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Drying characteristics of eggplant (*Solanum melongena* L.) slices under microwave-convective drying

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Abstract

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A laboratory scale microwave-convection dryer was used to dry the eggplant fruit, applying microwave power in the range of 270–630 W, air temperature in the range of 40–70°C and air velocity in the range of 0.5–1.7 m/s. Six mathematical models were used to predict the moisture ratio of eggplant fruit slices in thin layer drying. The results showed that the Midilli et al. model had supremacy in prediction of turnip slice drying behavior. Minimum and maximum values of effective moisture diffusivity (D_{eff}) were 1.52×10^{-9} and 3.39×10^{-9} m^2/s, respectively. Activation energy values of eggplant slices were found between 13.33 and 17.81 kJ/mol for 40°C to 70°C, respectively. The specific energy consumption for drying eggplant slices was calculated at the boundary of 86.47 and 194.37 MJ/kg. Furthermore, in the present study, the application of Artificial Neural Network (ANN) for predicting the drying rate and moisture ratio was investigated. Microwave power, drying air temperature, air velocity and drying time were considered as input parameters for the model.

Keywords: energy; modelling; microwave; effective moisture diffusivity; artificial neural network

Eggplant (*Solanum melongena* L.) is cultivated in North America, Asia and the Mediterranean area. Its limited shelf life is one of the important restrictions in the trade of eggplant as a fresh product. Dehydration constitutes an alternative method to provide more stable eggplant products, which may be shipped to foreign markets or used the whole year round (Puig et al. 2012).

Microwave energy offers several benefits compared to conventional heating methods, including speed of operation, energy savings, precise process control and quicker start-up and shut down times (Botha et al. 2012). A low microwave power may lead to a low drying temperature and a slow drying rate; while a high microwave power may lead to an undesirable high temperature, may enhance the uneven distribution of the microwave energy, and may damage the quality of the final product (Li et al. 2010). Therefore, microwave-drying method has been applied successfully to some food materials such as: bell-pepper (Arslan, Ozcan 2011) and fig (Sharifian et al. 2012).

Artificial neural networks (ANNs) have high learning ability and capability of identifying and modelling the complex non-linear relationships between the input and the output of a drying system (Nazghelichi et al. 2011a).

The main goal of this paper was to study kinetic modelling of the drying process and computes the effective moisture diffusivity, activation energy and specific energy consumption in eggplant fruit under

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microwave-convection drying. Also, the aim of this research is to develop and evaluate the feed and cascade forward ANN topologies as an approximating tool for prediction of moisture diffusivity and energy consumption performance of microwave-convection drying process.

MATERIAL AND METHODS

An experimental convective-microwave dryer was designed and implemented. By this device three parameters of air temperature, air velocity and microwave power were controlled. Eggplant fruit with average initial moisture content of 10.25% (d.b.) was chosen as the drying material. Experiments were conducted at input air temperatures of 40, 55 and 70°C. Three air velocity values of 0.5, 1.1 and 1.7 m/s were adjusted at each temperature. A programmable domestic microwave oven (R-I96T; Sharp, Bangkok, Thailand) with max. output of 900 W was used for drying experiments. This oven was equipped with three power levels of low (270 W), medium (450 W), and high (630 W).

The drying rate (*DR*) of eggplant fruit samples during drying experiments was computed using Eq. (1) and expressed as g (water)/g (dry solids) h (Demiray, Tulek 2012):

$$DR = \frac{W_{t1} - W_{t2}}{t_2 - t_1} \tag{1}$$

where:

t_1, t_2 – drying times (h) at different times during dying; W_{t1}, W_{t2} – moisture content of samples at time t_1 and t_2, respectively (dry basis)

Some commonly used equations in thin layer drying studies are shown in Table 1. The determination of coefficient (R^2) was one of the primary criteria for selecting the best equation to define a suitable model. In addition, reduced chi-square (χ^2) and root mean square error (*RMSE*) were used to determine the quality of the fit (Amiri Chayjan, Kaveh 2014).

