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PRE-TREATMENT (OHMIC AND OVEN) EFFECT ON THERMODYNAMIC PARAMETERS OF KIWI DRYING IN MICROWAVE DRYER

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ABSTRACT

In this article, have been investigated effects pre-treatment ohmic and oven on the amount of energy and exergy kiwi fruit drying in a microwave dryer. In the present study, multilayer perceptron (MLP) artificial neural network was selected. The results of the experiments showed that the oven and ohmic time is significant for the energy efficiency and exergy efficiency and specific energy and exergy loss. In total, with increasing ohmic and oven time and microwave power, the amount of energy and exergy efficiency of the microwave dryer would increase. Based on the results obtained, the maximum amount of R2 in a network containing 5 and 10 neurons was R2Oven = 0.9924 and R2Ohmic = 0.9890 in the hidden layer for energy efficiency, R2oven = 0.9930 R2ohmic = 0.9936 10 neuron and 5 neuron (First layer), 10 neuron (Second layer) in the hidden layer for specific energy loss, R2Oven = 0. 9877 and R2Ohmic = 0.9978 for exergy efficiency was observed 5 neuron (First layer) and 5 neuron (Second layer) in hidden layer and for specific exergy loss was best R2 value (R2Oven = 0. 9837 and R2Ohmic = 0.9865) in hidden layer with 10 neuron in first and second layer.

1.Introduction

Kiwi fruit (Actinidia deliciosa) has high vitamin C content. It is a very important fruit species in terms of healthy nutrition due to its low calorie level. Also, it can be stored between 2 and 6 months. Therefore, the shelf life of the kiwifruit can be extended with drying. (Özdemir *et al.*, 2017). Drying has a vital role in postharvest processing. It has always been of great importance for conserving agricultural products and for extending the food shelf life (Azadbakht *et al.*, 2017b)(Deshmukh *et al.*, 2013). Drying is known as the best method to preserve fruits and vegetables. Water removal during drying prevents microorganism evolution and harmful chemical reactions leading to longer storage time(Azadbakht *et al.*, 2017c)(Nikbakht *et al.*, 2014). Drying is one of the oldest unit operations and has recently become widespread in various industries to gain different utilities. There are more than 200 types of dryers and for each dryer, the process conditions, such as drying chamber temperature, pressure, air velocity (if the carrier gas is air), relative humidity and the product retention time, have to be determined according to feed, product, purpose and method (Azadbakht *et al.*, 2018b; Erbay and Icier 2011). Also drying is widely used to preserve porous medium products. It is a complicated process involving heat and mass transfer between the material surface and its surroundings (Prommas *et al.*, 2010).Microwave drying is a new addition in the existing drying techniques, vs. convective air drying (cabinet, fluidized bed, tunnel), spray, vacuum, foam mat and freeze drying. Microwave is an electromagnetic wave in the frequency range of 300–30000MHz. It is the combination of electrical and magnetic fields, with only the former being engaged in the conversion process when waves interact with the non-magnetic materials. The conversion of microwave energy into heat in the food is because of the presence of water(Sharma and Prasad 2006). Drying temperature and microwave power are the two most important factors in microwave drying of agricultural products. These two factors significantly influence the drying parameters such as drying time, drying curve, drying speed, drying efficiency, and the final product quality. To improve microwave drying, a number of studies have been conducted to investigate the effects of different microwave power levels and drying temperatures, and different prediction models have been established (Li *et al.,* 2010). Drying of fruits and vegetables is one of the most time and energy consuming processes. Drying rate must be accelerated to reduce the drying process and energy consumption without compromising the quality. One of the major obstacles in removing the moisture from the material is the outer layer of the material, the skin. It acts as the major resistance to the moisture transport from interior of the material to surface. Pre-treatment is an essential step before processing of food materials to overcome this problem up to great extent. It has been reported that pre-treatments can accelerate the drying rate by dissociating the wax and forming the fine cracks on the surface of the material for easy moisture removal (Deshmukh *et al.,* 2013). Ohmic treatment is one of the electron heating methods based on the passage of electrical current through a food product having electrical resistance. The electrical energy is converted to heat while the amount of heat generated through the food product is directly related to the voltage gradient and the electrical conductivity. Ohmic heating as an alternate processing method has shown to yield foods with higher quality compared to the conventional heating. This difference is mainly due to its ability to heat materials rapidly and uniformly leading to a less aggressive thermal treatment (Nouroallahi Soghani *et al.*, 2018).

Darvishi *et al*. (2014) analyzed the energy and exergy of white mulberries in the process of drying with microwave dryer and reported that the specific energy loss increases with increasing microwave power. Additionally, energy efficiency was reduced by decreasing the moisture content and microwave power. The best energy and exergy for white mulberry was observed at 100 W microwave power.

Darvishi *et al*. (2016) conducted energy and exergy analysis and modeled Kiwi slices with a microwave dryer and it was found that the energy and exergy efficiency increases with increasing microwave power and decreasing the thickness of kiwi slices. Additionally, this parameter decreases by reducing the moisture content of slices.

Salengke *et al*. (2005) performed an experiment on effect of Ohmic Pre-treatment on the Drying Rate of Grapes and Adsorption Isotherm of Raisins, which Results of this study reveal that the drying rate of the grapes was significantly increased by the ohmic pre-treatment, especially at low electrical frequencies. The effect of the ohmic pre-treatment on equilibrium moisture content of the raisins produced was evident at 0.75 or higher water activities but there was no or limited effect at low to moderate water activities.

Nouroallahi Soghani *et al.* (2018) Performed experiment on Ohmic blanching of white mushroom and its pre-treatment during microwave drying Which showed the results of this experiment blanched sample at low voltage and heating duration consumed the minimum total energy during the drying process.

The objective of this research is the energy performance analyses of energy and exergy of the microwave dryers for drying kiwi slices under pre-treatment (ohmic – oven) and non-treatment in order to reduce the energy consumption in the microwave dryer and increase the energy and exergy efficiency of the microwave with new processes. In addition, this research used artificial neural network to process the numbers in order to verify the accuracy of the numbers obtained. Additionally, sensitivity coefficient test was used to relate the energy and exergy factors to microwave and pre-treatment.

2. Materials and methods

2.1. Sample preparation

Newly-harvested kiwi fruit were purchased from the local store in Gorgan city of Iran, and were kept in the laboratory at 10 ° C. At the beginning of each experiment, the kiwi was washed and the slices were cut in circular in a thickness of 5 mm and they were weighted. Then, samples were placed in an oven with Temperature at 100 ° C for 3, 5 and 7 min to be pretreated. Also samples were placed in an ohmic heating with voltage 80 for 3, 5 and 7 min to be pretreated. Drying process was performed in a microwave dryer in the Bio System Mechanics Department of Gorgan University of Agricultural Sciences and Natural Resources (Figure 1).

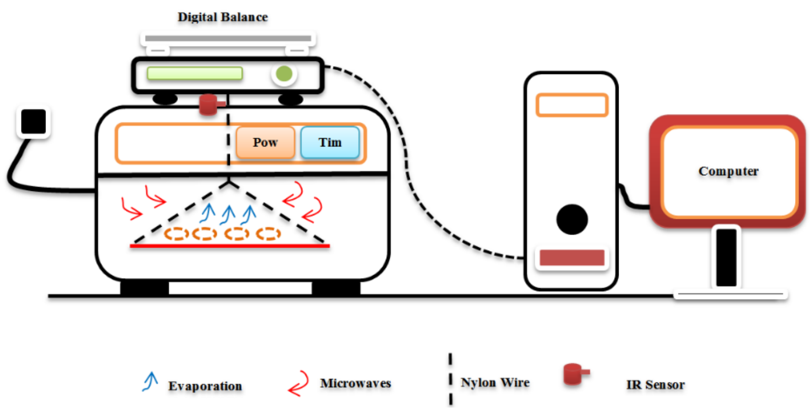

Figure 1. Diagram of microwave drying system

2.2. Experiment method

Slices were pretreated and placed in containers and dried at three powers of 360, 600 and 900 W. The weight of kiwi was measured using a 0.01 mg precision scale. The weight of each sample was measured and recorded at a time interval of 1 minute to reach constant moisture. For each of the treatments, the experiments were repeated three times. The experiment was conducted at a temperature of 20 ° C and relative humidity of 79%. The moisture content of kiwi was also calculated using equation (1) (Yogendrasasidhar and Pydi Setty 2018).

$$MC = \frac{W - We}{W} \qquad (1)$$

2.3. Energy analysis

Energy used in the drying and heating process is important for production processes in the industrial and household sectors. However, the price of this energy is extremely expensive; therefore, there is a strong incentive to invent processes that will use energy efficiently. Currently, widely used drying and heating processes are complicated and inefficient and are generally damaging to the environment. Thus, it is required to have a simplified lower-cost approach replicable in a wide range of situations (Jindarat *et al.*, 2011).

