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Original Article

Determination of fruit characteristics and biochemical contents of some almond cultivars (*P. amygdalus* L.) grown in the Afyonkarahisar/ Dinar region

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Abstract:

This study was conducted in a closed almond orchard in the Dinar district, of Afyonkarahisar Province, from 2023-2024. The study aimed to determine the fruit characteristics and biochemical contents of Ferragnes, Ferraduel, and Nonpareil almond cultivars. In the study, the fruit weight ranged from 2.01 g (Nonpareil) to 5.18 g (Ferragnes), the fruit width ranged from 19.87 mm (Nonpareil) to 26.65 mm (Ferragnes), the fruit length ranged from 32.66 mm (Nonpareil) to 39.72 mm (Ferragnes), and the shell thickness ranged from 1.75 mm (Nonpareil) to 3.58 mm (Ferraduel). The kernel weight varied between 1.07 g (Nonpareil) and 1.69 g (Ferragnes), the kernel width between 12.89 mm (Nonpareil) and 16.20 mm (Ferragnes), the kernel length between 22.54 mm (Nonpareil) and 28.40 mm (Ferragnes), the kernel thickness between 6.45 mm (Nonpareil) and 7.65 mm (Ferragnes), and the kernel ratio between 27.29% (Ferraduel) and 53.40% (Nonpareil). In terms of biochemical composition, total oil content ranged from 44.84% (Ferraduel) to 49.02% (Ferragnes), total phenolic content from 361.02 mg GAE/100 g (Nonpareil) to 429.2 mg GAE/100 g (Ferragnes), total flavonoid content from 30.49 mg CAE/100 g (Nonpareil) to 68.64 mg CAE/100 g (Ferragnes), total antioxidant content from 82.98% (Nonpareil) to 87.00% (Ferraduel), and total protein content from 16.64% (Ferragnes) to 19.16% (Ferraduel).

Key words:
Amygdalus communis L., kernel ratio, total phenolics, total oil

Apstrakt:

Određivanje karakteristika plodova i biohemijskog sastava nekih sorti bademа (*P. amygdalus* L.) uzgajanih u regionu Afjonkarahisar/ Dinar

Ova studija je sprovedena u zatvorenom zasadu badema u okrugu Dinar, u provinciji Afjonkarahisar, tokom perioda od 2023 do 2024. godine. Cilj istraživanja bio je da se odrede karakteristike plodova i biohemijski sastav sorti badema Ferragnes, Ferraduel i Nonpareil. U okviru studije, masa ploda varirala je od 2,01 g (Nonpareil) do 5,18 g (Ferragnes), širina ploda od 19,87 mm (Nonpareil) do 26,65 mm (Ferragnes), dužina ploda od 32,66 mm (Nonpareil) do 39,72 mm (Ferragnes), dok se debljina ljuske kretala od 1,75 mm (Nonpareil) do 3,58 mm (Ferraduel). Masa zrna varirala je između 1,07 g (Nonpareil) i 1,69 g (Ferragnes), širina zrna između 12,89 mm (Nonpareil) i 16,20 mm (Ferragnes), dužina zrna između 22,54 mm (Nonpareil) i 28,40 mm (Ferragnes), debljina zrna između 6,45 mm (Nonpareil) i 7,65 mm (Ferragnes), dok se udeo zrna kretao od 27,29% (Ferraduel) do 53,40% (Nonpareil). Što se tiče biohemijskog sastava, ukupni sadržaj ulja varirao je od 44,84% (Ferraduel) do 49,02% (Ferragnes), ukupni sadržaj fenola od 361,02 mg GAE/100 g (Nonpareil) do 429,2 mg GAE/100 g (Ferragnes), ukupni sadržaj flavonoida od 30,49 mg CAE/100 g (Nonpareil) do 68,64 mg CAE/100 g (Ferragnes), ukupni antioksidativni kapacitet od 82,98% (Nonpareil) do 87,00% (Ferraduel), dok je ukupni sadržaj proteina varirao od 16,64% (Ferragnes) do 19,16% (Ferraduel).