Fick's second equation of dissemination was used to calculate the effective moisture diffusivity (Revaskar et al. 2014):

$$MR = \frac{(W_t - W_e)}{(W_0 - W_e)} = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\exp\left(\frac{-D_{eff}(2n-1)^2\pi^2 t}{4L^2}\right) \tag{2}$$

where:

MR – moisture ratio; n = 1, 2, 3... – number of terms; t – drying time, (s); D_{eff} – effective moisture diffusivity (m^2/s); L – half of the slab thickness (m); W_t – moisture content of samples at time t (dry basis); W_e – equilibrium moisture content (dry basis)

An Arrhenius type equation was used to calculate the energy of activation (Amiri Chayjan et al. 2012):

$$D_{eff} = D_0 \exp\left(\frac{E_a}{R_g T_a}\right) \tag{3}$$

where:

E_a – energy of activation; R_g – universal gas constant (8.3143 kJ/mol); T_a – absolute air temperature (K); D_0 – constant

Specific energy consumption (*SEC*) for convective and microwave drying of eggplant fruit slices was calculated using the following equation (Amiri Chayjan et al. 2015):

$$SEC_{con} = (C_{pa} + C_{pv}h_a)\,Qt\,\frac{(T_{in} - T_{am})}{m_{vcon}V_h} \tag{4}$$

$$SEC_{mic} = \frac{60Pt}{m_{vmic}} \tag{5}$$

Table 1. Thin layer drying models used in modelling of eggplant fruit

Models	Equation	References
Midili et al.	$MR = a\exp(-kt^n) + bt$	Shen et al. (2011)
Page	$MR = \exp(-kt^n)$	Kose, Erenturk (2010)
Logestic	$MR = a/(1 + b\exp(kt)$	Cihan et al. (2007)
Logarithmic	$MR = a\exp(-kt) + b$	Arslan, Özcan (2011)
Two-term	$MR = a\exp(kt) + b\exp(k_1 t)$	Kouchakzadeh, Shafeei (2010)
Wang and Sing	$MR = 1 + at + bt^2$	Evin (2012)

MR – moisture ratio; a, b, k, k_1, n – drying constants; t – drying time (h)

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$$SEC = SEC_{\mathrm{con}} + SEC_{\mathrm{mic}} \quad (6)$$

where:

SEC_{con}, SEC_{mic} – specific energy consumptions for convective and microwave drying, respectively (kJ/kg); SEC – sum of specific energy consumption for convective and microwave drying (kJ/kg); C_{pv}, C_{pa} – specific heat of water vapour and air, respectively, (1,004.16 and 1,828.8 J/(kg °C)); Q – inlet air to drying chamber (m^3/min); t – total drying time (min); h_{a} – absolute air humidity (kg$_{\mathrm{vapour}}$/kg$_{\mathrm{dry\ air}}$); T_{in}, T_{am} – inlet air to drying chamber and ambient air temperatures, respectively (°C); m_{vcon}, m_{vmic} – mass of removal water for convective and microwave drying, respectively (kg); V_{h} – specific air volume (m^3/kg); P – microwave power (kW)

Feed (FFNN) and cascade (CFNN) forward neural networks were utilized in this study. There are two types of multi-layer perceptron (MLP) neural network. Two training algorithms including Levenberg-Marquardt (LM) and Bayesian regulation (BR) algorithms were used for updating network weights (Demuth et al. 2007).

Network topologies with three neurons in input layer (input air temperature, air velocity, microwave power and drying time) and two neuron in output layer drying rate (DR) and moisture ratio (MR) were considered. Topology and connection weights between input and output parameters of the network are indicated in Fig. 1. Data analysis was accomplished using neural network toolbox (Ver. 5) of Matlab software. Three transfer functions such as sigmoid (logsig), logarithmic (tangsig), and linear (purelin) were employed to achieve the optimized network structure. Mean square error (*MSE*) and mean absolute error (*MAE*) were utilized to minimize the training error.

RESULTS AND DISCUSSION

The moisture ratio fitted to six thin-layer drying models (Table 1). The statistical results from models are summarized in Table 2. The R^2 values of Wang and Sing, Logarithmic, Midilli et al. models were all above 0.9950. The Midilli et al. models give the highest values of R^2 and the lowest values of χ^2 and *RMSE.* The Midilli et al. model was selected as the suitable model to represent the thin layer drying characteristics of eggplant slices. Coefficients of Midilli et al. model for all temperatures and microwave power are represented in Table 3.

