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Research Note

Grape Drying

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In this paper, drying Iranian seedless white grape (sultana) was considered using a laboratory batch dryer. The effects of pretreatment and temperature on the drying rate of grape at constant air velocity were studied. Pretreatment solutions containing different alkaline materials with different concentrations and temperatures were considered. Dipping grape into an alkaline solution increases the drying rate substantially. Increasing the air temperature of the dryer from 60 °C to 70°C accelerated the drying rate (drying time decrease) of the pretreated grape. Depending on the pretreatment and air temperature conditions, the drying process took about 450 to 900 minutes. The shortest drying time and the best quality dried product were obtained with grapes dipped in a solution of potassium carbonate 5% at 42°C. The mean apparent diffusivity of moisture for K_2CO_3 pretreatment was calculated at 50, 60 and 70°C, and the values were fitted into an Arrhenius type model. Moisture sorption isotherms of currant were determined at 20, 30 and 40°C using static gravimetric methods. The modified Halsey equation was used to predict experimental data for a water activity range of 0.1 − 0.85.

INTRODUCTION

For centuries, exposing grape to direct sunlight has been the way to prepare raisins in several countries. However, in recent years this procedure has been widely replaced, due to economical and quality considerations, with drying in forced air convection ovens and many investigators have considered it [1-3]. The first step in the grape drying process is the selection of seedless grape, having a high sugar-to-acid ratio, after which pretreatment procedures are applied based on dipping the grapes in a suspension of alkaline materials and oil. Then, the grape is exposed to direct sunlight or placed in a convectional air dryer. It has been demonstrated that through grape pretreatment, surfactants, resulting from reactions of oil fatty acids and alkaline components, remove the grape waxy coating [4,5]. In this work, several solutions for the pretreatment procedure within a temperature range of 40 − 100°C were considered in order to find the optimum conditions for the drying process.

Grape drying is a composite process which involves simultaneous heat and mass transfer phenomena. The process is partially developed under unsteady conditions. Due to the complexity of the physical phenomena involved in the process, the common way to proceed has been a semi-empirical approach i.e., experimental drying data are correlated with simple mathematical equations without taking into account the physical laws governing the phenomena involved in the process. Liquid or vapor diffusion was assumed to be the primary mass transfer mechanism in the drying of grape.

Several investigators have reported sorption data for different types of grape [6-10]. In this study, the Iranian seedles white grape which has not been studied previously, is considered.

The objectives of this study can be characterized into three categories, first, to study the effects of different pretreatments on drying rate, second, to study sorption characteristics of grape in order to suggest a mathematical model for the prediction of the sorption behavior and third, to determine the diffusivity by the slope method and present a temperature relationship for diffusivity.

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EXPERIMENTAL WORK

Sorption Isotherms

The method considered here for determination of sorption isotherms is the standard static gravimetric method developed by the European Cooperation Project COST 90 [11]. The experimental apparatus consists of a thermostatically controlled oven accurate to 0.2°C containing eight 1-L air-tight jars. Eight saturated salt solutions were prepared with a range of 0.1 to 0.85 water activity. Samples of thin sliced raisins were dried using P_2O_5 for 15 days, which were, then, placed on wire dishes above the saturated salt solutions. Eight jars were kept in the oven at 20, 30 and 40°C for three to four weeks.

After equilibrium was attained, the samples were analyzed for their moisture content using the vacuum oven method (AOAC) [12].

Grape Drying

The four laboratory dryers are shown schematically in Figure 1. All dryers were designed similarly and worked simultaneously. The height of dryer wooden cabinet, covered with iron sheet construction, was 160 cm with a cross section of 45 × 50 cm. A turbine fan blew the air into the dryers over the two electric heaters (2 kW). The drying chamber consisted of a metal screen tray linked to the arms of a load cell (L). The dry bulb temperature was regulated by an electronic controller (DE).

The air velocity and temperature above and below the sample were measured by an electronic anemometer and thermometer, respectively.

The fan was turned off at regular intervals (five min.) so that the sample was equilibrated and could be weighed. Weight of the sample, temperature inside the dryer and ambient temperature and relative humidity were measured at each interval and were saved in a special program of a computer connected to the dryers.

