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Pomological and Biochemical Characterization of Eight Apricot (*Prunus armeniaca* L.) Cultivars Grown under Elbistan Ecological Conditions

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Abstract

This study aimed to evaluate the pomological and biochemical characteristics of eight apricot (*Prunus armeniaca* L.) cultivars grown under the ecological conditions of Elbistan, Türkiye. Significant differences ($P < 0.05$) were observed among cultivars for all investigated traits. Fruit weight varied markedly, ranging from 20.20 g to 46.62 g, while flesh thickness ranged between 7.25 mm and 11.75 mm, indicating substantial diversity in fruit size and structure. Peel color parameters (L*, a*, b*, hue, and chroma) also exhibited wide variation, reflecting genotype-dependent pigmentation differences. Total soluble solids (TSS) content ranged from 20.00% to 29.23%, with Soğanoğlu showing the highest value, whereas titratable acidity varied between 0.79% and 1.89%. Antioxidant capacity, total phenolic content, and total flavonoid content differed significantly among cultivars, with total phenolic content reaching up to 328.45 mg GAE/kg fresh weight. Multivariate analysis using Principal Component Analysis (PCA) effectively discriminated cultivars based on combined pomological and biochemical traits, revealing distinct varietal groupings. Overall, the results demonstrate considerable phenotypic and biochemical diversity among apricot cultivars under Elbistan ecological conditions and provide valuable information for cultivar selection, breeding programs, and the development of apricots with improved fruit quality and nutritional value.

Key words
Apricot, *Prunus armeniaca*, Biochemical compounds, PCA, Genotypes.

Introduction

Apricot (*Prunus armeniaca* L.) is one of the most economically and nutritionally important fruit species within the genus Prunus, cultivated widely across temperate regions of the world. Türkiye is recognized as one of the major centers of origin and genetic diversity for apricot, hosting numerous local cultivars and landraces adapted to diverse microclimates (Asma and Öztürk, 2005; Ercisli, 2009). The country also leads global apricot production, particularly in the Eastern Anatolia region, which supports both fresh-market and dried-apricot industries. This genetic richness provides an essential foundation for breeding programs targeting improved fruit quality, stress tolerance, and biochemical attributes.

Fruit quality in apricot is determined by a combination of pomological characteristics such as fruit weight, flesh thickness, firmness, peel color, soluble solids, and acidity, as well as biochemical properties including antioxidant activity, phenolic content, and flavonoid levels. These parameters strongly influence consumer acceptance, postharvest performance, industrial suitability, and nutritional value (Ruiz et al., 2005; Leccese et al., 2012). Numerous studies have highlighted wide variability among apricot cultivars for these traits, largely driven by genotype but also shaped by ecological conditions such as temperature, altitude, soil structure, and solar radiation (Dragovic-Uzelac et al., 2005).

Elbistan, located in the Eastern Mediterranean transition zone of Türkiye, presents a distinctive continental climate characterized by cold winters, hot summers, and significant diurnal temperature differences. These climatic characteristics are known to influence sugar accumulation, color development, and phenolic metabolism in stone fruits. Despite the presence of locally adapted apricot types and the region's expanding fruit production potential, comprehensive studies examining the pomological and biochemical performance of cultivars under Elbistan ecological conditions remain limited.

Understanding varietal performance in this region is essential for identifying cultivars with superior fresh-market qualities, industrial suitability, and enriched phytochemical composition. Moreover, such evaluations contribute to the conservation and utilization of Türkiye's apricot genetic resources. Therefore, this study aimed to investigate the pomological and biochemical characteristics of eight apricot varieties grown under Elbistan ecological conditions, and to assess their potential suitability for commercial production, processing, and nutritional use. The findings are expected to provide valuable insights for growers, breeders, and the apricot industry, while contributing to the scientific literature on genotype–environment interactions in apricot cultivation.

Materials and Methods

Plant material and study area

This study was conducted using eight apricot (*Prunus armeniaca* L.) cultivars grown under the ecological conditions of Elbistan, Kahramanmaraş, Türkiye. The evaluated cultivars were Acıkayısı, Akerik, Çataloğlu, Hacıhaliloğlu, Hacıkız, Hasanbey, Kabaaşı, and Soğanoğlu. All trees were mature, grafted on standard rootstocks, and cultivated under uniform orchard management practices. The region is characterized by a continental climate with cold winters, hot summers, and notable diurnal temperature differences, which are known to influence fruit quality parameters.

