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# Fatty acid composition, oxidative stability, and antioxidant properties of some Hungarian and other Persian walnut cultivars

**Géza BUJDOSÓ[1,2,*], Éva KÓNYA[3], Mária BERKI[3], Magdolna NAGY-GASZTONYI[3], Krisztina BARTHA-SZÜGYI[2], Balázs MARTON[2], Ferenc IZSÉPI[2], Nóra ADÁNYI[3]**

[1]Department of Pomology, Corvinus University of Budapest, Budapest, Hungary
[2]National Agricultural Research and Innovation Centre Fruitculture Research Institute, Budapest Hungary
[3]National Agricultural Research and Innovation Centre Food Research Institute, Budapest, Hungary

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**Abstract:** Ten different Persian walnut cultivars were examined for their compositional data, including eight Hungarian and two introduced varieties. Oil content and fatty acid composition were determined, as well as oxidative stability (indicated by induction time). Antioxidative capacity, total polyphenol measurements, and individual phenolic compounds were also determined. Not only dry samples but fresh and stored samples were included in this study. Large differences were found among the varieties within these parameters, for example in oxidative stability, which contributes to antioxidative capacity. In conclusion, the nutritional value of Hungarian walnut cultivars was the same or even higher than those of foreign ones.

**Key words**: Antioxidant properties, fatty acid composition, antioxidant, walnut varieties

## 1. Introduction

The Persian walnut (*Juglans regia* L.) is the most important shell fruit species in the Carpathian Basin. There are a lot of sites where this fruit species can be safely grown because this species might be native to this region (Terpó, 1976).

Based on orchard data collection from 2001, there were 3200 ha of nonbearing and bearing walnut orchards in Hungary (Hungarian Statistics Office, 2003), and this orchard surface had almost doubled by 2010 (Fodor et al., 2013). This is because there is a large demand and a good market price for Hungarian-bred walnut cultivars, due to their having the earliest ripening time within the northern hemisphere (Szentiványi, 2006). Moreover, walnut is an important part of the region's cuisine; thus, there is a high demand for it (Szentiványi, 2006).

The genus *Juglans* has a weak adaptation capability for different climate conditions. As a result, Hungarian growers prefer Hungarian-bred cultivars instead of foreign-bred cultivars, because foreign-bred cultivars do not adapt well to Hungarian climatic conditions. Their fruit size is smaller and their shell and kernel color are darker, and so foreign-bred cultivars grown under Hungarian climatic conditions have a handicap compared to the Hungarian-bred cultivars.

A walnut breeding program has been running at the National Agricultural Reseach and Innovation Centre Fruitculture Research Institute and its predecessors since 1950. The most important aims in walnut breeding are late leafing-out time, high yield on lateral buds, good fruit and kernel quality (at least 32 mm in diameter, round fruit shape is preferred, light shell and kernel color, smooth shell surface, at least 40% of kernel content, good taste, no aftertaste), tolerance to *Xanthomonas arboricola* pv. *juglandis* (Pierce) Dye and *Gnomonia leptostyla* (Fr.) Ces. et de Not., and adaptation to climatic conditions (such as winter and late spring frosts, drought) (Bujdosó et al., 2005). As a result of this breeding program, eight state-registered varieties that cover a 3- to 4-week ripening period starting from 10 or 15 September are on the Hungarian National List. The most commonly grown variety in Hungarian production is Milotai 10 (38% growing ratio), followed by Alsószentiváni 117 (22% growing ratio) (Hungarian Statistics Office, 2003). Some cultivars bred in neighboring countries are also cultivated in Hungary; their ratio has increased in the last decade due to a lack of grafted trees.

According to FAO statistics, Hungarian walnut production in 2010 was about 5637 t dried-in-shell walnut. The main walnut growing areas are located in the northeast part of the country in Szabolcs-Szatmár-Bereg

* Correspondence: resinfru@yahoo.com

county, where 30% of the total Hungarian production is produced, followed by Somogy county with 10% of the total Hungarian walnut production (Hungarian Statistics Office, 2003).

The walnut has advantageous properties that make it a recommended part of the human diet. Walnut oil is rich in unsaturated fatty acids that are susceptible to oxidation (Fukuda et al., 2003).

Beyond remarkably good fatty acid composition, the walnut also contains antioxidative compounds like tocopherols and phenolic compounds (Bujdosó et al., 2014). These compounds are another reason why walnut is recommended for the human diet (Kornsteiner et al., 2006).

Since nuts contain a higher amount of oil and the fatty acids are mainly mono- and polyunsaturated fatty acids, they contribute to a healthy diet (Arranz et al., 2008). As Table 1 shows, nuts differ drastically from each other in compositional data. Persian walnut oil content is similar to others, but its polyunsaturated fatty acid content is the highest. Persian walnuts have low copper and vitamin C content compared to other fruit species.

The compositions of Hungarian-bred walnut cultivars were studied previously for a 3-year period between 2004 and 2006. There were large differences in compositional data of the examined varieties; however, the effect of the year also had a significant influence on the examined compounds' concentration (Bujdosó et al., 2010). The aim of this paper is to compare the composition of Hungarian-bred cultivars to the most important foreign varieties.

