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DETERMINATION OF THE OPTIMAL HARVEST TIME OF TWO COMMON APRICOT CULTIVARS (*PRUNUS ARMENIACA* L.) BY PHYSICOCHEMICAL AND SENSORY METHODS

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Abstract

This study aimed to determine the optimal harvest time for two apricot cultivars (cv. Hacıhaliloğlu and Kabaaşı) by evaluating physical, chemical, and sensory changes during a 13-week ripening period. Fruit samples were collected at 7-day intervals throughout the study. Parameters such as weight, length, width, thickness, sphericity, color (L*, a*, b*), color indices, soluble solids content (SSC), pH, firmness, elasticity, phenolic content (gallic acid and catechin), and organic acids (citric acid and ascorbic acid) were evaluated. According to the results, a steady increase in physical properties was observed in both cultivars during ripening. Color values (L*, a*, b*) became brighter and more saturated as ripening progressed. The sugar-to-acid ratio increased in the later weeks, accompanied by an increase in pH and a decrease in titratable acidity. SSC generally increased but decreased slightly in the last weeks. Both organic acids (citric and ascorbic acid) and phenolic compounds (gallic acid and catechin) tended to decrease during ripening. While citric acid content in cv. Kabaaşı decreased significantly in the last week, it remained at a higher level in cv. Hacıhaliloğlu. These results indicate that the 12th week of ripening represents the optimal harvest time for both apricot cultivars to achieve maximum quality and full ripeness.

Key words: Apricot cultivars; Ripeness assessment; Quality characteristics; Fruit development; Turkey

Introduction

Apricot is one of the most economically important fruit species in Turkey and the second most produced stone fruit after the peach (Anon., 2024). Around 3.8 million tons of fresh apricots are produced worldwide every year, with 803.000 tons in Turkey, making it the largest producer in the world (Anon., 2024). Turkey is followed by Uzbekistan (451.262 tons), Iran (305.972 tons), and Italy (230.080 tons). In Malatya, which accounts for 85% of Turkey's dried apricot production, 60-65% of the crop is of the Hacıhaliloğlu cultivar. The Kabaaşı cultivar mainly accounts for the remaining 30-35%, while other varieties are produced in smaller quantities (Ünal, 2010; Asma, 2011). It is important to determine the physical and chemical changes in the growth, development, and ripening periods of fruit species and cultivars to apply cultural practices in a timely and appropriate manner (Köksal & Yılmaz, 1992; Özelçi *et al*., 2021). Fruits should not have nutritional deficiencies and thirst problems during the development period when cell division and growth are intensive. Ideal maintenance conditions during this period increase the quantity and quality of the products. It is important to know the physical and chemical changes in the development periods of the fruit in order to determine the maintenance conditions and enable economical fruit cultivation (Pehluvan *et al*., 2021; Nasir *et al*., 2024).

Determining the optimal harvest time is crucial for maximizing fruit quality and economic yield. Harvesting too early leads to weight loss and inferior flavor, while harvesting too late reduces storability and increases susceptibility to damage (Ganai *et al*., 2015; Kunwar *et al*., 2024). As the degree of ripeness cultivar depending on the variety, monitoring physical and chemical changes during ripening is essential (Güleryüz *et al*., 2001). The exact time of harvest also affects consumer satisfaction, labor scheduling and post-harvest respiration, which influences storage conditions (Kayışoğlu, 2020). Early harvested fruit may lack sugar and flavor, while late harvest increases the risk of disease and flavor loss. Therefore, accurate ripeness assessment ensures long-term storage and marketability (DeLong *et al*., 1999; Skic *et al*., 2016).

Although there are several studies in the literature to determine the optimum harvest time of apricots, research focusing on comparisons between varieties is quite limited (Özelçi *et al*., 2021a; Özelçi *et al*., 2021b; Özelçi *et al*., 2021c; Tan *et al*., 2023). This study aimed to determine the optimal harvest time of two well-known apricot cultivars, Hacıhaliloğlu and Kabaaşı, based on the physical, chemical, and color changes during fruit development, which contributes significantly to Turkey's apricot production and export.

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Material and Method

Plant materials and sampling: This study was conducted on two apricot cultivars, Hacıhaliloğlu and Kabaaşı, during the 2017 growing season. The fruit samples were collected from the orchard of a local producer in Kağızman district of Kars province. The first fruit samples were collected in the second week of May, two weeks after full bloom, and the fruits were harvested at weekly intervals until the last week of July (Fig. 1). Each week, 20 randomly selected fruit samples from different parts of the trees in the same orchard were placed in plastic bags and immediately taken to the laboratory for physical analysis. After physical analysis, the fruit samples were stored at -18°C until chemical analysis.

Physical and sensory properties

Color analysis: The skin color of the apricot was determined at three different points on the surface of the fruit using a colorimeter (Minolta, CR 410, Osaka, Japan) according to the method described by Karabulut *et al*., (2007). The color measurements were recorded as CIE L*, a* and b* values. In addition, C* (chroma) and h° (hue angle) were calculated using the following equations:

$$C^*=\sqrt{a^2+b^2}$$
$$h°= \arctan b^*/a^*$$

Physical and pomological analyses: The dimensions of the fruit samples, including length, width, and thickness, were measured using a digital caliper. The weight of the fruit was determined using a digital precision scale with a sensitivity of 0.01 g. The geometric mean diameter (Dg) and sphericity (S) of the fruits were calculated using the following formulas:

$$Dg = (lwt)^{1/3}$$
$$s = (((lwt)^{1/3})/l) * 100$$

Where Dg stands for the geometric mean diameter in millimeters (mm), and S for the sphericity in percent. The variables l (mm), w (mm), and t (mm) denote the fruit's length, width, and thickness of the fruit in millimeters.

