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Modeling the Aloe Vera Gel Drying Process in Microwave Oven by of Artificial Neural Network

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Abstract: Drying is one of the oldest methods of food preservation. Low efficiency of energy and long drying time during the drying wit downside speed is of major disadvantages of drying with hot air flow (displacement method). Due to thermal conductivity reduction of foodstuffs during descending speed, the drying process using displacement, velocity of heat transfer to the internal parts of the foodstuffs decreases. In order to alleviate these problems and prevent significant reduction in product quality and to achieve effective and rapid heat transfer process, using the microwave oven for drying food has been developed. In contrast to conventional heating systems, due to microwaves penetrate into the foodstuffs, the heat spreads throughout the foodstuffs. For this reason in microwave method the heat transfer rate is faster than other heating methods. Although, the space that equipment of microwave drying system compared with displacement dryer needs is just 20-35% but if it is not used properly, lead to loss of quality of product. The inner part of aloe vera leaf which has been separated from the green shell is called gel of aloe vera. In recent years, using this gel in the cosmetic and hygiene industry and in the formulation of foodstuffs has been widely grown. Aloe vera is from Liliaceae family. The >98-99% of aloe vera gel is composed of water and 60% of its solids composed of polysaccharide. The aim of this study is to investigate drying process of aloe vera gel with microwave. The main purpose of drying is produce products with higher maintenance and less costs for packaging and transport. Choosing an appropriate method for drying can lead to improve the final quality of the product.

Key words: Aloe vera, microwave, final drying, modeling, higher

INTRODUCTION

Due to the increasing world population and increasing need for food supplies, various methods of preserving and storing food and fruits in recent years has been of particular interest of researchers. Smoked out, drying and freezing or canning are the major strategies used in the food industry. Although, this method has long been used, but every day the complexity of processes of it increase.

Drying is one of the oldest methods of the vegetable preserving with high yield potential. Drying of fruits, spices and vegetables technically is worthwhile and in Iran has a long history as a way of preserving. Features such as longer life of shell, increased ease of transport and a sharp decline in volumes have been of the most important benefits of this method which can be expanded to further improvement of product quality and application of process. Drying causes preserve and increase shelf life of different materials and is applicable in a wide range of agricultural and commercial products (Galvez *et al*., 2007). Drying is a process in which due to simultaneous transfer of heat and mass, moisture is removed and reduce water content in the product. Ideally in the process is dehydration of food, maintain full structure, appearance and taste characteristics and odor. Consumers also always worried about the effects of dried products by different industrial physical and chemical methods and tend to more and more naturalization of drying processes. Today, there is much trend to foods with minimal processing and consumers tend to use more natural products that the storage time of them is increased without reducing their nutritional properties. Microwave is a physical method that in recent years has created a special place among available method in the food industry for itself (Albo and Tuszynski, 2004).

Conventional dryers work at high temperatures and usually lead to the product quality reduction. Microwave waves are part of the electromagnetic spectrum, which has about 300000-300 MHz frequency and unlike X-rays and gamma rays is not capable of breaking chemical bonds and damage to the molecules of food. During the absorption, microwaves waves by a dielectric material, give their microwave energy to the material and increase

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the temperature. Two important mechanisms that explain heat generation in the material that is placed in a microwave field are ionic polarization and dipole rotation.

Aloe vera is a member of the lily (Liliaceae) family. Gel texture leaves of this plant contain 98-99% water and more than 60% anhydrous substance of it composed of polysaccharides. Due to the therapeutic properties and beneficial effects of it on the human body, its use in the formulation of food is rising. Due to perishable nature of it, different processes in order to increase its useful life are done.

The aim of this research is study the use of microwaves for drying the aloe vera gel. Affecting parameters on the process of drying include drying time and temperature and microwave source power. In this study, these parameters have been considered as input of artificial neural network. Then, obtained results by dynamic famous models such as Newton, Henderson- Pablis and logarithmic was fitted and finally, the best model and the optimum conditions for maximum efficiency were presented.

