Experimental Study and Mathematical Modeling on Thin Layer Microwave Drying of Zucchini (*C. pepo*) Slices

Hakan Yoğurtçu

Munzur University, Engineering Faculty, Chemical Engineering Department, Tunceli,
+90 428 2131794, hakanyogurtcu@gmail.com

Received / Geliş: 16th August 2016
Accepted / Kabul: 4th October 2016
DOI: DOI: 10.18466/cbayarfbe.280595

Abstract

In this study, drying behavior of zucchini (*C. pepo*) that is a species of *Cucurbitaceae* family was investigated in microwave oven. Zucchini slices with 3, 6 and 8 mm thick were dried at different microwave output powers (90, 180, 360, 600 W at 2450 MHz frequency) by using domestic microwave oven and monitored pairs of drying time and zucchini mass. It was observed that drying rate of zucchini slices increased with increasing of the microwave output power. On the other hand the drying time for the final moisture contents of zucchini slices increased with increasing of the thick of them. Ten thin layer drying models, available in the literature, were used to evaluate the experimental data. It was observed that Weibull Distribution and Midilli et al. models among the models used are the best mathematical models represented the microwave drying behavior of zucchini slices.

Keywords — Mathematical modeling, microwave drying, zucchini slices

1 Introduction

Zucchini (*C. pepo*) is a member of cucurbits family (*Cucurbitaceae*) and an annual vegetable that contains approximately 90% water. It grows in warm and mild climates and it has green, yellow or white colored varieties. Its fruit is cylindrical and the pulp is in white color. Zucchini produced commonly in Anatolia and cooked as a vegetable in dishes. It is a vegetable rich in calcium, magnesium, potassium and vitamins C and B1, fibers and trace elements. According to Turkish Statistical Institute (TÜİK) data, 293.709 tons of zucchini were produced in Turkey in 2013 [1]. Cucurbits are excellent plants that incorporate most of the basic nutrients necessary for human health [2].

Drying is the oldest method used to preserve moist food products for use at a later time. Drying, which could simply be stated as removal of water from moist/wet material, is in reality a fact of heat and mass transfer exchange that occurs between the material and its environment [3]. Drying is the most appropriate method for food products to protect vitamin values, preservation of the image and the taste, reduced mass advantage in packaging, to improve storage and shipping possibilities. Drying methods such as contact drying, convective drying, drying by freezing, osmotic drying could be used in drying food products [4] and in some cases infrared rays [5] and 2450 MHz frequency microwaves could be used as well [4, 6]. Microwave drying method is an alternative to convective drying for its rapid drying capability, high energy efficiency, and less drying area requirement [7, 8]. Lately, microwave drying gained popularity in the food industry as an alternative drying method [9]. It is more advantageous to dry biologic products with high moisture content such as vegetables and fruits with microwave [10, 11].

Several studies analyzed microwave drying behavior of many materials such as potatoe [12], soybean [13], bean [14], green bean [15], grape [16], apple [17], carrot [18, 19], banana [20], kiwi [21, 22], parsley [23], and spinach [24]. No study was found in the literature that scrutinized drying of zucchini using microwave technique. This study aimed to investigate drying kinetics of zucchini vegetable in the microwave oven under different microwave output power and different zucchini slice thicknesses. Selected thin layer drying models in the literature were applied on the data obtained in experimental studies, and the suitability of the models was determined by the help of certain statistical parameters.

2 Material and Methods

2.1 Material and Experimental Setup

Zucchini used in the study was procured from the local market. Zucchini samples were washed and cleaned from the coarse dirt and kept in a refrigerator at + 4 °C until they were used for the tests. Initial moisture content for the zucchini samples that would be dried was determined at 92.7% ± 0.5 using halogen lamp moisture determination equipment (AND MX 50, USA). Microwave drying tests were conducted by a modified SIEMENS HF12G240 (220V 50 Hz, 2450 MHz) model microwave oven. Microwave drying test set is presented in Figure 1. 3, 6, and 8 mm thick zucchini slices were dried in Teflon plate under 90, 180, 360, and 600 W microwave output power. Changes in zucchini slices mass were followed up periodically using a chronometer and drying was continued until their mass reached 10 % of the initial sample mass. Drying tests were conducted twice with the samples with the same properties.

