Pak. J. Bot., 57(6): DOI: http://dx.doi.org/10.30848/PJB2025-6(27)

DETERMINATION OF FRUIT POMOLOGICAL AND CHEMICAL PROPERTIES OF SOME BLACKBERRY CULTIVARS IN TÜRKİYE

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Abstract

Blackberries are valued worldwide for their rich antioxidant content, which supports human health and disease prevention. Due to their adaptability and high market demand, blackberries play a significant role in the global berry industry. For this reason, cultivation areas are gradually increasing in Türkiye. We evaluated the fruit quality of several blackberry cultivars (Chester, Jumbo, Bursa 1, and Bursa 2) under the climatic conditions of Eskişehir. The fruits were harvested at full ripeness. In this study, both pomological traits (fruit width, length, weight, and color) and chemical characteristics (SSC, pH, NaOH, AsA, TPC, DPPH) of the fruits were analyzed. The Jumbo cultivar produced the largest fruits. The highest SSC value was observed in Chester (10.36 °Brix). The greatest titratable acidity (NaOH) was found in the Bursa 1 cultivar (2.59%). Jumbo also exhibited the highest ascorbic acid (AsA) content (54.74 mg/100 ml), while Chester had the lowest (48.70 mg/100 ml). The total phenolic content (TPC) reached its maximum in Jumbo (7648.33 mg GAE/100 g FW) and its minimum in Bursa 1 (7247.33 mg GAE/100 g FW). The highest antioxidant activity (DPPH) was recorded in Bursa 2 (86.11 IC50), whereas the lowest was measured in Jumbo (81.41 IC_{50}).

Key words: Blackberry, Eskişehir, Adaptation, Pomology, Phytochemical.

Introduction

The blackberry bush (Rubus spp.), which originates from North America, is a perennial shrub belonging to the Rubus genus in the Rosaceae family (Yang *et al*., 2015). The fruit consists of clustered berries that turn black when they ripen, resembling mulberries. Blackberries are packed with anthocyanins, superoxide dismutase (SOD), flavonoids, ellagic acid, tannins, and various other antioxidants, and they contain the highest levels of selenium compared to other fruits, offering protection against a range of diseases (Kaume *et al*., 2012). Additionally, blackberry leaves are traditionally used for their antibacterial, antiseptic, and anti-diarrheal properties, as well as their ability to aid in labor during pregnancy (Patel *et al*., 2004). Due to the growing demand for healthy and nutrient-dense fruits, the cultivation of blackberries is on the rise. The global area dedicated to blackberry farming was projected to grow by 34.92%, from 20,035 hectares in 2005 to 27,032 hectares in (Strik *et al*., 2007). The worldwide annual production of commercially grown blackberries exceeds 150,000 tons (Kaume *et al*., 2012).

The blackberry plant is an important plant with a medical history of 8000 years. Blackberry species are frequently found in various regions of our country, which shows that our country is one of the natural distribution areas of blackberries. While wild blackberry forms are generally found in wetlands and field edges as a part of the natural flora, hobby cultivation is common in garden edges (Erenoğlu & Öztürk, 2002). Blackberry is widely found in Turkiye, is gaining more and more importance due to its potential for industrial use as well as fresh consumption. Blackberry has become an economic product for agricultural and industrial enterprises with various processing methods. It is used as an indispensable berry-like fruit in industries such as fruit juice, marmalade, jam, beverages, ice cream, pastry and canning. In addition, it has a desired feature in jelly making thanks to the pectin it contains.

Commercial blackberry production throughout Turkey is concentrated especially in the Marmara Region, Bursa; and in the Mediterranean Region, especially around Silifke and Kahramanmaraş. Limited amounts of production are also made in the Black Sea Region. Since blackberry production grows naturally in our country, although it is not possible to obtain precise statistical data, it is thought that the production is estimated to be between 3-5 tons (Urfalı & Yılmaz, 2024).

Blackberry, which has a productive lifespan of 15-20 years, does not demand specific climate conditions and thrives in a variety of environments. It flourishes with plenty of sunlight, shelter from strong winds, adequate rainfall during harvest, moist soil, and regions with mild winters (Barut, 2004). Blackberry is a plant species that has a prominent position in ecological agriculture because it has fibrous roots and has the ability to spread over large areas. The root system generally spreads on the surface and has a structure that does not go deeper. However, this plant species has features such as strong root development and resistance to low temperatures. Blackberry also plays an effective role in erosion control; this feature is considered an important advantage in ecological agriculture practices and this feature is also known by the masses. The ability of this plant to prevent erosion contributes to the preservation of soil structure and is a preferred feature in sustainable agriculture practices. The different growth forms of blackberry are also noteworthy.

