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Experimental Investigation of Drying Behavior of Rosehip in a Cyclone-Type Dryer

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***Abstract*—**This paper describes an experimental investigation of the drying behavior and conditions of rosehip in a convective cyclone-type dryer. Drying experiments were conducted at air inlet temperatures of 50, 60 and 70 o C and air velocities of 0.5, 1 and 1.5 ms^{-1}. The parametric values obtained from the experiments were fitted to the Newton mathematical models. Consequently, the drying model developed by Newton model showed good agreement with the data obtained from the experiments. Concluding, it was obtained that; (i) the temperature is the major effect on the drying process, (ii) air velocity has low effect on the drying of rosehip, (iii) the C-vitamin is observed to change according to the temperature, moisture, drying time and flow types. The changing ratio is found to be in the range of 0.70-0.74.

***Keywords*—**Rosehip, drying, food quality.

I. Introduction

DRYING is a process in which liquid is removed from a wet product by warm air flow. The drying process which is an important subject in chemical and food industries include both heat and mass transfer together. Saving the food by drying is an ancient application. The fruits and vegetables or general foods are dried by solar heat or in the artificial driers. Some products are not possible to be dried with sun, and the desired quality may not be obtained when it is done. Therefore, drying in artificial dryers, namely technical drying has impetus due to it causes to decrease the drying time and to obtain the desired hygienic conditions [1, 2].

Rosehips have traditionally been used as a vitamin supplement in many European countries because of the fruits is rich sources of ascorbic acid [3-5]. Rosehip is also high in minerals (K, P) and other vitamins.

The study of drying behavior of different materials has been subject of interest for various investigators on both theoretical and application grounds during the past 60 years. Recently, there have been many studies on the drying behavior of various vegetables and fruits such as potato [6], onion [7], and green pepper [1], green bear and pumpkin [8] and pistachio [9].

In this study, the drying behavior of rosehip in a convective cyclone-type dryer has been investigated experimentally. New mathematical modeling by using drying models from the literature has been carried out. The results are presented with tables and graphs.

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II. General Information about Rosehip

Rosehips are used for herbal tea, jam, jelly, syrup, soup, beverages, pies, bread, wine, and marmalade. A few rose species are sometimes grown for the ornamental value of their hips, such as *Rosa moyesii*, which has prominent large red bottle-shaped fruits. Rosehips have recently become popular as a healthy treat for pet chinchillas and guinea pigs. These small rodents are unable to manufacture their own vitamin C and are unable to digest many vitamin-C rich foods. Rosehips provide a sugarless, safe way to increase their vitamin C intake [10].

Dried rosehips are also sold for primitive crafts and home fragrance purposes. Rosehips are scented with essential oils and can be used as a potpourri room air freshener. Rose hips are commonly used as a herbal tea, often blended with hibiscus and as an oil. They can also be used to make jam, jelly, marmalade and wine. Rosehip soup, "nyponsoppa," is especially popular in Sweden. Rhodomel, a type of mead, is made with rose hips [10]. Two subfigures including fresh and dried forms of rosehips are presented in Fig. 1.

(a)

(b)

Fig. 1 Rosehip (a) fresh rosehips (b) dried rosehips

III. Experimental Study

A. Experimental Setup

Drying experiments were carried out for rosehips grown in Elazig and Tunceli, Turkey. Extracted portions of fruit and flower stalks before used in experiments were stored in a freezer in plastic bags filled. Fruits used in the experiments have the average dimensions, 15 mm in width 20 mm in length, and average seed weight varies in the range of 2-3 gram**.** After the dryer reached up to steady state conditions, the whole rosehips are put on the trays of dryer and left to dry. The initial and final moisture contents of the rosehips were determined by using an *Infrared Moisture Analyzer* (*METTLER, LJ16, and Switzerland*).

