Journal of Thermal Engineering, Vol. 4, No. 1, pp. 1648-1655, January, 2018
Yildiz Technical University Press, Istanbul, Turkey

EFFECT OF PRE-TREATMENT AND AIR TEMPERATURE ON DRYING TIME OF CHERRY TOMATO

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ABSTRACT

The effects of pre-treatment and air temperature with on drying and rehydration characteristics of cherry tomato slices were studied. Drying experiments are carried out with the air temperature of 55, 65, and 75°C. Drying time decreased with pre-treatment, and it also decreased considerably with increase in air temperature. The results indicated that the cherry tomatoes which were pre-treated with potassium solution were explored within the shortest time. Furthermore, superior rehydration was observed the samples which were pre-treated with potassium solution. The moisture effective diffusivity calculated from the second Fick's law of diffusion ranged from 2.26 to 6.22×10^{-9} m^2/s over the temperature range studied. Activation energy was estimated by an Arrhenius type equation and the activation energy values varied from 26.51 to 32.79 kJ/mol.

Keywords: *Cherry tomato, Pre-treatment, Drying, Rehydration, effective moisture diffusivity, activation energy*

INTRODUCTION

Tomato (*Lycopersiconesculentum*) is the second important vegetable cultivated throughout the world with a production at about 162 million tons and Turkey is the fourth biggest producer after China, India and USA at about 11.35 million tons [1, 2]. Cherry tomato (*Lycopersiconesculentum var. Cerasiforme*) is a kind of a small tomato used in the salad dressing. Since tomatoes deteriorate within 2-3 weeks after harvesting, it is very important to improve their shelf life and make the fruit available when not in season for this reason tomatoes are often dried and sold in a dehydrated form [3].

Drying is a classical method of food preservation that enables an extended shelf-life, lighter weight for transportation, and less space needed for storage. Even with the development of newer drying techniques, most vegetables are still air-dried because this method of dehydration is still the simplest and most economical [4]. A lot of data has been reported in the literature on the drying properties of various products such as cocoyam [5], yam [6], tomato [2, 7], and Jerusalem artichoke [8] and others. In some studies, the effect of pre-treatment on the drying rate or time of agricultural products has been reported by various authors. Potassium and sodium hydroxide, potassium meta bisulphate, potassium carbonate, methyl and ethyl ester emulsions, ascorbic and citric acids, the most common and commercially used some pre-treatments [9-14]. Pre-treatments prevents loss of colour by inactivating enzymes, reduce the drying time by relaxing tissue structure and yield a good quality dried product [9]. No work has been found detailing the effect of dipping with pre-treatments before drying of cherry tomato slices. The main objectives of this study were to investigate the effect of air temperature and pre-treatments on drying and rehydration characteristics, and compute effective moisture diffusivity and activation energy of cherry tomato slices.

MATERIALS AND METHODS

Materials

Cherry tomatoes were obtained from a local supermarket in İstanbul. All samples of cherry tomatoes were cleaned with tap water to remove the dust and unwanted materials that will affect the experiments, then the surface moisture were removed using a paper towel. Two different pre-treatments were applied to the cherry tomatoes before drying, and untreated sample was used as a control. The details of pre-treatments are described in Table 1. After that the samples were cut into halves with the approximate diameter of 36.6 mm.

This paper was recommended for publication in revised form by Regional Editor Ahmed Kadhim Hussein
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Manuscript Received 15 June 2016, Accepted 5 August 2016

Table 1. List of pre-treatments

Code	Description
Potas	The samples were pre-treated with solution of potassium carbonate (3%) + olive oil (0.5%) at 20°C for 2 min. After pre-treatment, the samples were blotted with tissue paper to remove superficial water.
Citric acid	The samples were pre-treated with solution of citric acid (1%) at 20°C for 2 min. After pre-treatment, the samples were blotted with tissue paper to remove superficial water.
Control	The samples were no pre-treated with anything.

Moisture contents of the cherry tomatoes were determined using a method of AOAC [15]. For the method Ecocell LSIS-B2V/EC55 model incubator (MMM Medcenter Einrichtungen GmbH, Planegg, Germany) was used. Four parallel experiments for conducted and the average values of the moisture contents were calculated.

