Journal of International Scientific Publications: Materials, Methods and Technologies

Volume 8, ISSN 1314-7269 (Online), Published at: http://www.scientific-publications.net

AN EXPERIMENTAL STUDY ON MICROWAVE DRYING BEHAVIOR OF KIWI

Dinçer Akal[1], Soner Çelen[2], Kamil Kahveci[1], Ugur Akyol[2]

[1]Department of Mechanical Engineering, Faculty of Engineering, Trakya University, 22180 Edirne, Turkey

[2]Department of Mechanical Engineering, Çorlu Faculty of Engineering, Namik Kemal University,

59860 Çorlu, Tekirdag, Turkey

Abstract

In this study, microwave drying behavior of kiwi in two different microwave powers was studied experimentally. In the experimental study, 90W and 360W were selected as microwave powers. Another parameter considered in this study is slice thickness and kiwi slices was dried in 2mm, 4mm and 6mm thicknesses to investigate the effect of slice thickness on the drying behavior. Experimental results show that increase in the microwave power increases the drying rate significantly, slice thickness, on the other hand, has relatively little effect on drying speed. Depending on the effect on the drying rate, drying time decline drastically with the increase in the microwave power. In this study, a color analysis was also made to assess the effect of the microwave drying on product quality in terms of color. The results also show that the Midilli et al. model could be used to describe the microwave drying curves of kiwi slices. The results also indicate that at 360W microwave power there is a decrease in the quality of kiwi slices in terms of color.

Key words: *microwave drying, drying behaviour, kiwi, color analysis*

1. INTRODUCTION

Food materials, depending on the activities caused by water, become inconsumable in a relatively short time. Water inside the food materials should be removed in order to have a long-term product without a significant change in quality. Drying is one of the mostly used process for this purpose. The most widely used drying method for food materials is convective hot-air drying. In this method, the heated air is sent on product. As a result of the heated air, the equilibrium moisture content on food surface decreases. This creates a high moisture concentration difference between the inner and outer surfaces of the food material. Drying occurs largely by diffusion depending on the concentration difference between this internal and external surface. Moisture removal by diffusion is quite a slow process and thus the drying time takes quite a long time. Therefore, energy consumption due to the heating of drying air is rather high. This is the main reason why the usage of convective hot air drying decreases gradually as a drying process. Accordingly, the microwave drying of food materials is becoming more popular day by day. Microwave energy increases the kinetic energy of water molecules. The molecular activity causes friction forces and eventual evaporation of water. Evaporation increase the pressure inside the material and pressure difference moves the moisture inside the material toward the outer surface. The removal of water vapor by pressure difference instead of diffusion as in the convective hot air drying considerably increases the drying rate and thus drying time takes much lower values.

With the popularization of microwave drying, the studies performed on this topic have also increased. In one of these studies Soysal [1] examined the drying behavior of parsley in eight different microwave powers. It was observed that there will be 111 times reduction in drying time by the usage of microwave drying instead of convective air drying.

In another study, Ozkan et al. [2] examined the microwave drying behavior of spinach for different microwave power levels. Results show that the energy consumption for microwave power levels between 350W – 1000W is nearly stable; however, there is an important increase in energy consumption for microwave power levels between 90W and 160W. The results also show that the best product quality in terms of color is obtained by microwave drying with microwave power level of 750 W. The lowest energy consumption is also obtained for microwave power level of 750W.

Alibas [3] examined the drying behavior of pumpkin slices in convective hot-air, microwave and combination of both: convective hot-air and microwave. Results show that optimum drying condition in terms of drying time, color and energy consumption is for drying air temperature of 50°C and microwave power level of 350W when the combination of convective hot-air and microwave is used.

Kalse et al. [4] examined the microwave drying behavior of onion slices in four different microwave power levels. Though the results of the study show that it is seen a significant decrease in drying time with the increase in microwave power level, high levels of microwave power results in darkening of the product and a relevant decline in the quality of the product.

