ACTA Acta Sci. Pol. Hortorum Cultus, 22(1) 2023, 37–46

https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 https://doi.org/10.24326/asphc.2023.4807

ORIGINAL PAPER

Accepted: 1.08.2022
Published: 24.02.2023

DETERMINATION OF OPTIMUM HARVEST TIME AND PHYSICAL AND CHEMICAL QUALITY PROPERTIES OF SHALAKH (APRIKOZ) APRICOT CULTIVAR DURING FRUIT RIPENING

Betül Tan[1], Emrah Kuş[2], Kadir Tan[3], Ersin Gülsoy[4]✉, Duried Alwazeer[5]

[1] Iğdır Vocational School of Higher Education, Department of Hotel, Restaurant and Catering Services, Igdir University, 76000 Igdir, Türkiye

[2] Department of the Biosystems Engineering, Faculty of Agriculture, Igdir University, 76000 Igdır, Türkiye

[3] Research Center for Redox Applications in Foods (RCRAF), Igdir University, 76000 Igdır, Türkiye

[4] Department of Horticulture, Faculty of Agriculture, Igdir University, 76000 Igdır, Türkiye

[5] Department of Nutrition and Dietetics, Faculty of Health Sciences, Igdir University, 76000 Igdır, Türkiye

ABSTRACT

Shalakh (Aprikoz), the most common table apricot cultivar grown in Iğdır province of Turkey, is known for its delicious taste, large volume, high water content, and short shelf life. This study aimed to determine optimal harvest time of cv. Shalakh apricot by measuring some significant physical and chemical parameters. Fruits were collected periodically at interval of 7 day during the study period. Weight, length, width, thickness, sphericity, color, color indices, soluble solids content, pH, firmness, elasticity, phenolic content (gallic acid and catechin) and organic acids (citric acid and ascorbic acid) were evaluated. Weight, length, width, thickness and sphericity traits increased gradually and reached the highest levels at 10th week after the full bloom. Color parameters (L*, a*, b*, C*, h° and ΔE), hardness, elasticity and organic acids indicated the optimal harvest time of cv. Shalakh of 10th week after the full bloom. Unlike previous studies, SSC and pH didn't show clear information for harvest time.

Key words: optimal harvest time, quality characteristics, apricot, Shalakh, Iğdır

INTRODUCTION

Apricot (*Prunus armeniaca* L.) is a stone fruit and member of the Rosaceae family that includes about 100 genus and 2380–3100 species [Moustafa and Cross 2019]. The most cultivated species of apricots required cold winter and high temperatures in spring and initial of summer [Khursheed et al. 2020]. Today, the largest apricot production of the world is the Mediterranean region and the Central Asian countries such as Turkey, France, Spain, Algeria, Italy, Uzbekistan, and Iran [Çuhacı et al. 2021]. Turkey is one of the major producers of both the fresh and the dried apricot [Asma and Ozturk 2005]. Turkey is the leading apricot producing country with 833.398 tons in 2020 [FAO 2022] Although apricots are cultivated throughout Turkey, the best climate conditions for cultivation are in the central Eastern Anatolia region. Especially, Malatya, Aras valley (Iğdır-Kağızman), Erzincan and Mut provinces produce about 70–75% of Turkey's total apricot production [Ercisli 2009]. Iğdır is placed on Eastern Turkey and is a microcli-

✉ ersin.gulsoy@igdir.edu.tr

mate region that provides convenient conditions for agriculture [Hakgüder Taze 2017]. Shalakh is the most common apricot cultivar grown in Iğdır region with 90–95% percentage [Güleryüz et al. 1999] and consumed generally as fresh. Shalakh cultivar is originally synonym of Aprikoz cultivar and is originated from Soviet Union [Gecer et al. 2020].

