# The effect of thickness and power on the Hayward variety in drying process of kiwifruit using microwave

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**Abstract:**In this study, the rate of microwave drying method kiwifruit (Hayward variety) was studied.Samples in a completely randomized design with three different thicknesses of 4, 6 and 8 mm and weight of 15 g and three power of 200, 300 and 400W, with three replications, were dried in the microwave dryer. The samples were weighed every 30 s, and then moisture ratio was obtained. According to the results of experiments with different thicknesses Kiwifruit by increasing power, drying time decreased.The amount of effective moisture diffusion coefficient of kiwifruit slices with thickness of 4, 6 and 8mm, $3.25\times10^{-9}$ to $6.49\times10^{-9}m^2/s$ and $3.65\times10^{-9}$ to $1.83\times10^{-8}m^2/s$ and $1.29\times10^{-8}$ to $3.25\times10^{-8}m^2/s$ was changed. The value of the effective activation energy and constant moisture with thickness of 4, 6 and 8mm, -18.1 W/g and$10^{-8}$, -43.1 W/g and $9\times10^{-8}$ and -25.1 W/g and $9\times10^{-8}$ were obtained, respectively.

**Keywords:**dryer,kiwifruit,microwave,power,thickness

**Citation:** Azadbakht M. 2015. The effect of thickness and power on the Hayward variety in drying process of kiwifruit using microwave. AgricEngInt: CIGR Journal, 17(1): 300-305.

## 1 Introduction

Kiwifruit with the scientific name of Actinidiae-deliciosa is a kind of flowering plant and family of Actinidiaceae. It has high growth and it needs guardian for stagnation. The major countries producing kiwifruit in the world are Italy, New Zealand, Chili, France, Iran, Greece, America, Spain and Portugal (Taheri et al.,2009). Kiwifruit product has been distributed to domestic markets in Iran since 1998 from farms of Sari to Astara. Currently, this fruit is planted in three provinces of Mazandaran,80%, Gilan18% and Golestan2% near Caspian Sea in fine lands and it is increasingly growing (Rouzbeh-Nasiraei et al.,2006).Drying process is scientifically and economically important in most industries whose history dates back to the beginning of human civilization. This operation is done in order to remove moisture from products and to prevent it from biological corruption and to reach equilibrium moisture(Mowla et al., 2010). One of the methods which have been a hot spot in recent decades was using microwave beams as a source of dryer device energy. The beams are electromagnetic with long wave (frequency of 2450MHz)during passing these waves from nutrient tissue, and polar molecules such as $H_2O$ and salt are vibrated. This vibration causes the conversion of microwave energy to heat. It is worth to mention that despite other drying methods in which heat should penetrates from surface to depth, in this method heat is generated in the nutrient tissue and the level of damage and burning parts of the nutrients is avoided(Askari et al., 2005).A number of studies which have been conducted and are related to this researchare pointed out as follows:

Pieces of kiwifruit were put into a thick layer dryer. The sample size, temperature and speed of dryer and drying curve for each one of empirical date were measured. Fine curves for kiwi drying were estimated according to obtained data and this curve was compared to models and it proves that the best model for describing behavior of

**Received date:** 2014-12-03 **Accepted date:** 2015-01-13

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kiwi drying is Midilli Model (Mohammadi et al., 2008).Possibility of using microwave method for final drying of two types of grape. They realized that method of final drying can influence on the product color and also using the microwave for ultimate drying is subjected to the used power and type of product (Dehbooreh and Esmaeili, 2010).Investigatedthe effect of different drying methods (natural, oven and microwave), percent and components of Satureja medicinal herb essence and they found out about the significant effect of various drying methods on timing of drying and also level of essences samples. In the end they concluded that drying Satureja medicinal herb essences desirable using low powers of microwave in order to dry the plant (Ebadi et al.,2010). In order to evaluate and select the appropriate model for the drying of a thin layer of pomegranate seeds, eleven semi-theoretical and experimental models were fitted to experimental data (Motevali et al.,2010).To evaluate the mass loss by microwave drying, white onion flakes with different power levels are dried and found that the mass loss and water loss increased with increasing power(Kalse et al., 2012).Microwave method used for drying potatoes and a model was presented using factorial method for investigating effect of microwave power and sample dimensions on drying features. The model was a success for potato pieces. The results indicated that microwave power has the main effect in drying process (Daghbandanet al., 2006).For drying mint the method of vacuum microwave and hot air was used. They applied models of Luess, Paje and Fick to investigate description of drying under various drying conditions,they found out that microwave-vacuum drying can cause reduction of drying time in barge mint from 85 to 90 percent compared to hot air (Therdthai and Zhou, 2009).

