

## Determination of Physicochemical and Mineral Composition of Mulberry Fruits (*Morus alba* L.) at Different Harvest Dates

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**ABSTRACT:** This study was conducted to determine some physicochemical and mineral compositions of mulberry fruit at different harvest dates during a harvest season. The study was carried out on 25-year-old mulberry trees belonging to *Morus alba* L. cultivated in an orchard in Upper Coruh valley of Turkey in 2005 and 2006. Fruit size, total soluble solid (TSS), fruit dry yield (FDY), color (L, a, b) of fruits varied between 2.32-3.18 g, 24.07-31.33%, 27.10-31.33%, 36.41-51.74, 4.42-8.20, 23.66-28.42, respectively. As the mineral compositions of mulberry fruit, 3.10-3.36 g 100g<sup>-1</sup> N, 0.298-0.417 g 100g<sup>-1</sup> P, 1.82-2.12 g 100g<sup>-1</sup> K, 2.63-2.93 g 100g<sup>-1</sup> Ca, 0.593-0.723 g 100g<sup>-1</sup> Mg, 0.180-0.325 g 100g<sup>-1</sup> S, 63.7-71.2 mg kg<sup>-1</sup> Na, 114.3-126.3 mg kg<sup>-1</sup> Fe, 69.8-76.8 mg kg<sup>-1</sup> Mn, 29.0-36.2 mg kg<sup>-1</sup> Zn, and 11.2-17.2 mg kg<sup>-1</sup> Cu were determined. As a result, TSS, FDY, K, Ca, Mg, S and Zn minerals of the fruit were determined to increase towards the end of the harvest season.

**Keywords:** *Morus alba* L., mineral content, harvest dates



## Farklı Hasat Dönemlerinde Dut Meyvelerinin Fizikokimyasal ve Mineral Madde İçeriklerinin Belirlenmesi

**ÖZET:** Bu çalışmada bir hasat sezonu boyunca farklı tarihlerde hasat edilen dut meyvelerinin bazı fizikokimyasal ve mineral içerikleri belirlenmiştir. Çalışma yukarı Çoruh vadisinde 2005-2006 yıllarında 25 yaşlı dut ağaçlarında yürütülmüştür. Meyve ağırlığı, SÇKM, kuru randıman, renk (L,a,b) ölçüm değerleri sırasıyla 2.32-3.18 g, %24.07-31.33 g, %27.10-31.33, 36.41-51.74, 4.42-8.20, 23.66-28.42 arasında değişim göstermiştir. Dut meyvelerinin mineral madde içerikleri ise 3.10-3.36 g 100g<sup>-1</sup> N, 0.298-0.417 g 100g<sup>-1</sup> P, 1.82-2.12 g 100g<sup>-1</sup> K, 2.63-2.93 g 100g<sup>-1</sup> Ca, 0.593-0.723 g 100g<sup>-1</sup> Mg, 0.180-0.325 g 100g<sup>-1</sup> S, 63.7-71.2 mg kg<sup>-1</sup> Na, 114.3-126.3 mg kg<sup>-1</sup> Fe, 69.8-76.8 mg kg<sup>-1</sup> Mn, 29.0-36.2 mg kg<sup>-1</sup> Zn, 11.2-17.2 mg kg<sup>-1</sup> Cu arasında belirlenmiştir. Çalışma sonucunda, hasat sezonunun sonuna doğru meyvelerin SÇKM, kuru randıman değerleri ile K, Ca, Mg, S ve Zn gibi mineral içeriklerinin arttığı tespit edilmiştir.

**Anahtar kelimeler:** *Morus alba* L., mineral madde içeriği, hasat dönemi

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## INTRODUCTION

Mulberry, a fast-growing deciduous plant, grows under different ecological conditions such as tropical, subtropical and temperate worldwide (Arabshahi-Delouee and Urooj, 2007). It is believed that mulberry first originated in the foothills of Himalayas and later dispersed into Asia, Europe, Africa, and America (Sanchez, 2000) and has been cultivated in the Northern hemisphere for centuries (Doymaz, 2004).