Apricot commonly starts to bloom in mid-March period depending on cultivar and region, and it ripens from June to the middle of August according to variety [Moustafa and Cross 2019]. *Prunus* genera develop in three different stages. In the first stage, a rapid growth phase managed by cell division and expansion that occurs and lasts in 3–4 weeks. In the second stage, fruit stone begins to harden progressively. This stage is slow and takes about several weeks for early-maturing cultivars and longer for late-maturing cultivars. The last stage is a rapid growth phase in which ethylene, sugars and aroma compounds accumulate and generally start 4–6 weeks before harvest phase [Moustafa and Cross 2019]. The maturity level of harvested fruit is one of the most critical factors that establishes final quality [Petrisor et al. 2006]. Determination of the optimal harvest time is a very important issue; and different physical-biochemical parameters such as color, texture, soluble solids content, dry matter and acidity are used as significant quality indicators to establish optimal harvest time [Chira et al. 2012]. However, although previous studies investigated the optimal harvest time of apricot cultivars, these studies were limited with just two or three different maturity stages of fruit.

The aim of this study was to determine the optimal harvest time of Shalakh apricot cultivar grown in Iğdır region based on different physical and chemical properties for scheduling harvest and helping producers, merchants and consumers to determine the optimal time for harvesting Shalakh apricot cultivar at best quality properties phase.

MATERIAL AND METHODS

Plant materials and sampling

Shalakh apricot cultivar was collected from an orchard located in Iğdır, Turkey. First, fruit collection was made at first week of May after one week of full bloom, and fruits were harvested at 7-day intervals until the second week of July (Fig. 1). For every week, 30 fruits were harvested randomly from different trees (10 fruits from each tree from four sides) in the same orchard and then were placed in plastic bags, transferred to the laboratory for immediate physical analysis or stored at –18°C for chemical analysis.

Physical properties

Color measurement. Apricot skin color measurements were performed according to Karabulut et al. [2007] using a colorimeter (Minolta, CR 410, Osaka, Japan) by taking three different measurements of the fruit skin. The measurements were expressed as CIE L*, a*, and b* values. ΔE (total color difference), C* (chroma) and h° (hue angle) were calculated using the following equation:

$$\Delta E = [(L^*_i - L^*_f)^2 + (a^*_i - a^*_f)^2 + (b^*_i - b^*_f)^2]^{1/2}$$

$$C^* = \sqrt{a^2 + b^2}$$

$$h° = \arctan b^*/a^*$$

Weight, length, width, thickness and sphericity measurement. 30 apricot fruits were used for this morphological analysis. Measurements of fruit weight, length, width, thickness and sphericity were performed for each individual fruit sample. The four dimensions (length, width, thickness and sphericity) and weight of samples were measured by using a digital caliper (Astor, Turkey) and electronic weight balance (AND, FZ-5000i, Japan) with 0.01 g precision.

Fruit firmness and elasticity measurement. Fruit firmness and elasticity were measured using a texture analyzer (Model TA-XT2, Stable Microsystems, Surrey, UK) with a 2 mm diameter cylindrical stainless-steel probe. The test conditions were as follows: pre-speed and post-speed of 5 mm/s, test speed of 1 mm s^{-1}, and penetration distance of 3 mm [Cui et al. 2008].

Chemical properties

Soluble solid content (SSC) and pH measurements. Soluble solid content (SSC) of filtered apricot juice was measured using a refractometer (Boeco Digital Abbe Refractometer, BOE 32400, Germany) and expressed as °Brix. The pH of the filtered sample juice was determined by using a multiparameter ana-

Fig. 1. Growth and ripening stages of fruit of Shalakh (Aprikoz) apricot cultivar

lyzer (Consort, C3040, Belgium) with a pH electrode (SP10B, Consort, Belgium).

Sample extraction. The apricot samples were extracted according to the method proposed by Alwazeer and Örs [2019] with slight modifications. Fruit sample (5 g) was dissolved with 10 ml of 50% methanol (v/v) containing 0.1% HCl and homogenized (IKA Ultra Turrax, T18 model, Korea) at 1300 rpm for 1 min. The homogenate was left in the dark for 2 h at room temperature. The extract was centrifuged at 10,000 × g at 10°C for 15 min, and the supernatant was filtered with a Whatman No. 4 filter paper followed with an 0.45 µm filter. The filtrate was stored at −80°C until analysis.