A single layer of grape was placed on the tray and air passed, in cross flow, through the product (SH). In each drying experiment, about 1200 gr grape berries were separated from stems and dipped in one of the following solutions:

A1) NaOH 30 g/l solution at 85°C for 2 sec washed with water at 25°C for 5 min,

A2) NaOH 20 g/l solution at 85°C for 2 sec washed with water at 25°C for 5 min,

A3) NaOH 3 g/l solution at 85°C for 2 sec washed with water at 25°C for 5 min,

A4) NaOH 1.5 g/l solution at 85°C for 30 sec washed with water at 25°C for 5 min,

A5) NaOH 1.5 g/l solution at 100°C for 15 sec washed with water at 25°C for 5 min,

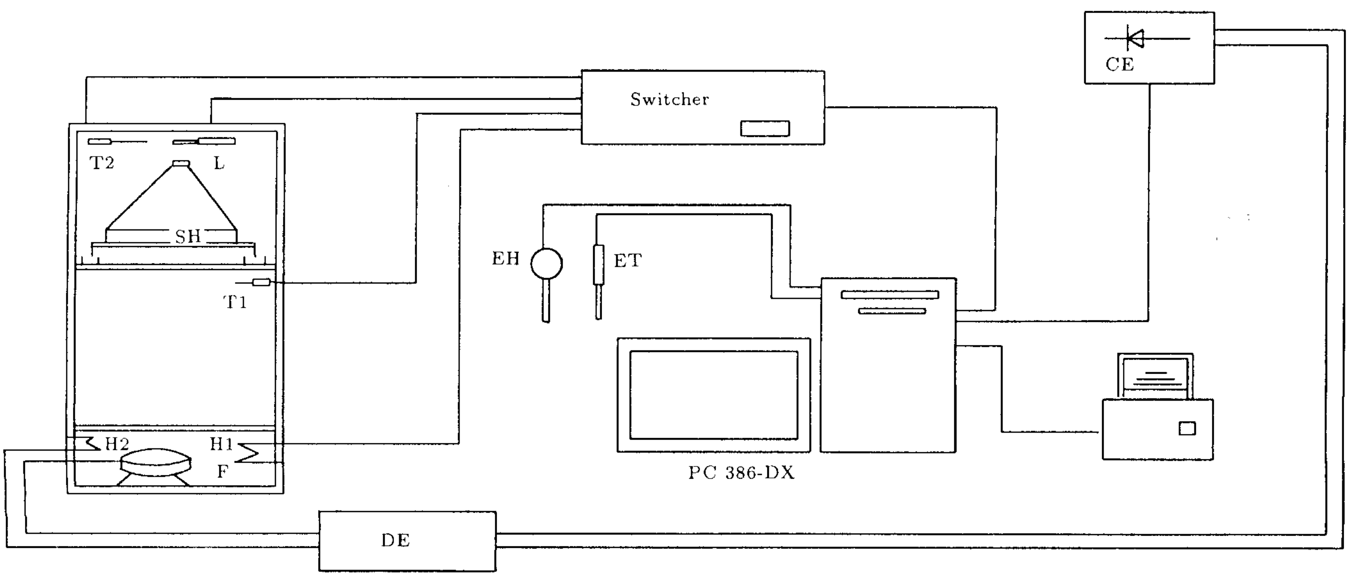
A6) K_2CO_3 50 g/l and 4 ml/l olive oil emulsion for 5 min at 42°C,

A7) Na_2CO_3 40 g/l solution at 42°C for 1 min,

A8) Na_2CO_3 5 g/l plus K_2CO_3 45 g/l and 4 ml/l olive oil emulsion for 5 min at 42°C,

A9) NaOH 3 g/l plus K_2CO_3 5 g/l and 4 ml/l olive oil emulsion for 2 sec at 85°C,

A10) No treatment.



L: Load cell, SH: Sample holder, T1 and T2: Temperature sensore, H1 and H2: Heaters, CE: Control electronic, F: Fan, EH: Environmental humidity sensor, DE: Drying electronic, ET: Enviromental thermometer.

Figure 1. Schematic diagram of experimental dryers.

Air drying was carried out at a constant temperature of 65°C, mean relative humidity 20% and air velocity 2 m/s. In another experiment, five samples (A4, A5, A6, A7 and A10) were chosen and the grapes were dried at 60, 65 and 70°C. Moisture content was expressed on a dry basis, x (kg water/kg dry solid). The dry solid of each sample was determined by the vacuum oven method (AOAC).