The mass and energy survival in the microwave dryers' chamber is shown in Figure 2. The general relation of mass moisture survival is calculated using Equation (2) (Darvishi *et al.,* 2016).

$$\sum m_{in} = \sum m_{out} \qquad (2)$$

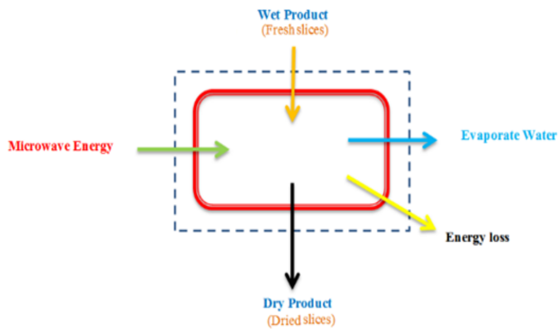

Figure 2. Volume control of microwave system

According to Equation 3, the initial mass of the sample is equal to the amount of water vapor removed and the rate of dried sample mass.

$$m_o = m_{ew} + m_p \qquad (3)$$

The mass of evaporated water is obtained using Equation 4 (Azadbakht *et al.,* 2018a)

$$m_{wt} = m_d(M_0 - M_t) \qquad (4)$$

The protected energy of the sensible heat, latent heat, and the thermal source of the microwave were calculated using Equation 5 and the input energy of the dryer was calculated using Equation 6(Jindarat et al. 2011). In equation 5, the lost energy is$P_{ref} + P_{tra}$. Equation 6 shows the amount of input energy of the microwave. This formula is composed of three parts, including absorbed energy, reflected energy, and passed energy. In equation (6) equals to the absorbed energy of product.

$$P_{in} = P_{abs} + P_{ref} + P_{tra} \qquad (5)$$

$$\mathrm{P_{in}} \times \mathrm{t} = \left(\left(\mathrm{mC_pT}\right)_{\mathrm{dp}} - \left(\mathrm{mC_pT}\right)_{\mathrm{wp}}\right) + \lambda_K m_w + E_{ref} + E_{tra} \qquad (6)$$

The latent heat of the kiwi samples is calculated using Equation 7 (Abdelmotaleb *et al.,* 2009).

$$\frac{\lambda_K}{\lambda_{wf}} = 1 + 23\exp\left(-40M_t\right) \qquad (7)$$

The latent heat of free water evaporation has been calculated by Broker et al and using Equation 8 (Darvishi 2017).

$$\lambda_{wf} = 2503 - 2.386(T - 273) \qquad (8)$$

The thermal capacity is a function of the moisture content and can be calculated through Equation 9) Brooker et al. 1992. (

$$C_P = 840 + 3350 \times \left(\frac{M_t}{1+M_t}\right) \qquad (9)$$

The thermal efficiency of the dryer is calculated using Equation 10 (Soysal et al. 2006).

$$\eta_{en} = \frac{energy\ absorption}{P_{in} \times t} \qquad (10)$$

The specific energy loss was measured using Equation 11 (Darvishi et al. 2014)

$$E_{loss} = \frac{E_{in} - E_{abs}}{m_w}\ or\ E_{loss} = (1 - \eta_{en}) \times \frac{P_{in} \times t}{m_w} \qquad (11)$$

2.4. Exergy analysis

With the onset of the energy crisis, energy and exergy (the maximum useful work that comes from a certain amount of available energy or from the flow of materials) analyses are among the leading thermodynamic research works. In the exergy analysis, the main purpose is to determine the location and amount of irreversible production during the various processes of the thermodynamic cycle and the factors affecting the production of this irreversibility. In this way, in addition to evaluating the performance of various components of the thermodynamic cycle, methods to increase cycle efficiency are also identified (Mokhtarian et al. 2016).

The general exergy equilibrium in the microwave chamber was stated as follows (Darvishi *et al.*, 2016)

$$EX_{in} = EX_{abs} + \underbrace{EX_{ref} + EX_{tra}}_{\text{Exergy loss}} \tag{12}$$

$$P_{in} \times t = \overbrace{((m \times ex)_{dp} - (m \times ex)_{wp}) + ex'_{exap} \times t)} + E_{ref} + E_{tra} \tag{13}$$

:

The amount of exergy transmitted due to evaporation in the drying chamber was calculated using Equation 14 (Sarker et al. 2015)

$$ex'_{exap} = \left(1 - \frac{T_0}{T_p}\right) \times m_{wv}\lambda_{wp} \tag{14}$$

In formula 14, m_{wv} is calculated using formula 15) Darvishi et al. 2016 (

$$m_{wv} = \frac{m_{t+\Delta t} + m_{wv}\lambda_{wp}}{\Delta t} \tag{15}$$

Specific exergy loss was calculated using formula 16: (Darvishi *et al.*, 2014)

$$ex = C_p\left[(T - T_0) - T_0 \ln\left(\frac{T}{T_0}\right)\right]$$

(16)

Exergy efficiency for each dryer system as the exergy rate used in drying the product to the exergy of drying source supplied to the system is calculated by the Equation 17 (Dincer and Sahin 2004)

$$\eta_{en} = \frac{exergy\ absorption}{P_{in} \times t} \times 100$$

(17)

The specific exergy loss was calculated using Equation 18(Darvishi 2017) .

$$EX_{loss} = \frac{EX_{in} - EX_{abs}}{m_w} \tag{18}$$

In this research, the source of temperature and pressure in the environment was 20 ° C and 101325 Pascal, respectively.

2.5. Artificial Neural Network Modeling

In this research, the artificial multilayer perceptron (MLP) neural network was used for modeling the energy and exergy of the microwave dryer to predict energy efficiency, specific energy loss, exergy efficiency and specific exergy loss by one and two hidden layer and the number of neurons is shown in the table 2 , for data analyses was used Neuro Solution 6 software. Hyperbolic tangent linear activation functions (Equation 19), which are the most common type of activation functions, were used in the in hidden input and output layer. In this paper, the Levenberg-Marquardt algorithm was used to learn the network. Additionally, 80% of the data were used for training, 20% of them were used for testing the network (Testing data) (Table 2). The microwave power and the duration of the ohmic and oven were considered as network inputs and the energy efficiency, specific energy loss, exergy efficiency, and the specific exergy loss were the considered network outputs. Five repetitions were considered to achieve the minimum error rate and maximum network stability as a mean of 5000 Epoch for the network. Error was estimated using algorithm with back propagation error. Statistical parameters including, Root Mean Square Error (RMSE), R2, and Mean Absolute Error (MAE) were calculated for inputs and relationships were calculated using the formulas shown in Table 1.

Table 1. Neural Network Relationships

Formula	Formula Number	Reference
$\text{Tanh} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$	) 19 (	(B. Khoshnevisan, Sh. Rafiee, M. Omid, 2013)
$R^2 = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{(P_i - O)^2}$	) 20 (	(Azadbakht, Vehedi Torshizi, & Ziaratban, 2016)
$r = \sqrt{1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{(P_i - O)^2}}$	) 21 (	(Azadbakht, Aghili, Ziaratban, & Vehedi Torshizi, 2017)
$\text{RMSE} = \sqrt{\sum_{i=1}^{n} \frac{(P_i - O_i)^2}{n}}$	) 22 (	(B. Khoshnevisan, Sh. Rafiee, M. Omid, 2013)
$\text{MAE} = \frac{\sum_{i=1}^{n} \lvert P_i - O_i \rvert}{n}$	) 23 (	(Azadbakht, Aghili, Ziaratban, & Vehedi Torshizi, 2017)

Table 2. Optimization values for artificial neural network parameters

Number of hidden layers	Learning rule	Type of activation function	The number of One hidden layer neurons	The number of two hidden layer neurons	Testing data %	Training data %
1	Levenberg Marquardt	Hyperbolic tangent	5	-	20%	80%
1	Levenberg Marquardt	Hyperbolic tangent	10	-	20%	80%
2	Levenberg Marquardt	Hyperbolic tangent	5	5	20%	80%
2	Levenberg Marquardt	Hyperbolic tangent	10	10	20%	80%
2	Levenberg Marquardt	Hyperbolic tangent	5	10	20%	80%
2	Levenberg Marquardt	Hyperbolic tangent	10	5	20%	80%

2.6. Statistical Analysis

The kiwi were dried in microwave at three powers of 360, 600, 900 and three ohmic heating and oven time of 3, 5 and 7 min, and the numbers obtained were sorted and calculated using the Excel spreadsheet software. All experiments were performed in three replications and the results were analyzed using a factorial experiment in a completely randomized design with SAS statistical software.