HPLC analysis of organic acids and phenolic content. Organic acid measurement were carried out isocratically according to Akin et al. [2008] with slight modifications using an Agilent 1260 series High-performance liquid chromatography (HPLC) system equipped with diode-array detection (DAD) and ACE GENERİX 5 C18 column (5 µm, 4.6 mm × 250 mm). HPLC elution was performed at 30°C using 98% Na_2HP_4 (pH 2.4 adjusted with H_3PO_4) and the mobile phase flow rate was 1 ml min^{-1}. The chromatograms were detected at 210 nm and 400 nm for citric acid and ascorbic acid, respectively.

Separation of phenolics (gallic acid and catechin) was performed using the method described by Hussain et al. [2013] with slight modifications using an HPLC (Agilent 1260 series) system equipped with DAD and Poroshell 120 EC-C18 column (2.7µm, 4.6 mm × 150 mm). A gradient mobile phase consisting of 83% phosphoric acid and 17% acetonitrile was used as mobile phase B at a flow rate of 1 ml/min, with an injection volume of 20 µl. The following gradient used was as follows: A = 83, T = 1 min; A = 70%, T = 2 min; A = 60%, T = 4; min and A = 83%, 10 min. Operating conditions were as follows: detector wavelength of 210 and 300 nm; injection volume of 20 µL; and column temperature of 20°C.

Statistical analysis. The data were analyzed statistically by one-way analysis of variance (ANOVA) with Duncan's multiple range tests ($P < 0.05$) using SPSS statistical software 18 (SPSS Inc., Armonk, NY, USA) presented as mean ± standard deviation.

RESULTS AND DISCUSSION

Color

Color is a crucial indicator for ripeness and harvest date of some fruits [Ninio et al. 2003]. The color values (L*, a*, b*, C*, h and ΔE) and color indices of Shalakh apricot cultivar determined during 11 weeks (from 1st week of May to 2nd week of July) are presented in Table 1. The L* value which represents lightness of the fruit, increased from the 1st week (36.86) to 10th week of ripening (84.17) followed by a decreasing phase. Although L* value was usually used for objective color definition in apricot, a* is the discriminant parameter of the color evaluation in apricot fruit and an indicator of the development of orange and red colors [Ayour et al. 2021]. b* value [blue (−)/yellow (+)] of cv. Shalakh increased gradually up to 10th week of ripening with the highest value of 53.62 followed by decreasing phase at the last week of ripening. This increase in a* and b* value can be explained by the loss of green color tones related with chlorophyll degradation and synthesis of another pigments such as carotenoids [Ayour et al. 2021] as well as the lower chlorophyllase activity during early ripening stages of fruit [Balaguera-López and Arévalo 2012]. Apricot shows a wide range of color diversity changing from light yellow to orange. Polyphenols and carotenes mostly β-caroten have a great role in this phenomenon and are responsible for characteristic color of apricot fruit [Karabulut et al. 2007, Gundogdu et al. 2017].

Table 1. Color values (L*, a*, b*, C*, h and ΔE) of Shalakh (Aprikoz) apricot cultivar