Drying procedure

Drying experiments were performed in a laboratory scale hot-air dryer, described previously by Doymaz (2004) [10] and installed in the Chemical Engineering Department of Yildiz Technical University, Istanbul, Turkey. Desired experiments conditions inside the dryer were obtained for at least 30 min prior to each run. Drying runs of tomato were conducted at three temperatures (55, 65, and 75ºC) with fixed airflow of 2.0±0.1 m/s at atmospheric conditions. About 85±2 grams of tomato slices were used for each run. Moisture loss was recorded at 30 min intervals during drying by means of a digital balance (Mettler-Toledo AG, Grefensee, Switzerland, model BB3000) with an accuracy of ±0.1 g. The drying was carried out to final moisture content of 10% from initial moisture content of about 93.8% (w.b.). After drying, all products were packed in polyethylene bags wrapped in aluminum foil to prevent light damage and stored at ambient temperature. Drying tests were triplicated at each air temperature and averages are reported.

Mathematical modelling

Cherry tomatoes' moisture content (*M*), drying rate (*DR*) and moisture ratio (*MR*) were calculated using equations (1), (2) and (3), respectively:

$$M = \frac{m_w}{m_d} \tag{1}$$

where *M,* m_w and m_d are the moisture content (kg water / kg dry matter), water content (g) and dry matter content (g), respectively.

$$DR = \frac{M_{t+dt} - M_t}{dt} \tag{2}$$

where *DR,* M_{t+dt} and *t* are the drying rate (kg water / kg dry matter × min), moisture content at $t + dt$(kg water / kg dry matter) and drying time (min), respectively.

$$MR = \frac{M_t - M_e}{M_i - M_e} \tag{3}$$

where *MR* is the moisture ratio (dimensionless), M_t, M_e and M_i are the moisture content at selected time, at equilibrium and the initial value in kg water/kg dry matter, respectively. The values of M_e are relatively small compared to M_t or M_i, hence the error involved in the simplification be assuming that $M_e$is equal to zero is negligible [16].

Determination of the effective moisture diffusivity

The values of effective moisture diffusivity values were calculated according to the equation (4) given below:

$$ln(MR) = ln\left(\frac{8}{\pi^2}\right) - \left(\pi^2 \frac{D_{eff}t}{4L^2}\right) \tag{4}$$

Where D_{eff}, L and t are the effective moisture diffusivity (m^2/s), the half-thickness of the slab (m), and the drying time (s), respectively. D_{eff} can be calculated from the plot of *ln(MR)* versus *t*.

Determination of the activation energy

The effect of temperature on moisture diffusivity can be described by an Arrhenius-type equation [17]:

$$D_{eff} = D_0 \, exp\left(-\frac{E_a}{RT}\right) \tag{5}$$

whereD_0 is the pre-exponential factor of the Arrhenius equation (m^2/s), E_a is the activation energy for the moisture diffusion (kJ/mol), R is the ideal gas constant (kJ/mol K), and T is the temperature in (K). Eq. (9) can be rearranged into the form:

$$ln(D_{eff}) = ln(D_0) - \frac{E_a}{RT} \tag{6}$$

Rehydration

Rehydration experiments were carried out in distilled water bath at constant temperature of 25 (±1°C). Approximately 2.5 g of dried samples were added to 300 ml distilled water, in a 400 ml beaker. After rehydration (approximately 300 min), samples were removed, blotted with tissue paper to eliminate excess water on the surface, and weighed. Weights of dried and rehydrated samples were measured using an electronic digital balance (Precisa, model XB220A, Precisa Instruments AG, Dietikon, Switzerland) having a sensitivity of 0.001 g. The rehydration ratio (*RR*) was calculated as follows [18]:

$$RR = \frac{W_r}{W_d} \tag{7}$$

where $W_r$and W_d are the weight after and before rehydration, respectively. Three repetitions were performed for each treatment and mean value was calculated.