Ključne reči:
Amygdalus communis L., udeo zrna, ukupan sadržaj fenola, ukupan sadržaj ulja

Introduction

Almond [*Prunus dulcis* (Mill.) D.A. Webb; sin. *P. amygdalus* Batsch] is one of the oldest fruit species cultivated worldwide. Türkiye's location within the Near East and Mediterranean basin, its favorable ecological conditions, and its position along migration routes have contributed to its rich genetic resources. For this reason, Türkiye, which allows the natural growth of 9 out of nearly 40 almond species, is among the genetic centers of almonds (Bayazit & Küden, 2023). However, despite its high almond production potential, Türkiye has not been able to fully utilize this capacity. The lack of standardization in almond production and producers' concerns about inconsistent yields are among the primary reasons for this situation. However, in recent years, increasing consumer awareness, the expansion of irrigated areas, and the development of clonal rootstocks and new varieties suitable for modern cultivation systems have contributed to the expansion of almond production areas, particularly in the Mediterranean and Southeastern Anatolia regions, due to their ecological suitability. Moreover, with the breeding and introduction of late-blooming and self-fertile new varieties, almond production has been steadily increasing both worldwide and in Türkiye in recent years. In the last 10 years, the global almond production area has increased by 27.01%, expanding from 18.281.300 hectares to 23.220.670 hectares, while production has increased by 92.22%, rising from 1.828.130 tons to 3.513.970 tons. The United States ranks first in global almond production with 1.791.690 tons. It is followed by Spain with 297.660 tons, Australia with 260.000 tons, and Türkiye with 170.000 tons (FAO, 2023). In the last 10 years, Türkiye's almond production area has increased significantly above the global average, expanding from 270.203 hectares to 686.966 hectares, an increase of 154.24%. Meanwhile, production has risen from 73.230 tons by 132.15% to 170.000 tons. In Türkiye, the highest almond production is recorded in Adıyaman with 21.299 tons, followed by Mersin with 19.052 tons and Muğla with 9.785 tons (TÜİK, 2023). Nuts are highly nutritious fruits with a high oil content. It has been reported that meeting daily fat intake through nuts can significantly reduce cholesterol levels in humans (Abbey et al., 1994). Its high content of unsaturated fatty acids, protein, minerals, fiber, phytosterols, phenolics, and tocopherols, along with its diverse uses and consumption forms (raw, roasted, blanched, in the chocolate and creamy cake industry, as well as in the pharmaceutical and dye industries, and in animal feed production), is among the characteristics that distinguish almonds from other nuts (Yada et al., 2011; Yıldırım et al., 2016a; Yıldırım et al., 2016b). Additionally, the high antioxidant content of almond oil allows it to be used by aromatherapists today as a natural emollient and anti-aging agent (Bolling, 2017; Barreca et al., 2020). Since most almond plantations have been propagated from seeds, there is a wide variation among types, leading to inconsistent yields and the inability to obtain standardized products. This situation results in low productivity despite the high number of almond trees in Türkiye. Therefore, it is necessary to identify suitable varieties for each region and establish new orchards using standardized rootstocks and cultivars to ensure high-quality products and increase production.

This study aims to determine some fruit characteristics and the biochemical content of the almond cultivars 'Ferragnes,' 'Ferraduel,' and 'Nonpareil' grown in the Afyonkarahisar/Dinar region.

Materials and Methods

Material

This study was conducted in Yeşilçat Village, Dinar District, Afyonkarahisar Province, between 2023 and 2024, on three almond varieties (Ferragnes, Ferraduel, and Nonpareil) grafted onto seedlings in a closed orchard planted with a 5 x 5 meter spacing. Regular cultural practices such as pruning, fertilization, irrigation, and weed control have been carried out in the orchard. The orchard is located at an average altitude of 900 meters above sea level, and the trees' irrigation needs were met using a double-line drip irrigation system.

