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Drying of sour cherry with microwave and infrared drying methods; investigation of drying kinetics and parameters

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In this study, sour cherry samples (*Prunus cerasus* L.) were subjected to infrared and microwave drying. Before drying, the physical and mechanical properties of the sour cherry samples were determined along with the moisture content. For infrared drying, three different drying temperatures (50, 60 and 70°C) were used, while for microwave drying, three different microwave power levels (140, 210 and 350 W) were used. Drying took place completely during the falling rate period. The results showed that the moisture content and drying rate were affected by increased drying power level and drying air temperature. Microwave drying shortened the drying time and increased effective moisture diffusion (D_{eff}) when compared to infrared drying. Six different drying models were applied for all temperatures and power levels and the Alibas model best fitted the data. The activation energies were found to be 0.020 and 3.56 kW kg^{-1} for microwave drying and infrared drying, respectively. High "*L*" and low "*ΔE*" values were obtained in infrared drying method of sour cherries.

Keywords: Sour cherry, microwave drying, infrared drying, quality

INTRODUCTION

Sour cherry (*Prunus cerasus L.*) is an important fruit produced especially in the Russian Federation, Turkey, Ukraine, Poland, Iran, the United States and Serbia. Based on Food and Agriculture Organization (FAO) statistics, Turkey produced approximately 143197 tons of sour cherries in 2019, ranking second in world cherry production after the Russian Federation [1]. About half of the total amount of cherry produced in Turkey is consumed as fresh fruit. The other half is used after processing as juice, sauces, pastilles, jam and frozen products [2].

A significant part of agricultural products need to be stored [3]. Storage conditions of dried fruits are more favorable and drying is preferred and applied due to economic gain.

Dried fruits, vegetables and spices constitute a large part of our exports, and the income from these products constitutes a large part of our total export income. In 2020, our country's total export of dried fruit was 477150 tons and its value was $1.4 billion. In the first five months of 2021, our exports continued with $514 million, an increase of 12 percent compared to the same period of the previous year. European Union countries and the USA come to the fore in our exports [4].

The aim in drying sour cherry is to reduce the moisture content to a level that will allow safe storage for a long time.

In other words, along with the decrease in water amount with the drying process, the possibility of enzymatic and microbiological spoilage is significantly reduced. However, since it is not possible to provide hygienic conditions with the sun drying method, which is widely used in Turkey, the products are polluted. In addition, due to the fact that drying takes a very long time, respiration continues especially in fruits for a while, and even a slight fermentation occurs most of the time, material losses occur and as a result, the quality of the products deteriorates. For this reason, the need to dry the products under controlled conditions arises and the necessity and number of drying facilities and systems is gaining importance day by day [5].

The most widely used method industrially is convection drying. Generally, products are dried with a tray dryer. In recent years, instead of drying with hot air due to long drying times, drying methods such as microwave and infrared have been studied. As for why, color quality and energy consumption of the product is very important in drying. Drying needs high energy input, but World's energy resources are limited. Thus, to balance energy demands, the development of energy systems with high efficiencies and minimal costs is important [6].

Due to the low thermal conductivity of food, heat transfer to the interior of the food is limited during conventional heating.

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This problem has resulted in the increased use of infrared radiation and microwaves in food drying to achieve fast and effective heat treatment.

In microwave drying, high-frequency waves rapidly pass through the dried material, are absorbed and converted into heat energy causing the water in the material to evaporate. The internal temperature of the food dried using microwave is higher than the surface temperature, and a more dynamic moisture transfer takes place compared to conventional drying [7].

One of the most important drying methods of foods with high moisture content is drying with infrared radiation. It penetrates into the material being dried and generates heat, but its penetrating power is limited. Certain features such as thermal efficiency, wavelength, fast heating rate, direct heat penetration into the product and reflectivity make IR heating more effective for some applications and provide significant reductions in energy consumption [8, 9].