3.Results and discussions

The results of analysis of variance of kiwi slices drying in different microwave power at different time Ohmic and oven for energy efficiency, specific energy loss, specific exergy loss, and exergy efficiency are shown in Table 3 and 4. According to the results, microwave power has been significant for energy efficiency, specific exergy loss, exergy efficiency and specific energy loss at 1% level and significant. Additionally, according to Table 3, the results obtained for ohmic time have shown the significance level of 1% energy efficiency, specific exergy loss, exergy efficiency and specific energy .Also, the results obtained for oven time have shown the significance level of 1% energy efficiency, specific exergy loss, exergy efficiency and specific energy.The interaction effect (Microwave power × Ohmic time) of energy efficiency and exergy efficiency at 5% level and non-significance for the specific energy and exergy loss. The interaction effect (Microwave power × Oven time) of energy efficiency and exergy efficiency at 1% and 5% level , Respectively and non-significance for the specific energy and exergy loss Thus, we compared the means with the LSD test, which its results are shown in figure 3 and 6.

Table 3. Analysis of variance of energy efficiency, specific lost energy lost, specific lost exergy and exergy efficiency under different powers and ohmic time

Parameter	Energy efficiency		Specific energy loss		Exergy efficiency		Specific exergy loss	
	Mean Square	F Value	Mean Square	F Value	Mean Square	F Value	Mean Square	F Value
Microwave power	746.860	183.36**	71.444	203.25**	465.470	109.74**	60.353	145.26**
Ohmic time	658.627	161.69**	2.521	7.17**	459.759	108.39**	23.098	55.59**
Microwave power × Ohmic time	24.988	6.13*	0.353	1ns	22.92	5.41*	0.023	0.06ns
ERROR	3.745		0.851		3.984		0.714	

Table 4. Analysis of variance of energy efficiency, specific lost energy lost, specific lost exergy and exergy efficiency under different powers and oven time

Parameter	Energy efficiency		Specific energy loss		Exergy efficiency		Specific exergy loss	
	Mean Square	F Value	Mean Square	F Value	Mean Square	F Value	Mean Square	F Value
Microwave power	599.852	198.68**	140.268	241.68**	378.53	89.24**	35.46	85.35**
Oven time	581.791	192.70**	15.470	26.66**	444.288	104.75**	27.92	67.21**
Microwave power × Oven time	31.193	10.33**	1.11	1.92ns	25.01	5.90*	0.696	1.68ns
ERROR	4.073		0.580		4.241		0.415	

3.1. Effect of microwave power and pre-treatment time (ohmic and oven time) on energy efficiency

Based on the Table 3, an interaction effect of power and pre-treatment time on energy efficiency is significant at the level of 1% and Figure 3 shows the interaction of these parameters on energy efficiency. According to the results obtained, energy efficiency increased significantly with increasing microwave power and pre-treatment time. In addition, based on the results obtained, with increasing the amount of pre-treatment time, the energy efficiency increased significantly and it can be justified by the fact that with increasing the pre-treatment time, the amount of mass reduction in kiwi, led to increase in kiwi dry matter and removed water from kiwi, and that's why it reduces the amount of drying time and the energy efficiency increases. Also, by increasing the amount of ohmic time, the surface hardness of the kiwi has been reduced, which also results in the easier removal of water from the surface of the sample.

The maximum amount of the energy efficiency is observed at power of 900 W and 7 min (57.34%$_{\text{Ohmic}}$ - 55.31% $_{\text{Oven}}$) and the minimum amount energy efficiency is observed in power of 360 W and 3 min (18.77 %$_{\text{Ohmic}}$ - 16.57% $_{\text{Oven}}$). Also, according to the results with Ohmic pre-treatment, the energy efficiency has been 1.97 times, and this value has been 1.90 for oven pre-treatment.

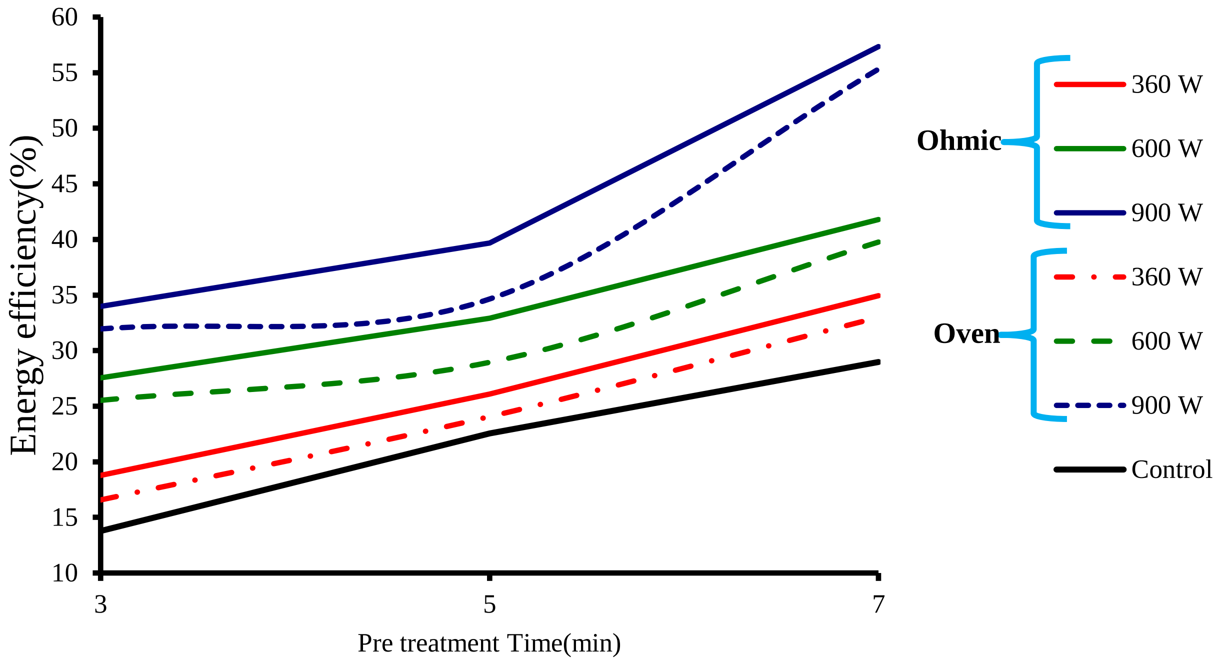

Figure 3. The interaction effect of pre-treatment time (Ohmic–Oven) and microwave power on the energy efficiency

3.2. Effect of microwave power and pre-treatment time (ohmic and oven time) on Specific energy loss

Figure 4 shows the results obtained. The maximum amount of the specific energy loss is observed at power of 360 W (6.457 $_{\text{Ohmic}}$ – 9.983 $_{\text{Oven}}$- 12.663 $_{\text{Control}}$ MJ) and the minimum amount of specific energy loss is observed in power of 900 W (5.495 $_{\text{Ohmic}}$ – 7.45 $_{\text{Oven}}$ – 9.980 $_{\text{Control}}$ MJ). Also, according to the figure, there is no significant difference between 360 and 600 watts, but there is a difference between 900 watts and two other powers. also the maximum amount of the specific energy loss in pre-treatment time is observed at time of 3 min (8.8 $_{\text{Ohmic}}$ – 12.53 $_{\text{Oven}}$ MJ) and the minimum amount of specific energy loss is observed in time of 7 min (3.18 $_{\text{Ohmic}}$ – 4.17 $_{\text{Oven}}$ MJ). As specific energy loss is inversely related to the water removed from the product, by increasing the amount of water removed from the product, the amount of specific energy loss decreases. Also changing the resistance to internal moisture diffusion by altering the microstructure due to physical damage to the sample, and this reduces the amount of drying time, and this cause , reduces the amount of energy Specific energy loss(Orikasa et al. 2018).