Priyadarshini et al. [5] investigated the microwave drying behavior of green peas in three different microwave power levels (20W, 40W, and 60W). Various pretreatments were also applied in this study to green peas before drying. The results show that branched green peas dry faster than other pretreatments used in the study. In addition, results show that the product quality is acceptable when green peas are dried in 40 W microwave power.

Darvishi et al. [6] examined microwave drying behavior of carrot slices in four different microwave power levels (200W, 300W, 400W, and 500W). The results show that with the increase in microwave power level, drying rate increases considerably and energy consumption takes lower values. The results also indicate that the drying occurs in two different stages. At first stage, an increase in drying rate is observed. At the second stage, on the other hand, the drying rate begins to decrease during drying process.

Wang et al. [7] investigated microwave drying behavior of pumpkin for different microwave power levels and pumpkin slice thicknesses. The experimental study was conducted in two different stages using the first and second stage power. The results indicate that the drying rate of the pumpkin increases significantly and a corresponding decrease at the energy consumption is seen with the increase of the microwave power level. Wang et al. [7] also observed that the thicker pumpkin sample dries quicker than the thinner sample during the first falling rate period, but the drying rate for the thin sample is slightly higher than the thicker sample during the second falling rate period. The results also show that for the first stage, drying load-power should be higher for lower energy consumption and rehydration and for the second-stage drying, load-power should be higher for lower rehydration and slightly lower for low energy consumption.

Yan et al. [8] examined the drying behavior of carrot pieces using different combined microwave drying methods. The combined drying methods performed in the study are microwave-assisted vacuum drying, microwave–assisted freeze drying, and microwave-enhanced spouted bed drying. It can be concluded from the study that the drying rate takes considerably higher values for the carrot slices dried with the microwave-assisted vacuum drying and microwave-enhanced spouted drying than that dried with microwave-assisted freeze drying. The results also indicate that the energy consumption gets its highest value the drying is performed with the microwave-assisted freeze drying method.

In this study, the microwave drying behavior of kiwi slices was examined experimentally for two different microwave power levels and the effects of microwave power and slice thickness on drying behavior have been determined.

2. MATERIAL AND METHODS

In this study, a microwave oven that has 2450MHz frequency, 800W capacity, and 19L inner volume was used in order to specify drying behavior of kiwi slices. The initial mass of the kiwi slices used in the experiments was 20±1g. The weight of kiwi slices was measured with a digital scale that has a capacity of 620g weight and ±0.001g accuracy. The kiwi slices used in the experiments was 20±1g. The dry mass of kiwi slices were also determined by drying the kiwi slices in an oven for 24 h at a temperature of 105°C. The results are given in Table 1.

Table 1. Dry weight of the kiwi slices for different slice thicknesses.

Thickness	Dry mass
2 mm	3.61 [g]
4 mm	3.69 [g]
6 mm	3.73 [g]

Kiwi slices sliced at the thicknesses given at Table 1 were placed on a glass plate. The progress of the drying process was monitored by weighting the glass plate containing kiwi slices at regular intervals of time on a digital scale of accuracy ±0.001g. Drying was continued until kiwi slices reaches a specific moisture content. The color analysis of the product was conducted by a Hunter Lab D25LT spectrophotometer.

3. RESULTS AND DISCUSSION

In this study, the drying behavior of different slice thicknesses of kiwi was investigated experimentally for two different microwave power levels. The experimental results were given in terms of the moisture content defined as follows:

$$m = \frac{M}{M_w} \tag{1}$$

where M and M_w are the instantaneous and initial mass of the kiwi slices.

Mathematical modelling of drying is rather difficult because drying can occur by a combinations of various drying mechanisms such as hydrodynamic flow, diffusion, and capillary flow. Furthermore, the complex structure of food material poses extra difficulty in mathematical modelling. Therefore, mostly empirical or semi-empirical models are used to model the drying behavior of food materials. Midilli et al. model [9], which is one of this type of models, is mostly used in drying modelling because of its success in defining the drying behavior of food materials. The Midilli et al. model is defined as follows:

$$m = a\exp(-kt^n) + bt \tag{2}$$

where t is the drying time and a, k, n, and b are the drying constants. The Midilli et al. model was used in this study to model the drying behavior of kiwi slices under microwave drying.

