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Original scientific paper

BIOCHEMICAL PROPERTIES OF FRESH AND DRIED FRUITS OF *MORUS NIGRA L.*

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Abstract

The study was carried out to compare the biochemical properties of fresh and dried fruits of black mulberry (*Morus nigra* L.) grown under the İlkadım (Samsun) ecological conditions. The fruit samples were dried in a fan dryer at 70°C until the moisture content was lowered to 15%. Soluble solids content (SSC), titratable acidity (TA), total phenolics, total flavonoids and antioxidant activity (according to DPPH and FRAP assays) were analysed as biochemical properties in fresh and dried black mulberry fruits. Dried fruits showed higher SSC (63.6% and 12.9%, respectively) and TA (3.58% and 0.82%, respectively) than fresh fruits. Total phenolics content was higher in dried fruits (826.4 mg kg^{-1} and 449.3 mg kg^{-1}) compared to fresh fruits. The highest total flavonoids content (456.1 mg kg^{-1}) was determined in dried fruits. According to DPPH and FRAP antioxidant assays, the highest antioxidant activity (859.6 mmol kg^{-1} and 9138 mmol kg^{-1}, respectively) was determined in dried fruits. As a conclusion, dried black mulberry fruits had higher biochemical content than fresh black mulberry fruits.

Keywords: Antioxidant, flavonoids, *Morus nigra* L., phenolics, soluble solids content.

1. Introduction

The mulberry plant exhibits a wide distribution across the world. Its high adaptability is known to be the most significant reason for this (Sharma et al., 2000). In Türkiye, which has different climate types, mulberry cultivation is carried out adapted to almost every region. In addition to its high adaptability, the fact that its seeds can be easily transported by living things and can be propagated by simple methods such as cuttings has been effective in the spread of mulberry fruit (Vijayan et al., 2021). Apart from this, the fact that it is a food that attracts people with its different colors, tastes and aromas has also been an important factor in mulberry cultivation.
Fruits are known to provide positive contributions to human health with the rich nutrients and bioactive compounds they contain. Especially fruits with red, purple and black pigments, with the anthocyanin source they contain (Stintzing et al., 2002; Liu et al., 2004; Chen et al., 2017), have been reported to be effective in preventing many diseases, especially cancer tumors (Yuan & Zhao, 2017). Among these fruits, mulberry (*Morus* spp.), especially black mulberry (*Morus nigra* L.), has an important place in traditional and modern eating habits (Erdoğan & Pırlak, 2005). Black mulberry stands out with its dark purple-black colored, juicy and sweet-sour flavored fruit; it is known among the public for its various effects such as diabetes, hypertension, anemia, immune system strengthening, arthritis treatment, antipyretic and blood forming (Kang et al., 2006; Kim & Park, 2006). It is generally used for tonsillitis, mouth and tooth sores (Yiğit et al., 2007). These healthy effects are related to the rich polyphenols, phenolic compounds, flavonoids, organic acids, vitamin C and various antioxidant substances contained in mulberry. Mulberry fruit is consumed partly fresh, but also as processed products such as molasses, fruit roll-up, walnut sausage, fruit ice cream, jam, spirit, vinegar (Bakkalbaşı et al., 2004; Beykaya & Artık, 2020; Kıralan & Gündoğdu, 2021). Apart from these, consuming mulberry fruit by drying is also a very old and preferred consumption habit. Apart from these, the fact that the mulberry fruit is unsuitable for transportation due to its texture and water content, and its short

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shelf and storage life have made drying necessary. Drying is a method applied to extend the shelf life of foods, increase their portability and consumability throughout the year (Gürhayta & Çağındı, 2015). In addition to these, the drying process plays a critical role in preserving the beneficial properties of fruits. With drying, most of the water in the fruit is removed and the desired amount of moisture is maintained (Kıralan & Gündoğdu, 2021). In this way, microbial spoilage is prevented, the transportation of the product becomes easier, its storability increases and its economic value increases by creating different usage opportunities (snacks, fruit cake-bread, or dried fruit mixtures, etc.). In this context, the dried form of black mulberry offers the opportunity of consumption throughout the year; It can provide more intense nutrient and bioactive substance content compared to fresh fruit. However, it is also known that some bioactive compounds may be lost during the drying process depending on factors such as temperature, duration and method (Kıralan & Gündoğdu, 2021). Therefore, it is of great importance to examine in detail the effect of drying on the functional properties of mulberry fruit.
This study was conducted to determine the changes in the biochemical contents of fresh and dried black mulberry fruits.