The effects of drying temperature, air velocity and microwave power on drying rate of the eggplant slices are given in Fig. 2. Drying rate showed an increase at the beginning of the process due to sample heating. After an initial short period, the drying rate reached a maximum value and then it followed falling rate in all drying conditions. No constant drying rate period was observed. Drying rate at the beginning of the process was affected by air velocity, especially at the temperature of 70°C, which implies that evaporation initially took place at the surface and was therefore more directly affected by air velocity. The initial surface evaporation was gradually replaced by evaporation front that receded to the interior of the solid. The predominance of air velocity was therefore succeeded by the moisture diffusion

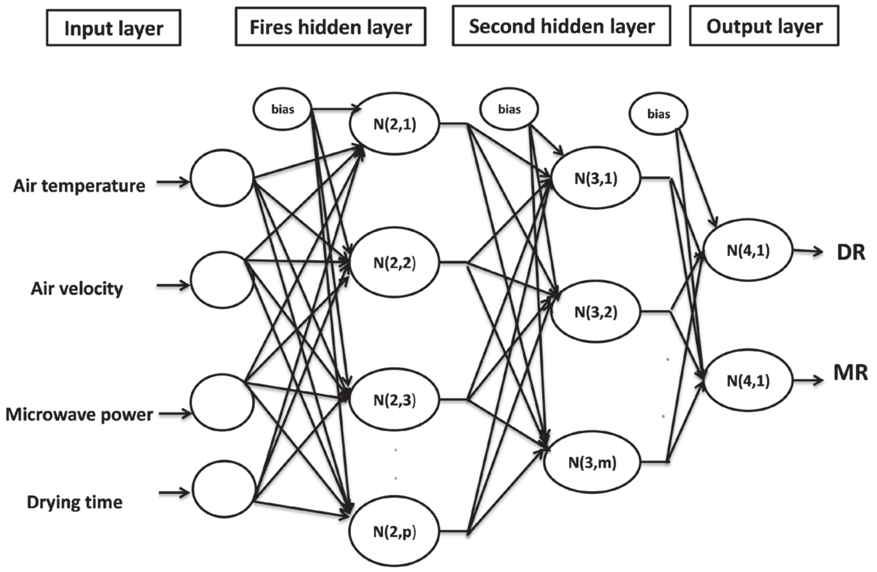

Fig. 1. Selected Artificial Neural Network structure with three hidden layers

N – neuron number, *DR* – drying rate, *MR* – moisture ratio

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Table 2. Statistical comparison for prediction of thin layer drying of eggplant at various air velocities