In this study, a color analysis was also carried out in order to have some knowledge on the quality of the dried product,. Three parameters, L (lightness), a (redness), and b (yellowness), were used for this purpose. L is the lightness of the product (black = 0 and white = 100). Color density C and hue angle H were also determined in this study. These parameters are defined as follows:

$$C = \sqrt{a^2 + b^2} \tag{3}$$

$$H = \arctan\frac{b}{a} \tag{4}$$

The following relations were used to specify the change in the color parameters with respect to the fresh product:

$$\Delta a = a_{fresh} - a \tag{5}$$

$$\Delta b = b_{fresh} - b \tag{6}$$

$$\Delta L = L_{fresh} - L \tag{7}$$

Experimental drying behavior for the two different microwave power levels and for the different slice thicknesses are shown in Figure 1 and 2. As it can be seen in figures, a significant decrease in the drying time is seen with the increase of the microwave power level from 90W to 360W. The drying time decreases from the range of 5400s- 5700s to the range of 300s – 390s when the microwave power level is increased from 90W to 360W. This shows that microwave power level has very significant effect on drying time. The effect of slice thickness on the drying time is relatively low. As is can be seen from the Figure 1 and 2, drying rate is relatively low at the beginning of drying. The drying rate at later stages of drying increases, and at the end of

drying, it again begin to decrease. The reason for a low drying rate at the beginning of drying is that the energy that is transmitted to the product is spent on the increase of temperature until the water within the product reaches the evaporation temperature. After the start of evaporation, a pressure gradient begins to develop, the moisture inside the product moves away from the product quickly and drying rate shows a significant increase. The reason for the decrease at the drying rate towards the end of drying is low level of moisture content within the product.

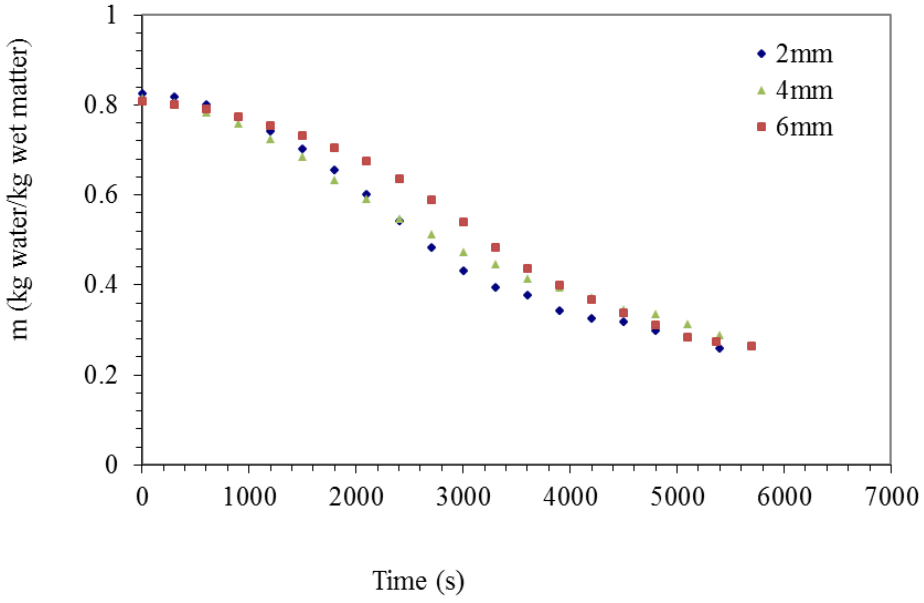


Figure 1. Variation of moisture content with drying time for microwave power of 90W.

