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İ Ç İ N D E K İ L E R / C O N T E N T S

Effects of Different Drying Methods on Drying Kinetics and Color Parameters of Strawberry Tree (*Arbutus unedo L.*) Fruit

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Changing of drying kinetics and color parameters of strawberry tree fruits that were notreated (NPT), ethyl oleate pretreated (EO) and water blanched at 80 ºC (WB) for one minute were evaluated during hot air drying at 50 °C, 60 °C and 70 °C and vacuum drying at 60 °C, 70 °C and 80 °C for halved and whole fruits. In addition to drying behaviors of strawberry tree fruits at different drying methods, tri-stimulus color parameters such as Hunter L*, a* and b* values were measured. HMF (formation of 5-hydroxymethylfurfural) occurring was also determined due to drying process. EO pretreatment was found highly effective on decreasing of drying time both for hot air drying and vacuum drying processes while WB pretreatment found to be more effective to keep color properties of strawberry tree fruits. Color properties were found to be better in half samples compared to whole dried fruits. HMF values verified this result. Hot air drying process caused to shorter drying time. High drying air temperatures (70 ºC for hot air drying and 80 ºC for vacuum drying) for all samples caused to occur HMF while HMF occurred in only whole dried NPT and WB treated fruits for hot air drying process at 60 ºC. All these data show that hot air drying method at 60 ºC drying temperature and, halving of fruits before drying can be proposed for drying of strawberry tree fruits in respect of drying kinetics, color and HMF values.

Key words: Strawberry tree fruits, color parameters, HMF, drying kinetics, pretreatments

Farklı Kurutma Metodlarının Kocayemiş Meyvesinin (*Arbutus unedo L.*) Kuruma Kinetikleri ve Renk Parametreleri Üzerine Etkileri

Önişlemsiz (NPT), etil oleat uygulanmış (EO) ve 80 ºC sıcak su kullanılarak 1 dakika boyunca haşlanmış (WB) koca yemiş meyvelerinin 50 °C, 60 °C ve 70 °C sıcaklıklarında yapılan sıcak havalı kurutma ve 60 °C, 70 °C ve 80 °C kurutma sıcaklıklarında yapılan vakum kurutma işlemleri sırasında oluşan kuruma kinetiklerindeki ve renk parametrelerindeki değişimler incelenmiştir. Kurutma işlemleri yarım ve tüm meyveler kullanılarak yapılmıştır. Koca yemiş meyvelerinin farklı kurutma metodlarında gösterdikleri kuruma davranışlarının yanı sıra Hunter *L**, *a** ve *b** gibi tri-stimulus renk parametreleri ölçülmüştür. Kurutma işleminden dolayı oluşan renk değişimi ve HMF (5-hydroxymethylfurfural oluşumu) arasındaki ilişkiyi bulmak amacıyla HMF içerikleri saptanmıştır. EO uygulamasının, hem sıcak havalı kurutma hemde vakum kurutma işlemlerinin sürelerini kısaltma açısından oldukça etkin olduğu bulunurken WB uygulamasının ise koca yemiş meyvelerinin renk özelliklerini koruması açısından daha etkin olduğu saptanmıştır. Renk özellikleri yarım olarak kurutulmuş meyvelerde, bütün olarak kurutulmuş meyvelere kıyasla daha iyi bulunmuştur. HMF içerikleride bu sonucu doğrulamıştır. Sıcak havalı kurutma işleminde kurutma süresi daha kısa ve renk özellikleri daha iyi olmuştur. Tüm örneklerde, yüksek kurutma sıcaklıkları (sıcak havalı kurutma için 70 ºC ve vakum kurutma için 80 ºC) HMF oluşumuna sebep olurken 60 ºC sıcak havalı kurutmada sadece tüm meyvelerin önişlem görmemiş (NT) ve sıcak suda haşlanmış (WB) olan örneklerinde HMF oluşmuştur. Bütün bu sonuçlar dikkate alınırsa, koca yemiş meyvesinin kurutulmasında kuruma kinetikleri, renk ve HMF değerleri açısından, 60 ºC'de sıcak havalı kurutma metodu ve kurutmadan önce meyvelerin yarıya kesilmesi önerilebilmektedir.

Anahtar Kelimeler: Koca yemiş meyvesi, renk parametreleri, HMF, kuruma kinetikleri, önişlemler

Introduction

Strawberry tree, Arbutus unedo L., belonging to the Ericaceae family is a typical species of Mediterranean fringe and climate, but today it is also cultivated in many other regions such as the Near East and Transcaucasia (Alarcao-e-Silva et al. 2001) . It is native to Greece, Lebanon, Ireland, Southern Europe and Anatolia (Turkey) (Celikel et al. 2008). The strawberry tree is a valuable ornamental plant due to its attractive red fruits in the fall and winter, and pinkish-white flowers in the fall. Its fruits are either consumed as fresh fruit or processed into traditional products such as jam, marmalade, wine, alcohol and liqueur (Alarcao-e-Silva et al., 2001 and Celikel et al., 2008). In Turkey, these traditional products are not commercial scale but its traditionally usage has been increasing day after day. Mature A. unedo fruits are characterized by the excessive value of sugars/acids ratio (from 42% to 52%) and high content of non-volatile content and total phenols content (14.6 mg/g dried fruit), and terpenoid compounds (Alarcao-e-Silva et al., 2001; Celikel et al., 2008; Ayaz et al., 2000).

