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Quality characteristics of the cv. Albion strawberry (*Fragaria* x *ananassa* Duch.) in different locations

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Abstract: Strawberries are one of the most popular berries in the world due to their distinctive aroma, flavor, and known health properties. A top day-neutral strawberry variety, the Albion, with its potential for high yields of large fruit, was grown in two different locations (Dağdibi and Hamidiye) at different altitudes (1410 and 1293 m) in Pozantı, a district of the Adana province in Türkiye, for late season production. Ripe fruits were harvested during the commercial harvest period, and several important physical and biochemical parameters were examined. In addition, the fruit's (berry's) external and flesh color, fruit length and width, soluble solid content (SSC), antioxidant capacity, total phenol and anthocyanin contents, individual sugars, organic acids, and volatile compounds were determined. Among these parameters, external fruit color, fruit width and length, SSC, total anthocyanin, total phenol, and ascorbic acid values showed differences between locations. In Hamidiye, the cv. Albion had the highest values of fruit width (32.04 mm) and total phenol content (51.80 mg gallic acid equivalent/100 g). In comparison, fruit length (44.22 mm), total acidity (1.65%), anthocyanin content (33.10 mg cyanidin-3-glucoside equivalent per 100 g), and ascorbic acid (53.42 mg/100 g) were higher in Dağdibi. The results indicate that locations at different altitudes affect the fruit's physical traits and the composition of strawberries.

Key words: Strawberry, altitude, Albion, quality

1. Introduction

As the world population increases, meeting nutritional needs is becoming increasingly important in agricultural production. To meet these needs, it is crucial to protect agricultural lands. However, in recent years, pollution and the degradation of natural resources in agricultural areas have negatively affected human health and destroyed nature (Nadeem et al., 2018; Alzuaibr, 2023; Asri et al., 2023). Thus, the desire to consume healthy foods has increased.

The strawberry (*Fragaria* x *ananassa* Duch.) is a popular fruit of high economic value because of its good taste and high nutrition ingredients. The plant is grown around the world, and its distinct genetic structures enable it to grow in different environmental circumstances (Pinheiro et al., 2021; Topcu, 2022; Patel et al., 2023)

World strawberry production is constantly increasing; in 2024, the total strawberry cultivation area in the world was 397,603 ha, and total production attained 9,569,864 t[1]. Due to the strawberry's short shelf life, worldwide strawberry production is relatively low compared to other fruits.

Strawberry cultivation in Türkiye uses modern and advanced techniques and has increased, especially in the last 10 years; the country is now one of the most important strawberry producers in the world (Urun et al., 2021; Gecer et al., 2022). Türkiye's total production was 351,834 t in 2012 and increased to 728,112 t in 2022. It is one of the world's major strawberry producers after China, the US, Egypt, and Mexico.[1]

Fruit color is one of the most important quality parameters when evaluating strawberries, often predetermining the consumer's expectation of taste and quality. The color of strawberries varies depending on several factors, such as genotype, ecological conditions, and maturity stage (Hargreaves et al., 2009; de Moura et al., 2012; Gunduz and Ozbay, 2018). Strawberries are unique because of their desirable taste and flavor. Compared to other fruits, they have higher antioxidant activity, which is associated with phenolic compounds and anthocyanins

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(Oszmiański and Wojdyło, 2009), flavonoids, ascorbic acid, vitamins, and carotenoids (Kelebek and Selli, 2011). In terms of nutritional content, strawberries contain 80%–90% water, 0.9%–1.2% fiber, 4.5%–10% sugar, 0.17%–0.25% tannin, B1, B6, and K vitamins, carotene, folic acid, iron, potassium, and calcium (Blanda et al., 2009). They are a rich source of L-ascorbic acid (vitamin C) and folic acid (folate) and contain a large amount of phenolics, the majority of which have an antioxidant effect (Kafkas et al., 2016a). The strawberry is known for its mineral content, carbohydrates, and organic acids. According to previous studies, the most important strawberry quality indicators are sugar content and total acids, which can be described as the sugar/acid ratio (Sturm et al., 2003; Pelayo et al., 2003; Kafkas et al., 2016a). Genetic factors, ecology, and growing conditions can affect fruit and antioxidant activity in strawberries (Parra-Palma et al., 2020; Urun et al., 2021). In addition to being consumed fresh, they are often used in the food industry in frozen or processed form (Casierra-Posada et al., 2011). Among fruit quality characteristics, color, volatile compounds, total phenol, total anthocyanin capacity, antioxidant capacity, sugars, and organic acids are the most important parameters for strawberries (Turemis et al., 2017; Kilic et al., 2021; Urun et al., 2021; Cankurt and İpek, 2023). Sugars and acids are the main components determining the flavor of the fruit. Total sugar content varies depending on different varieties, degree of maturity, and growing conditions. Glucose, fructose, and sucrose are the most common sugars in strawberries (Topcu, 2022). The organic acid content of fruits varies depending on the species, variety, and care conditions.