The plant is observed in three different growth forms: upright, semi-upright and creeping. These different growth forms reflect the plant's adaptation abilities and its adaptation to various ecological conditions, allowing for diversity in agricultural practices (Ağaoğlu, 1986).

Blackberry, packed with carotenoids, flavonoids, organic acids, natural sugars, essential minerals like iron, magnesium, calcium, phosphorus, and as well as vitamin C and powerful antioxidants, plays a vital role in supporting and maintaining human health (Sarkar *et al*., 2016; Lee, 2017; De Gomes *et al*., 2019). Nutritionists and health experts often encourage the intake of blackberries due to their numerous contributions to a well-rounded, nutritious diet (Kolbas *et al*., 2012). These berries, which help regulate blood sugar levels, also contain beneficial fatty acids, including omega-3 and omega-6. Furthermore, blackberries offer a range of advantages, such as aiding nervous system recovery, guarding against depression, and boosting memory, making them a top choice among fruits for these benefits (Özdal *et al*., 2016; Selma *et al*., 2017).

The primary objective of this study is to cultivate several blackberry cultivars, specifically Chester, Jumbo, Bursa 1, and Bursa 2, under the ecological conditions of Eskişehir, Türkiye, and to comprehensively evaluate the fruit quality characteristics of these cultivars. Although the current level of blackberry production in the Eskişehir region is statistically low and not yet economically significant, exploring the adaptability and performance of different cultivars holds great potential. By identifying cultivars that can thrive in the local climate and soil conditions while offering high-quality fruit, this research aims to contribute to the diversification of fruit production in the region. In this context, the investigation is considered crucial for expanding regional horticulture and promoting alternative fruit crops that could support both local agriculture and the broader market.

Material and Methods

Plant material: The experiment was conducted in the application and research field of the Faculty of Agriculture of Eskişehir Osmangazi University. Two important cultivars used in Turkiye, Chester Thornless and Jumbo, as well as Bursa-1 and Bursa-2 genotypes were used as plant material. The plants were 4 years old. Fertilization and irrigation were done regularly.

Trial design: The experiment was established with 5 replications and 40 plants in each replication.

Establishment and conduct of the experiment: The experiment was conducted between 2022-2024. For this purpose, blackberries were planted in the experimental field in 2022 with 3 replications and 40 plants in each replication, with 0.7cm × 3m row spacing and above. A drip irrigation system was installed in our experiment along with planting. Routine applications such as fertilization, pruning and weed cleaning were applied to the plants during the growing period.

Preparation of samples for analysis: After the fruit samples were harvested, they were brought to Eskişehir Osmangazi University, Faculty of Agriculture, Department of Horticulture, Pomology Laboratory and their physical and chemical measurements were made.

Characteristics Examined in the Research

Pomological characteristics: For the years 2023 and 2024, the fruit weight (g), fruit width (mm) and fruit length (mm) characteristics of the blackberry cultivars and genotypes used in the research were examined.

Fruit colour L*, a* and b*: Color assessment of blackberries was conducted using a 3NH NR20XE Precision Colorimeter (Shenzhen Threenh Technology Co., Ltd.), with five berries analyzed per replicate. For strawberries, surface coloration was characterized based on the L* (light to dark), a* (green to red), and b* (blue to yellow) color space parameters.

Determination of chemical properties: In order to determine the chemical properties of the samples belonging to the cultivars used in the research; SSC, pH and titratable acidity properties were examined. All chemical analyses were carried out in each harvest period (harvested every 15 days after the first harvest until the end of the season) 3 samples were taken for each variety and separate measurements were made.

Soluble solids contents (SSC) (°Brix): The SSC value in the fruit was read by dropping the sufficient amount of fruit juice obtained by filtering through cheesecloth onto the prism of the Graigar-D series digital refractometer (Cemeroğlu, 2007).

pH: The pH of the fruit juice was measured with a Hanna brand hand pH meter.