RESULTS AND DISCUSSION

Drying Curves

Figures 1, 2 and 3 show the effect of air drying temperature on the drying of cherry tomatoes. Drying curves are similar with the food products including fruits and vegetables drying studies. In the experiments studies, the drying times of untreated samples (control) needed for reaching the final moisture content are found as 1140, 870 and 660 min for the air temperatures of 55, 65 and 75°C, respectively.The average drying rate of control samples increased 1.72 times, respectively, as air drying temperature increased from 55°C to 75°C. Similar trend was observed for pre-treated samples at same temperatures. In the literature, it is explained that the higher heat absorption leads to higher product temperature, higher mass transfer driving force, faster drying rates and shorter drying times [2, 19, 20].

Effect of dipping solution

The effects of the dipping solution on changes in the moisture content of cherry tomato slices with drying time are shown in Figures 1, 2 and 3. The pre-treated samples dried faster than the control ones, thus confirming the fact that pre-treatment reduces the resistance to the movement of moisture thereby increasing the drying rate. The drying of control tomato slices took about 1140, 870 and 660 min at 55, 65 and 75°C, respectively. Corresponding values for the pre-treated samples such as citric acid and potas codes were 1110, 780 and 630 min, and 900, 570 and 420 min at same temperatures, respectively. Pre-treatment solutions caused a decrease in the drying times by about 2.70-57.14%. A similar effect of pre-treatment solution has been reported by Doymaz (2004) for apricots [10] and Kingsly *et al.* (2007) [9] for tomatoes.

Effect of moisture diffusivity

The effective moisture diffusivity values for different temperatures, calculated from Eq. (4), are given in Figure 4. It can be seen that the values of D_{eff} increased greatly with dipping solution. Due to influence of dipping solution on internal mass transfer of tomato slices during drying, pre-treated samples had higher effective moisture diffusivity values. The diffusivity values of pre-treated and control samples found between 2.26 to 6.22x10^{-9} m^2/s.

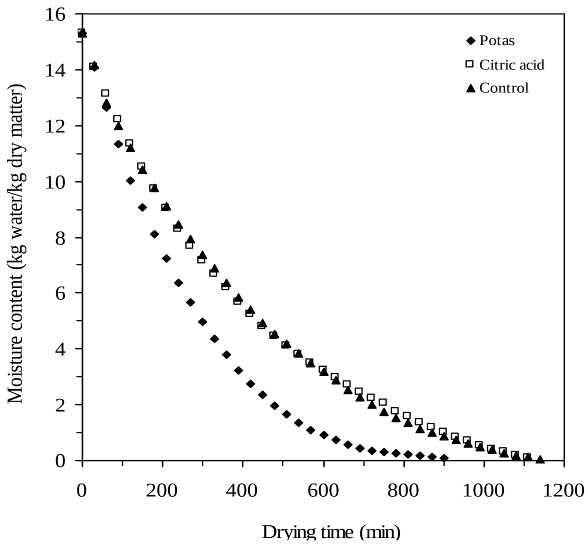

Figure 1. Changes in moisture content on a dry basis (kg water/kg dry matter) during drying at 55°C for pre-treated and untreated tomato slices

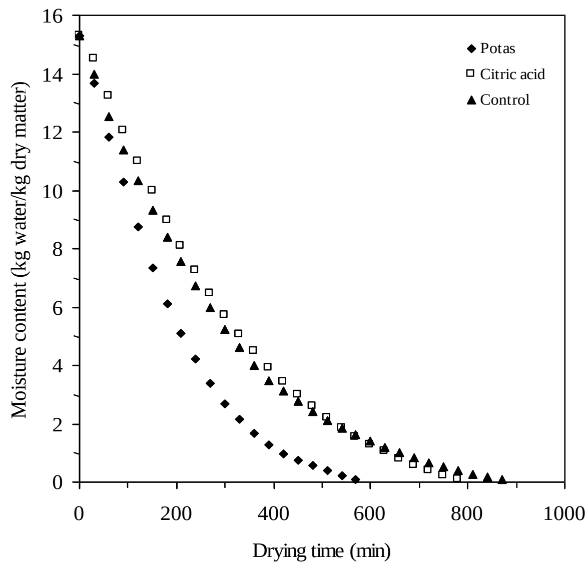

Figure 2. Changes in moisture content on a dry basis (kg water/kg dry matter) during drying at 65°C for pre-treated and untreated tomato slices

