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Comparison of Some Quality Parameters in Fresh and Dry Samples of *Morus Rubra* Fruits[#]

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ABSTRACT

In Turkey, three species of mulberries, white (*M. Alba*), black (*M. Nigra*), and red-purple (*M. Rubra*) are grown commonly. These widely can be consumed fresh as well as dry. However, its rapid post-harvest decay raises major concerns about the sustainability of the fruit for both food and economic purposes. In this regard, besides the fresh consumption of black mulberry fruit, it can consume as dried it also offers an alternative way. In this study, it was aimed to compare some quality parameters in fresh and dry samples of *Morus rubra* fruits grown in Tokat. It was applied different temperatures to Morus rubra fruits that at collected in two different maturity levels (semi-ripe and full-ripe). In the drying process, mulberry fruits were dried in a hot air dryer at 40, 50, 60, and 70°C. Total phenol, Total phenol, total monomeric anthocyanin, total antioxidant capacity, colour values (*L, a, b*) chroma, hue (h°), and browning indices values will be measured in fresh and dried products. In addition, different mathematical models will be tried by constantly noting the weight drops of the products at certain time intervals and determining which mathematical model will best predict the drying kinetics.

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Introduction

Mulberry is a member of the family *Moraceae* and genus *Morus* and is found all over the world in a variety of climatic settings ranging from tropical to temperate Morera or mora in Spanish, Moreira in Portuguese, Murier in French, Tut in Urdu, and Sahtut in Hindi are some of the names given to it. There are over a thousand mulberry cultivars available for sericulture in China, the world's leading sericulture nation. *Morus alba* L. is the most dominant species among the 24 species and 1 subspecies (Herman et al., 2022). Mulberry is a fast-growing deciduous plant and it grows under different climatic conditions such as tropical, subtropical, and temperate throughout the world. It has been cultivated in the Northern hemisphere for centuries. In Türkiye, mulberry fruits are as important as the other temperate fruit species such as apricot, walnut, sour cherry, etc. Mulberry trees are extensively grown in southern Europe, India, and China for their foliage as foods for silkworms. However, in Türkiye and Greece mulberries are grown for fruit production rather than foliage. In Türkiye, growing conditions in the most agroecological region are very suitable for cultivating high-quality mulberry fruits, mainly from *Morus alba, Morus nigra*, and *Morus rubra* (Güngör and Şengül, 2008). Mulberry production number of 69,475 tonnes in the year of 2021 (Turkish Statistical Institute- TUIK, 2018). Mulberry, because of the short harvesting season and their sensitivity to storage, fresh mulberry fruits should be preserved in some form. Unwashed berries can be kept in a container for several days in a refrigerator. Another preservation method is drying. Also, it is used in mulberry pekmez (a concentrated mulberry juice product), juices, paste, and marmalade (Doymaz, 2004). Drying is one of the oldest and most common methods used to preserve foods and it can be carried out either traditionally, by sun drying, or industrially by solar, hot air, infrared, and other drying methods (Golpour et al., 2020). The fruits are easily spoiled after harvest due to their high moisture content. For this reason, fruits are subjected to either drying processes or cold storage processes so that they can be preserved for a long time without spoiling (Doymaz, 2011). Drying agricultural products; ensures that the moisture in their content can be removed and stored for a long time. With the drying process, the physical structure of the products is reduced, making them much easier to transport. It ensures that products that need to be consumed quickly after harvesting have a longer shelf life. In Türkiye, the drying process is mostly done in an open environment. Although the cost of this drying method is low, it negatively affects the quality of the dried product, prolongs the drying time, and does not provide a hygienic drying environment. In order to eliminate these disadvantages, drying methods have been developed in which drying is done in a closed environment and product-specific drying conditions are controlled. In the drying process, which is one of these methods, the air temperature can be controlled, the drying process can be carried out in a shorter time and a high-quality final product can be obtained (Figie, 2010).

Materials and Methods

Materials

Fruits to be Dried and Ripening Levels Semi and full-ripe purple mulberry fruits to be used as the drying material were harvested from a grower orchard in it was carried out in the rooting greenhouse of Tokat Gaziosmanpaşa University Agricultural Research and Application Center province on 11th of July, 2022.

