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INFORMATION PROCESSING IN AGRICULTURE XXX (2018) XXX–XXX

journal homepage: www.elsevier.com/locate/inpa

ANFIS and ANNs model for prediction of moisture diffusivity and specific energy consumption potato, garlic and cantaloupe drying under convective hot air dryer

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A R T I C L E I N F O

Article history:
Received 28 January 2018
Received in revised form
2 May 2018
Accepted 3 May 2018
Available online xxxx

Keywords:
Convective hot air drying
Drying kinetics
Effective moisture diffusivity
ANFIS
ANNs

A B S T R A C T

The main purpose of this study was to develop and apply an adaptive neuro-fuzzy inference system (ANFIS) and Artificial Neural Networks (ANNs) model for predicting the drying characteristics of potato, garlic and cantaloupe at convective hot air dryer. Drying experiments were conducted at the air temperatures of 40, 50, 60 and 70 °C and the air speeds of 0.5, 1 and 1.5 m/s. Drying properties were including kinetic drying, effective moisture diffusivity (D_{eff}) and specific energy consumption (SEC). The highest value of D_{eff} obtained 9.76×10^{-9}, 0.13×10^{-9} and 9.97×10^{-10} m^2/s for potato, garlic, and cantaloupe, respectively. The lowest value of *SEC* for potato, garlic, and cantaloupe were calculated 1.94×10^5, 4.52×10^5 and 2.12×10^5 kJ/kg, respectively. Results revealed that the ANFIS model had the high ability to predict the D_{eff} ($R^2 = 0.9900$), *SEC* ($R^2 = 0.9917$), moisture ratio ($R^2 = 0.9974$) and drying rate ($R^2 = 0.9901$) during drying. So ANFIS method had the high ability to evaluate all output as compared to ANNs method.

1. Introduction

Heat and mass transfer happen during the drying process. Mass transfer must be controlled for production of qualitative samples [1]. Drying technology has many advantages that can easily reduce the sample volume and weight after drying treatment. As a result, it can save energy the with giving high quality products [2].

Drying of food products is a usual process used to improve their stability and preserve fruit and vegetable quality. So, in the years ago, drying process had been used for preserving quality of different products. The drying process can be able to remove the moisture from a food product using evaporation, as a result, it increase the shelf-life of products [3]. Sun drying is an old method for agricultural products drying. But various disadvantages of this method are including of control lack during drying, unwanted changes of food quality, long

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Peer review under responsibility of China Agricultural University.
https://doi.org/10.1016/j.inpa.2018.05.003
2214-3173

time of drying and product pollution. Sun drying must be replaced using industrial drying (e.g. hot air drying) to improve the product quality [4].

The convective hot air dryer is applied as a successful technique of drying. The advantages of this drying method are including: (1) high ratio of heat and mass transfer, (2) temperature steady of samples, (3) well control of temperature and application of the high temperature for drying and (4) high capacity of drying [5,6]. The energy efficiency of convective dryers is very importance. The *SEC* is advantageous over the energy efficiency as it has a well-defined benchmark value for an adiabatic dryer [7].

Predicting drying kinetics of agricultural products under different conditions is very important to design process and equipment, management of energy and fuel, select of suitable storage, transferring materials and so on. ANNs and ANFIS can adequately and precisely predict the drying process [8]. ANNs are mathematical tools whose acting is inspired by that of the human brain. They are a promising tool for simulating variables of processes because of their simplicity. Also, ANNs can be applied for nonlinearities systems [9,10].

ANFIS is a soft computation method applied to solve the complex and non-linear problems. ANFIS can be able to produce and predict one output [11,12].