The values reported herein are within the general range of 10^{-8} to 10^{-12} m^2/s for biological materials [21]. The calculated values of D_{eff} were in consistency with the values given in literature such as 2.3-9.1×10^{-9} m^2/s for tomatoes dried from 60°C to 110°C [22], 3.72-12.27×10^{-9} m^2/s for tomatoes dried from 45°C to 75°C [23], 5.13-10.26×10^{-10} m^2/s for tomato dried from 50 to 80°C [2], and 3×10^{-10} and 5×10^{-10} m^2/s for cherry tomato by using convective drying [7]. The differences between the results can be explained by effect of type, slice thickness, composition, and tissue characteristics of the tomatoes and the proposed model used for calculation.

Activation energy

Temperature dependence of the effective moisture diffusivity values was described by an Arrhenius-type relationship. The activation energy was calculated by Eq. (6), and presented in Figure 5. Eqs. (8), (9), and (10) show the effect of temperature on D_{eff} of the pre-treated and the control tomato slices with following coefficients:

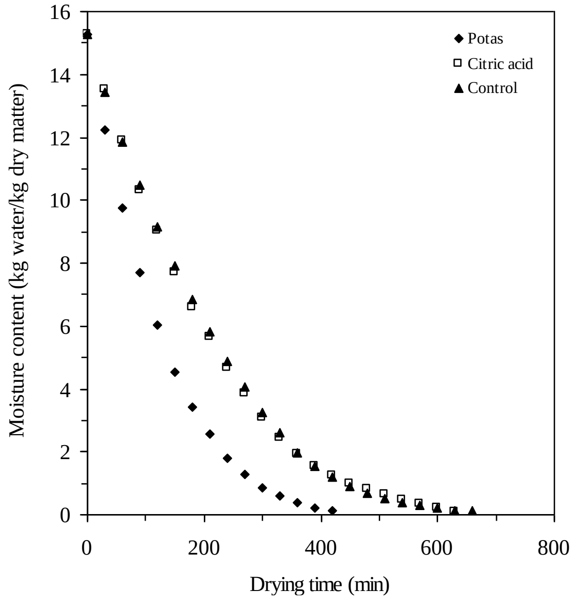

Figure 3. Changes in moisture content on a dry basis (kg water/kg dry matter) during drying at 75°C for pre-treated and untreated tomato slices

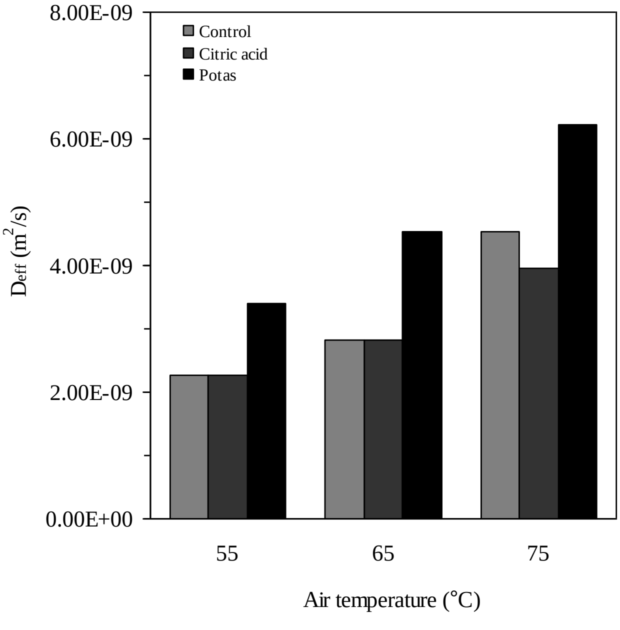

Figure 4. Variation of effective moisture diffusivity with air temperature

Potas:

$$D_{eff} = 1.280 \times 10^{\ 4}\, exp\left(-\frac{3460.6}{T}\right) \quad (R^2 = 0.9978) \tag{8}$$

Citric acid:

$$D_{eff} = 3.687 \times 10^{\ 5}\, exp\left(-\frac{3189.4}{T}\right) \quad (R^2 = 0.9823) \tag{9}$$

Control:

$$D_{eff} = 3.600 \times 10^{\ 4}\, exp\left(-\frac{3944.4}{T}\right) \quad (R^2 = 0.9524) \tag{10}$$

The activation energy values of potas, citric acid and control tomato slices found to be 28.77, 26.51 and 32.79 kJ/mol, respectively. The values of activation energy lie within the general range of 12.7-110 kJ/mol for food materials [21]. The pre-treated tomato slices showed lower activation energy than the control samples. Pre-treating of tomato slices resulted in a decrease in the activation energy require for mass diffusion during air drying.