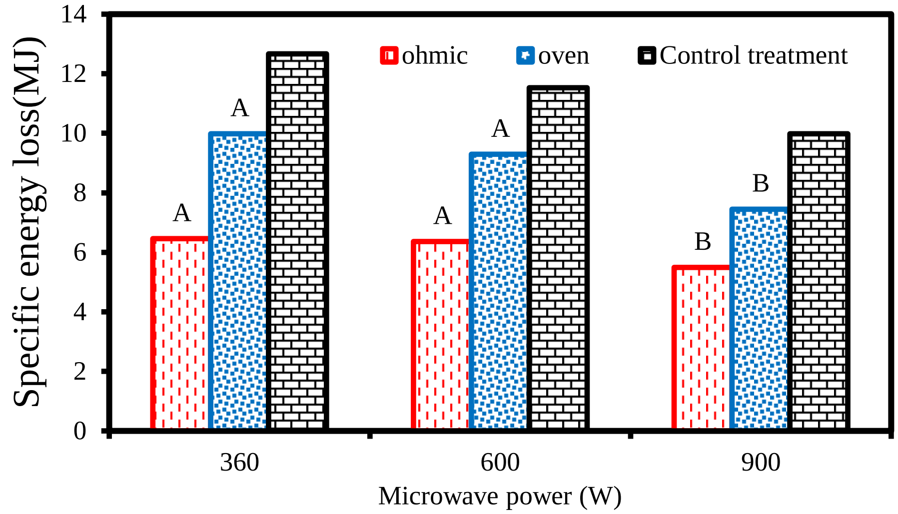

Figure 4. Effect of microwave power on the Specific energy loss

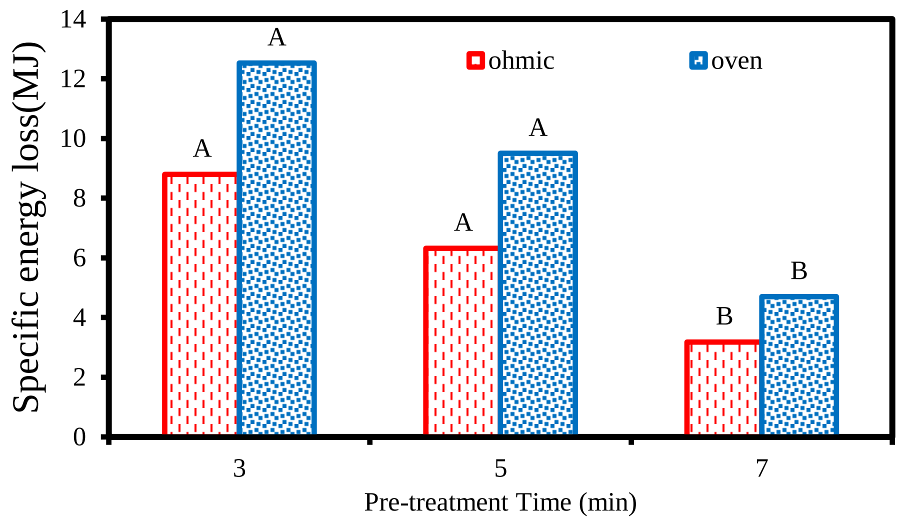

Figure 5. Effect of pre-treatment time (ohmic-oven) on the Specific energy loss

3.3. Effect of microwave power and pre-treatment time (ohmic and oven time) on energy efficiency

Figure 6 shows the interaction of these parameters on exergy efficiency. According to the results obtained, exergy efficiency increased significantly with increasing microwave power and pre-treatment time. The maximum amount of the exergy efficiency is observed at power of 900 W and 7 min (46.737%Ohmic – 42.72% Oven) and the minimum amount exergy efficiency is observed in power of 360 W and 3 min (26.37 $\%_{\text{Ohmic}}$ -22.38% $_{\text{Oven}}$). Also, according to the results with Ohmic pre-treatment, the exergy efficiency has been 2.128 times, and this value has been 1.946 times for oven pre-treatment.

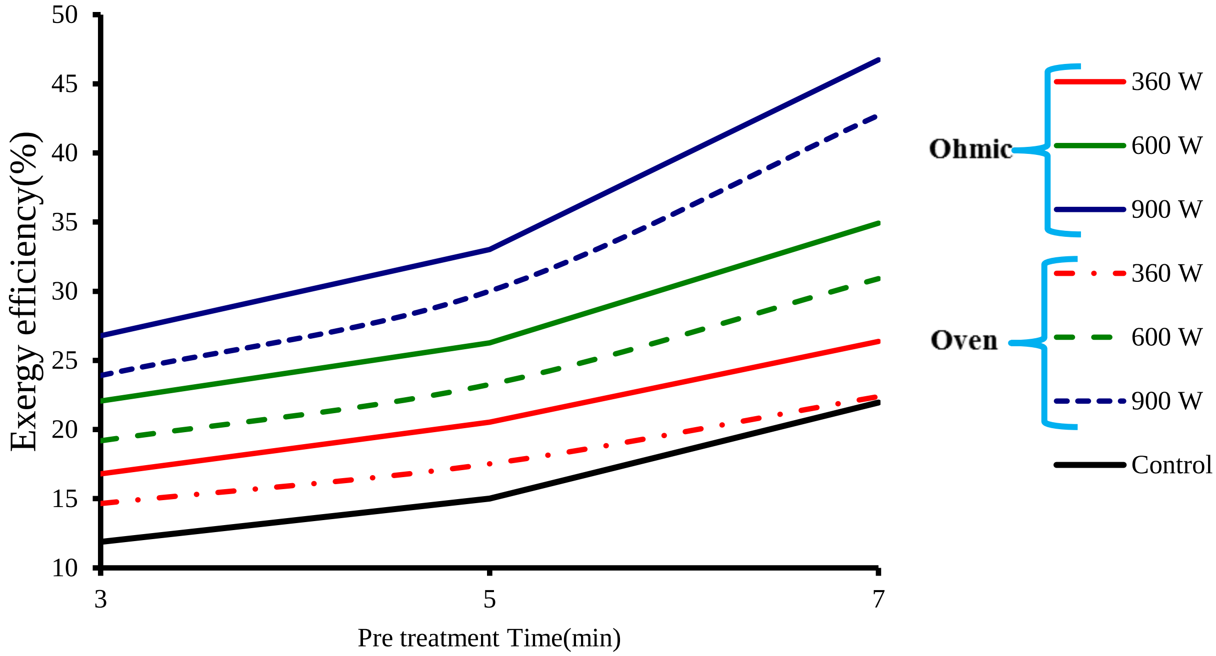

Figure 6. The interaction effect of pre-treatment time (Ohmic–Oven) and microwave power on the exergy efficiency

3.4. Effect of microwave power and pre-treatment time (ohmic and oven time) on Specific exergy loss

Figure 7 shows the results obtained. The maximum amount of the specific exergy loss is observed at power of 360 W (9.973 $_{Ohmic}$ – 12.23 $_{Oven}$- 16.52 $_{Control}$ MJ) and the minimum amount of specific exergy loss is observed in power of 900 W (6.77 $_{Ohmic}$ – 8.86 $_{Oven}$ – 12.16 $_{Control}$ MJ). Also, according to the figure, there is significant difference between 360, 600 and 900 watts. also the maximum amount of the specific energy loss in pre-treatment time is observed at time of 3 min (10.92 $_{Ohmic}$ – 12.66 $_{Oven}$ MJ) and the minimum amount of specific energy loss is observed in time of 7 min (5.74 $_{Ohmic}$ – 8.69 $_{Oven}$ MJ). Also, given that the amount of Specific exergy loss in oven pre-treatment is more than ohmic pre-treatment, the reason for this could be stated as follows that, ohmic pre-treatment has softened the fruit tissue than oven pre-treatment that this also reduces the drying time and the easier absorption of temperature for the fruit.