The main determinant of the taste characteristics of fruits is their sugar–acid balance and content. Fruit acids affect flavor and aroma formation and various physiological processes. The most abundant acids in fruits are citric, malic, and tartaric acids (Karakasova et al., 2017). Aroma compounds contribute to the flavor of fruits and create their characteristic aroma. The principal aroma compounds in fruits are esters, alcohols, aldehydes, ketones, lactones, terpenoids, and apocarotenoids. These compounds are affected by many factors, such as genetic structure, degree of maturity, environmental conditions, postharvest processing, and storage. Approximately 350 aroma compounds can be found in strawberries, which have some of the most complex aromas in the fruit family (El Hadi et al., 2013).

Strawberry varieties are more sensitive to environmental conditions (Ariza et al., 2021; Patel et al., 2023). The relative contribution of genotypic and environmental conditions to fruit quality in the strawberry has not been extensively studied. Additionally, the extent to which these fruit quality traits remain stable throughout changing environmental conditions is unknown. Thus, this study aimed to determine the effect of various environmental conditions on the quality of the cv. Albion strawberry.

2. Materials and methods

2.1. Locations, plant material, and experimental design

The experiment was conducted in two locations in the Pozantı district of Adana province in Türkiye. Late-season strawberry production was carried out in these two locations, each with different altitudes. The first location, Hamidiye (37°33′33.0″N, 34 °58′47.0″E), has an altitude of 1410 m. The second, Dağdibi (37°38′31.0″N, 35°00′12.0″E), lies at an altitude of 1293 m. There was a 15-day difference between the two locations regarding the harvest period due to the difference in altitude.

Commercially standard cold-stored plants of Albion strawberry variety were used as material. The cold-stored plants were kept frozen at –2.2 °C before planting. All plants were transplanted in 24-cell tray plates (660 mm long, 330 mm wide, and 100 mm high, cell column: 107 mL) and filled with commercial potting medium (peat and perlite mixture). The tray plants, each with 4–5 leaves, were planted on a black plastic-covered waiting bed system.

In 1999, the Albion variety was selected from a breeding program (Diamante x Cal 94.16-1.) at the University of California. The Albion is a day-neutral variety; its typical fruit is elongated, conical, and highly symmetrical. This variety is known for its fruit sizes, ranging from large to very large. It has very hard fruit, is durable for long periods, even in humid times, and produces high-market quality fruit. The Albion's fruit is bright red, and the fully ripe (harvested) berry has a sweet and pleasant flavor. This variety is moderately sensitive to powdery mildew and fruit anthracnose and resistant to *Verticillium* wilt (Cankurt and Ipek, 2023).

2.2. Climatic data

The highest average maximum temperature was 39.5 °C in September, and the minimum average temperature was –3 °C in November.[2] The average temperature from the first harvest to the last harvest period in the experimental areas (Pozantı) is given in Table 1.

2.3. Fruit physical parameters

The weight, diameter, and length of marketable fruits were recorded with a scale sensitive to 0.01 g and a digital caliper.

2.4. Biometrical parameters

2.4.1. Determination of the external and flesh color of the fruit

Color measurements were made with a Chroma Meter (CR-400 Minolta, Osaka, Japan). External and flesh fruit color was determined in terms of *L, a, b*, Chrome (C), and hue. *L* indicates the change in color brightness (*L*: 0

[1]FAO Food and Agriculture Organization (2024). [online]. Website http://www.fao.org/faostat/en/#data/QCL. [accessed 10 January 2024].