Mulberry production dates back at least 400 years and it is as important as the other temperate fruit species in Turkey. Most of the agro-ecological regions of Turkey are very suitable for producing high quality mulberry fruits, mainly from *Morus alba*, *Morus nigra* and *Morus rubra* (Ercisli, 2004; Ercisli and Orhan, 2007). Therefore, Turkey is known to be one of the most important mulberry fruit producers in the world. The production of mulberry was 65140 t in 2008 (Anonymous, 2009). Mulberry fruit can be eaten fresh or dried. It can also be processed into mulberry juices, paste, jam, pulp or jelly (Maskan and Gogus, 1998) and several traditional products such as “Mulberry Pekmez”, “Mulberry Pestil”, Mulberry Kome” in the Eastern and Central part of Turkey (Orhan et al., 2007).

Mulberry fruits used for medicinal purposes (Baytop, 1996) have some biological activities such as antimicrobial (Nomura et al., 1978), antifungal (Takasuki et al., 1979), anti-HIV (Takasuki et al., 1982), anti-allergic (Lee et al., 1998), antioxidant (Hikino et al., 1985; Kim et al., 1999) and hypoglycemic activity (Kusano et al., 2002). Mulberry fruits are rich in phenolics, anthocyanins and minerals (Ercisli and Orhan 2007; Gungor and Sengul 2008). In human metabolism, minerals play a significant role for health (Korel and Balaban, 2006). They are required for normal cellular function and critical for enzyme activation, bone formation, hemoglobin composition, gene expression, and amino acid, lipid and carbohydrate metabolism (Wall, 2006).

Mulberry trees can be harvested many times for their fruits in a long harvest season about 2-3 months (Erdogan and Cakmakci, 2006). Since, harvested mature berries may show variation in terms of mineral concentrations at every harvest date. To our knowledge, there was little information available on comparison of mulberry fruit from different harvest periods in minerals. Hence, the aim of this research was to evaluate the effect of different harvest dates on some physicochemical properties and mineral composition of mulberry

fruit in a harvest season. This information would help to know when mulberry fruit should be harvested for mineral-rich berries which may be more useful for human health.

## MATERIAL AND METHODS

### Field Experiments

Field experiments were conducted on 25-year-old mulberry trees belonging to *Morus alba* L. cultivated in an orchard in Upper Coruh valley of Turkey in the years 2005 and 2006. Five mulberry trees, which are similar growth status, were selected from the orchard. Selected mulberry trees were harvested 11 times with five days of interval between 5<sup>th</sup> of July and 25<sup>th</sup> of August in the years 2005 and 2006. Mulberry fruits harvested only mature stages every harvest times. In each harvest, all fruits from 5 trees were mixed and about 2 kg of samples were taken with three parallels. Mulberry fruits of different harvesting dates were investigated in terms of some physicochemical characteristics such as fruit size (g), total soluble solid (TSS, %), fruit dry yield (FDY, %) and color L, a, b of fruits, and mineral composition of fruits such as N, P, K, Ca, Mg, S, Na, Fe, Mn, Zn and Cu.

### Physicochemical Analysis of Mulberry Fruits

Average fruit weight was determined with an electronic balance in 0.001 g sensitivity; TSS was determined with a Palet PR-32 refractometer; FDY, dried in an incubator at 60 °C fixed temperature for 24 h, were determined as the ratio of dry weight to fresh weight. Determination of fruits color (L, a, b) was performed in air dried fruit samples. For color analysis, the instrument was calibrated with a white reference before measurements. Color of mulberry fruit was analyzed through Hunter L (brightness; 100: white, 0: black), a (+: red; -: green) and b (+: yellow; -: blue) parameters with a colorimeter (Model CR 300, Chromometer, Minolta, Japan).

### Mineral Analysis of Mulberry Fruits

In order to determine the mineral contents of mulberry fruits, samples were oven-dried at 68°C for 48 h and ground to pass 1mm sieve. The Kjeldahl method and a Vapodest 10 Rapid Kjeldahl Distillation Unit (Gerhardt, Königswinter, Germany) were used to deter-

mine total N (Bremner, 1996). Macro- (P, S, K, Ca, Mg and Na) and micro-elements (Fe, Mn, Zn, Cu, and B) were detected after wet digestion of dried and ground sub-samples using a HNO<sub>3</sub>-H<sub>2</sub>O<sub>2</sub> acid mixture (2:3 v/v) with three steps (first step; 145°C, 75%RF, 5 min; second step; 180°C, 90%RF, 10 min and third step; 100°C, 40%RF, 10 min) in microwave (Bergof Speedwave Microwave Digestion Equipment MWS-2) (Mertens, 2005a). Tissue P, K, S, Ca, Mg, Na, Fe, Mn, Zn and Cu were determined using an Inductively Coupled Plasma Spectrophotometer (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA) (Mertens, 2005b).