Mechanical analysis: The firmness and elasticity of the fruit were determined using a TA-XT2 texture analyzer (Stable Microsystems, Surrey, UK), equipped with a cylindrical stainless-steel probe of 2 mm diameter and a 30 kg load cell. The measurement parameters included an initial and final velocity of 5 mm/s, a test speed of 1 mm/s, and a penetration depth of 3 mm, following the method outlined by Cui *et al*., (2008).

Chemical properties

Soluble solid content (SSC) and pH measurements: A digital refractometer (Boeco Digital Abbe Refractometer, BOE 32400, Germany) was used to measure the soluble solids content (SSC) of the filtered apricot juice, and the results were expressed in Brix. The pH of the filtered juice was analyzed using a multiparameter analyzer with a pH electrode (Consort C3040, Belgium, SP10B).

Sample extraction: The apricot samples were prepared using the modified protocol of Alwazeer & Örs (2019). A 5 g portion of the fruit sample was mixed with 10 ml of 50% methanol (v/v) with 0.1% HCl and homogenized using an IKA Ultra Turrax T18 homogenizer (Korea) at a speed of 1300 rpm for 1 minute. The resulting homogenate was allowed to stand for 2 hours in the dark at room temperature. Subsequently, the mixture was centrifuged at 10.000 ×g for 15 min at 10°C, and the supernatant was filtered through Whatman No. 4 filter paper and then through a 0.45 µm membrane filter. The final extract was stored at −80°C for future analysis.

Analysis of organic acids and phenolic compounds by HPLC: The organic acids were analyzed isocratically after slight modifications based on the method described by Akin *et al*., (2008). The analysis was performed using an Agilent 1260 series high-performance liquid chromatography (HPLC) system equipped with a diode array detector (DAD) and an ACE GENERIX 5 C18 column (5 µm, 4.6 mm × 250 mm). The mobile phase consisted of 98% Na_2HPO_4 adjusted to a pH of 2.4 with H_3PO_4 at a flow rate of 1 mL/min. Detection was performed at 210 nm for citric acid and 400 nm for ascorbic acid.

Phenolic compounds, especially gallic acid and catechin, were analyzed according to the method of Hussain *et al*. (2013) with slight modifications. Separation was performed on an Agilent 1260 series HPLC system with a diode array detector (DAD) and a Poroshell 120 EC-C18 column (2.7 µm, 4.6 mm × 150 mm). A gradient mobile phase comprising 83% phosphoric acid and 17% acetonitrile at a flow rate of 1 mL/min and an injection volume of 20 µL was used. The elution profile of the gradient was as follows: 83% A for 1 min, 70% A for 2 minutes, 60% A for 4 min, and 83% A for 10 min. The operating conditions included detection wavelengths of 210 nm and 300 nm, an injection volume of 20 µL, and a column temperature of 20°C.

Fig. 1. The different development stages of the cultivars of Hacıhalioğlu and Kabaaşı.

Statistical analysis

The data were analyzed using one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test at a significance level of $p<0.05$. Statistical analysis was performed using SPSS software (version 18; SPSS Inc., Armonk, NY, USA), and results are expressed as mean ± standard deviation.

Results and Discussion

Physical and pomological properties: The sound apricot fruits are generally used for fresh consumption due to their favorable appearance, while defective fruits are considered for processing. Therefore, fruit size is a decisive criterion for quality and consumer preference (Muradoğlu *et al.*, 2022). The fruit weight of both fruit cultivars increased regularly from the 1^{st} to the 13^{th} harvest. In cv. Hacıhaliloğlu, the fruit weight steadily increased from 0.89 g in the 1^{st} week to 25.55 g in the 13^{th} week and in cv. Kabaaşı from 1.04 g to 28.74 g. Although the weight gain was regular in both cultivars, a sudden increase was observed in Kabaaşı, especially during the transition from the 9^{th} to the 10^{th} week (Table 1). A steady and progressive increase in dimensions-namely length, width, and thickness-was observed in fruit cultivars throughout the ripening period. In cv. Hacıhaliloğlu, fruit length increased from 17.48 mm to 38.55 mm; width increased from 10.60 mm to 35.15 mm; and thickness increased from 9.03 mm to 33.57 mm. Similarly, in cv. Kabaaşı, the length expanded from 20.24 mm to 43.13 mm, the width from 11.28 mm to 35.56 mm, and the thickness from 9.31 mm to 32.52 mm over the same period (Table 1).