Table 1. Average minimum and maximum temperature of Pozantı in 2020.

Year/month	May	June	July	August	September	October	November
Max. temperature (°C)	33.5	36.3	37.6	38.5	32.6	30.0	23.8
Min. temperature (°C)	7.4	7.9	17.4	15.2	8.9	2.9	–1.3

black, 100 white), *a* indicates a color change from green to red (positive values = red; negative values = green), and *b* specifies a color change from yellow to blue (positive values = yellow; negative values = blue) (McGuire, 1992). For each fruit, two readings were taken at two diametrically opposite sites.

2.4.2. Determination of soluble solids contents, pH, and total acidity

Soluble solids content (SSC), pH, and total acidity (TA) were measured using three replicates and 30 fruits in each replicate.

The amount of soluble solids in the juice was measured using a hand refractometer (ATC-1, Atago, Tokyo, Japan). TA was determined by titration in terms of citric acid. Fruit juice pH was determined with an HI 255 Combination Meter digital pH meter (Hanna Instruments, Woonsocket, RI, USA).

Commercially ripened strawberry fruits were first picked. The fruits were then classified according to their size and surface color, and damaged fruits were sorted and transported to the laboratory refrigerator. Postharvest evaluations evaluated 60 randomly selected marketable fruits per replicate. The fruit samples were divided into three groups for replication, and each group of 20 fruits was considered a replication. Strawberry flesh was homogenized using a kitchen hand blender. Samples homogenized in the food processor were extracted. Samples extracted with water and 80% methanol and as pure were centrifuged, and the supernatants were subjected to further analysis in the freezer at –20 °C.

These homogenized materials were used in additional biochemical analyses (sugars, organic acids, total phenolics, volatile compounds, total anthocyanins, total phenol, and antioxidant capacity analyses).

2.5. Biochemical parameters

2.5.1. Determination of total antioxidant capacity

Antioxidant capacity was determined with DPPH inhibition according to Brand-Williams et al. (1999). Approximately 0.06 of µM methanolic DPPH (2,2-Diphenyl-1-picrylhydrazyl) was freshly prepared according to this method. After adding 1950-µL DPPH to 50-µL supernatant (homogenized fruit), the mixture was shaken in the mixer for 1 min and left in the dark for 30 min at room temperature. Absorbance was measured at 515 nm against the blank reagent. A spectrophotometer (Thermo Fisher Scientific, Multiskan GO, FI-01620, Vantaa, Finland) was used in this analysis.

2.5.2. Determination of total phenolic content

Total phenol content was determined using the Folin–Ciocalteau method modified by Spanos and Wrolstad (1990). In the analysis, 250 µL of Folin–Ciocalteau reagent was added to 50-µL supernatant (homogenized fruit); following this, 750-µL 20% (w/v) Na_2CO_3 was added and shaken. This mixture was left in the dark at room temperature for 2 h. Absorbance was read against a blank sample at a wavelength of 760 nm. A UV/VIS spectrophotometer (Thermo Fisher Scientific, Multiskan GO, FI-01620, Vantaa, Finland) was used in this analysis. It was calculated through a calibration curve prepared daily with known gallic acid standard concentrations. Results are expressed as mg GAE per 100-g strawberry fresh weight (FW).

2.5.3. Determination of total anthocyanin content

Total anthocyanin content was determined by modifying the method of Wrolstad (1976), which is to add 100 µL of supernatant (homogenized fruit), one with pH 1.0 potassium chloride buffer (1.86-g KCl in 1 L distilled water), and the other with pH 4.5 sodium acetate buffer. Two extracts were prepared (54.43-g $CH_3CO_2Na.3H_2O$ in 1 L distilled water), and an additional two extracts ($CH_3CO_2Na.3H_2O$) were prepared. The absorbance of the extracts was incubated for 15 min at room temperature. Readings were taken on a spectrophotometer at 510 and 700 nm (Thermo Fisher Scientific, Multiskan GO, FI-01620 Vantaa, Finland). Anthocyanin content in the extracts was determined as mg of cyanidin 3-glucoside equivalents per L.

