PAPER

DRYING CHARACTERISTICS OF ‘ANKARA’ PEAR SLICES

Y.B. ÖZTEKIN*[1] and K. SACILIK[2]

[1]Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Ondokuz Mayis University, 55139, Samsun, Turkey

[2]Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Ankara University, 06130, Ankara, Turkey

*Corresponding author: Tel.: +90 3623121919; Fax: +90 362 4576034

Email: yurtlu@omu.edu.tr

ABSTRACT

This study evaluated the effects of drying temperature and pre-treatment on the rehydration capacity and color parameters of sliced pears (*cv. Ankara*). Drying trials were conducted at 55, 65, and 75°C. Pre-treatment consisted of immersion of pear slices in a citric-acid solution or blanching in hot water. Pre-treatment was found to have a significant effect on both rehydration capacity and color, with higher temperatures and pre-treatment resulting in decreases in drying time and increases in rehydration capacity. Effective diffusivity values ranged between 1.12×10^{-10} and 2.94×10^{-10} m^2/s. Blanched pear slices had the lowest E_a values (15.51 kJ/mol), followed by the samples immersed in citric acid (28.03 kJ/mol) and the untreated samples (33.48 kJ/mol). The Midilli *et al.* model displayed the best fit to the drying data of five models tested based on the statistical criteria evaluated. Natural color of fresh pear was best preserved with lower drying temperatures and pre-treatment with citric acid.

Keywords: color properties, convective drying, moisture content, rehydration capacity

1. INTRODUCTION

Pear is one of the most important fruits in Turkey and around the world. In 2017, Turkey accounted for approximately 503,004 tons of the 24.17 million tons of pears produced world-wide, making it the 5th largest pear producer behind China (16.53 million tons), Argentina (930,340 tons), the United States (677,891 tons) and Italy 772,577 tons) (FAOSTAT, 2019). Turkey is also a center of genetic diversity, with over 600 of the more than 5,000 varieties found throughout the world (KARADENİZ, 1999). One of the most important pear varieties in Turkey is the 'Ankara' pear, which originated in Ankara and is grown mainly in Turkey's Central Anatolia region, especially in the province of Ankara (ERDOĞAN *et al.*, 2007). 'Ankara' pear trees produce medium-sized, green fruit with smooth surfaces, thin skins, short, thick stalks and juicy, fragrant flesh that melts in the mouth. The fruit are also easy to store (DUMANOĞLU *et al.*, 2006; ERDOĞAN *et al.*, 2007).
Vegetables and fruits contain basic nutrients that are important for human health. Because fruits and vegetables are cultivated on a seasonal basis and have a high-water content that makes them easily perishable, various preservation techniques have been developed so that fruits and vegetables can be consumed throughout the year (QUILES *et al.*, 2005). Dehydration, although a highly complicated product-processing technique (MASKAN, 2000), is the basic method used for reducing moisture levels in order to minimize on-going microbial reactions, prevent deterioration (KROKIDA and MARINOS-KOURIS, 2003), and increase the shelf life (DAS *et al.*, 2001) of agricultural products. Of the many drying methods available, convective drying, which represents one of the most common of all postharvest technologies, allows for high-quality products that preserve close to their original color (DOYMAZ, 2004).
Pears are consumed in various forms, both fresh and dried. Dried pears are consumed directly as snacks and are also widely used as inputs in the food industry. The design, operation, and maintenance of fruit-drying systems require a good understanding of drying characteristics. Studies have evaluated drying characteristics of different varieties of pears, such as 'd'Anjou' (PARK *et al.*, 2002) and 'Deveci' (DOYMAZ, 2013), as well as different techniques, including convective drying (GONZÁLEZ-MARTÍNEZ, 2006) air-drying (DOYMAZ, 2013; DOYMAZ and İSMAIL, 2012), osmo-vacuum drying (AMIRIPOUR *et al.*, 2015), mid-infrared-freeze drying (ANTAL *et al.*, 2017), and microwave-vacuum drying (TASKIN *et al.*, 2019). However, the literature includes no data on the drying behavior of the 'Ankara' pear variety, whose texture varies greatly from that of other varieties, especially the 'Deveci' pear. Thus, this study was carried out to examine how drying temperature and pre-treatment by either immersion in a citric acid solution or blanching in hot water affect the drying characteristics and quality parameters (i.e. moisture content, rehydration capacity, color) of 'Ankara' pear.