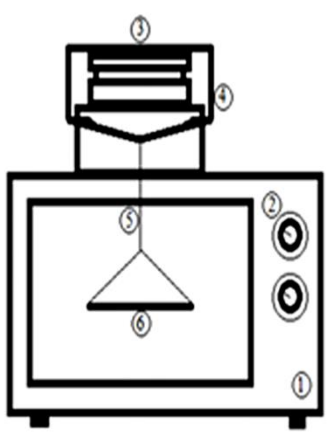

Figure 1. Microwave drying test set

2.2 Modeling of the Drying Curves

Moisture content, non-dimensional moisture ratio, and drying rate of the zucchini samples that were dried in the microwave oven were calculated using equations (1), (2), and (3), respectively.

$$MC=\frac{w_t - w_d}{w_d} \tag{1}$$

$$MR=\frac{M_{C_t} - M_{C_e}}{M_{C_0} - M_{C_e}} \tag{2}$$

$$DR=\frac{M_{C_{t+dt}} - M_{C_t}}{dt} \tag{3}$$

where, w_t (kg) and w_d (kg) are zucchini masses at any given time and the end of drying, respectively, *MC* (kg moisture/kg dry matter) is the moisture content of zucchini slice, *MR* is the dimensionless moisture ratio and *DR* (kg moisture/kg dry matter · min) is the drying rate at t-$t+dt$ time interval.

Equilibrium moisture content was accepted as zero [7]. Mass variation in time was monitored and drying kinetics were analyzed and selected thin layer drying models used in the literature and displayed in Table 1 were applied. Parameters for drying models and the suitability of the models were determined using Statistica (Version 10) data analysis software. Success rates of thin layer drying models utilized were identified with khi-square (χ^2) and Root Mean Square Error (*RMSE*) statistical parameters displayed in equations (4) and (5), respectively [25].

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

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (MR_{exp,\, i} - MR_{pre,\, i})^2}{N}} \tag{5}$$

where, $MR_{exp,i}$ is the i^{th} experimentally observed moisture ratio, $MR_{pre,i}$ is the i^{th} predicted moisture ratio, N is the number of observations, z is the number of constants in the model.

Table 1. Thin layer drying models used

No	Model name	Model	References
1	Newton	$MR = exp(-k\ t)$	[26]
2	Page	$MR = exp(-k\ t^n)$	[4]
3	Henderson & Pabis	$MR = a\ exp(-k\ t)$	[11]
4	Logarithmic	$MR = a\ exp\ (-k\ t) + c$	[25]
5	Two-Term Exponential	$MR = a\ exp\ \ (-k\ t) + (1-a)\ exp(-k\ a\ t)$	[27]
6	Simplified Fick's Diffusion	$MR = a\ exp\ \left(-c\ (t/L^2)\right)$	[28]
7	Midilli et al.	$MR = a\ exp\ \ (-kt^n) + b\ t$	[3]
8	Weibull Distribution	$MR = a - b\ \ exp\ \ (-(k\ t^n))$	[29]
9	Aghlasho	$MR = exp\ \ (-k_1 t/1 + k_2 t)$	[30]
10	Jena & Das	$MR = a\ exp\ \ (-k\ t + b\ \sqrt{t}\ ) + c$	[31]

3 Results and Discussion

3.1 Drying Behavior of Zucchini Slices

The effect of microwave output power on drying behavior of the zucchini slices was evaluated for zucchini samples in different thicknesses. Figure 2 shows the change in moisture ratio of 3 mm thick zucchini samples in time under different microwave output power values. Drying behavior of zucchini slices was similar to related studies in the literature [12, 17, 18, 20, 21]. It was observed that, as the microwave output power increased, the time required for drying decreased significantly. It was reported in studies conducted to dry pumpkin slices in convective dryers that as the temperature, which is the driving force, increased, the time required for drying was shortened [32, 33, 34]. When compared to the drying times observed in these studies (120 – 400 minutes based on the thickness of the pumpkin), the time required to dry using microwave is quite short. The material to be dried commences to heat from the outer surface in convective drying, while in drying with microwave, heating starts inside the material, and hence the interior temperature of the material is higher than the outer surface. Thus, a more dynamic moisture transfer occurs when compared to convective [35, 36].