Time (week)	L*	a*	b*	C*	h	ΔE
1	36.86 ±0.34^{a}	–5.01 ±0.24^{e}	7.09 ±0.26^{a}	8.68 ±8.68^{a}	125.22 ±0.52^{g}	–
2	48.47 ±3.80^{b}	–16.17 ±2.17^{ab}	30.01 ±3.14^{c}	34.09 ±3.71^{c}	118.16 ±1.53^{f}	28.01
3	52.43 ±6.5^{bc}	–17.37 ±2.34^{a}	30.86 ±4.84^{c}	35.41 ±5.36^{c}	119.45 ±0.63^{f}	30.98
4	54.54 ±3.02^{cd}	–16.73 ±1.37^{ab}	30.97 ±2.1^{c}	35.20 ±2.48^{c}	118.36 ±0.52^{f}	31.94
5	52.67 ±1.30^{bc}	–15.94 ±0.89^{ab}	29.77 ±1.81^{c}	33.77 ±2.01^{c}	118.17 ±0.34^{f}	29.72
6	50.67 ±0.81^{bc}	–12.51 ±0.64^{cd}	23.81 ±1.1^{b}	26.90 ±1.24^{b}	117.71 ±0.62^{ef}	22.95
7	58.92 ±3.54^{d}	–15.12 ±1.97^{ab}	32.11 ±5.04^{c}	35.50 ±5.40^{c}	115.30 ±0.76^{e}	34.85
8	75.85 ±8.60^{f}	–14.70 ±1.06^{bc}	45.02 ±7.65^{d}	47.39 ±7.52^{d}	109.19 ±3.79^{d}	55.25
9	73.85 ±6.37^{f}	–10.39 ±3.30^{d}	43.71 ±5.05^{d}	45.04 ±4.98^{d}	103.43 ±4.50^{c}	52.33
10	84.17 ±5.06^{g}	2.37 ±2.28^{g}	53.62 ±5.73^{e}	53.71 ±5.79^{e}	87.63 ±2.35^{a}	66.76
11	74.85 ±2.36^{f}	–2.79 ±2.35^{f}	47.24 ±0.51^{d}	47.37 ±0.60^{d}	93.36 ±2.82^{b}	55.32

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

The highest positive a* value [green (–)/red (+)] was obtained at 10th week (2.37) of ripening period with significant difference ($p < 0.05$).

Chroma (C*) is used to define the degree of difference between hue and a grey color with the same lightness [Granato and Masson 2010]. According to the C* measurements of Shalakh cultivar, the lowest and highest values were observed in samples of first week and 10th week of ripening, respectively. The high chroma values represent high color intensity of samples perceived by human's eye [Pathare et al. 2013]. Hue angle (h*) is a useful indicator of maturity stage and is expressed in degrees: 0 (red), 60 (yellow), 120 (green), 180 (cyan), 240 (blue) and 300 (magenta) [Kamal et al. 2014]. h* value of the cv. Shalakh decreased gradually from 1st week (125.22°) to 10th week (87.63°) of ripening stage and increased again at the last week with 93.36°. Since the higher hue angle value demonstrates a lesser yellow color according to the Pathare et al. [2013], samples of 10th week of ripening stage which represents the lowest h* value with significant difference ($p < 0.05$) has more yellow color than the other samples. Total color differences (ΔE) were measured by reference of samples in the first week, and the maximum color difference was obtained for samples at 10th week (66.76). According to the Pathare et al. [2013], differences in perceivable color can be categorized analytically as small difference ($1.5 < \Delta E$), distinct ($1.5 < \Delta E < 3$) and very distinct ($\Delta E > 3$). Since even the lowest ΔE value (22.95) was >3, differences between each week and first week were very distinct.

Weight, length, width, thickness and sphericity

One of the most important parameters affecting consumers' demand is fruit size and weight. These traits have a direct effect on the sales and acceptance of fruits for fresh and processed markets [Hashemi and Khadivi 2020]. A progressive and significant increase in fruit weight, length, width, thickness and sphericity of cv. Shalakh was obtained up to 10th week (Fig. 2). As Singh et al. [2001] stated, the increase in these morphological parameters might have been due to the increase in cell size, intercellular spaces of the flesh and carbohydrate accumulation during the ripening process. Maximum values of weight were 39.60 g, 48.34 mm for length, 40.50 mm for width, 38.99 mm for thickness and 87.79% for sphericity at 10th week of ripening period.