Moisture Determination Process

In order to determine the moisture content, an average of 50±1.5 g of fresh fruit was used and dried at 70°C with 5 replications until the weight change was stabilized in both maturity stages (Abuska and Doğan, 2010).

Drying Process

The products to be subjected to the drying process within the scope of the experiment were first sorted and placed in aluminium containers in equal amounts and dimensions in a thin layer drying model as 4 replications and weighed with a precision balance with 0.01 g sensitivity. The products prepared for the drying process were weighed in an oven dryer at 40, 50, 60, and 70°C at regular intervals until the moisture content decreased to 10% humidity and the drying process was carried out. Colour measurements of the products falling to the determined moisture level were made (Polatcı and Taşova, 2017).

Oven

The oven used in the study is Şimşek Laborteknik brand and model ST-120. The cabin temperature is measured with the sensors in the oven and transmitted to the control unit. The drying air temperature is adjusted via the control unit on the oven.

Drying Models

During the drying process of the products, the available moisture content (ANO) values were calculated in accordance with the given equation.

$$ANO = \frac{M - M_e}{M_0 - M_e}$$

ANO : Separable humidity
M : Instant moisture content of the product
Me : Equilibrium moisture of the product
Mo : Initial moisture content of the product

Equations of the models used

Model name	Equality	Source
Page	MR= exp (-h.(t^j))	Liu et al. (2009)
Modifiye Page	MR=exp[(-kt)^n]	Toğrul (2006)
Lewis	MR=exp(-kt)	Doymaz (2006)

In order to process the data obtained after the drying process of the products, Page, Yağcıoğlu, Midilli, et al. equations are used. As a result of drying, the moisture rates in the products were calculated with the given equations and the acceptable humidity rate was modelled with the model equations. It was determined which model predicted the available moisture content better.

Colour Measurements

Colour measurements of mulberry fruits after drying were made with a Minolta brand CR400 (Japan) colourimeter and L, a, b values were determined.

(L) refers to the brightness value of the product and varies between 0-100. When L gets the value of 0 (zero), it means that the colour is black, that is, there is no reflection, and when it takes the value of L 100, it means that the product colour is white, that is, the reflection is complete. The value (a) denotes red-green, and (b) denotes yellow-blue colours and takes (+, -) values, respectively. If the colour values are a = 0 and b = 0, it shows that the colour is Gray (McGuire, 1992). Other colour values to be calculated will be determined using the measured colour values.

Table of colour equations to be calculated

Colour Value	Equality
Croma, C	$C = (a^2 + b^2)^{1/2}$
Hue, º	$h° = \tan^{-1}(\frac{b}{a})$
colour change, ΔE	$\Delta E = \sqrt{(L-L^*)^2 + (a-a^*)^2 + (b-b^*)^2}$

Here, Croma (C): hue of the colour, hue°: angle value of the colour, colour change (ΔE): indicates the colour change value after drying compared to fresh.

Chemical Analyses

Total Solution Soluble TSS

After the fruits were pureed in the homogenizer, the juices were extracted by centrifugation. Then, in a digital refractometer calibrated according to pure water (Atago PAL-1, USA) readings were made and the values were expressed as %.

Total phenolic content

Total phenolic content was measured according to the procedure described by Singleton and Rossi (1965). 40 ml of water was added to 10 g of dried mulberry sample and kept at +4°C for 3 days. It was then extracted with a buffer containing acetone, water and acetic acid (70:29.5:0.5 v/v) for 24 hours in the dark. The extracts were combined with Folin-Ciocalteu's phenol reagent and water and incubated in the room for 8 minutes, then 7% sodium carbonate was added. After 2 hours, absorbance at 750 nm was measured in an automated UV-vis spectrophotometer (Model T60U, PG Instruments). Gallic acid was used as standard. Results were expressed as micrograms (µg) gallic acid equivalent (GAE) g^{-1} (Aglar et al., 2017).