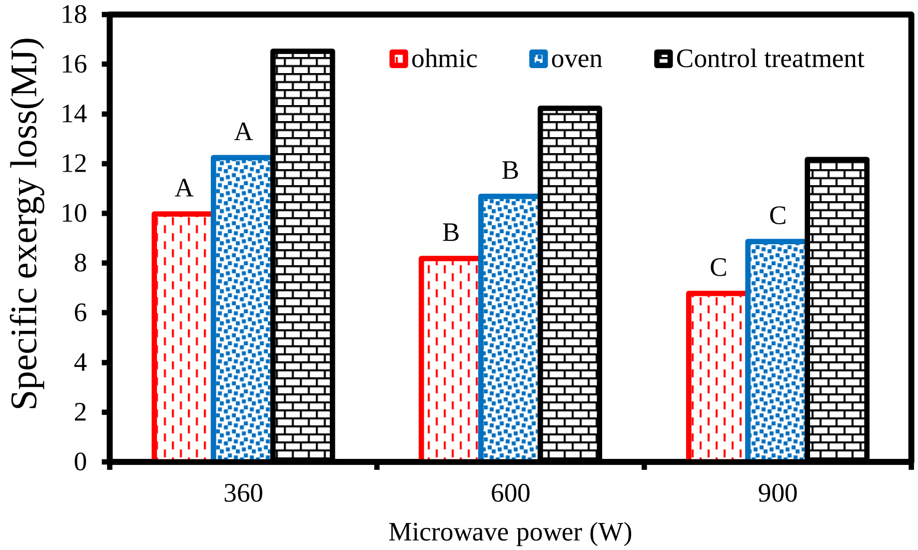

Figure 7. effect of microwave power on the Specific exergy loss

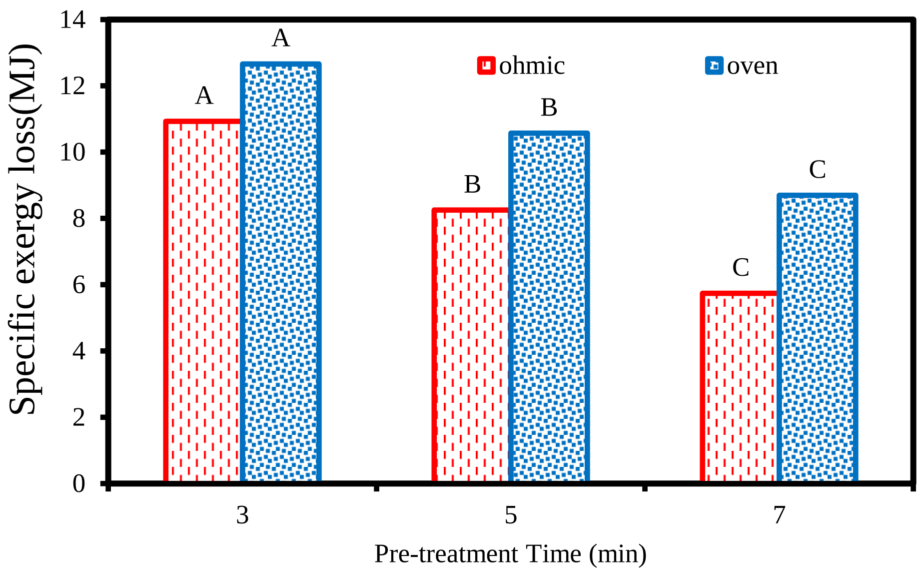

Figure 8. effect of pre-treatment time (ohmic-oven) on the Specific exergy loss

3.5. Artificial neural network

In order to predict energy efficiency, specific energy loss, exergy efficiency, and specific exergy loss, a multi-layered perceptron (MLP) neural network model was used. The duration of kiwi samples placement in ohmic, oven and microwave power were considered as input and energy efficiency, specific energy loss, exergy efficiency, and specific exergy loss were considered as network output. As lower error value was obtained by using the hyperbolic tangent activation function, this type of function was selected as the activation function in the hidden layer and the output. Based on the test method, 80% of the data were used for training and the network could learn the relationships between inputs and outputs well and 20 % of the data were used to test (Table 5).

Table 5. Error values in predicting experimental data using optimal artificial neural network (Oven Pre-Treatment)

			MSE		RMSE		MAE		R	
			Training	Test	Training	Test	Training	Test	Training	Test
Energy efficiency	Two layer	5-5	2.863	6.601	1.6920	2.5692	1.354	2.272	0.9861	0.973
		10-10	2.823	4.914	1.6802	2.2168	1.387	1.902	0.9878	0.9806
		5-10	2.840	5.227	1.6852	2.2863	1.390	2.131	0.985	0.98461
		10-5	2.104	8.108	1.4505	2.8475	1.227	1.98	0.9899	0.9475
	One Layer	5	2.020	11.140	1.4213	3.3377	1.135	3.061	0.99241	0.6287
		10	2.943	4.568	1.7155	2.1373	1.501	1.664	0.988223	0.99161
Specific energy loss	Two layer	5-5	0.481	0.0460	0.6935	0.2145	0.507	0.184	0.979	0.9977
		10-10	0.263	1.788	0.5128	1.3372	0.370	1.13	0.9890	0.8448
		5-10	0.192	1.813	0.4382	1.3465	0.368	0.920	0.9914	0.9517
		10-5	0.3698	0.693	0.6081	0.8325	0.369	0.764	0.98459	0.952
	One Layer	5	0.369	0.956	0.6075	0.9778	0.412	0.817	0.950	0.979
		10	0.180	2.027	0.4243	1.4237	0.362	0.9492	0.993061	0.93085
Exergy efficiency	Two layer	5-5	1.647	18.390	1.2834	4.2884	1.088	3.383	0.98713	0.8876
		10-10	2.931	4.122	1.7120	2.0303	1.389	1.920	0.9793	0.9930
		5-10	2.048	9.049	1.4311	3.0082	1.172	2.319	0.9822	0.959
		10-5	2.618	5.63	1.6180	2.3728	1.411	1.890	0.9769	0.9915
	One Layer	5	2.948	4.689	1.7170	2.1654	1.383	2.072	0.981911	0.90684
		10	1.971	8.568	1.4039	2.9271	1.123	2.358	0.9861	0.89533
Specific exergy loss	Two layer	5-5	0.251	0.6886	0.5010	0.8298	0.408	0.7492	0.9771	0.9151
		10-10	0.193	1.280	0.4393	1.1314	0.332	1.062	0.9831	0.6237
		5-10	0.234	1.088	0.4837	1.0431	0.379	1.0139	0.9797	0.90563
		10-5	0.2812	0.393	0.5303	0.6269	0.444	0.5194	0.97530	0.9365
	One Layer	5	0.2225	0.6991	0.4717	0.8361	0.411	0.7311	0.9709	0.9707
		10	0.235	0.7749	0.4848	0.8803	0.386	0.8517	0.9812	0.8233

The results showed that neural network has 5 neurons in the hidden layer for energy efficiency (R^2 $_{training}$ = 0.9924-RMSE $_{training}$ =1.421 -MAE $_{training}$ =1.135), and 10 neuron in hidden layer for specific energy loss (R^2 $_{training}$ = 0.9930-RMSE $_{training}$ =0.424 -MAE $_{training}$ = 0.362) and the neural network 5 (First layer) and 5 (Second layer) neuron in the hidden layer for exergy efficiency ($R^2_{training}$ = 0.9871-RMSE training =1.283 -MAE training =1.088) and the neural network 10 (First layer) and 10 (Second layer) neurons in the hidden layer for specific exergy loss (R2 training = 0.9831-RMSE training =0.439 -MAE training =0.332) can predict energy efficiency, specific energy loss, exergy efficiency, and specific exergy loss in different oven times and microwave powers (table 5).For energy efficiency, the best value of R^2 Test is observed in a network with 10 neurons in one hidden layer and for specific energy loss in two hidden layer with 5 (First layer) and 5 (Second layer) neuron and for Exergy efficiency in two hidden layer with 10 (First layer) and 10 (Second layer) and Specific exergy loss in hidden layer with 5 neuron . Also for a better understanding of the value of R^2, in Figure 9 R^2 value of training data is shown.