2. MATERIALS AND METHODS

2.1. Material

The pears used in this study (*cv. Ankara*) were obtained from a local market in Ankara, Turkey. Pears were kept refrigerated at 5ºC and removed 12 hours prior to the trials to obtain equilibrium. Pears were then sliced into sound, homogenous samples of 5±0.5 mm thickness and randomly distributed among 3 groups according to pre-treatment, as follows: Citric Acid: pear slices were immersed in a citric-acid solution (5 g/L) for 3 min at room temperature; Blanching: pear slices were blanched in 85°C water for 3 min and then rinsed with running water; Untreated: pear slices received no pre-treatment.

2.2. Drying

Pears were dried according to SACILIK *et al.* (2010) using a convective hot-air dryer (57 x 68 x 57 cm) comprised of a perforated basket (576 cm^2 x 12 cm), an adjustable fan, an electric heater, and a load-cell system attached to a PC (Fig. 1). Drying runs were carried out at 55, 65 and 75 °C, with a constant air velocity of 1 m/s (IZLI *et al.*, 2019). A minimum of 250 g of pear slices was used for each run. Pear slices were dried with tissue paper and then placed uniformly into the basket, which was positioned in the drying system after it had been allowed to idle for 20 min to reach thermal stabilization. Initial moisture content of pears was measured at 120 ºC using an HB43-S Halogen Moisture Analyzer (Mettler Toledo, Switzerland) and recorded as 572.04% d.b. (85.12% w.b.). During the drying process, moisture loss from samples in the drying basket was measured using a load cell and continuously recorded using specially developed software connected to a PC. Once moisture-loss measurements were completed, dried samples were evaluated for rehydration capacity and color.

2.3. Effective diffusivity and activation energy

A falling-rate drying period can be observed in drying pear slices, with moisture and/or vapor migration controlled by diffusion. In this case, Fick's second law can be derived as follows (CRANK, 1975; SACILIK and UNAL, 2005):

$$\frac{\partial M_l}{\partial t} = \nabla(D_{eff}\nabla M_l) \qquad (1)$$

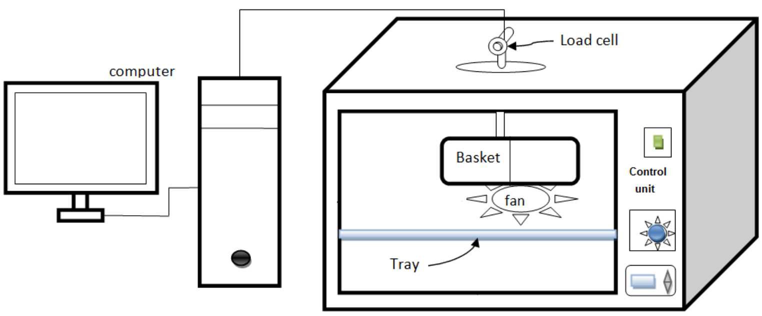


Figure. 1. The diagram of drying system.

where M_l is the local moisture content in % d.b., t is the drying time in min, and D_{eff} is the effective diffusivity in m^2/s. Assuming moisture migration to be realized through diffusion, shrinkage to be negligible, and diffusion coefficients and temperatures to be constant (CRANK, 1975) yields the following equation:

$$M_R = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(\frac{-(2n+1)^2 \pi^2 D_{eff} t}{4h^2} \right) \quad (2)$$

For long drying periods, by considering only the first term in the series and, given the relatively small size of M_e as compared to M and M_0, reducing moisture ratio (M_R) to M/M_0 Equation 2 can be simplified to yield Equation 3:

$$\ln \frac{M}{M_0} = \ln \frac{8}{\pi^2} - \left(\frac{\pi^2 D_{eff} t}{4h^2} \right) \quad (3)$$

where M_R is the dimensionless moisture ratio, M is the moisture content at any time in % d.b., M_e is the equilibrium moisture content in % d.b., M_0 is the initial moisture content in % d.b., h is the half-thickness of the slab in sample in m, and n is a positive integer.
Effective diffusivity and drying air temperature are correlated using the Arrhenius equation (Equation 4):

$$D_{eff} = D_0 \exp\left(-\frac{E_a}{RT_a} \right) \quad (4)$$

where D_0 is the pre-exponential factor of the Arrhenius equation in m^2/s, E_a is the activation energy in kJ/mol, R is the universal gas constant in kJ/mol.K, and T_a is the absolute air temperature in K.