Fruit samples representing the tree from four different directions were collected from each almond variety and transported to a laboratory for measurement and analysis. The pomological analysis of the collected fruit samples was carried out in the laboratories of the Department of Horticultural Sciences at Isparta University of Applied Sciences, Faculty of Agriculture.

Method

In the study, a total of 810 fruit samples were used, with 30 fruits per repetition for each variety, in order to determine their pomological characteristics. The collected fruits were transported to the pomology laboratory of the Department of Horticultural Sciences at Isparta University of Applied Sciences, Faculty of Agriculture, where the green hulls (mesocarp) were removed and the fruits were subjected to a drying process at 50-55 °C until their moisture content stabilized.

The harvested fruits were measured for various parameters, including the fruit length, fruit width, shell thickness, kernel length, kernel width, and almond thickness. These measurements were made using a digital caliper with an accuracy of 0.01 mm (Yıldırım, 2007). The nut fruit weight and kernel weight were determined using a sensitive balance with an accuracy of 0.01 g (Yıldırım, 2007).

The total phenolic content was determined using the Folin-Ciocalteu method as described by Singleton & Rossi (1965). Homogenized fruit pulp was subjected to extraction in tubes for 1 h using a solution of acetone, water, and acetic acid (70:29.5:0.5). Accordingly, the samples were mixed in 0.1 ml of extract with de-ionized water and 0.1 ml (2N) Folin-Ciocalteu indicator and kept at room temperature for 6 min. Then, 0.5 ml of 20% sodium carbonate solution was added and incubated at room temperature for 30 min for color development. After color development, the absorbance values of the samples were read in a spectrophotometer at 760 nm wavelength (Model T60U, PG Instruments USA).

The total flavonoid content was determined according to the method described by Kim et al. (2003). First, 1 ml of each sample was mixed with 0.3 ml of 5% sodium nitrite ($NaNO_2$) solution and incubated for 5 min. 0.3 ml of 10% aluminium chloride ($AlCl_3$) solution was added for an additional 6 min incubation. Afterwards, 2 mL of 1 M sodium hydroxide (NaOH) was added, and the mixture was allowed to stand for 2 minutes. Subsequently, 4 ml of distilled water was added thoroughly mixed, and the absorbance values of the samples were read at 510 nm wavelength.

The total antioxidant capacity was determined using the method reported by Kumaran & Karunakaran (2006), employing 1,1-diphenyl-2-picrylhydrazyl (DPPH). First, 2 g of each sample were grounded and incubated in 20 ml of 80% methanol at -20 °C for 2 h. Then, the mixture was centrifuged at 2.000 rpm for 5 min, and the supernatant was collected for analysis. Following this step, 2 ml of 0.1 mM DPPH dissolved in methanol was added to 100 µL of the supernatant. After 30 min of incubation, the absorbance was measured at 517 nm wavelength.

In the study, the total oil content in the fruits was determined and calculated using the Soxhlet method. The results were evaluated as percentages (James, 1995). The oils of the samples were extracted using the Soxhlet method. Hexane was used as a solvent. The oil samples obtained from seeds and fruits were converted to methyl esters using a mixture of sodium methoxide and methanol according to the method specified by Knothe (2013). Fatty acid analyses were performed using a Shimadzu GC 2010 Plus instrument with a CP-WAX52CB 60 m column. Helium gas was used as a carrier at a flow rate of 3 ml/min. The column temperature was 80 °C, the detector temperature was 265 °C, and the injection block temperature was 250 °C. The oven temperature programme. After holding the initial temperature of 80 °C for 4 minutes, the temperature was increased to 175 °C at a rate of 20 °C/min and held for 25 minutes. It was then increased to 215 °C at a rate of 4 °C/min and held for 2 minutes, and finally increased to 250 °C at a rate of 2 °C/min and held for 20 minutes. Fatty acid methyl esters of fruit and seed samples were determined by comparison with the peak time of standards (37 FAME mix, Supelco).