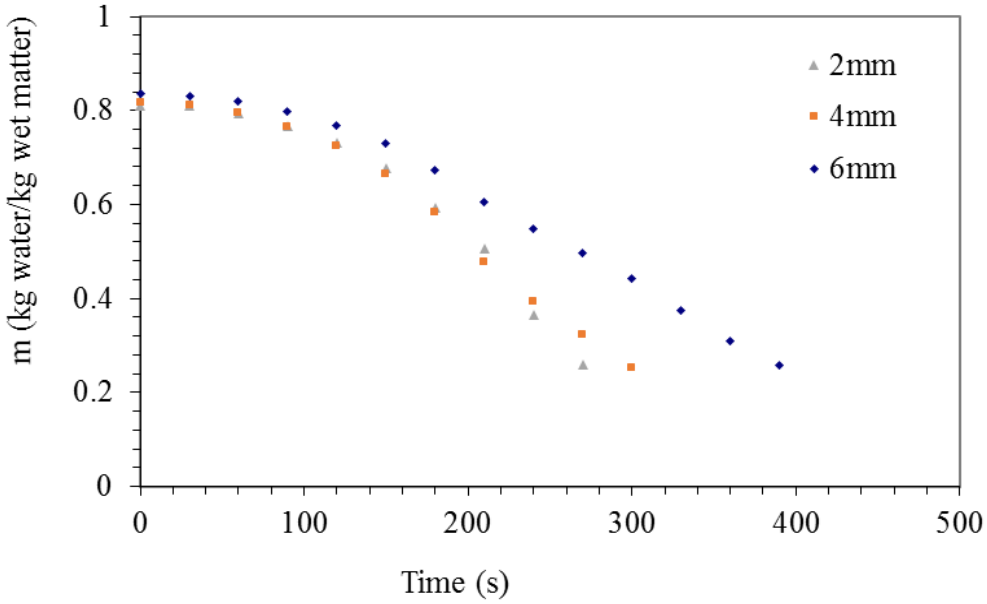


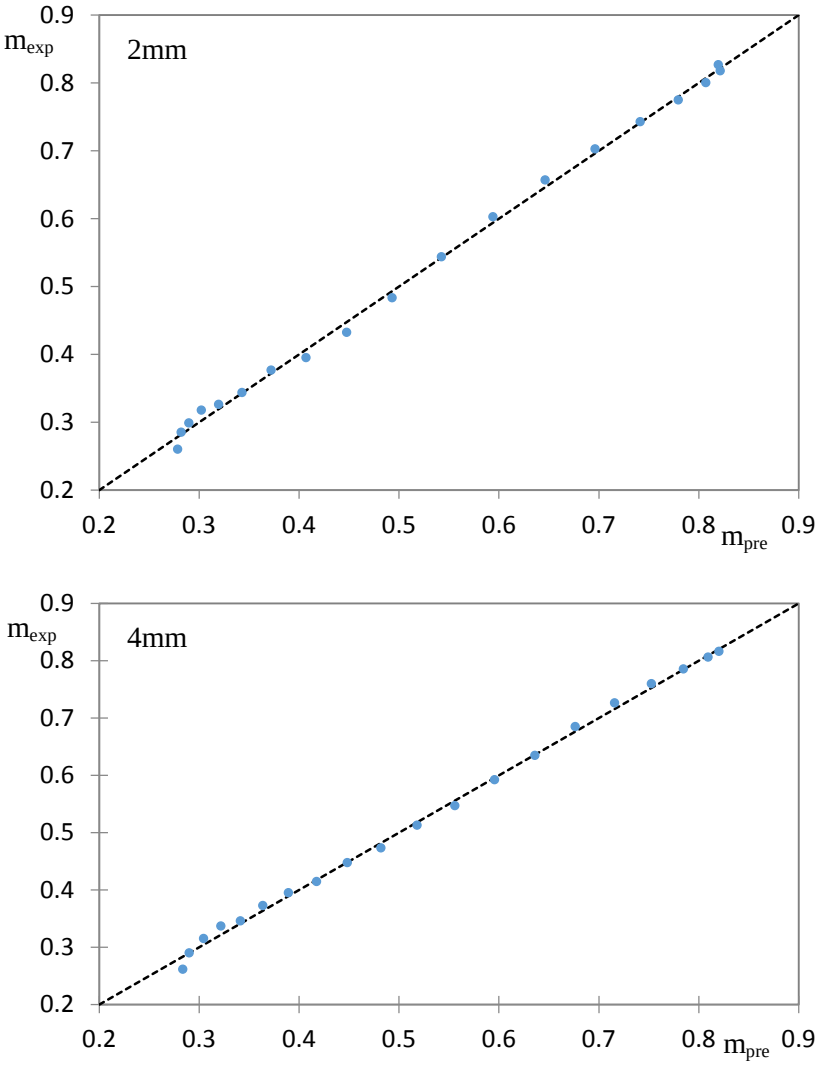
Figure 2. Variation of moisture content with drying time for microwave power of 360W.