Fresh fruits cannot be preserved for a long time due to especially high moisture content and nutrients for microbes to grow. Drying is one of the common techniques to inactivate and restrain microbial growth to inactivate enzymes, and to provide for preservation of seasonal plants for the whole year (Lijuan et al., 2005; Krokida et al., 2001; Dadalı et al., 2007). Drying process is practical and preferred process for strawberry tree (Arbutus unedo L.) fruits because its good sources of energy, minerals, and vitamins, bioactive compounds and antioxidant activity. But thermal damage is occured during drying especially related to drying temperature, and time. There are such phenomena as shrinking, change of color, oxidizing and reduction reactions, decrease of the content of valuable nutritive components, and other components (Kammski and Tomczak, 2000). The color is one of the most important quality parameters and plays a very important role in appearance, processing, and acceptability of products. It is very important to keep color parameters after thermal processes including drying. The common method is applying the pretreatments to reduce these thermal damages including color change. Blanching is one of the most widely used pretreatments applicated before drying of vegetables for inactivation of enzymes, preventing of changes in tissue structure, getting shorter drying time and increasing drying rates (Lewicki, 2006; Tembo et al., 2008; Doymaz, 2008). In addition to blanching, hot or cold chemical pretreatments such as ethyl oleate, potassium carbonate and sodium hydroxide are also applied to increase the drying rate by removing the surface resistance of fruits or vegetables (Pangavhane et al., 1999; Doymaz, 2007). Quantitative and systematic researches on drying of strawberry tree fruits are not satisfactory. Few authors performed researches for determination of nutritional, color and chemical characteristics of fresh strawberry tree fruits at different mature stages (Alarcao-e-Silva et al., 2001; Ozcan and Hacıseferogullari, 2007). On the other hand drying process have good potential to provide an increase the economic viable to this fruit. Demirsoy et al. (2007) investigated the effects of drying process on some properties of strawberry tree fruits. In their research two different genotypes of Turkish strawberry tree fruits (Arbutus unedo L.) were dried at 70 and 80 °C using a parallel air flow type drier. Fruit color and vitamin C amount after drying process were determined.

Drying kinetics and changing of color properties of strawberry tree (Arbutus unedo L.) fruits using different drying methods and applying different pretreatments were not investigated fully. Therefore, this research was performed to compare the effects of air and vacuum drying methods and pretreatments (ethyl oleate pretreatment that is the most widely-used pretreatment agent and water blanching by dipping into 80 °C hot water) on drying kinetics, to determine changes in the color values of the fruits after air and vacuum drying methods and different pretreatments and to determine changing of the HMF development during air and vacuum drying process after different pretreatments. Drying experiments were repeated for halved and whole fruits to determine the effect of fruit form on the drying kinetics, color and HMF values.

Materials and Methods

Raw Material

Ripe fresh strawberry tree fruits (Arbutus unedo L.) were used for all the experiment in this research. The fruits were collected from Çanakkale province, Lapseki subprovince and Şevketiye village at high about 100-200 m from sea level in Turkey. Strawberry fruits were kept in cooled bags for transport to the laboratory. The fruits were sorted visually according to their color and selected fully ripened ones for drying. Later, they were cleaned to remove all foreign matter such as dust, dirt, and damaged fruits. Pretreatments were performed later. Whole fruits were dried and they were cut into uniform halves for drying by hot air dryer and vacuum dryer.

Pretreatments

Strawberry tree fruits were treated two different solutions for increase the water permeability of fruits and decreasing to drying time. In first pretreatments whole fruits were dipped into 2 % ethyl oleate + 4 % potassium carbonate solution for one minute at room temperature (Ethyl oleate application; EO). In second pretreatments method whole fruits were dipped in hot water (80 ºC) for one minute. We selected the temperature of 80 ºC after different blanching tests because texture of fruits remained tough at this temperature (Water blanching application; WB). In addition to these samples, control samples (non pretreatment) were also prepared for using as control materials (NPT). Before drying process, fruits were transversely divided into two halves. Experiments were performed also for whole fruits.

Hot Air Drying Experiments (AD)

Hot air drying experiments were carried out in a constant-air temperature box at 50, 60 and 70 °C drying air temperatures (Yamamoto et al., 2002; Aktas et al., 2007). The drying air velocity was fixed as 1.5 m/s (measured by a hot wire digital anemometer). The relative humidity in the constant air temperature box was maintained by using silica gel as a dessicant. Sufficient amount of silica gel was kept within the box to keep the air dry throughout the drying process. Before the all drying experiments the silica gels were dried to remove the absorbed moisture. So the air relative humidity in the drying box was maintained below 12% during experiments. Relative humidity was checked throughout the experiments by using a hygrometer (Aktas et al., 2007). Samples were placed onto a wire net basket which was connected to electronic balance placed above the drying chamber. The sample weight measuring interval was 10 minutes to check changing of sample moisture.

Vacuum Drying Experiments (VD)

The vacuum drying process was conducted in MMM Medcenter Vacucell 22 Blue Line Vacuum Dryer that has 22 liter capacity stainless steel chamber. This vacuum drier is connected with KNF Laboport N810 FTP Diaphragm Vacuum Pump. This pump can be reached the value of 75 mmHg ultimate vacuum. Drying experiments were carried out at the drying temperatures of 60, 70 and 80 °C and vacuum chamber pressure of 10 kPa.

Color Measurements

Color measurements of the samples that were dried after pretreatments using different drying methods were performed using Hunter-Lab tristimulus colorimeter (D25LT model). The color changes of fruits were evaluated both external and internal side of dried fruits, because the color of fruits is red on external side and deep yellow on internal side. The whole fruits were divided to half after drying for determination of inside color. CIE L*, a*, b* color parameters of samples were measured from 10 points of each sample pile just after drying processes. Color parameters were measured either for external (skin) or internal side (fleshy part) of fruit. Measurements were performed as three replications. Similar to other many dry fruits, there is no color standard for dry strawberry tree fruit therefore color properties of fresh strawberry tree fruit samples were measured to check the effect of drying methods (Aktas et al., 2008).