2. Materials and methods

2.1. Plant materials: The plant material for research consisted of black mulberry fruits grown in a producer garden located in İlkadım (Samsun/Türkiye) district. The mulberry trees was divided into four sections, and approximately 500 g of fruit was harvested from each section, totaling 2 kg of fruit. Mulberry trees were divided into four sections and approximately 500 g, a total of 2 kg of fruit was harvested from each section. A total of 4 kg of fruit was harvested for dry and fresh mulberry applications. The harvested fruits were transported to laboratory on the same day. Defective and fruits of different ripeness levels were removed to ensure homogeneity. The fresh fruit analysis, drying process and subsequent analyses were conducted on the fruits considered to have achieved homogeneity. The drying process was carried out using a fan-assisted dryer (Dalle, Dehydrator, model LT-27). About 500 g of fruit were arranged in a single row on a drying rack and kept at 70°C until the moisture content reached (8 h) about 15%. Subsequently, biochemical analyses were performed on both dried and fresh fruits.

2.2. Soluble solids content and titratable acidity: In order to perform biochemical analyses, fresh fruits were pureed using a blender (Philips, Turkey). In dried fruits, a certain amount of dried fruit was combined with a certain amount of distilled water and then pureed. Some of the pureed fruits were then stored in falcon conical tubes at -20°C so that bioactive compounds could be analyzed. The other part was filtered to obtain fruit juice. Soluble solids content (SSC) and titratable acidity (TA) were examined from this juice. To determine the SSC content, a certain amount of fruit juice was dropped on the lens of the refractometer (PAL-1, Atago, USA) reading device and the reading button was pressed. The value appearing on the screen gave the SSC content and was presented as %.
For TA, 10 mL of fruit juice sample was taken and 10 mL of distilled water was added. 0.1 mol L^{-1} (N) sodium hydroxide (NaOH) was added until the pH value of the new mixture reached 8.2 and it was titrated continuously during this period. Based on the amount of NaOH used in the titration, the values were calculated in terms of malic acid (g malic acid 100 mL^{-1}) (Ozturk et al., 2019). For the SSC and TA analyses in the dried fruits, the samples were diluted at a ratio of 1:1. The SSC and TA values were calculated taking the dilution factor into account.

2.3. Antioxidant activity, total flavonoids and total phenolics: Before the analyses, the fruit samples that were stored in the freezer in falcon conical tubes for the determination of bioactive contents were removed from the refrigerator. The frozen samples were kept at room conditions to completely thaw. The thawed samples were used to determine the total phenolics, total flavonoids, DPPH and FRAP antioxidant amounts. Analyses were performed with a UV-Vis spectrophotometer made by Shimadzu, Japan. Total phenol was performed according to the procedure outlined by Singleton & Rossi (1965) and the results were presented as mg gallic acid equivalent (GAE) 100 g^{-1} fw (fresh weight). Total flavonoids were performed according to the method specified by Ozturk et al. (2019) and the results were presented as mg quercetin equivalent (QE) 100 g^{-1} fw. To determine the antioxidant of mulberry fruit, 2,2-diphenyl-1-picrylhydrazyl (DPPH) according to Blois (1958) and iron reducing ability of plasma (FRAP) analyses according to Benzie & Strain (1996) were used. DPPH and FRAP results are presented as mmol kg^{-1} Trolox equivalent (TE) fw.

2.4. Statistical analysis: The data are expressed as the mean of three independent experiments, each with a triplicate analysis. The normality of the data was tested using the Kolmogorov-Smirnov test, and the homogeneity of variances among groups was confirmed using the Levene's test. Subsequently, t test was employed to determine significant differences among the fresh-dried fruit. All statistical analyses were performed using JMP 16.0 (trial) statistical package program.

3. Results and discussion

Soluble solids content, represent a technological parameter applied in the evaluation of mulberry maturity (Wang et al., 2022). In the study, significant differences were determined in terms of SSC and TA content between fresh and dried mulberries ($p<0.05$). The highest SSC was determined in the dried fruit (63.6%) and the lowest in the fresh fruit (12.9%). Also, dried fruits have the highest TA (3.58%), while fresh fruits (0.82%) have the lowest (Table 1). Ercisli & Orhan (2007) Fresh black mulberries reported total acid content as 1.40 and total soluble solids content as 16.7%. Different drying methods were reported to significantly affect the SSC content in mulberries. Higher SSC was obtained in freeze drying (VFD) and vacuum drying (VD) methods in particular, compared to fan drying. It was stated that during the drying process by these methods (VFD and VD), pigment browning and sugar oxidation were effectively prevented under low oxygen conditions, leading to good retention of SSC. In addition, it was stated that in fan drying, slow hydrolysis reaction and Maillard reaction reduced the content of SSC (Zhang et al., 2024). In the current study, the positive effect of drying on both SSC and TA content was determined.