## 2. Materials and methods

Ten walnut cultivars were included in this study. The eight Hungarian-bred varieties from the Hungarian National Variety List used in this study were Alsószentiváni 117, Milotai 10, Tiszacsécsi 83, Milotai bőtermő, Milotai kései, Milotai intenzív, Bonifác, and Alsószentiváni kései. The most commonly grown hybrid cultivar from the United States (Chandler) and a traditional French cultivar (Franquette) were also examined in this paper. Table 2 lists the most important characteristics of the selected walnut cultivars.

The fruit samples were taken at optimal ripening time, meaning that 50% of husks were open, from Juglans Hungaria Ltd.'s walnut orchard located in Lengyeltóti (42°46′13.02″N, 17°38′25.01″E). After harvest, the husk was eliminated by hand and the samples were washed and dried to 10% moisture content in dryer machines at 35 to 37 °C air temperature for 36 or 48 h, depending on the sample's moisture content. The samples were not bleached during the preparation process. After drying, half of the samples were examined in the lab, and the other half were stored as dried-in-shell walnuts at 8 °C for two months, until December. After the 2-month storage period, the samples were measured again because December is the most important walnut-selling period of the year.

**Table 1.** Comparison of different nut compositions.

| | Fat (%) | Saturated (%) | MUFA (%) | PUFA (%) | Cu (mg/100 g) | Vitamin E (mg/100 g) |
|---|---|---|---|---|---|---|
| Almond | 55.8 | 4.7 | 34.4 | 14.2 | 1.00 | 24.0 |
| Brazil nut | 68.2 | 16.4 | 25.8 | 23.0 | 1.76 | 7.2 |
| Cashew | 50.9 | 10.1 | 29.4 | 9.1 | 2.04 | 1.3 |
| Chestnut | 2.7 | 0.5 | 1.0 | 1.1 | 0.23 | 1.2 |
| Coconut | 68.8 | 59.3 | 3.9 | 1.6 | 0.56 | 1.4 |
| Hazelnut | 63.5 | 4.7 | 50.0 | 5.9 | 1.23 | 25.0 |
| Macadamia | 77.6 | 11.2 | 60.8 | 1.6 | 0.43 | 1.5 |
| Peanut | 46.1 | 8.2 | 21.2 | 14.3 | 1.02 | 10.1 |
| Pecan | 70.1 | 5.7 | 42.5 | 18.7 | 1.07 | 4.3 |
| Pine nut | 68.6 | 4.6 | 19.9 | 41.1 | 1.32 | 13.7 |
| Pistachio | 30.5 | 4.1 | 15.2 | 9.8 | 0.46 | 2.3 |
| Sesame seed | 58.0 | 8.3 | 21.7 | 25.5 | 1.46 | 2.5 |
| Sunflower seed | 47.5 | 4.5 | 9.8 | 31.0 | 2.27 | 37.8 |
| Walnut (Persian) | 68.5 | 5.6 | 12.4 | 47.5 | 1.34 | 3.8 |

**Table 2.** Short pomological descriptions of Persian walnut varieties and genotypes used in this study.

| | Origin | Ripening time | Fruit size (mm) | Kernel ratio (%) | Kernel color** |
|---|---|---|---|---|---|
| Alsószentiváni 117 (A 117) | Landscape selected from Hungary | IX. 1 d* | 33–36 | 50 | Light brown |
| Milotai 10 | Landscape selected from Hungary | IX. 2 d* | 32–34 | 48 | Yellowish brown |
| Tiszacsécsi 83 | Landscape selected from Hungary | IX. 3 d – X. 1 d* | 32–34 | 50 | Yellowish brown |
| Milotai bőtermő | Milotai 10 × Pedro | IX. 3 d – X. 1 d* | 34–36 | 49 | Yellowish brown |
| Milotai intenzív | Milotai 10 × Pedro | IX. 3 d – X. 1 d* | 32–34 | 52 | Yellowish brown |
| Milotai kései | Milotai 10 × Pedro | IX. 3 d – X. 1 d* | 32–34 | 44 | Light brown |
| Bonifác | A 117 × Pedro | X. 1 d* | 32–34 | 46 | Light brown |
| Alsószentiváni kései | A 117 × Pedro | X. 1 d* | 32–34 | 48 | Yellowish brown |
| Chandler | Pedro × UC 56-224 | IX. 3 d – X. 1 d* | 28–30 | 49 | Light brown |
| Franquette | Landscape selected | X. 1 d* | 31–34 | 40–44 | Yellowish brown |

*d: Decade (10-day period).
**Sources: Szentiványi (2006), Hendricks et al. (1998), based on literature data.

**2.1. Determination of shell and kernel color**

Shell and kernel color of the samples was measured in the lab using a Konica Minolta Chroma Meter CR-400 (Konica Minolta, Japan). The CIELAB color space/system and the L* value were used, because this value shows how light the shell and kernel colors are.

**2.2. Determination of water content**

Water content was measured according to MSZ 20604 (Hungarian Standardization Office, 1994) at 103 °C (±2 °C) for 6 h at atmospheric pressure.

**2.3. Determination of oil content**

Oil content was extracted according to MSZ EN ISO Part 1 (Hungarian Standardization Office, 2000). The solvent was removed by a rotary vacuum evaporator.