Total Antioxidant Capacity (TEAC)

For the standard TEAC assay, ABTS+ was dissolved in acetate buffer and prepared with potassium persulfate. The mixture was diluted in an acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700±0.01 at 734 nm for longer stability. For the spectrophotometric assay, 2.97 mL of the ABTS+ solution and 20µL of fruit extract were mixed and incubated for 10 min and the absorbance was determined at 734 nm (Gündüz et al., 2013).

Statistical Analysis

In order to determine the effects of drying temperatures on the colours, drying values, and chemical analyses of mulberry fruit in two different maturity stages, a comparison was made according to the P<0.05 importance level in the SPSS package program.

Result and Discussion

The first moisture contents of semi-ripe and fully ripe purple mulberries before drying are given in Table 1.

The final moisture values and drying times of the dried products are given in Table 2.

According to the table, the shortest drying time was observed in the semi-mature product at a drying temperature of 870 minutes and 70°C, while the longest drying time was observed in the semi-mature product at a temperature of 7590 minutes and 40 °C. It was determined that the increase in drying temperature decreased the drying time for all products.

The R2 values calculated in the thin layer drying model of the dried products are given in Table 3.

According to the table, the model that best predicts drying was determined as 0.9999 in fully mature product and Wang Singh at 40°C drying temperature.

When Table 4 is examined, L, a and b values were statistically different from fresh at a 5% significance level.

However, when the L value was examined, there was no statistical difference between 40 and 70°C drying temperatures in semi-ripe fruit and 40 and 60°C in fully mature fruit. In the study, when the a value was examined, it was determined that there was no statistical difference at 40, 50, and 70°C drying temperatures in semi-ripe fruit, and at 40, 60, and 70°C drying temperatures in fully mature fruit. Looking at the b value; It was determined that there was no statistical difference in the drying temperatures of 40 and 50 C in semi-ripe fruit, and in 40, 60, and 70°C in fully ripe fruit.

Table 1 initial moisture content of semi-ripe and full-ripe purple mulberries

First Moisture Content	
Full- Ripe	Semi- Ripe
73.10	79.72

Table 2 final moisture values and drying times of dried products

Product	Drying Temperature	Average Final Moisture (%)	Drying Time(Min)
Full- Ripe	40	10.63	6810
	50	9.93	3150
	60	9.67	2070
	70	9.83	1350
Semi- Ripe	40	10.04	7590
	50	10.59	2970
	60	10.00	1530
	70	10.31	870

Table 3. R^2 values calculated in the thin layer drying model of the dried products

		Drying Temperature			
Product	Drying Model	40	50	60	70
Full- Ripe	PAGE	0.9945	0.9983	0.9976	0.9936
	LEWIS	0.9769	0.9887	0.9912	0.9664
	WANG SINGH	0.9999	0.9897	0.9993	0.9960
	Midilli Küçük	0.9998	0.9989	0.9984	0.9967
Semi- Ripe	PAGE	0.9950	0.9956	0.9953	0.9936
	LEWIS	0.9740	0.9793	0.9723	0.9664
	WANG SINGH	0.9996	0.9994	0.9994	0.9960
	Midilli Küçük	0.9995	0.9991	0.9994	0.9967

Table 4. Fresh and dried L, a, b, values of semi-ripe and fully ripe purple mulberries

Semi- Ripe			
Drying Temperatures(°C)	L	a	B
Fresh	51.46[a]	2.11[c]	13.35[a]
40°C	33.55[b]	5.58[a]	5.70[c]
50°C	30.11[c]	5.04[a]	5.54[c]
60°C	18.99[d]	3.36[b]	-1.18[d]
70°C	32.51[b]	5.07[a]	8.34[b]
Full- Ripe			
Drying temperatures(°C)	L	a	B
Fresh	21.94[c]	10.45[a]	0.22[b]
40°C	28.92[ab]	5.12[b]	2.36[a]
50°C	27.74[b]	3.39[c]	-0.62[b]
60°C	28.80[ab]	4.80[b]	2.00[a]
70°C	30.16[a]	4.90[b]	1.77[a]

Table 5 Chrome (C), Hue (H º), and Color Change (ΔE) of fresh and dried products

	Drying Method	Drying Condition	C	H º	ΔE
Full-Ripe	Fresh	-	10.52	1.94	-
	Oven	40	5.76	21.90	23.84
		50	3.47	-9.71	24.54
		60	5.37	18.60	24.00
		70	5.29	17.94	25.35
Semi-Ripe	Fresh	-	13.74	50.24	-
	Oven	40	8.33	39.61	26.30
		50	7.53	46.11	23.47
		60	3.58	-17.57	16.02
		70	9.83	55.49	24.21

Table 6. The effects of different maturity stages on phytochemical contents and TSS amounts in purple mulberry fruit.