The phenolic compounds of the fruits were determined using a Shimadzu HPLC device according to the method of Artik et al. (1998). For this purpose, 10 g of sample was taken; 0.1 g of BHT (2,6-di-tert-butyl-4-methylphenol) and 20 mL of extraction solution were added, then crushed in a homogeniser. After being placed for 45 minutes in an ultrasonic bath and then 45 minutes on a shaker, it was filtered through Whatman filter paper. The filtrate was passed through a 0.45 µm filter, and 20 µL of it was injected into the HPLC apparatus. The results were expressed in µg/g (extraction solution: 80% methanol with 1% HCl).

Statistical Analyses

The research was designed according to a randomized block design with 3 replications and 3 trees per replication. The data obtained from the study were analyzed using the Minitab statistical software. Significant differences between the means were determined using the Tukey multiple comparison test ($p \leq 0.05$) and are indicated by different letters.

Results and discussion

In the study, the fruit and kernel characteristics of the almond varieties are presented in **Tab. 1.** Statistically significant differences were found between the almond cultivars in terms of both fruit and kernel characteristics ($p \leq 0.05$). In the study, the fruit weight ranged from 2.01 g (Nonpareil) to 5.18 g (Ferragnes); fruit width from 19.87 mm (Nonpareil) to 26.65 mm (Ferragnes); and fruit length from 32.66 mm (Nonpareil) to 39.72 mm (Ferragnes). The kernel length ranged from 1.75 mm (Nonpareil) to 3.58 mm (Ferraduel). The kernel attributes were recorded as follows: the kernel weight ranged from 1.07 g (Nonpareil) to 1.69 g (Ferragnes), kernel width from 12.89 mm (Nonpareil) to 16.20 mm (Ferragnes), kernel length from 22.54 mm (Ferraduel) to 28.40 mm (Ferragnes), and kernel thickness from 6.45 mm (Nonpareil) to 7.65 mm (Ferragnes). The kernel ratio ranged from 27.29% (Ferraduel) to 53.40%

Table 1. Fruit and kernel characteristics of almond cultivars

Cultivars	FW (g)	FW (mm)	FL (mm)	ST (mm)	KW (g)	KW (mm)	KL (mm)	KT (mm)	KR (%)
Ferragnes	5.18±0.03^{a}	26.65±0.03^{a}	39.72±0.18^{a}	3.32±0.07^{a}	1.69±0.02^{a}	16.20±0.13^{a}	28.40±0.13^{a}	7.65±0.10^{a}	32.76±0.13^{b}
Ferraduel	4.86±0.09^{b}	23.03±0.11^{b}	32.92±0.17^{b}	3.58±0.07^{a}	1.30±0.01^{b}	13.84±0.20^{b}	22.54±0.05^{c}	7.06±0.17^{b}	27.29±0.18^{c}
Nonpareil	2.01±0.05^{c}	19.87±1.37^{c}	32.66±0.49^{b}	1.75±0.30^{b}	1.07±0.02^{c}	12.89±0.08^{c}	23.15±0.09^{b}	6.45±0.05^{c}	53.40±0.53^{a}

The differences between values represented by different letters in the same column are statistically significant ($p<0.05$).
(FW: Fruit Weight, FW: Fruit Width, FL: Fruit Length, ST: Shell Thickness, KW: Kernel Weight, KW: Kernel Width, KL: Kernel Length, KT: Kernel Thickness, KR:Kernel Ratio)