**2.4. Determination of fatty acid composition**

Fatty acids were analyzed from the extracted oil by gas chromatography (Agilent 7890A GC System) of methyl esters of fatty acids (Tóth-Márkus and Sass-Kiss, 1993). Ten milligrams of fat was saponified with 250 µL of 0.5 M KOH/methanol in a 2-mL screw-cap glass vial and heated for 15 min in a block thermostat at 140 °C. The transesterification was performed with boron trifluoride in methanol (14%, Sigma, Inc., USA) for 15 min, and then 250 µL of p.a. heptane (Merck, Germany) was added and everything was brought to a boil. After cooling, a saturated sodium chloride solution was added. After standing for 1 h, the separated upper phase was moved into a test vial containing a 1-mm layer of dry sodium sulfate, to which 0.5 mL of heptane was added. The column was a Supelco SP-2560 with film dimensions of 100 m × 0.25 mm × 0.2 µm (Supelco, USA). The oven temperature program was 5 min at 140 °C, which was then increased by 4 °C/min until 240 °C, with 10 min for the final temperature. The injector temperature was 220 °C and the detector temperature was 250 °C. The carrier gas was hydrogen, with a column flow of 1 mL $min^{-1}$ and an automatic injection amount of 1 µL. Oils were stored in a deep freezer for a very short time until analysis.

**2.5. Determination of oxidative stability**

The determination of oxidative stability was carried out with a Rancimat 743 measurement system. With the Rancimat method, the sample is exposed to an air flow at a constant temperature of 100 °C. Highly volatile secondary oxidation products (especially formic acid) are transferred into the measuring vessel with the air flow, where they are absorbed in the measuring solution (distilled water). Here the conductivity is continuously registered. The organic acids can thus be detected by increasing conductivity. The time it takes for these secondary reaction products to occur is referred to as the induction time or induction period, which is a good indicator for the oxidation stability (Rancimat, 2009).

**2.6. Determination of antioxidant capacity**

Antioxidant capacity was determined according to Brand-Williams et al. (1995). Samples were extracted by methanol, stored at 4 °C for 24 h, and filtered after 30 min of shaking. The color reaction was carried out with 2,2-diphenyl-1-picrylhydrazyl at 36 °C for 30 min in a dark place, and the absorbance decrease against a blank sample was measured at 517 nm (ATI Unicam UV-Vis Spectrometer UV2, Unicam, UK). The antioxidant capacity is given in Trolox equivalent per 100 g dry matter.

### 2.7. Determination of total polyphenols

Total polyphenols were determined according to MSZ No. 9474 (Hungarian Standardization Office, 1980). Defatted samples were extracted by methanol, stored at 4 °C for 24 h, and filtered after 30 min shaking. Color reaction with Folin–Ciocalteu reagent was performed and absorbance was measured at 750 nm. The results are given as gallic acid equivalent per 100 g dry matter (GAE/100 g DM).

### 2.8. Determination of phenolic compounds

Phenolic compounds were determined from green husks of Alsószentiváni 117 and Milotai 10 and defatted samples. The phenolic compounds in the green husks of other cultivars were not analyzed due to financial constraints. The extraction was made with 20 mL (in cases of green husk) or 14 mL (for walnut kernels) of 2% acetic acid/MeOH.

The measurement system consisted of a Waters 2696 HPLC platform with 250 × 4.6, 5 µm Nucleodur C18 Pyramid column and Waters 2996 UV/photodiode array detector (Waters Corporation, USA). The detection wavelength was set to 250, 280, 320, and 360 nm. A gradient elution was applied and the eluents were 1% formic acid and acetonitrile. The flow rate was 0.7 mL $min^{-1}$.

### 2.9. Statistical analyses

All the analyses were carried out in triplicate. Statistical evaluation was made using Duncan's homogeneity evaluation of ANOVA analysis for one factor in PSAW 18 software. There were no significant differences among the data marked by same letters in tables, $P < 0.05$.

## 3. Results and discussion

Ten different walnut cultivars were examined for their compositional data. The study included the color data of the shells and kernels, the compositional data for oil content and others belonging to it (oxidative stability, fatty acid composition), and the antioxidative properties of the samples.

Based on measured color data, it can be stated that the Hungarian-bred walnut varieties had a better value as in-shell walnuts than as kernels. The novel Hungarian-bred cultivars (Milotai intenzív, Bonifác, and Milotai bőtermő), as well as both foreign-bred ones, had a slightly darker shell color in December (stored samples) than after the harvest in October (dried samples). Other cultivars had the opposite characteristics; the L* values were slightly higher in December compared to the first measurement made in October. The highest difference was observed in Milotai kései (Figure 1). Milotai bőtermő, Milotai kései, and Chandler varieties had lighter kernel colors after 8 weeks of storage. Other varieties had the same kernel color before and after storage (Figure 2). There were no significant differences in the cultivars' shell L* values after drying, but Chandler had a significantly lighter kernel than the other cultivars. Thus, it is recommended for Hungarian growers to sell Hungarian-bred cultivars as dried, shelled walnuts instead of as kernels in order to remain competitive.