Fruit sampling

For each cultivar, fruit samples were collected at commercial maturity based on skin color development and soluble solid accumulation. A minimum of 60 fruits per cultivar were randomly harvested from all sides of the tree canopy to ensure representative sampling. Samples were immediately transported to the laboratory and analyzed on the same day to prevent biochemical degradation.

Pomological measurements

Fruit Dimensions and Weight

Fruit weight (g) was determined using a precision digital scale (±0.01 g). Fruit diameter, fruit length, and flesh thickness (mm) were measured using a digital calliper with a sensitivity of ±0.01 mm.

Fruit Firmness

Fruit firmness (kg/cm²) was measured using a hand-held penetrometer fitted with an 8-mm plunger tip. Two opposite sides of each fruit were peeled and measured, and mean values were recorded.

Stone Characteristics

Stone weight (g), stone diameter (mm), and stone length (mm) were measured after manually removing and cleaning the stones from fresh fruits. Measurements were performed using a digital calliper and digital scale.

Color Measurements

Peel color was evaluated using CR 400 Minolta Colorimeter, providing L* (lightness), a* (red–green axis), and b* (yellow–blue axis) values. Color intensity (chroma) and hue angle were calculated using standard formulas:

- Chroma (C) = $\sqrt{(a^2 + b^{*2})}$**
- Hue angle (°) = arctan(b/a)**

Three readings were taken per fruit from sun-exposed peel areas.

Chemical analyses

Total Soluble Solids (TSS)

TSS (%) was determined using a digital refractometer at 20°C. Fruit juice was extracted manually and filtered prior to measurement.

Titratable Acidity (TA) and pH

Titratable acidity (%) was measured by titrating fruit juice with 0.1 N NaOH using phenolphthalein as an indicator and expressed as % malic acid.

pH was measured using a calibrated digital pH meter.

Antioxidant Capacity

Antioxidant capacity (mM Trolox/ml) was determined using the Trolox Equivalent Antioxidant Capacity (TEAC) assay. Absorbance readings were taken with a UV–Vis spectrophotometer and compared with Trolox standards.

Total Phenolic Content

Total phenolics were quantified using the Folin–Ciocalteu method and expressed as mg gallic acid equivalents (GAE) per kg of fresh weight. Absorbance was measured at 765 nm.

Total Flavonoid Content

Flavonoid content was determined using the aluminum chloride colorimetric method and expressed as mg catechin equivalents (CE) per kg. Absorbance was recorded at 510 nm.

Statistical analysis

All data were analyzed using ANOVA (Analysis of Variance) to determine the significance of differences among cultivars. Mean comparisons were performed using Tukey's HSD test at $P < 0.05$. Correlation coefficients among traits were calculated using Pearson correlation analysis. Principal Component Analysis (PCA) and biplot graphs were generated to evaluate multivariate relationships and cultivar clustering using OriginLab (OriginPro 2024).

Results and Discussion

Fruit Morphology

Apricot varieties exhibited significant variation in fruit weight, diameter, length, and flesh thickness under Elbistan ecological conditions. Larger-fruited cultivars such as Hasanbey (46,62 g), Kabaaşı (45,01 g), and Acıkayısı (39,01 g) consistently produced superior fruit mass and flesh thickness, whereas Akerik (20,20 g) and Hacıkız (20,60 g) represented the lower end of the size spectrum. Such variability is frequently attributed to the combined effects of genotype and environmental factors, particularly temperature regime and soil fertility (Table 1).

Table 1. Fruit weight, fruit diameter, fruit length and flesh thickness values of apricot varieties examined in the experiment

Varieties	Fruit weight (g)	Fruit diameter (mm)	Fruit length (mm)	Flesh thickness (mm)
Acıkayısı	39,01±1,64a	41,21±0,66a	44,16±0,52b	**10,63±0,34a**
Akerik	20,20±0,39c	33,07±0,46c	38,74±0,31c	**7,38±0,72b**
Çataloğlu	27,19±1,65bc	36,02±0,80b	33,72±0,37d	**8,79±0,71b**
Hacıhaliloğlu	22,19±0,69bc	33,45±0,24c	35,19±0,30d	**7,25±0,05b**
Hacıkız	20,60±1,12c	32,65±0,93c	30,78±0,46e	**7,69±0,63b**
Hasanbey	46,62±4,20a	41,90±1,13a	48,93±1,43a	**10,67±0,35a**
Kabaaşı	45,01±3,54a	42,31±0,76a	44,75±0,41b	**11,75±1,40a**
Soğanoğlu	29,57±5,51b	36,52±0,41b	38,49±0,58c	**8,77±0,52b**
$P_{0.05}$	**P<0,0001**	**P<0,0001**	**P<0,0001**	**P<0,0001**

Similar findings were reported by Asma and Öztürk (2005), who observed strong genotype-dependent variability in Turkish apricot germplasm. The larger fruit size of Kabaaşı and Hasanbey also aligns with earlier observations by Asma et al. (1999), who categorized these cultivars among the high-yield commercial types.