Table 2. Biochemical contents of almond cultivars

Cultivars	Total Phenolic Content (mg GAE/100 g)	Total Flavanoid Content (mg CAE/100 g)	Total Antioxidant Capacity (% inhibisyon)	Total Protein (%)	Total Oil (%)
Ferragnes	429.2±20.0^{a}	68.64±2.50^{a}	84.86±0.83^{a}	16.64±1.52^{a}	49.00±2.24^{a}
Ferraduel	408.77±7.21^{a}	33.07±1.20^{b}	87.00±1.35^{a}	19.16±1.00^{a}	44.82±1.01^{a}
Nonpareil	361.02±3.34^{b}	30.49±1.39^{b}	82.98±4.73^{a}	17.48±0.25^{a}	46.41±2.11^{a}

The differences between values represented by different letters in the same column are statistically significant ($p<0.05$)

(Nonpareil).

The study reveals significant variations in the fruit characteristics between the cultivars. Previous studies have also reported differences in fruit and kernel characteristics between cultivars and genotypes (Viti & Loreti, 1993; Yıldırım, 2007; Rapposelli et al., 2018; Karaat, 2019; Karahan, 2021; Demirdaş, 2022; Khojand et al., 2023; İsen, 2023). Segura & Kodad (2009) reported that the genetic traits of cultivars significantly influence the physical properties of almond fruits. In a high-quality almond variety, a thin shell and high kernel yield are desirable. The shell of almonds varies according to cultivars but constitutes 35-75% of the fruit (Li et al., 2018). Therefore, in hard-shelled almond varieties, shell thickness is one of the most important traits affecting fruit quality and kernel yield. While shell thickness is essentially a cultivar characteristic, it is also influenced by drought and cultural practices (Goldhamer et al., 2006; Romero et al., 2017; Yıldırım et al., 2023). Previous studies showed variations in fruit and kernel characteristics compared to our research results. In almond cultivation, ecological factors have a significant impact on quality traits (Yıldız & Perdahcı, 2019; Bayazit & Alaz, 2022), as well as cultural practices, especially plant nutrition, tree age, and yield conditions, also affect kernel fullness, size, and other characteristics (Küden et al., 2000). Similarly, environmental factors, cultural practices, and genetic traits have an impact on fruit quality, with cultivar, rootstock, and tree age having a stronger influence than genetic traits (Atay et al., 2009; Bayazit & Alaz, 2022).

The biochemical contents of almond varieties are presented in **Tab. 2**. Statistically significant differences were determined between almond cultivars in terms of total phenolic, flavonoid, and fat content ($p≤0.05$). The total phenolic content ranged from 361.02 mg GAE/100 g (Nonpareil) to 429.2 mg GAE/100 g (Ferragnes); the total flavonoid content ranged from 30.49 mg CAE/100 g (Nonpareil) to 68.64 mg CAE/100 g (Ferragnes); the total antioxidant content ranged from 82.98% (Nonpareil) to 87.00% (Ferraduel); the total protein content ranged from 16.64% (Ferragnes) to 19.16% (Ferraduel); and the total oil content ranged from 44.84% (Ferraduel) to 49.02% (Ferragnes).

In previous studies, it has been reported

Table 3. Phenolic content of almond cultivars (mg/kg)

Cultivars	Gallic acid	Catechin	p-hydroxybenzoic acid	Chlorogenic acid	Caffeic acid	Epicatechin	Kaempferol	Luteolin
Ferragnes	2.00±0.00^{c}	50.04±0.43^{a}	5.13±0.07^{a}	11.01±0.11^{a}	4.14±0.06^{a}	20.71±0.17^{a}	6.10±0.02^{a}	0.00±0.00^{b}
Ferraduel	4.63±0.04^{a}	33.82±0.25^{b}	4.62±0.05^{b}	7.85±0.03^{b}	2.07±0.02^{b}	17.52±0.14^{b}	2.05±0.07^{b}	3,52±0.06^{a}
Nonpareil	2.88±0.02^{b}	13.56±0.06^{c}	1.48±0.03^{c}	2.50±0.05^{c}	0.87±0.02^{c}	4.20±0.05^{c}	1.67±0.00^{c}	0.00±0.00^{b}