Titratable acidity amount (NaOH %): The fruit juice was extracted by pressing the fruits, resulting in a uniform mixture. A volume of 10 ml of this juice was combined with 20 ml of distilled water at room temperature in a beaker. A digital handheld pH meter electrode was then placed into the solution, and 0.1 N NaOH was gradually added until the pH value reached 8.1, indicating the acid-base equivalence point for fruit juice. Using the values obtained, total acidity was calculated as a percentage, expressed in terms of citric acid, by applying the formula provided below (Karaçalı, 2002).

% Acidity: Amount of NaOH consumed × 0.1 × 0.061 / 10 (10 ml fruit juice)) × 10

(Normality of Base: 0.1 Milliequivalent Value of Citric Acid: 0.061)

Determination of vitamin-C (Ascorbic acid): The spectrophotometric method was used to determine the amount of vitamin C. The reduction of 2.6-

Dichlorophenolinedephenol (2.6-D) dye by ascorbic acid was utilized. For this purpose, standard curves were obtained with solutions prepared with oxalic acid, ascorbic acid and 2.6-D dye. 10 ml of fruit juice was squeezed and diluted 10 times with oxalic acid, 1 ml was drawn into 2 tubes, one was mixed with 9 ml of pure water and the other with 9 ml of 2.6 D dye. The solutions obtained were read at 518 nm wavelength in a spectrophotometer. The absorbance (Abs) readings were applied to the standard calibration curve to determine the corresponding concentrations of ascorbic acid. As the fruit juice samples had been diluted tenfold, the calculated values were multiplied by 10 and expressed as milligrams per 100 milliliters (mg/100 ml) (Hışıl, 1993).

Total phenolic content determination: Total phenol content was determined using Folin-Ciocalteu's chemical as described by Singleton & Rossi (1965). Fruit extract, Folin-Ciocalteu's chemical and pure water were mixed at a ratio of 1:1:18 and waited for 8 minutes. Then, 7% sodium carbonate was added. After two hours of incubation in the dark, the absorbance of the solution that acquired a bluish color was measured in a spectrophotometer at a wavelength of 750 nm. The results were calculated in terms of gallic acid as µg gallic acid equivalent/g fresh weight (µg GAE/g FW).

Determination of free radical scavenging (DPPH) activity: The determination of 2,2-diphenyl-1-picryl-hydrazyl (DPPH) free radical scavenging activity of phenolic substances with hydrogen bonding ability in blackberry fruits was made according to Dorman *et al*., (2003). 50 µL of phenolic extracts obtained from blackberry juices were pipetted into tubes and 450 µL of Tris-HCl buffer (50 mM, pH 7.4) was added. Finally, 1.00 mL of DPPH (0.10 mM, in methanol) solution was added to the mixture and kept in the dark for 30 minutes. At the end of the reaction period at room temperature, the absorbance of the solution was read at 517 nm on a spectrophotometer (T70+UV/VIS spectrophotometer, PG Instruments, England). DPPH (2,2-diphenyl-1-picryl-hydrazyl) free radical scavenging activity was calculated using the formula below and the results were given as % inhibition.

$$\% \text{ Inhibition (DPPH)} = \frac{(\text{AbsControl-AbsSample})/}{\text{AbsControl}} \times 100$$

Statistical analysis

Blackberry fruit data, including metrics like weight, dimensions, color, soluble solids content, pH, titratable acidity, and biochemical traits such as vitamin C, total phenolics, and antioxidant levels, were initially organized in Microsoft Excel. Descriptive statistics including averages and standard deviations were calculated, and visualizations were produced. To determine significant differences among the cultivars, ANOVA followed by Tukey's test was applied at a 5% confidence level using the SPSS 22 software. Subsequently, correlations among the quality attributes were assessed with the 'corrplot' package in R. Moreover, hierarchical clustering was carried out using the FactoMineR package, and principal component analysis (PCA) accompanied by biplot visualizations was conducted with the factoextra package.

Result and Discussions

The values of fruit pomological traits of the cultivars are given in Fig. 1. Pomological characteristics were statistically significantly different among the cultivars ($p<0.05$). Fruit weight (Fig. 1a) was determined as the highest in Jumbo (7.84 g). The lowest fruit weight was found in Bursa 2 (5.86 g). Fruit width (Fig. 1b) was determined as the highest in Jumbo (23.06 mm) and Chester (22.87 mm) cultivars. Bursa 1 and Bursa 2 cultivars had the lowest. The values of the color parameters are presented in Fig. 1 (d, e and f). Color values were statistically significantly different among the cultivars ($p < 0.05$). The L value (Fig. 1d) was found to be the highest in the Chester variety (18.41), the lowest in the Jumbo variety (14.27). The a value (Fig. 1e) was found to be the highest in the Bursa 1 variety (3.25), the lowest in the Chester (2.19) variety. No statistically significant difference was observed in the b value (Fig. 1f) in all cultivars.

