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Pomological, biochemical and bioactive characteristics in fruits of quince cultivars grown in Türkiye

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ABSTRACT

Quince fruits (*Cydonia oblonga*), known for their nutritional value, with intense aroma, flavour and tartness, are commonly used in jams, jellies, compotes, juices and alcoholic drinks. The study aimed to assess the quality of quince fruits through a pomological study and biochemical analysis. Skin and juice of eight commercially known cultivars (from Pozanti, Türkiye) were analysed. The results revealed the pomological and biochemical variations among the studied cultivars. Among cultivars, 'Ekmek' had the highest fruit weight, while 'Tekec' exhibited significantly lower fruit weight. In terms of biochemical analysis, pH was in the range from 3.56 ('Altinayva') to 3.04 ('Osmancik'), while lower pH indicates a tart flavour of fruits. Acidity peaked in 'Ekmek' and 'Kalecik' cultivars, whilst soluble solids content (SSC) value was highest in 'Acem' cultivar (20.20%), suggesting sweeter fruit taste. 'Kalecik' cultivar showed highest ascorbic acid content (21.41 mg · 100 g^{-1} fresh fruit). As for antioxidant parameters, antioxidant capacity (AC) was highest in 'Acem' cultivar, followed by 'Ekmek' and 'Kalecik', and 'Altinayva' showed the lowest value of AC. Similarly, the highest total phenolic content was determined for 'Acem' cultivar, and thus this indicator also confirmed the excellent properties and potential of this cultivar. These findings underscore the importance of genetic selection of quince fruits for optimising traits such as fruit size and weight, sweetness, acidity and antioxidant properties to meet the quality, consumer preferences and market demands.

Keywords: antioxidant potential, *Cydonia oblonga*, physiochemical properties, pomological parameters, quality

INTRODUCTION

Quince (*Cydonia oblonga*) fruits are popular for their unique, pleasant aroma and golden yellow colour, commonly used in jams, jellies, compotes, juices and alcoholic drinks. The fruit grows in temperate climates, such as in Türkiye, with an abundance of local and introduced cultivars, with many wild edible fruits. This situation, therefore, highlights the importance of studying the characteristics of fruits from different genetic sources (Ercisli et al., 2008; Ozturk et al., 2022; Göksel, 2024; Ňorbová et al., 2024).

Quince fruit is an apple and pear-shaped, with hair-covered peel and mucilage-coated seeds and acidic taste (Khoubnasabjafari and Jouyban, 2011; Blanda et al., 2020). The peel is covered with many hairs, which disappear upon ripening. Harvesting time is during October and November, similar to winter

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pear; however, there is no fruit maturity index. The harvesting begins when fruit changes colour from deep green to light green. Because of its astringent taste, fruit can be consumed after processing and presents numerous commercial processing opportunities (jam, jellies, juices, etc.). Quince seeds have a hydrocolloid structure and are used as an excellent thickening source in cane industry (Abdollahi, 2019; Rezagholi et al., 2019).

The origin of the quince is in the north and west of Iran, the North Caucasus, the Caspian Sea and Northern Anatolia, and it has been known since ancient times. Its culture passed from Anatolia to Greece and Rome in the years before Christ. Later, it was spread to Central and Eastern Europe. Quince is nowadays grown nearly everywhere, except Australia. Mediterranean countries and North African countries are at the forefront of world quince production. Also, Türkiye is among the major producers of quince, contributing nearly 200000 tons out of the global production of 690000 tons. Approximately 73% of Türkiye's quince cultivation is concentrated in six provinces, namely Sakarya (55% of total production), Bursa (8%), Denizli (4%), Çanakkale (4%), Bilecik (4%) and Isparta (3%) (Ozturk et al., 2022; TUIK, 2022; FAO, 2023; İlhan, 2023).

As recommended by the World Health Organization (WHO), the consumption of adequate levels of fruits represents one of the fundamental elements of a healthy diet. Due to the presence of the macro- and micronutrients and bioactive components in fruits, consuming fruits at adequate levels reduces the risk of several chronic diseases, such as cancer, cardiovascular diseases, hypertension, digestive system diseases, strengthens the immune system and delays aging (Devirgiliis et al., 2024). Quince, one of the great fruits of cold winter months, is beneficial in preventing some of these diseases. It contains vitamins B and C, and it is rich in copper, zinc, selenium, potassium, iron and phosphorus. Further, it contains fibre that is highly beneficial for the stomach, increases the secretion of gastric juices, which facilitates peristaltic movement and digestion, prevents conditions such as constipation and protects the body from more serious conditions such as colorectal cancer. Quince, which does not increase blood sugar quickly, provides a long-term feeling of satiety with its fibrous structure (Carvalho et al., 2010; Al-Snafi, 2016; Ashraf et al., 2016; Kostecka-Gugała, 2024; Berktas and Cam, 2025).

One hundred grams of quince contains approximately 40 calories. It restores the body's general balance with the vitamins and minerals and accelerates fat burning. The fruit contains high levels of polyphenols and phytochemicals. According to research results, it is suggested that these compounds may contribute to the fight against cardiovascular disease, asthma and diabetes. In addition, quince fruit peel contains a flavonoid quercetin that strengthens the heart by reducing inflammation in human blood vessels (Wojdyło et al., 2014; Al-Zughbi and Krayem, 2022; Dimitriu et al., 2023; Najman et al., 2023).