The differences between values represented by different letters in the same column are statistically significant (*p*<0.05)

Table 4. Phenolic content of almond cultivars (mg/kg)

Cultivars	Ferragnes	Ferraduell	Nonpareil
Myristic acid	0.01±0.00^{b}	0.00±0.00^{c}	0.03±0.00^{a}
Palmitic asit	5.99±0.03^{c}	6.49±0.03^{b}	6.65±0.01^{a}
Palmitoleic asit	0.53±0.00^{c}	0.59±0.00^{b}	0.75±0.00^{a}
Heptadecanoic acid	0.05±0.04^{a}	0.10±0.00^{a}	0.10±0.00^{a}
Stearic acid	2.12±0.01^{b}	2.03±0.00^{c}	2.17±0.00^{a}
Oleic acid	77.63±0.02^{a}	70.53±0.01^{b}	68.18±0.01^{c}
Linoleic acid	13.41±0.01^{c}	20.07±0.03^{b}	21.89±0.01^{a}
Arachidic acid	0.07±0.00^{a}	0.08±0.00^{a}	0.08±0.00^{a}
Linolenic acid	0.06±0.00^{a}	0.06±0.01^{a}	0.07±0.00^{a}
Behenic acid	0.02±0.00^{a}	0.00±0.00^{b}	0.02±0.00^{a}
Arachidonic acid	0.01±0.00^{a}	0.00±0.00^{b}	0.01±0.00^{a}
Arachidic acid	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}

The differences between values represented by different letters in the same column are statistically significant (*p*<0.05)

that there are differences in total phenolic, flavonoid, antioxidant, protein, and oil content between cultivars and genotypes. It has been noted that the biochemical contents of almonds show considerable variation across cultivars, regions, and years, and these differences are influenced by factors such as cultural practices, ecology, ripeness, soil composition, post-harvest storage conditions, fungi, bacteria, and pests (Yildız et al., 2014; Maestri et al., 2015; Rapposelli et al., 2018; Oliveira et al., 2018; Küçük, 2019; Ossama et al., 2021; Özcan, 2023; Khojand et al., 2023; İsen, 2023; Çakmak, 2023). Furthermore, İsen (2023) stated that the chemical composition of the fruit in almond breeding could be considered a selection criterion; however, certain markers, such as total protein, is heavily influenced by environmental factors, making their use as a sole selection criterion misleading (Beltrán Sanahuja et al. 2021).

In this study, the phenolic compounds of almond cultivars are presented in **Tab. 3**. Statistically significant differences were determined between almond cultivars in terms of phenolic compounds (p≤0.05). The amounts of gallic acid ranged from 2.00 mg/kg (Ferragnes) to 4.63 mg/kg (Ferraduel), catechin from 13.56 mg/kg (Nonpareil) to 50.04 mg/kg (Ferragnes), p-hydroxybenzoic acid from 1.48 mg/kg (Nonpareil) to 5.13 mg/kg (Ferragnes), chlorogenic acid from 2.50 mg/kg (Nonpareil) to 11.01 mg/kg (Ferragnes), caffeic acid from 0.87 mg/kg (Nonpareil) to 4.14 mg/kg (Ferragnes), epicatechin from 4.20 mg/kg (Nonpareil) to 20.71 mg/kg (Ferragnes), kaempferol from 1.67 mg/kg (Nonpareil) to 6.10 mg/kg (Ferragnes), and luteolin from 0.00 mg/kg (Nonpareil, Ferragnes) to 3.52 mg/kg (Ferraduel). Bolling et al. (2010) stated that there were statistically significant differences between cultivars regarding phenolic content, with catechin having the highest value and naringenin the lowest. Colic et al. (2017) reported that catechin, with an average of 46.3% of total phenols, was the dominant phenolic compound, followed by chlorogenic acid and rutin. In this study, lower values were obtained for some phenolic compounds and higher values for others. As mentioned in previous studies, this variation may be influenced by factors such as fungi, bacteria, pests, air, and light, and environmental factors in the growing region, cultivation techniques, fruit ripeness, soil properties of the region, and the genetic characteristics of species and cultivars may also play a role (Yıldırım et al., 2016; Colic et al., 2017; Banjanin et al., 2020).