The green husks of two cultivars (Alsószentiváni 117 and Milotai 10) were also examined. The dry matter content was similar in the two green husks. In green walnut husks, the most important phenolic compound is juglone, which is toxic. The amount of juglone in Milotai 10 (1314

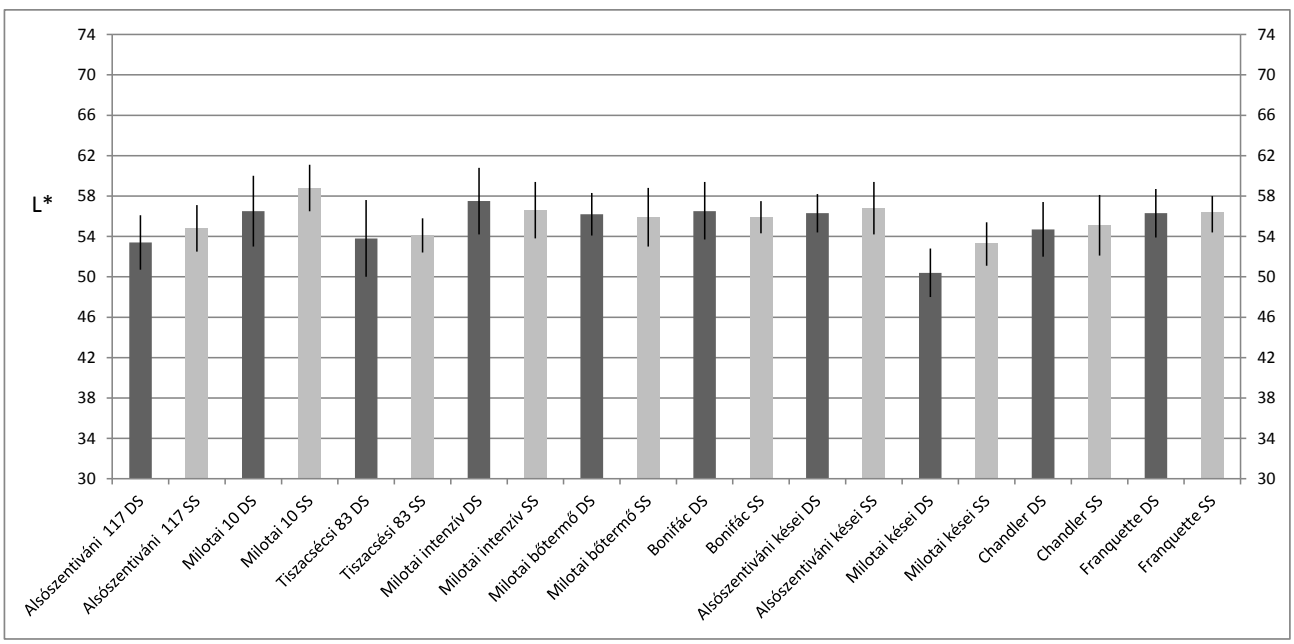


**Figure 1.** Changes in Persian walnut cultivars' shell color during short-term storage.

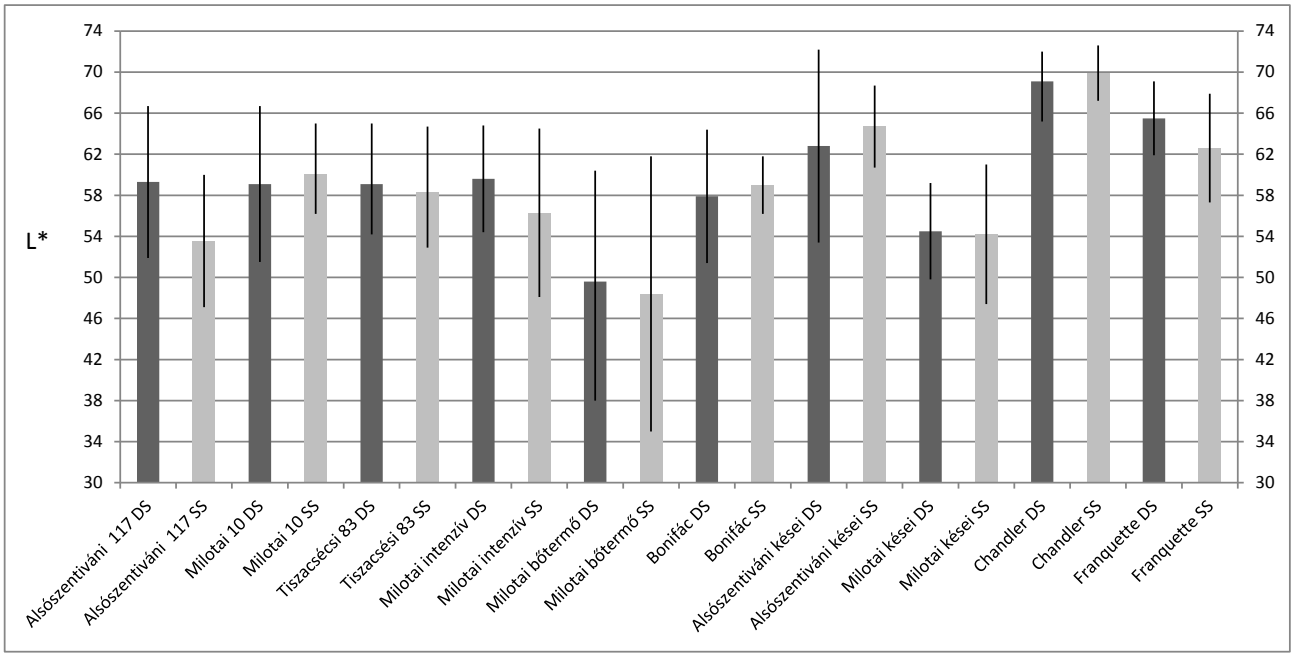


**Figure 2.** Changes in Persian walnut cultivars' kernel color during short-term storage.

mg rutin equivalent/100 g DM) was about 1.5 times higher than in Alsószentiváni 117 (532 mg rutin equivalent/100 g DM); the same ratio also applied to total polyphenol compounds (Table 3).

According to the oil content results, there were differences among the cultivars and the storage stages (Table 4). The Bonifác fresh sample had the lowest oil content in all stages. Comparing the Hungarian cultivars to Chandler and Franquette, all cultivars had similar values except for Chandler, which had lower oil content in fresh samples. There were some significant differences in fatty acid composition among the samples. In Milotai intenzív, the fatty acid composition changed slightly over time, because its polyunsaturated fatty acid (PUFA) content decreased, while its monounsaturated fatty acid content increased. The fatty acid composition in Hungarian cultivars is similar to those of international ones; from a nutritional