### Data Analysis

Descriptive statistics for each trait were expressed as Mean ± SE. Harvest dates and years were considered as factors in the statistical analysis. There were no statistical differences between years. Therefore, the obtained data from two years was pooled. The statistical analysis was performed using GLM (General Linear Model) procedure of SAS package software. Mean Separation was determined by Duncan's multiple comparison test.

## RESULTS

### Physicochemical Properties of Mulberry Fruit:

Some physicochemical properties of mulberry fruit are given in Table 1. At different harvest dates, fruit size, TSS, FDY, color L, a, b for Mulberry fruits var-

ied between 2.32-3.18 g, 24.07-31.33%, 27.10-31.33%, 36.41-51.74, 4.42-8.20, 23.66-28.42, respectively. Statistically significant differences (P<0.01) were found between harvest dates in terms of fruit weight, TSS, FDY and color L, a, b of fruits. TSS, FDY and color L value of fruit increased towards the end of the harvest season.

**Mineral Contents of Mulberry Fruits:** Mulberry fruit mineral contents, at different harvest dates, are given Table 2. The mineral compositions of the fruits were determined between 3.10 and 3.36 g 100g<sup>-1</sup> for N, 0.298 and 0.417 g 100g<sup>-1</sup> for P, 1.82 and 2.12 g 100g<sup>-1</sup> for K, 2.63 and 2.93 g 100g<sup>-1</sup> for Ca, 0.593 and 0.723 g 100g<sup>-1</sup> for Mg, 0.180 and 0.325 g 100g<sup>-1</sup> for S, 63.7 and 71.2 mg kg<sup>-1</sup> for Na, 114.3 and 126.3 mg kg<sup>-1</sup> for Fe, 69.8 and 76.8 mg kg<sup>-1</sup> for Mn, 29.0 and 36.2 mg kg<sup>-1</sup> for Zn, 11.2 and 17.2 mg kg<sup>-1</sup> for Cu during the harvest season. There were significant differences (P<0.01) between the harvest dates in terms of P, K, Ca, Mg, S, Na, Fe, Zn and Cu content of mulberry fruits and statistical differences (P<0.05) were also found in Mn. Whereas, no significant differences were found in N, K, Ca, Mg, S and Zn minerals increased towards the end of the harvest season, but Na and Fe were their highest level even at the beginning of the harvest season.

## DISCUSSION

In the current study, both physicochemical properties such as TSS, FDY and color L value of fruit and