Determination of 5-Hydroxymethylfurfural Content (HMF)

The HMF content was determined quantitatively following the procedure described by Cemeroglu (Cemeroglu 2007) based on the colorimetric reaction between barbituric acid, p-toluidine and HMF, forming a red collared complex. The intensity of red color was measured at 550 nm with a Hitachi U-2000 spectrophotometer.

Statistical Analysis

All experiments were conducted as a completely randomised block design and performed in two replicate. Data were analysed by using MSTAT statistical program (Version 3.00/EM, Package Program) (Anonymous, 1982).

Result and Discussion

Hot Air and Vacuum Drying Kinetics of Strawberry Tree Fruits

Drying kinetics of hot air dried strawberry tree fruits at 50, 60 and 70 °C drying air temperatures are given in Figure 1. In this figure, it is visible how the increase in temperature accelerates the drying process. While moisture content of notreated samples stabilised after more than 30 hours about 0.32 (w.b.) at 50 °C drying air temperature, same moisture content for samples was obtained 11 hours later by increasing of drying temperature to 70 °C. Also dividing of fruits into two halve decreased the drying time. As seen in Figure 1, moisture content of halved notreated fruits decreased to about 0.13 (w.b.) only 22 hours later at 50 °C. Same findings on effect of sample size were found especially for different slice thickness for many agricultural products and they found that decreasing of sample thickness increases the drying rate (Bhuyan and Prasad, 1990; Diamente and Munro, 1993). Ertekin and Yaldız (2004) also performed a research on drying of eggplant and they also investigated the effect of slice thickness of eggplant samples on drying time in their research. They determined that when the slice thickness increased to 1.27 and 2.54 cm, drying time increased by about 104% and about 294% according to a slice thickness of 0.635 cm, respectively. They explained its reason as thinly sliced products dried faster due to the reduced distance the moisture travels and increased surface area exposed for a given volume of the product.

These drying kinetic results for hot air drying show that pretreatment of ethyl oleate coded as EO is an important step to decrease the drying time compared to process of dipping in 80 ºC hot water blanching pretreatment coded as WB (Figure 1). Even WB pretreatment decreased the drying time, according to drying kinetics results, it can be concluded that EO pretreatment is highly effective on decreasing of drying time. As seen in Figure 1, while moisture content of EO pretreated halved samples was about 0.17 (w.b.) after 13 hours drying at 50 °C, moisture content values of notreated and WB samples after 13 hours drying at the same temperature were found as 0.30 and 0.28 (w.b.), respectively. On the other hand drying period of whole samples for same conditions took rather long time compared to halved samples did. Increasing of drying air temperature decreased the drying time of pretreated samples more than untreated samples did. By increasing of temperature to 70 °C, moisture content of notreated halved sample was found to be 0.17 (w.b.) only 7 hours later while it was found to be 20 hours for drying at 50 °C. On the other hand moisture content of EO pretreated halved samples was found about 0.17 (w.b.) only 5 hours later for drying at 70 °C while it was found to be 13 hours for drying at 50 °C. Similar results were determined for the whole dried fruit samples. Decreasing of drying time by EO applications can be explained that EO pretreatment increases effective moisture transfer diffusion coefficient (Deff) according to results of Doymaz (2004) that was performed for plum air drying experiments. The increasing of effective moisture transfer diffusion coefficient in strawberry tree fruits treated with ethyl oleate is attributed to the partial chemical breakdown of the sample skins resulting in higher permeability of water (Saravacos and Raouzeos, 1986).

The effect of drying temperature, fruit shape (half and whole fruits) and pretreatments (EO and WB) on the characteristic of vacuum drying kinetics is depicted in Figure 2 at four drying air temperatures (60 °C, 70 °C, and 80°C) at 10 kPa. As seen in these figures, all vacuum drying processes took longer time than in the case of hot air drying even at high drying air temperature. Longer vacuum drying period can be explained with texture of a lush tropical and gritty skin and high initial moisture content. Also absence of air stream to remove the air in drying cabin can be one of other reason. So it maybe needs lower vacuum pressure for faster drying. Therefore in future studies, different vacuum pressure levels must be tried.

Similar to hot air drying results, the drying time needed to reach the equilibrium moisture content was shortened notably with an increase in drying temperature due to a larger driving force for heat and mass transfer at higher drying temperature, which is in agreement with previous reports (Wu et al., 2007; Thorat et al., 2010). While moisture content of notreated whole and halved sample was found as 0.36 (w.b.) after 36.5 hours and 23 hours respectively at 60 °C drying air temperature, same moisture content for whole and halved samples obtained around 17 and 12 hours later by increasing of drying air temperature to 80 °C. As seen in these results halving of fruits highly decreased the vacuum drying time to same moisture content.

As it can be seen, pretreatments decreased the drying time. Especially effects of EO pretreatment at 60 °C can be seen clearly in Figure 2. In all drying air temperatures and both for whole dried and halved dried samples, EO pretreatment accelerated the drying time. At 60 °C temperature, after 21 hours drying period, moisture content of EO pretreated halved sample was found as 0.16 (w.b.) while it was found as 0.39 and 0.40 for WB and notreated samples, respectively. This period was found longer for dried fruits as whole. These values were found as around 0.61, 0.49 and 0.44 for notreated, WB, and EO pretreated samples, respectively. Accelerating effect of EO pretreatment on drying time was found also for 70 and 80 °C temperatures. By increasing of drying air temperature from 60 °C to 70 and 80 °C, WB pretreatment effects were found similar to EO effect for halved fruits (in Figure 2). It can be explained that dividing of fruits accelerated the water migration to surface.