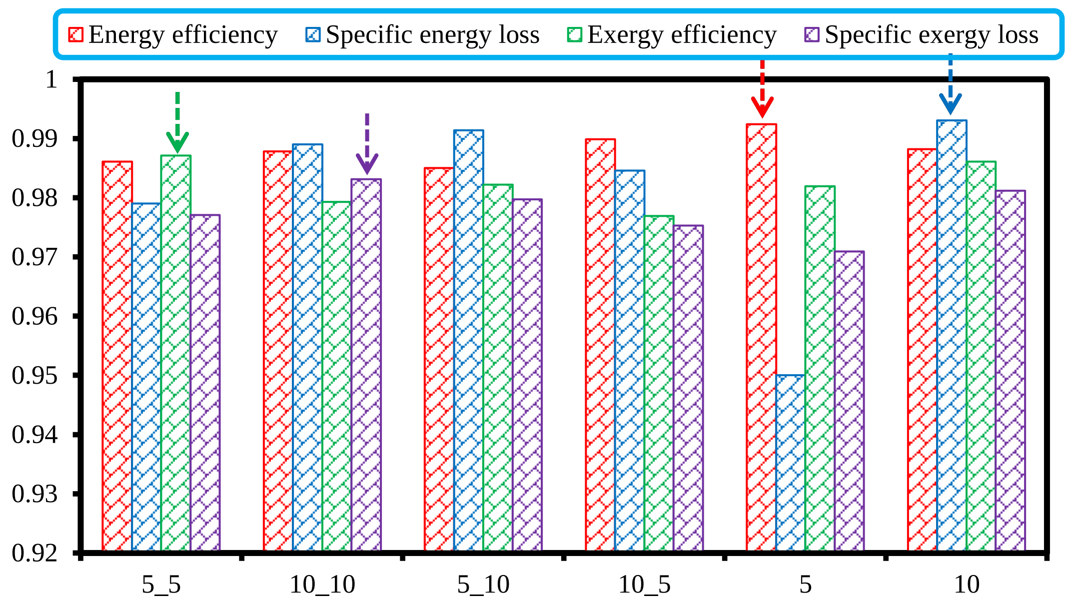

Figure 9. R^2 Value for training data (oven pre-treatment)

Table 6 also shows the best network between input data and data simulated by network for each of neurons in the hidden layer. Lower value of Epoch indicates that the number of neurons in the layer has been able to have learning from the neural network compared to other number of neurons.

As shown in Table 6, the best network for energy efficiency at Training (Run = 1, Epoch = 15) in the 10 (First layer) and 10 (Second layer) neuron state in the hidden layer reaches to constant value after about 15 generations of error, and the best network for the specific energy loss in Training (Run = 1, Epoch = 16) in 5,10 (First layer) and 10,5 (Second layer) neuron in the hidden layer, it reaches to constant value after about 16 generations of errors. For exergy efficiency of Training value (Run = 1, Epoch = 15), it was found in 5, 10 (First layer) and 10, 10 (Second layer) state in the hidden layer, and for the specific exergy loss (Run = 1, Epoch = 16), it was found in the 5,10,5 (First layer) and 10, 5, 5 (Second layer) state in the hidden layer.

Table 6. Some of the best MLP neural network topologies to predict test values (Oven Pre-Treatment)

			EPOCH	RUN
Energy efficiency	Two layer	5-5	19	1
		10-10	15	1
		5-10	18	2
		10-5	17	1
	One Layer	5	20	2
		10	17	3
Specific energy loss	Two layer	5-5	18	5
		10-10	16	2
		5-10	16	1
		10-5	16	1
	One Layer	5	18	4
		10	17	2
Exergy efficiency	Two layer	5-5	17	1
		10-10	15	1
		5-10	15	1
		10-5	18	2
	One Layer	5	19	5
		10	18	1
Specific exergy loss	Two layer	5-5	16	1
		10-10	16	1
		5-10	16	1
		10-5	19	1
	One Layer	5	20	1
		10	19	1

The results table 7 showed that neural network has 10 neurons in the hidden layer for energy efficiency (R^2 $_{training}$ = 0.9889-RMSE $_{training}$ =1.532), and 5 (First layer) and 10 (Second layer) neuron in hidden layer for specific energy loss (R^2 $_{training}$ = 0.9936-RMSE $_{training}$ =0.265 -MAE $_{training}$ = 0.207) and the neural network 5 (First layer) and 5 (Second layer) neuron in the hidden layer for exergy efficiency (R^2 $_{training}$ = 0.9987-RMSE training =1.208 - MAE training =0.939) and the neural network 10 (First layer) and 10 (Second layer) neurons in the hidden layer for specific exergy loss (R2 training = 0.9865-RMSE training =0.401 -

MAE training =0.302) can predict energy efficiency, specific energy loss, exergy efficiency, and specific exergy loss in different ohmic times and microwave powers (table 5).For energy efficiency, the best value of R^2 Test is observed in a network with 5 (First layer) and 5 (Second layer) neuron in hidden layer and for specific energy loss in hidden layer with 5 neuron and for Exergy efficiency in two hidden layer with 10 (First layer) and 10 (Second layer) and Specific exergy loss in hidden layer with 5 neuron. Also for a better understanding of the value of R^2, in Figure 10 R2 value of training data is shown.

Table 7. Error values in predicting experimental data using optimal artificial neural network (ohmic Pre-Treatment)

			MSE		RMSE		MAE		R	
			Training	Test	Training	Test	Traini ng	Test	Training	Test
Energy efficiency	Two layer	5-5	2.868	4.033	1.694	2.008	1.392	1.868	0.9815	0.9902
		10-10	6.433	2.770	2.536	1.664	1.805	1.429	0.979	0.9867
		5-10	2.751	3.502	1.659	1.871	1.350	1.631	0.98706	0.9667
		10-5	2.364	6.389	1.538	2.528	1.337	1.786	0.9880	0.9799
	One Layer	5	2.860	8.899	1.691	2.983	1.398	2.694	0.98701	0.95660
		10	2.347	6.500	1.532	2.550	1.358	2.090	0.9889	0.9705
Specific energy loss	Two layer	5-5	0.087	1.205	0.295	1.098	0.243	0.761	0.9914	0.9513
		10-10	0.565	0.201	0.752	0.448	0.554	0.3395	0.9868	0.9809
		5-10	0.0700	1.404	0.265	1.185	0.207	0.849	0.9936	0.9119
		10-5	0.2476	0.2494	0.498	0.499	0.353	0.4397	0.9781	0.9905
	One Layer	5	0.302	0.1242	0.550	0.352	0.442	0.3327	0.9729	0.99215
		10	0.2496	0.250	0.500	0.500	0.358	0.4115	0.9794	0.9869
Exergy efficiency	Two layer	5-5	1.459	18.66	1.208	4.320	0.939	4.174	0.9978	0.9711
		10-10	3.249	2.922	1.802	1.709	1.529	1.433	0.9849	0.9777
		5-10	3.032	3.553	1.741	1.885	1.423	1.698	0.9790	0.9759
		10-5	2.582	5.64	1.607	2.375	1.358	2.085	0.9804	0.9770
	One Layer	5	2.832	7.939	1.683	2.818	1.332	2.442	0.9807	0.9512
		10	2.322	8.170	1.524	2.858	1.251	2.491	0.9834	0.9661
Specific exergy loss	Two layer	5-5	0.251	0.693	0.501	0.832	0.404	0.749	0.9830	0.9151
		10-10	0.161	1.280	0.401	1.131	0.302	1.0624	0.9865	0.7678
		5-10	0.2347	1.08	0.484	1.039	0.379	1.01	0.9843	0.8173
		10-5	0.281	0.393	0.530	0.627	0.444	0.519	0.9814	0.9415
	One Layer	5	0.2340	0.694	0.484	0.833	0.411	0.702	0.9779	0.9748