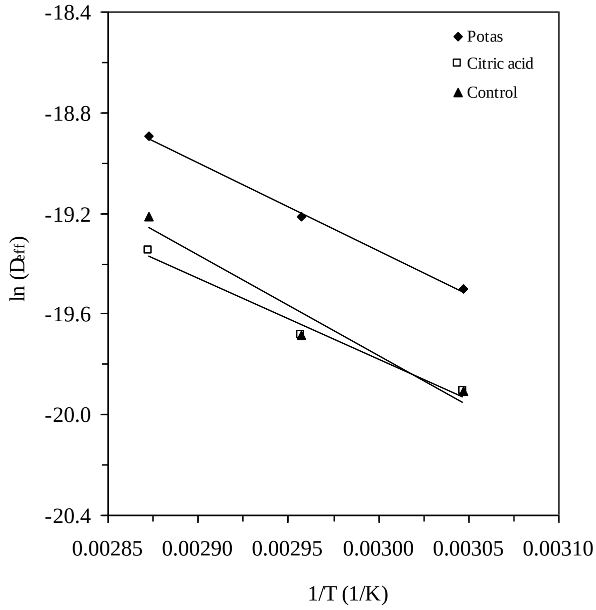

Figure 5. Arrhenius-type relationship between effective diffusivity and reciprocal absolute temperature

Rehydration ratio

Rehydration characteristics have been considered as a measure of the induced damage in the material during drying. The ability of food products to reconstitute depends primarily on the internal structure of the dried pieces and the extent to which the water-holding components (e.g., proteins and starch) have been damaged during drying [24]. The values of rehydration ratio of cherry tomato slices at different rehydration temperatures, calculated from Eq. (7) are shown in Figure 6. In the same figure, rehydration ratio was affected by the drying temperatures, since absorbed water decreased with temperature. As seen in Figure 6, the rehydration ratio of potas samples resulted in the highest rehydration, compared to citric acid and control samples.

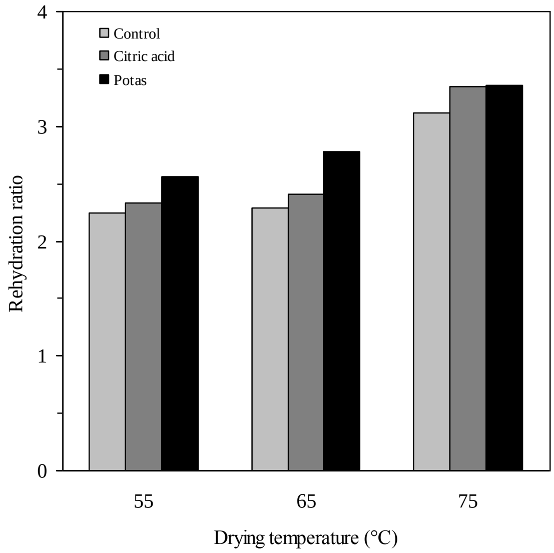

Figure 6. Effect of pre-treatment and air temperature on rehydration ratio of tomato slices

CONCLUSION

In the present study, the influence of pre-treatment and air temperature with on drying and rehydration characteristics of cherry tomato slices was investigated. According to the obtained results, it was seen that the air temperature and pre-treatment had more significant effects on drying and rehydration characteristics of tomato slices. The moisture effective diffusivity calculated from the second Fick's law of diffusion equation. The values of effective moisture diffusivity are found between $2.26\times10^{-9}$and 6.22×10^{-9} m^2/s as temperature increased from 50 to 70°C. The activation energy values of tomato slices were determined to be 28.77, 26.51 and 32.79 kJ/mol for potas, citric acid and control codes, respectively, being similar to values reported for other vegetables.

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