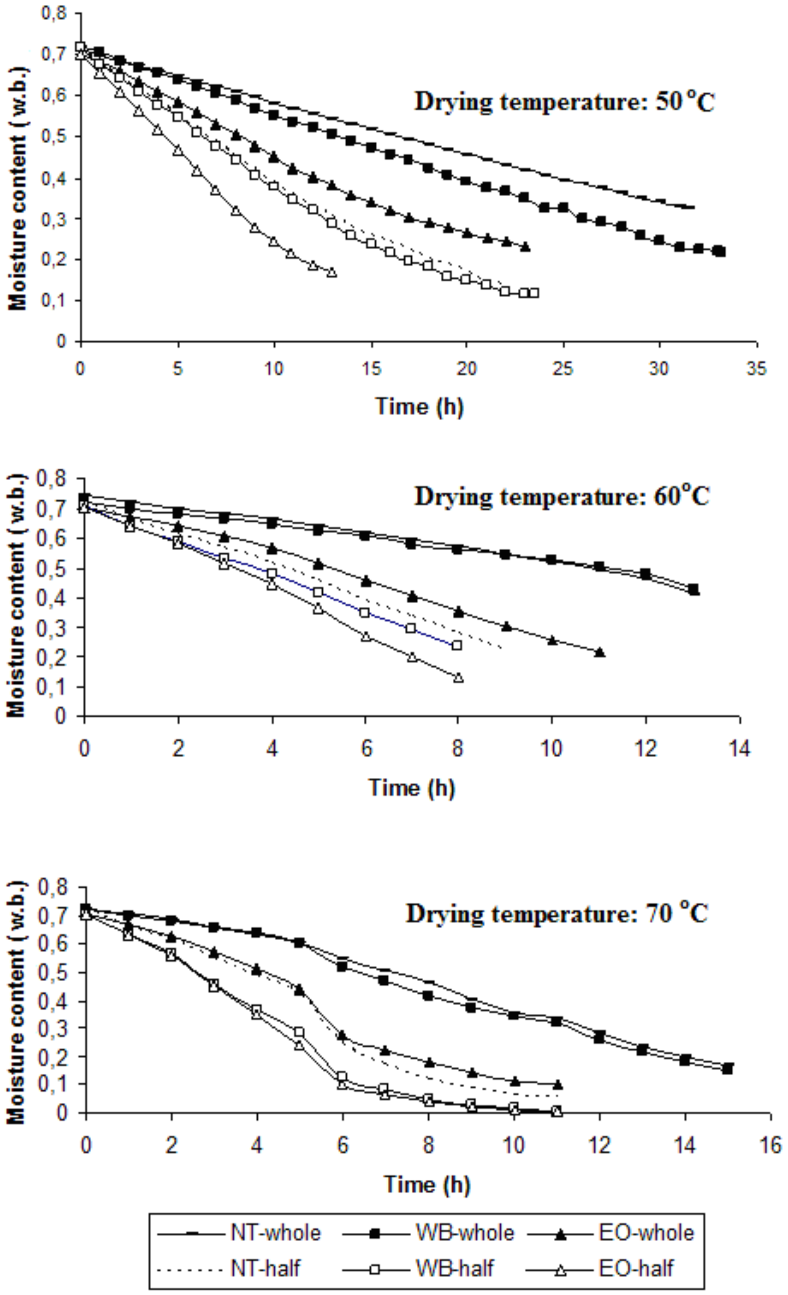


Figure 1. Effects of hot air drying temperatures and pretreatments on drying kinetics of strawberry tree fruits.

