022; Biswas et al., 2022).

In Table1, seven thin layer drying models, which were applied to the drying data obtained at different microwave powers, are shown.

Table 1. Mathematical thin-layer drying models

No	Model name	Equation	References
1	Lewis (Newton)	$MR = exp(-kt)$	(Doymaz & İsmail, 2011)
2	Page	$MR = exp(-kt^n)$	(Jangam et al., 2008)
3	Henderson & Pabis	$MR = a\ exp(-kt)$	(Zarein et al., 2015)
4	Logaritmic	$MR = exp(-kt)+c$	(Darvishi et al., 2013)
5	Midili	$MR = exp(-kt^n)+bt$	(Midilli et al., 2002)
6	Wang & Singh	$MR = a + bt + ct^2$	(Wang et al., 2022)
7	Parabolic	$MR = 1 + at + bt^2$	(Tunde-Akintunde & Ogunlakin, 2013)

The moisture ratio (MR) of turnip slices during drying was determined by Eq. (1); (Horuz et al., 2020):

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

where: M_t: Moisture content at any time (kg water/kg dry matter), M_0: initial moisture content and M_e: equilibrium moisture content. M_e values are considered relatively small compared to M_t or M_0, especially for microwave drying. Therefore, Eq. (2) can be used to calculate *MR* (Zhao et al., 2019):

$$MR = \frac{M_t}{M_0} \quad (2)$$

Drying rate is the amount of water removed from the samples as a function of time. Using Eq. (2) drying rate values can be calculated and the changes in drying rate versus drying time can be shown with different microwave powers. The models in Table 1 were evaluated using the nonlinear regression procedure of MATLAB software (R2018b). The coefficient of correlation (R^2), Standard error of estimated (*SEE*) and root mean square error (*RMSE*) are the statistical parameters used in determining the quality fit of model (Gull et al., 2017). The lower *SEE* and *RMSE* values and the higher the R^2 value, the better the goodness of fit (Doymaz & İsmail, 2011; Doymaz et al., 2015). The coefficient of correlation (R^2) was primary criterion for selecting the most suitable equation to describe the microwave drying curves which can be calculated from the following Eq. (3):

$$R^2 = \frac{\sum_{i=1}^{N}\left(MR_{Pre,i} - MR_{exp,avg}\right)^2}{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{exp,avg}\right)^2} \quad (3)$$

Standard error of estimated (*SEE*) and the root mean square error (*RMSE*) may be computed from the following Eq. (4) and (5); (Gull et al., 2017):

$$SEE = \sqrt{\frac{\sum_{i=1}^{N}\left(MR_{Pre,i} - MR_{exp,i}\right)^2}{N - n_i}} \quad (4)$$

$$RMSE = \sqrt{\frac{\left(\sum_{i=1}^{N}(MR_{Pre,i}) - \sum_{i=1}^{N}(MR_{exp,i})\right)^2}{N}} \quad (5)$$

Using Eq. (6), drying rate (DR) was calculated (Horuz et al., 2020):

$$DR = \frac{M_t - M_{t+\Delta t}}{\Delta t} \quad (6)$$

where: $M_{t+\Delta t}$: Moisture content at $t + \Delta t$ (kg water/kg dry matter) and t: time (min).

Effective Moisture Diffusivity

Fick's second law can describe the moisture transport in the descending stage of the drying process. It is accepted that the drying curve is in the falling period, so the diffusion model was used to analyze the drying process. The second law of Fick's diffusion equation, which can be used as the mass diffusion equation for drying agricultural products in the period of falling rate, is shown in Eq. (7); (Doymaz et al., 2015; Gharehbeglou et al., 2014; Taghinezhad et al., 2021):

$$\frac{\partial X}{\partial t} = D_{eff}\frac{\partial^2 X}{\partial X^2} \quad (7)$$

Fick's second law of unsteady state diffusion given in Eq. (7) can be used to determine the moisture ratio in Eq. (8). This law is related to mass diffusion in the descending stage of the drying process, which can be solved for different geometries using appropriate boundary conditions.