Model	Temperature (°C)-micro-wave power (W)	R^2			χ^2			*RMSE*		
		0.5 m/s	1.1 m/s	1.7 m/s	0.5 m/s	1.1 m/s	1.7 m/s	0.5 m/s	1.1 m/s	1.7 m/s
Midili et al.	40-270	0.9995	0.9994	0.9992	0.00115	0.00136	0.00138	0.03082	0.03335	0.03342
	55-270	0.9974	0.9984	0.9990	0.00527	0.0025	0.00153	0.06450	0.04409	0.03420
	70-270	0.9980	0.9990	0.9993	0.00351	0.00118	0.00078	0.04941	0.02903	0.02323
	40-450	0.9987	0.9986	0.9988	0.00275	0.0027	0.00215	0.04718	0.04647	0.04147
	55-450	0.9978	0.9991	0.9992	0.00376	0.0012	0.00115	0.05362	0.03024	0.02936
	70-450	0.9981	0.9994	0.9993	0.00333	0.00072	0.00077	0.04613	0.02232	0.02278
	40-630	0.9981	0.9986	0.9990	0.00394	0.00258	0.00180	0.05614	0.04513	0.03769
	55-630	0.9979	0.9994	0.9995	0.00298	0.00074	0.00064	0.05130	0.02329	0.02179
	70-630	0.9986	0.9992	**0.9998**	0.00186	0.00081	**0.00009**	0.03735	0.02323	**0.00756**
Page	40-270	0.9976	0.9966	0.9964	0.00570	0.00758	0.00730	0.07214	0.08301	0.08127
	55-270	0.9916	0.9904	0.9944	0.017001	0.01810	0.00891	0.12333	0.12684	0.08866
	70-270	0.9928	0.9894	0.9940	0.01193	0.01340	0.00721	0.10168	0.10717	0.07810
	40-450	0.9940	0.9934	0.9948	0.01321	0.01373	0.00985	0.10928	0.11116	0.09415
	55-450	0.9914	0.9886	0.9934	0.01530	0.01667	0.00979	0.11619	0.12077	0.09260
	70-450	0.9922	0.9904	0.9930	0.01189	0.01130	0.00787	0.10099	0.09761	0.08098
	40-630	0.9927	0.9924	0.9944	0.01521	0.01481	0.00989	0.11696	0.11507	0.09406
	55-630	0.9919	0.9870	0.9932	0.01391	0.01957	0.00965	0.11028	0.13023	0.09145
	70-630	0.9930	0.9920	0.9938	0.01032	0.00851	0.00644	0.09502	0.08416	0.07258
Logestic	40-270	0.9991	0.9986	0.9984	0.00216	0.00323	0.00313	0.04333	0.05281	0.05179
	55-270	0.9952	0.9936	0.9956	0.00984	0.0108	0.00540	0.09102	0.09486	0.06668
	70-270	0.9948	0.9908	0.9946	0.00846	0.01161	0.00637	0.08226	0.09551	0.07000
	40-450	0.9972	0.9968	0.9978	0.00607	0.00667	0.00435	0.07213	0.07529	0.06080
	55-450	0.9952	0.99221	0.9958	0.00850	0.01137	0.00625	0.08366	0.09611	0.07126
	70-450	0.9944	0.9916	0.99364	0.00877	0.00994	0.00714	0.08301	0.08744	0.07317
	40-630	0.9966	0.9962	0.9972	0.00681	0.00740	0.00479	0.07608	0.07894	0.06351
	55-630	0.9954	0.9904	0.9952	0.00785	0.01309	0.00667	0.07986	0.10233	0.07304
	70-630	0.9946	0.9926	0.9912	0.00774	0.00798	0.00612	0.07930	0.07736	0.06671
Logarithmic	40-270	0.9968	0.9974	0.9984	0.00779	0.00572	0.00307	0.08230	0.07028	0.05129
	55-270	0.9973	0.9980	0.9990	0.00550	0.00348	0.00143	0.06805	0.05385	0.03431
	70-270	0.9982	0.9956	0.9972	0.00302	0.00562	0.00326	0.04915	0.06645	0.05007
	40-450	0.9980	0.9982	0.9984	0.00439	0.00355	0.00304	0.06134	0.05493	0.05083
	55-450	0.9980	0.9980	0.9990	0.00359	0.00286	0.00147	0.05437	0.04820	0.03456
	70-450	0.9982	0.9954	0.9964	0.00271	0.00531	0.00405	0.04614	0.06391	0.05511
	40-630	0.9974	0.9986	0.9990	0.00518	0.00263	0.00169	0.06635	0.04706	0.03772
	55-630	0.9980	0.9964	0.9988	0.00330	0.00471	0.00169	0.05178	0.06138	0.03677
	70-630	0.9986	0.9948	0.9950	0.00179	0.00557	0.00509	0.03813	0.06463	0.06084

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Table 2 to be continued

Model	Temperature (°C)-micro-wave power (W)	R^2			χ^2			*RMSE*		
		0.5 m/s	1.1 m/s	1.7 m/s	0.5 m/s	1.1 m/s	1.7 m/s	0.5 m/s	1.1 m/s	1.7 m/s
Two-term	40-270	0.9971	0.9978	0.9986	0.00701	0.00542	0.00257	0.07604	0.06659	0.04561
	55-270	0.9972	0.9984	0.9990	0.00547	0.00256	0.00150	0.06571	0.04462	0.03386
	70-270	0.9983	0.9906	0.9946	0.00274	0.01182	0.00640	0.04482	0.09188	0.06656
	40-450	0.9964	0.9940	0.9818	0.00777	0.01237	0.02552	0.07931	0.09947	0.14288
	55-450	0.9982	0.9824	0.9990	0.00326	0.00257	0.00146	0.04992	0.04390	0.03309
	70-450	0.9852	0.9916	0.9928	0.02310	0.00989	0.00818	0.12845	0.08274	0.07384
	40-630	0.9974	0.9988	0.9990	0.00515	0.00228	0.00153	0.06418	0.04242	0.03475
	55-630	0.9982	0.9844	0.9904	0.00297	0.02101	0.01360	0.04719	0.12412	0.09986
	70-630	0.9938	0.9926	0.9912	0.00893	0.00795	0.00603	0.08183	0.07280	0.06194
Wang and Sing	40-270	0.9993	0.9995	0.9995	0.00165	0.00106	0.00089	0.03881	0.03104	0.02848
	55-270	0.9984	0.9972	0.9978	0.00308	0.00473	0.00330	0.05249	0.06484	0.05396
	70-270	0.9982	0.9896	0.9916	0.00294	0.01322	0.00995	0.05047	0.10644	0.09175
	40-450	0.9992	0.9992	0.9990	0.00157	0.00171	0.00165	0.03768	0.03923	0.03853
	55-450	0.9982	0.9948	0.9964	0.00323	0.00742	0.00544	0.05338	0.08057	0.06899
	70-450	0.9970	0.9880	0.9892	0.00454	0.01421	0.01210	0.06238	0.10965	0.10029
	40-630	0.9985	0.9984	0.9980	0.00297	0.00296	0.00352	0.05170	0.05146	0.05612
	55-630	0.9978	0.9906	0.9942	0.00357	0.01280	0.00823	0.05589	0.10532	0.08445
	70-630	0.9962	0.9852	0.9775	0.00536	0.01595	0.03574	0.06848	0.11528	0.17100