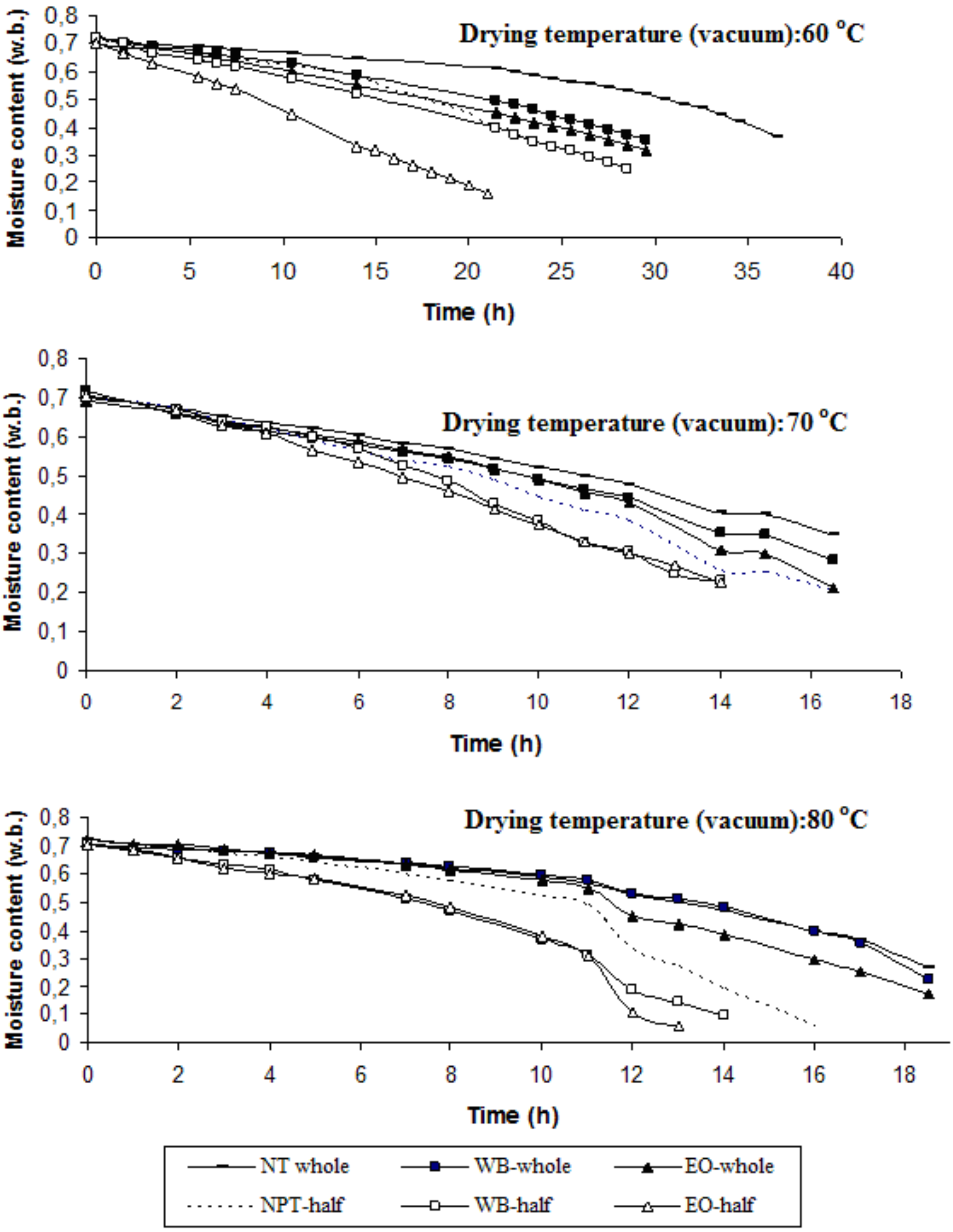


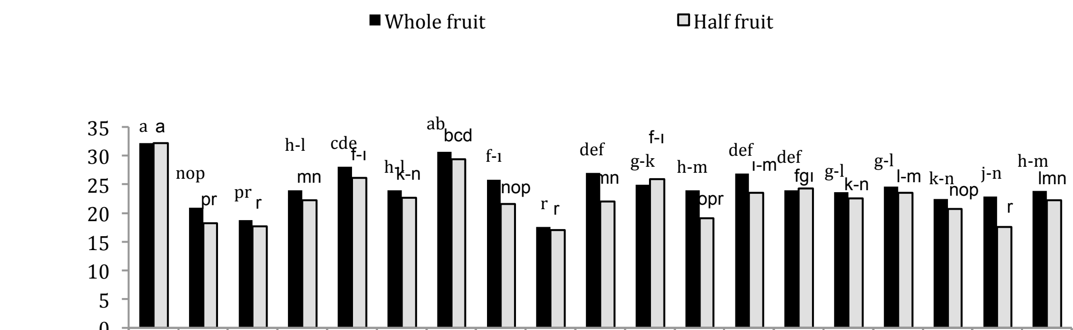
Figure 2. Effects of vacuum drying temperatures and pretreatments on drying kinetics of strawberry tree fruits

Color Parameters

The Hunter color parameters (*L*, a** and *b**) of fruits were evaluated both external and internal side of dried fruits, because the color of fruits is red on external side and deep yellow on internal side. Proliac and Raynaud (1981) reported that carotenoids may be responsible for the yellow color in the flesh of the fruits, but the external red color is mainly due to the presence of other phenolic pigments, identified as 3-glucosylcyanidin.

The results of brightness (*L**) value for the external side and internal side of strawberry tree fruits, in the fresh form and after drying at different conditions were given in Figures 3, 4. As it can be seen from Figure 3, all drying processes caused the decreasing in *L** values in external side when compare to *L** values of fresh fruits and the differences between pretreatments was found significantly important (*P<0.05*). According to fruit shapes, *L** values of whole fruits were found to be higher than those of half fruits in external side. Concerning the pretreatments, the EO applications exhibited a decrease in the brightness of external side of fruits in both drying methods. In general, *L** values of external side of WB pretreated fruits found to be higher than those of EO pretreated samples. The lowest *L** value was determined in dried samples at 70 °C hot air drying after EO pretreatment while the highest *L** value was determined in dried samples at 60 °C at hot air drying after WB pretreatment. According to results, it was thought that brightness values of samples changed also related to moisture content. According to mean values of drying methods, the brightness value for external side of fruits was determined in the following order: *60°C AD > 60°C VD > 70°C VD > 70°C AD > 80°C VD > 50°C AD* . It has been stated that the decrease of brightness value could be taken as a measure of browning (Avila and Silva, 1999; Ibarz et al., 1999; Ergunes and Tarhan, 2006; Lee and Coates, 1999). Browning was due to the non-enzymatic browning reaction. Therefore it can be concluded that higher temperatures and longer drying process could be cause the browning reaction in external side of strawberry tree fruits.