Literature review

Mechanism of heating method and drying with microwaves: Ionic conductivity and dipole spin in microwave heating of foods had many fans. The main hypothesis associated with microwave heating involving microwave interaction with the non-homogeneous food product which has materials is highly influenced by the electric component of the electromagnetic field. In foods, there are polar molecules that interact most with microwaves waves to generate heat. Water is the most common and one of the main components in most foods.

About dipole spin water molecules due to non-uniform load distribution or severe dipole try to align with the field. Since, microwave field per second is to reverse its polarity millions of times, water molecules, when they have to be reversed and move in another direction, begin their movement only in one direction. In this regard, the kinetic energy is achieved from the microwave field and heat by internal molecular friction can be achieved. In addition, the function of absorbing components of microwave in the material is as a function of the material state which, are the particles of materials free or restricted? For example, water molecules are limited which show less absorption capability of microwaves from them.

The ionic conductivity is another important mechanism of microwave heat. Ions are electrically charged and under the influence of microwave field. Ions in a solvent first in one direction and then, along with the reversal of the field and in one direction flow and ionic compounds, after accepting the influence of an electric field, randomly collide with non-ionic groups. The kinetic energy of these ions as heat is transferred during such collides. Thermal conductivity, when vegetable or animal tissues are exposed to microwave energy, occurs in the cellular fluid. Long periods of time in conventional methods are caused by the mechanism that includes heating (environment-space) outside of the food through convection of heated air of oven. Inside of food is heated by conduction of heat from the surface. Thermal conduction of foods is not high. As a result in the way of warm up too much time is needed to required temperature of inside the food. Another major problem is early formation of level and shrinkage of the product which leads to reduced volume and the rate of heat transfer which is in turn lead to low-value products (Cariolato *et al*., 2008).

Compared with conventional methods of drying, drying using microwave radiation can drastically reduce drying time of biological material. When microwave energy is used for heating food, food mainly heated by the heat creation inside the food and as a result, the arrival of food to cooking temperature decreases. The air inside the food and stove is heated only when they receive heat from the food. As a result, microwaves energy makes possible efficient processing. Increased pores size due to swelling properties, makes it possible easy release moisture through the sample which resulted to achieving more mass transfer rate (Cariolato *et al*., 2008).

Drying using microwave waves like conventional drying methods due to water vapor pressure differences between the interior and surface areas, which provides the driving force for the transfer of moisture and in the products below 20%, which are used in a number of processes of drying, has the maximum effect (Cariolato *et al*., 2008).

Microwave characteristics of foods: In microwave engineering processes not only thermal properties of foods that are not sensitive to the temperature differences but also a number of electrical characteristics associated with processing which are changed with the frequency of process and are associated with temperature-time profiles of product as well, are examined. At microwave frequencies, the main electrical characteristics are dielectric constant and dielectric loss factor. The dielectric constant is a measure of the ability of a substance to absorb electrical energy while the dielectric loss is a measure of its ability in the distribution of electrical