values in bold – the best result ; R^2 – coefficient of determination; χ^2 – chi-square; *RMSE* – root mean square error

process, which became the most important factor (Yadollahinia, Jahangiri 2009).

The values of effective moisture diffusivity (D_{eff}) ranged from 1.52 × 10^{-9} m^2/s at 270 W and 40°C to 3.39 × 10^{-9} m^2/s at 500 W and 70°C. In Fig. 3a, it was observed that D_{eff} increased with the increase of microwave power and air temperature. The D_{eff} values were reported within the general range of 10^{-11}–10^{-9} m^2/s for food materials (Doymaz 2012). This is due to an increased heating energy, which

Table 3. Coefficients of Midilli et al. model for prediction of kinetic drying of eggplant fruit at different temperatures and microwave powers

Air velocity	Coefficients	Air temperature (°C)-microwave power (W)								
		40-270	55-270	70-270	40-450	55-450	70-450	40-630	55-630	70-630
(0.5 m/s)	*a*	0.9823	0.9810	0.9934	0.9754	0.9810	0.9924	0.9700	0.9796	0.9925
	k	2.2879	2.3809	2.9961	2.1573	2.4027	3.0684	2.3284	2.6996	3.2618
	n	1.3074	1.1386	1.0510	1.2005	1.0903	1.0036	1.1902	1.0808	0.9760
	b	–0.0392	–0.1116	–0.1573	–0.0834	–0.1523	–0.1854	–0.0876	–0.1498	–0.2053
(1.1 m/s)	*a*	0.9822	0.9940	1.0113	0.9772	0.9978	1.0094	0.9765	1.0019	1.0095
	k	2.2407	1.8167	1.5931	2.1540	1.4498	1.7526	2.1354	1.3325	1.9906
	n	1.2703	0.9436	0.7105	1.1669	0.7983	0.7037	1.1063	0.6908	0.7002
	b	–0.0557	–0.2337	–0.4432	–0.1020	–0.3951	–0.4568	–0.1263	–0.4840	–0.4380
(1.7 m/s)	*a*	0.9850	0.9943	1.0102	0.9795	0.9933	1.0096	0.9808	0.9950	1.1382
	k	2.1842	2.1907	2.2067	2.3158	2.1786	2.2883	2.2715	2.2422	1.7976
	n	1.1958	0.9835	0.7910	1.1623	0.9234	0.7552	1.0655	0.8680	0.4933
	b	–0.0793	–0.1765	–0.3301	–0.0933	–0.2191	–0.3917	–0.1160	–0.2531	–0.6117