Fruit Peel Color

Color parameters (L*, a*, b*, hue, chroma) differed markedly among the varieties. Akerik exhibited the highest lightness (L*), while Soğanoğlu showed intense red coloration (a*) and high chroma, suggesting visually appealing pigmentation. Peel coloration is largely governed by carotenoid and anthocyanin accumulation, which are influenced by genetic structure and climatic factors such as sunlight intensity (Table 2).

Table 2. Fruit peel color values of apricot varieties examined in the experiment

Varieties	Skin L* value	Skin a* value	Skin b* value	Skin hue value	Skin chroma value
Acıkayısı	58,58±4,70de	10,21±1,83abc	37,40±3,14bcd	74,85±1,34cd	**38,78±3,51bc**
Akerik	75,71±1,42a	0,95±1,10d	45,01±2,56ab	88,87±1,3a3	**45,03±2,58ab**
Çataloğlu	60,48±0,88cde	3,80±0,86cd	34,43±1,20cd	83,71±1,62abc	**34,65±1,10bc**
Hacıhaliloğlu	70,20±0,99ab	2,94±2,88cd	42,66±3,03abc	86,08±3,94ab	**42,83±2,98bc**
Hacıkız	59,39±2,19cde	9,69±4,66abc	36,61±2,04bcd	75,32±6,81cd	**38,05±2,27bc**
Hasanbey	66,05±0,55bcd	12,36±0,19ab	42,99±0,99abc	73,99±0,57cd	**44,74±0,90ab**
Kabaaşı	53,47±7,35e	7,99±6,26bcd	32,02±6,45d	76,72±8,10bcd	**33,25±7,49c**
Soğanoğlu	68,79±0,79abc	17,05±0,59a	50,53±0,83a	71,39±0,89d	**53,33±0,60a**
$P_{0.05}$	**P<0,0001**	**P<0,0001**	**P=0,0001**	**P=0,0003**	**P=0,0002**

These results parallel the work of Ruiz and Egea (2008), who reported significant genotype-driven differences in apricot peel color, who emphasized the role of altitude and radiation exposure in enhancing redness (a*) in apricots. The strong coloration of Soğanoğlu may therefore be partly attributed to Elbistan's high solar radiation and large diurnal temperature fluctuations.

Fruit Firmness and Stone Characteristics

Fruit firmness ranged widely among cultivars, with Hacıhaliloğlu (8,14 kg/cm^2) exhibiting the highest firmness and Hasanbey (4,17 kg/cm^2) the lowest. Firmness is a key determinant of postharvest behavior, and firmer cultivars such as Hacıhaliloğlu may tolerate long-distance transport and extended storage. Similar behavior was recorded by Güleryüz et al. (1999), who noted that firmness varies significantly among Turkish apricot cultivars and is a critical trait for marketability (Table 3).

Stone characteristics also varied substantially. Acıkayısı (2,96 g) and Kabaaşı (2,80 g) had heavier stones, whereas Hacıkız (1,60 g) had the smallest. Variability in stone size is often associated with the fruit-to-stone ratio, an important quality parameter. Studies by Asma et al. (2007) similarly documented strong genetic effects on stone morphology, supporting the current findings.

Table 3. Fruit firmness, stone weight, stone diameter and stone length values of the apricot varieties examined in the experiment

Varieties	Fruit firmness (kg/cm^2)	Stone weight (g)	Stone diameter (mm)	Stone length (mm)
Acıkayısı	4,68±0,80cd	2,96±0,18a	21,13±0,21a	**30,83±0,56b**
Akerik	5,93±0,81bcd	1,80±0,02b	17,90±0,34bc	**24,89±0,37c**
Çataloğlu	5,71±0,81cd	1,84±0,10b	16,97±0,17bcd	**21,57±0,23d**
Hacıhaliloğlu	8,14±0,78a	1,81±0,01b	16,35±0,11cd	**25,51±0,19c**
Hacıkız	5,19±0,42cd	1,60±0,05b	16,43±0,21cd	**20,64±0,20d**
Hasanbey	4,17±0,22d	2,81±0,25a	18,64±1,85b	**34,14±1,10a**
Kabaaşı	7,82±0,50ab	2,80±0,14a	18,86±0,27b	**29,74±0,38b**
Soğanoğlu	6,11±0,45bc	1,61±0,06b	15,77±0,18d	**24,98±0,25c**
$P_{0.05}$	**P<0,0001**	**P<0,0001**	**P<0,0001**	**P<0,0001**