point of view, they are as valuable as the others. As a part of determining the oil content, oxidative stability was measured and given as induction time (h). The induction time shows an interesting picture (Table 5). Chandler and Franquette have a low induction time, which means that they will develop rancidity in a short time, resulting in a shorter storage period. On the other hand, Milotai intenzív, Bonifác, and Alsószentiváni kései have a higher (<11 h) induction time, indicating that these cultivars are less susceptible to rancidity. According to Vidrih et al. (2010), the correlation between an oil's induction time and PUFA content is negative, so induction time increases as linoleic and linolenic acid content decreases. Current results show the same tendency.

The analyses of some antioxidative properties of the samples indicate that the antioxidant capacity change over time was similar for almost every cultivar. The dried samples had a higher antioxidant capacity than the fresh ones, but during storage it decreased. Chandler had the lowest antioxidant capacity during all stages. Milotai intenzív, Bonifác, and Alsószentiváni kései had high

**Table 3.** Results for green husks of walnut species.

| | Milotai 10 | Alsószentiváni 117 |
|---|---|---|
| Dry matter content | 14.24 | 13.56 |
| Total polyphenolic compounds (mg GAE*/100 g DM) | 6125 | 4099 |
| Juglone (mg RE**/100 g DM) | 1314 | 532 |

*GAE: gallic acid equivalent, **RE: rutin equivalent.