2.5.4. Determination of sugar content

The sugar content was determined using the method developed by Miron and Schaffer (1991). Before analysis, the fruit juice samples were allowed to melt at room temperature. Ultrapure water (4 mL) (Millipore Corp., Bedford, MA, USA) was added to these samples (1 mL) and then shaken. The mixtures were placed in an ultrasonic bath and sonicated at 80 °C for 15 min. The samples were centrifuged at 5500 rpm for 15 min, filtered (Whatman nylon syringe filters: 0.45 µm and 13 mm in diameter), and transferred to a high-performance liquid chromatograph (HPLC) device. Sugar content was determined using three replicates: an HPLC (Shimadzu, Prominence LC-

[2]MGM Turkish State Meteorological Service (2024). [online]. Website https://www.mgm.gov.tr [accessed 10 January 2024].

20A, Kyoto, Japan), a refractive index detector, and a Coregel-87C (300 mm × 7.8-mm inner diameter, 5 µm). Separations were performed at 70 °C at a flow rate of 0.6 mL min^{-1}. The elution was isocratic ultrapure water. The calibration curves of the references used were created, and their contents were made according to these curves. Individual sugars were calculated according to standards and determined as a FW percentage.

2.5.5. Determination of organic acids

Organic acids were prepared according to the method developed by Bozan et al. (1997). Precisely 4 mL of 3% metaphosphoric acid was added to 1 mL of the fruit juice samples and shaken. They were then sonicated in an ultrasonic water bath at 0 °C for 15 min. Following this, the mixtures were centrifuged at 5500 rpm for 15 min, filtered into HPLC vials (Whatman nylon syringe filters, 0.45 m, 13 mm, diameter), and loaded into the device. Extracts were analyzed using an HPLC apparatus (Shimadzu LC 20AVP, Kyoto, Japan) equipped with an 87H column (5 µm, 300 mm, 7.8 mm; Transgenomic, Omaha, NE, USA) and UV detector (SPD 20A VP, Shimadzu Corp., Kyoto, Japan). The operating conditions column temperature was set at 40 °C, injection volume: 20 µL; detection wavelength: 210 nm, 242 nm; flow rate: 0.8 mL/min, and 0.05 mM of sulfuric acid was used as the solvent. Identifying organic acids and determining peaks are based on the retention times of peaks and the comparison of spectral data according to standards. The identified acids were evaluated according to the relevant standard calibration curves. The malic, succinic, and citric acids were calculated according to their standards and expressed as a percent FW. The L-ascorbic acid results are expressed as mg per 100 g.

2.5.6. Determination of volatile compounds

Aroma analyses were determined according to the method developed by Kraujalytė et al. (2013). Volatile compounds were extracted via solid-phase microextraction (SPME). Exactly 1 g of strawberries was weighed into the Headspace bottles, and 1 mL $CaCl_2$ was added and then mixed. The resulting mixture was sonicated in an ultrasonic water bath at 40 °C for 30 min. An SPME fiber 85-µm CAR/PDMS (Carboxen/polydimethylsiloxane; red) was used for analysis. Adsorbed flavor compounds of the strawberries were analyzed using a Shimadzu GC-2010 Plus Gas chromatography-mass spectrometry (GC/MS). An HP-Innowax Agilent column (30 m × 0.25 mm i.d 0.25-µm thickness) was used with helium as the carrier gas. The GC oven temperature was kept at 40 °C and programmed to 260 °C at a rate of 5 °C/min; after this, it was kept constant at 260 °C for 40 min. The injector temperature was 250 °C. The MS was taken at 70 eV. The mass range was m/z 30–400. A library search was carried out using the Wiley, NIST, and Flavor GC/MS Libraries. Mass spectra were also compared with those of reference compounds and validated with the aid of retention indices from published sources. The relative percentage amounts of the separated compounds were calculated from the total ion chromatograms in the computer environment.

2.5.7. Statistical analysis

Statistical analyses were performed using SPSS statistics software (version 26, IBM Corp., Armonk, NY, USA), and the means and calculated standard errors were noted.