The aim of the research is to gain kiwi drying rate (*Hayward variety*), to calculate effective moisture penetration and energy activation in powers and various thicknesses.

## 2 Materials and methods

### 2.1 Preparation of samples

Kiwifruit of Hayward variety was prepared from a local market in Gorgan. Before processing samples were kept in the fridge for 24 h in 4 ℃. Primary moisture of the samples was 80.8%according to calculations and based on wetness and then they were measured by drying in the oven in 80±2 ℃(ASAE, 1979).

### 2.2 Testing method

The machine used for conducting the research is Samsung microwave;M945model with maximum power of 1 kW. Digital Scale, model GD-6000 made in Japan was used for measuring mass changes during drying process.To conduct the tests, Kiwifruit samples were cut with three different thicknesses of 4, 6 and 8 mmwith mass of 15 g.Then for drying process, they were placed in microwave machine with three powers of 200, 300 and 400 W and three repetitions. After that the samples were distributed with time intervals of 30 s. To calculate of moisture relation Equation 1 was used:

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

In which *MR* is moisture ration, $M_t$is product moisture in every moment, $M_e$isequilibrium moisture contentand$M_o$is primary moisture of the product. According to conducted researches, in products which have high level of moisture, Equation 1 can be simplified in form ofEquation 2(Diamante and Munro, 1991).

$$MR=\frac{M_t}{M_o} \qquad (2)$$

As a result,to calculate the relative humidity there is no need tomeasureequilibrium moisture content. Diffusion model to analyze the process of drying with a discount rate was used. Then by using Fick's second law we have Equation 3 (Crank, 1975):

$$\frac{\partial m}{\partial t}= \nabla^2(D_{eff}M) \qquad (3)$$

If we assume that in the studied condition for drying kiwifruit slices, the effective diffusion coefficient is independent of the moisture content of the product and temperature naturalization was expressed through the Arheniusequation.During drying phase, moisture and air pressure are the same for all slices of the product. Also moisture transmission from center to the cut surface of has been in fallowing phase of drying. This process is mainly achieved through molecular diffusion and then we can solve Equation 3 in form of Equation 4:

$$MR=\frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp[\frac{\pi^2(2n+1)^2}{4}\frac{D_{eff}\,t}{a^2}] \quad (4)$$

Where $D_{eff}$ is effective moisture penetration $(\frac{m^2}{s})$, $t$ is drying time (S) and a halved thickness of kiwi (m).

For long hours, the first term of Equation 4 is considered. Logarithm form of this equation can be written as Equation 5.

$$MR=\frac{8}{\pi^2}\exp[-\frac{\pi^2 tD_{eff}}{4L^2}] \quad (5)$$

Chart Ln MR is based on drying time of one right line with a slope (K) according to which level of effective moisture penetration can be calculated according to Equation 6:

$$K=\frac{\pi^2 D_{eff}}{4L^2} \quad (6)$$

### 2.3 Calculation of activation energy

Accurate temperature measurement inside a microwave dryer is not possible. So for themeasurement activation energy, the Arheniusequation, Equation 7 was amended(Ozbek and Dadali, 2007).

$$D_{eff}=D_o\exp(\frac{E_a\,m}{p}) \quad (7)$$

Where $P$ is microwave power (W), $m$ is sample mass (g),$E_a$is activation energy (W/g) and$D_o$is effective diffusion coefficient ($m^2$/s).

## 3 Results and discussion

### 3.1 Drying time

Figure 1, Figure 2 and Figure 3 show general time of drying against output power of microwave for kiwi samples in three thicknesses of 4, 6 and 8 mm. In lower power, drying time is too long.With the increasingpower from 200W to 400W, drying time of kiwi samples in thickness of 4mmwill be reduced to 670s, in thickness of 6mm it became 730s and in thickness of8 mm it will be reduced to 690 s. Using microwave method can reduce drying time (Motevali et al., 2010; Therdthai and Zhou, 2009).