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TSS, Titratable Acidity, and pH

Among biochemical traits, TSS exhibited remarkable variation, with Soğanoğlu presenting exceptionally high levels (29.23%), indicating superior sweetness and potential suitability for drying. High TSS is commonly favored in drying apricots because it enhances flavor and reduces drying time. Previous studies, including Asma and Öztürk (2005) and Ercisli (2009), reported similar TSS ranges and emphasized genotype as the major determinant (Table 4).

Table 4. TSS, titratable acidity and pH values of apricot genotypes examined in the experiment

Varieties	TSS (%)	Titratable acidity (%)	pH
Acıkayısı	20,00±1,00b	1,41±0,12b	**4,29±0,05d**
Akerik	22,00±1,20b	1,89±0,07a	**4,35±0,06d**
Çataloğlu	21,20±1,00b	0,96±0,04d	**4,86±0,05c**
Hacıhaliloğlu	22,13±0,81b	1,53±0,03b	**5,16±0,04b**
Hacıkız	22,33±1,53b	0,84±0,01de	**4,85±0,05c**
Hasanbey	21,93±1,10b	0,86±0,02de	**5,45±0,05a**
Kabaaşı	20,93±1,10b	1,17±0,04c	**5,08±0,08b**
Soğanoğlu	29,23±0,75a	0,79±0,03e	**5,35±0,05a**
$P_{0.05}$	**P<0,0001**	**P<0,0001**	**P<0,0001**

Acidity values were highest in Akerik(1,89%), while pH was greatest in Hasanbey (0,86%) and Soğanoğlu (0,79%). The inverse relationship between acidity and pH observed here is consistent with organic acid behavior described by Ruiz et al. (2005). The combination of high TSS and moderate acidity in Soğanoğlu suggests a well-balanced flavor profile, making it attractive for both fresh consumption and industrial uses.

Antioxidant Capacity, Total Phenolics, and Flavonoids

Remarkable differences were observed across cultivars for antioxidant capacity, total phenolic content, and flavonoid levels. Hacıhaliloğlu, Çataloğlu, and Soğanoğlu exhibited particularly high phenolic content, while Acıkayısı had the highest antioxidant capacity.

These findings are consistent with published reports demonstrating that apricots possess variable but generally high phenolic concentrations. Dragovic-Uzelac et al. (2005) and Ruiz et al. (2005) found that phenolic profiles are strongly genotype-dependent and influenced by environmental stress. Additionally, Gündoğdu et al. (2017) confirmed that apricots from high-altitude or continental climates often accumulate more phenolics due to oxidative stress, supporting the strong biochemical values observed under Elbistan conditions (Table 5).

Table 5. Antioxidative capacity, total phenolic substance and total flavonoid content values of apricot varieties examined in the experiment

Variety	Antioxidant capacity (mMtroloks/ml)	Total phenolic content (mg GAE/kg)	Total flavonoid content (mg Catechin/kg)
Acıkayısı	3,37±0,01a	237,63±0,85de	**85,55±3,29abc**
Akerik	2,96±0,07ab	199,92±4,40f	**86,96±2,60abc**
Çataloğlu	2,60±0,10bc	285,93±7,00b	**94,79±3,00a**
Hacıhaliloğlu	3,08±0,26ab	328,45±10,82a	**83,20±7,53bc**
Hacıkız	3,32±0,10a	268,77±21,40bc	**85,55±1,41abc**
Hasanbey	1,59±0,03d	210,37±13,17ef	**53,41±1,13d**
Kabaaşı	2,10±0,47cd	250,34±2,97cd	**81,47±3,61c**
Soğanoğlu	3,06±0,16ab	289,32±2,12b	**92,76±2,04ab**
$P_{0.05}$	**P<0,0001**	**P<0,0001**	**P<0,0001**

The high flavonoid content in Çataloğlu and Soğanoğlu also aligns with results presented by Leccese et al. (2012), who reported that cultivars with intense peel pigmentation often exhibit high flavonoid concentrations.