$$MR = \frac{(X-X_e)}{(X_0-X_e)} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}exp\left[-(2n+1)^2\left(\frac{\pi^2 D_{eff}t}{4L^2}\right)\right] \quad (8)$$

Where, D_{eff} is the effective diffusivity (m^2/s); L is the half thickness of slab (m); X_e, X_0 and X are these respectively the equilibrium moisture content, the initial moisture content and the amount of moisture on the basis of dry base; *t* is the required time for sampling and MR is a moisture ratio (Gharehbeglou et al., 2014). For long drying times, only the first term in Eq. (8) is significant and the equation simplifies to (Eq. (9)); (Zadhossein et al., 2021):

$$MR = \frac{8}{\pi^2}\ exp\left(\frac{\pi^2 D_{eff}t}{4L^2}\right) \quad (9)$$

Eq. (9) can be written in a logarithmic form as follows:

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{eff}t}{4L^2}\right) \quad (10)$$

Effective moisture diffusivity values were determined by plotting experimental drying data in terms of ln (MR) versus drying time in Eq. (10). The slope of the obtained line can be substituted in Eq. (10) to determine the diffusion coefficient (Zadhossein et al., 2021).

$$\text{Slope} = \left(\frac{\pi^2 D_{eff}}{4L^2}\right) \quad (11)$$

Based on the above explanations, to calculate the effective moisture diffusivity (D_{eff}), ln(MR) is computed, and then its curve is plotted against drying time at powers of 550, 770, and 1100 watts. The effective moisture diffusivity is obtained from the slope of the fitted line on each of the curves.

Activation Energy

The Arrhenius relationship shows that the activation energy (Ea) depends on temperature. But in a microwave oven, temperature is not a directly measurable quantity in the drying process. Therefore, Eq. (12) can be used to calculate the activation energy. This equation is a modified form of the Arrhenius equation presented by Zhao et al. , in which instead of temperature, microwave power per sample weight is used (Zhao et al., 2019).

$$D_{eff} = D_0 exp\left(-\frac{E_a m}{P}\right) \quad (12)$$

where: D_0: pre-exponential factor of Arrhenius equation (m^2/s); Ea: activation energy (W/kg); P: microwave power (W) and m: sample weight (kg).

To calculate the activation energy, the D_{eff} effect must be plotted against m/P, then the activation energy can be determined based on the Arrhenius equation (Eq. 12) using an exponential curve fitting.

RESULTS AND DISCUSSION

Drying curves

The drying curves of turnip during microwave drying are shown in Figure 1. Similar to curves in other agricultural product research, moisture content decreased continuously with drying time. Also, in all experimental tests, moisture content decreased more rapidly at higher microwave powers. The drying times required to reach the final moisture content of the samples were 240, 360 and 600 s at microwave powers of 1100, 770 and 550 W, respectively. As the drying process progressed, the moisture content decreased as water molecules were successfully evaporated. By increasing the microwave power from 550 to 110 W, the average drying rate of the samples increased by 2.5 times. Higher microwave power causes more heat absorption, which increases product temperature, increases mass transfer, increases drying rate and consequently reduces drying time. In other words, at higher microwave power levels, higher microwave energy and thus additional heat are produced, leading to faster moisture evaporation. Increased microwave drying speed with increasing power levels has been reported in the literature. The results were in agreement with the studies of Mokhtarian et al., 2021 (Pistachio nut); Karami and Lorestani (Karami & Lorestani, 2021) (Thyme); Gull et al. (Gull et al., 2017) (pasta); Gharehbeglou et al. (Gharehbeglou et al., 2014) (Turnip); Abano (Abano et al., 2012) (tomato slices).