The blackberry fruit weight observed in this study is lower than the findings reported by Milivojević *et al*., (2010) in Serbia, where the average weight was 2.47 g. However, it is higher than the results from Yilmaz *et al*., (2009) in southern Turkey, where the average weight was 1.1 g, and also greater than the wild blackberry fruit weights reported by Ochmian *et al*., (2009) in Poland, which had an average weight of just 1.23 g. The initial impression consumers have when buying fruits is often based on their color. Consumers tend to prefer blackberries that are dark and glossy, as dull colors are commonly linked to a lack of freshness and over-ripeness (Tkacz *et al*., 2020; Tosun *et al*., 2008). Our findings revealed that blackberries harvested during the S1 and S2 stages had the highest L* values, which are associated with brighter fruit surfaces, making them more appealing to consumers. Therefore, harvesting blackberries earlier in the season can enhance their brightness. No significant differences were observed in the L*, a*, and b* values between different nitrogen treatments, suggesting that the type of nitrogen used doesn't have a notable impact on fruit color. This is likely because fruit color results from a combination of factors, such as variety, soil conditions, humidity, temperature, cultivation practices, and harvest timing (Croge *et al*., 2019).

pH, SSC and NaOH values are given in Fig. 2. These parameters were statistically significantly different among the cultivars ($p<0.05$). The highest pH (Fig. 2a) was detected in Chester variety (4.75) and the lowest pH was detected in Bursa 1 (3.97). No statistically significant difference was found between the SSC values (Fig. 2b). The highest SSC value was detected in Bursa 2 (10.63 °Brix) variety, the lowest value was detected in Bursa 1 (8.67°Brix). NaOH values (Fig. 2c) were found to be highest in Bursa 1 (2.59 %) variety and the lowest value was found in Jumbo variety (0.62 %).

