Spouted Bed Drying Characteristics of Rosehip (Rosa Canina L.)

Duygu Evin

Department of Mechanical Engineering, Firat University
Elazig, Turkey
devin@firat.edu.tr

Abstract: Drying kinetics, effective moisture diffusivity and activation energy of rosehip (Rosa Canina L.) dried in a spouted bed dryer were investigated. The effects of the spouted bed drying and the inlet air temperature in the range of 40-80°C on the moisture ratio degradation and the drying rate of rosehip (Rosa Canina L.) were studied experimentally. Drying took place in the falling rate period. Drying time was reduced by 83% using a temperature of 80°C instead of 40°C. The effective moisture diffusivities of rosehip under spouted bed drying ranged from 2.5x10-10 to 2.56 x10-9 m2/s. The values of diffusivities increased with the increase in inlet air temperature. An Arrhenius relation with an activation energy value of 51.6 kJ/mol expressed the effect of temperature on the diffusivity.

Keywords: Spouted bed drying; rosehip; drying kinetics; effective moisture diffusivity; activation energy.

1. INTRODUCTION

In recent years, much attention has been paid to the quality of foods during drying. Both the method of drying and physicochemical changes that occur during drying affects the quality of the dehydrated product [1]. Since rosehip fruits are rich source of vitamin C and also have a rich composition (K, P minerals and vitamin contents), they have traditionally been used as a vitamin supplement or for health food products in many European countries. Rosehip extracts also possess high antioxidant capacity as well as antimutagenic effects [2].

Spouted bed technology in solid-gas system [3] has been proven to be an effective means of contacting for gas and course solid particles such as Geldart type D particles [4]. Since the agitation of solids which permits the use of high air temperature provides rapid drying without the risk of thermal damage, drying of coarse, heat sensitive granular materials has been the most popular application of the spouted beds.

In present study, drying kinetics, effective moisture diffusivity, and activation energy of rosehips dried in the spouted bed dryer were investigated. The effects of the spouted bed drying, the inlet air temperature and the initial moisture content of the rosehips on the investigated properties were discussed.

2. MATERIAL AND METHOD

2.1. Samples

Fresh rosehips (Rosa Canina L.) were harvested by hand. They were collected in different months (September and October) because it was also aimed to investigate the effect of the initial moisture content of the rosehips on drying. Rosehips approximately the same size were selected and the average length and the diameter were measured as 2.02 and 1.125 cm, respectively. An infrared moisture analyzer (Sartorius MA45, Germany) was used to determine the initial moisture contents.

2.2. Drying procedure

The experimental set-up of Paraboloid Based Spouted Bed (PBSB) dryer and the spouted bed drying mechanism are given in Fig.1 and Fig.2, respectively. The details of the experimental set-up and the spouted bed drying procedure were given in a previous study of the author [5].

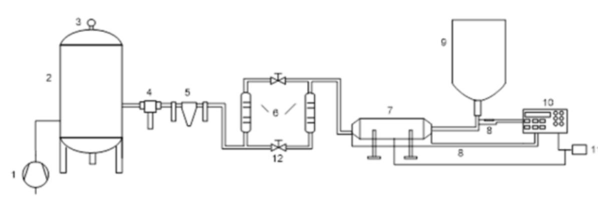

Figure 1. (1) Screw type compressor, (2) Air tank, (3) Pressure gauge, (4) Air filter, (5) Pressure regulator, (6) Rotameters, (7) Electric heater, (8) T type thermocouples,

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(9) Spouted bed, (10) Data acquisition board, (11) PID controller.

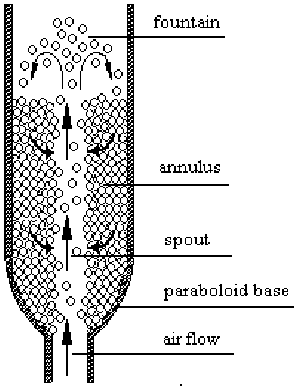

Figure 2. The spouted bed drying mechanism.

1.5 kg of rosehips were dried at 40, 70 and 80oC inlet air temperatures with 85 m3/h air flow rate. At ten minute intervals, rosehip samples (approximately 5 g) were removed from the spouted bed. The moisture content of the samples during drying was determined with an infrared moisture analyzer (Sartorius MA45) to obtain the variation of moisture content with drying time.