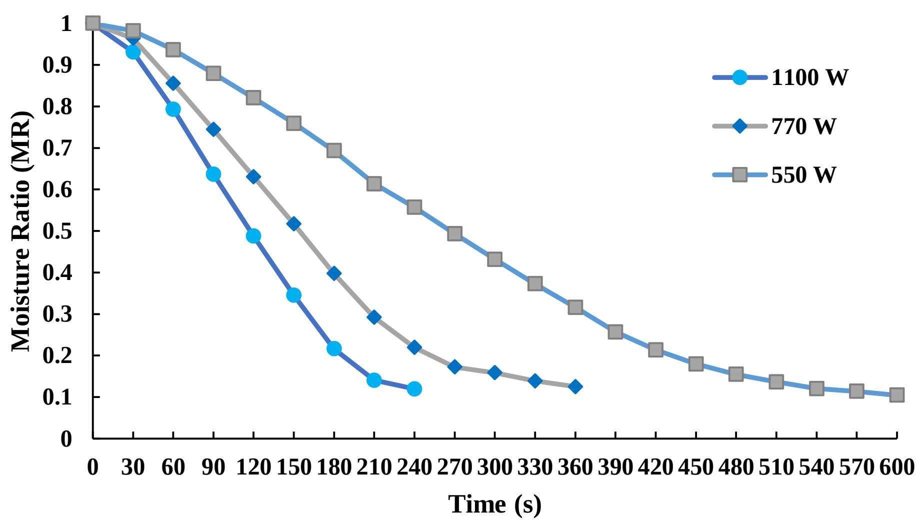

Figure 1. Drying curves of pasta at different powers

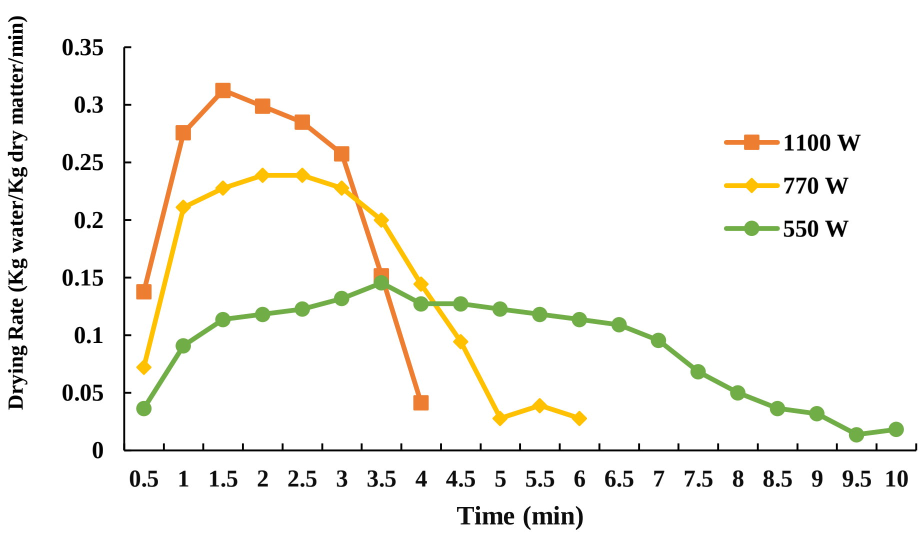

Figure 2. Drying rate versus drying time at different powers

Drying Rate

The drying rate is expressed as the amount of water removed from the samples as a function of time. Using equation 2, the drying rate values were calculated and then the variations of drying rate versus drying time were shown with different microwave powers (Figure 2). Microwave drying involved an initial activation or short heating phase, characterized by a slight initial increase in drying rate. In general, a period of deceleration occurred at all power levels examined. The drying process of turnip slices was carried out during the rate reduction period. The Figure shows that the drying rate increased with increasing microwave power, hence the mass and heat transfer is higher at high power. On the other hand, the drying rate was higher at the beginning of the drying process and gradually decreased with decreasing moisture content. The decrease in rate may be due to the decrease in porosity of the samples due to increased shrinkage, in which case the resistance to water movement increased and caused a further decrease in the drying rate.