Drying experiments were carried out at the drying air temperatures; 50, 60 and 70°C and drying air velocities 0.5, 1, 1.5 m/s. Drying was continued until the final moisture content of the samples reached to the level of 20% approximately. During the experiments, ambient temperature, relative humidity, inlet and outlet temperatures of drying air in the dryer chamber were recorded. For all test conditions, the variation of the moisture with respect to drying time at constant temperature, constant velocity and dry condition base are presented in the figures.

Fig. 2 illustrates the schematic diagram of the cyclone type dryer. Briefly, it consists of fan, resistance and heating control systems, air-duct, drying chamber in cyclone type, and measurement instruments. The heating system consisted of an electric 4000 W heater placed inside the duct. The rectangular duct included air fan and resistance was constructed from sheet iron in 1000 mm length, 200 mm width and 250 mm height. The drying chamber was constructed from sheet iron in 600 mm diameter and 800 mm height cylinder. In the measurements of temperatures, J type iron-constantan thermocouples were used with a manually controlled 20-channel automatic digital thermometer (ELIMKO, 6400, Turkey), with reading accuracy of ±0.1 °C. A thermo hygrometer (EXTECH, 444731, China) was used to measure humidity levels at various locations of the system. A 0-15 miss range anemometer (LUTRON, AM-4201, Taiwan) measured the velocity of air passing through the system. Moisture loss was recorded at 20 minutes intervals during drying for determination of drying curves by a digital balance (BEL, Mark 3100, Italy) in the measurement range of 0-3100 g and an accuracy of ± 0.01 g.

B. Data Reduction

The drying rate of rosehip was calculated by using Eq. (1). [1]

$$Drying\ rate = \frac{dM}{dt} = \left(\frac{M_{t+dt} - M_t}{dt}\right)_{k.t} \quad (1)$$

Moisture content was calculated using Eq. (2).

$$\%M = \frac{W_s}{W_k}.100 \quad (2)$$

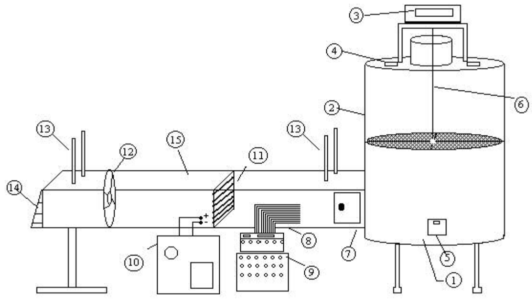


Fig. 2 Experimental set-up (1- Drying chamber, 2- Tray, 3- Digital balance, 4-Observed windows, 5-Digital thermometer, 6-The balance bar, 7-Control panel, 8-Thermocouples, 9-Digital thermometer and channel selector, 10-Rheostat, 11- Resistance, 12- Fan, 13- Wet and dry thermometers, 14- Adjustable flab, 15- Duct)

The moisture ratio of rosehip during the thin layer drying experiments was calculated using the following equation;

Moisture ratio ;

$$MR = \frac{M - M_e}{M_0 - M_e} \quad (3)$$

where;

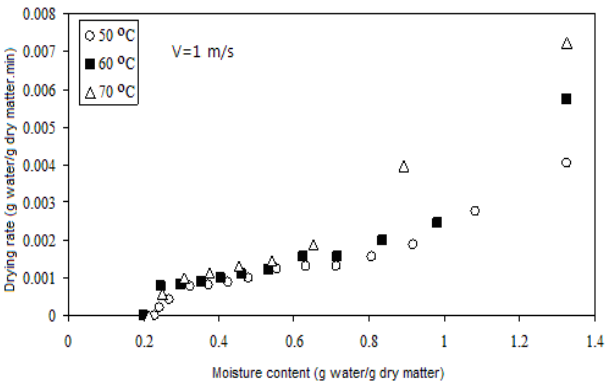
- M: moisture content, (% dry basis)
- t : time (min)
- M_e: equilibrium moisture content, (% dry basis)
- W_s: water weight of the product
- M_o: initial moisture content, (% dry basis)
- W_k: dry weight of the product
- M_t : moisture content at t, (% dry basis)
- M_{t+dt} : moisture content at t+dt, (% dry basis)