In previous studies, Akin et al. [2008], Karaat and Serçe [2019] and Gecer et al. [2020] reported as 32.33 g, 38.61 g and 38.67 g respectively, the average fruit weight of Shalakh (Aprikoz) apricot cultivar. While results of fruit weight were in agreement with

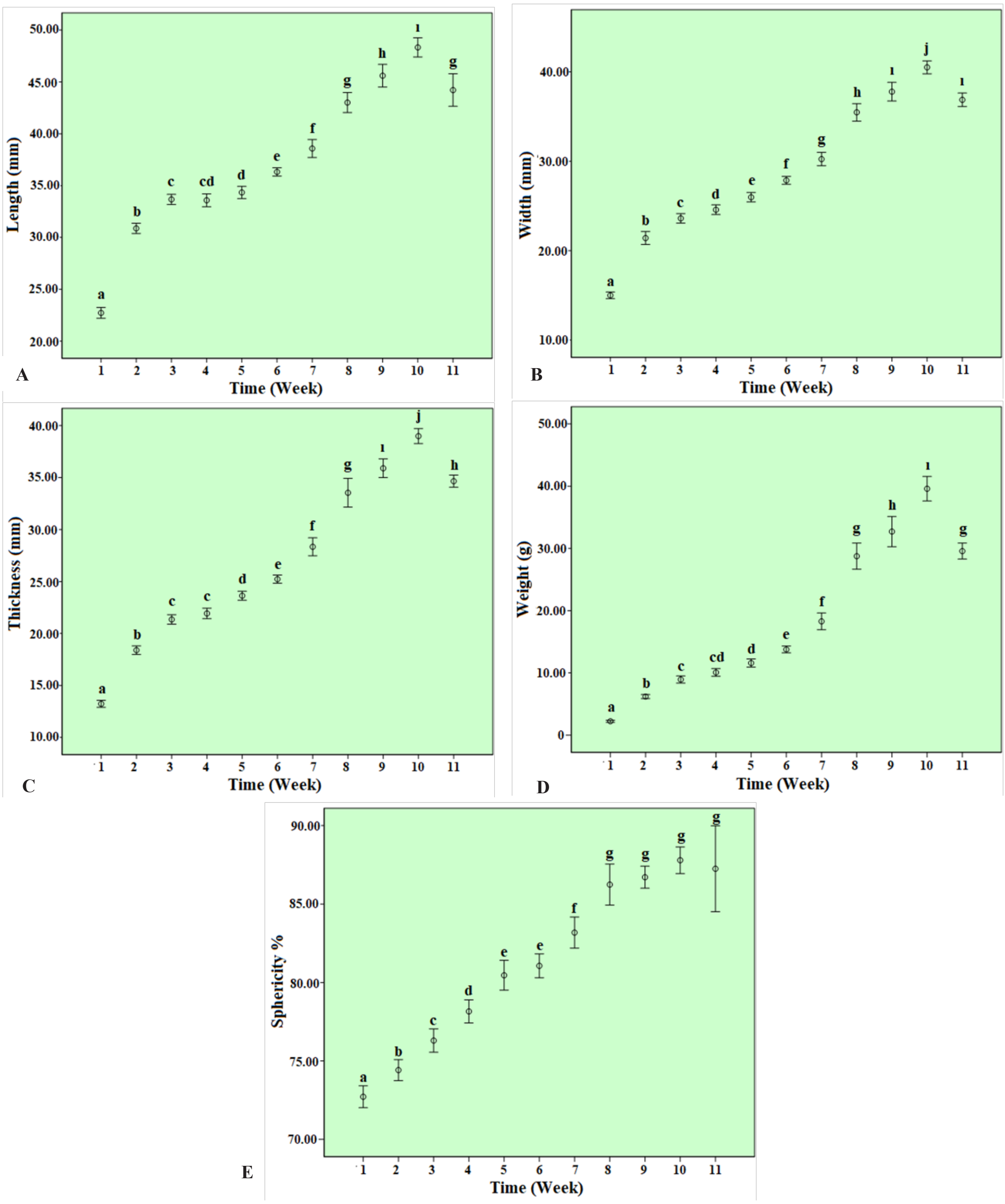

Fig. 2. Changes in weight, length, width, thickness and sphericity of Shalakh (Aprikoz) apricot cultivar during ripening period. The vertical bars represent the standard deviation and results are the mean of thirty different fruit sample experiments (n = 30)

those observed by Karaat and Serçe [2019], and Gecer et al. [2020], our results were higher than those obtained by Akin et al. [2008].