Changes in drying rates for zucchini slices in different thicknesses under 90 W microwave output power are displayed in Figure 3. As the thickness of the zucchini slices increased, drying rate decreased. Similar changes were observed under 180, 360 and 600 W microwave output power values.

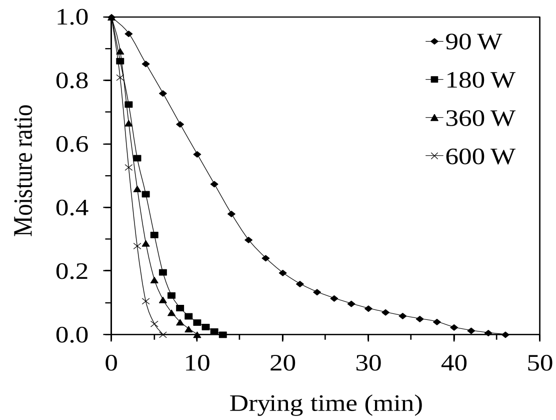

Figure 2. Moisture ratio of 3 mm thick zucchini slices versus drying time at different microwave output powers

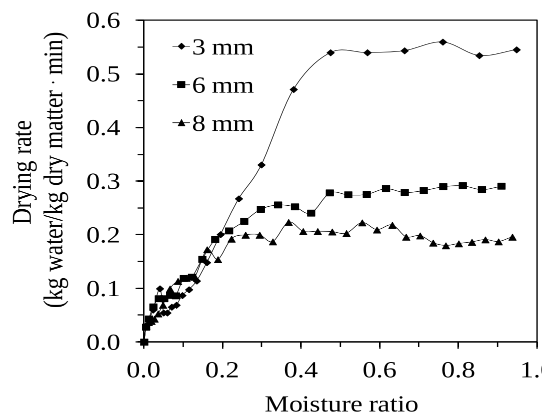

Figure 3. Drying rates versus moisture ration of zucchini slices in different thicknesses at 90 W microwave output power

While the drying rates were observed as 0.52, 1.22, 1.65 and 2.37 (kg moisture/kg dry matter minute) with 90, 180, 360 and 600 W microwave output power for 3 mm thick zucchini slices when the moisture ratio was 0.45, for zucchini slices 8 mm thick, the same rates were observed as 0.2, 0.45, 1.09, 1.71 (kg moisture/kg dry matter minute), respectively. As the zucchini slice thickness increased, drying rate decreased, while the drying rate for the zucchini slices with same thickness increased as the microwave output power increased. When the zucchini thickness decreased from 8 mm to 3 mm, net drying times at 90, 180, 360 and 600 W microwave output power values also decreased approximately 36, 41, 33 and 40 %, respectively. This means that as the zucchini thickness increases, due to the increase in the diffusion path that should be surpassed to remove the water content in the zucchini and the cytoplasmic density, a longer drying time; or to obtain shorter drying times, higher microwave output power would be needed.

3.2 Implementation of Drying Models

Model constants established for ten mathematical models used to represent the drying behavior of zucchini samples are presented in Table 2. Generally, in almost all of the drying models, as the microwave output power increased, drying rate constant, k, increased as well. This demonstrated that as the microwave output power increased, drying rate also increased. It was observed that, at a given microwave output power, an increase in zucchini slice thickness resulted in a decrease in value of drying rate constant.