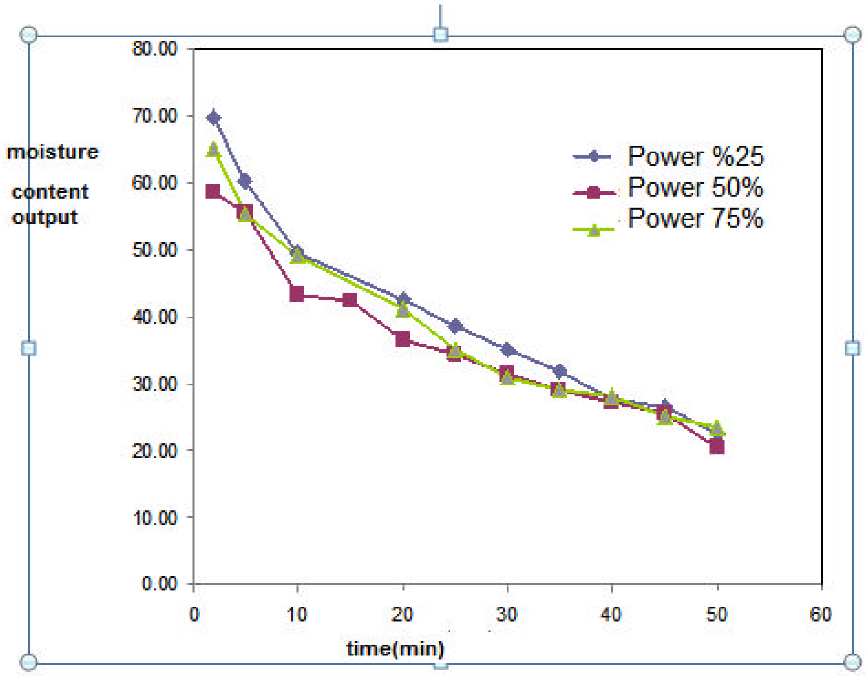

Fig. 1: Speed curve of Aloe vera gel by microwave and in the powers of 25, 50 and 75% W and 2-50 min

energy to heat. By determining the dielectric constant and dielectric loss factor for a substance, the complex permeability of biological material can be calculated using the following equation:

$$\varepsilon = \varepsilon' - j\varepsilon'' \quad (1)$$

Where:

- ε' = Relative dielectric constant
- ε'' = Relative factor of dielectric loss
- J = complex number $\sqrt{1}$

The amount of power that a material can absorb can be calculated by the following Eq. 2:

$$P = \sigma E^2 \left(\frac{\text{Watts}}{\text{cm}^2}\right) \quad (2)$$

Where:

- P = Power absorbed in W cm^{-1}
- σ = Conductivity of equivalent dielectric
- E = Electric field gradient in volts/cm

With dielectric conductivity that can be obtained as follows:

$$\sigma = 2\pi\varepsilon_0\varepsilon'' f \quad (3)$$

Where:

- f = Frequency of energy source
- ε_0 = Vacuum dielectric constant (8.85×10^{-12} farads m^{-1})
- ε'' = Dissipation factor of dielectric of material

Depth seepage is the depth in which in which microwave power level of 37% of face value is (or 1/e). The equation of results of dielectric characteristics conversion to depth seepage is as follows Eq. 4:

$$dp = \frac{1}{2\alpha_e} \quad (4)$$

Where: α_e Given damping constant for:

$$\alpha_e = 2\pi/\lambda_0\sqrt{\left(\varepsilon'/2\left(\sqrt{\left(1+\varepsilon''/\varepsilon'\right)}-1\right)\right)} \quad (5)$$

MATERIALS AND METHODS

The materials used in this study include Aloe vera slices that firstly amount of its moisture or weight is measured. The main tool in this research is the microwave generator 2000 W with a frequency of approximately 22 kHz which is the generator of its mechanical piezoelectric waves. Type of generator is probe and radiation is conducted directly. In order to compare the obtained results the microwave drying process with a digital scale with accuracy of at least a tenth of a gram is used.

Testing process: In short description of all planned experiments and analysis in this study is shown in Fig. 1. In short, the tests can be outlined as follows:

- Preparation of aloe vera
- After sample preparation of Aloe vera plant leaf and separation of its intended and gel part, it was cut to the desired thickness and with the same size were placed in oven at certain temperature and prepared for drying (this process at different temperatures: 50, 60, 70 and 80°C were repeated). In the end, the initial moisture content of the samples was calculated
- Using digital scale tenth of a gram samples were carefully weighed and the original form of it was photographed
- In two different series of experiments (variable microwave power and constant exposure time) and (constant microwave power fixed and variable exposure time) and tests were performed
- After each round of radiation the wave was photographed and weight of the samples was recorded and relative humidity of product was calculated

RESULTS AND DISCUSSION

Analysis: In this study, for modeling the speed of Aloe vera gel drying by artificial neural network, MATLAB software has been used. More than thirty sets of experimental data to create networks that are located in two groups of inputs and outputs have been used. Network inputs include drying time and power respectively. Network inputs and error made by guessing the selected output parameters have been the time and dryer power. Network outputs by guessing and performed error have been selected among parameters such as the amount of output moisture.