Nowadays, the interest in fruit species that are important for nutritional qualities and for human health has grown. Lesser-known fruits, including quince, are gaining increasing popularity among both food producers and consumers. Therefore, it is important to determine the characteristics of quince cultivars grown under the same conditions more objectively. It is also of great significance to study the genetic variation of quince cultivar traits. The genetic research of the quality traits of quince fruits primarily focuses on quince cultivar selection and comparative analysis of pomological, biochemical and molecular characteristics in cultivars.

Thus, this study aimed to investigate the pomological and biochemical qualities in fruits of eight quince cultivars grown together in Pozanti Agricultural Research and Application Center (Türkiye), at an elevation of 1050 m.

MATERIALS AND METHODS

Plant material

Eight cultivars of quince, namely 'Acem', 'Altinayva', 'Bardacık', 'Ekmek', 'Eşme', 'Kalecik', 'Osmancik' and 'Tekeç' (Figure 1) were grown on BA29 rootstock, harvested in October 2023 when fruit reached maturity, indicated by yellow peel colour. The harvesting took place in Pozanti Agricultural Research and Application Center, University of Cukurova, based on their commercial importance and genetic diversity. A total of 30 fruits per cultivar were randomly selected to ensure a range of variant characteristics and transported to the laboratory for subsequent analysis. All assays were conducted on 30 fruits per parameter (10 fruits per replicate) to ensure accuracy and reliability.

Pomological characteristics

Pomological traits, such as fruit weight, dimensions, fruit shape index (width/length), number of seeds per fruit and fruit firmness, were determined. Thirty fruits were sampled from each cultivar, and the mean values were calculated, with three replicates. Fruit weight was measured using digital balance. Length, height and width of the fruits were measured with Vernier Calliper (Mitutoyo series 532, Tokyo, Japan). Fruit shape was determined based on length/width. Fruit firmness was evaluated using penetrometer (Landtek FHT-1122, Guangzhou, China), with 8 mm probe and a measuring scale that read the force of penetration in N, from two opposite sides of each fruit.

Biochemical analyses

Soluble solids content

The soluble solids content (SSC) was determined using a digital refractometer (RX-5000α, Mettler Toledo,

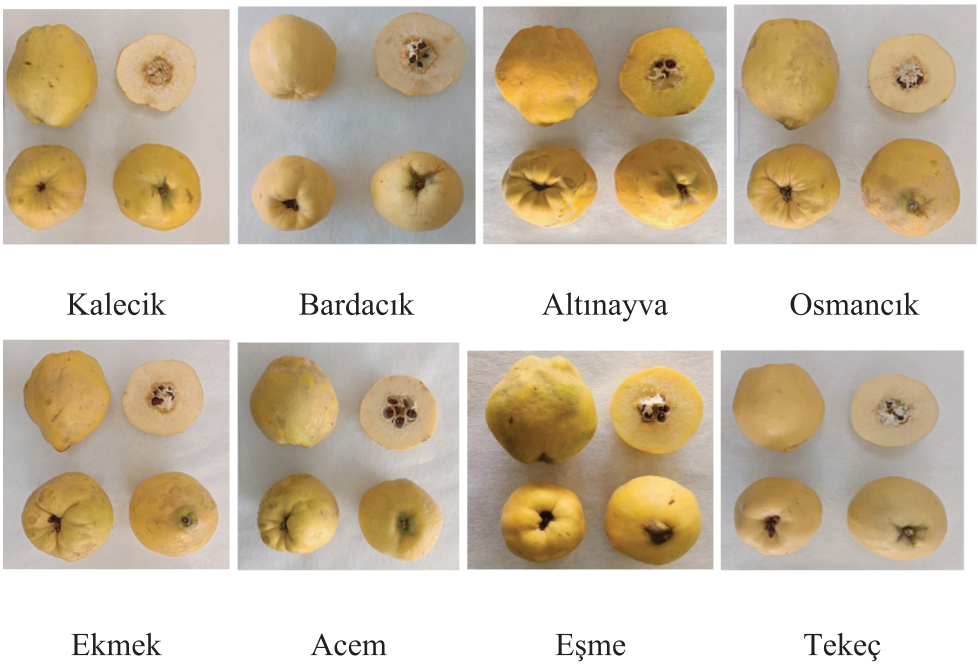

Figure 1. Quince cultivars used in this study.

Columbus, OH, USA). The fruit juice was extracted from a composite sample of 30 fruits per cultivar.

Titratable acidity

Titratable acidity (TA) was determined as described by İmrak et al. (2024). TA was calculated as a percentage of malic acid using the formula (1):

$$TA = a \times K \times V/V_1 \times O \times 100(\%) \quad (1)$$

a = volume of NaOH (mL)
V = stock solution volume (mL)
V_1 = titrate volume (mL)
O = sample (g)
K = acid factor

pH

After cutting quince fruits, seeds were manually extracted and counted, and the pH value was measured from the homogenising fruits.