Also, as the drying process continues, mass transfer (reduce moisture content) in the product reduces microwave power absorption, thereby reducing the drying rate. The results obtained are similar to previous studies on agricultural products. (Al-Ali & Parthasarathy, 2019; Gull et al., 2017; Karami & Lorestani, 2021; Kaveh & Amiri Chayjan, 2017; Kaveh et al., 2018; Minaei et al., 2013)

Effective moisture diffusivity

Figure 3 shows the curve of ln(MR) versus drying time at 550, 770 and 1100 W. From the slope of the fitted line on each of the curves, the effective moisture diffusivity (D_{eff}) was obtained.

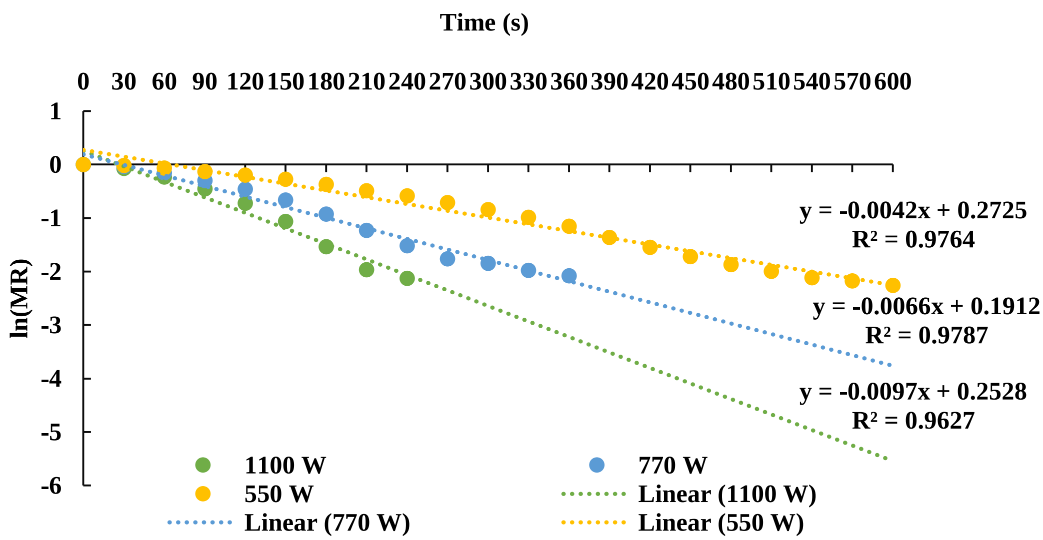

Figure 3. Variation of moisture ratio with drying time at different powers

The effective moisture diffusion values for different microwave powers are given in Table 2. The highest D_{eff} was obtained at the highest power (1100 W) with a value of 8.845×10^{-9} m^2/s and the lowest D_{eff} was obtained at the lowest power (550 W) with a value of 3.829×10^{-9} m^2/s. It is observed that the D_{eff} values increased with increasing microwave power.

Table 2. Effective moisture diffusion values at different microwave powers

Power (W)	D_{eff} (m^2/s)	R^2
550	3.829×10^{-9}	0.976
770	6.018×10^{-9}	0.979
1100	8.845×10^{-9}	0.963

The effective moisture diffusivity depends on the temperature and composition of the sample material. As the microwave power increases, the temperature inside the oven chamber increases and ultimately the temperature of the samples rises faster. For this reason, the D_{eff} increases at higher powers. Therefore, it can be concluded that the effective moisture diffusivity measured increases with increasing power level due to the higher heating rate achievable at higher microwave power levels. This, in turn, increases the activity of water molecules, leading to a higher moisture diffusivity.