Fruit firmness and elasticity

Texture is often associated with cell wall structure and composition, but other factors such as cell packing, turgor, morphology, shape, size and contents also affect this characteristic [Ella Missang et al. 2012]. According to Figure 3A, the hardness of cv. Shalakh increased in the first three weeks of ripening stage followed by a stable period up to 6th week. However, after this period a significance decrease ($p < 0.05$) was observed with the progress of ripening, and no significant difference was found between the last two weeks (10 and 11 weeks) ($p > 0.05$). On the other hand, the elasticity increased after 6th week (Fig. 3B). Softening of fruit flesh is mainly associated with different phenomena such as breakdown of insoluble protopectines that form the main component of cell wall into soluble pectic compounds, shortening of the polymer chain length, dimethylation of carboxylic group, and diactylation of hydroxy group. These changes influence the cell wall stability with cellulose and hemicelluloses [Singh et al. 2001].

Soluble solids content (SSC) and pH

Soluble solids content (SSC) is one of the most important biochemical traits that was widely used for measurement of the soluble components of fruit including mainly sugars and organic acids in the juice [Hirsch et al. 2012]. During ripening period, a significant decrease ($p < 0.05$) was observed in SSC value of cv. Shalakh at 2th week followed by an increase phase up to the last week (Fig. 4A). No significance difference was found between the last four weeks of ripening process with SSC values ranged from 10.67% to 11.27%. The increase in SSC value could be associated with hydrolysis of starch and polysaccharides in cell wall into simple sugars [Balaguera-López and Arévalo 2012]. Concentration of sugars stored in vacuole usually increase in parallel with a decrease in organic acids content during the progress of ripening, except some fruits such as citrus that acid content increases through time [Bae et al. 2014]. Since SSC affects fruit taste and flavor with feasible accumulation mechanism of flavor compounds [Su et al. 2020], it is reported that SSC should be higher than 12% in fruits and equal to or higher than 11% in table apricots for a preferable taste and flavor [Çuhacı et al. 2021].