Bioactive content

Sugars

Specific sugars, namely glucose, fructose and sucrose, in both the skin and juice of eight quince fruits cultivars were determined as described by Crisosto (1997). Quince skin and juice (1 mL) were mixed with 4 mL of ultrapure water, sonicated at 80°C for 15 min and centrifuged at 5500 rpm for 15 min. The supernatant was filtered (0.45 µm Whatman syringe) and analysed by HPLC (Shimadzu LC 20A VP, Kyoto, Japan), using a Corregel-87C (7.8 mm × 300 mm) column, and refractive index detector (RID), in triplicate. Sugars were identified by comparing retention times with standards. Quantification was based on a standard calibration curve. The results were expressed as amount per 100 g fresh weight (FW).

Organic acids and vitamin C

Organic acids and vitamin C in both fruits' skin and juice of eight quince cultivars were determined using HPLC, as described by Bozan et al. (1997). One millilitre of quince sample was mixed with 4 mL of 3% metaphosphoric acid solution, sonicated at 80°C, followed by centrifugation at 5500 rpm for 5 min. The supernatant was filtered (0.45 µm) and organic acids and vitamin C levels were measured in three replicates. The results were expressed as amount per 100 g FW.

Total phenolic content

Total phenol content in both fruits' skin and juice of eight quince cultivars was determined using Folin–Ciocalteu method. Results were calculated based on calibration curve and expressed as milligrams of gallic acid equivalents per 100 g of FW (Spanos and Wrolstad, 1990).

Total antioxidant capacity

Total antioxidant capacity (TAC) in both fruits' skin and juice of eight quince cultivars was determined using 2,2-diphenyl-1-picrylhydrazyl (DPPH) method as described by Brand-Williams et al. (1995) with slight modifications. Ten grams of sample was mixed with 50 mL of 80% (v/v) methanol and vortexed for 5 min. The mixture was centrifuged at 10000 rpm for 15 min at 4°C, and the supernatant was filtered through a 0.45 µm membrane filter. A total of 1950 µL of DPPH solution was added to 50 µL of freshly prepared sample and the mixture was vortexed. After 30 min of incubation at room temperature in the dark, the absorbance was recorded at 517 nm using a spectrophotometer.

A control solution (1 mL methanol + 3 mL DPPH) and a blank were used to ensure the validity of results. The percentage of DPPH radical inhibition was calculated with the formula (2):

$$Inhibition\ \% = \frac{\mathrm{A}\left(\mathrm{Control}\right) - \mathrm{A}\left(\mathrm{sample}\right)}{\mathrm{A}\left(\mathrm{Control}\right)} \times 100 \quad (2)$$

A (control)—absorbance of control at 517 nm
A (Sample)—absorbance of sample at 517 nm

Data analysis

The study investigated differences among eight quince fruit cultivars in terms of some pomological and biochemical and antioxidant measurements. Data were analysed with the SPSS package programme version 23.0 (SPSS Inc., Chicago, IL, USA). All data were analysed by one-way analysis of variance (ANOVA). Differences were considered significant at $p < 0.05$. Hierarchical Cluster Heatmap Analysis (HCA-Heatmap) (Double Dendrograms) (with Euclidean distance and Ward method) was performed using OriginPro 2024 (OriginLab Corporation, Northampton, MA, USA) to show similarities and differences between cultivars and measurements.

RESULTS AND DISCUSSION

Pomological characteristics

Pomological analysis in fruits of eight quince cultivars showed significant differences in fruit weight, width, length, fruit firmness and number of seeds per fruit (Figure 2). Among eight quince cultivars, 'Ekmek' had the highest fruit weight (494.41 g) and also the largest dimensions of a fruit with the width of 89.50 mm, 93.56 mm in fruit length and 116.99 mm in fruit height. The results were statistically significant at 5% level. The fruit weight of 'Osmancik' cultivar was also relatively high (474.20 g) while it showed a slightly lower fruit height (110.54 mm) (Figure 2). In contrast, cultivars 'Bardacık' and 'Altinayva' had relatively lower fruit weight (442.88 g and 406.94 g, respectively), and 'Tekeç' had the significantly lowest fruit weight (311.73 g) and the dimensions, specifically a fruit height (Figure 2).

Fruit shape index was found non-significant among cultivars and varied from 0.94 to 0.96, indicating that all cultivars had flattened fruit shape (Figure 2).

Fruit firmness, crucial for the fruit texture, was highest in 'Eşme' cultivar, 306.00 N, suggesting that this genotype is best suited for certain culinary uses or transportation, while 'Ekmek' and 'Osmancik' cultivars showed significantly lower firmness values, ranging from 160.33 N to 181.50 N, which may affect their suitability for fresh consumption demands, thus affecting their market potential.

The number of seeds per fruit varied among cultivars, and 'Altinayva' and 'Acem' cultivars had the highest number of seeds per fruit (45.00 and 44.00, respectively) while 'Eşme' cultivar had the lowest (16.66). 'Osmancik' had higher number of seeds (29.00) than 'Ekmek' cultivar (20.33). Abdollahi (2019) and İlhan (2023) support the idea that genetic and environmental factors influence important agronomic qualities, as indicated by the differences in fruit weight, size and firmness among quince genotypes.