MLP neural network with a created hidden layer have been hidden layer function transfer and output layer of hyperbolic tangent function. In each run of network, about 65% of the data have been used for network training, 15% to Cross Validation and the remaining data for network testing shown in Table 1.

In Fig. 1 experimental results curve at different times and different powers has been plotted. As can be seen in waves with more power, more moisture is absorbed quickly. Also with fitted and mathematical models comply with the experimental results following results were obtained. After network training, to evaluate its efficacy in predicting the absorption process, output results of network have been compared with experimental data and mathematical models. In Fig. 2-3 obtained experimental data of network compared with experimental data of and mathematical models are presented.

Table 1: Changes range of network input parameters

Time (min)	Wavelength
2-50	0/25-0/75

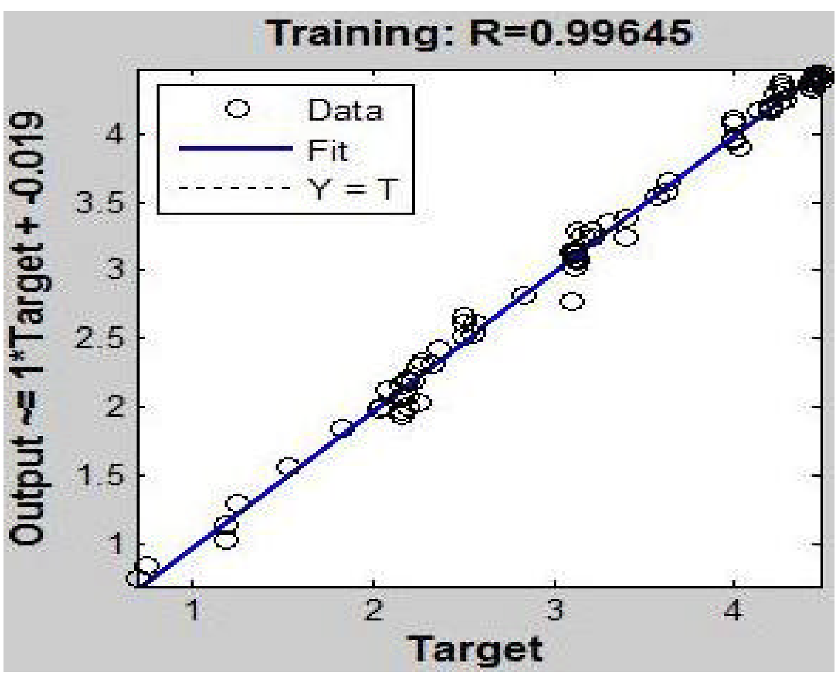

Fig. 2: Simulation results of network for change data of moisture content of drying with artificial neural networks network compared with its real data to training data with tangent activation function sigmoid

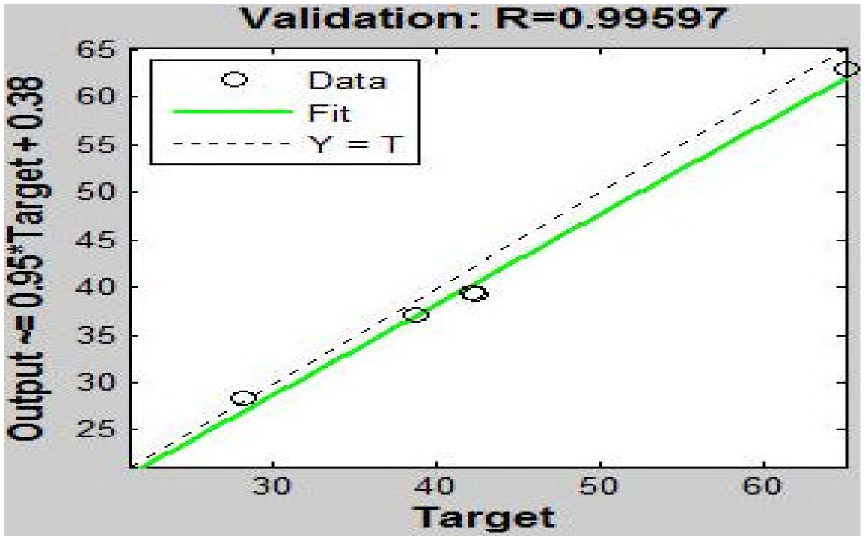

Fig. 3: Moisture content changes of drying with artificial neural networks compared with real data for data validation (evaluation) by stimulating function of tangent sigmoid: a) power of 25 W; b) power of 50 W and c) be 75 W