The increase in effective moisture diffusivity with increasing microwave power has been similarly reported in the literature. Other researchers reported the effective moisture diffusivity of turnips in the range of 10^{-10} to 10^{-9} m^2/s, such as (Taghinezhad et al., 2021); (Kaveh & Amiri Chayjan, 2017) and (Gharehbeglou et al., 2014) using hot air. Also, for other products, the effective moisture diffusivity has been reported to be in the range of 10^{-10} to 10^{-9} m^2/s, such as: banana (Laskar et al., 2023); beetroot (Ahmed et al., 2023); red pepper (Horuz et al., 2020). Based on Figure 4, the relationship between microwave power and effective moisture diffusivity is expressed by the following equation (Eq. 13):

$$D_{eff} = 9\times10^{-9} P - 1\times10^{-9} \quad (R^2 = 0.9983) \qquad (13)$$

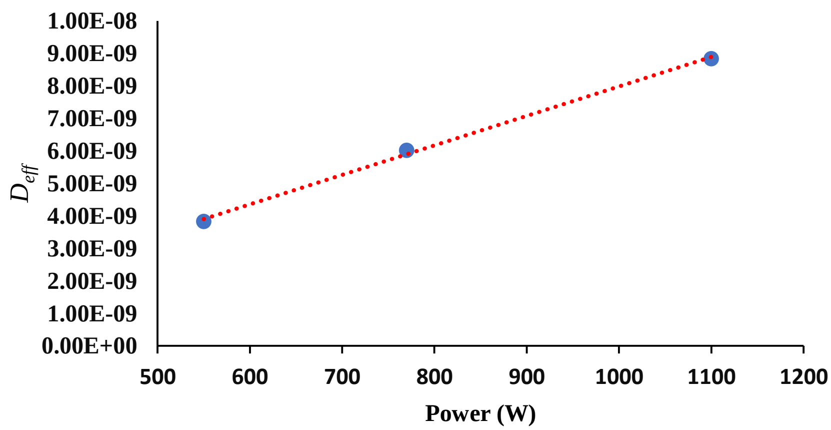

Figure 4. Effective moisture diffusivity versus microwave power

Activation energy

Activation energy (E_a) is a key factor in determining a material's reaction kinetics and transport properties. Activation energy indicates the sensitivity of effective moisture penetration to microwave power. In fact, activation energy is a measure of the energy required to initiate the diffusion of moisture from the interior of a material to its surface. Activation energy is defined as the minimum energy required in the chemical reaction. In modeling and optimizing the drying process, the role of activation energy is very important and is completely dependent on the thermal energy and moisture content (Laskar et al., 2023). This property can be defined as the time when water molecules cross the energy barrier during moisture transfer. During the drying process, higher moisture release rates occur at lower activation energy levels (Ahmed et al., 2023). In fact, lower activation energy means easier moisture removal (Zhao et al., 2019). The effect of D_{eff} versus m/P was plotted (Figure 5). Based on the Arrhenius equation (Eq. 12) by fitting an exponential curve, the activation energy can be determined.

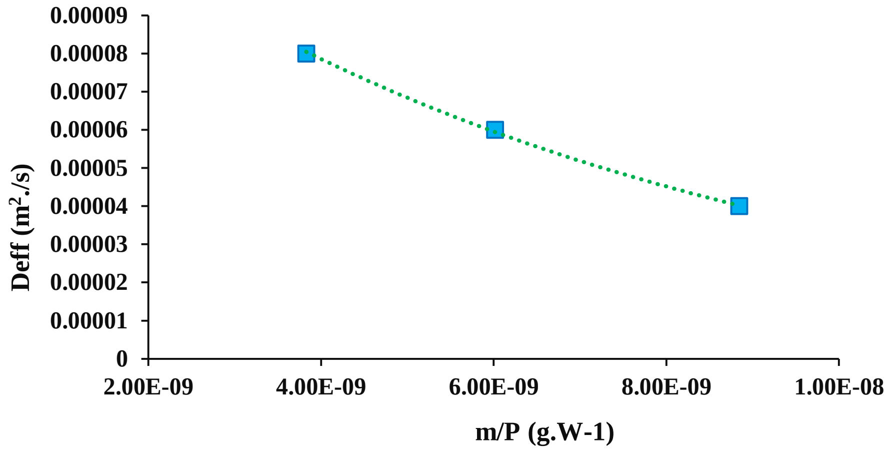

Figure 5. Plot of D_{eff} versus m/P of Turnip

According to the obtained equation (14), the values of E_a and D_0 were determined as 20.869 *W/g* and 2.0×10^{-8} m^2/s, respectively.