2.4. Modelling of drying data

Drying data were fitted to five selected models (Table 1). Moisture ratios were determined using the following equation:

$$M_R = \frac{M - M_e}{M_0 - M_e} \quad (5)$$

where M_R is the moisture ratio, M, M_e and M_0 are, respectively, the moisture content at any time, the equilibrium moisture content, and the initial moisture content in % d.b.
M_R was further reduced to M/M_0, given the continuous fluctuation of relative humidity during the drying processes, (DIAMENTE and MUNRO, 1993). Data were analyzed by using Statistica 6.1 (StatSoft Inc., USA) software package. Drying rate constants and model coefficients were calculated according to Levenberg-Marguardt, and the statistical validity of the selected drying models was assessed according to the criteria put forth in Equations 6, 7 and 8 (SACILIK *et al.*, 2010; YURTLU, 2011):

$$P = \frac{100}{N} \sum_{i=1}^{N} \frac{\left| M_{R,ex,i} - M_{R,pre,i} \right|}{M_{R,\exp,i}} \quad (6)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(M_{R,ex,i} - M_{R,pre,i}\right)^2\right]^{1/2} \tag{7}$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(M_{R,ex,i} - M_{R,pre,i})^2}{N - z} \tag{8}$$

where $M_{R,ex,i}$ is the ith experimental moisture ratio, $M_{R,pre,i}$ is the ith predicted moisture ratio, N is the number of observations, and z is the number of constants.
R^2 was used as the primary comparison criteria. Goodness of fit was also examined based on P, $RMSE$ and χ^2 (YURTLU, 2011).

Table 1. Selected drying models.

Model no	Model name	Model	References
1	Page	$M_R = \exp(-kt^m)$	Agrawal and Singh (1977)
2	Logarithmic	$M_R = a\exp(-kt) + c$	Yagcioglu *et al.* (1999)
3	Two-term	$M_R = a\exp(-kt) + b\exp(-k_0t)$	Henderson (1974)
4	Approximation of diffusion	$M_R = a\exp(-kt) + (1 - a)\exp(-kbt)$	Yaldiz and Ertekin (2001)
5	Midilli *et al.*	$M_R = a\exp(-kt^m) + bt$	Midilli *et al.* (2002)

2.5. Rehydration capacity and color parameters of pear slices

Rehydration capacity is of paramount importance for dried products. In this study, rehydration capacity was determined by immersing 10 g of dried pear slices into 85 °C water for 3 min, drying the pear surfaces with paper towels, and measuring the mass of the rehydrated sample using an electronic digital scale (±0.001 g), with rehydration capacity expressed as the ratio of the mass of the rehydrated sample to the mass of the dried sample (PRAKASH *et al.*, 2004).
Color properties are also among the important quality parameters of dried fruits (ELICIN and SACILIK, 2005). In this study, color measurements were obtained from 5 points on the surface of each pear sample using a Minolta CR-300 Chromameter, and the average measurement was calculated. Hue angles and color differences between raw and dried samples were calculated with the help of Equation 9 and Equation 10 (SACILIK and UNAL, 2005):

$$H = \tan^{-1}\left(\frac{b^*}{a^*}\right) \tag{9}$$

$$\Delta E = \sqrt{(L_0 - L_f)^2 + (a_0 - a_f)^2 + (b_0 - b_f)^2} \tag{10}$$

where H is the hue angle°, ΔE is the color difference, L_0, a_0 and b_0 are the color lightness, green-red and blue-yellow values of raw pear slices, and L_f, a_f and b_f are the color lightness, green-red and blue-yellow values of dried pear slices.

3. RESULTS AND DISCUSSION

3.1 Hot-air drying curves of pears

Pear (*cv. Ankara*) drying characteristics are presented in Figs. 2, 3 and 4 according to drying temperature and pre-treatment procedures. As the Figs show, pear moisture content was observed to decrease continuously over time from 572.04% d.b. to between 4.43% d.b. and 19.22% d.b. Moisture content was significantly affected by drying temperature, citric-acid treatment, and blanching. Untreated pears required drying times of 1,560, 1,080 and 900 min at 55, 65 and 75 °C, respectively, to reach their final moisture content, as compared to 1,140, 900 and 660 min for pear samples pre-treated with citric acid and 840, 720 and 600 min for samples blanched in hot water. These Figs. – representing decreases in drying time of 46% at 55°C and 33% at 65°C and 75°C for blanched pears as compared to untreated pears – demonstrate that water diffusion increases with pre-treatment. Similar results have been reported by DOYMAZ (2010) for Amasya red apples, by DOYMAZ (2013) for pear, by VARDIN and YILMAZ (2018) for pomegranate arils, and by PANDEY *et al.* (2019) for green peas.