Fruit size is one of the important factors affecting fruit quality and is also an important economic trait; it is of great concern for consumers. The comprehension and mastery of genetic variation in important traits lays the fundamental basis for fruit breeding and cultivar selection. In many quince-producing countries, fruit weight and fruit shape serve as pivotal characteristics employed by consumers for cultivar identification and selection. With the largest fruit weight and dimensions, 'Ekmek' stood out and may offer advantages in commercial production due to its superior genetic makeup (Abdollahi, 2019; Blanda et al., 2020; İlhan, 2023). Larger fruit sizes are frequently associated with increased marketability, in line with research by Rop et al. (2011). However, all environmental factors like climate, soil type and water availability play a role in this relationship (Cankurt and İpek, 2023; İlhan, 2023).

On the other hand, 'Altinayva' cultivar showed similar fruit width but shorter fruit length, probably because of certain patterns of resource distribution inside the fruit. Although smaller fruits might appeal to niche markets for culinary uses, the reduced size of the 'Tekeç' cultivar may reflect a genetic restriction. Previously, quince cultivars and genotypes show a great variation in terms of fruit weight and fruit firmness (Ercisli et al., 2009, 2015; Tok, 2020).

Fruits of quince cultivars were found to have a more rounded shape, indicating that they are apple-shaped. Pear-shaped quinces are more elongated in shape, with the outline of a pear. The differentiation is primarily the shape, and there is no remarkable difference in taste between the two types (İlhan, 2023). Previously, Ercisli et al. (2009) reported the shape index between 0.88 and 1.21, indicating that most of the quince genotypes had pyriformis fruit shape, which contrasts with our results.

pH, SSC and acidity

Table 1 shows pH, SSC and acidity values in fruit juices of eight quince cultivars. The pH of quince fruits ranged from 3.04 to 3.56, with 'Altinayva' cultivar exhibiting the highest pH and lowest acidity, while 'Osmancik' had the lowest pH, indicating higher acidity. Higher acidity was found in other four cultivars according to data in Table 1. Acidity is one of the important parameters used as a quality criterion. One of the most common and practical methods used to determine acidity in fruits is pH measurement. Certain pH values of each fruit species in horticultural plants impact the fruit flavour and preservation qualities (Dogan et al., 2014).

SSC values varied significantly among cultivars, with the highest values of 'Acem' and 'Altinayva' cultivars