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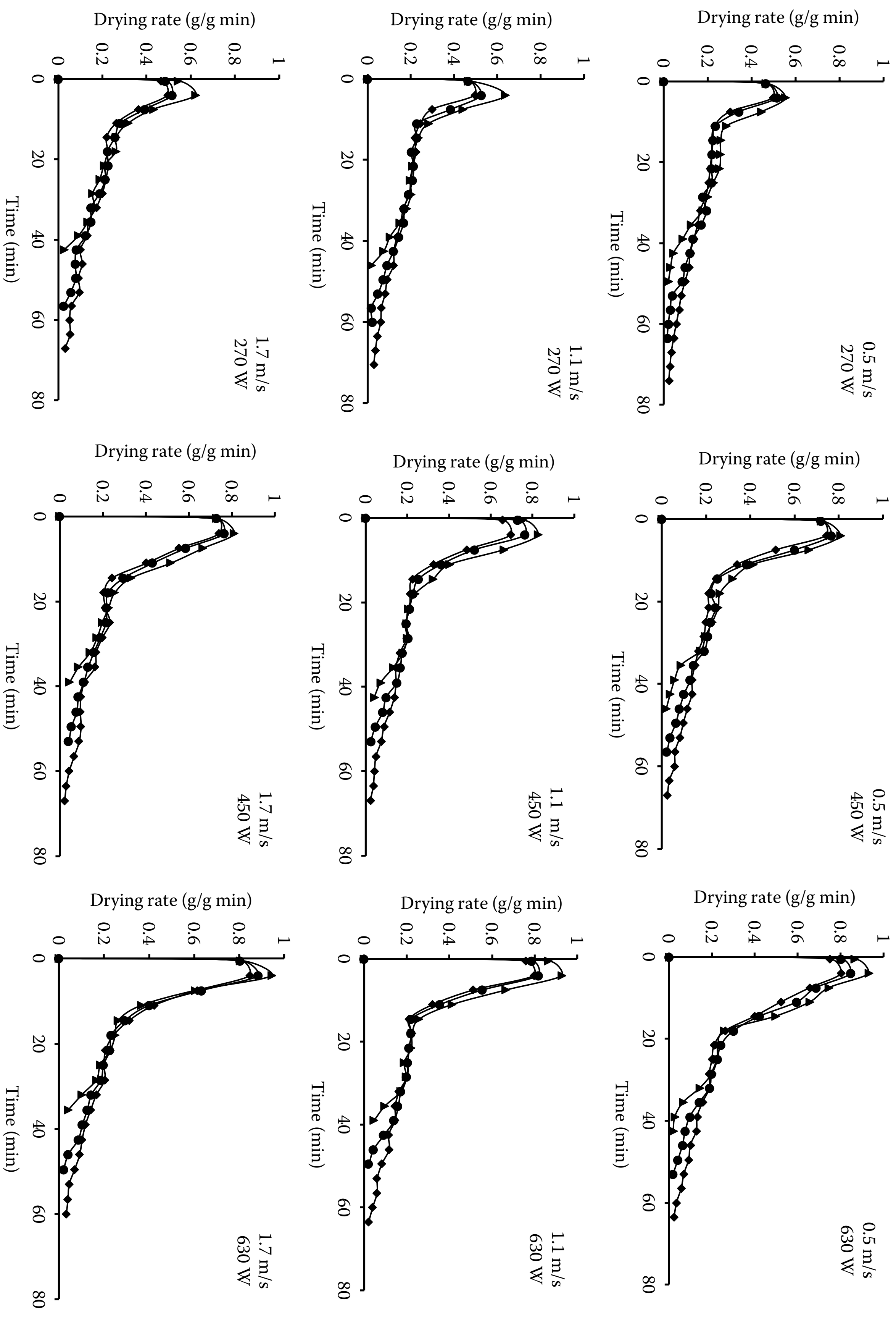

Fig. 2. Variation of drying rate as a function of time (min) at various air temperatures (▲ 40°C, ● 55°C and ◆ 70°C) drying of eggplant fruit