The regression analysis results of the Midilli et al. model are shown in Table 2 and Figures 3 and 4 for various slice thicknesses and microwave power levels. The root mean square deviation (rmse) take lower values, which represents that there is a good fit between experimental and predicted moisture contents. As shown in Figures 3

and 4 the biggest deviation between experimental and predicted moisture contents occur at the beginning and at the end of drying. However, overall agreement between the experimental and predicted values is very well. The deviation increases with the increase of the microwave power level.

Table 2. The regression analysis results.

m. p.	thickness	a	k	n	b	rmse
90	2	0.81969	$3.23473x10^{-7}$	1.85860	$4.23716x10^{-5}$	1.02E-02
	4	0.82029	$4.63164x10^{-6}$	1.49088	$2.5968\ x10^{-5}$	9.34E-03
	6	0.82628	$3.08724x10^{-7}$	1.80338	$2.13462x10^{-5}$	1.58E-02
360	2	0.77266	$-6.01335x10^{-2}$	0.44006	$-4.69101x10^{-3}$	4.19E-02
	4	0.79564	$-3.83677x10^{-2}$	0.49274	$-4.\ 14744x10^{-3}$	2.62E-02
	6	0.92378	$1.86916x10^{-8}$	2.40314	$-1.55658x10^{-3}$	3.55E-02