**Table 4.** Composition data (dry matter, oil content, induction time, fatty acid composition) of walnut cultivars I.

| | | Dry matter (%) | Oil content (% d.m.) | Induction time (h) | Palmitic acid C16:0 (%) | Stearic acid C18:0 (%) | Oleic acid C18:1 (%) | Linoleic acid C18:2 (%) | Linolenic acid C18:3 (%) | Arachidic acid C20:0 (%) | Saturated (%) | MUFA** (%) | PUFA*** (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alsószentiváni 117 | GH | 79.1 d | 57.8 c | n.t.* | 6.25 a | 2.90 a | 25.04 a | 56.48 a | 8.35 d | | 9.15 | 25.04 | 64.83 |
| | FS | 86.8 c | 70.3 b | 7.39 | 6.09 c | 2.82 b | 24.44 b | 55.41 d | 9.95 b | 0.09 | 9.01 | 24.44 | 65.35 |
| | DS | 96.6 a | 73.5 a | 9.68 | 6.11 c | 2.88 a | 24.24 c | 55.64 c | 10.02 a | 0.10 | 9.08 | 24.24 | 65.67 |
| | SS | 95.4 b | 70.1 b | 9.60 | 6.19 b | 2.78 c | 24.47 b | 56.16 b | 9.33 c | | 8.97 | 24.47 | 65.49 |
| Milotai 10 | GH | 79.2 d | 55.7 b | n.t.* | 6.99 a | 2.53 b | 21.30 c | 58.49 a | 9.59 a | | 9.52 | 21.30 | 68.08 |
| | FS | 80.8 c | 54.6 c | 6.64 | 6.78 c | 2.67 a | 21.74 b | 57.93 b | 9.38 b | 0.09 | 9.54 | 21.74 | 67.31 |
| | DS | 95.9 a | 68.8 a | 9.59 | 6.88 b | 2.69 a | 20.93 d | 58.36 a | 9.62 a | 0.10 | 9.67 | 20.93 | 67.98 |
| | SS | 94.9 b | 68.4 a | 7.76 | 6.78 c | 2.66 a | 22.47 a | 57.36 c | 9.33 b | | 9.43 | 22.47 | 66.68 |
| Tiszacsécsi 83 | FS | 81.4 b | 44.4 c | 5.34 | 6.89 b | 2.45 a | 16.30 a | 62.39 b | 10.36 b | 0.09 | 9.43 | 16.30 | 72.76 |
| | DS | 96.0 a | 71.0 a | 9.76 | 7.00 a | 2.47 a | 16.34 a | 61.54 c | 10.95 a | 0.12 | 9.60 | 16.34 | 72.50 |
| | SS | 95.4 a | 70.5 b | 10.00 | 6.82 c | 2.47 a | 16.18 b | 62.66 a | 10.34 b | | 9.29 | 16.18 | 73.00 |
| Milotai intenzív | FS | 82.8 b | 45.2 c | 6.83 | 7.13 a | 2.36 a | 25.65 c | 52.77 a | 10.58 a | 0.09 | 9.58 | 25.65 | 63.35 |
| | DS | 96.1 a | 72.1 a | 12.01 | 6.29 c | 2.14 c | 29.20 b | 51.59 b | 9.56 b | | 8.43 | 29.20 | 61.15 |
| | SS | 95.6 a | 69.2 b | 13.17 | 6.65 b | 2.21 b | 30.14 a | 50.10 c | 9.20 c | | 8.85 | 30.14 | 59.30 |
| Milotai bőtermő | FS | 79.0 b | 56.2 c | 7.22 | 6.78 c | 2.49 c | 19.15 b | 59.18 b | 10.99 b | 0.08 | 9.35 | 19.15 | 70.17 |
| | DS | 95.9 a | 71.6 a | 8.71 | 7.07 a | 2.81 a | 18.83 c | 59.70 a | 10.13 c | 0.09 | 9.97 | 18.83 | 69.83 |
| | SS | 95.2 a | 70.5 b | 8.72 | 6.97 b | 2.56 b | 19.33 a | 58.22 c | 11.42 a | | 9.54 | 19.33 | 69.65 |
| Milotai kései | FS | 87.6 c | 59.3 c | 6.62 | 7.12 a | 2.22 a | 21.98 a | 54.21 b | 13.14 b | 0.09 | 9.43 | 21.98 | 67.35 |
| | DS | 96.6 a | 72.3 a | 9.13 | 7.04 b | 2.13 b | 21.29 b | 54.14 b | 13.72 a | 0.09 | 9.25 | 21.29 | 67.86 |
| | SS | 95.1 b | 70.3 b | 6.66 | 7.01 b | 2.15 b | 21.27 b | 55.16 a | 12.74 c | | 9.16 | 21.27 | 67.90 |
| Bonifác | FS | 73.7 c | 38.0 b | 7.98 | 7.14 a | 1.94 a | 19.12 b | 58.63 b | 11.61 b | 0.08 | 9.16 | 19.12 | 70.24 |
| | DS | 95.3 a | 61.3 a | 12.77 | 7.08 b | 1.96 a | 18.76 c | 59.73 a | 11.06 c | | 9.05 | 18.76 | 70.79 |
| | SS | 93.7 b | 60.6 a | 8.60 | 7.05 b | 1.96 a | 19.77 a | 57.96 c | 11.91 a | | 9.01 | 19.77 | 69.86 |
| Alsószentiváni kései | FS | 86.1 b | 53.8 c | 8.04 | 6.23 b | 2.41 a | 28.32 c | 52.08 a | 9.72 b | 0.09 | 8.73 | 28.32 | 61.79 |
| | DS | 95.8 a | 69.2 a | 11.80 | 6.30 a | 2.35 b | 29.34 a | 50.93 c | 9.88 a | 0.09 | 8.74 | 29.34 | 60.81 |
| | SS | 95.1 a | 68.1 b | 9.30 | 6.29 a | 2.39 a | 28.82 b | 51.41 b | 9.71 b | | 8.68 | 28.82 | 61.13 |
| Chandler | FS | 78.3 c | 44.1 c | 6.54 | 6.24 b | 2.40 b | 17.77 b | 58.64 b | 13.54 b | 0.08 | 8.72 | 17.77 | 72.19 |
| | DS | 92.3 b | 67.8 b | 3.92 | 6.29 a | 2.39 b | 17.94 a | 59.13 a | 12.82 c | | 8.68 | 17.94 | 71.95 |
| | SS | 95.7 a | 71.6 a | 10.77 | 6.23 b | 2.43 a | 17.95 a | 57.93 c | 14.19 a | | 8.66 | 17.95 | 72.13 |
| Franquette | FS | 89.6 b | 55.5 b | 4.19 | 7.77 a | 2.59 b | 17.46 b | 59.37 b | 11.35 a | | 10.36 | 17.46 | 70.72 |
| | DS | 95.5 a | 69.2 a | 8.49 | 7.05 b | 2.61 ab | 18.92 a | 58.92 c | 11.13 b | | 9.66 | 18.92 | 70.06 |
| | SS | 95.4 a | 68.8 a | 8.69 | 7.00 b | 2.63 a | 17.59 b | 60.63 a | 10.75 c | | 9.63 | 17.59 | 71.38 |

*not tested, **MUFA: monounsaturated fatty acid (C18:1), ***PUFA: polyunsaturated fatty acid (C18:2+C18:3)). GH: green husk. FS: fresh sample, DS: dried sample, SS: stored sample.