3. Results and discussion

3.1. Fruit external and flesh color

The external fruit and flesh color of the Albion strawberry variety grown in two different locations is shown in Table 2.

The results show a difference between the two locations for most color parameters. The external brightness (*L*) color was 32.5 in Dağdibi and 33.2 in Hamidiye. Similar results were obtained by Kilic et al. (2021) on strawberry fruits. Our results also show similarities with de Jesús Ornelas-Paz et al. (2013). The increase of the *L* value indicates increases in color lightness, and the *a* value indicates the intensity of the color. The higher a value indicates a higher red intensity, and the *a* value was found to be 38.4 for Dağdibi and 37.5 for Hamidiye. The *b* color value was 21.8 for Dağdibi and 23.3 for Hamidiye. Our *a* and *b* fruit external color indices show similarities with Kilic et al. (2021). External fruit C values were the same (44.2) in both locations. Hue (color angle value) values were 29.5 for Dağdibi and 31.7 in Hamidiye, respectively. The C and hue values are close to each other in both locations.

The fruit flesh color of the cv. Albion strawberries grown in the two different locations are shown in Table 2. The *L* values were 57.2 and 55.8 in Dağdibi and Hamidiye, and *a* values (31.0 vs. 31.3), *b* values (25.1 vs. 25.7), and hue

Table 2. Fruit external and flesh color values of strawberry cv. Albion grown in two locations.

Fruit external color						Fruit flesh color				
Locations	*L*	*a*	*b*	C	Hue	*L*	*a*	*b*	C	Hue
Dağdibi	32.5 ± 0.39	38.4 ± 0.41	21.8 ± 0.57	44.2 ± 0.62	29.5 ± 0.43	57.2 ± 0.78	31.0 ± 0.8	25.1 ± 0.51	39.9 ± 0.94	39.1 ± 0.22
Hamidiye	33.2 ± 0.43	37.5 ± 0.45	23.3 ± 0.65	44.2 ± 0.66	31.7 ± 0.54	55.8 ± 0.82	31.3 ± 1.18	25.7 ± 0.82	40.5 ± 1.42	39.6 ± 0.34

Data are shown as mean ± standard error of three replicates.

values (39.1 vs. 39.6) were similar in both locations. The C values were higher in Hamidiye (40.5) than Dağdibi (39.6). During the ripening process, the color of strawberries changes from white to red. The value of *b* decreases during this process in strawberry. Color change is an indicator of a very significant change in the ripening process of the strawberry. This change is a process of synthesizing pigments like anthocyanins in the strawberry. Generally, a bright red color comes from the fruit's anthocyanin content, and anthocyanins are an essential aspect of strawberry quality and commercial value (Matsushita et al., 2016; Gunduz and Ozbay, 2018). Fruit with an intense, bright red coloration is preferred, although color—in most cases—does not contribute to an actual increase in strawberries' nutritional value or sensory quality (Erturk et al., 2012; Cecatto et al., 2013).

3.2. Fruit weight, width, and length

The values corresponding to the fruit weight, width, and length of cv. Albion strawberries grown in the two different locations are shown in Table 3. Fruit weight was similar in both places (20.59 g in Dağdibi and 20.68 g in Hamidiye). Fruit width was determined as 30.36 mm in Dağdibi and 32.04 mm in Hamidiye. Regarding fruit length, there were differences between the two locations (41.72 mm in Hamidiye and 44.22 in Dağdibi). Fruit weight and other dimension-related results are similar to those found in de Jesús Ornelas-Paz et al.'s study (2013). Considering the results of Capocasa et al. (2016) and Cankurt and İpek (2023), our fruit weight results are high. Colak (2023) reported fruit weight, width, and length in cv. Albion strawberries grown in western Türkiye to be 16.33 g, 28.87 mm, and 39.63 mm, respectively, which indicate slightly lower values than those of the present study. In our study, the results indicate that, at a lower elevation, the fruits tended to be longer, considering fruit shape values (high length/width ratio in Dağdibi); at higher elevations, the shapes were flattened (low length/width ratio in Hamidiye). A strawberry's size depends on the interaction between flower position, the number of achenes developed, competition between fruits, and the plant's vigor. In addition, larger fruits are produced at the beginning of the harvest period (Ercisli et al., 2005; Erturk et al., 2012).