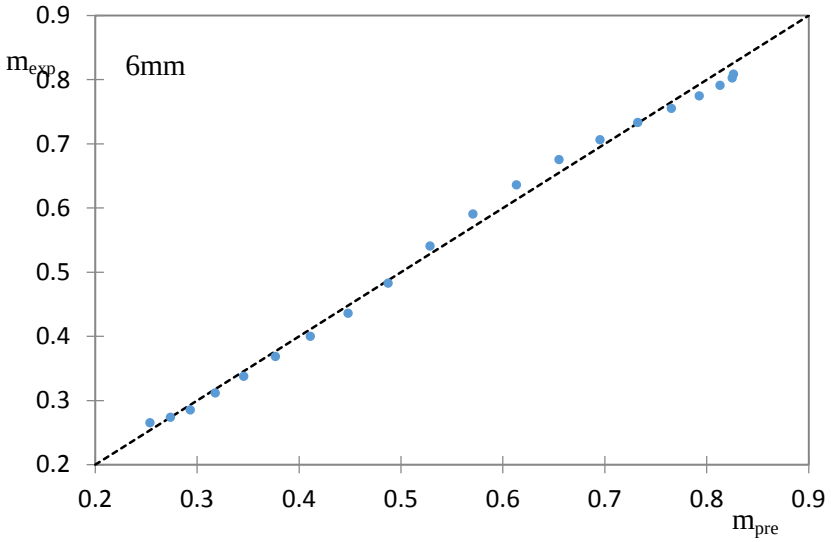
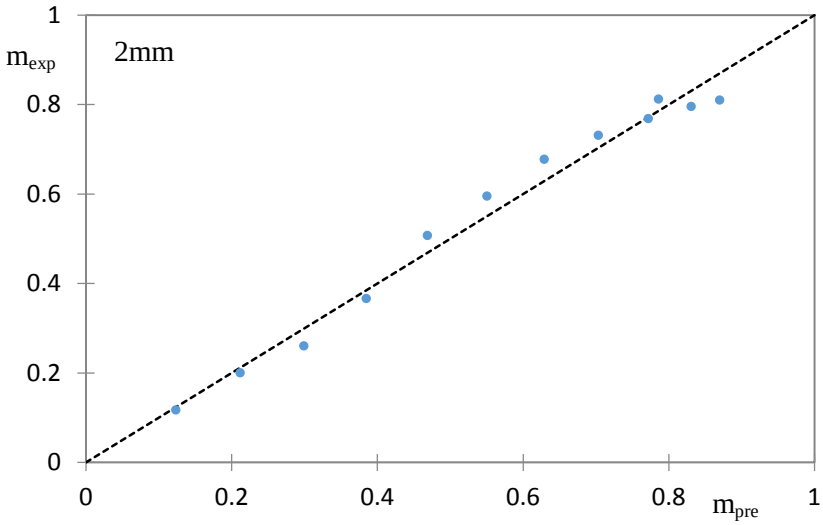
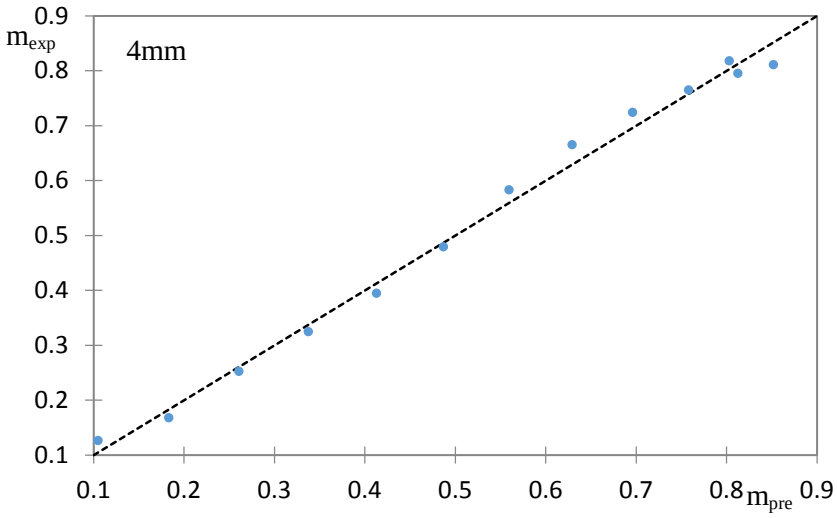


Figure 3. Experimental and predicted moisture contents for microwave power of 90W.





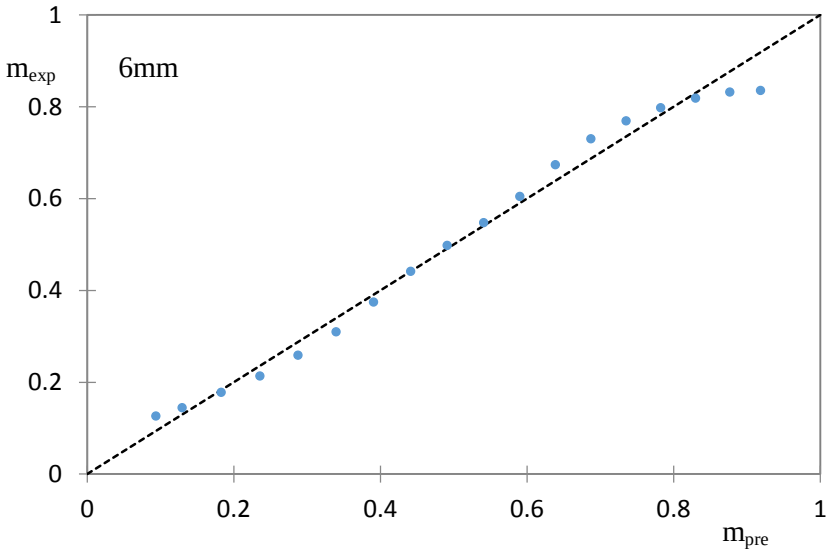


Figure 4. Experimental and predicted moisture contents for microwave power of 360W.