**Table 5.** Compositional data (total polyphenol content, antioxidant capacity, phenolic compounds) of walnut cultivars II.

| | | Total polyphenols (mg GAE**/ 100 g DM) | Antioxidant capacity (mmol TE***/ 100 g DM) | Gallic acid (mg RE****/ 100 g DM) | Catechin (mg RE/ 100 g DM) | Epicatechin (mg RE/ 100 g DM) | Syringic acid derivative (mg RE/ 100 g DM) | Unknown (mg RE/ 100 g DM) | Myricetin derivative (mg RE/ 100 g DM) | Quercetin derivative (mg RE/ 100 g DM) | Kaempferol derivative (mg RE/ 100 g DM) | Ellagic acid derivative (mg RE/ 100 g DM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alsószentiváni 117 | GH | 1238 d | 20.21 bc | 35.05 a | 2.04 b | 8.15 b | 31.11 a | 65.76 a | n.t.* | n.t.* | 1.82 a | 56.03 a |
| | FS | 1341 c | 21.51 b | 12.21 b | 0.76 c | 14.35 a | 28.13 b | 31.50 b | n.t.* | n.t.* | 0.83 b | 58.73 a |
| | DS | 1483 b | 24.01 a | 5.84 c | 4.87 a | 2.17 c | 9.99 c | 21.83 c | 5.79 a | 1.05 b | 0.51 c | 49.75 b |
| | SS | 1578 a | 21.50 b | n.t.* | 2.24 b | n.t.* | 5.94 d | 17.12 d | 2.75 b | 4.36 a | 0.73 b | 48.12 b |
| Milotai 10 | GH | 1295 d | 20.30 c | 31.51 a | 4.61 c | 18.02 b | 22.31 d | 101.96 a | n.t.* | n.t.* | 2.07 a | 57.66 c |
| | FS | 1669 c | 30.87 a | 18.51 b | 12.74 b | 45.41 a | 59.09 a | 97.92 a | n.t.* | n.t.* | 1.05 b | 109.52 a |
| | DS | 3877 a | 25.13 b | 1.04 c | 15.78 a | n.t.* | 43.98 b | 11.31 c | 3.79 a | 1.37 b | 0.18 d | 68.21 b |
| | SS | 1953 b | 23.01 b | n.t.* | 3.70 d | 2.96 b | 29.62 c | 17.09 b | 1.97 b | 3.05 a | 0.79 c | 64.32 b |
| Tiszacsécsi 83 | FS | 1775 b | 18.48 c | 5.94 | 1.07 b | 7.23 a | 6.95 c | 135.99 a | 0.15 c | n.t.* | 4.51 a | 64.46 a |
| | DS | 3234 a | 24.62 a | n.t.* | 3.82 a | n.t.* | 33.76 b | 59.16 b | 0.41 b | n.t.* | 1.44 c | 55.81 b |
| | SS | 1970 b | 22.16 b | n.t.* | 0.87 b | n.t.* | 46.87 a | 58.48 b | 1.65 a | 4.20 | 1.83 b | 54.43 b |
| Milotai intenzív | FS | 1961 a | 19.93 c | 25.97 a | n.t.* | n.t.* | 16.84 c | 140.81 a | 3.05 a | n.t.* | 5.50 a | 86.35 a |
| | DS | 1906 a | 41.01 a | 3.11 b | n.t.* | n.t.* | 21.41 b | 25.91 c | 0.59 c | 1.22 b | 0.77 c | 52.15 b |
| | SS | 2175 a | 23.67 b | n.t.* | n.t.* | n.t.* | 35.79 a | 37.65 b | 1.40 b | 2.54 a | 1.32 b | 59.39 b |
| Milotai bőtermő | FS | 1314 b | 21.07 b | 26.64 | n.t.* | n.t.* | 12.97 b | 132.71 a | 0.52 c | n.t.* | 3.22 a | 108.9 a |
| | DS | 2143 a | 29.60 a | n.t.* | n.t.* | n.t.* | 11.92 c | 54.05 c | 0.68 b | 2.60 b | 0.52 c | 84.33 b |
| | SS | 2028 a | 28.05 a | n.t.* | n.t.* | n.t.* | 21.42 a | 96.46 b | 2.52 a | 3.10 a | 1.25 b | 71.91 c |
| Milotai kései | FS | 1926 a | 22.57 a | 21.13 a | 1.53 b | 9.93 a | 34.96 b | 58.24 a | 2.24 a | 2.04 b | 1.11 a | 74.89 a |
| | DS | 1622 b | 19.21 b | 11.86 b | 4.09 a | 2.54 b | 32.27 b | 52.31 b | 0.63 c | 2.10 b | 0.75 b | 43.56 b |
| | SS | 1690 b | 20.20 b | n.t.* | 0.80 c | n.t.* | 47.38 a | 25.01 c | 0.96 b | 3.69 a | 0.30 c | 45.99 b |
| Bonifác | FS | 628 b | 15.18 c | 70.75 | n.t.* | n.t.* | 36.78 c | 168.39 a | n.t.* | n.t.* | 2.27 a | 121.47 a |
| | DS | 2098 a | 32.98 a | n.t.* | n.t.* | n.t.* | 70.51 b | 33.27 c | n.t.* | 0.18 a | 0.22 c | 55.83 c |
| | SS | 2099 a | 26.54 b | n.t.* | n.t.* | n.t.* | 81.51 a | 54.94 b | 4.25 | 0.23 a | 0.62 b | 61.69 b |
| Alsószentiváni kései | FS | 1683 a | 22.01 b | 26.60 | 28.69 | n.t.* | 14.77 c | 88.26 a | 0.27 c | 1.36 b | 1.65 a | 53.19 a |
| | DS | 1596 b | 27.33 a | n.t.* | n.t.* | n.t.* | 40.94 a | 29.63 b | 3.75 a | 0.00 | 0.49 b | 43.36 b |
| | SS | 1611 ab | 18.15 c | n.t.* | n.t.* | n.t.* | 34.57 b | 30.71 b | 3.11 b | 2.66 a | 0.40 b | 34.44 c |
| Chandler | FS | 207 c | 7.49 c | 25.95 | 3.14 | n.t.* | 1.97 c | 137.56 a | 0.57 c | 0.72 b | 8.70 a | 43.80 a |
| | DS | 1557 a | 16.80 a | n.t.* | n.t.* | n.t.* | 3.74 b | 51.60 b | 2.11 a | 0.30 c | 3.73 b | 31.53 b |
| | SS | 1326 b | 15.92 b | n.t.* | n.t.* | n.t.* | 22.74 a | 47.08 b | 1.79 b | 1.02 a | 2.07 c | 28.25 b |
| Franquette | FS | 1865 a | 25.72 b | 16.12 | n.t.* | n.t.* | 27.36 a | 60.66 a | 1.51 c | 0.32 b | 3.16 a | 48.17 a |
| | DS | 1454 c | 29.99 a | n.t.* | n.t.* | n.t.* | 21.56 c | 29.12 b | 1.96 b | 0.35 b | 1.32 b | 31.31 c |
| | SS | 1543 b | 16.72 c | n.t.* | n.t.* | n.t.* | 23.90 b | 30.07 b | 2.19 a | 0.60 a | 0.66 c | 38.54 b |