3.3. Soluble solid content, total acidity, and pH

The SSC, TA, and the pH values of the cv. Albion grown in the two locations can be seen in Table 4. From the postharvest quality parameters assessed, SSC and TA show differences between the two locations. Considering the SSC, TA, and pH results, the cv. Albion had higher values (9.7% SSC, 1.65% TA, and 3.47 pH) at a lower altitude in Dağdibi and lower values in Hamidiye (9.0% SSC, 1.39% TA, and 3.45 pH). Sezer (2010) reported that the Albion strawberry variety grown under organic conditions had an SSC content of 10.25%. Studies conducted on different strawberry varieties reported that the SSC content varies between 8.20%–9.90% (Urun et al., 2021; Kilic et al., 2021). In our study, the SSC content (TSS) value was higher than the result found by Capocasa et al. (2016). The pH value was higher than the one determined in Kafkas et al.'s study (2007). The authors reported pH values between 3.29–3.43 in their strawberries. Compared to de Jesús Ornelas-Paz et al.'s (2013) results, our SSC result was high, and the pH value was low. We found similar results regarding SSC and TA to Kilic et al.'s study (2021), whose authors used many strawberry varieties. The quality of strawberries is crucial because, in addition to presenting an excellent appearance, the fruits must meet consumer demand in terms of sweetness, flavor, acidity, and color. For horticultural crops, pH is critical—microbiologically and chemically—because most chemical reactions occurring during the processing and storing phases (i.e. during the postharvest stage) are profoundly altered by the variation in the environment's hydrogen concentration (Rahman and Rahman, 2020).

Table 3. Fruit physical characteristics of cv. Albion grown in two locations.

Locations	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)
Dağdibi	20.59 ± 0.43	30.36 ± 0.32	44.22 ± 0.57
Hamidiye	20.68 ± 0.63	32.04 ± 0.57	41.72 ± 0.81

Data are shown as mean ± standard error of three replicates.

Table 4. SSC, total acidity and pH of cv. Albion grown in two locations.

Locations	SSC (%)	Total acidity (%)	pH
Dağdibi	9.7 ± 0.06	1.65 ± 0.26	3.47 ± 0.01
Hamidiye	9.0 ± 0.00	1.39 ± 0.13	3.45 ± 0.01

Data are shown as mean ± standard error of three replicates.

3.4. Antioxidant capacity, total anthocyanin, and total phenol content

The antioxidant capacity, total anthocyanin, and total phenol content of the Albion strawberries grown in the two locations are shown in Table 5. The percentage of DPPH inhibition was 85.2% in the fruits grown in Dağdibi and 84.7% in those grown in Hamidiye, indicating that almost similar values existed in the two locations. Fruit antioxidant capacity is affected by several factors, including genetic background, growing area, and maturity stage. However, genotype has proven to be the most important factor influencing fruit's total antioxidant capacity (Urun et al. 2021; Boyaci et al. 2023).

The Albion variety had a higher anthocyanin content in Dağdibi, with 33.1 mg/L, whereas it was 28.7 mg/L in Hamidiye. Turemis et al. (2017) reported higher anthocyanin content than our results. The amount of anthocyanins in our study is similar to that found in de Jesús Ornelas-Paz et al.'s study (2013). Anthocyanins (mainly derivatives of pelargonidin and cyanidin) are the main pigments in strawberries, and their content can affect the fruit's color, which is an important quality parameter (Pillet et al., 2015). The characteristic red color develops during ripening through the production of anthocyanins, which reaches a peak at full ripening (Carbone, 2009).