IV. Results and Discussions

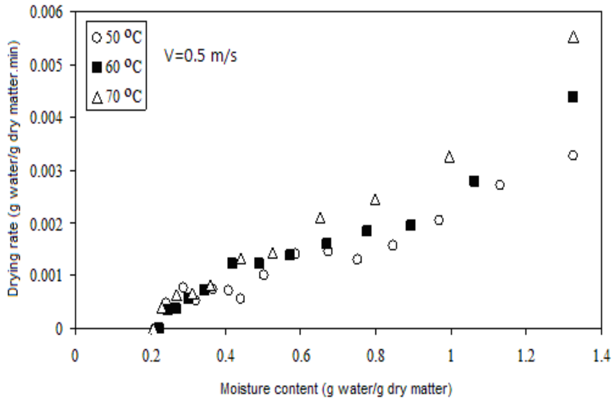
Attention is now directed to the experimental results and their detailed discussions. It was found that temperature is the dominant parameter that affects the drying process of rosehips. On the other hand the velocity was found the weakest parameter on the drying process.

There is an inverse relationship between air temperature and air velocity with drying time; an increase in air temperature resulted in a decrease in the drying time. At the temperature above 70^{o}C discoloration of the fruit was observed and it was seen that fruit is cooked and its color is turning to black.

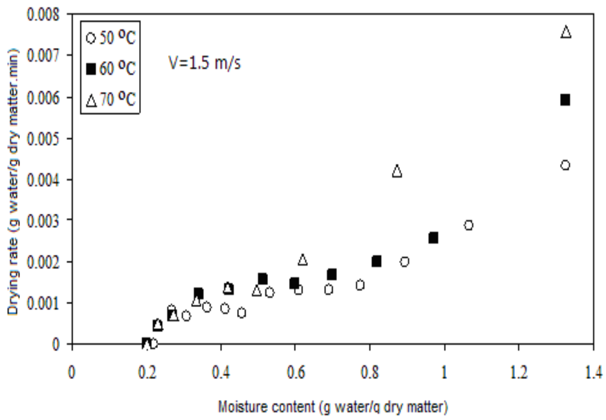
By use of Eq. (1) the time dependent derivation of drying rate is calculated, by this derivation the drying velocity versus each time interval is found out and then presented by graphs. The variation of drying velocity versus moisture rate for constant drying air velocity and variable drying air temperatures is shown in Fig. 3 and 4.



(a)



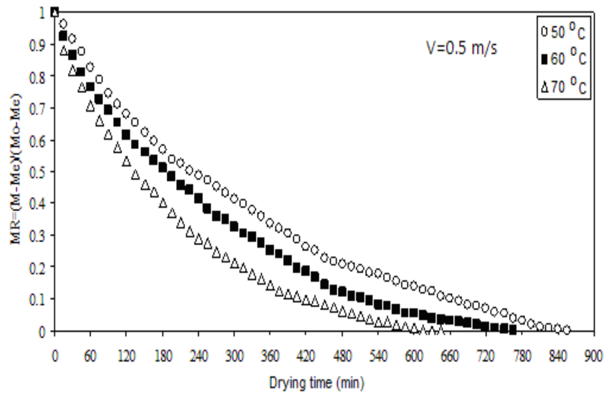
(b)



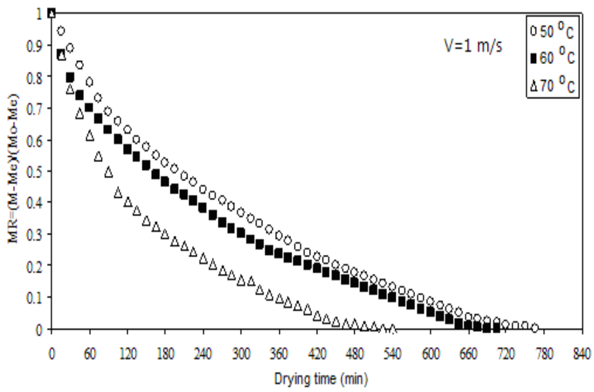
(C)