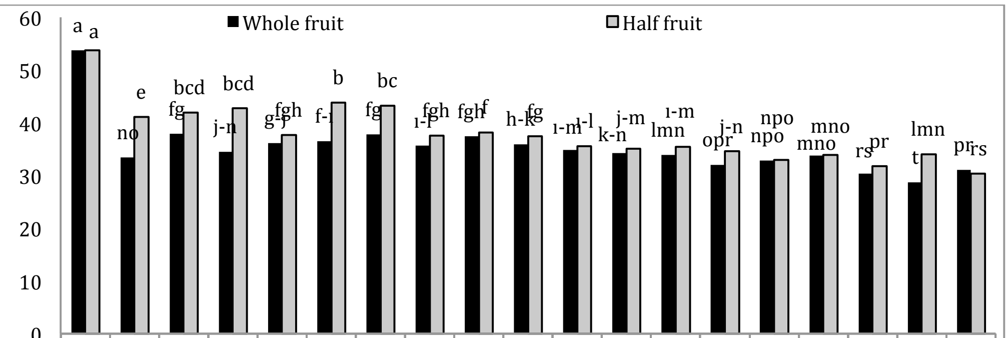
The brightness of internal side of strawberry tree fruits are shown in Figure 4. As seen in this figure, all drying applications decreased the *L** values compared to L* values of fresh fruits. Vacuum drying applications at 60 and 70 °C decreased the L* values higher than hot air drying process at the same temperatures. This can be explained with rather longer period in vacuum drying process. *L** values also decreased at higher drying air temperatures both hot and vacuum drying methods. *L** values of fruits dried at 70 °C by hot air drying were determined lower than 50 °C and 60 °C and similarly, *L** values of fruits at 80 °C were determined lower than those of dried at 60 °C and 70 °C by vacum drying method.



	FRESH FRUIT	NPT	EO	WB	NPT	EO	WB	NPT	EO	WB	NPT	EO	WB	NPT	EO	WB	NPT	EO	WB
		50 °C AD			60 °C AD			70 °C AD			60 °C VD			70 °C VD			80 °C VD		
Whole fruit	32,19	20,93	18,76	23,92	28,06	23,92	30,69	25,84	17,56	26,96	24,93	23,92	26,84	23,92	23,67	24,57	22,45	22,84	23,83
Half fruit	32,19	18,25	17,66	22,22	26,09	22,68	29,42	21,55	17,04	21,98	25,9	19,12	23,51	24,31	22,55	23,53	20,76	17,61	22,23

Figure 3. L* value of external side of fresh and dried fruits. *Different letters of upper index within the column is indicating significant differences at P<0.05 level (*n = 2).*

Average value of drying treatments; 50°C AD : 20.61c , 60°C AD: 27.47a, 70°C AD : 21.82c , 60°C VD : 23.95b, 70°C VD : 24.59b, 80°C VD: 21.62c.



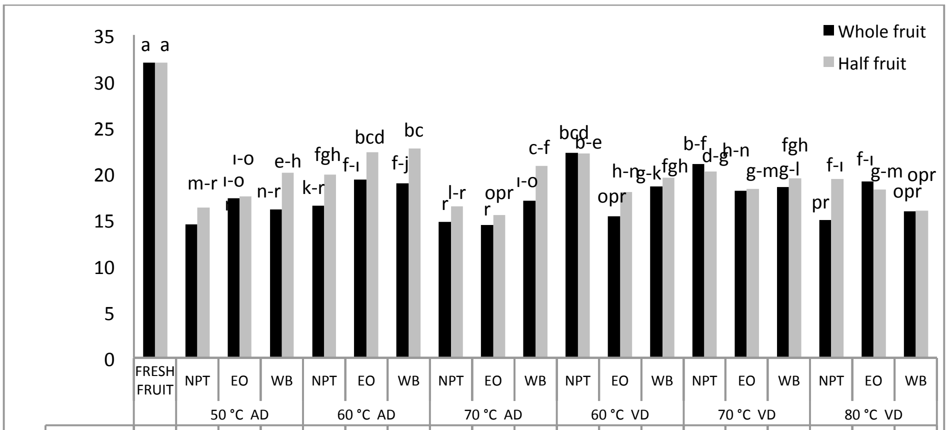
	FRESH FRUIT	50 °C AD NPT	50 °C AD EO	50 °C AD WB	60 °C AD NPT	60 °C AD EO	60 °C AD WB	70 °C AD NPT	70 °C AD EO	70 °C AD WB	60 °C VD NPT	60 °C VD EO	60 °C VD WB	70 °C VD NPT	70 °C VD EO	70 °C VD WB	80 °C VD NPT	80 °C VD EO	80 °C VD WB
Whole fruit	53,75	33,37	37,86	34,54	36,12	36,51	37,79	35,61	37,42	35,93	34,79	34,24	33,85	32,05	32,84	33,78	30,34	28,7	31,1
Half fruit	53,75	41,12	41,89	42,71	37,69	43,79	43,28	37,55	38,19	37,4	35,54	35,05	35,42	34,57	32,96	33,84	31,8	34,07	30,37

Figure 4. L* value of internal side of fresh and dried fruits. *Different letters of upper index within the column is indicating significant differences at P<0.05 level (n=2).

Average value of drying treatments; 50°C AD : 37.91b , 60°C AD: 39.16a, 70°C AD : 37.07c, 60°C VD : 35.45c, 70°C VD : 34.03d, 80°C VD: 31.06e

According to mean values, the highest brightness value for internal side of fruits was determined for 60 °C hot air drying method (WB pretreatment) and this finding is similar to brightness of external side. If the results are checked in respect of the shape of fruits, *L** values of whole fruits were found to be lower than half fruits in internal side. It can be said that longer drying period of whole samples (Figures 1 and 2) was effective on *L** values negatively. Differences between WB fruits and EO pretreatments were found to be significant but very close to each other in both vacuum drying and hot air drying processes in general. On the other hand EO and WB pretreatments could kept brightness of fruit in internal side higher than NPT samples for hot air drying process and it could be explain the decreasing of drying time in these pretreatments.