**Table 1.** Some physicochemical characteristics of mulberry fruit at different harvest dates

Harvest Dates	Average of 2005 and 2006					
	Average Fruit weight (g)	Total Soluble Solid (TSS, %)	Fruit dry yield (FDY, %)	Color Value		
				L	a	b
5 July	2.32±0.06 <sup>g</sup>	24.07±0.44 <sup>g</sup>	27.10±1.14 <sup>f</sup>	36.41±0.93 <sup>c</sup>	8.20±0.29 <sup>a</sup>	23.66±0.40 <sup>g</sup>
10 July	2.99±0.03 <sup>bc</sup>	26.58±0.49 <sup>f</sup>	31.26±0.92 <sup>c</sup>	39.50±1.86 <sup>de</sup>	7.88±0.23 <sup>a</sup>	24.33±0.32 <sup>fg</sup>
15 July	3.10±0.03 <sup>ba</sup>	28.27±0.12 <sup>c</sup>	33.05±0.52 <sup>d</sup>	41.60±0.43 <sup>d</sup>	5.97±0.55 <sup>b</sup>	25.26±0.36 <sup>d-f</sup>
20 July	3.18±0.10 <sup>a</sup>	29.06±0.07 <sup>d</sup>	33.44±0.54 <sup>d</sup>	43.06±1.19 <sup>cd</sup>	5.93±0.46 <sup>b</sup>	25.17±0.66 <sup>ef</sup>
25 July	2.84±0.11 <sup>dc</sup>	30.54±0.22 <sup>c</sup>	34.78±0.35 <sup>c</sup>	46.11±1.83 <sup>bc</sup>	5.88±0.37 <sup>b</sup>	26.98±0.84 <sup>a-c</sup>
30 July	2.79±0.12 <sup>de</sup>	30.63±0.17 <sup>bc</sup>	36.00±0.29 <sup>ab</sup>	46.94±1.71 <sup>b</sup>	5.90±0.31 <sup>b</sup>	27.88±0.62 <sup>ab</sup>
5 August	2.79±0.10 <sup>de</sup>	30.56±0.19 <sup>c</sup>	35.23±0.25 <sup>bc</sup>	47.16±1.80 <sup>b</sup>	5.56±0.16 <sup>b</sup>	28.42±0.42 <sup>a</sup>
10 August	2.66±0.09 <sup>fc</sup>	31.05±0.11 <sup>a-c</sup>	35.84±0.32 <sup>ab</sup>	49.47±0.7 <sup>ab</sup>	4.86±0.25 <sup>c</sup>	27.41±0.21 <sup>a-c</sup>
15 August	2.60±0.08 <sup>f</sup>	31.09±0.09 <sup>a-c</sup>	35.93±0.29 <sup>ab</sup>	51.62±1.01 <sup>a</sup>	4.42±0.18 <sup>c</sup>	26.47±0.50 <sup>b-c</sup>
20 August	2.39±0.12 <sup>g</sup>	31.17±0.10 <sup>ab</sup>	36.42±0.20 <sup>a</sup>	51.74±0.66 <sup>a</sup>	4.42±0.22 <sup>c</sup>	26.08±0.44 <sup>c-e</sup>
25 August	2.35±0.11 <sup>g</sup>	31.33±0.02 <sup>a</sup>	36.84±0.04 <sup>a</sup>	50.16±0.92 <sup>ab</sup>	4.57±0.18 <sup>c</sup>	26.75±0.40 <sup>b-d</sup>
Average	2.73±0.04	29.49±0.28	34.17±0.37	45.80±0.69	5.78±0.17	26.22±0.22
F value	30.20**	172.8**	77.5**	15.6**	34.9**	8.8**
LSD	0.15	0.50	0.93	3.65	0.61	1.42