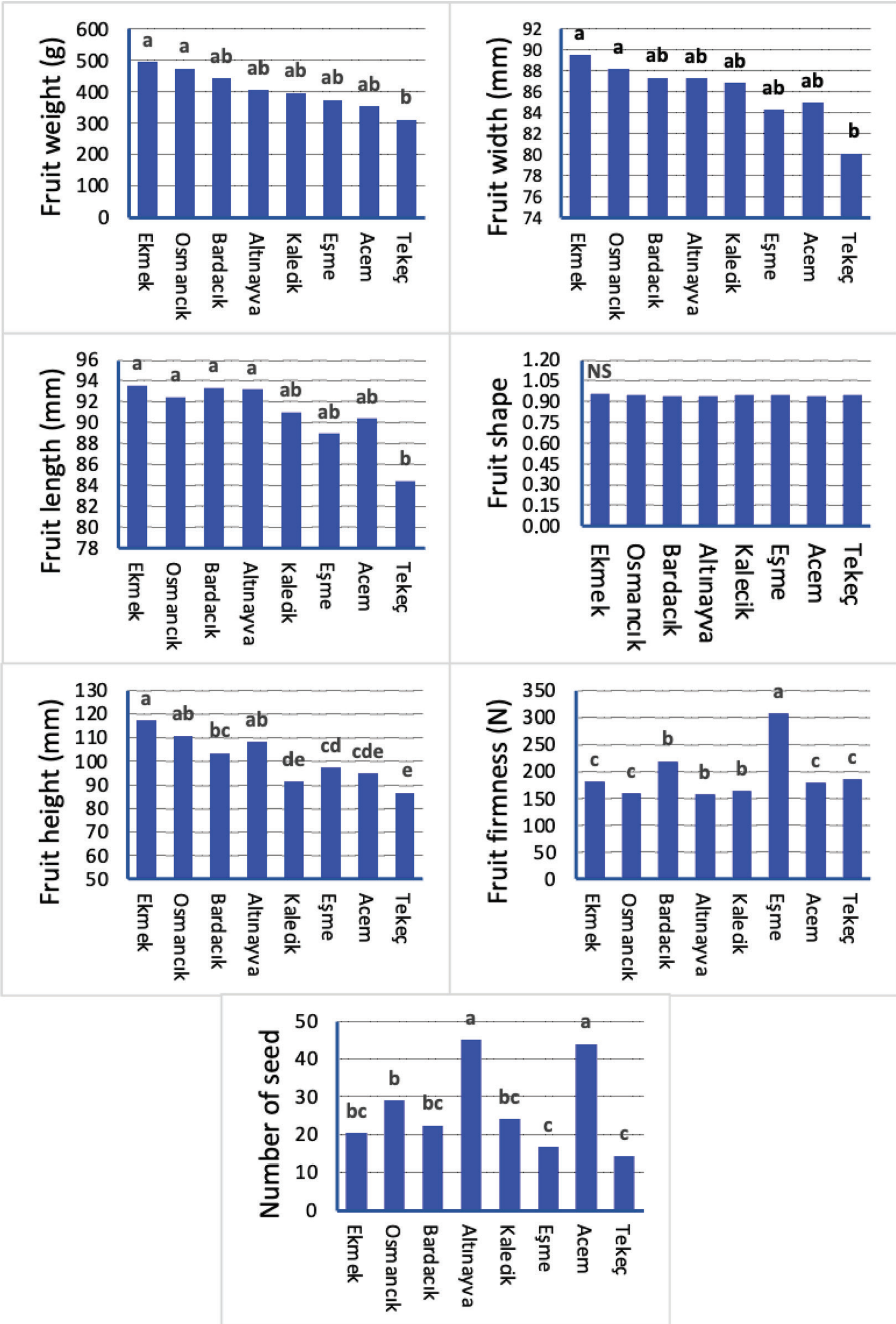

Figure 2. Pomological parameters of eight quince cultivars. Different letters indicate statistically significant differences at 0.05 level. NS, non-significant.

(20.20% and 19.06%, respectively) and a potentially sweeter taste of fruit. SSC value of 'Acem' cultivar indicates the sweetness, which is consistent with the research of Mir et al. (2016) and Rasheed et al. (2018). High SSC cultivars are more desirable for direct consumption and have great commercial potential when processed into sweets and jams. 'Osmancik' had the lowest value of SSC, 15.43% (Table 1). Lower SSC cultivars, on the other hand, are suitable for processing products in which more sugar is added. Tok (2020) reported cultivars with lower SSC, between 9.46% and 13.68%, for a great number of quince genotypes. Ercisli et al. (2009) determined SSC

Table 1. pH, SSC and acidity values in fruits of eight quince cultivars.

Cultivar	pH	SSC (%)	Acidity (%)
Ekmek	3.10 cd*	15.80 cde	0.52 a
Osmancık	3.04 d	15.43 de	0.46 a
Bardacık	3.29 bc	15.63 de	0.51 a
Altınayva	3.56 a	19.06 ab	0.23 b
Kalecik	3.33 b	17.92 bc	0.54 a
Eşme	3.23 bcd	16.26 cde	0.43 ab
Acem	3.27 bc	20.20 a	0.52 a
Tekeç	3.19 bcd	14.16 e	0.43 ab

*Different letters in same column indicate statistically significant differences at 0.05 level.
SSC, soluble solids content.

values between 11.80% and 16.00% for a number of local quince cultivars in Northeastern Anatolia. SSC, along with acidity, are important quality and harvest criteria for most of the fruit species that are used in particular for the harvest time determination.

For quince fruits, there was a notable variance in the amount of acids, with 'Kalecik', 'Acem' and 'Ekmek' cultivars exhibiting higher acidity levels. Because of their sourer flavour, these cultivars are perfect for processing and long-term storage because their increased acidity promotes preservation (Ercisli et al., 2009). On the other hand, 'Altinayva' with low acidity (0.23%) makes it more appealing for fresh drinking, with a more pleasant flavour. The current results confirm the findings of İlhan (2023), thereby providing further evidence of the influence of genotype and environmental factors on acidity.

Fruit with the highest percentage of acidity was 'Ekmek' and 'Kalecik', at 0.54%. This shows that the flavour of these genotypes is tarter. On the other hand, 'Altın' exhibited the least acidity 0.23%, which is considerably less than that of other cultivars, indicating softer flavour. Quince fruit flavour is mostly influenced by the balance between acidity and sweetness (İlhan, 2023).

Finally, quince cultivars differed each other significantly in terms of pH, SSC and acidity characteristics. These factors are crucial in deciding whether quince is fine to eat raw or can be processed into drinks, sweets and jams. For example, 'Osmancik' had the lowest pH (3.04) linked to a tarter flavour and superior preservation capabilities due to increased acidity. Leonel et al. (2016) evaluated 10 quince cultivars and found that De Patras and IAC CHA-43, with a less acidic flavour, were therefore more suitable for fresh consumption.

Sugars

As indicated in Table 2, all quince cultivars had a higher value of fructose, followed by glucose and sucrose in both skin and juice. Regarding skin tissue, cultivars 'Altinayva' and 'Kalecik' had similar but the highest fructose content (5.82%), followed by 'Ekmek' (5.75%). The juice of 'Ekmek' cultivar contained the highest fructose amount (6.82%), followed by Bardacık (6.40%) and 'Altinayva' (6.35%). Cultivar 'Osmancik' had the lowest fructose content in both skin and juice samples (4.22 and 4.56%, respectively). Regarding glucose in skin sample, cultivar 'Bardacık' had the highest value (3.21%) while 'Osmancik' had the lowest one (2.02%). In juice samples, 'Ekmek' cultivar had the highest amount of glucose (3.8%) while 'Osmancik' had the lowest (2.17%) (Table 2). Sucrose values of cultivars were in the range of 0.70%–1.27% in skin quince samples, and from 1.10% to 1.82% in juice samples. Sweeter taste in quince fruit is perhaps characterised by higher sucrose content.