		10	0.2225	0.7749	0.472	0.880	0.386	0.851	0.9853	0.9176

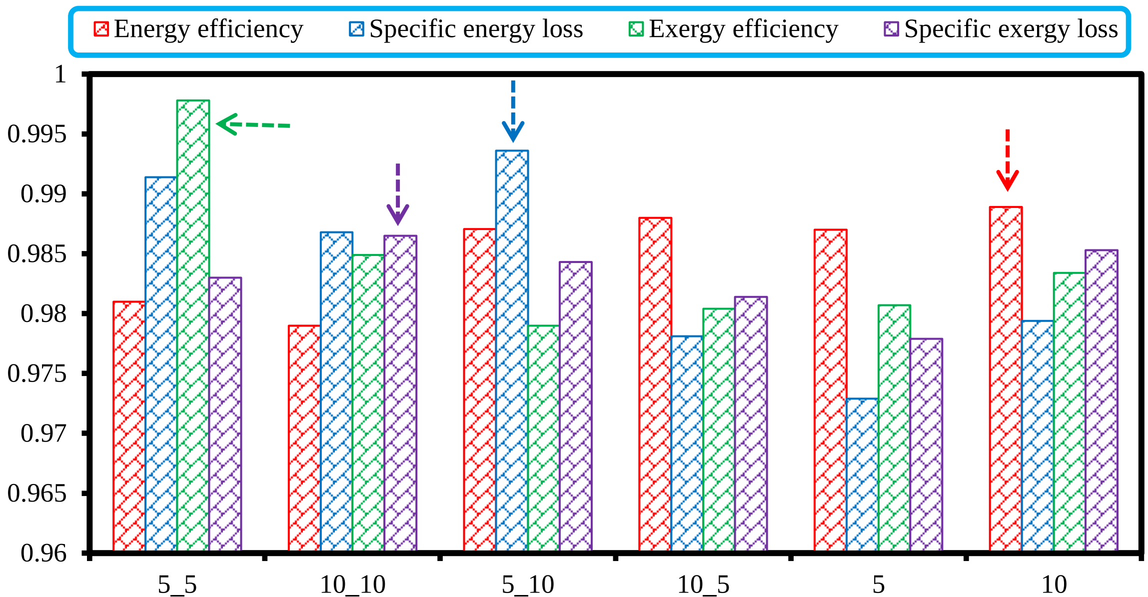

Figure 10. R^2 Value for training data (Ohmic pre-treatment)

s shown in Table 8, the best network for energy efficiency at Training (Run = 1, Epoch = 17) in the 5 (First layer) and 10 (Second layer) neuron state in the hidden layer reaches to constant value after about 17 generations of error, and the best network for the specific energy loss in Training (Run = 1, Epoch = 16) in 10,10 (First layer) and 10,5 (Second layer) neuron in the hidden layer, it reaches to constant value after about 16 generations of errors. For exergy efficiency of Training value (Run = 1, Epoch = 17), it was found in 10 (First layer) and 10 (Second layer) state in the hidden layer, and for the specific exergy loss (Run = 1, Epoch = 13), it was found in the 10 neuron state in the hidden layer.

Table 8. Some of the best MLP neural network topologies to predict test values (Ohmic Pre-Treatment)

			EPOCH	RUN
Energy efficiency	Two layer	5-5	20	1
		10-10	18	2
		5-10	17	1
		10-5	18	2
	One Layer	5	22	4
		10	18	2

Specific energy loss	Two layer	5-5	17	1
		10-10	16	1
		5-10	21	2
		10-5	16	1
	One Layer	5	23	2
		10	18	2
Exergy efficiency	Two layer	5-5	18	5
		10-10	17	1
		5-10	23	3
		10-5	18	2
	One Layer	5	25	2
		10	20	1
Specific exergy loss	Two layer	5-5	20	1
		10-10	16	1
		5-10	19	1
		10-5	18	1
	One Layer	5	16	2
		10	13	1

3.5.1. Sensitivity coefficient for ohmic pre-treatment

As shown in Figure 11 and 12, the ohmic time in a neural network with 5 (First layer) and 10 (Second layer) neurons in the hidden layer was considered as the most effective factor in predicting energy and exergy efficiency and for specific energy and exergy loss, the highest sensitivity was obtained for the ohmic time in the hidden layers with 10 (First layer) and 5 (Second layer). The results of the sensitivity analysis for microwave power are shown in Figure 10. Based on this figure, the highest sensitivity for energy and exergy efficiency was obtained for the microwave power in the one hidden layers with 5 neurons and for specific energy and exergy loss, the highest sensitivity was obtained for the microwave power in the one hidden layers with 10 and in the two hidden layers 10 (First layer) and 10 (Second layer) Respectively.