Based on evaluation of models, Henderson model and "reformed Pabis model", February and two binomials, the highest amount (R^2) and the lowest (SSE) are among the other models and showed better results. Figure 2 shows the output results of trained neural network in comparison with experimental data. In the following the network results in anticipate change in the moisture content based on operating parameters were evaluated. As is clear in a fore mentioned figure, network results show good agreement with experimental data.

In the chart neural network after distribution (Propagation) for neural network arrangement based on training data set with 10 processing elements in the input layer has been obtained. In this Fig. 1, the values of moisture content change data of drying on the vertical axis using after distribution (propagation) pattern and learning rule of Levenberg Marquardt by implementing artificial neural network has been met.

In the chart neural network after distribution (Propagation) for neural network arrangement based on validation data set with 10 processing elements in the input layer has been obtained. In this Fig. 1, the values of moisture content change data of drying on the vertical axis using after distribution (propagation) pattern and learning rule of Levenberg Marquardt by implementing artificial neural network has been met.

In the chart neural network after distribution (Propagation) for neural network arrangement based on validation data set with 10 processing elements in the input layer has been obtained. In this figure, the values of moisture content change data of drying on the vertical axis using after distribution (propagation) pattern and learning rule of Levenberg Marquardt by implementing artificial neural network has been met shown in Fig. 4. In Fig. 4 and 5) neural network after distribution (Propagation) for neural network arrangement based on validation data set with 10 processing elements in the input layer has been obtained. In this figure, the values of moisture content change data of drying on the vertical axis using after distribution (propagation) pattern and learning rule of Levenberg Marquardt by implementing artificial neural network has been met.

High values of efficiency of artificial neural network are in predicting the moisture content during the drying process. However neural network prediction about the power of 75 W is better than other powers. (Due to the correlation coefficient). Probably due to the more dependence of drying kinetics parameters considered to be 75 W as neural network input. Laboratory results and the results of multi-layer neural network showed error estimation of time for Aloe vera drying in the microwave in powers of 25, 50 and 75 W was appropriate. In fact the results showed that complete accuracy of MLP neural network based on input data can be very good estimation of drying time of moisture content shown in Fig. 5-8.

In Fig. 6-8 the results of training process and simulated error changes to neural network run after distribution (propagation) based on optimized overall data set with 10 processing elements in the input layer