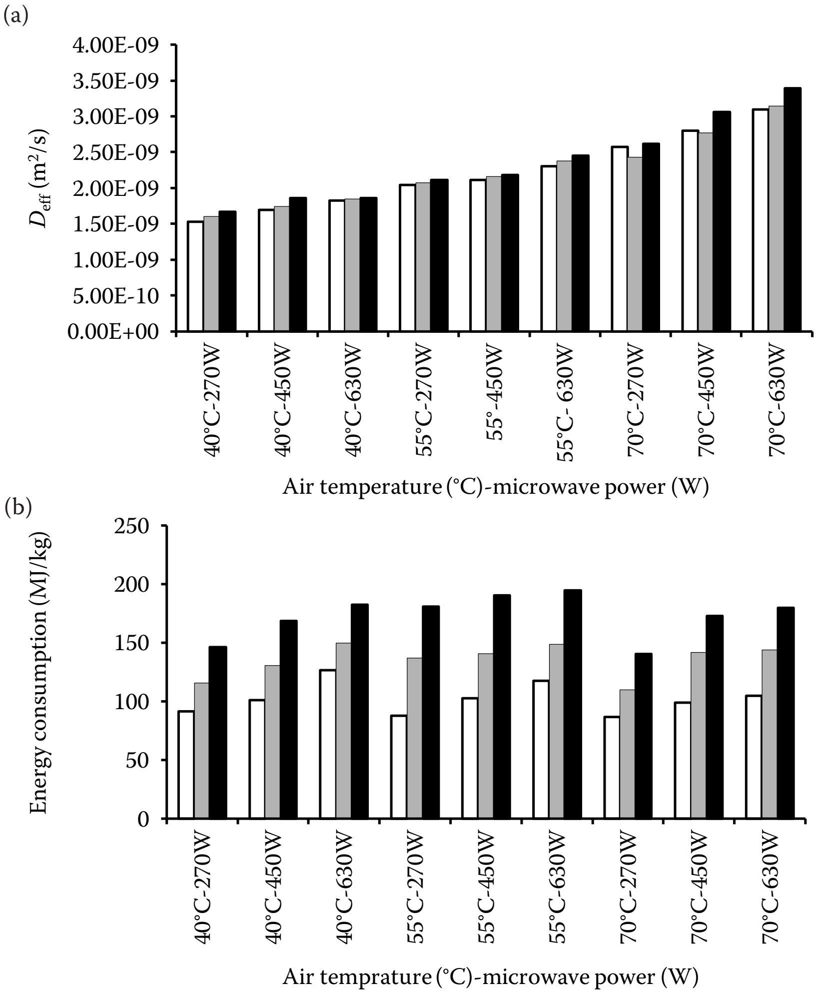

Fig. 3. Effective moisture diffusivity (a) and specific energy consumption (b) for thin layer drying of high moisture eggplant fruit at different levels of air temperatures, velocities (☐ 0.5 m/s, ▨ 1.1 m/s and ■ 1.7 m/s) and microwave powers

would increase the water activity of the molecules leading to higher moisture diffusivity value when samples were processed at higher microwave power density. The values of D_{eff} are comparable with the reported values of 5.97×10^{-9} to 87.39×10^{-9} m²/s for the drying of bell-pepper in the microwave power range of 210–700 W (Arslan, Ozcan 2011). The relationship between D_{eff} and the independent variables is as follow:

$$D_{eff} = 2.15 \times 10^{-9} + 2.12 \times 10^{-10}w + 5.82 \times 10^{-10}T_c + 5.90 \times 10^{-11}v + 1.01 \times 10^{-10}T_c w + 1.07 \times 10^{-10}T_c^{2};\ R^2 = 0.9915 \qquad (7)$$

where:

w – microwave power (W); v – the air velocity (m/s); T_c – air temperature (°C)

Activation energy was calculated for each value of air velocity and microwave power (Table 4). The activation energy (E_a) of eggplant slices was 13.33 to 17.81 kJ/mol calculated. It is in the range of 12.7–110.0 kJ/mol for most food materials (Aghbashlo et al. 2009). Also E_a value of apricot fruit varied from 29.35 to 33.78 kJ/mol at different values of air velocities (Mirzaee 2009).

Fig. 3b shows the specific energy consumption (SEC) values at different amounts of convective-microwave drying of eggplant fruit slices. The maximum value of *SEC* (194.37 MJ/kg) was achieved at air velocity of 1.7 m/s with drying air temperature of 55°C and microwave power of 630 W. The minimum value of *SEC* was obtained (86.47 MJ/kg) while air velocity, air temperatures and microwave were 0.5 m/s, 70°C and 270 W, respectively. Similar results were reported for tomato (Ruiz Celma et al. 2012). Relationship between specific energy consumption and input parameters is as follow:

$$SEC = 142.08 + 7.10w + 33.65v - 10.29T_c w;\ R^2 = 0.9487 \qquad (8)$$

The static artificial neural network (ANN) with different configuration of the learning epochs and number of neurons were applied for kinetics analysis of microwave-convection drying of eggplant

Table 4. Activation energy values and related correlation coefficient for air velocities and microwave powers of eggplant fruit