Table 1. Soluble solids and titratable acidity contents of fresh and dried black mulberry fruits

Black Mulberry	Soluble solids content (%)	Titratable acidity (%)
Fresh	12.9 b	0.82 b
Dried	63.6 a	3.58 a

According to the Tukey test, the means with the same letter in the same column are not statistically different. $P<0.05$.

Total phenols and flavonoids are the main functional components of mulberry fruit. Phenolics are functional components with good antioxidant activity and make significant contributions to improving product quality. Flavones, an important secondary metabolite, have anti-tumor and anti-bacterial effects. The content of total phenolics, flavonoids and antioxidant substances in

mulberries has a great influence on the antioxidant capacity of mulberries, and the content of functional components, especially phenolic substances, in mulberry fruits is affected by different drying methods. The drying method also determines the oxidation resistance (Yu et al., 2021; Wang et al., 2023, 2024).

The highest total phenolics was determined in the dried fruit (826.4 mg GAE kg^{-1}) and the lowest in the fresh fruit (449.3 mg GAE kg^{-1}). Similarly, dried fruits have the highest total flavonoid (456.1 mg QE kg^{-1}), while fresh fruits (265.4 mg QE kg^{-1}) have the lowest. According to DPPH and FRAP assays, the highest antioxidant activity was recorded in the dried fruit (859.6 mmol TE kg^{-1} and 9138 mmol TE kg^{-1}, respectively) and the lowest in the fresh fruit (482.8 mmol TE kg^{-1} and 3846 mmol TE kg^{-1}, respectively) (Table 2).

Table 2. Biochemical properties of fresh and dried black mulberry fruits

Black Mulberry	Total phenolics (mg GAE kg^{-1})	Total flavonoids (mg QE kg^{-1})	Antioxidant activity (mmol TE kg^{-1})	
			DPPH	FRAP
Fresh	449.3 b	265.4 b	482.8 b	3846 b
Dried	826.4 a	456.1 a	859.6 a	9138 a

According to the Tukey test, the means with the same letter in the same column are not statistically different. $P<0.05$.

The drying process has led to an increase in all bioactive contents. Additionally, when comparing the bioactive content of fresh and dried fruits, significant differences were observed in terms of total phenolics, total flavonoids and antioxidant activity (according to DPPH and FRAP assays) (Table 2). In consistent with the results of the present study, many researchers reported higher phenolic, flavonoid and antioxidant activity in dried mulberry fruits compared to fresh mulberry fruits (Ates 2023; Krzykowski et al., 2023).

Çetin et al. (2023) reported that microwave power and temperature had a positive effect on total phenol content and antioxidant activities. Contrary to our study findings, Kamiloglu et al. (2013) reported that total phenolic, total flavonoid content, DPPH and FRAP activities of dried *Morus nigra* fruits were lower than fresh ones. Apart from these, Ercisli & Orhan (2007) reported that bioactive contents may vary depending on the variety and determined the total phenolic content as 1422 mg GAE/100 g fw and total flavonoid content as 276 mg QE/100 g fw in fresh black mulberry fruits. Hojjatpanah et al. (2011) determined in their study that black mulberry concentrate changed depending on different heating materials.

4. Conclusions

This study aimed to investigate the biochemical changes between fresh and dried black mulberry fruits. The conducted analyses revealed a significant impact of the drying process on fruit quality. In comparison to fresh fruits, dried fruits exhibited an important increase in soluble solids content and higher titratable acidity levels. There was also a similar increase observed in phenolic and flavonoid contents. In terms of antioxidant activities, dried fruits exhibited higher activity. These findings indicate that drying has a positive effect on the bioactive compounds and antioxidant activity of black mulberry fruits.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions
UA: Project administration, conducting test, data collection, formal analysis, writing and editing of manuscript and analyses. **OK:** Project administration, conducting test, data collection, formal analysis, writing and editing of manuscript and analyses.

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Not applicable.

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Data availability

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