In studies on apricot cv. Kabaaşı, Kan (2005) reported the fruit width, thickness, height, and weight as 41.27 mm, 37.65 mm, 43.57 mm, and 33.60 g, respectively; Yılmaz (2008) reported 35.07 mm, 32.84 mm, 39.20 mm and 26.58 g, respectively; and Özelçi *et al.*, (2021) reported 33.56 mm, 35.12 mm, 38.54 mm and 30.45 g, respectively. Similarly, for cv. Hacıhaliloğlu, Demirtaş *et al.*, (2010) determined the fruit width, length, and weight to be 35.27 mm, 37.65 mm, and 31.99 g, respectively, while Özelçi *et al.*, (2021c) determined 36.18 mm, 38.15 mm, and 37.25 g, respectively. The data obtained were consistent with these studies. A regular increase in the sphericity ratio over the weeks was observed in both cultivars. In cv. Hacıhaliloğlu, the sphericity increased from 67.85% in the 1^{st} week to 92.63% in the 13^{th} week; in cv. Kabaaşı, it increased from 63.39% in the 1^{st} week to 87.07% in the 13^{th} week. The increase in the spherical value of the fruit is due to the sugar regulated by genetic factors, the softening of the cell wall, the loss of water, and the tissue remodeling controlled by ripening hormones (Gapper *et al.*, 2013). Özelçi *et al.*, (2021b) reported that about 50% of the increase in fruit weight at different ripening stages (1^{st} day, 15^{th} day, 30^{th} day, 44^{th} day, 59^{th} day, 74^{th} day, 96^{th} day, 103^{rd} day and 110^{th} day) in cv. Soğancı apricot was realized in the last one-month period, and fruit sizes reached the largest value (length: 38.82 mm, width: 40.86 mm, thickness: 45.78 mm) at the full ripening stage on the 110^{th} day.

Table 1. Changes in selected physical characteristics of apricot cultivars Hacihaliloğlu and Kabaaşı throughout the ripening period.

Cultivars	Harvest number	Fruit width (mm)	Fruit length (mm)	Fruit thickness (mm)	Fruit weight (g)	Sphericity (%)
Hacıhaliloğlu	1	10.60 ± 0.16^{j}	17.48 ± 0.17^{o}	9.03 ± 0.14^{p}	0.69 ± 0.42^{r}	67.85 ± 0.29^{k}
	2	19.50 ± 0.38^{i}	27.33 ± 0.16^{m}	16.35 ± 0.14^{o}	4.64 ± 0.97^{p}	75.22 ± 0.50^{j}
	3	21.95 ± 0.18^{hi}	28.24 ± 0.20^{l}	19.25 ± 0.15^{n}	6.63 ± 0.12^{o}	80.92 ± 0.31^{g}
	4	23.11 ± 0.18^{hi}	29.38 ± 0.24^{k}	20.17 ± 0.64^{lm}	7.84 ± 0.18^{no}	80.83 ± 1.49^{g}
	5	31.59 ± 7.00^{bcd}	29.23 ± 0.18^{k}	20.85 ± 0.19^{kl}	8.43 ± 0.17^{mn}	87.22 ± 3.23^{cd}
	6	25.19 ± 0.22^{fgh}	30.31 ± 0.20^{j}	22.50 ± 0.18^{hij}	10.09 ± 0.21^{kl}	$85.12 \pm 0.33^{c-f}$
	7	24.98 ± 0.20^{fgh}	30.52 ± 0.19^{ij}	22.37 ± 0.17^{ij}	9.87 ± 0.19^{l}	84.34 ± 0.29^{ef}
	8	25.08 ± 0.24^{fgh}	30.71 ± 0.19^{ij}	22.86 ± 0.22^{h}	10.35 ± 0.18^{kl}	84.69 ± 0.31^{def}
	9	$27.95 \pm 0.33^{d-g}$	32.47 ± 0.31^{h}	25.30 ± 0.28^{g}	13.93 ± 0.74^{i}	87.53 ± 0.38^{c}
	10	30.64 ± 0.41^{cde}	34.77 ± 0.46^{f}	29.25 ± 0.38^{e}	18.10 ± 0.61^{gh}	90.54 ± 0.43^{b}
	11	$31.82 \pm 0.34^{a-d}$	35.65 ± 0.35^{f}	30.73 ± 0.28^{d}	18.81 ± 0.82^{fg}	91.65 ± 0.27^{ab}
	12	34.45 ± 0.27^{abc}	37.53 ± 0.42^{de}	33.02 ± 0.19^{bc}	23.70 ± 0.46^{e}	93.24 ± 0.51^{a}
	13	35.15 ± 0.23^{abc}	38.55 ± 0.27^{c}	33.57 ± 0.20^{ab}	25.55 ± 0.39^{d}	92.63 ± 0.33^{ab}
Kabaaşı	1	11.28 ± 0.34^{j}	20.24 ± 0.22^{n}	9.31 ± 0.14^{p}	1.04 ± 0.44^{r}	63.39 ± 0.57^{l}
	2	19.48 ± 0.15^{i}	31.31 ± 0.19^{i}	16.49 ± 0.14^{o}	5.11 ± 0.11^{p}	68.93 ± 0.23^{k}
	3	23.04 ± 0.18^{hi}	33.68 ± 0.28^{g}	19.63 ± 0.18^{mn}	7.92 ± 0.19^{no}	73.62 ± 0.28^{j}
	4	24.22 ± 0.22^{gh}	34.81 ± 0.28^{f}	21.70 ± 0.25^{jk}	9.61 ± 0.26^{lm}	75.68 ± 0.24^{ij}
	5	25.63 ± 0.30^{fgh}	35.13 ± 0.31^{f}	22.78 ± 0.30^{hi}	11.28 ± 0.40^{jk}	77.88 ± 0.33^{hi}
	6	$26.65 \pm 0.33^{e-h}$	35.54 ± 0.26^{f}	23.38 ± 0.51^{h}	12.55 ± 0.40^{j}	78.87 ± 0.75^{gh}
	7	$28.21 \pm 0.37^{d-g}$	37.16 ± 0.28^{e}	25.29 ± 0.35^{g}	15.04 ± 0.52^{i}	80.17 ± 0.47^{gh}
	8	29.63 ± 0.29^{def}	38.13 ± 0.22^{cd}	26.47 ± 0.27^{f}	17.03 ± 0.40^{h}	81.38 ± 0.42^{g}
	9	31.40 ± 0.27^{bcd}	38.88 ± 0.34^{c}	28.56 ± 0.32^{e}	19.59 ± 0.47^{f}	84.04 ± 0.47^{f}
	10	34.64 ± 0.48^{abc}	41.42 ± 0.44^{b}	32.44 ± 0.50^{c}	25.94 ± 0.96^{cd}	86.75 ± 0.33^{cde}
	11	35.70 ± 0.31^{ab}	42.96 ± 0.29^{a}	33.43 ± 0.26^{ab}	27.85 ± 0.50^{ab}	$86.48 \pm 0.40^{c-f}$
	12	36.46 ± 0.40^{a}	43.46 ± 0.38^{a}	34.20 ± 0.34^{a}	28.79 ± 0.74^{a}	87.07 ± 0.40^{cd}
	13	35.56 ± 0.77^{ab}	43.13 ± 0.51^{a}	35.52 ± 0.26^{c}	27.15 ± 1.06^{bc}	$85.33 \pm 0.32^{c-f}$
Sig.		0.000	0.000	0.000	0.000	0.000