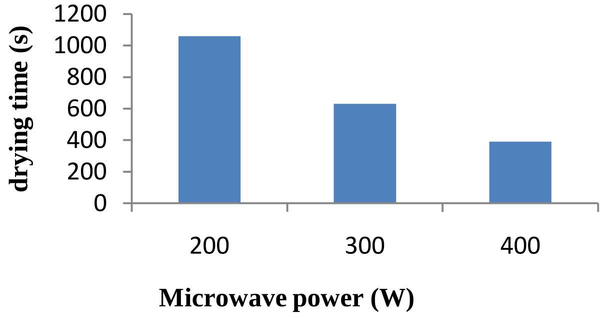


Figure 1Drying time changes in various levels of microwave power for kiwi slices with 4 mm thickness

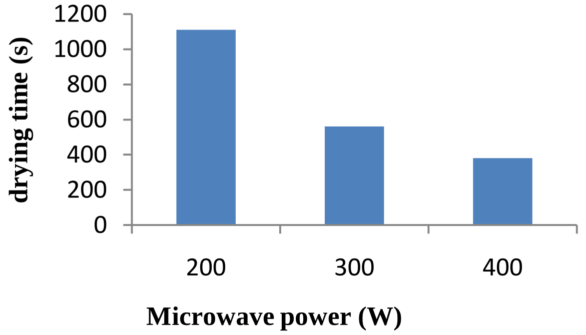


Figure 2Drying time changes in various levels of microwave power for kiwi slices with 6 mm thickness

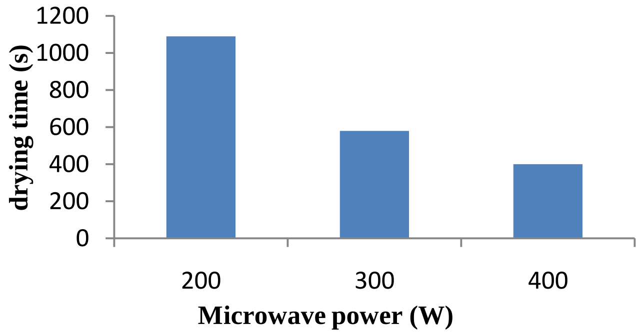


Figure 3Drying time changes in various levels of microwave power for kiwi slices with 8 mm thickness

### 3.2 Investigating drying rate

Mass reduction and water loss can increase with power rise (Kalse et al., 2012). Figure 4, Figure 5 and Figure 6 indicate curve of kiwi’s drying phase in three thicknesses of 4, 6 and 8 mm. Increase of output power of microwave can reduce relative humidity of the product. It seems that with increase of output power, the temperature inside the case and intensity of microwave beams can increase and they may reduce moisture level(Askari et al., 2006).

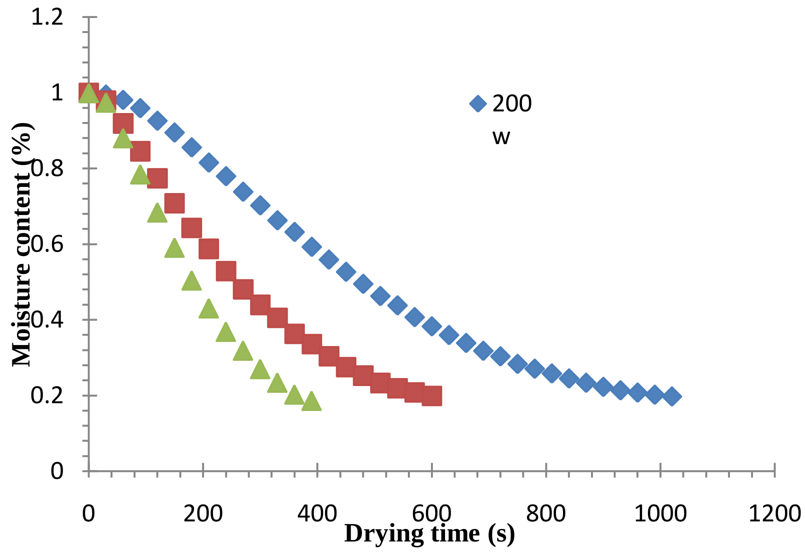


Figure 4Moisture changes based on drying time for kiwi slices with thickness of 4 mm

