Prediction of Moisture Content of Bergamot Fruit during Thin-Layer Drying Using Artificial Neural Networks

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Abstract. In this study thin-layer drying of bergamot was modelled using artificial neural network. An experimental dryer was used. Thin-layer of bergamot slices at five air temperatures (40, 50, 60, 70 & 80 ºC), one thickness (6 mm) and three air velocities (0.5, 1 & 2 m/s) were artificially dried. Initial moisture content (M.C.) during all experiments was between 5.2 to 5.8 (g.g) (d.b.). Mass of samples were recorded and saved every 5 sec. using a digital balance connected to a PC. MLP with momentum and levenberg-marquardt (LM) were used to train the ANNs. In order to develop ANN’s models, temperatures, air velocity and time are used as input vectors and moisture ration as the output. Results showed a 3-8-1 topology for thickness of 6 mm, with LM algorithm and TANSIG activation function was able to predict moisture ratio with $R^2$ of 0.99936. The corresponding MSE for this topology was 0.00006.

Keywords: bergamot, thin-layer, artificial neural network, levenberg-marquardt, momentum.

1 Introduction

Citrus are of great important among agricultural products in the world. Iran produces 3.5 million tonnes of citrus and is ranked 22nd in the world (Anonymous, 2010). Bergamot is an evergreen and a small tree from Rue family (Fig. 1). Its fruit is pear like and bergamot oil is extracted from the skin which is used as an ingredient in perfume industries. The fruit skin with bitter and fragrant taste is used in jam production and also in pharmaceutical and medical applications. The name of the tree

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is citrus bergamia and belongs to bergamot family. Another citrus fruit from Rue family is citron which is called cedrate. The tree is called citrus medica and the fruit is used in jam production as well (Shry and Reiley, 2010).

Bergamot fruit consists of flevedo, albedo and an oval shape meat. The flevedo is initially green and as the fruit ripens, becomes yellow. The albedo is white in both green and yellow stages of the flevedo and its thickness is manifold than that of the flevedo. The meat is edible and very sour and can be used in place of lemon juice or in making various pickles.

Bergamot is usually grown in south Iran like Jahrom (in Fars province). Before the yellow stage, the crop is harvested and the skin is dried. Dried skins are used in jam production in seasons that fresh fruit is not available. In addition, bergamot as dried fruit is exported to many countries (Mojtahedi, 2006).

Drying is defined as a process of moisture removal due to simultaneous heat and mass transfer (Hernandez, 2009). It is also a classical method of food preservation, which provides longer shelf-life, lighter weight for transportation and smaller space for storage. Natural sun drying is practiced widely in the world and also in Iran, but has some problems related to the contamination by dirt and dust and infestation by insects, rodents and other animals. Therefore, the drying process should be undertaken in closed equipments, to improve the quality of the final product.

Artificial neural networks in reality are the simplified model of man mind which is one of the tools for predicting physical phenomena, and were considered as an application on 50s of 20th century for the first time, when Frank Rosenblatt introduced Perceptron network in 1958 (Menhaj, 2001).

The smallest unit of artificial neural network is Neuron. Every network consists of one input, one output and one or several middle layers. Each layer’s neurons are connected to next layer neurons by some neurons. In the network training process, these weights and the permanent amounts are added to them and named Bias idiomatically, changes continuously until the sum of the squares of error gets minimum. Weights and biases changes are on the base of learning law. For transferring every layer outcome to next layers, actuator functions are used. Sigmoid, linear, and preliminary functions can be mentioned from famous actuator functions. To build artificial neural network, data are divided to two series of instruction data and examination data. About eighty percent of data are applied to instruction and the remaining is used for examination and evaluation. In the duration of learning process, network learning level is being measured continuously by some error indices and finally, the network is being selected which has minimum error (Kishan et al., 1996).

One of the important usages of artificial neural network is training and predicting outcome with new data. In FFBP network, with BP learning algorithm, at first, outcome layer weights are compared with optimum values. If error is excessive, outcome layers weights will be modified on the basis of updating rules and if training error is less than predefined error, learning process will finish. Also, CFBP network uses BP algorithm for weight correction like FFBP network. But the main property of that network is every layer’s neurons are connected to all of the neurons of previous

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1 Feed-Forward Back Propagation.
2 Error Back Propagation.
3 Cascade-Forward Back Propagation.