Means with different letters in the same column differ significantly (Duncan's test, $p<0.05$) (n=30)

Table 2. Changes in color values of the apricot cultivars Hacıhaliloğlu and Kabaaşı during the ripening period.

Cultivars	Harvest number	L	a*	b*	Hue	C*
	1	28.99 ± 0.25^{j}	-3.92 ± 0.21^{cd}	9.45 ± 0.37^{i}	112.52 ± 0.60^{ab}	10.23 ± 0.41^{j}
	2	46.21 ± 0.39^{i}	-13.37 ± 0.16^{g}	26.47 ± 0.29^{fgh}	116.80 ± 0.40^{ab}	29.66 ± 0.26^{f-i}
	3	50.40 ± 0.57^{ghi}	-14.13 ± 0.60^{g}	30.26 ± 0.46^{bcd}	115.01 ± 0.90^{ab}	33.41 ± 0.54^{efg}
	4	46.13 ± 0.56^{i}	-11.93 ± 1.27^{efg}	23.82 ± 1.49^{def}	116.19 ± 1.19^{ab}	26.67 ± 1.88^{hi}
	5	48.51 ± 0.60^{hi}	-11.15 ± 0.69^{efg}	22.66 ± 0.90^{gh}	116.09 ± 0.62^{ab}	25.26 ± 1.10^{i}
	6	48.37 ± 0.80^{hi}	-12.47 ± 0.63^{fg}	24.32 ± 1.29^{gh}	117.17 ± 0.36^{a}	27.33 ± 1.42^{hi}
Hacıhaliloğlu	7	48.49 ± 1.81^{hi}	-11.69 ± 1.08^{efg}	24.39 ± 2.76^{gh}	115.94 ± 0.85^{ab}	27.07 ± 2.93^{hi}
	8	50.71 ± 1.73^{ghi}	-12.86 ± 0.88^{fg}	25.69 ± 2.31^{gh}	116.80 ± 0.70^{ab}	28.74 ± 2.44^{ghi}
	9	55.24 ± 1.48^{ef}	-13.63 ± 0.33^{g}	31.45 ± 1.13^{de}	113.53 ± 0.83^{ab}	34.29 ± 1.07^{ef}
	10	66.49 ± 1.15^{bcd}	-8.49 ± 1.85^{ef}	39.80 ± 0.65^{c}	102.02 ± 2.67^{c}	40.91 ± 0.49^{cd}
	11	70.40 ± 2.03^{b}	-7.69 ± 0.96^{de}	45.85 ± 1.59^{b}	99.72 ± 1.46^{c}	46.57 ± 1.44^{b}
	12	64.55 ± 0.11^{cd}	4.00 ± 2.66b	40.47 ± 0.24^{a}	84.48 ± 3.73^{e}	41.10 ± 0.28^{cd}
	13	79.38 ± 1.39^{a}	7.92 ± 2.58^{b}	55.81 ± 0.52^{g}	81.97 ± 2.62^{e}	56.66 ± 0.52^{a}
	1	29.77 ± 0.20^{j}	-3.46 ± 0.30^{c}	8.39 ± 0.54^{i}	112.28 ± 0.65^{ab}	9.08 ± 0.61^{j}
	2	46.85 ± 0.834^{hi}	-11.42 ± 0.63^{efg}	2659 ± 0.64^{fgh}	113.25 ± 1.24^{ab}	28.97 ± 0.63^{ghi}
	3	48.53 ± 1.19^{hi}	-11.39 ± 1.01^{efg}	28.45 ± 1.31^{efg}	111.62 ± 0.94^{ab}	30.66 ± 1.58^{fgh}
	4	48.33 ± 0.64^{hi}	-13.38 ± 0.43^{g}	27.58 ± 0.71^{efg}	115.87 ± 0.28^{ab}	30.66 ± 0.82^{fgh}
	5	51.31 ± 1.47^{fgh}	-12.38 ± 1.75^{fg}	25.33 ± 2.21^{gh}	115.25 ± 1.85^{ab}	28.25 ± 2.72^{hi}
	6	49.39 ± 0.81^{ghi}	-12.49 ± 0.59^{fg}	26.64 ± 0.66^{fgh}	115.16 ± 1.34^{ab}	29.46 ± 0.55^{ghi}
Kabaaşı	7	53.29 ± 0.94^{fg}	-13.48 ± 1.16^{g}	26.38 ± 2.43^{fgh}	117.17 ± 0.59^{a}	29.60 ± 2.68^{f-i}
	8	57.87 ± 1.38^{e}	-15.14 ± 0.35^{g}	33.68 ± 1.03^{d}	119.24 ± 0.43^{ab}	36.93 ± 1.05^{de}
	9	66.70 ± 2.48^{bc}	-15.26 ± 0.34^{g}	40.24 ± 1.79^{c}	110.99 ± 1.31^{b}	43.09 ± 1.55^{bc}
	10	65.38 ± 2.89^{cd}	-0.03 ± 2.76^{c}	41.33 ± 1.74^{bc}	90.06 ± 3.78^{d}	42.11 ± 1.74^{bc}
	11	68.36 ± 2.98^{bc}	4.31 ± 2.75^{b}	45.57 ± 2.50^{b}	84.24 ± 3.63^{e}	46.22 ± 2.36^{b}
	12	62.22 ± 0.47^{d}	14.26 ± 2.45^{a}	43.80 ± 0.45^{bc}	72.10 ± 3.05^{f}	46.38 ± 0.39^{b}
	13	65.36 ± 0.32^{cd}	13.79 ± 0.11^{a}	43.50 ± 0.54^{bc}	72.41 ± 0.27^{f}	45.64 ± 0.50^{b}
Sig.		0.000	0.000	0.000	0.000	0.000