Regarding total phenol content, the Albion variety had a lower content (46.4 mg GAE/100 g) in Dağdibi and was highest in Hamidiye (51.8 mg GAE/100 g). The total phenol value in this study is similar to that of Urun et al. (2021). According to Colak (2023), the total phenol content of strawberry varieties is between 43 and 231 mg GAE/100 g. The total phenol content in our samples was comparable to that of the above studies. Any differences could be due to extraction methods, varieties used, or growth and cultivation conditions. Environmental factors, including light, temperature, soil nutrients, and altitude, also influence the total phenolic content in fruits (Celik et al., 2007; Crespo et al., 2010; Sariburun et al., 2010)

3.5. Individual sugar content

The individual sugar content of Albion strawberry varieties grown in the two locations is shown in Table 6. The results show that the sucrose, glucose, and fructose content of the variety observed in both locations resemble each other. Moreover, the average individual sugar content of strawberries from both locations is similar (sucrose average: 1.45%; glucose average: 1.30%; fructose average: 1.45%). The glucose content was 1.3% in both locations; the sucrose content was higher in Dağdibi (1.5%) than in Hamidiye (1.4%), and the fructose content was higher in Hamidiye (1.5%) than in Dağdibi (1.4%). Previously, Kilic et al. (2021) reported similar sucrose values in strawberries, and the fructose and glucose values in that study were high. Turemis et al. (2017) also reported that the strawberries in their study contained mainly fructose, followed by glucose and sucrose. Kafkas et al. (2007) found a low sugar content in the strawberries in their research.

3.6. Organic acid

The organic acid content of the cv. Albion strawberries grown at the two locations are presented in Table 7. The ascorbic acid content was highest in the fruits grown in Dağdibi (53.42 mg/100 g); the same content was 50.17

Table 5. Antioxidant activity, total anthocyanin and total phenol content of cv. Albion grown in two locations.

Locations	% DPPH inhibition	Total anthocyanin (mg/L)	Total Phenol (mg GAE/100 g)
Dağdibi	85.2 ± 0.3	33.1 ± 0.8	46.4 ± 0.5
Hamidiye	84.7 ± 0.3	28.7 ± 0.8	51.8 ± 1.6

Data are shown as mean ± standard error of three replicates.

Table 6. Individual sugar contents of Albion strawberry variety in two locations.

Locations	Sucrose (%)	Glucose (%)	Fructose (%)	Total Sugar (%)
Dağdibi	1.5 ± 0.1	1.3 ± 0.1	1.4 ± 0.1	4.2 ± 0.3
Hamidiye	1.4 ± 0.1	1.3 ± 0.1	1.5 ± 0.1	4.2 ± 0.2

Data are shown as mean ± standard error of three replicates.

Table 7. Organic acid contents of cv. Albion in two locations.

Locations	Ascorbic acid (mg/100 g)	Citric acid (mg/100 g)	Malic acid (mg/100 g)	Succinic acid (mg/100 g)
Dağdibi	53.42 ± 2.8	0.61 ± 0.1	0.05 ± 0	0.07 ± 0
Hamidiye	50.17 ± 2.3	0.55 ± 0.1	0.05 ± 0	0.06 ± 0

Data are shown as mean ± standard error of three replicates.

mg/100 g in Hamidiye. Citric acid was dominant in both sets of fruits (0.61 mg/100 g in Dağdibi and 0.55 mg/100 g in Hamidiye). The malic and succinic acid contents in the strawberries were negligible. Previous studies indicated that strawberries have ascorbic acid between 40–65 mg/100 g, depending on the variety (Kafkas et al., 2007; Turemis et al., 2017; Kilic et al., 2021; Urun et al., 2021; Colak, 2023). The authors of these studies also indicated that the ascorbic acid content in strawberries varies depending on climate conditions, fruit type, and cultivation techniques applied. Turemis et al. (2017) reported higher organic acid levels in organically grown strawberries.

3.7. Volatile compounds

The results of the volatile profiles of the strawberries grown in the two different locations are given in Table 8. As presented in Table 7, a total of 52 volatile compounds and seven chemical groups, including ketones, alcohols, aldehydes, esters, terpenes, acids, and other compounds, were identified. Ketone compounds were determined to be 49.53% in the cv. Albion fruits harvested from Dağdibi

Table 8. Volatile compounds of cv. Albion at two locations.