The drying process is usually carried out in thin layers. Therefore, modeling the convective thin layer drying of sour cherry slices is necessary for better control of the drying process and quality drying of sour cherries in accordance with the standards of the importing countries. Unfortunately, there are very few studies on the drying behavior of sour cherry by microwave and infraared drying methods in the literature. Methods for hot-air drying of sour cherry [2, 10-12] are some examples. In contrast, Ghaderi *et al*. (2011) [13] and Motavali *et al.* (2013) [14] developed microwave-vacuum drying techniques to study the drying of sour cherry. Amiri Chayjan *et al*. (2014) [9] on the other hand, tried to model some drying properties of sour cherry using mathematical models and artificial neural networks under infrared irradiation.

Although a lot of information has been collected about physical and mechanical properties, effective moisture diffusion, activation energy and color parameters for various food products, there is very little published literature on effective moisture diffusion, activation energy and color parameters for sour cherry by infrared and microwave drying. The main purpose of this research is to determine the effective moisture diffusion, activation energy and color parameters of sour cherry during microwave and infrared thin layer drying process and model it using microwave power and IR radiation temperature. In order to compare the infrared method with the microwave method for drying sour cherries, the drying kinetics, the values of effective moisture diffusivity, activation energy and color changes were determined. The moisture ratios were modeled using six thin-layer drying models.

MATERIALS AND METHODS

Materials

Sour cherries, which are grown in Çorlu location (Tekirdağ, Turkey) were provided from a local market in Çorlu in August 2021 and were kept in a refrigerator at a temperature of 4°C. The average length, width and thickness of the sour cherry are 17.20 ± 1.98, 18.90 ± 2.22 and 18.45 ± 2.25 mm, respectively. Before the drying experiments and moisture determination the cherry samples were removed from the refrigerator and kept in a desiccator at room temperature for 2 h. Dry matter and moisture contents of the sour cherry samples were determined prior to the drying process. To determine the initial moisture content, four 10 g-samples were dried in an oven (Memmert UM-400, Germany) at 105°C for 24 h [15]. The average initial moisture content of the sour cherry was found to be about 74.40% w.b.

Determination of dimensional properties of sour cherry samples

The dimensions of 20 randomly selected sour cherry samples were determined. Using an electronic caliper with a precision of 0.01 mm, the three fundamental axial dimensions of the sour cherry samples were measured.

The arithmetic mean diameter (AMD), geometric mean diameter (GMD), sphericity index (SP), surface area (S) and aspect ratio (AR) of cherry samples were calculated using equations (1)-(5) obtained as a result of literature review. The formulas are as follows [16-19]:

Arithmetic mean diameter (AMD or D_a) mm:
$$D_a = (L+W+T)/3 \quad (1)$$
Geometric mean diameter (GMD or D_g), mm:
$$D_g = (L*W*T)^{1/3} \quad (2)$$
Sphericity index (Sp), %:
$$S_p = (D_g/L)100 \quad (3)$$
Surface area (S), mm^2:
$$S = \pi(D_g^2) \quad (4)$$
Aspect ratio (AR or Ra):
$$R_a = W/L \quad (5)$$

Drying equipment and drying procedure

Microwave drying process was performed in a home type Delonghi MW205S model microwave dryer with a working interval of 140-790 W (Delonghi, Treviso, Italy).

Before drying, the core of the samples was removed and divided into two parts. The sour cherry samples (approximately 15 ± 0.2 g) were dried in a microwave dryer at 140, 210 and 350W power level until the water content decreased to about 8.5% (w.b). The dried samples were removed from the microwave at intervals of 60 s for 140W, 30 s for 210W, and 15 s for 350W, and their weights were measured with a digital balance (model BB3000, Mettler-Toledo AG, Greifensee, Switzerland) with an accuracy of 0.1 g.

Infrared drying experiments were performed using the MA 50.R model infrared moisture analyzer which works with 230 V at 50 MHz (Radwag Balances and Scales, Radom, Poland). Taking into account the effect of temperature, the sour cherries were dried in an infrared dryer at 50, 60 and 70°C. Sample weight was noted from the infrared radiation dryer screen at 15 min intervals for each temperature in infrared drying method. The drying process was terminated when the moisture content decreased to about 8.5% (w.b.) from an initial value of 74.40% (w.b.). All drying experiments were repeated three times and average values were used in the calculations.