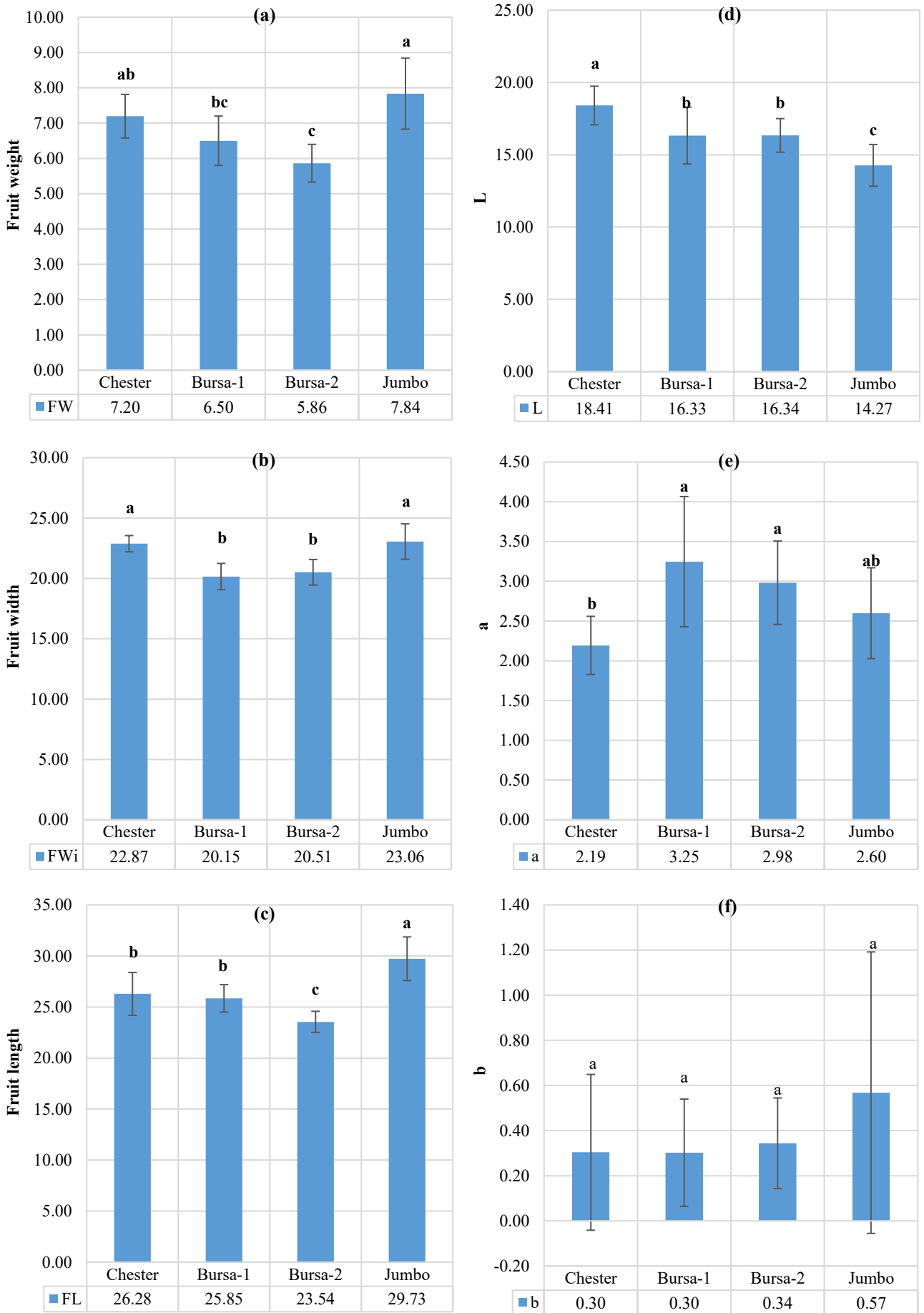
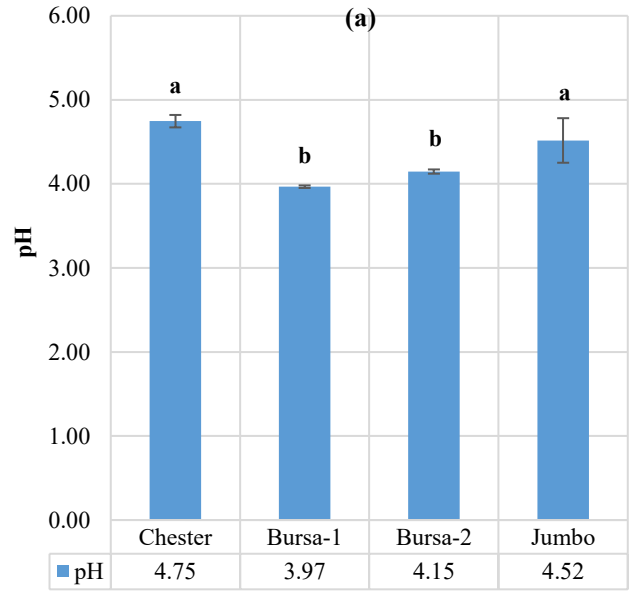
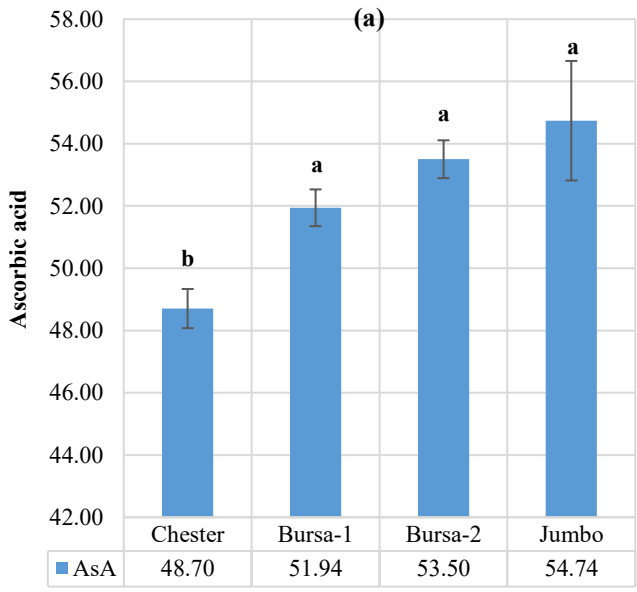
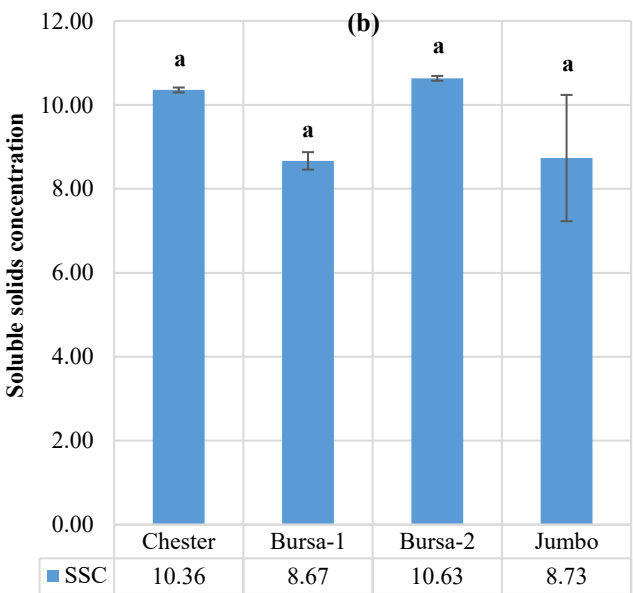
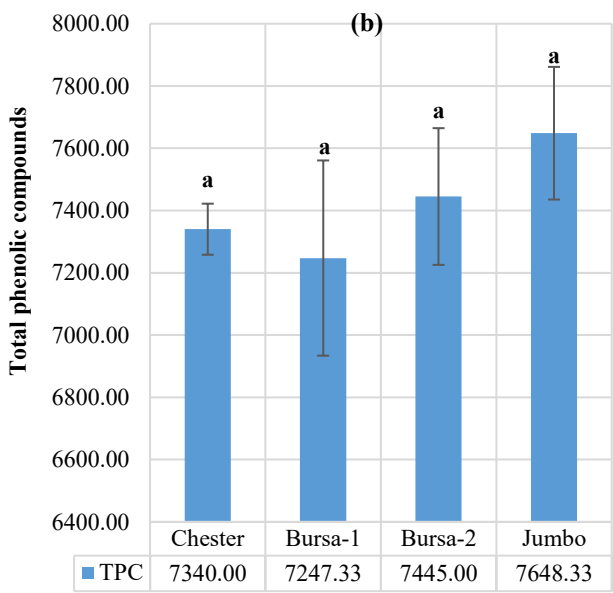