*Color values are the mean of two replicate experiments with three samples analyzed per replicate (n = 6)

Table 3. Changes in firmness, elasticity, pH, and SSC of the apricot cultivars Hacıhaliloğlu and Kabaaşı during the ripening period.

Cultivars	Harvest number	Firmness (g)	Elasticity (mm)	pH	SSC (%)
	1	1104.21 ± 63.49^{ef}	2.27 ± 0.10^{a}	4.23 ± 0.58^{efg}	6.57 ± 0.54^{g}
	2	1516.19 ± 2014^{ijk}	1.17 ± 0.02^{fgh}	3.28 ± 0.04^{j}	7.07 ± 0.38^{g}
	3	1673.12 ± 15.99^{kl}	1.07 ± 0.03^{gh}	3.08 ± 0.04^{j}	7.60 ± 0.12^{g}
	4	1714.89 ± 10.84^{l}	1.09 ± 0.02^{gh}	3.33 ± 0.02^{j}	8.67 ± 0.08^{efg}
	5	1713.17 ± 100.81^{l}	1.04 ± 0.01^{gh}	3.38 ± 0.02^{ij}	9.73 ± 0.12^{def}
	6	1714.46 ± 29.11^{l}	0.96 ± 0.07^{h}	3.46 ± 0.02^{ij}	10.43 ± 0.28^{de}
Hacıhaliloğlu	7	1497.72 ± 63.11^{ijk}	1.13 ± 0.02^{gh}	3.55 ± 0.02^{hij}	10.53 ± 0.20^{de}
	8	1491.02 ± 96.50^{hij}	1.11 ± 0.02^{gh}	3.83 ± 0.04^{ghi}	10.47 ± 0.32^{de}
	9	1215.11 ± 23.48^{fg}	1.10 ± 0.04^{gh}	3.97 ± 0.07^{fgh}	10.47 ± 0.37^{de}
	10	878.41 ± 25.42^{d}	1.26 ± 0.06^{e-h}	4.22 ± 0.11^{efg}	16.50 ± 0.92^{bc}
	11	654.41 ± 24.83^{c}	1.44 ± 0.03^{d-g}	4.38 ± 0.04^{def}	14.70 ± 0.30^{c}
	12	622.05 ± 28.13^{c}	1.78 ± 0.22^{bcd}	4.65 ± 0.05^{cde}	20.70 ± 1.40^{a}
	13	464.74 ± 5.81^{ab}	2.16 ± 0.25^{ab}	5.03 ± 0.10^{abc}	16.50 ± 0.15^{bc}
	1	1015.03 ± 37.59^{de}	1.68 ± 0.07^{cde}	3.42 ± 0.20^{ij}	7.93 ± 0.34^{fg}
	2	1341.78 ± 36.62^{gh}	1.15 ± 0.02^{gh}	3.32 ± 0.02^{j}	7.77 ± 0.64^{fg}
	3	1474.10 ± 32.25^{hi}	1.12 ± 0.02^{gh}	3.19 ± 0.06^{j}	8.00 ± 0.20^{fg}
	4	1648.19 ± 34.13^{jkl}	1.28 ± 0.33^{e-h}	3.39 ± 0.02^{ij}	8.00 ± 0.60^{fg}
	5	1525.97 ± 93.01^{ijk}	1.13 ± 0.03^{gh}	3.51 ± 0.06^{hij}	9.70 ± 0.10^{def}
	6	1545.58 ± 67.96^{ijkl}	1.05 ± 0.09^{gh}	3.49 ± 0.05^{ij}	10.10 ± 0.42^{de}
Kabaaşı	7	1570.75 ± 23.01^{ijkl}	1.19 ± 0.03^{fgh}	3.56 ± 0.05^{hij}	10.87 ± 0.23^{d}
	8	1205.93 ± 26.39^{fg}	1.14 ± 0.01^{gh}	4.05 ± 0.12^{fg}	11.43 ± 0.79^{d}
	9	1028.83 ± 122.73^{de}	1.10 ± 0.03^{gh}	4.18 ± 0.14^{efg}	11.73 ± 1.11^{d}
	10	641.83 ± 49.26c	1.51 ± 0.08^{d-g}	4.80 ± 0.14^{bcd}	16.40 ± 1.46^{bc}
	11	495.76 ± 1.94bc	1.61 ± 0.09^{c-f}	5.10 ± 0.17^{abc}	17.00 ± 0.74^{b}
	12	410.99 ± 26.09ab	1.97 ± 1.97^{abc}	5.22 ± 0.51^{ab}	22.53 ± 0.97^{a}
	13	320.12 ± 35.52a	2.33 ± 0.39^{a}	5.33 ± 0.27^{a}	21.20 ± 0.60^{a}
Sig.		0.000	0.000	0.000	0.000