Organic acids and ascorbic acid

Table 3 presents organic acid patterns of quince cultivars. For the skin of fruit samples, ascorbic acid content varied significantly among cultivars. 'Eşme' cultivar had the highest value (21.41 mg · 100 g^{-1}), followed by 'Acem' (16.95 mg · 100 g^{-1}), while 'Osmancik' had the lowest value (11.23 mg · 100 g^{-1}). For juice samples, the highest ascorbic acid value was obtained from 'Acem' cultivar (20.79 mg · 100 g^{-1}), followed by 'Altinayva' (17.62 mg · 100 g^{-1}), while the lowest ascorbic acid in juice samples was determined for 'Osmancik' cultivar (8.81 mg · 100 g^{-1}) (Table 3).

According to Davey et al. (2000), vitamin C (ascorbic acid) content, a crucial nutritional characteristic, was highest in the skin samples of 'Eşme' (21.41 mg · 100 g^{-1}) and 'Acem' (20.79 mg · 100 g^{-1}), highlighting its function in immune support and antioxidant defence. In comparing cultivars, 'Osmancik' had lower vitamin C content (11.23 mg · 100 g^{-1}) in the skin and 8.81 mg · 100 g^{-1} in the juice of 'Osmancik'. It indicates that its potential as an antioxidant is restricted. The vitamin C concentration of quince cultivars varies and in line with the findings as described by Wojdyło et al. (2014), Sharma et al. (2011) and Fattouch et al. (2007.

Malic acid content of cultivars was between 0.54% and 1.24% in the skin and 0.60%–2.06% in the juice samples. Malic acid content was highest in 'Ekmek' and 'Acem' skin samples. High acidic values indicating strong acidic profile, which could impact fruits flavour and preservation qualities.

'Ekmek' cultivar exhibited the highest level of succinic acid (1.02%) in skin tissue, followed by 'Acem' (0.87%). For juice samples, the highest value of 0.96% was observed in 'Acem' cultivar. 'Osmancik' cultivar had the lowest succinic acid content, 0.48%, among all quince fruit samples, which might impact flavour properties of the fruit.

Antioxidant capacity and total phenolic content

Results of a comprehensive analysis of antioxidant capacity (AC) and total phenolic content (TPC) in the skin and juice of eight quince cultivars are given in Table 4. Quince cultivars revealed significant variations in DPPH inhibition and TPC (Table 4).

Table 2. Sugars (%) in skin and juices of quince fruits.

Cultivar	Skin			Juice		
	Glucose (%)	Fructose (%)	Sucrose (%)	Glucose (%)	Fructose (%)	Sucrose (%)
Ekmek	2.78 cd*	5.75 a	1.00 bc	3.87 a	6.82 a	1.32 d
Osmancık	2.02 e	4.22 e	0.77 de	2.17 f	4.56 e	1.37 cd
Bardacık	3.21 a	4.57 d	0.92 cd	2.72 d	6.40 b	1.10 e
Altınayva	2.63 d	5.82 a	1.04 bc	2.78 cd	6.35 bc	1.47 bc
Kalecik	2.80 cd	5.82 a	0.70 e	2.52 e	6.03 c	1.73 a
Eşme	2.85 bcd	5.08 c	1.27 a	2.92 bc	6.26 bc	1.82 a
Acem	3.00 abc	5.46 b	1.09 abc	3.09 b	6.10 bc	1.53 b
Tekeç	3.10 ab	5.25 bc	1.14 ab	2.34 f	5.63 d	1.27 d

*Different letters in same column indicate statistically significant differences at 0.05 level.

Table 3. Organic acids in skin and juices of quince fruits.

Cultivar	Skin			Juice		
	Malic (%)	Succinic (%)	Ascorbic (%)	Malic (%)	Succinic (%)	Ascorbic (%)
Ekmek	1.24 a	1.02 a	16.95 bc	1.74 ab	0.48 cd	15.11 bc
Osmancık	0.54 e	0.48 f	11.23 d	0.60 d	0.10 f	8.81 e
Bardacık	0.94 d	0.67 cde	16.37 bc	1.78 ab	0.65 b	17.09 b
Altınayva	1.08 c	0.64 def	12.08 d	1.99 ab	0.65 b	17.62 ab
Kalecik	0.87 d	0.53 ef	13.73 cd	1.14 c	0.18 ef	10.65 de
Eşme	1.20 ab	0.74 bcd	21.41 a	1.74 b	0.62 bc	16.21 b
Acem	1.10 bc	0.87 ab	16.98 bc	2.06 a	0.96 a	20.79 a
Tekeç	1.06 c	0.83 bc	18.14 b	1.27 c	0.34 de	12.48 cd

Different letters in same column indicate statistically significant differences at 0.05 level.

Table 4. AC and TPC in the skin and juice of quince fruits.