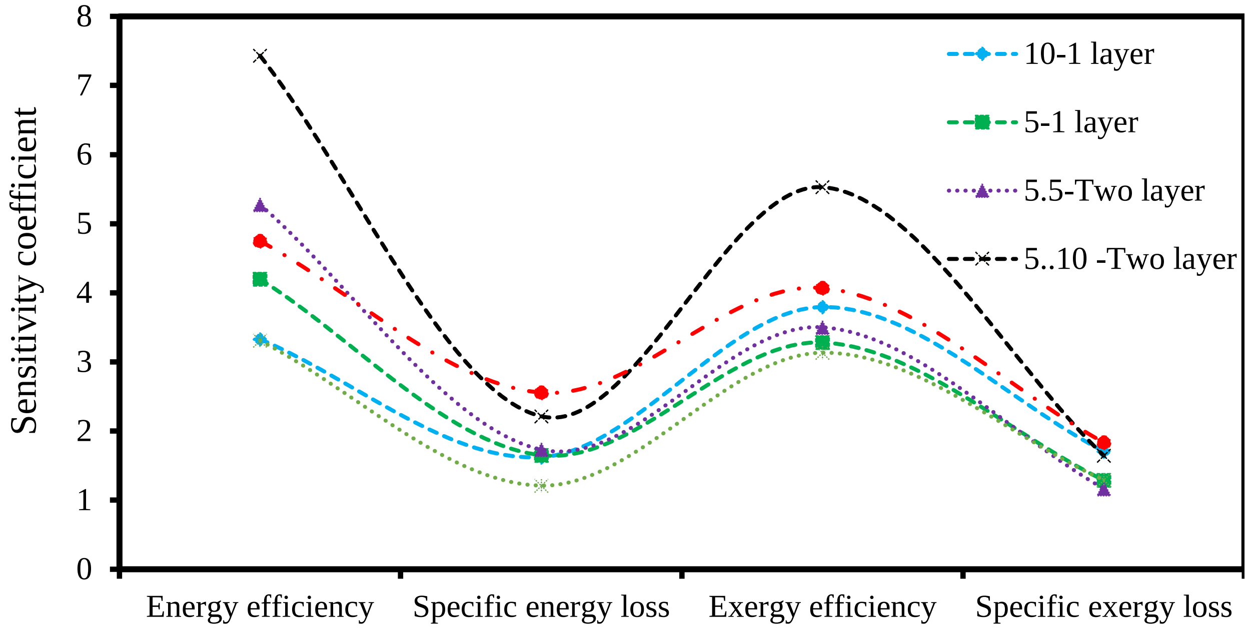

Figure 11. Sensitivity coefficient for ohmic time

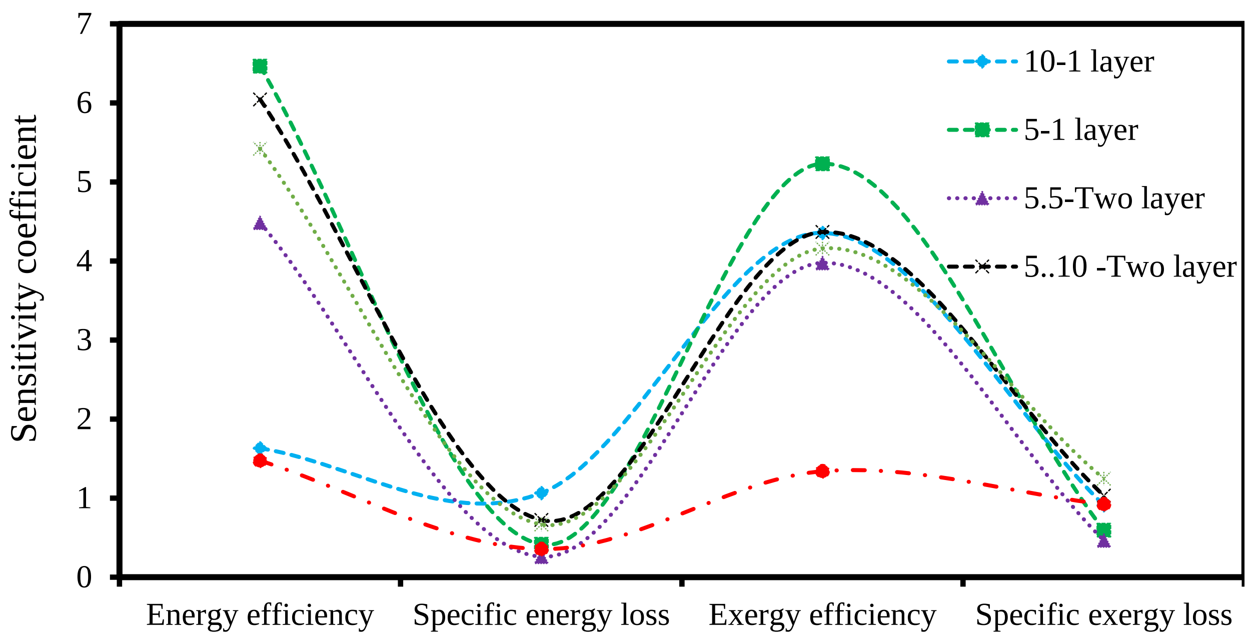

Figure 12. Sensitivity coefficient for microwave power in ohmic pre-treatment

3.5.2. Sensitivity coefficient for oven pre-treatment

As shown in Figure 13 and 14, the oven time in a neural network with 5 and 10 neurons in the hidden layer was considered as the most effective factor in predicting energy and exergy efficiency, Respectively, and for specific energy and exergy loss, the highest sensitivity was obtained for the oven time in the one hidden layers with 10 neuron and two hidden layers with 10 (First layer) and 5 (Second layer) neuron, Respectively. The results of the sensitivity analysis for microwave power are shown in Figure 14. Based on this figure, the highest sensitivity for energy and exergy efficiency was obtained for the microwave power in two hidden layers with 5 (First layer) and 5 (Second layer) neuron and one hidden layer with 10 neuron, Respectively, and for specific energy and exergy loss, the highest sensitivity was obtained for the microwave power in the two hidden layers with 5 (First layer) and 5 (Second layer) and in the two hidden layers 10 (First layer) and 10 (Second layer) Respectively.

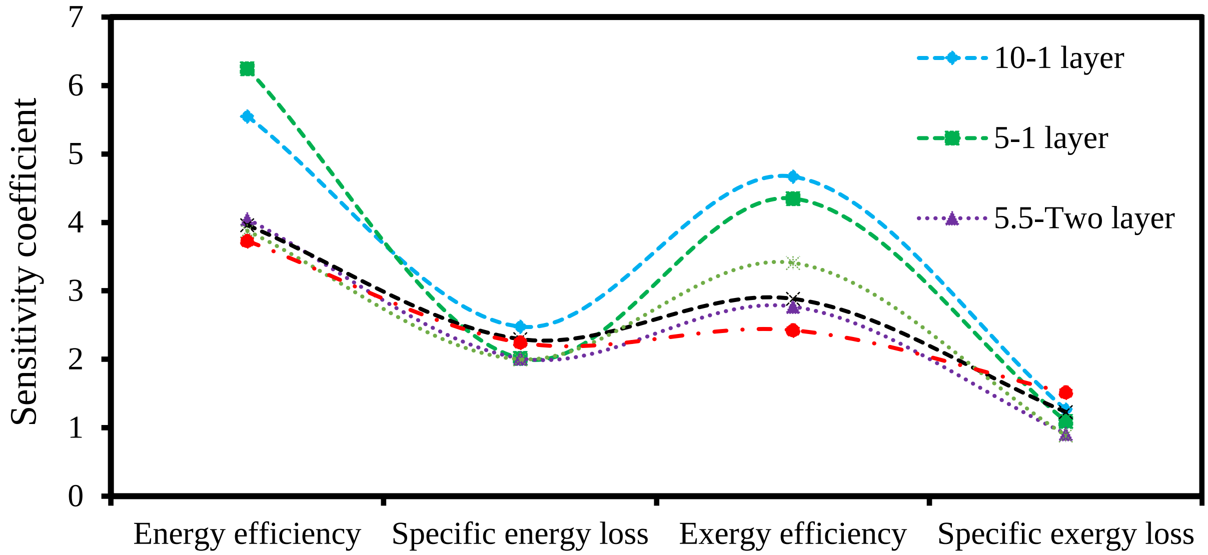

Figure 13. Sensitivity coefficient for oven time

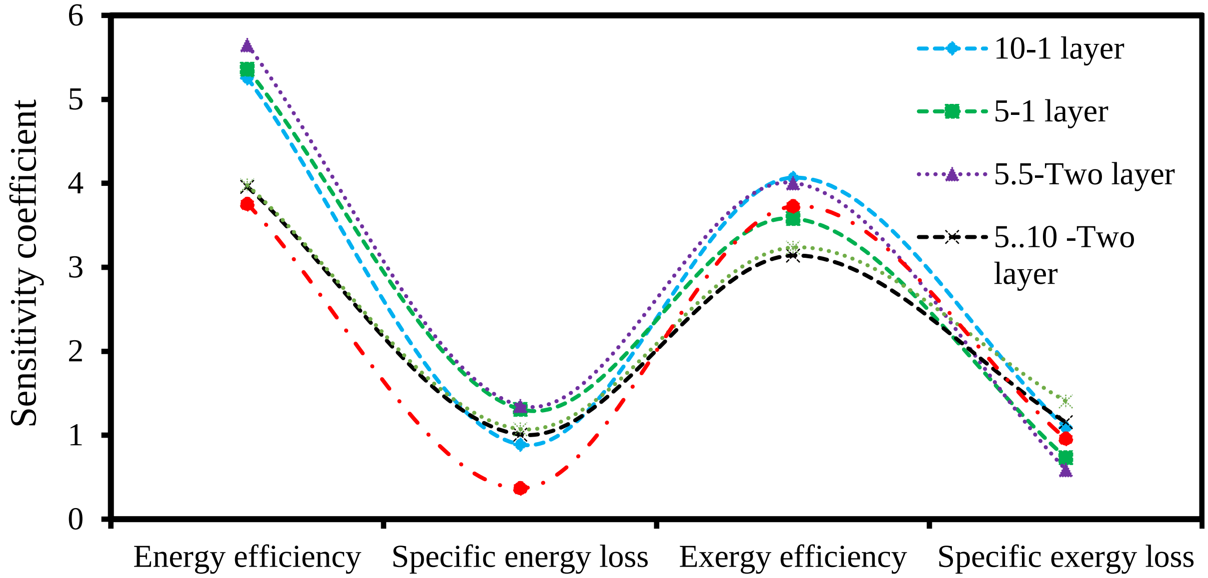

Figure 14. Sensitivity coefficient for microwave power in oven pre-treatment

4. Conclusions

- Microwave power plays an important role in determining the characteristic of kiwi drying. Increasing microwave power increases the energy and exergy efficiency drying, leading to reduced drying time.
- Oven and ohmic pre-treatment has significant effect on energy and exergy loss.
- Ohmic pre-treatment increased the absorption of heat in kiwi, led to an increase in the energy and exergy efficiency during drying.
- Ohmic Pre-treatment has a greater effect on exergy and energy than oven pre-treatment.
- Increasing the ohmic and oven time and microwave power had a significant effect on the amount of energy and exergy.

- Based on the results obtained, ohmic time had more effect on the energy efficiency than the exergy efficiency.
- Also, according to the results with Ohmic pre-treatment, the exergy efficiency has been 2.128 times, and this value has been 1.946 times for oven pre-treatment.
- Also, according to the results with Ohmic pre-treatment, the energy efficiency has been 1.97 times, and this value has been 1.90 for oven pre-treatment.
- Two hidden layer network has shown a higher sensitivity factor for ohmic time and highest sensitivity for power microwave in ohmic pre-treatment was in network by one hidden layer.
- One hidden layer network has shown a higher sensitivity factor for oven time and highest sensitivity for power microwave in oven pre-treatment was in network by two hidden layer.
- Data obtained from network and the initial data obtained from the experiment overlap for the energy efficiency, the specific exergy loss, and the exergy efficiency.
- Given the results obtained for R2, RMSE and Epoch, it can be stated that the neural network has the ability to predict the energy efficiency, specific energy loss, exergy efficiency and specific exergy loss at an acceptable level for kiwi
- To predict the exergy efficiency and specific exergy loss is obtained the best network in a two-hidden layer network.
- To predict the energy efficiency and specific energy loss is obtained the best network in a one-hidden layer network.

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