Statistical analysis results demonstrating the compliance between the empirical data and the models used are displayed in Table 3. High R^2 and low RMSE and χ^2 values indicate that the mathematical model applied is a more appropriate model [25]. While Two-Term Exponential Model was more successful in representing the drying behavior of 3 mm thick zucchini slice at 90 W microwave output power based on the highest R^2 and lowest RMSE and χ^2 values; for 6 mm and 8 mm thick zucchini slices, Weibull Distribution and Aghlasho models were more efficient, respectively. It was observed that Weibull Distribution Model was the best mathematical model representing the drying behavior of zucchini at all slice thicknesses and at 180, 360, and 600 W microwave output power values. However, under the conditions of this study, it could be argued that Weibull Distribution and Midilli et al. models, which have close R^2, RMSE and χ^2 values, were the most efficient models that represented the drying behavior of the zucchini slices. Newton Model was the least efficient in representing the empirical data in the study.

4 Conclusions

It was observed that the increase in microwave output power was resulted in an increase in drying rate during the drying tests of 3, 6, and 8 mm zucchini slices at 90, 180, 360, and 600 W microwave output powers. As the zucchini slice thickness increased, the drying rate decreased due to the increase in the diffusion path and cytoplasmic density. In the beginning of the tests a constant drying rate was observed, however for moisture ratio lower than 0.45 the falling rate period.

It was observed that, among the model equations used to represent the drying behavior of zucchini slices mathematically, Weibull Distribution and Midilli et al. models were the most efficient models in all zucchini slice thicknesses and microwave output power values, and it was determined that Newton Model had the lowest representative efficiency.

It could be argued as a result of the findings of the study that microwave method could be used as a rapid and efficient drying method for drying zucchini. The decision on the microwave output power and zucchini slice thickness for the best quality product should be made based on the parameters such as color, smell, taste, vitamin and fiber content. These parameters should be a guide for future studies.

Table 2. The constants and coefficients of the thin layer drying models

Microwave Output Power (W)	*No*	*Zucchini slice thicknesses*								
		3 mm			*6 mm*			*8 mm*		