Correlation and Biplot Interpretation

Correlation analysis revealed positive associations among fruit size parameters, consistent with the expected biological relationship where larger fruit weight corresponds to increased diameter, length, and flesh thickness (Figure 1). Similar correlations have been documented in works by Asma et al. (2007) and Güleryüz et al. (1999).

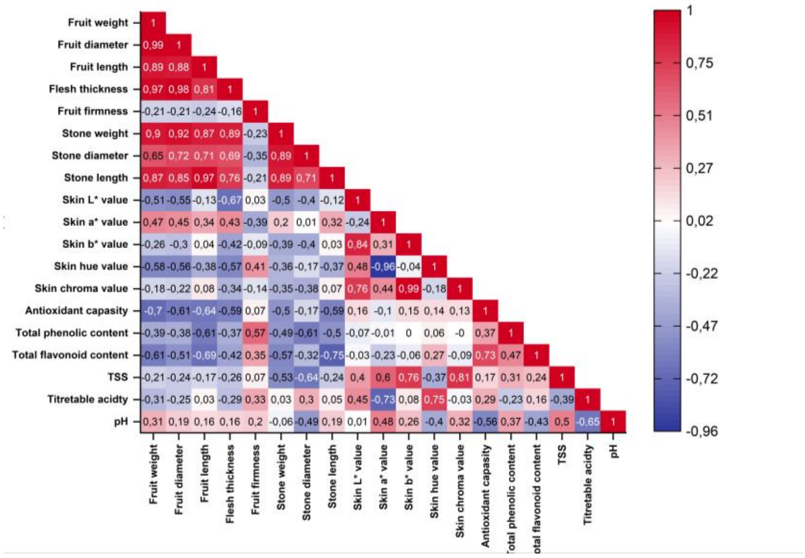

Figure 1. Correlation values between fruit characteristics of apricot varieties

Biplot analysis showed clear clustering of the eight apricot varieties based on both pomological and biochemical variables (Figure 2). Varieties such as Soğanoğlu (high TSS and flavonoids) and Hasanbey (large fruit size) formed distinct clusters, indicating specialized trait profiles. Principal component–based varietal separation has been widely reported in apricot studies, including the work of Asma and Öztürk (2005) and Bacchichet et al. (2022), confirming its reliability for cultivar classification and breeding decisions.

Conclusion

This study clearly demonstrates substantial pomological and biochemical diversity among apricot varieties cultivated under Elbistan ecological conditions. Key findings include major differences in fruit size, peel color, firmness, TSS, acidity, phenolic composition, and antioxidant activity. Varieties such as Kabaaşı and Hasanbey stand out for fruit size characteristics, whereas Soğanoğlu is notable for its exceptionally high TSS. Hacıhaliloğlu and Çataloğlu exhibit superior phenolic content, suggesting enhanced nutritional value.

These results provide valuable information for breeders, growers, and the food industry, supporting the selection of varieties tailored to fresh consumption, processing, storage, or nutraceutical uses. The diversity observed highlights both the genetic richness of apricot germplasm and the potential for further improvement under the ecological conditions of Elbistan.

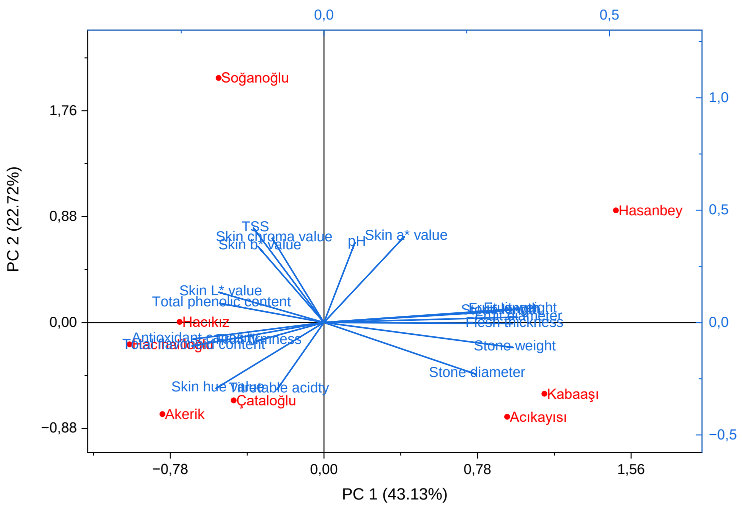

Figure 2. Biplot analysis of eight apricot varieties

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Author's Contributions

The authors contributed equally to this manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

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