2.3. Effective moisture diffusivity

The experimental drying data for determination of diffusivity was interpreted by using Fick's second law.

$$\frac{\partial M}{\partial t} = D_{eff}\frac{\partial^2 M}{\partial r^2} \quad (1)$$

The solution to Eq. (1) developed by Crank (1975) [6] can be used for various regularly shaped bodies. Assuming uniform initial moisture distribution, constant diffusion coefficient and negligible shrinkage Eq. (2) can be applicable for particles with cylindrical geometry.

$$MR = \frac{4}{\pi^2}\exp\left(-\pi^2\frac{D_{eff}\,t}{r^2}\right) \quad (2)$$

where MR is the moisture ratio and Deff is the effective moisture diffusivity, m^2/s.

2.4. Activation energy

The factors affecting Deff are significant to clarify the drying characteristics of a food product. Temperature is one of the strongest factor that effects on Deff. This effect can generally be described by an Arrhenius equation [9]:

$$D_{eff} = D_0\exp\left(-10^3\frac{E_a}{\bar{R}T}\right) \quad (3)$$

where, D_0 is the Arrhenius factor (m2/s), E_a is the activation energy for diffusion (kJ/mol), R¯ is the universal gas constant (kJ/mol.K), and T is the air temperature (K).

3. RESULTS AND DISCUSSION

3.1. Drying Kinetics

The spouted bed drying curve of rosehip in which the moisture content decreases with the drying time is given in Fig 3. The effect of the air temperature on drying of rosehips can also be seen in this figure. Moisture content decreases gradually at 40^{o}C. On the other hand, there is a sharp decrease in moisture content at 80^{o}C. The drying time required for reducing the moisture content of rosehip from 0.44 to 0.07 (g water/g dry matter) changed between 1035 and 180 min depending on the air temperature. Increasing the air temperature in a certain air temperature range (40-80^{o}C in this study) accelerates the drying process.

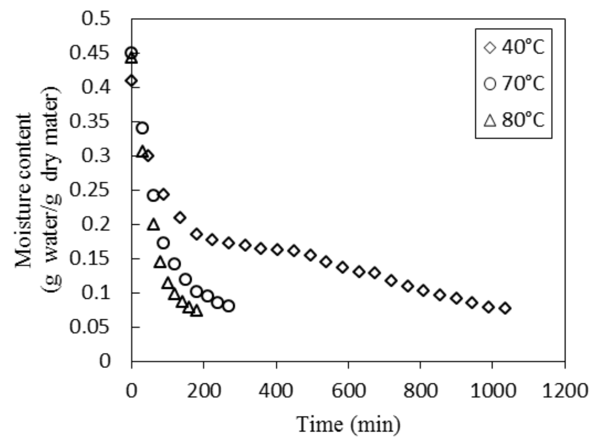

Figure 3. The spouted bed drying curve of rosehip.

The variation of drying rate with moisture ratio which explains the spouted bed drying behavior of rosehip is represented by Fig. 4. The curve shows only the falling rate period. In spouted bed drying, the whole surface of the solid is in contact with the air, so high heat and mass transfer coefficients cause a rapid evaporation at the surface. Therefore, main drying takes part in the spout region. However, moisture needs time to be transferred from the inner part of the solid to the surface. This especially occurs in the falling rate period at which the internal diffusion is essential. In the annulus region of the spouted bed, the moisture distribution of the particles are homogenized while traveling from the top to the bottom. As can be seen from this figure, drying rate increased with the increasing air temperature. The highest drying rates were achieved for spouted bed drying at 80oC inlet air temperature.

Effect of the initial moisture content on spouted bed drying of rosehip and variation of the drying rate for 0.44 and 0.8 initial moisture contents are represented in Fig. 5 and Fig. 6, respectively. So as to investigate the effects of initial moisture ratio on drying kinetics, a group of rosehips were harvested in September and the other in October.

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Therefore rosehips with two different initial moisture contents (Mo) 0.44 and 0.80 (g water/ g dry matter) were dried in the spouted bed. Increase in the initial moisture content from 0.44 to 0.80 db increased the drying time by 55%.