		$k/k_1/k_2$	n/a	b/c	$k/k_1/k_2$	n/a	b/c	$k/k_1/k_2$	n/a	b/c
	1	0.071	-	-	0.037	-	-	0.028	-	-
	2	0.023	1.399	-	0.004	1.688	-	0.001	1.833	-
	3	0.078	1.109	-	0.043	1.156	-	0.033	1.167	-
	4	0.066	1.156	-0.074	0.020	1.624	-0.551	0.009	2.310	-1.246
	5	0.109	1.979	-	0.061	2.093	-	0.047	2.125	-
	6	-	1.109	0.177	-	1.156	0.388	-	1.167	0.527
90	7	0.022	1.427	0.0003	0.005	1.726	-0.001	0.002	1.726	-0.001
			1.005	-		0.993	-		0.981	-
	8	0.021	1.449	-0.987	0.005	1.553	-1.066	0.002	1.671	-1.098
			0.017	-		-0.073	-		-0.118	-
	9	0.051	-	-	0.020	-	-	0.014	-	-
		-0.015	-	-	-0.014	-	-	-0.013	-	-
	10	0.105	-	0.146	0.038	-	0.074	0.022	-	0.051
			1.005	-0.018		1.237	-0.261		1.489	-0.521
	1	0.240	-	-	0.140	-	-	0.080	-	-
	2	0.118	1.447	-	0.026	1.837	-	0.008	1.904	-
	3	0.258	1.082	-	0.161	1.154	-	0.092	1.140	-
	4	0.194	1.179	-0.130	0.059	1.925	-0.851	0.010	5.556	-4.505
	5	0.363	1.967	-	0.238	2.166	-	0.141	2.173	-
	6	-	1.082	0.581	-	1.154	1.447	-	1.14	1.475
180	7	0.113	1.456	-0.0006	0.029	1.720	-0.004	0.012	1.633	-0.007
			0.988	-		0.999	-		1.006	-
	8	0.113	1.449	-0.996	0.030	1.685	-1.067	0.014	1.545	-1.267
			-0.008	-		-0.067	-		-0.261	-
	9	0.155	-	-	0.069	-	-	0.038	-	-
		-0.064	-	-	-0.060	-	-	-0.038	-	-
	10	0.310	-	0.213	0.143	-	0.155	0.050	-	0.063
			1.048	-0.055		1.298	-0.309		1.845	-0.848
	1	0.296	-	-	0.147	-	-	0.127	-	-
	2	0.136	1.578	-	0.025	1.934	-	0.017	1.963	-
	3	0.321	1.098	-	0.170	1.148	-	0.148	1.167	-
	4	0.236	1.218	-0.150	0.019	5.442	-4.386	0.034	2.842	-1.766
	5	0.483	2.115	-	0.259	2.187	-	0.224	2.209	-
	6	-	1.099	0.723	-	1.148	1.528	-	1.167	2.376
360	7	0.138	1.583	0.0009	0.031	1.685	-0.012	0.021	1.791	-0.005
			1.008	-		1.007	-		1.004	-
	8	0.137	1.596	-0.997	0.033	1.603	-1.222	0.023	1.739	-1.106
			0.010	-		-0.216	-		-0.103	-
	9	0.181	-	-	0.069	-	-	0.058	-	-
		-0.089	-	-	-0.071	-	-	-0.061	-	-
	10	0.483	-	0.392	0.097	-	0.095	0.112	-	0.132
			1.028	-0.031		1.796	-0.800		1.481	-0.492
	1	0.413	-	-	0.253	-	-	0.189	-	-
	2	0.195	1.738	-	0.070	1.896	-	0.037	1.963	-
	3	0.440	1.077	-	0.283	1.123	-	0.215	1.143	-
	4	0.236	1.437	-0.396	0.086	2.234	-1.176	0.042	3.253	-2.191
	5	0.690	2.179	-	0.440	2.209	-	0.331	2.208	-
	6	-	1.077	0.990	-	1.123	2.546	-	1.143	3.446
600	7	0.196	1.691	-0.003	0.007	1.758	-0.007	0.043	1.778	-0.009
			0.997	-		1.003	-		1.003	-
	8	0.196	1.676	-1.020	0.078	1.720	-1.075	0.045	1.718	-1.121
			-0.023	-		-0.072	-		-0.119	-
	9	0.214	-	-	0.120	-	-	0.086	-	-
		-0.157	-	-	-0.113	-	-	-0.090	-	-
	10	0.600	-	0.426	0.278	-	0.237	0.163	-	0.154
			1.101	-0.102		1.294	-0.297		1.503	-0.507