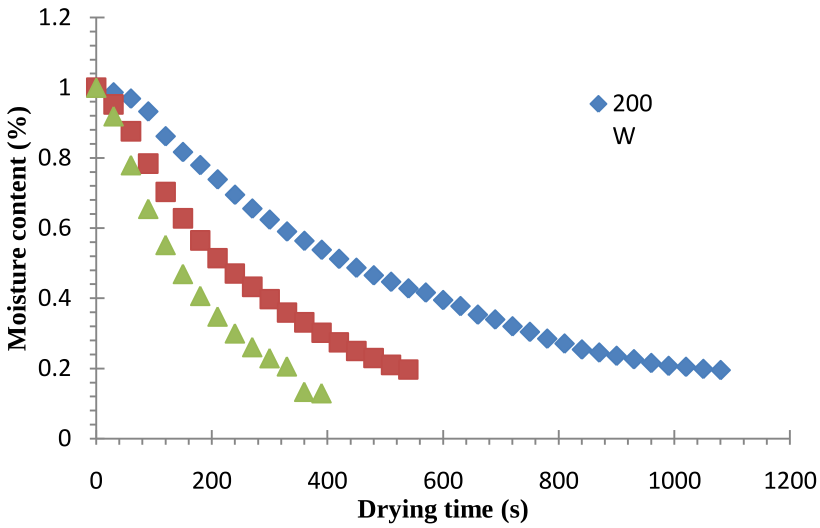


Figure 5 Moisture changes based on drying time for kiwi slices with thickness of 6 mm

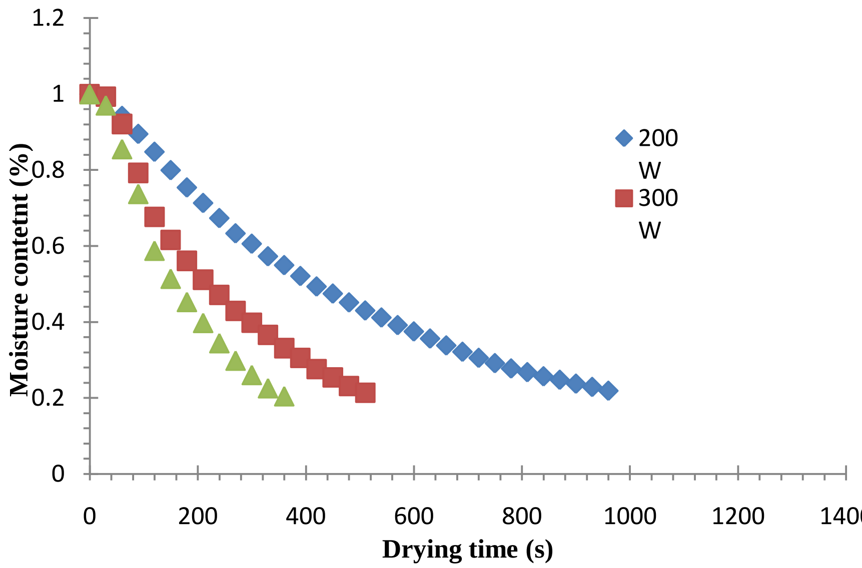


Figure 6 Moisture changes based on drying time for kiwi slices with thickness of 8 mm

### 3.3 Effective diffusion coefficient and activation energy

The previous research results indicate that drying time can control speed descending of resistance (Dehbooreh and Esmaeili, 2010). As a result effective influence coefficient can be calculated from equation5.Changes in effective moisture penetration in various power levels for kiwifruit samples with thickness of 4, 6 and 8 mmare shown in Table 1.