Cultivar	Skin		Juice	
	AC (%)	TPC (mg GAE · 100 g^{-1} FW)	AC (%)	TPC (mg GAE · 100 g^{-1} FW)
Ekmek	97.60 a*	345 a	97.14 a	200 c
Osmancık	97.43 a	339 a	91.83 ab	333 a
Bardacık	97.60 a	270 bc	96.80 ab	260 b
Altınayva	87.13 c	74 e	83.98 c	72 h
Kalecik	96.72 ab	193 d	90.19 b	157 d
Eşme	95.49 b	276 bc	92.66 ab	132 f
Acem	97.09 a	247 c	91.72 ab	111 g
Tekeç	95.55 b	284 b	94.45 ab	140 e

*Different letters in same column indicate statistically significant differences at 0.05 level.
AC, antioxidant capacity; FW, fresh weight; TPC, total phenolic content.

Considering fruit skin tissue, 'Ekmek' and 'Bardacık' cultivars showed the highest DPPH inhibition (97.60%), followed by 'Osmancik' (97.43%), 'Acem' (97.09%) and 'Kalecik' (96.72%). The lowest AC was evaluated for 'Altinayva' (87.13%), significantly lower than other cultivars (Table 4). Similar to skin results, 'Ekmek' (97.14%) and 'Bardacık' (96.80%) showed the highest AC for juice samples. The lowest AC was obtained again for 'Altinayva' (83.98%) (Table 4). According to the results, most of the quince cultivars, except 'Altinayva', exhibited high DPPH inhibition indicating robust antioxidant activity. For all cultivars, the skin samples showed higher AC than juice samples (Table 4).

In skin samples, 'Ekmek' cultivar had the highest value (345 mg GAE · 100 g^{-1} FW) of TPC, followed by 'Osmancik' (339 mg · 100 g^{-1}), 'Tekeç' (284 mg · 100 g^{-1}) and 'Eşme' (276 mg · 100 g^{-1}). 'Altinayva' samples showed the lowest TPC (74 mg · 100 g^{-1} FW), hence reduced antioxidant potential. In juice samples, 'Osmancik' cultivar had the highest content (333 mg GAE · 100 g^{-1} FW), followed by 'Bardacık' (260 mg · 100 g^{-1} FW) and 'Kalecik' (157 mg · 100 g^{-1} FW). 'Altinayva' cultivar samples again showed the lowest total phenol content (72 mg · 100 g^{-1} FW) (Table 4). İlhan (2023) reported, among 10 quince samples from Türkiye, TPC between 290 mg and 432 mg GAE per 100 g, which is similar to our results.

Total phenol content is an indicator of AC, and the cultivars that had higher TPC also had higher AC (Table 4).

Quince (*C. oblonga* Mill.) has a wide range of health benefits, including reducing oxidative stress and inhibiting the development of cancer cells. It has tremendous promise in both nutritional and agronomic contexts (Al-Zughbi and Krayem, 2022). These results are consistent with studies showing quince as a rich source of antioxidants, especially phenolic compounds that work well to combat free radicals (Wojdyło et al., 2014).

A robust AC of quince fruits implies a possible function in mitigating oxidative stress and averting chronic illnesses including cancer and cardiovascular problems (Scalzo et al., 2005; Wojdyło et al., 2014). The results of this study support the previous research of Silva et al. (2002), highlighting the significance of environmental factors and genotype in phenolic content determination.

Overall, a considerable variation in fruit quality attributes is revealed by the pomological and biochemical examination of quince cultivars. The better weight and dimensions of 'Ekmek', 'Bardacık' and 'Osmancik' make it ideal for high-yield production; on the other hand, 'Ekmek', 'Bardacık' and 'Osmancik' are excellent in terms of nutritional value, especially in terms of antioxidant activity. Because they are firm, they could be chosen as a material for transportation, especially 'Eşme' cultivar. To enhance quince fruit for fresh consumption and processing, some additional genetic changes are required, with an emphasis on improving sweetness, firmness and antioxidant qualities. The results provide information for breeding efforts targeted at enhancing the agronomic and nutritional value of quince highlighting the significance of genetic selection and environmental factors in influencing the qualitative attributes of quince.

The heat map clustering was performed using a normalised data matrix. According to the variable measurements and analysis results, the quince cultivars were clustered on the vertical axis of the heatmap (Figure 3). The heatmap cluster divided quince cultivars and measured traits into two main classes. Accordingly, the 'Osmancik' cultivar formed a separate group from the other cultivars. Furthermore, the other cultivars were grouped into two subsets within themselves. The 'Altınaayva' cultivar represented a separate subset, while 'Tekeç', 'Eşme', 'Kalecik', 'Acem', 'Bardacık' and 'Ekmek' cultivars represented the other subset. 'Osmancik' cultivar with the lowest fruit firmness, pH, glucose (skin), fructose (skin), glucose (juice), fructose (juice), malic acid (skin), succinic acid (skin), ascorbic acid (skin), malic acid (juice), succinic acid (juice) and