The performance of pretreatments can be evaluated with their effects on retaining the original colors for both external side (*a** color parameter namely redness) and internal side (*b** color parameter namely yellowness) of fruits. It is expected that *a** values for external side of fruits should be higher as much as possible. For this reason, the *a** values of fruits for external side were given were given in Figure 5. As seen in this figure, the *a** values of dried strawberry tree fruits in external side decreased by drying methods and differences was found statistically important (*P<0.05*). Drying at 70 °C by hot air drying method highly decreased the *a** values and according to mean values the lowest *a** value was determined in this treatment. Pretreatments had positive effect on redness and WB pretreatments showed higher values than EO pretreatments. While the drying time is decreased by EO application, it may be caused the decreasing in redness by solving of color pigments from the external side. This losing in color pigments could be effected brightness of external side. According to mean values, the redness of vacuum dried samples at 60 °C was found lower than those of hot air dried samples at the same drying temperature. Highest deviations from original redness were found in notreated samples for hot air drying method. When we checked the hot air drying results, it can be seen that *a** values of dried half fruits were found to be higher than those of dried as whole samples. Similar results it can be seen in vacuum drying process.

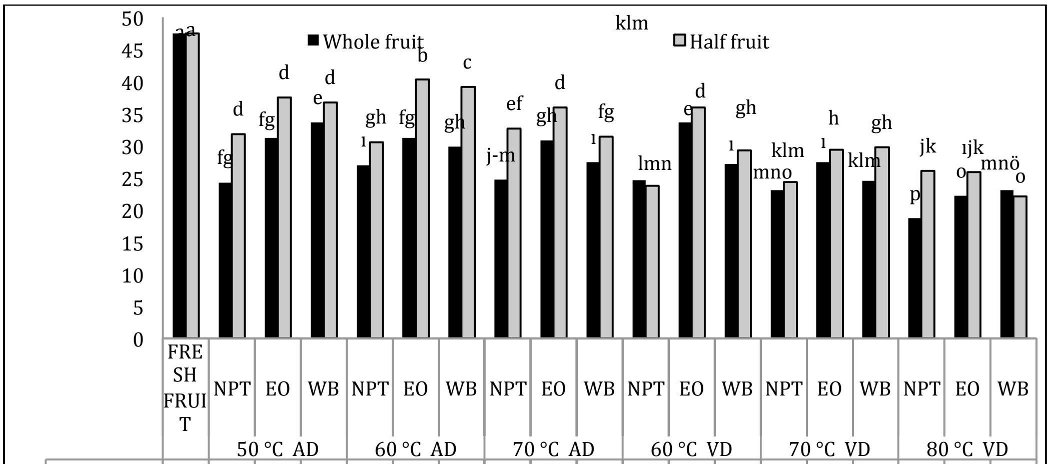


	FRESH FRUIT	50 °C AD			60 °C AD			70 °C AD			60 °C VD			70 °C VD			80 °C VD		
		NPT	EO	WB	NPT	EO	WB	NPT	EO	WB	NPT	EO	WB	NPT	EO	WB	NPT	EO	WB
Whole fruit	31,99	14,44	17,3	16,11	16,47	19,33	18,91	14,74	14,39	17,01	22,23	15,36	18,56	21,01	18,08	18,49	14,92	19,1	15,85
Half fruit	31,99	16,26	17,52	20,07	19,84	22,3	22,71	16,44	15,45	20,81	22,13	18	19,49	20,2	18,34	19,43	19,39	18,25	15,97

Figure 5. a* value of external side of fresh and dried fruits.
Average value of drying treatments; 50°C AD: 16.95e , 60°C AD: 28.32a, 70°C AD: 16.47f, 60°C VD : 19.16c, 70°C VD: 20.09b , 80°C VD: 17.24d

It is known that yellowness namely *b** values for internal side of strawberry tree fruits should be higher as much as possible due to its natural yellow color. For this reason *b** values of fruits were evaluated and given for only its internal side in Figure 6. Similar to the behavior of *a** values, strawberry tree berries lost their internal yellowness (*b**) when they were dried by hot air drying and vacuum drying methods compared to values of fresh fruits (Figure 6). It is seen in Figure 6 increasing temperature is increased the degradation of color inside of fruits. Changes in yellowness were occurred different related to preparation of fruits before drying. Less change in yellowness of internal side of fruits dried as halved was found generally compared to dried fruit as whole especially for hot air drying process. According to statistical mean values, deviation of yellowness was found higher in vacuum drying process compared to yellowness deviation in hot air dried fruits for both halved and whole fruits. EO and WB pretreatments protected the original color for dried fruits both whole and halved fruits compared to *b** values in internal side. It could be explain that the decreasing of drying time. Differently from external redness of fruits, the internal side of fruits more effected by drying time and drying temperature. It is seen in Figure 6, lower temperatures and lower drying periods positively effected of inside color of fruits. The highest *b** values for internal side of strawberry tree fruits was determined EO pretreated halved fruits. Owing to the EO solution was not effected inside color before drying by solving, the inside color only related drying time, temperature or shape. Therefore, the decreasing in drying time by EO pretreatments could be protected inside color higher than external color.

When color parameters are checked, it can be seen that EO treatment decreased the drying time while it was not so effective on color parameters. Similarly Ergunes and Tarhan (2006) found that all pretreatments using ethyl oleate significantly accelerated drying process. On the other hand using of only 2% ethyl oleate (I) decreased the all color parameters while using of 2% ethyl oleate + 2% NaOH solution (II) increased the all color parameters remarkable compared to 2% ethyl oleate solution results. When they used the solution of 2% ethyl oleate + 2% NaOH + 4% potassium carbonate (III), color parameters increased compared to the results obtained from II. solution. But increasing between results obtained from II. and III. was rather lower than increasing between results obtained from I. and II. According to this results, it can be said that in these solutions 2% ethyl oleate solution was not effective on the keeping color properties of samples. Adding 2% NaOH to this solution may be improved ability of keeping color parameters of samples. Therefore in future researches on the drying of strawberry tree fruit, 2% ethyl oleate + 2% NaOH + 4% potassium solution could be replaced instead of 2% ethyl oleate + 4% potassium carbonate solution that used in this research.