Maturity Stage	TP (µg GAE/g)	TEAC (µmol TE/g)	TSS (%)
Semi-ripe	3561.40b	4.58	63.55
Full- Ripe	5532.90a	4.74	73.84
Materiality Level	0.013*	0.765[NS]	0.260[NS]

NS: Non Significant (P>0.05). *: P<0.05.

When Table 5 is examined, the chroma value, which shows the color saturation of the fresh fruit, was calculated as 10.52 in the fully ripe fruit.Taşova and Polatcı (2019), determined the color and some physical properties of finger mulberry fruit in their study. They found the chroma value between 6.16 and 10.85. In semi-ripe fruit, the chroma value was calculated as 13.74. In the fully ripe fruit, the lowest chroma value was found at 3.47 to 50°C drying air, and the highest chroma value was found at 5.76 to 40°C drying air temperature. In semi-ripe fruit, the lowest chroma value is 3.58, and 60°C drying air temperature, The highest chroma value was calculated at a drying air temperature of 9.83 and 70°C. When the total color change was examined, it was found that the highest drying temperature was 70°C in fully ripe fruit and 40°C in semi-ripe fruit. Tasova et al. (2021), in their study, determined the drying performance and color values of black mulberry fruit dried under different conditions. As a result of the study, the total color change for the black mulberry fruit was determined between 20-28 and the values show similar characteristics. When the color characteristics are examined, it is recommended to dry the semi-ripe fruit at 70°C and the fully ripe fruit at 40°C.

The phytochemical contents of semi-mature and fully mature levels of mulberry samples, regardless of temperature values, are given in Table 6. A statistically significant difference was found between semi-mature and fully mature products in the determination of total phenolic compounds. When compared at maturity levels, the phenolic content of fully mature products was 5532.90 (µg GAE/g), while it was found to be 3561.40 (µg GAE/g) in semi-ripe products.There was no statistical difference between maturity levels in the determination of total antioxidant capacity. However, as the maturity level increased, the antioxidant capacity increased, the antioxidant capacity increased. Antioxidant capacities were found as 4.58 (µmol TE/g) in semi-ripe fruits and 4,74 (µmol TE/g) in fully ripe fruits. Although there is no statistical difference between the maturity levels in the amount of water-soluble dry matter, it increases in direct proportion with the increase in the maturity level. It was found as 63.55 (%) in semi-ripe products and 73.84 (%) in fully mature products. Many biochemical events such as the metabolization of sugars and acids, the hydrolysis of pectins, the production of carotenoids, and the exchange of phenolic compounds occur with the ripening of fruits and vegetables (Brummell, 2006; Prasanna et al., 2007; Tepe, 2020).

Regardless of their maturity level, different drying temperatures applied to the products and the phytochemical contents of fresh products are given in table 7. When all drying temperatures were compared with the fresh sample in the determination of total phenolic compounds, the difference between them was found to be statistically significant. The lowest phenolic content was found at 1253.06 (µg GAE/g) in fresh samples, while the highest phenolic content was 6607.65 (µg GAE/g) at 70°C drying temperature. In addition, it was found that the total phenolic content showed an increasing trend with increasing drying temperatures. A statistical difference was found between fresh samples and drying temperatures in total antioxidant content. The lowest value was found as 2.13 (µmol TE/g) in fresh samples, and the highest value was 5.58 (µmol TE/g) at 40°C.

Meral (2017) examined the effects of different drying temperatures on the antioxidant capacity in study on uskun fruit and found that the antioxidant value decreased with the increase in temperature and shortening of the time.