A good quality product should have a light yellow color, a soft texture and no crystallized sugar [1,5,13].

Moisture Diffusivity

White seedless grapes of uniform size were selected for study (20 grape berries). The grapes were pretreated with 5% K_2CO_3 and 0.4% olive oil (A6). Experiments were conducted at the temperature of 50, 59 and 70°C under constant air velocity (2 m/s).

Moisture loss was determined by weighing the sample on an electronic balance (0.01 gr) at predetermined time intervals. Drying process was continued untill the grapes dried into raisins (with 13% moisture content).

RESULTS AND DISCUSSION

Sorption Isotherms

Moisture sorption isotherms of raisin at 20, 30 and 40°C are shown in Figure 2. In general, moisture content is expected to decrease with increasing temperature at a given water activity. This was observed for raisins in the water activity region below 0.5. However, above this region the opposite result was observed. Raisins adsorbed more water at higher temperatures. This means that in high humidity regions, the water activity at constant moisture content decreased as the temperature increased. At high water activity, sugar is the determining factor for water sorption in raisins. At low water activity, the physical state of the sugars may have an important effect on the sorption properties. In [7,14], it has been shown that the amorphous sugar can absorb more water than crystalline sugar. At water activity higher than 0.7 and high temperatures, sugar is transformed to an amorphous form, resulting in an increase in the amount of water adsorption.

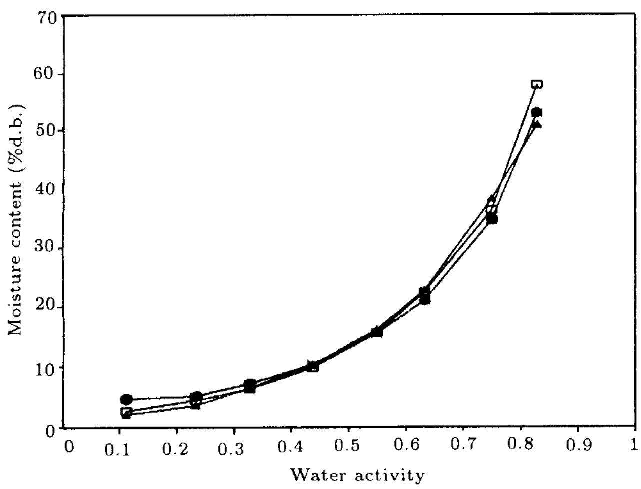


Figure 2. Sorption isotherms of raisin at • 20, □ 30 and ▲ 40°C.

Table 1. Analysis of sorption data according to the modified Halsey equation.

Temp. (°C)	k	C	r	RMS%
20	1.1210	4.9601	0.7092	14.6612
30	1.2090	3.6066	0.55555	8.9281
40	1.3301	3.5431	0.5001	9.8049

Theoretical and empirical equations like BET, GAB, Halsey, Modified Halsey [15], Iglesias and Chirife [10,15,16] were investigated for fitting the obtained experimental data. The modified Halsey equation presented more satisfactory results over a wide range of temperature and water activity (0.1-0.85), as shown in Table 1, while the same was not true for the other equations. The linearized form of the modified Halsey equation is:

$$\ln\ln(k/a_w) = \ln c - r\ln x, \qquad (1)$$

where a_w is water activity, x is moisture content and c, k and r are constants. The experimental data were fitted into Equation 1, using a linear regression method. The adequacy of fitting was checked through calculating the relative mean square roots of the error (RMS%):

$$\text{RMS\%} = \sqrt{(((X_{\text{cal}} - X_{\text{exp}})^2/X_{\text{exp}}^2)/N)} \times 100, \qquad (2)$$

where X_{exp} and X_{cal} are experimental and calculated moisture content and N is number of experimental points, the results of which are shown in Table 1.

Pretreatment Effect

In this study, pretreatment solutions were divided into two parts: A1, A2, A3, A4, A5 and A9 were called hot solutions, A6, A7 and A8 were called cold solutions. The study regarding the best dipping hot solution showed that short drying time and good quality raisins were obtained by pretreating the grapes in a solution of 3% NaOH (A1). Pretreatment at lower concentrations required longer dipping time (2-30 sec). The shortest drying time and the best quality raisins pretreated with cold solutions were obtained for the pretreatment with solution of 5% K_2CO_3 for 5 min (A6). Dipping the grapes at higher temperature (42°C) resulted in poor quality dried product and skin damage.