Mathematical modeling of drying curves

The moisture content of drying samples at time t can be transformed to moisture ratio (*MR*) [20]:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \tag{6}$$

where: M_t is the moisture content at time (g water/g dry matter), M_o is the initial moisture content (g water/g dry matter), M_e is the equilibrium moisture content (g water/g dry matter).

The drying rate *(DR)* of sour cherry samples was calculated using equation (7):

$$DR = \frac{M_t - M_{t+\Delta t}}{\Delta t} \tag{7}$$

where: $M_{t+\Delta t}$ is the moisture content at $t+\Delta t$ (g water/g dm), and *t* is time (min).

In this study, drying curves were fitted to six different thin-layer drying models to select a suitable model to describe the drying process of sour cherry samples. (Table 1). The *MR* in these equations represents the moisture content or moisture ratio and drying time of the samples at any given moment. The moisture ratio was simplified to M_t/M_o instead of equation 1 by some investigators [21, 22].

The obtained data were fitted to the models and their corresponding constants were calculated using Statistica 6.0 program software (Statsoft Inc., Tulsa, OK). In addition, one-way analysis of variance (ANOVA) and multiple comparisons (post-hoc LSD; least significant-difference test) were used to evaluate the significant differences of the data at p≤0.05. The data were expressed as means ± standard deviation (SD).

Table 1. Mathematical models applied to the sour cherry samples drying curves

Model name	Equation	Ref.
Aghbashlo *et al.*	$MR = e^{\left(\frac{-k_1 t}{1+k_2 t}\right)}$	[23]
Alibas	$MR = ae^{(-kt^n)} + bt + g$	[24]
Jena and Das	$MR = ae^{(-kt+bt^{0.5})} + c$	[25]
Parabolic	$MR = a + bt + ct^2$	[21]
Verma	$MR = ae^{(-kt)} + (1-a)e^{(-gt)}$	[26]
Wang and Singh	$MR = 1 + at + bt^2$	[26]

a, b, c, k, n, g: Constants in models, *MR*: Moisture ratio, *t*: Drying time

To determine the best fitted model, the coefficient of determination (R^2), root mean square error (*RMSE*) and reduced chi-square (χ^2) statistical evaluation methods were applied. In the literature, higher R^2 values and lower (χ^2) and *RMSE* values were accepted as better results.

These parameters can be calculated using equations (8) and (9):

$$x^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N-z} \tag{8}$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{exp,i}\right)^2\right]^{\frac{1}{2}} \tag{9}$$

where: $MR_{exp,i}$ and $MR_{pre,i}$ represent the experimental and predicted values of moisture ratios, respectively. *N* is the total number of experiments, and *z* is the number of constants in the model.

Calculation of moisture diffusivity and activation energy

In drying, diffusion is used to indicate the rate of moisture flow or the movement of moisture out of the material. The drying process (infrared-microwave drying) of foodstuffs usually takes place during the falling rate period. Moisture is transferred *via* molecular diffusion during the falling rate period.

A diffusion model (based on some assumptions) based on Fick's second diffusion law was used to determine the effective moisture diffusion coefficients and equation (10) can be simplified as given in [20]:

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

$$S = \frac{\pi^2 D_{eff}}{4L^2} \tag{10}$$

where, D_{eff}, *L*, *t* and *S* are the effective moisture diffusivity (m^2/s), the half-thickness of the samples (cm), the drying time (s) and the slope, respectively.

The dependence of the effective diffusivity on temperature and power level is described by the Arrhenius equation [22, 27].

$$D_{eff} = D_o exp\left(-\frac{E_a}{RT}\right) \quad (11)$$

where: D_o (m^2/s), E_a (J/mol), R (8.314 J/(mol×K)) and T (Kelvin) are the pre-exponential factor of Arrhenius equation, activation energy, universal gas constant and temperature, respectively.

$$D_{eff} = D_o exp\left(-m\frac{E_a}{P}\right) \quad (12)$$

where: P is the drying power level and m is the sample weight (g).