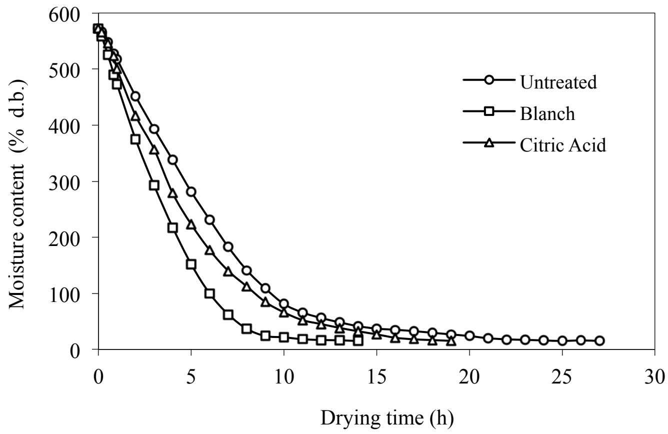


Figure 2. Drying curves for 'Ankara' pear at 55°C.

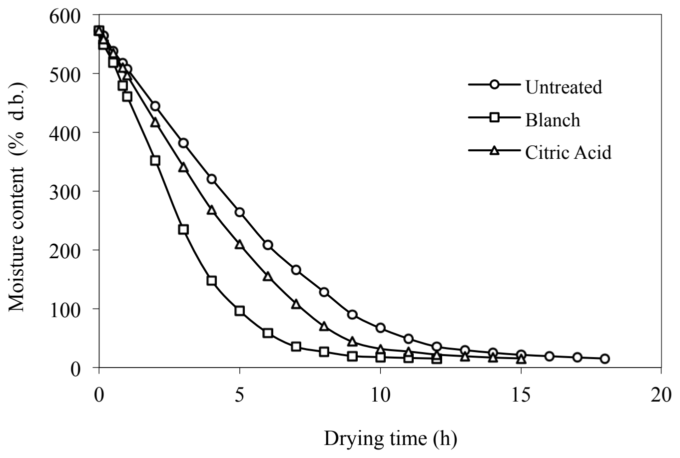


Figure 3. Drying curves for 'Ankara' pear at 65°C.

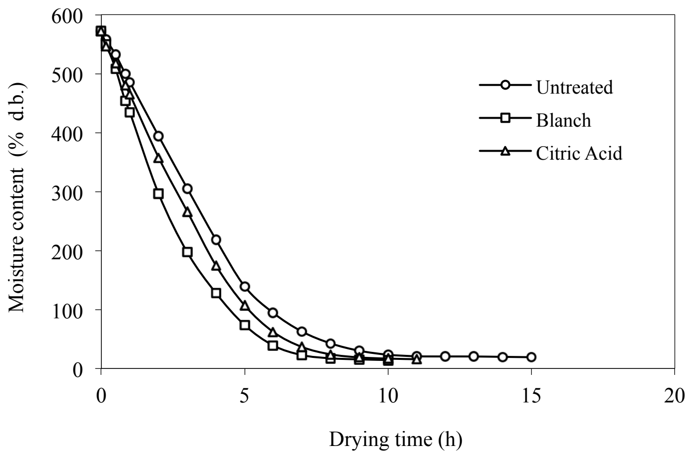


Figure 4. Drying curves for 'Ankara' pear at 75°C.

3.2. Effective diffusivity and activation energy

From Equation 3, a plot of ln(M_R) vs. the time provides a straight line with a slope *s* of:

$$s = \frac{\pi^2 D_{eff}}{4h^2} \tag{11}$$

The highest D_{eff} values were obtained for the blanched pear samples, followed by the citric-acid treated and the untreated samples (Table 2). D_{eff} values were observed to increase with increases in air temperature due to accelerated moisture diffusion, which could be due to an increase in water permeability caused by cracks in the sample surfaces. The D_{eff} values obtained for 'Ankara' pear slices in the present study are comparable to values ranging from 1.59×10^{-10} to 7.64×10^{-10} m^2/s obtained for 'd'Anjou' pear at 40 ºC - 80 ºC (PARK *et al.*, 2002), from 2.27×10^{-10} to 4.97×10^{-10} m^2/s for "organic apple" at 40 ºC - 60 ºC (SACILIK and