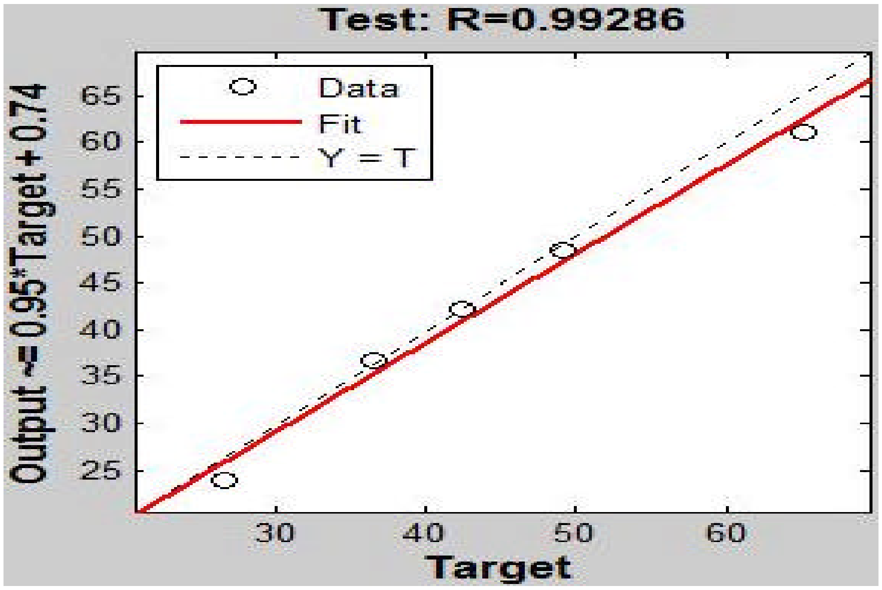

Fig. 4: Moisture content changes of drying with artificial neural networks compared with real data for data validation (evaluation) by stimulating function of tangent sigmoid: a) Power of 25 W; b) Power of 50 W and c) 75 W

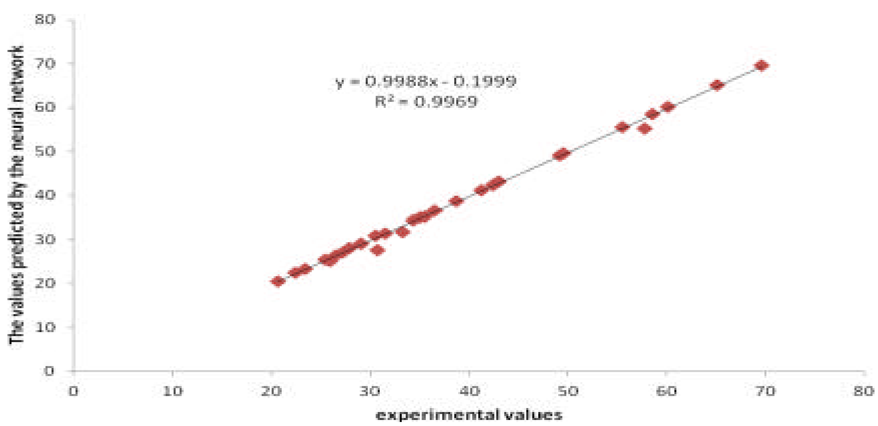

Fig. 5: Moisture content changes of drying with artificial neural networks compared with real data for data validation (evaluation) by stimulating function of tangent sigmoid: (a Power of 25 W; b) Power of 50 W and c) 75 W

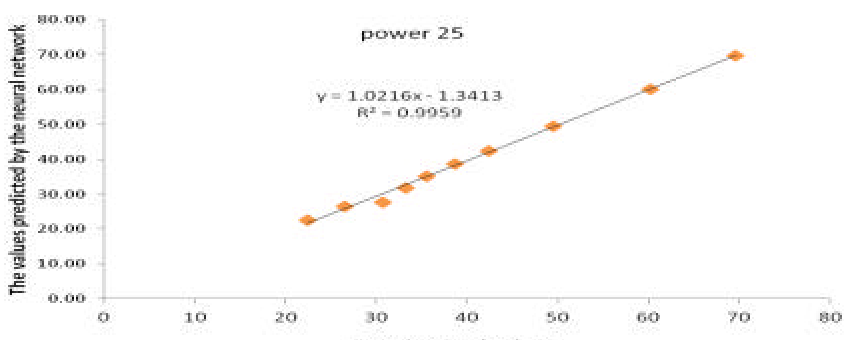

Fig. 6: The training process and simulation error changes for network with 25 neurons in hidden layer of 25 watts