Table 3. Statistical parameters of thin layer drying models

Microwave Output Power (W)	*No*	*Zucchini slice thicknesses*								
		3 mm			*6 mm*			*8 mm*		
		R^2	*RMSE*	*χ^2*	*R^2*	*RMSE*	*χ^2*	*R^2*	*RMSE*	*χ^2*
	1	0.9719	0.0534	0.0030	0.9289	0.0891	0.0082	0.9056	0.1033	0.0110
	2	0.9983	0.0133	0.0002	0.9975	0.0166	0.0003	0.9942	0.0256	0.0007
	3	0.9833	0.0412	0.0018	0.9551	0.0708	0.0054	0.9367	0.0846	0.0076
	4	0.9895	0.0325	0.0012	0.9928	0.0284	0.0009	0.9919	0.0302	0.0010
90	5	**0.9989**	**0.0104**	**0.0001**	0.9894	0.0344	0.0013	0.9791	0.0487	0.0025
	6	0.9833	0.0412	0.0018	0.9551	0.0708	0.0054	0.9367	0.0846	0.0076
	7	0.9986	0.0118	0.0002	0.9995	0.0077	0.0001	0.9986	0.0126	0.0002
	8	0.9987	0.0114	0.0002	**0.9995**	**0.0074**	**0.0001**	0.9986	0.0125	0.0002
	9	0.9921	0.0283	0.0009	0.9981	0.0147	0.0002	**0.9992**	**0.0093**	**0.0001**
	10	0.9975	0.0161	0.0003	0.9974	0.0170	0.0003	0.9957	0.0222	0.0006
	1	0.9692	0.0581	0.0036	0.9135	0.1025	0.0112	0.8991	0.1089	0.0129
	2	0.9986	0.0125	0.0002	0.9980	0.0158	0.0003	0.9945	0.0253	0.0008
	3	0.9765	0.0508	0.0030	0.9410	0.0846	0.0082	0.9266	0.0929	0.0104
	4	0.9899	0.0332	0.0014	0.9892	0.0363	0.0016	0.9945	0.0255	0.0009
180	5	0.9965	0.0195	0.0004	0.9874	0.0392	0.0018	0.9805	0.0478	0.0027
	6	0.9765	0.0508	0.0030	0.9410	0.0846	0.0082	0.9266	0.0929	0.0104
	7	0.9988	0.0115	0.0002	0.9994	0.0082	0.0001	0.9995	0.0073	0.0001
	8	**0.9988**	**0.0115**	**0.0002**	**0.9995**	**0.0080**	**0.0001**	**0.9996**	**0.0070**	**0.0001**
	9	0.9978	0.0157	0.0003	0.9966	0.0202	0.0005	0.9975	0.0172	0.0004
	10	0.9964	0.0198	0.0005	0.9970	0.0190	0.0005	0.9992	0.0097	0.0001
	1	0.9580	0.0713	0.0056	0.8954	0.1110	0.0134	0.8945	0.1138	0.0138
	2	0.9992	0.0100	0.0001	0.9956	0.0227	0.0006	0.9973	0.0182	0.0004
	3	0.9688	0.0615	0.0046	0.9257	0.0936	0.0103	0.9284	0.0939	0.0101
	4	0.9837	0.0444	0.0027	0.9937	0.0273	0.0010	0.9896	0.0357	0.0016
360	5	0.9993	0.0089	0.0001	0.9814	0.0469	0.0026	0.9831	0.0455	0.0024
	6	0.9688	0.0615	0.0046	0.9257	0.0936	0.0103	0.9284	0.0938	0.0101
	7	0.9994	0.0088	0.0001	0.9997	0.0058	0	0.9995	0.0079	0.0001
	8	**0.9994**	**0.0086**	**0.0001**	**0.9998**	**0.0054**	**0**	**0.9995**	**0.0077**	**0.0001**
	9	0.9919	0.0314	0.0012	0.9968	0.0195	0.0005	0.9959	0.0226	0.0006
	10	0.9991	0.0103	0.0002	0.9991	0.0104	0.0002	0.9974	0.0180	0.0004
	1	0.9434	0.0871	0.0089	0.9117	0.1070	0.0129	0.8975	0.1134	0.0142
	2	0.9994	0.0092	0.0001	0.9980	0.0161	0.0003	0.9965	0.0209	0.0005
	3	0.9515	0.0806	0.0091	0.9319	0.0939	0.0113	0.9245	0.0974	0.0116
	4	0.9849	0.0454	0.0036	0.9873	0.0407	0.0025	0.9894	0.0365	0.0018
600	5	0.9943	0.0276	0.0011	0.9878	0.0397	0.0020	0.9823	0.0472	0.0027
	6	0.9515	0.0806	0.0091	0.9319	0.0939	0.0113	0.9245	0.0974	0.0116
	7	0.9998	0.0054	0.0001	0.9995	0.0078	0.0001	0.9992	0.0099	0.0002
	8	**0.9998**	**0.0052**	**0.0001**	**0.9996**	**0.0075**	**0.0001**	**0.9993**	**0.0097**	**0.0001**
	9	0.9975	0.0183	0.0005	0.9959	0.0230	0.0007	0.9965	0.0210	0.0005
	10	0.9982	0.0157	0.0006	0.9983	0.0148	0.0004	0.9977	0.0169	0.0004

5 References

[1] URL:http://www.tuik.gov.tr/PreTablo.do?alt_id=1001, June, 2014.

[2] Shirivastava, A.; Roy, S. J. Medicinal Plants Studies. 2003; 4(1), 16-20.

[3] Midilli, A.; Kucuk, H.; Yapar, Z. Drying Technology. 2002; 20(7), 1503-1513.

[4] Yagcioglu, A.; Degirmencioglu, A.; Cagatay, F. Proceedings of the 7th international congress on agricultural mechanization and energy, Adana, Turkey, 26–27 May 1999.

[5] Aktas, M.; Ilbas, M.; Yalcin, A.; Sahin, M. J. The Faculty of Engineering and Architecture of Gazi University. 2013; 28(4), 767-775.