Means in the same column with different letters differ significantly (Duncan's test, $p<0.05$)

Color properties: The color of the skin is an important indicator of the ripeness of the fruit and an important criterion for determining the right time to harvest (Ninio *et al*., 2003). In the present study, both apricot cultivars showed a noticeable increase in L, a, and b* values as ripening progressed. In the Hacıhaliloğlu cultivar, the L* value increased from 28.99 to 79.38, the a* value from -3.92 to 7.92, and the b* value from 9.45 to 55.81 between the initial and final weeks of the ripening period. Similarly, in the Kabaaşı cultivar, the L* value increased from 29.77 to 65.36, the a* value from -3.46 to 13.79, and the b* value from 8.39 to 43.50 (Table 2). In both cultivars, the increase in L* from the 1st week to harvest caused a lighter and brighter fruit color, while the increase in a* indicated a decrease in green tones and the appearance of red tones. Similarly, the increase in b* showed the dominance of yellow tones. These changes are important to determine the degree of ripeness and harvest time.

In apricots, the chlorophyll content is higher at the unripe stage, while the anthocyanin content increases significantly as the fruit ripens. This increase particularly promotes the formation of red coloration on the sun-exposed sides of the fruit (Aslantaş, 2016). Femenia *et al*., (1998) reported that the color of apricot fruit changes from green to yellow and red during ripening. Abacı (2007) reported an increase in L*, a*, and b* color parameter values with increasing maturity in a study conducted on five apricot cultivars. The results on the changes in fruit skin color in both apricot cultivars were consistent with the results of previous studies.

Hue angle (h*) defines the main color (wavelength) and is expressed in degrees: 0-60° for red, 60-120° for yellow, 120-180° for green, 180-240° for cyan, and 240-300° for blue (Manamohana *et al*., 2020). During the ripening process, the hue angle value of the cv. Hacıhaliloğlu decreased from 112.52 in the 1st week to 81.87 in the last week. This value also fell for cv. Kabaaşı from 112.28 in the 1st week to 72.41 in the last week. The Hue angle was similarly high for both cultivars in the first 9 weeks, but after the 10th week, it decreased significantly for both cultivars. Chroma reflects the intensity or brightness of a color, with higher chroma values indicating more saturated colors and lower values representing paler hues (Granato & Masson, 2010). During ripening, the chroma value of Hacıhaliloğlu increased significantly from 10.23 to 56.66 from the first to the last week, while Kabaaşı rose from 9.08 to 45.64, indicating lower color saturation. This result demonstrates that Hacıhaliloğlu developed more vivid colors as it matured.

Fruit firmness and elasticity: Fruit texture is a physical property that results from the complex interaction of cell structure, water content, pectin, and fiber content, ripeness stage, and genetic characteristics and is perceived by the consumer as softness or firmness (Li *et al*., 2010). In both cultivars, firmness (hardness) increased rapidly in the first 7 weeks, from 1104.21 g to 1714.89 g for cv. Hacıhaliloğlu and from 1015.03 g to 1570.75 g for cv. Kabaaşı. From the 7th week, the firmness of both varieties began to decrease, reaching 464.74 g for Hacıhaliloğlu and 320.12 g for Kabaaşı at the end of the ripening process (Table 3). Fluctuations in the elasticity values were observed in both cultivars. In cv. Hacıhaliloğlu, the elasticity was 2.27 in the first week, decreased to 0.96 in the following weeks, increased sharply to 11.23 in the 8th week, then reduced again and reached its highest value (2.16) in the 13th week. In cv. Kabaaşı, the elasticity started at 1.68 in the first week, reached its lowest point at 1.05 in the 6th week, then gradually increased and reached its highest value (2.33) in the 13th week (Table 3). Fruit elasticity is important because it increases resistance to mechanical damage, maintains freshness, indicates the optimum degree of ripeness, and extends shelf life, ensuring better quality and consumer satisfaction (Paliyath *et al*., 2009). The breakdown of pectin causes fruit softening, the dissolution of cell walls, and the influence of the hormone ethylene (Tucker *et al*., 2017).