**Table 1 Changes in effective moisture penetration in various power levels for kiwifruit samples with thickness of 4, 6 and 8 mm**

| Power (W) | Effective diffusivity($m^2/s$) | | |
|---|---|---|---|
| | 4mm | 6mm | 8mm |
| 200 | 3.25E-09 | 3.65E-09 | 1.29E-08 |
| 300 | 4.87E-09 | 1.09E-08 | 2.59E-08 |
| 400 | 6.49E-09 | 1.83E-08 | 3.25E-08 |

Changes in moisture penetrationversus (m/p) are shown in Figure7, Figure 8 and Figure 9. According to the Figuresactivation energy from kiwi obtained with thickness of 4 mm equals -18.1, thickness of 6mm equals -43.1 and thickness of 8mm equals -25.1. This indicates that with power increase, activation energy can increase as well. Also according to the obtained results gained, activation energy in thickness of 4mm had the least level and in thickness of 6mm it had the highest level.

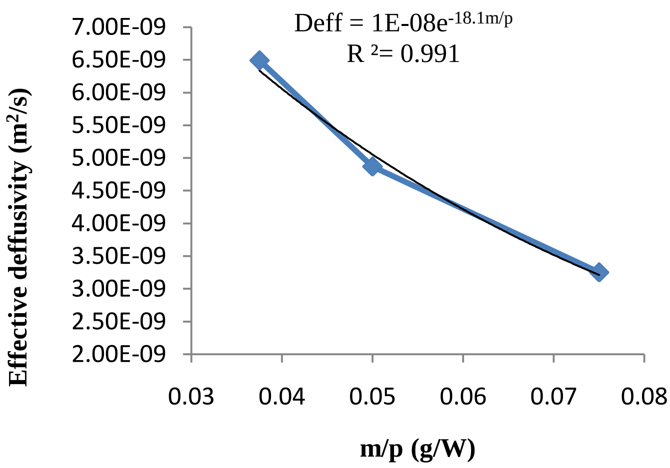


Figure 7Changes in effective moisture penetration based on m/p for kiwifruit slices with thickness of 4 mm

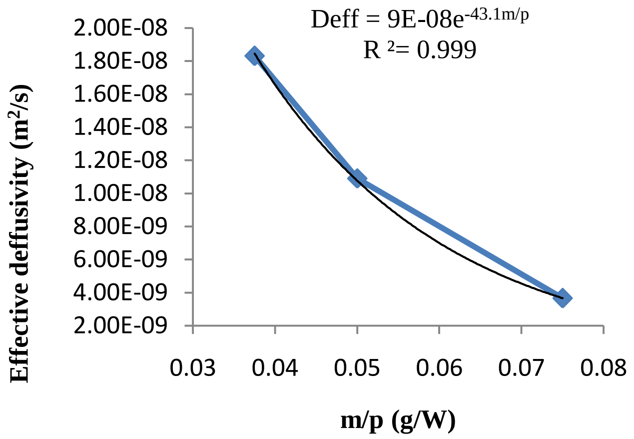


Figure 8 Changes in effective moisture penetration based on m/p for kiwifruit slices with thickness of 6 mm

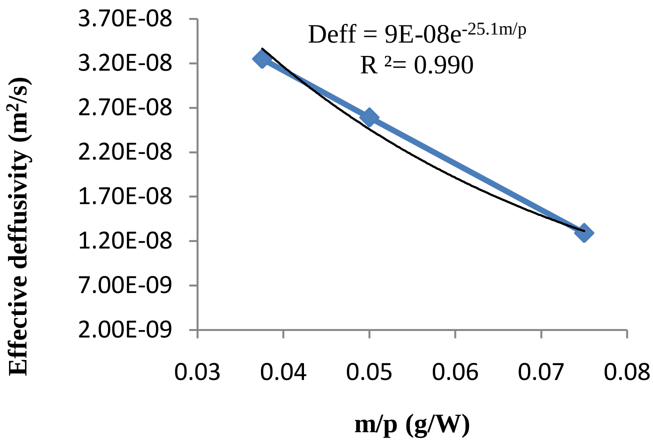


Figure 9 Changes in effective moisture penetration based on m/p for kiwifruit slices with thickness of 8 mm

## 4 Conclusions

With power increase, relative humidity of the product will bereduced and drying time of kiwi slices with different thickness will be reduced. Also with power and thickness, effective moisture diffusivity coefficient increases and level of energy needed for drying can become less with power increase and it can increase with thickness rise. According to the results obtained out of this research we can consider microwave method a suitable one for drying because of reduction in drying time and its being efficient.

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