ELICIN, 2006), from 2.66×10⁻¹⁰ to 4.56×10⁻¹⁰ m²/s for Üryani plum at 50ºC - 70ºC (SACILIK *et al.*, 2006), from 0.85×10⁻¹⁰ to 2.18×10⁻¹⁰ m²/s for pear slices at 55ºC - 75ºC (DOYMAZ, 2012), and from 8.56×10⁻¹¹ to 2.25×0⁻¹⁰ m²/s for 'Deveci' pear slices at 50ºC - 71ºC (DOYMAZ, 2013). Activation energy values were obtained by plotting ln(D_{eff}) vs. 1/T (Fig. 5), which yielded a straight line indicating an Arrhenius dependence on temperature. Using Equation 4, activation energy values for untreated pear samples, pear samples treated with citric acid, and blanched pear samples were obtained using Equations 12, 13 and 14, respectively, as follows:

Table 2. Effective diffusivity for 'Ankara' pear at various air temperatures.

	Air temperature, °C	D_{eff}x10^{10}, m^2/s	R^2
Untreated	55	1.12	0.9747
	65	1.56	0.9878
	75	2.26	0.9713
Citric acid	55	1.45	0.9951
	65	1.90	0.9839
	75	2.61	0.9821
Blanched	55	2.12	0.9709
	65	2.44	0.9756
	75	2.94	0.9825

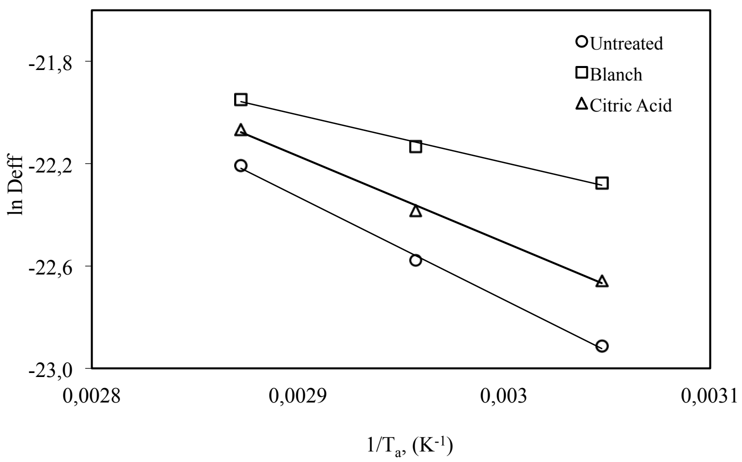


Figure 5. Arrhenius-type relationship between D_{eff} and T_a.

Untreated samples:

$$D_{eff} = 2.36 \times 10^{-5} \exp\left(-\frac{4026.23}{T}\right) \quad (12)$$

(R^2=0.9979),
Citric acid-treated samples:

$$D_{eff} = 4.15 \times 10^{-6} \exp\left(-\frac{3371.19}{T}\right) \quad (13)$$

(R^2=0.9965),
Blanched samples:

$$D_{eff} = 6.19 \times 10^{-8} \exp\left(-\frac{1865.72}{T}\right) \quad (14)$$

(R^2=0.9916).

The highest value of activation energy was obtained for the untreated samples (E_a=33.48 kJ/mol), followed by the citric-acid treated samples (E_a=28.03 kJ/mol) and blanched samples (E_a=15.51 kJ/mol). These values are in line with the range (15-40 kJ/mol) specified by Rizvi (1986) for various foods.

3.3. Parameter estimation

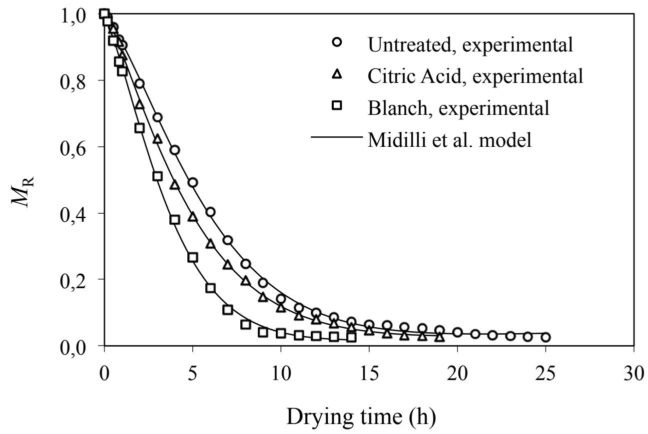
Estimated values of drying models and comparison criteria (R^2, P, $RMSE$ and χ^2) are given in Table 3. Selected models offered a good fit to data. Of the 5 models examined, the MIDILLI *et al.* had highest R^2 and lowest P, $RMSE$ and χ^2 values, indicating it to be the best model in terms of fitness to data. Comparisons of the experimental data and the predicted moisture ratios obtained using the MIDILLI *et al.* model for 'Ankara' pear slices at 55, 65 and 75°C are presented in Fig 6. As the Fig. show, there is very good conformity between the actual and the predicated data, confirming the goodness of fit of the MIDILLI *et al.* model.