A similar result of this judgment was found in our study at 40°C. It was observed that the dried purple mulberry products preserved their antioxidant capacity more with the long drying time and low temperature. The difference between fresh samples and drying temperatures in the amount of water-soluble substances was found to be statistically significant. The highest value was found at 70°C with 82.75%, while the lowest value was found at 21.80% in fresh samples. With the increase in temperature, the amount of water-soluble dry matter increased. The reason for this is that the amount of soluble dry matter in water is expected to increase as the volumes of the products decrease and liquid losses are experienced.

Phytochemical results of semi-ripe fresh and dried purple mulberry samples are given in Table 8. There was a statistical difference between the applications in the determination of total phenolic. While the highest value was 4218.07 (µg GAE/g) at 70°C, the lowest value was 1222.23 (µg GAE/g) in the semi-ripe fresh products. Statistically, differences were found between the applications in total antioxidant values of semi-ripe products. The highest value was 6.01 (µmol TE/g) at 70°C, while the lowest value was 2.02 (µmol TE/g) in semi-ripe fresh samples. There are statistical differences between applications in the amount of water-soluble dry matter. Values were found between 19.07 – 78.67%.

Phytochemical contents of fully ripe fresh and dried purple mulberry samples are given in Table 9. In terms of total phenolic values, statistical differences were determined between the applications. The results ranged from 1283.89 to 8997.23 (µg GAE/g). In addition, it was observed that the phenolic content increased with the increase in drying temperatures. Statistically, differences were found between applications in total antioxidant content and the highest value was 40°C 6.14 (µmol TE/g) while the lowest value was 2.25 (µmol TE/g) when fully ripe. There were statistical differences between the applications in terms of the amount of water-soluble dry matter. Values range from 24.53% to 88.83%.

Table 7. The effect of different drying temperatures on phytochemical contents and TSS amounts in purple mulberry fruits

Drying Temperatures(°C)	TP (µg GAE/g)	TEAC (µmol TE/g)	TSS (%)
Fresh	1253.06 c	2.13 b	21.80 b
40	4432.65 b	5.58 a	75.25 a
50	5068.07 ab	4.98 a	82.17 a
60	5374.32 ab	5.04 a	81.50 a
70	6607.65 a	5.57 a	82.75 a
Materiality Level	0.001**	0.001**	0.001**

**: P<0.01.

Table 8. Effect of different drying temperatures on phytochemical content and TSS amount in purple (semi-ripe) mulberry fruits.

Maturity Drying Temperatures(°C)	TP (µg GAE/g)	TEAC (µmol TE/g)	TSS (%)
Semi-ripe Fresh	1222.23c	2.02c	19.07d
Semi-ripe 40	3401.40b	5.02ab	66.67c
Semi-ripe 50	4388.90a	5.16ab	78.67a
Semi-ripe 60	4576.40a	4.68b	76.67b
Semi-ripe 70	4218.07a	6.01a	76.67b
Materiality Level	0.001**	0.001**	0.001**

**: P<0.01.

Table 9 Effect of different drying temperatures on phytochemical content and TSS amount in purple (full-ripe) mulberry fruits.

Maturity Drying Temperatures(°C)	TP (µg GAE/g)	TEAC (µmol TE/g)	TSS (%)
Full- Ripe Fresh	1283.89d	2.25d	24.53d
Full- Ripe 40	5463.90c	6.14a	83.83c
Full- Ripe 50	5747.23bc	4.79c	85.67b
Full- Ripe 60	6172.23b	5.39b	86.33b
Full- Ripe 70	8997.23a	5.13bc	88.83a
Materiality Level	0.001**	0.001**	0.001**

Conclusion

There are two important criteria for phytochemicals in the drying process, temperature and time. In some products, higher losses may occur even at low temperatures due to the negative effect of time. In such studies, comments can be made about the best drying method time and temperature for different species by conducting experiments at different maturity levels and temperatures. The model that best predicted the drying curves was determined as WANG SINGH. If a semi-ripe berry is being dried and it is not desired to lose its antioxidant values, we recommend it to be dried at a high degree. If a full ripe mulberry is to be dried and its antioxidant values are to be preserved, we recommend low temperature.

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