Fig. 3 Variation of drying rate with moisture content

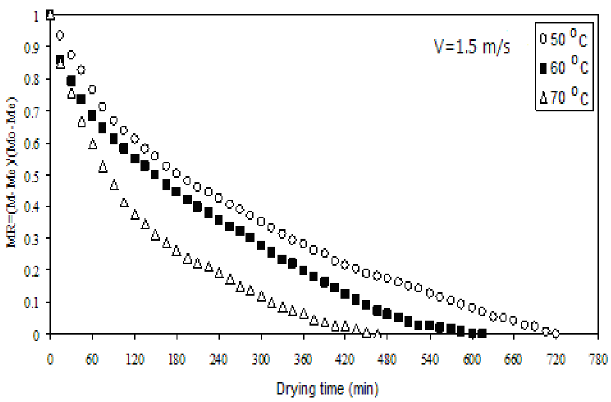
Drying process occurred in the decelerating drying velocity period, and the constant drying velocity period is observed in the experiments. It was also observed that, when the temperature and the velocity of drying air increases, moisture rate and drying time rapidly decreases and the drying velocity increases meanwhile. According to the experimental results, the highest drying velocity is obtained at the air temperature 70 °C, and air velocity 1.5 m/s, on the other hand the lowest drying velocity is observed at the air temperature 50 °C and air velocity 0.5 m/s. It is for sure that, increasing the temperature has an effect on drying velocity.



(a)



(b)



(c)

Fig. 4 Variation of drying grate with drying time

This is because; as the relative humidity of the drying air decreases with temperature increment, the diffusion becomes faster. The effect of air velocity on drying velocity increment is stronger than the effect of air velocity increment. A vapor film is observed on the surface of drying material during the drying process. Air velocity forces this vapor film to move and by that way causes to increase the drying velocity directly.

The moisture rate versus drying velocity of the rosehip samples are presented in Table I. The variation of drying velocity with moisture rate has an exponential trend ($\frac{dM}{dt} = a.M^b$). The regression coefficient of the empirical equation is found to be in the range of (R^2) 0.90 -0.98.

TABLE I
REGRESSION COEFFICIENTS OBTAINED BY APPLYING NEWTON-RAPHSON MODEL ON TO THE OBTAINED DATA

Temperature	Correlation	Regression coefficient
	Air velocity: 0.5 m/s	
50 ºC	$dM/dt = 0.0021*M^{1.1076}$	$R^2 = 0.908$
60 ºC	$dM/dt = 0.0028*M^{1.3611}$	$R^2 = 0.9544$
70 ºC	$dM/dt = 0.0036*M^{1.4121}$	$R^2 = 0.9851$
	Air velocity: 1 m/s	
50 ºC	$dM/dt = 0.0025*M^{1.3351}$	$R^2 = 0.9115$
60 ºC	$dM/dt = 0.0027*M^{1.0802}$	$R^2 = 0.8991$
70 ºC	$dM/dt = 0.0043*M^{1.4383}$	$R^2 = 0.9626$
	Air velocity: 1.5 m/s	
50 ºC	$dM/dt = 0.0024*M^{1.0686}$	$R^2 = 0.8775$
60 ºC	$dM/dt = 0.0031*M^{1.1795}$	$R^2 = 0.9042$
70 ºC	$dM/dt = 0.0048*M^{1.508}$	$R^2 = 0.9808$

From the curves of moisture rate versus time, the last value which shows the end of the drying process is considered as the balance moisture rate (0.20 $g_{water}/g_{solidmaterial}$). The dimensionless moisture ratio $\left(\frac{M - M_e}{M_o - M_e}\right)$ at each time interval is determined. The variation of dimensionless moisture rate versus time under the conditions of constant drying air velocity, variable drying air temperatures are presented in Figure 4.