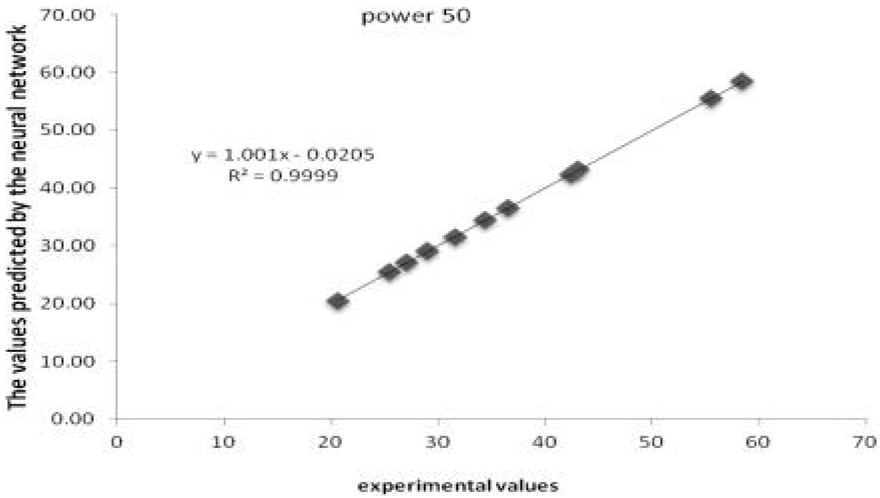

Fig. 7: The training process and simulation error changes for network with 25 neurons in hidden layer of 50 W

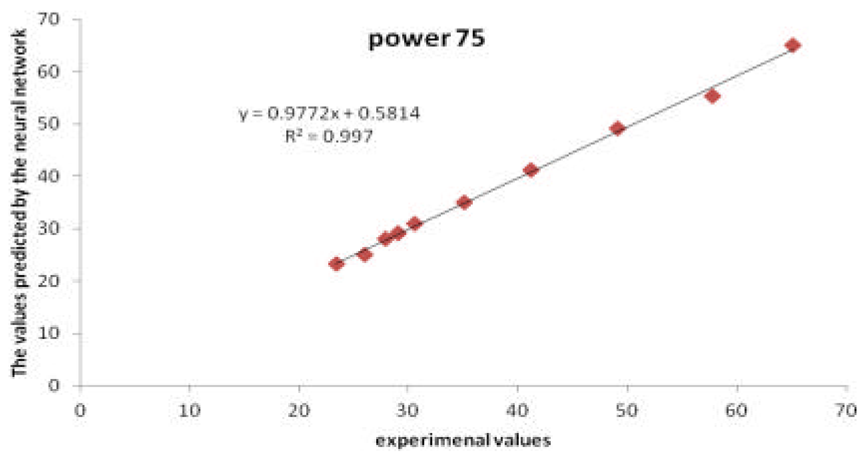

Fig. 8: The training process and simulation error changes for network with 25 neurons in hidden layer of 75 W

has been obtained. In this chart, training process and simulated error changes for data values of kinetics drying of moisture content using after distribution (propagation) pattern and learning rule of Levenberg Marquardt by implementing artificial neural network has been met.

The results obtained from pre-processing of the input data of three defined models for neural network are shown in Table 2-4. To optimize the f model in the hidden layer different neurons have been used to determine the optimal number of it. The number of used neurons initially was low and then gradually increase the number of neurons until the error had no effect on the improvement was continued. As can be seen in Fig. 2-3, the results from fitting models show that the mathematical model of Henderson and "reformed Pabis model" were highly adapted with the experimental results. Also, the neural network with mentioned features had excellent adaptability with the experimental data.

Based on the results, the most models had appropriate estimation accuracy for predicting changes moisture content in the Aloe vera at powers of 25, 50 and 75 watts of microwave. But, among them -20-1 model with the determination coefficient, respectively, in powers of 25, 50 and 75 watts equal R^2 = 0.995R2, 0.9994 and 0.997 had higher accuracy than other models. The results showed that the Feed-forward model based on input data can be a very powerful alternative to other experimental models of old. In fact, the results showed that the complete accuracy of data of feed-forward model based on input data can satisfactorily predict changes in the moisture content of Aloe vera powers at powers of 25, 50 and 75 watts of microwave.