	FRESH FRUIT	50 °C AD NPT	50 °C AD EO	50 °C AD WB	60 °C AD NPT	60 °C AD EO	60 °C AD WB	70 °C AD NPT	70 °C AD EO	70 °C AD WB	60 °C VD NPT	60 °C VD EO	60 °C VD WB	70 °C VD NPT	70 °C VD EO	70 °C VD WB	80 °C VD NPT	80 °C VD EO	80 °C VD WB
Whole fruit	47,52	24,27	31,25	33,62	26,98	31,19	29,85	24,71	30,86	27,42	24,58	33,66	27,11	23,05	27,46	24,51	18,7	22,21	23,05
Half fruit	47,52	31,8	37,5	36,75	30,57	40,27	39,15	32,7	35,98	31,42	23,76	35,93	29,23	24,33	29,37	29,75	26,05	25,85	22,1

Figure 6. b* value of internal side of fresh and dried fruits.
Average value of drying treatments; 50°C AD: 32.50a , 60°C AD: 32.93a, 70°C AD: 30.48b, 60°C VD : 29.36c, 70°C VD: 26.36d , 80°C VD: 22.96e

When color parameters are checked, it can be seen that EO treatment decreased the drying time while it was not so effective on color parameters. Similarly Ergunes and Tarhan (2006) found that all pretreatments using ethyl oleate significantly accelerated drying process. On the other hand using of only 2% ethyl oleate (I) decreased the all color parameters while using of 2% ethyl oleate + 2% NaOH solution (II) increased the all color parameters remarkable compared to 2% ethyl oleate solution results. When they used the solution of 2% ethyl oleate + 2% NaOH + 4% potassium carbonate (III), color parameters increased compared to the results obtained from II. solution. But increasing between results obtained from II. and III. was rather lower than increasing between results obtained from I. and II. According to this results, it can be said that in these solutions 2% ethyl oleate solution was not effective on the keeping color properties of samples. Adding 2% NaOH to this solution may be improved ability of keeping color parameters of samples. Therefore in future researches on the drying of strawberry tree fruit, 2% ethyl oleate + 2% NaOH + 4% potassium solution could be replaced instead of 2% ethyl oleate + 4% potassium carbonate solution that used in this research.

HMF Values

After drying processes, HMF was not observed in fruits which were dried by hot air drying method at 50 °C, vacuum drying method at 60 °C and vacuum drying method at 70 °C. In hot air drying process, the formation of HMF increased with increasing of drying temperature. It can be seen that Table 1, with increasing of hot air drying temperature to 70 °C, the HMF value increased in all samples. Pretreatments decreased the HMF values for both half and whole fruits compared to HMF values determined in notreated samples. It was also determined that HMF occurring in whole fruits was found higher than HMF occurring in halved fruits. In vacuum drying method, the HMF occurring was detected only in 80 °C drying air temperature. In this method pretreatments decreased formation of HMF similarly AD drying methods. We can conclude that from these results decreasing the drying time by pretreatments and dividing fruits into two parts decreased also HMF formation due to shortening of the drying time. Additionally, increasing drying temperature caused the increasing of HMF formation in dried fruits. On the other hand, although the HMF formation was observing in hot air drying at 70 °C, no HMF formation observed in VD method at the same temperature. Therefore it can be concluded that HMF occurrence can be reduced by drying process at under low pressure. Cernisev (2010) hypothesized that drying optimization through product temperature control is perspective to apply for the major heat sensitive foodstuffs for inhibit HMF formation.

Table 1. HMF value of dried strawberry tree fruits (mg/kg)

Pretreatments / Drying Methods	NPT		EO		WB	
	Whole	*Half*	*Whole*	*Half*	*Whole*	*Half*
50 °C AD	nd	nd	nd	nd	nd	nd
60 °C AD	2.32	nd	nd	nd	0.45	nd
70 °C AD	4.81	2.09	2.53	1.91	3.85	1.86
60 °C VD	nd	nd	Nd	nd	nd	nd
70 °C VD	nd	nd	Nd	nd	nd	nd
80 °C VD	5.29	4.80	4.28	0.68	4.56	1.46

(nd: not detected)

Conclusions

In conclusion, drying methods, pretreatments and shape of fruits showed significant effects on the drying behaviors, color properties and HMF occurrence of dried strawberry tree fruits. In terms of shape of fruits, to divide the fruits to half resulted the decreasing the drying time, significantly. Beside this conclusion, color characteristic in respect of brightness of internal side, redness of external side and yellowness of internal side was determined higher than whole fruits. In terms of pretreatments, EO and WB pretreatments were highly shortened the drying time of berries. Especially EO pretreatment decreased the drying time for both half and whole dried fruits. Ethyl oleate has been used commercially to accelerate the drying of vegetables and fruits. The ethyl oleate solution is applied to the surface of the fruit by dipping, resulting in a coating which apparently breaks down the waxy cuticular fruit surface, resulting in a reduced resistance to moisture loss (Williams, 1989). This increases the drying rate. On the other hand when color values were checked, WB pretreatment kept the original color properties of fruits better than EO pretreatments. Similarly, Ergunes and Tarhan (2006) found that all pretreatments using ethyl oleate significantly accelerated drying process while using of only 2% ethyl oleate decreased the all color parameters. Therefore, according to this research results, hot air drying method at 60 ºC drying air temperature, halving of fruits before drying and water blanching pretreatment are suggested for drying of strawberry tree fruits in respect of drying kinetics, color and the occurrence of HMF determined after hot air drying and vacuum drying processes.

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