3.4. Quality parameters (rehydration and color retention)

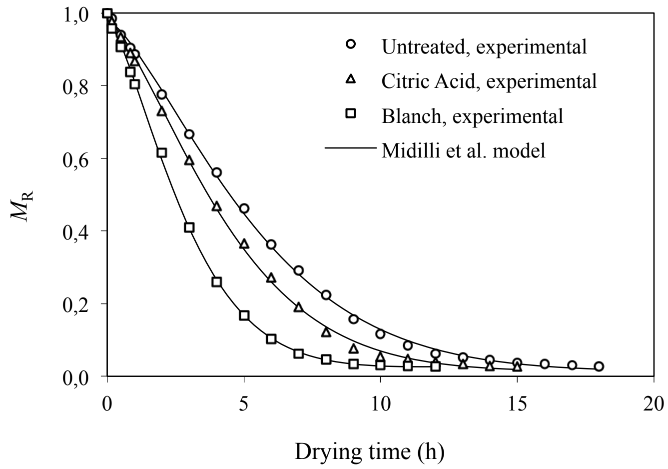
Air temperature as well as pre-treatment, either with a citric-acid solution or by blanching, significantly affected the rehydration capacity of 'Ankara' pears (Table 4). The highest rehydration values were observed for the blanched pear slices dried at 75ºC. At every temperature examined, the blanched pear slices showed the greatest rehydration capacity, followed by the samples treated with citric acid and the untreated samples. Increases in air temperatures during drying resulted in increases in rehydration capacity, with increases of 5.43%, 4.64% and 10.54%, respectively, for untreated samples, samples treated with citric acid, and blanched samples when temperatures were increased from 55 to 75 ºC. This finding can be explained by an increase in the rate of moisture removal with increases in air temperature, which leads to less shrinkage and thus an accelerated rate of rehydration. Similar results have been reported by AMIRIPOUR *et al.* (2015), HEBDA *et al.* (2019) and SINGH *et al.* (2006).
Table 5 shows the Hunter color values for pears by air temperature and pre-treatment procedures. The lowest a^* values and the highest L^* and H values were observed at 55°C regardless of pretreatment. H and L^* values decreased with increases in temperature, whereas a^* values increased with increases in temperature, demonstrating that browning occurred as a result of temperature increases. Similar results were reported by WANG and CHAO (2003), ELICIN and SACILIK (2005) and SACILIK and ELICIN (2006).

Table 3. Statistical criteria of the models for 'Ankara' pear.