Soluble solids content (SSC) and pH: Soluble solids content (SSC), measured in degrees Brix, indicates the concentration of dissolved sugars in fruits and vegetables and reflects the degree of ripeness, sweetness, and flavor quality (Hirsch *et al*., 2012). Both cultivars showed a general increase in sugar content during the ripening process. For cv. Hacıhaliloğlu, the SSC (Brix) value increased from 6.57% in the first week to 10.53% in the 7th week and peaked at 20.70% in the 12th week before dropping to 16.50% in the 13th week. Fluctuations in the sugar content were observed throughout the process. In cv. Kabaaşı, the SSC value increased steadily, starting at 7.93% in the first week and reaching 16.40% in the 10th week. The highest value of 22.53% was recorded in the 12th week and decreased slightly to 21.20% in the 13th week (Table 3). The SSC value increases during ripening as starch is enzymatically converted into simple sugars such as glucose, fructose, and sucrose. (Magwaza *et al*., 2015). In a study, Karabulut *et al*., (2018) reported SSC in unripe and ripe apricot fruits as 16.25% and 23.50% for cv. Hacıhaliloğlu and 18.73% and 22.60% for cv. Kabaaşı, respectively. On the other hand, the acidity of both cultivars decreased, and the pH value increased in a similar way with the ripening process. While the pH of cv. Hacıhaliloğlu started at 4.23 and reached 5.03 at week 13, the pH of cv. Kabaaşı increased from 3.42 to 5.33. Kabaaşı reached a higher pH than Hacıhaliloğlu, indicating that it has a less acidic structure.

Organic and phenolic components: The contents of organic acids (ascorbic acid and citric acid) and phenolic components (gallic acid and catechin) of the cv. Hacıhaliloğlu and Kabaaşı are shown in Figure 2. The ascorbic acid content of both cultivars fluctuated in the individual weeks. The highest value was recorded in the 4th week (436.68 mg 100 g^{-1} fw) for the cv. Hacıhaliloğlu and in the 5th week (449.31 mg 100 g^{-1} fw) for the cv. Kabaaşı. The ascorbic acid decreased in both cultivars from the 6th week (Fig. 2). Generally, no significant difference was observed between the two cultivars regarding ascorbic acid content. Citric acid reached higher values in cv. Hacıhaliloğlu than in cv. Kabaaşı. Citric acid reached the highest value in cv. Hacıhaliloğlu in the 8th week (5398.88 mg 100 g^{-1} fw), and although it decreased from the 9th week onwards, it remained at a high level compared to cv. Kabaaşı. Citric acid amount of cv. Kabaaşı followed a fluctuating course during the growth period. The values started low in the first few weeks, peaked in the 7th and 9th weeks (868.17 mg 100 g^{-1} fw and 1486.74 mg 100 g^{-1} fw, and then fell rapidly to 47.73 mg 100 g^{-1} fw in the 13th week.

In previous studies, Shiratake & Martinoia (2007) found that organic acids increase in the early ripening stage (30-60 days after full bloom), and therefore the fruits have an acidic taste until ripening. Fan *et al.* (2017) found the ascorbic acid content in seven apricot cultivars at commercial and tree-ripened stages of 18–7 100 g^{-1} fw and 7.1–15.3 100 g^{-1} fw, respectively. Su *et al.*, (2020) reported that citric acid accounted for between 8.32% and 63.60% of the total organic acid content in five different apricot cultivars and that this acid was the second most abundant organic acid. Gottingerova *et al.*, (2021) reported an ascorbic acid content between 1.86 and 10.78 100 g^{-1} fw in 15 apricot cultivars.

The main polyphenols in apricot fruit are phenolic acids (chlorogenic, ferulic, and gallic) and flavonoids (rutin, catechin, and epicatechin) (Gundogdu *et al.*, 2017). In both cultivars in the study, the catechin content was highest in the 1st week 287.33 100 g^{-1} fw and 204.30 100 g^{-1} fw respectively and decreased significantly in the following weeks (Fig. 3). Although the cv. Kabaaşı had a higher catechin content than cv. Hacıhaliloğlu in the 1st week, this decreased very quickly, especially in the 2nd week. Cv. Hacıhaliloğlu, on the other hand, showed a more gradual decrease. Both cultivars had the lowest catechin content in the 13th week 8.37 100 g^{-1} fw and 6.31 100 g^{-1} fw, respectively.

Gallic acid was the highest in both cultivars in the 1st week. In the 1st week, cv. Hacıhaliloğlu (2643.24 100 g^{-1} fw) contained about 2 times more gallic acid than cv. Kabaaşı (1381.68 100 g-¹ fw). In the following weeks, cv. Kabaaşı showed a low, stable decrease in gallic acid content, while cv. Hacıhaliloğlu showed a faster decrease. In the last week, gallic acid levels were similar in both cultivars (374.79 100 g^{-1} fw for Hacıhaliloğlu and 354.96 100 g^{-1} fw for Kabaaşı) (Fig. 3).

In a previous study, Gundogdu *et al.*, (2017) reported that catechin content varied between 8.84-220.12 µg g^{-1} dw matter and gallic acid content varied between 9.68-127.76 µg g^{-1} dw in 8 apricot cultivars. Gottingerova *et al.*, (2021) reported that catechin content in 15 apricot varieties ranged from 0.55 to 10.75 mg100 g^{-1} fw. Tan *et al.*, (2023) found that in cv. Shalakh, gallic acid content decreased significantly during fruit growth, while catechin content initially decreased but then showed a steady increase or no decrease. These differences in bioactive compounds are mostly related to climate, soil structure, variety, and ripening time (Çuhacı *et al.*, 2021).