Table 2: Summary results of comparing the effect of numbers of hidden layers and number of neurons in each hidden layer on changes prediction accuracy of moisture content of drying in powers of 25, 50 and 75 watts of microwave

	Feed-forward							
	Logarithmic				Tangent sigmoid			
Datum	Neurons in the hidden layer	Validation (R^2)	Experiment (R^2)	MSE	Neurons in the hidden layer	Validation (R^2)	Experiment (R^2)	MSE
Microwave in 25 W	5	0.866	0.816	0.814	1	0.816	0.796	0.72
	10	0.884	0.87	0.68	5	0.835	0.848	0.62
	15	0.915	0.87	0.59	10	0.866	0.859	0.732
	20	0.919	0.928	0.191	15	0.9935	0.955	0.131
	25	0.915	0.87	0.341	20	0.89	0.859	0.321
Microwave in 50 watts	5	0.855	0.805	0.95	1	0.8778	0.8558	0.84
	10	0.873	0.843	0.64	5	0.8987	0.9152	0.51
	15	0.903	0.853	0.49	10	0.9317	0.9273	0.38
	20	0.988	0.984	0.28	15	0.998	0.9994	0.11
	25	0.903	0.858	0.37	20	0.9625	0.9295	0.33
Microwave in 75 watts	5	0.863	0.8140	0.825	1	0.814	0.793	0.76
	10	0.873	0.867	0.720	5	0.833	0.846	0.682
	15	0.881	0.867	0.53	10	0.863	0.856	0.42
	20	0.913	0.98	0.21	15	0.993	0.997	0.12
	25	0.913	0.867	0.34	20	0.887	0.856	0.292

CONCLUSION

Choose an appropriate method for drying Aloe vera can be lead to improve the final quality of the product. This study aimed to investigate Aloe vera gel drying process using microwave. The inner part of Aloe vera leaf separated from green shell called Aloe vera gel. In recent years, using this gel in the cosmetic and hygiene industry and in the formulation of foodstuffs has been widely grown. Aloe vera is from Liliaceae family. More than 98-99% of Aloe vera gel is composed of water and 60% of its solids composed of polysaccharide. The aim of this study is to investigate drying process of Aloe vera gel with microwave. The main purpose of drying is produce products with higher maintenance and less costs for packaging and transport. Choosing an appropriate method for drying can lead to improve the final quality of the product.

In this study, feasibility of microwave for drying aloe vera the study of effective parameters on drying was evaluated. Experiments in three power (20/25, 0/50 and 0/75 Watt) and the range of 5 to 50 minutes were done. Today, the use of computer models due to higher accuracy and speed than many classical, laboratory and experimental methods have been considered in many developed countries and are used in industries. One of the important issues that decision making researchers and scientists, are face with is selection of the variables influencing the model output. Artificial intelligence for modeling to predict the quality parameters with high accuracy and speed, has gained a special place in the food industry. In the industry these models are used in order to control and correct the effective parameters on quality as well as adoption appropriate decisions. With regard to product quality prediction by the neural network factors contributing to defects in the product can be controlled.

Because of the limitations of the study do not allow identification of all variables to determine and forecast models that have been designed for this purpose to be applied and on the other hand necessarily all the variables are identified, will not have an appropriate effect on output, therefore, the adoption of procedures for screening input data to decision making models and prediction based on the mathematical models is very important. To evaluate the performance of progressive after distribution (propagation) network of multi-layered different topologies with different number of neurons were used.

In the first step network was trained, MSE error of network test was calculated and selected on the basis of the best topology. For this purpose, one to twenty-five different neurons and different stimulant tangent sigmoid functions and linear were used in the hidden layer which the results of a number of topology are provided in Table 2-4. For network training, a default value of 1000 epoch was used. Each epoch is a sweep of all laboratory results of samples taken to train the network in order to reduce errors using reverse distribution error algorithms.

Cross validation is one of the most effective methods to stop networks training. When cross validation error increases, the network training must be stopped and at this point the network has been the best mode of generalization. Many attempts are done to reduce network training error with increase number of hidden layers and number of neurons of them and results showed increasing the number of hidden layers (more than one hidden layer) didn't increase the function of network considerably but increasing the number of neurons of hidden layer in both types of provided network to a certain number could reduce more their error function. Finally, a network with a hidden layer and 20 neurons could produce the best results. According to contents of Table of 2-4 neural network according to more regression coefficient and produce fewer errors has shown a better performance than the mathematical models. So using the neural network method is better at predicting experimental results.

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