Many researchers applied ANNs and ANFIS method to explain the drying properties of many products of agriculture. Rodríguez et al., [8] predicted the thyme moisture content (MC) during convective drying by ANNs. Martinez-Martinez et al., [13] used the ANNs to predict the MC of switch grass. Kaveh and Chayjan, [14] predicted the *MR*, *DR*, *SEC*, D_{eff} and shrinkage for terebinth using fluidized bed dryer by ANNs. They showed that the highest R^2 was obtained 0.9965, 0.9730, 0.9855, 0.9932 and 0.9917 for *MR*, *DR*, *SEC*, D_{eff} and shrinkage, respectively. Samadi et al., [15] predicted *MR* and *DR* of apple slice during drying by using hybrid heat and power dryer by ANNs. They calculated the amount R^2 for *MR* and *DR*, 0.9989 and 0.9985, respectively. Also, the value of $MSE = 0.0013$ was obtained. Pusat et al., [16] investigated the MC of coal in convective dryer using ANFIS. The ANFIS network achieves quite satisfying scientific results with acceptable deviations. The *MSE* and R^2 values were calculated as 1.899 and 0.998, respectively, for the testing stage. Azadeh et al., [17] applied the ANNs, ANFIS and PLS to control the drying process. In the proposed approach, the PLS analysis is used to pre-process actual data and to provide the necessary background to apply ANN and ANFIS approaches. They showed that the PLS-ANFIS model performed better with a higher $R^2 = 91.06$ and lower $MSE = 0.000834$. Al-Mahasneh et al., [18] reported the advantages of ANFIS models for food processing and technology. They feature the ANFIS model compared to ANNs, FLS and multiple regressions to predict food drying, prediction of food properties, microbial growth and thermal process modeling, applications in food quality control and food rheology, Applications have been implemented to control the quality of food and diet. It is concluded that, in most applications, ANFIS outperforms other modeling tools such as ANNs, FIS or multiple linear regression.

To our knowledge, No study has been reported about prediction of *MR*, *DR*, *SEC*, D_{eff} value by ANNs and ANFIS methods for potato, garlic, and cantaloupe product. The main objectives of this research was to predict *MR*, *DR*, *SEC*, D_{eff} for potato, garlic, and cantaloupe product using convective hot air dryer by ANNs and ANFIS method.

2. Materials and methods

2.1. Raw material

The fresh potato, garlic, and cantaloupe samples were provided from a market in Nalac city, West Azarbaijan province, Iran. The samples maintained in double layers of polyethylene bags and refrigerator with temperature 3 ± 1 °C before the experiment. The initial MC was measured using oven dryer (70 ± 1 °C for 24 h). The initial MC of fresh potato, garlic and cantaloupe was obtained 3.99, 60.81, and 17.89% (d.b.), respectively.

2.2. Drying process

The drying of potato, garlic, and cantaloupe samples were performed in a convection hot air dryer (laboratory scale) (Fig. 1). The dryer consists a centrifugal fan with one phase electrical motor (0.375 kW), and air heating unit. Air heating unit installed behind the fan with six electrical heating parts (2 kW). Drying chamber was drum type with 150 mm and 320 mm in diameter and height, respectively. The inlet air temperature and velocity was controlled using a digital thermostat (Model of Atbin mega, Iran) and an inverter (Model of Vincker VSD2, Taiwan), respectively. Also, the measurement of air temperature and relative humidity was performed using a thermometer (Model of Lutron TM-903, Taiwan) and a hygrometer (Model of Lutron TM-903, Taiwan), respectively. Laboratory temperature and relative humidity of air was in the range of 23–28 °C and 24–32%, respectively.

2.3. Experimental procedure

The sliced potato, garlic and cantaloupe cubes of 40 g were placed on the tray in the drying cabinet and arranged in one layer. The experiments of samples drying were performed at the drying air temperature (from 40 to 70 °C (interval 10 °C))

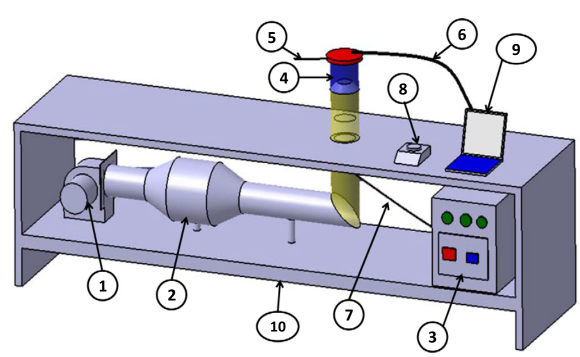

Fig. 1 – Schematic of laboratory scale fluid bed dryer: (1) fan and electro motor, (2) speed/frequency inverter, (3) control panel, (4) drying chamber, (5) air velocity recorder, (6) outlet air temperature recorder, (7) input air temperature recorder, (8) scale, (9) computer, (10) chassis.

Please cite this article in press as: Kaveh M et al. ANFIS and ANNs model for prediction of moisture diffusivity and specific energy consumption potato, garlic and cantaloupe drying under convective hot air dryer. Info Proc Agri (2018), https://doi.org/10.1016/j.inpa.2018.05.003