\*\* : p<0.01

**Table 2.** Mineral content of mulberry fruit at different harvest dates

Average of 2005 and 2006											
Harvest Dates	N (g 100g <sup>-1</sup> )	P (g 100g <sup>-1</sup> )	K (g 100g <sup>-1</sup> )	Ca (g 100g <sup>-1</sup> )	Mg (g 100g <sup>-1</sup> )	S (g 100g <sup>-1</sup> )	Na (mg kg <sup>-1</sup> )	Fe (mg kg <sup>-1</sup> )	Mn (mg kg <sup>-1</sup> )	Zn (mg kg <sup>-1</sup> )	Cu (mg kg <sup>-1</sup> )
5 July	3.36±0.12	0.298±0.02 <sup>d</sup>	1.91±0.03 <sup>bc</sup>	2.63±0.03 <sup>d</sup>	0.593±0.03 <sup>ef</sup>	0.180±0.01 <sup>d</sup>	71.2±1.78 <sup>a</sup>	125.7±3.60 <sup>a</sup>	69.8±3.87 <sup>c</sup>	29.2±1.17 <sup>e</sup>	11.2±1.08 <sup>c</sup>
10 July	3.10±0.08	0.363±0.03 <sup>bc</sup>	1.97±0.06 <sup>bc</sup>	2.69±0.05 <sup>cd</sup>	0.578±0.01 <sup>f</sup>	0.195±0.02 <sup>d</sup>	66.5±1.26 <sup>ab</sup>	126.0±4.36 <sup>c</sup>	71.8±2.26 <sup>bc</sup>	31.5±1.03 <sup>bc</sup>	14.0±0.78 <sup>ac</sup>
15 July	3.15±0.06	0.417±0.02 <sup>a</sup>	1.93±0.04 <sup>bc</sup>	2.73±0.05 <sup>bc</sup>	0.597±0.03 <sup>cf</sup>	0.210±0.01 <sup>cd</sup>	64.7±2.33 <sup>b</sup>	126.5±0.72 <sup>a</sup>	76.8±1.54 <sup>a</sup>	29.8±0.31 <sup>c-e</sup>	15.0±1.44 <sup>ab</sup>
20 July	3.14±0.08	0.395±0.03 <sup>ab</sup>	2.01±0.05 <sup>b</sup>	2.75±0.07 <sup>bc</sup>	0.590±0.01 <sup>ef</sup>	0.257±0.03 <sup>b</sup>	64.5±1.48 <sup>b</sup>	118.0±1.32 <sup>bc</sup>	71.8±1.54 <sup>bc</sup>	29.0±1.71 <sup>e</sup>	13.7±2.11 <sup>ac</sup>
25 July	3.15±0.03	0.342±0.02 <sup>cd</sup>	1.97±0.02 <sup>bc</sup>	2.73±0.02 <sup>bc</sup>	0.645±0.02 <sup>bc</sup>	0.248±0.01 <sup>b</sup>	64.5±3.70 <sup>b</sup>	120.2±6.54 <sup>a-c</sup>	73.7±2.81 <sup>ac</sup>	30.0±0.68 <sup>c-e</sup>	13.8±2.02 <sup>ac</sup>
30 July	3.22±0.05	0.330±0.01 <sup>cd</sup>	1.95±0.02 <sup>bc</sup>	2.75±0.04 <sup>bc</sup>	0.650±0.01 <sup>bed</sup>	0.237±0.02 <sup>bc</sup>	63.7±1.73 <sup>b</sup>	124.0±1.03 <sup>ab</sup>	72.0±1.16 <sup>bc</sup>	29.8±1.82 <sup>c-e</sup>	11.2±0.31 <sup>c</sup>
5 August	3.10±0.04	0.313±0.01 <sup>cd</sup>	1.88±0.02 <sup>cd</sup>	2.72±0.01 <sup>bc</sup>	0.720±0.01 <sup>a</sup>	0.230±0.01 <sup>bc</sup>	57.7±3.05 <sup>c</sup>	115.2±1.62 <sup>c</sup>	72.7±3.06 <sup>ac</sup>	29.5±0.34 <sup>de</sup>	13.7±1.09 <sup>ac</sup>
10 August	3.20±0.02	0.337±0.01 <sup>cd</sup>	1.82±0.03 <sup>d</sup>	2.78±0.05 <sup>b</sup>	0.678±0.01 <sup>ab</sup>	0.303±0.02 <sup>a</sup>	64.3±3.02 <sup>b</sup>	114.3±5.41 <sup>c</sup>	73.5±1.52 <sup>ac</sup>	32.8±1.14 <sup>bc</sup>	17.2±3.07 <sup>a</sup>
15 August	3.22±0.02	0.310±0.01 <sup>cd</sup>	1.99±0.10 <sup>b</sup>	2.93±0.01 <sup>a</sup>	0.723±0.01 <sup>a</sup>	0.317±0.02 <sup>a</sup>	67.3±2.03 <sup>ab</sup>	124.2±4.40 <sup>ab</sup>	72.2±3.38 <sup>bc</sup>	36.2±0.79 <sup>a</sup>	12.3±1.31 <sup>bc</sup>
20 August	3.27±0.01	0.330±0.01 <sup>d</sup>	2.12±0.03 <sup>a</sup>	2.92±0.02 <sup>a</sup>	0.690±0.01 <sup>ab</sup>	0.325±0.01 <sup>a</sup>	69.7±1.36 <sup>a</sup>	126.0±2.78 <sup>a</sup>	75.5±1.31 <sup>ab</sup>	33.8±1.20 <sup>ab</sup>	16.2±2.71 <sup>a</sup>
25 August	3.21±0.04	0.298±0.02 <sup>cd</sup>	2.01±0.07 <sup>b</sup>	2.91±0.01 <sup>a</sup>	0.653±0.03 <sup>bc</sup>	0.317±0.01 <sup>a</sup>	69.5±1.75 <sup>a</sup>	126.3±3.51 <sup>a</sup>	72.0±3.61 <sup>bc</sup>	32.7±0.42 <sup>bd</sup>	16.0±2.60 <sup>a</sup>
<i>Average</i>	<i>3.19±0.02</i>	<i>0.342±0.01</i>	<i>1.96±0.02</i>	<i>2.78±0.02</i>	<i>0.647±0.01</i>	<i>0.256±0.01</i>	<i>65.8±0.77</i>	<i>122.4±1.16</i>	<i>72.9±0.74</i>	<i>31.3±0.40</i>	<i>14.0±0.57</i>
<i>F value</i>	<i>1.8ns</i>	<i>5.1**</i>	<i>6.6**</i>	<i>13.2**</i>	<i>8.0**</i>	<i>24.9**</i>	<i>6.2**</i>	<i>4.3**</i>	<i>2.0*</i>	<i>5.4**</i>	<i>3.2**</i>
<i>LSD</i>	<i>0.17</i>	<i>0.05</i>	<i>0.09</i>	<i>0.08</i>	<i>0.05</i>	<i>0.03</i>	<i>4.24</i>	<i>6.36</i>	<i>3.90</i>	<i>2.83</i>	<i>3.15</i>