Humidity curves ($MR = \frac{M - M_e}{M_0 - M_e}$) in the literature are compared to Newton's equation for moisture content. Equation used in the regression coefficient (R^2) ranged from 0.81 to 0.94. Some data obtained by applying Newton-raphson correlation are found out and new regression coefficients are listed in Table II.

During the drying process, the protection of some vitamins and nutritional value of the temperature-sensitive foodstuffs is an indication of quality. Rosehip fruit makes an important feature of food due to its taste and vitamin C value. Vitamin C, depending on temperature and moisture content are known to disappear over time [11]. Therefore, change of vitamin C in fruit after drying was investigated.

At the beginning of the experiments, fresh fruit vitamin C value analysis was conducted. The vitamin value of fresh fruit is named as C_0. And after the drying experiments had done, similar analysis was conducted to obtain the vitamin value of dried fruit, which is called as C. The ratio of C/C_0 is calculated and the results are exhibited in Table III.

TABLE II
RECO REGRESSION COEFFICIENTS OBTAINED BY APPLYING NEWTON-RAPHSON MODEL ON TO THE OBTAINED DATA OF DIMENSIONLESS HUMIDITY

Temperature	Drying air velocity	R^2
	0.5 m/s	
50 ºC	MR=1.4459*exp(-0.0046*t)	0.8744
60 ºC	MR= 1.4747*exp(-0.0058*t)	0.9335
70 ºC	MR= 1.6086*exp(-0.0078*t)	0.8611
	1 m/s	
50 ºC	MR= 1.5116*exp(-0.0054*t)	0.8734
60 ºC	MR= 1.4674*exp(-0.006*t)	0.8093
70 ºC	MR=1.4782*exp(-0.0092*t)	0.8571
	1.5 m/s	
50 ºC	MR= 1.254*exp(-0.0048*t)	0.9029
60 ºC	MR= 1.5995*exp(-0.0074*t)	0.8474
70 ºC	MR= 1.1842*exp(-0.0088*t)	0.9397

TABLE III
CHANGES IN VITAMIN C AT THE END OF DRYING EXPERIMENTS

Drying air velocity m/s	Vitamin C change (C/C_0)		
	50ºC	60ºC	70ºC
0.5	0.70	0.72	0.73
1	0.71	0.72	0.73
1.5	0.71	0.73	0.74

V. CONCLUSIONS

Effects of process parameters on drying of rosehip fruit and some findings from the tests were discussed. As a result, some remarks are concluded as follow:

1. The most effective parameter on drying of rosehip fruit is temperature. Drying time is reduced by the increase of the temperature. Temperatures that are below 50ºC are not suitable for drying, since a long drying time is required. At the temperature above 70ºC, discoloration of the fruit was observed and it was seen that fruit is cooked and its color is turning to black.
2. There is no significant effect of air velocity on drying of rosehip fruit. Since the outer shell of the fruit has a great resistance to drying, the leakage of the moisture from the fruit to the outside becomes hard. Air velocity is effective especially in the cases, in which moisture is stored on the outer shells, meaning the drying which is performed under constant air velocity. Since the diffusion is much more effective than the convection on the drying of rosehip,

keeping the air velocity at low degrees gains importance by means of the cost.

3. Humidity equation ($MR=\frac{M-M_e}{M_o-M_e}=\exp(-kt)$) versus moisture ratio curves has an identical trend to that of Newton's trend cited in the literature. Mathematical expressions considering different temperature, air velocity and flow are presented in the tables. Equation used in the regression coefficient (R^2) ranged from 0.82 to 0.94.
4. Drying the fresh fruit and keeping it store will cause a loss of vitamin value. The C-vitamin is observed to change according to the temperature, moisture, drying time and flow types. The changing ratio is found to be in the range of 0.70-0.74.

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