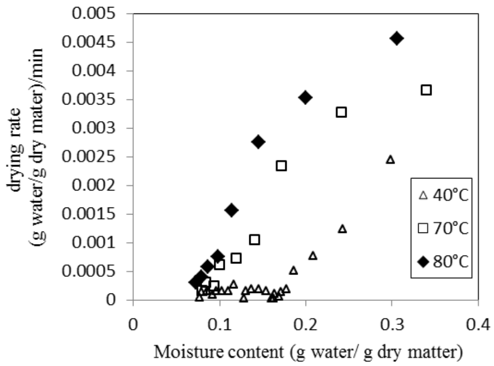

Figure 4. The variation of drying rate with moisture ratio.

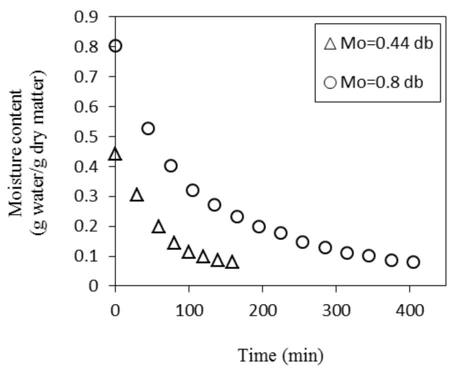

Figure 5. Effect of the initial moisture content on spouted bed drying of rosehip and variation of the drying rate for 0.44 and 0.8 initial moisture contents.

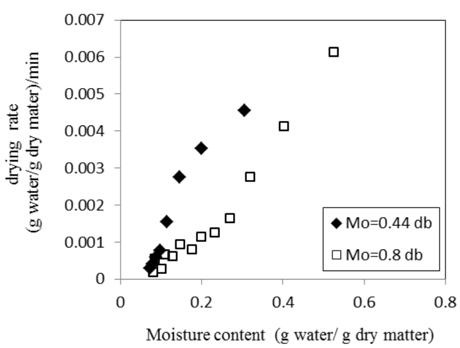

Figure 6. Effect of the initial moisture content on spouted bed drying of rosehip and variation of the drying rate for 0.44 and 0.8 initial moisture contents.

3.2. Effective moisture diffusivity and activation energy

Values of the effective moisture diffusivities of rosehip determined by Eq.7 are given in Table 2. The effective diffusivities of rosehip under spouted bed drying at 40-80oC ranged from 2.5x10-10 to 2.56 x10-9 m2/s. The values of diffusivities increased with the increase in inlet air temperature. The determined values lie within the general range of 10-11 to 10-9 m2/s for food materials [10].

Fig.7 shows the influence of temperature on the effective diffusivity. The values of ln(Deff) plotted versus 1/T was found to be essentially a straight line in the range of temperatures indicating Arrhenius dependence.

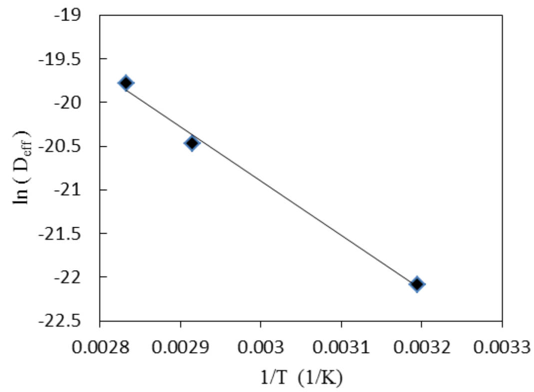

Figure 7. The influence of temperature on the effective diffusivity.

The activation energy of rosehip was found to be 51.6 kJ/mol. This activation energy for water diffusion in rosehip is higher than those given in the literature for convective drying of other foods such as; red chilli, 37.76 kJ/mol [11]; potato, 12.32-24.27 kJ/mol [12]; green bean, 35.43 kJ/mol [13]; carrot 28.36 kJ/mol [14], and pistachio nuts, 30.79 [15], but lower than mint 82.93 kJ/mol [16] and coconut 81.11 kJ/mol [17].

4. CONCLUSION

Drying took place in the falling rate period. Increasing the air temperature in a certain air temperature range (40-80oC in this study) accelerated the drying process. Drying time was reduced by 83% using a temperature of 80°C instead of 40°C. The effective diffusivities of rosehip under spouted bed drying at 40-80oC ranged from 2.5x10-10 to 2.56 x10-9 m2/s. The values of diffusivities increased with the increase in inlet air temperature. The activation energy of rosehip was found to be 51.6 kJ/mol. Increase in the initial moisture content from 0.44 to 0.80 db increased the drying time by 55%.

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