$$D_{eff} = 2.0 \times 10^{-8}\, exp\left(-20.869\,\frac{m}{P}\right) \qquad (14)$$

R^2= 0.9986

Eq. 12 shows the effect of sample weight/microwave power on sample D_{eff}. The values of E_a and D_0 are 20.864 *W/g* and 2.0×10^{-8} m^2/s, respectively. The values of activation energies for food items were noted in the range of 12.8–110 *W/g* (Ahmed et al., 2023). The results of this study are within the reported range of previous research. The results obtained are similar to other studies such as (Ahmed et al., 2023; Dadalı et al., 2007; Guemouni et al., 2022; Laskar et al., 2023).

Evaluation of Drying Models

The experimental data were fitted with 7 thin layer drying models (Table 1) using MATLAB software (R2018b). The results of statistical analyses on moisture and drying time modeling are shown in Table 3. To select the best model, the highest R^2 value and the lowest *SEE* and *RMSE* values should be considered.

Table 3. Statistical analysis of models at various microwave power levels

Model	Power (W) 550			770			1100		
	R^2	*SEE*	*RMSE*	R^2	*SEE*	*RMSE*	R^2	*SEE*	*RMSE*
Lewis (Newton)	0.9377	0.1266	0.07957	0.9459	0.06984	0.07629	0.9316	0.06266	0.0885
Page	0.9987	0.00255	0.01159	0.9946	0.006998	0.02522	0.9988	0.001142	0.01277
Midili	**0.9993**	**0.001438**	**0.009198**	**0.9991**	**0.001194**	**0.01152**	**0.9991**	**0.000868**	**0.01318**
logaritmic	0.9883	0.02384	0.03639	0.9807	0.02488	0.04988	0.9865	0.01235	0.04537
Henderson & Pabis	0.9638	0.07366	0.06227	0.9659	0.044	0.06324	0.9508	0.04512	0.08029
Wang & Singh	0.983	0.03456	0.04265	0.9768	0.02992	0.05215	0.983	0.01558	0.04717
Parabolic	0.9906	0.01905	0.03254	0.9858	0.01834	0.04283	0.9875	0.01149	0.04377