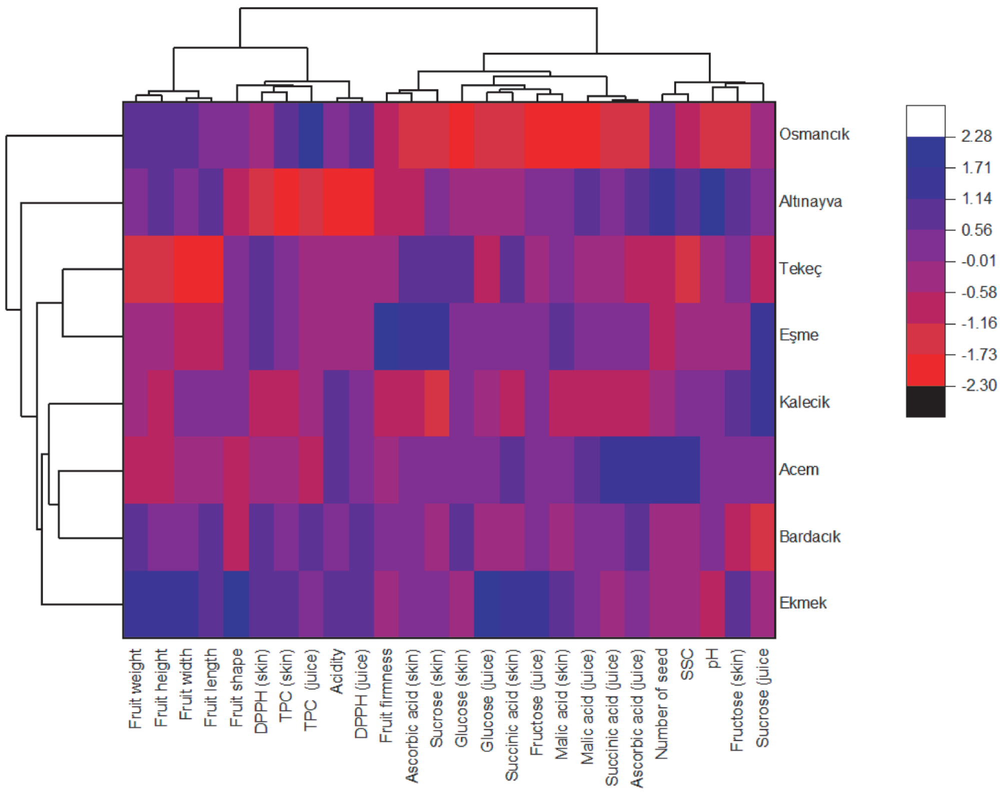

Figure 3. Heat map clustering prepared with normalised data matrix of 8 quince cultivars and measured 29 fruit characteristics. DPPH, 2,2-diphenyl-1-picrylhydrazyl; SSC, soluble solids content; TPC, total phenolic content.

ascorbic acid (juice) were categorised in a separate group from other cultivars. Additionally, 'Ekmek' cultivar with the highest fruit weight, fruit width, fruit length, fruit shape, fruit height, fructose (skin), glucose (juice), fructose (juice), malic acid (skin), succinic acid (skin), AC (DPPH) (skin), TPC (skin) and AC (DPPH) (juice) was the cultivar having the most distant resemblance to 'Osmancik' cultivar. On the other hand, it was observed that the measurements and analyses grouped on the horizontal axis of the heat map were also classified in two main groups. Fruit weight, fruit height, fruit width, fruit length, fruit shape, AC (DPPH) (skin), TPC (skin), TPC (juice) and AC (DPPH) (juice) parameters were included in the first of two clusters, while fruit firmness, ascorbic acid (skin), sucrose (skin), glucose (skin), glucose (juice), succinic acid (skin), fructose (juice), malic acid (skin), malic acid (juice), succinic acid (juice), ascorbic acid (juice), number of seeds, SSC, pH, fructose (skin) and sucrose (juice) parameters were collected in the second cluster. Similarly, Liang et al. (2021) reported that kiwifruit cultivars were grouped in two separate clusters in the heat map clustering prepared by using phenolic compound data obtained from the pulp and peels of 15 kiwifruit cultivars.

CONCLUSIONS

Minor fruits, including Quince, are important source of food for mankind. The in-depth research on the diversity of minor fruit germplasm resources helps to understand and protect their survival status and evolutionary potential. This is not only beneficial to agricultural production but also crucial for maintaining the stability and diversity of ecosystems. Nutrient profiling in the current finding of quince fruit revealed that the analysed cultivars are comparable in terms of nutrient content to those cultivated at various worldwide locations. As the result of this study, due to pomological characteristics, 'Ekmek', 'Bardacık' and 'Osmancik' cultivars stand out as superior cultivars for both fresh and processed usage. AC was highest in 'Acem', 'Bardacık' and 'Osmancik' cultivars, while 'Altinayva' showed the lowest value. Similarly, the highest TPC was determined for 'Acem' and 'Osmancik' cultivars. The slight variation in nutrients among cultivars depends on genetic makeup and the climatic conditions of the cultivating area. These findings underscore the importance of genetic selection of quince fruits for optimising traits to meet the quality, consumer preferences and market demands.

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AUTHOR CONTRIBUTIONS

B.I. and N.E.K. – conceptualisation. S.E., A.E.G., S.Y. and M.S.D. – methodology. B.I. and A.E.G. – formal analysis. B.I., N.E.K. and S.Y. – investigation. B.I. and A.E.G. – data curation. B.I., N.E.K., S.E., J.M., S.S. and M.S.D – writing original draft. S.E., M.S.D., S.S and J.M – writing–review and editing. All co-authors reviewed the final version and approved the manuscript before submission.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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