*not tested, **GAE: gallic acid equivalent, ***TE: Trolox equivalent, ****RE: rutin equivalent.

antioxidant activity, resulting in a higher induction time and greater oxidative stability (12 h or higher). The total polyphenol content ranged from 207 to 3877 mg GAE/100 g DM. Milotai 10 and Tiszacsécsi 83 dried samples had a high total polyphenol content (3877 mg GAE/100 g DM and 3234 mg GAE/100 g DM, respectively), while Chandler and Bonifác fresh samples had a low total polyphenol content (207 mg GAE/100 g DM and 628 mg GAE/100 g DM, respectively). In the case of the other samples, the values were all about half of that of Milotai 10 and Tiszacsécsi 83.

As for phenolic compounds, gallic acid, catechin, epicatechin, syringic acid, myricetin, quercetin, kaempferol, and ellagic acid derivatives were found. A still-unknown compound was dominant in the samples, though its retention time suggests that it may have been a juglone derivative. Its concentration was similar to ellagic acid derivatives in fresh samples, but decreased during storage to one-fifth or less of its original levels. Gallic acid had a higher concentration in fresh samples, but decreased during storage to a nondetectable amount. High amounts of syringic acid derivatives and ellagic acid derivatives were observed in the samples; the tendency in ellagic acid derivatives was similar to gallic acid, but for syringic acid there were no significant changes in the quantity between the stages. Ellagic acid content for Milotai 10 and Milotai bőtermő was high in the fresh samples, but it decreased almost to half during storage. Bonifác had a higher amount of syringic acid derivatives, but Chandler's was lower than the others. In the case of myricetin and quercetin, the fresh samples had a nondetectable or very low concentration of these compounds, but they increased in dried and stored samples. The changes of the kaempferol content in the samples was similar to gallic acid; the amount decreased during storage. Catechin and epicatechin were not present in Milotai intenzív, Milotai bőtermő, Bonifác, and Franquette, while catechin was detected in all stages of Alsószentiváni 117, Milotai 10, Tiszacsécsi 83, and Milotai kései (Table 5).

Compared to the results of Arranz et al. (2008), this study did not find significant correlations between the antioxidant capacity or total polyphenol content and tocopherols or induction time, but the whole kernel, not only the oils, was analyzed.

In conclusion, in this study, the authors examined ten different walnut cultivars for their compositional data. Samples were tested for important parameters: shell and kernel color, oil content and joined properties (fatty acid composition, extent of rancidity), and antioxidative properties (antioxidative capacity, total polyphenols, phenolic compounds). The cultivars showed different tendencies for these parameters. Alsószentiváni 117 and Milotai bőtermő had higher values for most parameters, as well as Bonifác. Despite its lower dry matter and oil content, Bonifác was a valuable cultivar when other parameters were taken into consideration. However, Chandler was less valuable than the others with lower values. Summarizing all the results, it can be stated that drying and storage had significant effects on the different compositional data, but there was no specific tendency.

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