Color parameters

Color measurements of fresh and dried sour cherry samples were done with Chroma Meter (PCE-CSM 1, PCE GmbH, Germany). Five random readings for each selected sample were recorded. The color was measured in terms of CIEL, procedure was based on the determination of values *L* (lightness/darkness), *a* (redness/greenness), and *b* (yellowness/blueness). The total color changes (ΔE) of the sour cherry samples were calculated from the equation below [22]:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (13)$$

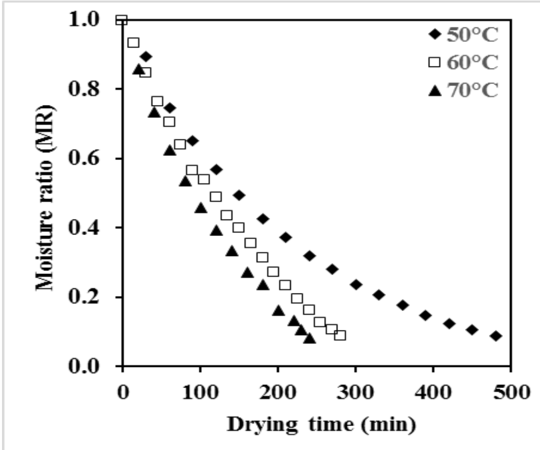
RESULTS AND DISCUSSION

Calculation of dimensional properties

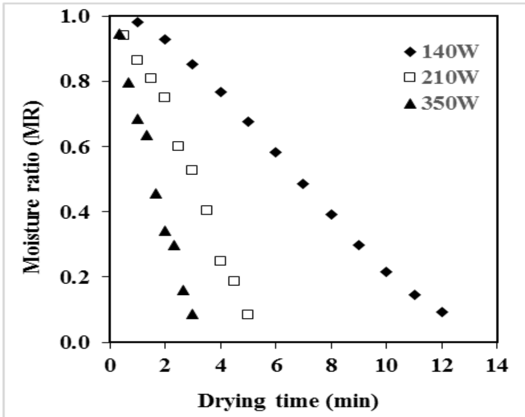
The necessary measurements were carried out on 20 randomly selected samples from sour cherries purchased from the market. The average principle dimensions of the sour cherries, *viz.* longitudinal axis, intermediate axis, and transverse axis were found to be 17.20 ± 1.98, 18.90 ± 2.22 and 18.45 ± 2.25 mm, respectively. The average sour cherries arithmetic mean diameter (AMD) and geometric mean diameter (EMD), were found to be 18.18 ± 2.07 mm, and 18.16 ± 2.06 mm, respectively. These average diameters will help us in evaluating the projection area of a fruit particle moving in the turbulent region of an air flow and in drying the fruits [17]. The sphericity index (SP), surface area (S) and aspect ratio (AR) were calculated as 105 ± 4.32, 1035.5 ± 229.75 mm^2 and 1.09 ± 0.07, respectively. The fruit's flow ability characteristics can be seen in terms of aspect ratio and sphericity. Pradhan *et al.* have proved in 2012 that these two parameters affect the flow of the fruit [28]. A sphericity value between 1 and 0.90 indicates perfection for the fruit [29]. The value of 1.05 found for sour cherry is considered to be a high sphericity index value.

Change of moisture ratio and drying rate during microwave and infrared drying

The drying curves (drying time *versus* moisture ratio) of the sour cherries microwave dried at 140, 210 and 350W and infrared dried at 50, 60 and 70°C are presented in Figure 1.



(A)



(B)

Figure 1. Drying curves of sour cherries with infrared and microwave drying methods at different temperatures (A) and power levels (B).

Drying of sour cherries with both microwave and infrared dryers started at an initial moisture content of approximately 74.40% (w.b.) and continued until a final moisture content of 8.50% (w.b.) was reached.

As shown in Figure 1, the times to reach 8.50% (w.b.) moisture content from the initial moisture content of sour cherries in microwave drying at 140, 210 and 350W were found to be 12, 5 and 3 min, respectively whereas in infrared drying the times were found to be 480, 280, and 240 min for drying at 50, 60, and 70°C, respectively. Reducing the moisture content of foods down to between 10 to 20% by weight prevents bacteria, mold, yeast and enzyme damage [27].