Air velocity (m/s)	0.5	0.5	0.5	1.1	1.1	1.1	1.7	1.7	1.7
Microwave power (W)	270	450	630	270	450	630	270	450	630
Activation energy (kJ/mol)	15.49	14.89	15.65	13.33	13.75	13.93	13.38	14.13	17.81
Coefficient of determination	0.9983	0.9890	0.9913	0.9931	0.9943	0.9997	0.9753	0.9351	0.9941

slice using four inputs. Table 5 summarizes a list of the best neural network topology structures, threshold functions and different applied algorithms in predicting drying rate and moisture ratio for drying of eggplant fruit. The most applied topologies and threshold functions have proper training. The FFNN structure with 4 inputs, 7 neurons in the first hidden layer, 6 neurons in the second hidden layer and 2 neuron in the output layer has the lowest *MSE* (0.00011), *MAE* (0.02201 and 0.00927 for drying rate and moisture ratio, respectively) values and the highest R^2 (0.9748 and 0.9989 for drying rate and moisture ratio, respectively) values.

For the final selected ANN model, 4-7-6-2, the mean value of training *MSE* was lower than 0.00011. Ideally, the training *MSE* values should be close to zero, indicating that the model well learned the relationship among the input and output parameters. This again confirms that given sufficient hidden units, multi-layer feed forward neural network architectures can approximate virtually any function of interest to any desired degree of accuracy. Two hidden layers with an arbitrarily large number of neurons may be enough to approximate any function.

Nazghelichi et al. (2011b) predicted the drying rate and moisture ratio of carrot cubes in fluidized bed drying with the highest R^2 = 0.9492 and R^2 = 0.9927 and the lowest *MAE* = 0.0098 and *MAE* = 0.0140 values in the test period, respectively.

CONCLUSION

Midilli et al. model was the best for predicting of the drying kinetics of eggplant slices. Effective moisture diffusivity was (1.52–3.39) × 10^{-9} m^2/s. The activation energy was (13.33–17.81) kJ/mol. The max. value of specific energy consumption was calculated at air temperature of 75°C, air velocity of 1.7 m/s and microwave power of 270 W. The best ANN model consisted of two hidden layers with seven neurons in

Table 5. Best selected topologies including training algorithm, different layers and neurons for FFNN and CFNN for drying rate and moisture ratio

Network	Training algorithm	Threshold function	No. of layers and neurons	*MSE* (*DR*)	R^2 (*DR*)	R^2 (*MR*)	*MAE* (*DR*)	*MAE* (*MR*)	Epoch
FFNN	LM	TAN- LOG- PUR	4-7-6-2	0.00011	0.9748	0.9989	0.02201	0.00927	86
		TAN- TAN -TAN	4-5-5-2	0.00027	0.9732	0.9983	0.02382	0.01096	47
		PUR- TAN- TAN	4-7-7-2	0.00022	0.9733	0.9984	0.02283	0.01078	47
	BR	TAN- TAN -TAN	4-6-6-2	0.00021	0.9741	0.9985	0.02255	0.00951	78
		PUR- LOG- TAN	4-10-10-2	0.00027	0.9669	0.9984	0.02513	0.01082	59
		TAN- LOG - TAN	4-8-6-2	0.00078	0.9565	0.9956	0.03289	0.01329	37
CFNN	LM	TAN- PUR -TAN	4-6-5-2	0.00028	0.9650	0.9982	0.02921	0.01072	58
		TAN- TAN- TAN	4-8-8-2	0.00089	0.9443	0.9954	0.04051	0.01676	56
		LOG- TAN- TAN	4-5-4-2	0.00057	0.9600	0.9974	0.03033	0.01246	64
	BR	TAN- TAN- TAN	4-4-4-2	0.00050	0.9635	0.9977	0.02934	0.01202	43
		TAN- TAN- TAN	4-10-10-2	0.00045	0.9629	0.9983	0.03051	0.01099	42
		TAN- TAN- PUR	4-15-10-2	0.00024	0.9711	0.9984	0.02593	0.00959	87

DR – drying rate; *MR* – moister ratio, FFNN – feed forward neural network; CFNN – cascade forward neural network; LM – multi-layer perceptron; BR – Bayesian regulation; values in bold – the best result

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the first hidden layer and six neurons in the second hidden layer. This topology has the highest coefficient of determination 0.9748 and 0.9989 for drying rate and moisture ratio, respectively.

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