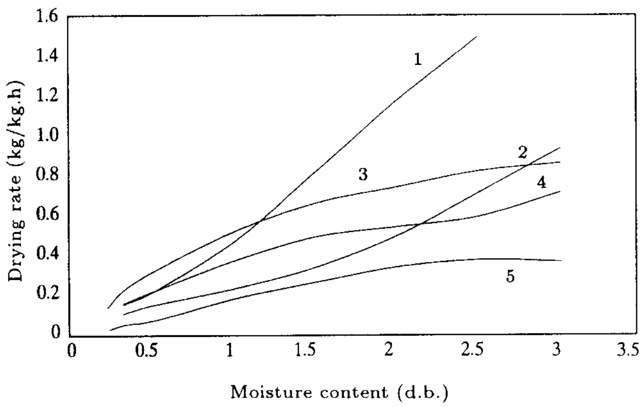


Figure 3. Drying rate for 5 sample grapes: 1) NaOH 2% (A2); 2) NaOH 1.5% (A5); 3) K_2CO_3 5% (A6); 4) Na_2CO_3 4% (A7); 5) no treatment (A10).

Figure 3 illustrates the drying rate (dx/dt) versus the moisture content (dry basis) of 5 grape samples. All the samples were dried in the falling rate period with no indication of a constant rate. An increase in temperature, increases the rate of drying as well.

Pretreatment with alkaline solution is more effective in increasing the drying rate during the early period (high moisture in grape).

The color of treated grapes was lighter than that of untreated grapes. More intense browning of grapes results from low temperature and long drying time. Skin damage may result from pretreatment (high alkaline concentration solution) or improper drying conditions. Some skin burning was observed in grapes which were dried at 70°C. Over dipping was not seen in cold pretreatment solutions.

Moisture Diffusivity

Dimensionless moisture [$W = (M - Me/Mo - Me)$] versus drying time at different temperatures were plotted in Figure 4, showing an increase in drying rate with increase in temperature. Equilibrium data were obtained from sorption isotherms.

The initial moisture content of grapes was 70-73% (wet base) and the relative humidity during the experiment was between 10-30%.

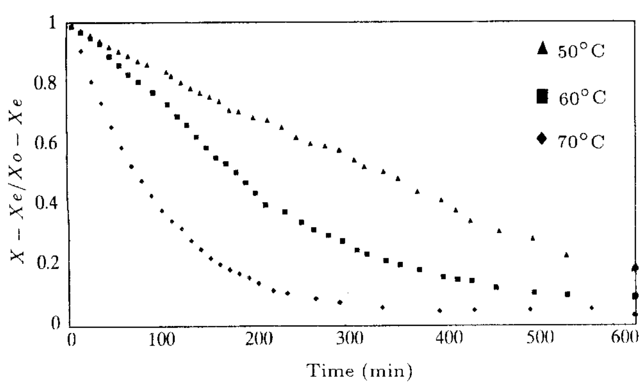


Figure 4. Dimensionless moisture vs drying time.

Table 2. Diffusivities divided by R^2 in the drying process at different temperatures.

T (°C)	D/R^2	Re^2
50	4.98 10-6	0.9856
59	8.61 10-6	0.9919
70	1.27 10-5	0.9746

The method of slope [17] was used for the estimation of the moisture diffusivity at various moisture contents [3,18]. Diffusivity was calculated according to the following equation:

$$D = [(dW/dt)_{\exp}/\pi^2].R^2. \quad (3)$$

The slope of the experimental drying curve, $(dW/dt)_{\exp}$ was estimated using a regression method from experimental data. Table 2 gives the values of D/R^2 computed from the slope of the straight line obtained when experimental values of $\ln W$ versus time were plotted.

The effect of temperature on the diffusivity was also studied. The values of D/R^2 versus $1/T$ were plotted using semilogarithmic scales. Through fitting the experimental points to a straight line using a least squares technique, the following equation is obtained:

$$\ln(D/R^2) = 3.8023 - 5161.48/T, \quad Re = 0.9904. \quad (4)$$

Activation energy is obtained from the slope of this line. The value computed in this work is 2384 kJ/kg which is similar to those obtained by Berna et al. 2361 kJ/kg [3], and Simal et al. 2036 kJ/kg [19].