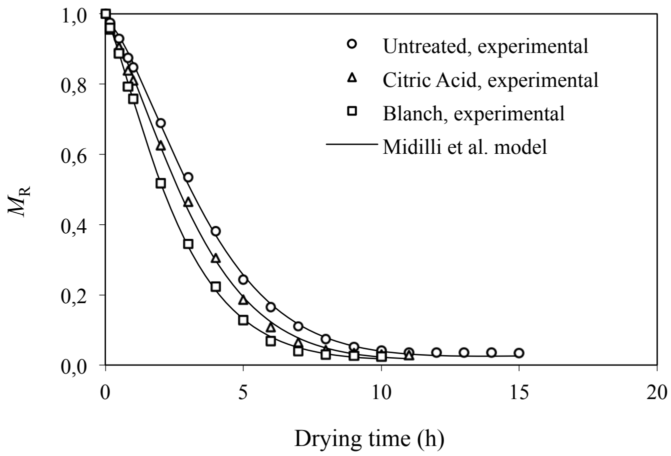
	°C	Model no	Model coefficients	R^2	P (%)	RMSE	χ^2
Untreated	55	1	k=0.0985; m=1.2518	0.9974	25.54	$1.84x10^{-2}$	$3.65x10^{-4}$
		2	a=1.0627; k=0.164; c=-0.0126	0.9932	23.20	$3.06x10^{-2}$	$10.15x10^{-4}$
		3	a=-0.0405; k_0=0.5464; b=1.4754; k_1=0.2142	0.9980	21.22	$1.69x10^{-2}$	$3.11x10^{-4}$
		4	a=6.901; k=0.113; b=0.9935	0.9915	28.90	$3.42x10^{-2}$	$12.67x10^{-4}$
		5	a=0.99; k=0.082; m=1.3664; b=0.0015	0.9993	9.65	$1.02x10^{-2}$	$1.14x10^{-4}$
	65	1	k=0.0982; m=1.3124	0.9988	10.84	$1.33x10^{-2}$	$1.97x10^{-4}$
		2	a=1.12; k=0.1527; c=-0.0858	0.9942	26.81	$2.98x10^{-2}$	$9.92x10^{-4}$
		3	a=05257.; k_0=0.1863; b=0.5265; k_1=0.1863	0.9894	29.24	$4.14x10^{-2}$	$19.24x10^{-4}$
		4	a=-7.4478; k=0.3419; b=0.908	0.9920	10.02	$1.34x10^{-2}$	$1.99x10^{-4}$
		5	a=0.9795; k=0.0836; m=1.395; b=0.00061	0.9992	7.24	$1.15x10^{-2}$	$1.49x10^{-4}$
	75	1	k=0.156; m=1.3316	0.9962	44.90	$2.24x10^{-2}$	$5.47x10^{-4}$
		2	a=1.0545; k=0.273; c=0.0065	0.9904	35.97	$3.65x10^{-2}$	$14.54x10^{-4}$
		3	a=2.2259; k_0=0.3951; b=-1.2366; k_1=0.6568	0.9965	42.11	$2.24x10^{-2}$	$5.51x10^{-4}$
		4	a=9.9874; k=0.1899; b=0.9696	0.9878	50.74	$4.11x10^{-2}$	$18.46x10^{-4}$
		5	a=0.9826; k=0.1336; m=1.4489; b=0.00165	0.9994	9.72	$0.96x10^{-2}$	$1.03x10^{-4}$
Citric acid	55	1	k=0.1352; m=1.1923	0.9991	12.76	$1.09x10^{-2}$	$1.32x10^{-4}$
		2	a=1.0648; k=0.1897; c=-0.0213	0.9970	13.48	$2.08x10^{-2}$	$4.83x10^{-4}$
		3	a=0.5246; k_0=0.2011; b=0.5246; k_1=0.2009	0.9965	8.83	$2.31x10^{-2}$	$5.99x10^{-4}$
		4	a=-5.7317; k=0.121; b=1.0676	0.9955	17.59	$2.57x10^{-2}$	$7.36x10^{-4}$
		5	a=1.0034; k=0.131; m=1.2332; b=0.0012	0.9997	3.73	$0.64x10^{-2}$	$0.45x10^{-4}$
	65	1	k=0.1254; m=1.3216	0.9987	12.84	$1.40x10^{-2}$	$2.23x10^{-4}$
		2	a=1.1207; k=0.1869; c=-0.0836	0.9937	29.66	$3.20x10^{-2}$	$11.74x10^{-4}$
		3	a=0.4054; k_0=0.2271; b=0.6489; k_1=0.2271	0.9891	30.74	$4.35x10^{-2}$	$21.85x10^{-4}$
		4	a=-6.8642; k=0.4215; b=0.899	0.9987	11.83	$1.44x10^{-2}$	$2.39x10^{-4}$
		5	a=0.9798; k=0.1081; m=1.4065; b=0.0007	0.9991	8.66	$1.24x10^{-2}$	$1.78x10^{-4}$
	75	1	k=0.198; m=1.3054	0.9982	13.01	$1.69x10^{-2}$	$3.41x10^{-4}$
		2	a=1.1148; k=0.2576; c=-0.0823	0.9931	30.98	$3.49x10^{-2}$	$14.66x10^{-4}$
		3	a=0.5247; k_0=0.3119; b=0.5247; k_1=0.3119	0.9886	31.51	$4.67x10^{-2}$	$26.72x10^{-4}$
		4	a=-5.384; k=0.147; b=1.1161	0.9929	32.32	$3.53x10^{-2}$	$14.97x10^{-4}$
		5	a=0.9738; k=0.1699; m=1.4089; b=0.0011	0.9988	8.65	$1.48x10^{-2}$	$2.69x10^{-4}$
Blanched	55	1	k=0.1757; m=1.2674	0.9987	17.28	$1.41x10^{-2}$	$2.29x10^{-4}$
		2	a=1.0863; k=0.2434; c=-0.0475	0.9944	32.44	$3.03x10^{-2}$	$10.62x10^{-4}$
		3	a=-0.0407; k_0=0.2745; b=1.01; k_1=0.2746	0.9922	26.57	$3.71x10^{-2}$	$16.11x10^{-4}$
		4	a=-5.789; k=0.4965; b=0.8918	0.9988	16.57	$1.41x10^{-2}$	$2.29x10^{-4}$
		5	a=0.9843; k=0.1584; m=1.3390; b=0.00098	0.9990	9.79	$1.32x10^{-2}$	$2.03x10^{-4}$
	65	1	k=0.2161; m=1.2946	0.9987	17.90	$1.44x10^{-2}$	$2.45x10^{-4}$
		2	a=1.0827; k=0.2986; c=-0.0391	0.9927	28.95	$3.56x10^{-2}$	$15.06x10^{-4}$
		3	a=-0.4799; k_0=0.3298; b=0.5734; k_1=0.3298	0.9911	21.92	$4.11x10^{-2}$	$20.21x10^{-4}$
		4	a=-4.5469; k=0.6298; b=0.859	0.9989	16.06	$1.37x10^{-2}$	$2.21x10^{-4}$
		5	a=0.9813; k=0.1921; m=1.3988; b=0.0021	0.9995	2.65	$9.61x10^{-2}$	$1.11x10^{-4}$
	75	1	k=0.281; m=1.2235	0.9996	11.58	$0.83x10^{-2}$	$0.82x10^{-4}$
		2	a=1.08; k=0.3377; c=-0.0442	0.9963	24.31	$2.55x10^{-2}$	$7.96x10^{-4}$
		3	a=-2.7851; k_0=0.7071; b=3.7845; k_1=0.5749	0.9996	11.08	$0.86x10^{-2}$	$0.93x10^{-4}$
		4	a=0.1349; k=0.3568; b=0.9989	0.9914	28.21	$3.91x10^{-2}$	$18.68x10^{-4}$
		5	a=0.9936; k=0.2729; m=1.257; b=0.00103	0.9996	7.70	$0.78x10^{-2}$	$0.75x10^{-4}$