ns: no significant

\*: P&lt;0.05

\*\*: P&lt;0.01

some minerals of fruit such as K, Ca, Mg, S and Zn increased from beginning to the end of the harvest season (Table 1 and Table 2). In mulberries, harvest season is long about 2-3 months (Erdogan and Cakmakci, 2006). Fruit load at the beginning of harvest was very high whereas, it was the lowest at the end of harvest season. Since their nutritional status of berries may have changed. The fruit load and tree's ability to nourish the berries may have varied over time as in the present study. As long as the fruit load increases, fruit weight, TSS and mineral content of fruit decrease in many fruit species reported by Lenz (2000), Wünsche et al. (2000), Cengiz (2007), Ersoy and Demirsoy (2006).

In the other previous studies, fruit weights of mulberry genotypes grown in different ecological conditions were determined to be a range of 1.13 to 6.41 g (Polat, 2004; Islam et al., 2006; Burgut and Turemis, 2006). The TSS of white mulberries was reported between 20.4% and 28.50% (Ercisli and Orhan 2007; Gungor and Sengul 2008). It was also reported that color L, a and b value of white mulberry fruits were found to be between 31.24 and 78.4, 2.46 and 15.68 and 4.58 and 21.74, respectively (Ercisli and Orhan, 2007; Gungor and Sengul, 2008). Our fruit weight, TSS and color values (L, a and b) results are comparable with the data from these studies.

Previously, mineral compositions of white mulberry fruit were stated to be between 0.3 and 4.2 mg 100 g<sup>-1</sup> for Fe, 19 and 106 mg 100 g<sup>-1</sup> for Mg, 152 and 510 mg 100 g<sup>-1</sup> for Ca, 45 and 1668 mg 100 g<sup>-1</sup> for K, 0.2 and 0.5 mg 100 g<sup>-1</sup> for Cu, 0.4 and 2.8 mg 100 g<sup>-1</sup> for Zn, 2 and 3.8 mg 100 g<sup>-1</sup> for Mn, 3 and 60 mg 100 g<sup>-1</sup> for Na, 247 and 7483 mg 100 g<sup>-1</sup> for P (Ercisli and Orhan, 2007; Gungor and Sengul, 2008). In the current study, mulberry fruits were harvested 11 times and data from 11 harvest dates. However, literature values are only one harvest date. Therefore, this study shows differences with results of Gungor and Sengul (2008), and Ercisli and Orhan (2007). These differences may also be ascribed to genotypes, fruit maturity, agricultural practice, ecological conditions, such as climate, altitude, soil factors.

## CONCLUSIONS

According to the results, physicochemical properties of fruits such as TSS and FDY and mineral content of fruits such as K, Ca, Mg, S and Zn increased towards the end of the harvest season. Especially this increase

in mineral content of fruits suggests that late harvested fruits may be more useful for human health compared to earlier ones in the same harvesting season.

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