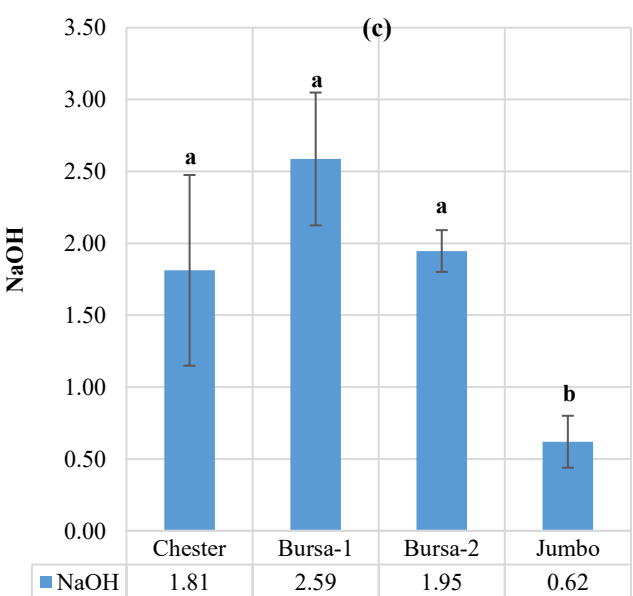
Fig. 1. Pomological characteristic values.











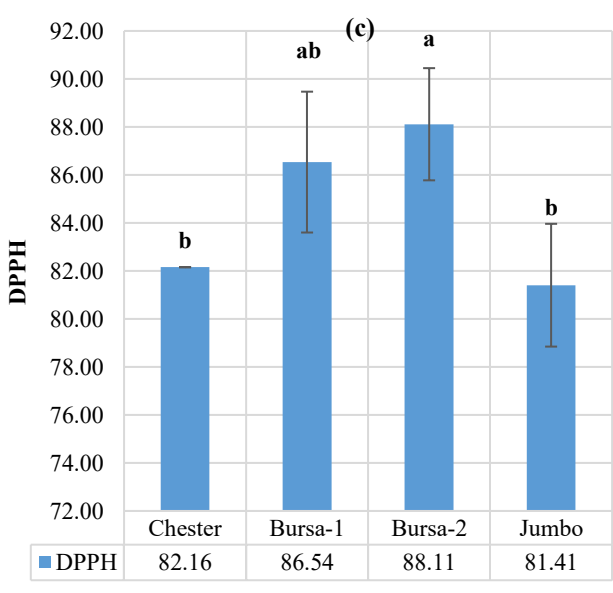


Fig. 2. pH, SSC and NaOH (TA) values.