R.T	Compound name	Hamidiye	Dağdibi
	Ketones		
25.638	(E)-dihydro-Carvone	6.05	8.58
20.306	2,5-Dimethyl 4-methoxy furan-3-one	0.17	
31.991	α-Ionone	0.15	0.39
33.761	β-Ionone	0.30	
26.543	Neryl Acetone	0.25	0.26
18.314	Pseudolimonene	0.21	0.23
32.665	γ-Decalactone	41.81	40.30
	Alcohols		
13.758	1-Hexanol	0.15	
22.806	α-Terpineol	3.19	3.71
15.273	Cyclohexanol	0.12	
22.169	Farnesol	0.29	
17.235	n-Heptanol	0.27	0.29
16.216	Linalool oxide	0.20	0.28
19.082	Linalool	5.59	6.43
26.32	Nerol	0.31	0.33
30.498	Nerolidol	32.51	26.12
16.996	Trans-Linalool oxide	0.32	0.48
	Aldehydes		
21.553	(E)- 2-Decenal		1.17
6.381	Hexanal	0.26	0.31
14.998	Nonanal		0.25
21.152	Trivertal	0.18	
	Esters		
13.38	(E)- 2-Hexen-1-ol acetate	0.59	0.46
23.409	octyl-Acetate	0.11	
6.181	Acetic acid, butyl ester	0.17	
11.615	Acetic acid, hexyl ester	0.41	0.32
10.068	n-Butyl butanoate		1.29
5.396	Ethyl butanoate	1.18	0.39
15.6	n-Hexyl butanoate	0.54	0.53
4.393	Methyl butanoate	1.07	1.31
20.914	n-Butyl butyrate	2.84	2.96
21.596	2-Methylbutyl 2-methylbutanoate	0.48	
25.553	Acetic acid, octyl ester	0.58	0.35

Table 8. (Continued.)

19.301	heptyl-Formate	0.19	0.25
10.05	Isoamyl-Formate	1.26	1.26
33.413	Geranyl propanoate	0.36	
10.516	Hexanoic acid ethyl ester	0.38	0.27
9.2	Hexanoic acid methyl ester	0.32	0.36
26.66	Linalyl acetate	0.15	
21.03	Tetrahydrofurfuryl acetate	0.13	
27.383	Tetrahydrofurfuryl butyrate		0.20
24.164	Tetrahydrofurfuryl propionate	0.55	1.36
17.236	Isopropyl-Tiglate	0.62	0.32
21.594	butyl-Valerate	0.66	
	Terpens		
11.856	α-Terpınolene	0.15	0.28
5.451	Methyl- Benzene		3.27
34.01	β-Bisabolene	0.42	0.55
	Acid		
31.062	Capric acid	0.16	
33.135	Nonanoic acid	0.12	0.62
31.05	Octanoic acid		0.40
	Other compounds		
29.871	Phenol		0.49
36.076	2,4-Di-tert-butylphenol		0.20

and 48.34% in Hamidiye, exhibiting similar values in the two locations. However, alcohol compounds were quite different in the strawberries from the two locations, determined as 37.64% in Dağdibi and 42.95% in Hamidiye. Among the ketones, γ-Decalactone, and among the alcohols, Linalool and Nerolidol, were found to be high in both locations. Kafkas et al. (2016b) found that the highest aroma compounds were ester compounds (85.86%) in the strawberries in their study, followed by alcohol compounds (9.8%). In addition to nonvolatile secondary metabolites, strawberries produce volatile metabolites (Haugeneder et al., 2018). These compounds are significant components in fruit flavor, and even slight changes can modify the taste, even though these compounds account for 0.001%–0.01% of a fruit's weight (Yan et al., 2018).

4. Conclusion

This study on Albion strawberries in two different adaptation conditions of Adana province (Dağdibi and Hamidiye) determined that the Albion variety grown in the Dağdibi region was superior in terms of fruit characteristics. The fruit quality of strawberries depends on many factors, such as ecology, genotype, and variety. The fruit can be affected by ecological conditions, genetic factors, and growing conditions. The fruit quality of strawberries depends on many other factors, such as ecology, genotype, and variety. The strawberry can also be impacted by ecological conditions, genetic factors, and growing conditions.

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