NOMENCLATURE

a_w	water activity, air humidity at equilibrium
c	constant
D	diffusivity (m^2/s)
k	constant
M	local moisture content (kg water/kg dry mass)
Me	equilibrium moisture content (kg water/kg dry mass)
Mo	initial moisture content (kg water/kg dry mass)
r	constant
R	radius of grape berries (m)
Re	regression coefficient
t	time (min)
T	air drying temperature (°C)
W	dimensionless moisture content ($M - Me/Mo - Me$)

REFERENCES

1. Riva, M., Peri, C. and Lovino, R. "Effects of pretreatments on kinetics of grape drying", in *Food Engineering and Process Applications*, Elsevier, Amsterdam, pp 461-472 (1986).
2. Massi, P. and Riva, M. "Modelling grape drying kinetics", in *Preconcentration and Drying of Food Materials*, Bruin, S., Ed., Elsevier, Amsterdom, pp 203-214 (1988).
3. Berna, A., Rossello., C., Canellas, J. and Mulet, A. "Drying kinetics of majorcan seedless grape variety", *Drying 91*, Edited by A.S. Mujumdar and I. Filkova, Elsevier Science Publishers, Amsterdam (1990).
4. Grncarevic, M. "Effect of various dipping treatments on the drying rate of grapes for raisins", *Am. J. Enol. Vitic.*, **14**, pp 230-234 (1963).
5. Pointing, J.D. and McBean, D.M. "Temperature and dipping treatment effects on drying rates and dipping times of grapes, prunes and other waxy fruits", *Food Technol.*, **24**, pp 403-1406 (1970).
6. Bolin, H.R. "Relation of moisture to water activity in prunes and raisins", *Journal of Food Science*, **45**, p 1190 (1980).
7. Saravacos, G.D., Tsiourvas, D.A. and Tsami, E. "Effect of temperature on the water adsorption isotherm of sultana raisins", *J. Food Sci.*, **51**, pp 381-383 (1986).
8. Vagenos, G.D., Tsami, E. and Saravacos, G.D. "Moisture sorption isotherm of sultana raisins", *Chimika Chronika New Series*, **15**, p77 (1986).
9. Tsami, E., Maroulis, Z.B., Marinos-Kourise, D. and Saravacos, G.D. "Water sorption isotherms of raisins, currant, figs prunes and apricots", *Journal Food Science*, **55**(6), pp 1594-1597 (1990).
10. Ayrancl, E., Aryancl, G. and Dogantan, Z. "Moisture sorption isotherms of dried apricot, fig and raisins at 20 and 36°C", *Journal of Food Science*, **55**(6), p 1591-1593 (1990).
11. Spiess, W.E.L. and Wolf, W.R. "The results of COST 90 project on water activity", in *Physical Properties of Food*, R. Jowitt et al., Ed., p 65, Applied Science Publ. London, UK (1984).
12. AOAC "Official methods of analysis", *Association of Official Analytical Chemists*, Arlinton V.A. (1995).
13. Mahmutoglu, T., Emir, F. and Biral Saygi, Y. "Sun/solar drying of differently treated grapes and storage stability of dried grapes", *J. Food Engineering.*, **29**, pp 289-300 (1996).
14. Weisser, H. "Influence of temperature on sorption equilibrium", in *Properties of Water in Food*, D. Simatos and J.I. Multon, Eds., Martinus, Nijhoff Publ. Dordrecht (1985).
15. Halsey, G. "Physical adsorption in non-uniform surface", *J. Chem. Phys.*, **16**, p 931 (1948).
16. Alzamora, S.M., Chirife, J. and Voillaz, P. "A simplified model for predicting the temperatures of foods during air dehydration", *J. Food Technol.*, **4**, p 369-380 (1979).
17. Perry, R.H., Green, D.W. and Maloney, J.O., *Perry's Chemical Engineering Handbook*, 6th Ed., McGraw Hill, New York (1984).
18. Mulet, A., Berna, A., Borras, F. and Pinaga, F. "Effect of air flow rate on carrot drying", *Drying Technology*, **5**(2), pp 245-258 (1986).
19. Simal, A., Mulet, P.J. "Moving boundary model for simulation moisture movement in grapes", *J. Food Sci.*, **61**(1), pp 157-160 (1996).