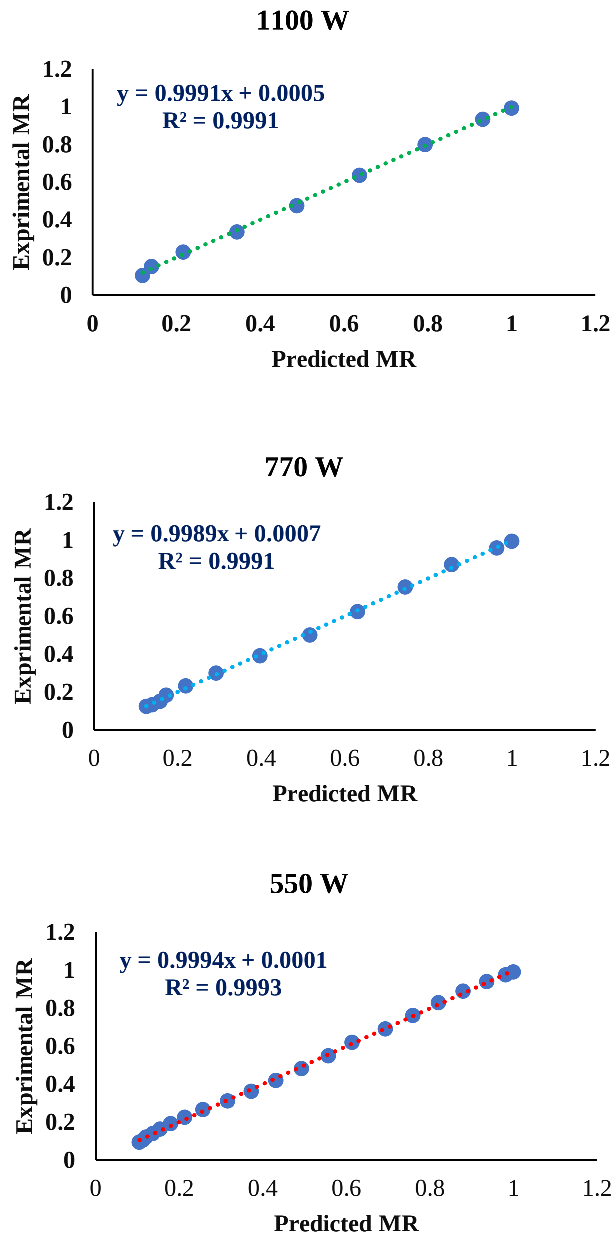

Figure 6. Comparison of experimental and predicted MR values of turnip slices by Midili model.

The R^2 values ranged from 0.9377 to 0.9993 for 550 W, 0.9459 to 0.9991 for 770 W and 0.9316 to 0.9991 for 1100 W, also the *RMSE* values ranged from 0.009198 to 0.07957 for 550 W, 0.01152 to 0.07629 for 770 W and 0.01318 to 0.0885 for 1100 W. The Midili model was selected as the best drying kinetics of turnip slices with high R^2 value and low *RMSE* and *SEE* values. To validate the selected model, the experimental MR values and the MR predicted by the Midili model were plotted (Figure 6). Good agreement was observed between the experimental and predicted MR values, thus confirming the suitability of the model for predicting the drying characteristics of turnip slices. (Gharehbeglou et al., 2014) and (Kaveh & Amiri Chayjan, 2017) also proposed the Midili model to predict the drying of turnip slices. The Midili model has also been proposed for other agricultural products such as trapiá (Moura et al., 2021), pistachio kernel (Jahanbakhshi et al., 2020), Thyme Essential (Karami & Lorestani, 2021), Kumquat (Pir Moradi & Mostafaei, 2018).

The estimated values of the parameters and constant coefficients of the Midilli model at different microwave power levels are shown in Table 4.

Table 4. Midilli model coefficients for predicting the drying behavior of turnip slices at different microwave power levels

Microwave power (W)	a	k	n	b
550	0.9916	5.176E-05	1.714	0.00007239
770	0.994	0.0001013	1.785	0.0002745
1100	0.9947	0.0001641	1.767	0.000143

CONCLUSIONS

This study aimed to investigate the drying kinetics of turnip slices for different microwave power levels. It was observed that with increasing power, the drying period to reach the final moisture content decreased. The drying times required to reach the final moisture content of the samples were 240, 360 and 600 s at microwave powers of 1100, 770 and 550 W, respectively. The drying rate was investigated and observed to increase at the beginning of the drying process and gradually decrease with decreasing moisture content. The decrease in rate may be due to the decrease in porosity of the samples due to increased shrinkage. As the microwave power increases, the temperature inside the oven chamber increases and ultimately the temperature of the samples increases faster. Therefore, the highest D_{eff} was obtained at the highest power with a value of 8.845×10^{-9} m^2/s and the lowest D_{eff} was obtained at the lowest power with a value of 3.829×10^{-9} m^2/s. During the drying process, higher moisture release rates occur at lower activation energy levels. The values of E_a and D_0 were determined as 20.869 *W/g* and 2.0×10^{-8} m^2/s, respectively. Experimental data from the drying process were fitted with 7 thin layer drying models. The Page model was the most appropriate method for interpreting the drying curves at all three microwave power levels (550, 770 and 1100 W) with the highest R^2 value (0.9993, 0.9991 and 0.9991 respectively) and the lowest *SEE* (0.001438, 0.001194 and 0.000868 respectively) and *RMSE* (0.009198, 0.01152 and 0.01318 respectively) values. To validate the selected model, experimental and predicted MR values were plotted and good agreement was observed between experimental and predicted MR values at all three power levels. It is suggested that the effect of other thicknesses of turnip slices and the temperature of the samples after each heating cycle be investigated. These findings may be useful and effective for future research in developing innovative drying processes and strengthening existing methods to improve the quality of drying processes.

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