As expected, the increase in drying temperatures and power levels resulted in a decrease in the drying time of the sour cherry samples for both drying methods. A fast decrease in the moisture content was observed for all drying conditions applied at the beginning of the drying process; however, this drying rate decreased as the drying proceeded. Similar results were also reported for fruit products by earlier researchers [30, 31].

Sour cherry samples dried by the microwave drying method were found to have a shorter drying time by comparison with infrared drying method and the results show that microwave drying was a more effective method for drying sour cherry samples.

The changes in drying rates *versus* moisture content for both microwave and infrared dryers are shown in Figure 2.

The drying rate decreased continuously with increasing drying times or decreasing moisture content. These findings are also in agreement with previous studies [32]. The microwave drying method showed higher drying rate at all three conditions as compared to the infrared drying method. As the temperature and power level increased, drying rate increased in both drying methods.

When analyzing Figure 2, two different periods can be defined: warming and falling rate periods. In the drying rate curves of both drying methods, no constant-rate drying period was obtained. Drying occurred in the falling rate period for both drying methods. In other words; initially, when the moisture content was high, the drying rate at all drying conditions increased with time corresponding to a transition period in which isothermal and non-isobaric conditions were present, but then decreased steadily as the moisture content decreased. The presence of falling rate drying behavior is indicative of a gradual increase in both mass and internal resistance to heat transfer [33]. It may be that the porosity of the samples decreases over time, the resistance to the movement of water increases as a result of shrinkage as drying progresses, leading to a further reduction in drying rates [34].

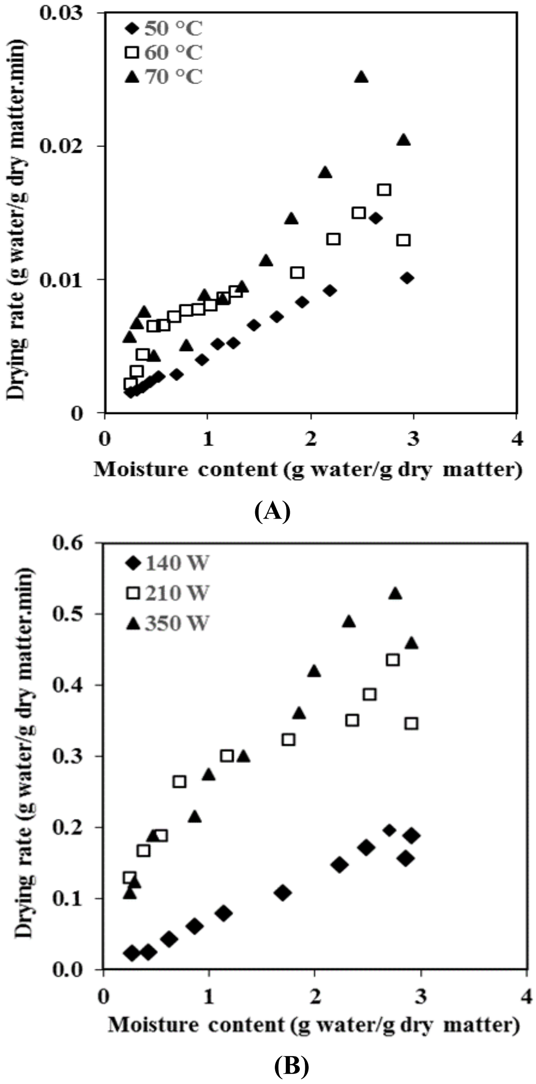


Figure 2. Drying rates *versus* moisture content of sour cherry samples at different temperatures (A) and power levels (B)

Evaluation of the models

Thin-layer drying models, preliminary evaluation of all drying processes, have significant practical value for engineers. Moisture contents of sour cherry samples were converted to dimensionless moisture ratio so that modeling studies could be carried out easily. Moisture ratio values of sour cherry samples were calculated by using Equation 6. The experimental data were fitted to the models given in Table 1 and statistical data are shown in Table 2.