Fig. 3. Ascorbic acid (AsA), total phenolic compounds (TPC) and DPPH values.

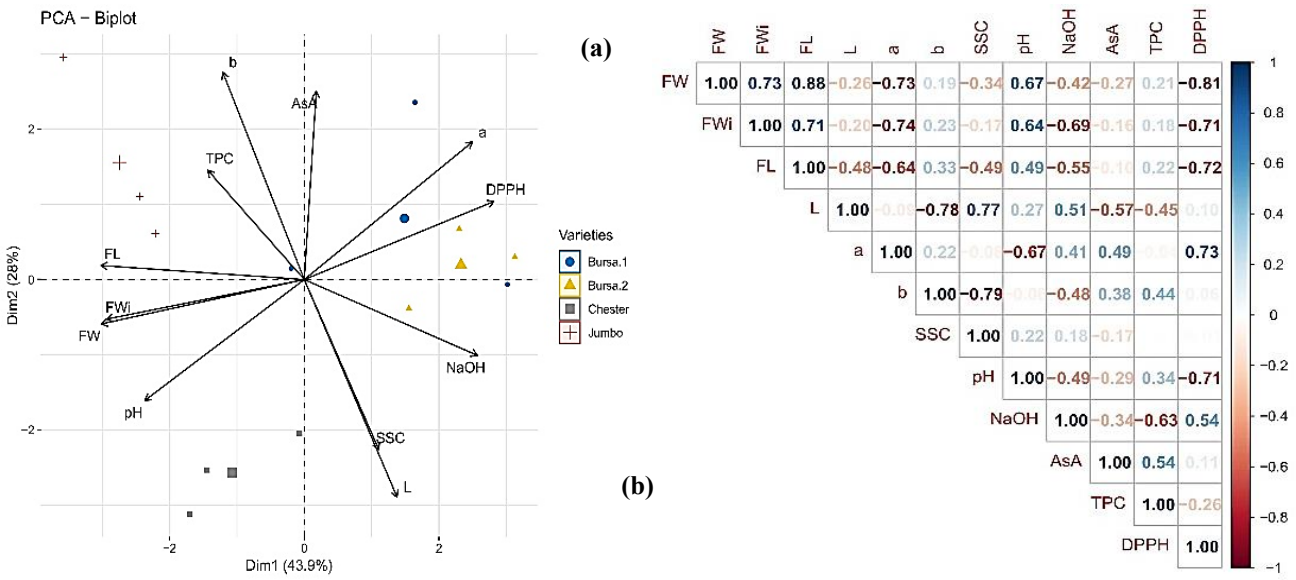


Fig. 4. PCA and correlation analysis of cultivars.

The fruit weight, SSC, pH, and acidity of blackberry cultivars cultivated in various regions of Turkey have been previously documented to range from 2.0 to 6.6 g, 8.98 to 20.2°Brix , 3.3 to 3.6, and 1.0 to 3.1%, respectively (Agaoglu *et al*., 2007; Cangi & Islam, 2003; Gercekcioglu *et al*., 2003). For wild-growing blackberries in Turkey, the corresponding values for fruit weight, SSC, pH, and acidity were reported between 1.5 and 2.1 g, 11.3 and 13.1 °Brix, 3.33 and 3.35, and 0.7 and 1.0%, respectively (Celik *et al*., 2003). The results we obtained for fruit weight, SSC, pH, and acidity were generally consistent with these earlier findings. Variations in fruit weight, SSC, pH, and acidity across blackberry fruits can be attributed to factors such as cultivar differences, environmental conditions, and the nutritional status of the growing sites.

Ascorbic acid (AsA), Totale Phenolic Compounds (TPC) and DPPH values are given in Fig. 3. AsA, TPC and DPPH values were statistically different among the cultivars ($p<0.05$). The highest AsA (Fig. 3a) value was found in Jumbo (54.74 mg/100 ml) variety. The lowest value was found in Chester (48.70 mg/100 ml). The highest TPC value (Fig. 3b) was determined in Jumbo (7648.33 µg GAE/g FW) variety and the lowest value was determined in Bursa 1 (7247.33 µg GAE/g FW) variety. The highest DPPH (Fig. 3c) was measured in Bursa 2 (86.11%) variety and the lowest value was measured in Jumbo (81.41%) variety.