[6] Saltiel, C.; Datta, A.K. Advances in Heat Transfer. 1998;

32, 1-94.
[7] Ren, G.; Chen, F. J. Food Engineering.1998; 35, 433–443.
[8] Schiffmann, R.F. Microwave Processes for the Food Industry. Handbook of Microwave Technology for Food Applications; Datta, A.K., Anantheswaran, A.R.C., Eds., MarcelDekker, New York, 2001; 299-338.

[9] Cui, Z.W.; Xu, S.Y.; Sun, D.W. J. Food Engineering. 2004; 65, 157-164.
[10] Schiffmann, R.F. Microwave and dielectric drying. Handbook of industrial drying; Mujumdar, A.S., Edt., Taylor & Francis, New York, 1995; 345-372.
[11] Arslan, D.; Ozcan, M.M. LWT-Food Science and Technology. 2010; 43, 1121-1127.
[12] Bouraout, M.; Richard, R.; Durance, T. J. Food Process Engineering. 1994; 17, 353–363.
[13] Adu, B.; Otten, L. Canadian Agricultural Engineering. 1994; 36(3), 135–141.
[14] Adu, B.; Otten, L. J. Agricultural Engineering Research. 1996; 64, 71-78.
[15] Doymaz, I.; Kipcak, A.S.; Piskin, A. Czech Journal of Food Science. 2015; 33(4), 367-376.
[16] Tulasidas, T.N.; Ratti, C.; Raghavan, G.S.V. Canadian Agricultural Engineering. 1997; 39(1), 57–67.
[17] Feng, H.; Tang, J. J. Food Science. 1998; 63(4), 679–683.
[18] Lin, T.M.; Durance, T.D.; Seaman, C.H. Food Research International. 1998; 4, 111–117.
[19] Litvin, S.; Mannheim, C.H.; Miltz, J. J. Food Engineering. 1998; 36, 103–111.
[20] Maskan, M. J. Food Engineering. 2000; 44, 71–78.
[21] Maskan, M. J. Food Engineering. 2001; 48(2), 177–182.
[22] Tian, Y.; Wu, S.; Zhao, Y.; Zhang, Q.; Huang, J.; Zheng, B. J. Food Processing and Preservation. 2015; 39(6), 2620-2629.
[23] Soysal, Y. Biosystems Engineering. 2004; 89(2), 167–173.
[24] Ozkan, I.A.; Akbudak, B.; Akbudak, N. J. Food Engineering. 2007; 78, 577–583.
[25] Yaldiz, O.; Ertekin, C. Drying Technology. 2001; 19, 583–596.
[26] Doymaz, I. Energy Conversion Management. 2012; 56, 199-205.
[27] Yaldiz, O.; Ertekin, C.; Uzun, H.I. Energy. 2001; 26(5), 457–465.
[28] Diamante, L.M.; Munro, P.A. Int. J. Food Science and Technology. 1991; 26, 99-109.
[29] Corzo, O.; Bracho, N.; Pereira, A.; Vasquez, A. J. Food Science and Technology. 2008; 41, 2023-2028.
[30] Aghbashlo, M.; Kianmehr, M.H.; Khani, S.; Ghasemi, M. Int. Agrophysics. 2009; 23, 313-317.
[31] Jena, S.; Das, H. J. Food Engineering. 2007; 79, 92-99.
[32] Doymaz, I. J. Food Engineering. 2007; 79, 243-248.
[33] Nawirska, A.; Figiel, A.; Kucharska, A.Z.; Sokoł-Łetowska, A.; Biesiada, A. J. Food Engineering. 2009; 94, 14-20.
[34] Guiné, R.P.F.; Pinho, S.; Barroca, M.J. Food and Bioproducts Processing. 2011; 89, 422-428.
[35] Torringa, E.; Esveld, E.; Scheewe, I.; Vanden Berg, R.; Bartels, P. J. Food Engineering. 2001; 49(2-3), 185–191.
[36] Wang, J.; Sheng, K. LWT-Food Science and Technology. 2006; 39, 247–255.