Table 2. Statistical results obtained with the different thin-layer drying models for sour cherries samples compared with experimental values

Models	Parameters	Microwave drying			Infrared drying		
		140 W	210 W	350 W	50°C	60°C	70°C
Aghbashlo *et al.*	R^2	0.9989	0.9995	0.9972	0.9961	0.9985	0.9946
	χ^2	0.000098	0.000084	0.000029	0.000356	0.000184	0.000742
	RMSE	0.009102	0.007273	0.004791	0.017238	0.012423	0.021694
Alibas	R^2	0.9996	0.9999	0.9992	0.9987	0.9991	0.9995
	χ^2	0.000054	0.000008	0.000145	0.000156	0.000137	0.000052
	RMSE	0.006152	0.004684	0.010183	0.010837	0.005065	0.005809
Jane and Das	R^2	0.9991	0.9974	0.9963	0.9994	0.9995	0.9996
	χ^2	0.000210	0.000604	0.000977	0.000104	0.000201	0.000161
	RMSE	0.012062	0.020064	0.024937	0.001802	0.011973	0.011284
Parabolic	R^2	0.9971	0.9956	0.9953	0.9982	0.9989	0.9992
	χ^2	0.000831	0.001167	0.001205	0.000544	0.000347	0.000264
	RMSE	0.025279	0.029579	0.029608	0.021163	0.016517	0.01492
Verma	R^2	0.9763	0.9664	0.9948	0.9991	0.9990	0.9973
	χ^2	0.005980	0.008911	0.001466	0.000058	0.000080	0.000564
	RMSE	0.067822	0.081751	0.032654	0.006932	0.007923	0.02179
Wang and Singh	R^2	0.9946	0.9958	0.9949	0.9972	0.9989	0.9991
	χ^2	0.001166	0.001116	0.001287	0.000889	0.000444	0.000130
	RMSE	0.031415	0.03049	0.03245	0.028013	0.019504	0.016404

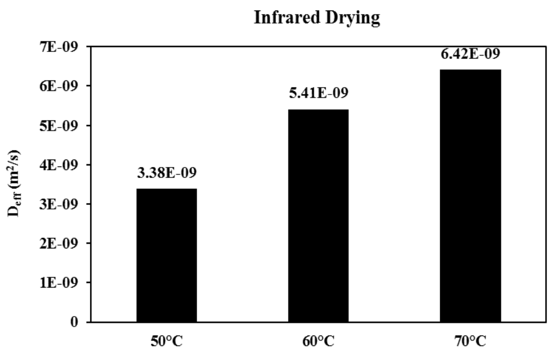
The best model describes the thin-layer drying properties of sour cherry samples chosen as the model with the highest R^2 values and the lowest χ^2 and *RMSE* values. As can be seen from Table 2, the R^2 values were higher than 0.9664 which indicates a good fit because a R^2 value close to one implies that the predicted drying data are close to the experimental drying data.

Another statistical parameter calculated to compare the accuracy of the model is the root mean square error (*RMSE*) and reduced chi-square (χ^2) values, which represent the differences between the estimated and experimental values. It is desirable that χ^2 and *RMSE* be close to zero. As a result, the Alibas model was found to be the best model for all drying methods and drying conditions.

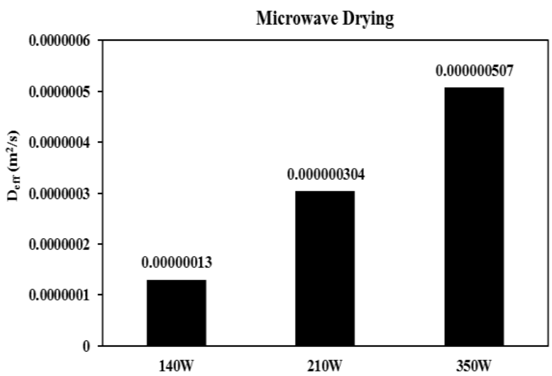
Determination of effective diffusivity

The variation of effective diffusion coefficients with temperature and power levels is shown in Figure 3.