In this study, the fatty acid composition of almond cultivars is presented in **Tab. 4**. Statistically significant differences were determined between almond cultivars in terms of fatty acids ($p \leq 0.05$). The results showed that oleic acid, linoleic acid, palmitic acid, and stearic acid were the dominant fatty acids, making up 99% of the total oil content. Among the unsaturated fatty acids, oleic acid ranged from 68.18% (Nonpareil) to 77.63% (Ferragnes), linoleic acid ranged from 13.41% (Ferragnes) to 21.89% (Nonpareil), and among the saturated fatty acids, palmitic acid ranged from 5.99% (Ferragnes) to 6.65% (Nonpareil), stearic acid ranged from 2.03% (Ferraduel) to 2.17% (Nonpareil). These results are similar to those found by Özcan et al. (2011), Kodad et al. (2014), and Colic et al. (2017). However, Banjanin et al. (2020) reported higher results. It has been reported that factors such as variety, location, harvest time, cultural practices, storage conditions, tree age, and ecology have a significant impact on characteristics such as fat, protein, mineral content, vitamins, and phytochemicals in almonds (Yıldırım, 2016; Özcan, 2023).

Conclusion

This study aims to determine the fruit characteristics and some biochemical contents of Ferragnes, Ferraduel, and Nonpareil almond varieties grown in an almond orchard located in Yeşilçat Village, Dinar District, Afyonkarahisar Province.

In the study, the fruit weight ranged from 2.01 g (Nonpareil) to 5.18 g (Ferragnes), fruit width from 19.87 mm (Nonpareil) to 26.65 mm (Ferragnes), fruit length from 32.66 mm (Nonpareil) to 39.72 mm (Ferragnes), and shell thickness from 1.75 mm (Nonpareil) to 3.58 mm (Ferraduel). The kernel weight varied between 1.07 g (Nonpareil) and 1.69 g (Ferragnes), kernel width between 12.89 mm (Nonpareil) and 16.20 mm (Ferragnes), kernel length between 22.54 mm (Nonpareil) and 28.40 mm (Ferragnes), kernel thickness between 6.45 mm (Nonpareil) and 7.65 mm (Ferragnes), and kernel ratio between 27.29% (Ferraduel) and 53.40% (Nonpareil).

The study determined total oil content ranging from 44.84% (Ferraduel) to 49.02% (Ferragnes), total phenolic content from 361.02 mg GAE/100 g (Nonpareil) to 429.2 mg GAE/100 g (Ferragnes), total flavonoid content from 30.49 mg CAE/100 g (Nonpareil) to 68.64 mg CAE/100 g (Ferragnes), total antioxidant content from 82.98% (Nonpareil) to 87.00% (Ferraduel), and total protein content from 16.64% (Ferragnes) to 19.16% (Ferraduel).

This research is of great importance because it serves as a model for producers in a region where fruit cultivation is developing. This is especially significant since no previous studies have been conducted on almond cultivation using standard cultivars. The results indicate that almond cultivation is feasible in the Dinar District of Afyonkarahisar, a region characterised by severe winter cold and frequent late spring frosts. This is because the results of fruit weight and kernel ratio, the main quality attributes of almonds, are consistent with studies conducted in more suitable ecological conditions. In addition, the study highlights the need to conduct adaptation trials for extra-late almond cultivars, taking into account the regional ecology. The results of this research are expected to contribute to the fruit industry, pomology, and almond cultivation in the Dinar district of Afyonkarahisar.

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