(a)



(b)



(c)

Figure 6. Conformity of the Midilli *et al.* for 'Ankara' pear at 55°C (a), at 65°C (b) and at 75°C (c).

Table 4. Rehydration capacity for 'Ankara' pear at various temperatures.

	Air temperature, °C	Rehydration capacity
Untreated	55	3.31
	65	3.35
	75	3.49
Citric acid	55	3.45
	65	3.54
	75	3.61
Blanched	55	3.51
	65	3.69
	75	3.88

Table 5. Color values for 'Ankara' pear at various temperatures.

	Air temperature	Hunter color values				
	°C	*L**	*a**	*b**	*ΔE*	*H°*
Untreated	55	72.69	5.04	33.27	10.09	81.40
	65	68.04	4.46	26.33	14.62	80.13
	75	66.38	6.57	29.22	15.43	77.50
Citric acid	55	78.16	2.91	34.03	8.97	85.25
	65	75.69	5.79	34.96	9.41	80.58
	75	67.71	5.20	31.98	12.85	80.56
Blanched	55	69.45	6.26	30.73	12.54	78.43
	65	64.72	6.99	30.77	16.61	77.65
	75	63.98	7.69	34.37	16.29	77.60

In terms of pre-treatment, the present study found samples pre-treated with citric acid had higher H and L^* values as compared to blanched and untreated samples at each air temperature tested. Moreover, the samples treated with citric acid had smaller ΔE values than both the blanched and untreated samples, indicating that pre-treatment with citric acid helped to preserve the original color of pear slices. Overall, the natural color of fresh pear was best preserved when slices were pre-treated with a citric-acid solution and dried at the lowest air temperature (55°C).

4. CONCLUSIONS

In conclusion, drying temperature and pre-treatment with either a citric-acid solution or by blanching in hot water significantly affected the moisture content, rehydration capacity and color parameters of 'Ankara' pear slices. Blanched pear slices required shorter drying times than samples treated with citric acid as well as untreated samples. When compared to untreated pears, blanched pear slices required 46% less time for drying at 55ºC and 33% less time at 65ºC and at 75ºC. D_{eff} values were observed to decrease with decreases in temperature and were lower for untreated pears than for pre-treated pears. E_a values were highest for untreated samples (33.48 kJ/mol), followed by citric acid-treated (28.03 kJ/mol) and blanched samples (15.51 kJ/mol). Based on the evaluated statistical criteria, the MIDILLI *et al.* model showed the best fit to the drying data of all the models tested. Rehydration capacity of pear slices was seen to decrease with decreases in drying temperature. The natural color of fresh pear slices was best retained when the samples were pre-treated with citric acid and dried at the lowest air temperature.

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