As seen in Figure 3, based on the analytical solution of Fick's second law, the effective moisture diffusion of sour cherries was found in the range of 1.30×10^{-7} and 5.07×10^{-7} m^2/s in microwave drying, 3.38×10^{-9} and 6.42×10^{-9} m^2/s in infrared drying. The result is that the effective moisture diffusion increased with the increase in drying temperature and power levels. In addition, it was observed that the effective moisture diffusion values in the microwave drying method were higher than the infrared drying method. From this research, effective diffusion values were found in the reference range of 10^{-12} to 10^{-8} m^2/s for the drying of foodstuffs [35].



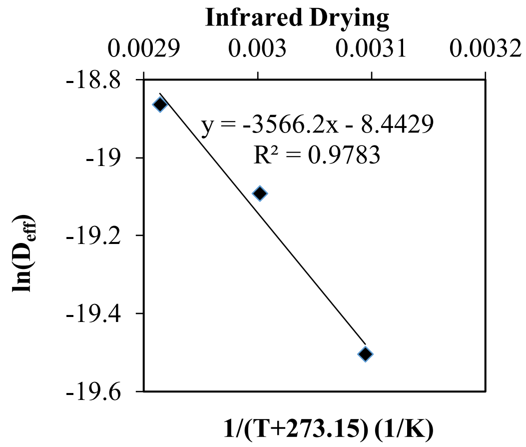
(A)



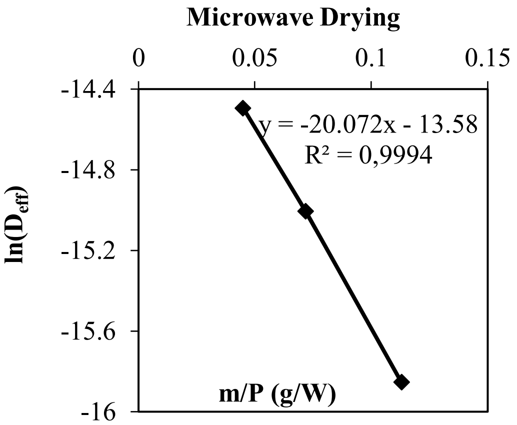
(B)

Figure 3. The effective moisture diffusivity obtained for sour cherry samples dried at different temperatures (A) and power levels (B).

Activation energy is defined as the minimum energy required for the moisture transfer to begin and continue. The logarithm of effective diffusivity (D_{eff}) as a function of the reciprocal of absolute temperatute (T) and power level (P) is plotted in Figure 4.



(A)



(B)

Figure 4. Variation of ln(D_{eff}) with $1/T$ (A) and m/P (B).

The Arrhenius equation should sometimes be viewed simply as a method of curve-fitting, without physical interpretation, where the D_o and E_a values represent suitable nonlinear regression constants. The activation energy can be calculated from the slope of the plot of ln(D_{eff}) *vs*. $1/T$ ($1/K$) or m/P (g/W) and estimated E_a values are 3.56 and 0.020 kW/kg, for the infrared and microwave drying methods, respectively. Again from the same equations, the estimated D_o values of the sour cherry samples dried by infrared and microwave drying methods were found as 2.156×10^{-4} m^2/s and 1.267×10^{-6} m^2/s, respectively. The estimated D_o values obtained in the present work were found to be compatible with the values reported in the literature [36-38].

Color analysis

The drying process changes the surface properties of foods. This causes reflection and color change. Therefore, the operating temperatures should be kept low. In this study, the total color change (ΔE) value was measured to determine color differences between fresh and dried sour cherries for both methods. *L, a*, and *b,* and corresponding ΔE values are shown in Table 3.

Variance analysis of the color parameters was carried out to examine the influence of the main factors, namely drying methods and conditions.