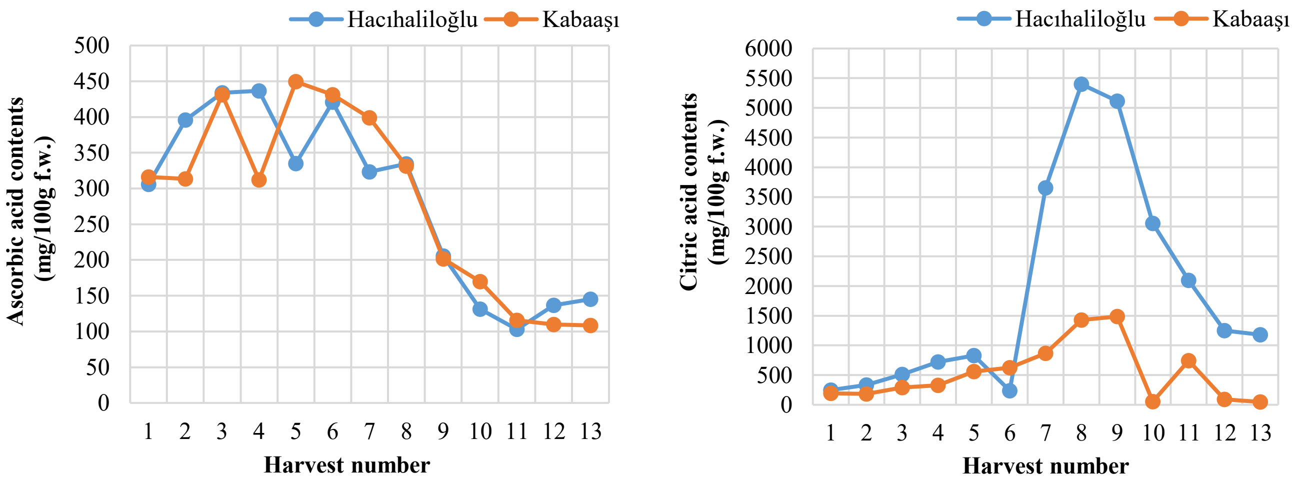

Fig. 2. Changes in organic acid content during the ripening period of Hacıhaliloğlu and Kabaaşı apricot cultivars.

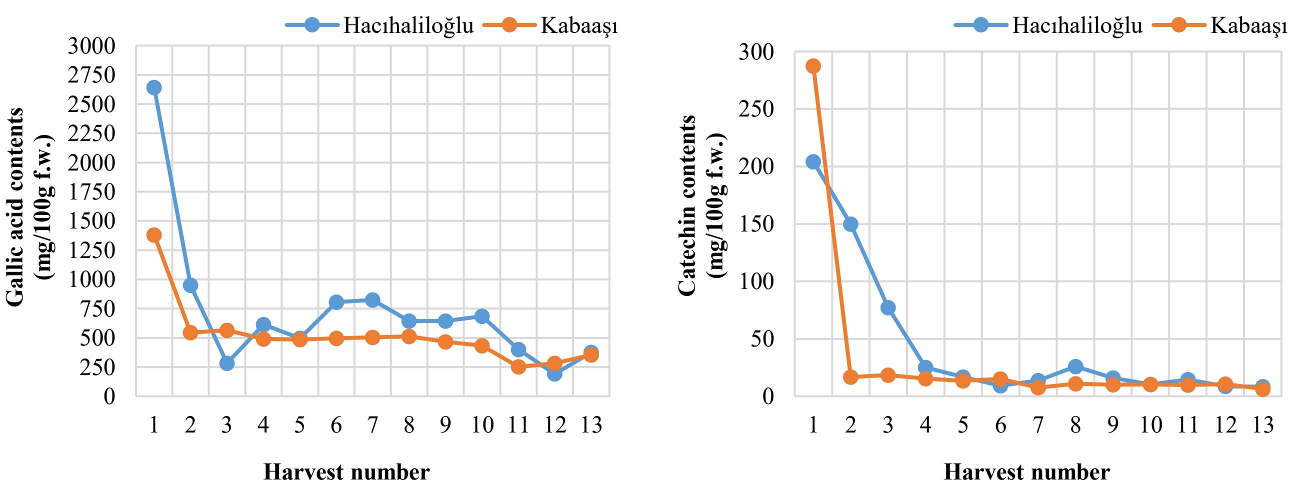

Fig. 3. Changes in phenolic acid content during the ripening period of Hacıhaliloğlu and Kabaaşı apricot cultivars.

Conclusion

In this study, the physicochemical changes of the apricot cultivars Hacıhaliloğlu and Kabaaşı during ripening were investigated, and the role of these changes in determining the optimal harvest time was evaluated. Significant changes in fruit weight, size, color parameters, pH, sugar content, hardness, and biochemical components were observed in both varieties throughout the study. A steady increase in fruit weight and size was observed in both cultivars, and growth accelerated in both cultivars, especially after week 9. Fruit sphericity increased, while textural traits firmness and elasticity showed significant changes in the later weeks of ripening. The changes in color parameters (L*, a*, b*) showed that the fruits changed significantly during ripening in brightness, redness, and yellowness. These changes play a decisive role in determining the time of harvest.

In chemical analysis, pH increased, acidity decreased, and sugar content increased in both varieties. Sugar content peaked in the 12th week, and this week was determined to be the peak of chemical maturity for both varieties. Differences in organic acids and phenolic compounds were observed between the varieties; the Hacıhaliloğlu variety had a richer profile in citric acid, while the decreases in gallic acid and catechin levels were similar in both varieties.

In summary, this study comprehensively evaluated the ripening process of Hacıhaliloğlu and Kabaaşı cultivars provided a scientific basis for determining the optimum harvest time in apricot cultivation and provided important information to guide producers to maximize fruit quality. In particular, the findings are expected to help meet consumer expectations and improve industrial processing efficiency. Based on these results, it is recommended that growers and industry stakeholders carefully monitor ripening parameters around the 12th week to precisely time harvests, thereby maximizing fruit quality, extending shelf life, and enhancing processing performance.

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