The color parameters of kiwi slices before and after microwave drying are shown in Table 2 for microwave powers levels of 90W and 360W. The brightness decreases and the change in the color increases as the microwave power increases from 90W to 360W. As shown in Figure 5, for microwave powers of 360W, a little darkening develops in the product due to the high temperature towards the end of drying.

Table 2. The color parameters for microwave powers of 90 W and 360 W.

m. p.	**thickness**	**L**	**a**	**b**	**C**	**H**
fresh	-	58.24	-5.15	19.06	19.74	105.13
90[W]	2 [mm]	20.47	5.87	38.06	38.51	81.23
	4 [mm]	31.28	13.03	30.06	34.83	68.03
	6 [mm]	47.42	-2.07	31.39	31.46	93.77
360[W]	2 [mm]	4.10	8.16	30.06	31.15	74.80
	4 [mm]	29.03	4.98	37.98	38.30	82.52
	6 [mm]	32.66	1.98	29.15	29.21	86.12

a) a) a)



2 mm 4 mm 6 mm

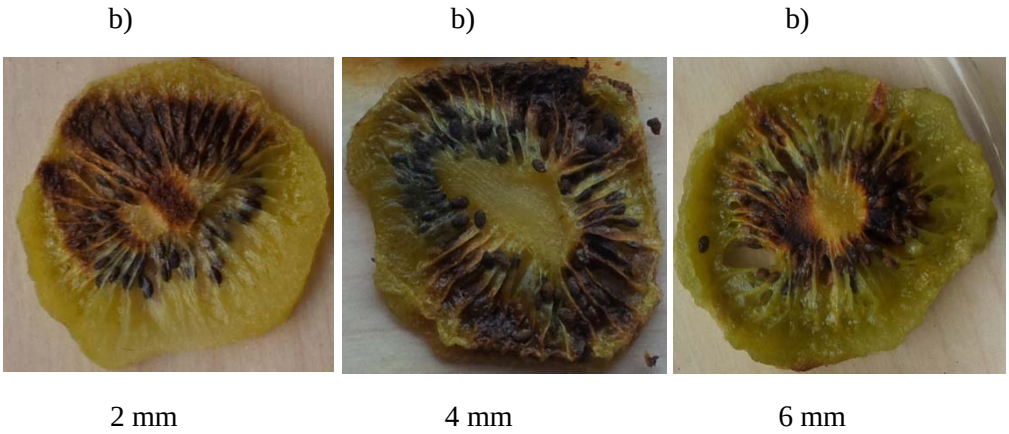


Figure5. Kiwi slices after microwave drying for a) 90W and b) 360W.

REFERENCES

Soysal Y, Microwave drying characteristics of parsley, Biosystem Engineering, 2004; 89: 167-173.

Ozkan A, Akbudak B, Akbudak N, Microwave drying characteristics of spinach, Journal of Food Engineering, 2007, 78; 577-583.

Alibas I, Microwave, air and combined microwave–air-drying parameters of pumpkin slices, LWT, 2007; 40: 1445-1451.

Kalse, SB, Patil MM, Jain SK, Microwave drying of onion slices, Research Journal of Chemical Sciences, 2012, 2: 57-60.

Priyadarshini R, Shukla N, Mishra AA, Microwave drying characteristics of green peas and its quality evaluation, International Journal of Agriculture and Food Science Technology, 2013; 4: 445-452.

Darvishi H, Banakar A, Zarein M, Mathematical modeling and thin layer drying kinetics of carrot slices, Global Journal of Science Frontier Research Mathematics and Decision Sciences, 2012; 12: 57-64.

Wang J, Wang JS, Yu Y, Microwave drying characteristics and dried quality of pumpkin, International Journal of Food Science and technology, 2007; 42: 148-156.

Yan WQ, Zhang M, Hunag LL, Tang J, Mujumdar AS, Sun JC, Studies on different combined microwave-drying of carrot pieces, International Journal of Food Science and Technology, 2010; 45: 2141–2148.

Midilli A, Kucuk H, and Yapar Z, A new model for single layer drying, Drying Technology, 2002, 20(7): 1503-1513.