As seen in Table 3, the color values were measured as 15.14 ± 0.23, -9.71 ± 0.18 and 20.55 ± 0.69 for "*L*", "*a*" and "*b*", respectively in the fresh sour cherry samples. A significant decreased in "*b*" values was observed in both drying methods while "*a*" values have increased slightly. The coordinate "L" values of cherries dried by microwave and infrared drying methods has changed very little compared to the fresh sample. In other words, while some decrease in "L" values was observed in the microwave drying method at 210 and 350 W, "L" values increased slightly in infrared drying. For drying by infrared and microwave methods, the differences in lightness, redness and yellowness are not so evident ($p < 0.05$).

When using fresh cherry samples as a reference, higher ΔE represents a greater color change from the reference material. Since total color difference (ΔE) is a function of the three CIE L*, a*, and b* coordinates (Eq.(13)), the ΔE values ranged between 9.84 ± 0.09–14.06 ± 0.15 and 7.53 ± 0.06–13.20 ± 0.13 for the microwave and infrared drying methods, respectively. Increasing the drying temperature and power level generally resulted in lower color change. Color changes caused by drying temperatures and power levels in sour cherry samples may be closely related to pigment degradation, formation of brown pigments by non-enzymatic (Maillard reaction) and enzymatic reactions. The Maillard reaction usually occurs when foods are heated. The parameters affecting the Maillard reaction are primarily sugars and proteins, temperature and duration of the heat treatment [39]. The lowest total color change was observed in infrared drying at 70°C.

The analysis showed a statistically significant influence of the drying temperature and method on the sour cherries color. An ANOVA analysis of total color change of the dried sour cherries samples showed the existence of four groups which differed significantly from one another ($p < 0.05$; post-hoc LSD) depending on the different drying conditions.

Table 3. Color values of fresh and dried sour cherries

Drying method	Drying Conditions	Color Parameters			ΔE
		L	a	b	
	Fresh	15.14 ± 0.23[b]	-9.71 ± 0.18[a]	20.55 ± 0.69[b]	0
Microwave Drying	140 W	15.65 ± 0.07[a]	-5.74 ± 0.19[b]	7.06 ± 0.27[d]	14.06 ± 0.15[a]
	210 W	14.98 ±0.08[c]	-7.00 ± 0.30[d]	8.79 ± 0.82[a]	12.06 ± 0.16[c]
	350 W	14.56 ±0.32[d]	-8.15 ± 0.56[b]	10.84 ± 0.32[d]	9.84 ± 0.09[b]
Infrared Drying	50°C	15.90 ± 0.18[a]	-5.46 ± 0.19[c]	8.07 ± 0.56[c]	13.20 ± 0.13[d]
	60°C	15.38 ±0.19[b]	-6.30 ± 0.25[b]	9.20 ± 0.11[b]	11.85 ± 0.35[c]
	70°C	15.60 ± 0.41[c]	-7.45 ± 0.32[d]	13.37 ± 0.52[b]	7.53 ± 0.06[b]

Note: Means ± SD are given in the Table; significantly ($P < 0.05$). [a b c d] - groups that are statistically significantly ($p < 0.05$) different from each other according to drying temperature.

When infrared drying and microwave drying are compared, sour cherries samples dried with infrared drying yielded lower total color change (*ΔE*) than microwave drying at all drying conditions. Similar results have been reported by Wojdyło *et al*. [40]. and Sumic *et al*. [41] for sour cherries.

CONCLUSION

Both methods of drying have greatly influenced the drying characteristics of the sour cherry samples.

The drying rate and product quality was significantly influenced by the drying method, power level and temperatures. In both drying methods, the drying time decreased with increasing power level and temperature, but the effective diffusion coefficient increased.

The microwave drying method was found to provide shorter drying time and increased moisture diffusion; therefore, the microwave drying method could be the first choice for dehydration of foods.

In order to explain the drying behavior of sour cherry samples, six different thin-layer drying models were compared according to their coefficient of determination, reduced chi-square and root mean square error values. For both drying methods, the Alibas model showed a better fit to the experimental sour cherry data compared to the other models.

According to the results obtained, infrared drying method has a significant effect on the final quality (*ΔE*) of dried sour cherry samples.

Based on the results of the present investigation, it may be concluded that microwave drying is suitable for large-scale production in terms of short drying time, while infrared drying - in terms of product quality.

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