The phenol content values found in this study are notably lower than those reported for Turkish wild blackberry populations, which ranged from 61.0 to 145.5 µg GAE/g FW (Yilmaz *et al*., 2009), as well as the field populations of wild blackberries, where the value was 137.8 µg GAE/g FW (Ochmian *et al*., 2009). In the Navaho variety, Yilmaz *et al*., (2009) observed a higher phenol concentration than in our study, with a value of 73.07 µg GAE/g FW. In Montenegrin wild blackberry populations, Ćujić *et al*., (2011) reported a phenol content of 27.4 µg GAE/g FW, which was slightly lower than our findings. For Croatian wild blackberry populations of *Rubus fruticosus* L., Voća *et al*., (2008) recorded a phenol content of 37.06 µg GAE/g FW, which is quite similar to the results of this study. Overall, it can be concluded that wild blackberry genotypes typically contain higher levels of total phenols compared to commercial cultivars, making them a valuable source of natural antioxidants that could play an important role in promoting human health. Blackberry fruits are packed with phenolic compounds, particularly anthocyanins and ellagic acid, which possess strong antioxidant properties and contribute significantly to the fruit's high nutritional value. Additionally, sugars and organic acids are the primary water-soluble components in blackberries, playing a key role in their flavor profile. The composition and balance of these nutrients, including organic acids and sugars, are crucial factors in assessing the inherent quality of the fruit (Mikulic-Petkovsek *et al*., 2021). The significant differences observed in the outcomes of these studies could be attributed to factors such as soil fertility, climate conditions, the age of the trees, and the specific variety used.

Due to the strong interrelationships among the quality traits, principal component analysis (PCA) was performed based on the correlation matrix. The proportion of variance accounted for by each eigenvalue revealed that the first principal component alone represented 43.9% of the overall variation, while the second component contributed an additional 28%. Combined, these two components accounted for 71.9% of the total variability observed in the dataset (Fig. 4a). It was revealed that Bursa 1 and Bursa 2 blackberry cultivars were grouped in close proximity, but Jumbo and Chester cultivars were grouped in different locations. It was also observed that the Bursa 1 and Bursa 2 cultivars are superior in DPPH and colour a. On the other hand, the Chester variety was seen to be superior for pH, FWi and FW. Finally, the FL, TPC and colour b were higher at Jumbo variety. The other quality characteristics were not found to be indicator for any of the cultivars. The results of the correlation analysis

performed to examine the relationship between the quality parameters of blackberry fruits are presented in Fig. 4b. According to these results, the highest positive correlation was found among FW-FL (0.88), FW-FWi (0.73), L-SSC (0.77). In a similar pattern, strong positive associations were observed between fruit weight (FW) and pH, as well as between fruit width (FWi) and pH, and between the 'a' color parameter and DPPH activity. The most pronounced negative correlation, with a value of 0.81, was identified between FW and DPPH. Additionally, DPPH exhibited significant negative correlations with FWi, fruit length (FL), and pH.

Conclusions

In this study, pomological and phytochemical properties of blackberry fruits were investigated in Eskişehir conditions to investigate the fruit quality of different blackberry cultivars. The largest fruits were detected in Jumbo variety. No statistical difference was found in SSC ratio in 4 cultivars. AsA content was highest in Jumbo variety, but Jumbo, Bursa 1 and Bursa 2 cultivars were statistically the same. TPC did not have statistical difference in all cultivars. However, DPPH ratio was highest in Bursa 2 variety. According to PCA analysis; It was revealed that Bursa 1 and Bursa 2 blackberry cultivars were grouped in close proximity, but Jumbo and Chester cultivars were grouped in different locations. The results of the correlation analysis; the highest positive correlation was found among FW-FL (0.88), FW-FWi (0.73), L-SSC (0.77). The research results can be said that the investigated cultivars have similar chemical values, except for pomological features. However, the Jumbo variety stood out in terms of fruit size.

Acknowledgement

Scientific Research Projects Coordination Unit of Eskisehir Osmangazi University supported this study. Project no: FBA-2022-2217.

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(Received for publication 22 January 2025)