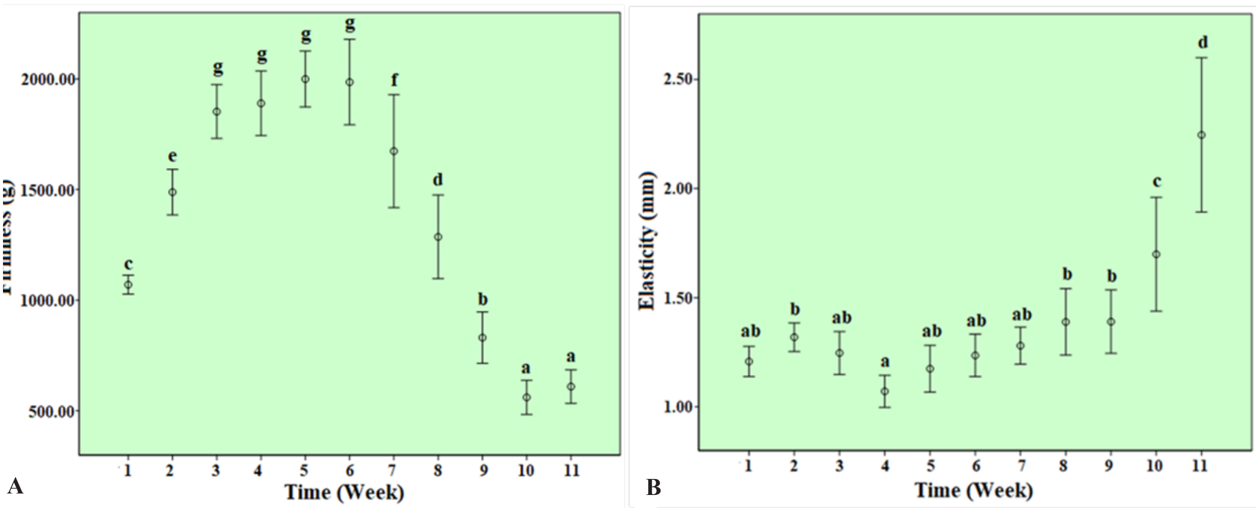

Fig. 3. Changes in hardness (g) and elasticity (mm) values of Shalakh (Aprikoz) apricot cultivar during ripening period. The vertical bars represent the standard deviation and results are the mean of three replicate experiments with three samples analyzed per replicate (n = 9)

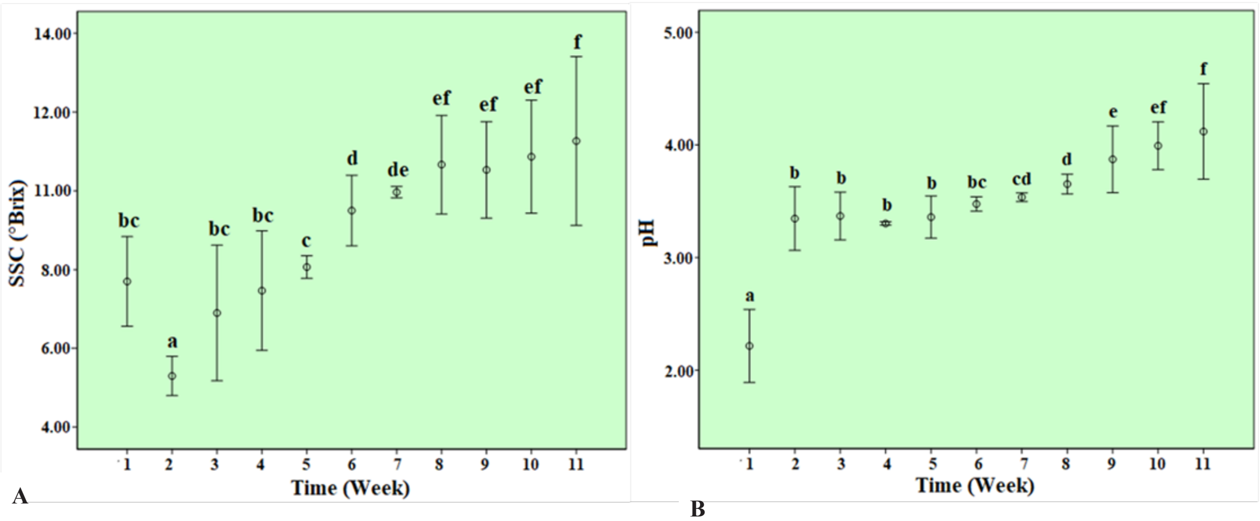

Fig. 4. Changes in soluble solids content (SSC) and pH values of Shalakh (Aprikoz) apricot cultivar during ripening period. The vertical bars represent the standard deviation and results are the mean of two replicate experiments with three samples analyzed per replicate (n = 6)

According to the Figure 4B, pH increased with values ranged from 2.22 to 4.12, with the highest pH value found at 11th week of ripening with statistical similarity with that of 10th week.

Organic acids and phenolic content

Organic acids (ascorbic and citric acid) and phenolic compounds (gallic acid and catechin) of cv. Shalakh were presented in Figure 5. Citric acid showed a significant increase (460.44–4170.02 mg 100 g^{-1} f.w.) up to 8th week, and then decreased reaching the lowest value of 1409.84 mg 100 g^{-1} f.w. at 10th week of the ripening (Fig. 5A). Su et al. [2020] stated that citric acid was the second largest abundant organic acid in five different apricot cultivars and it presented 8.32–63.60% of the total organic acid content. Since organic acid usually increased in the early stage of the ripening period (30–60 days after full bloom), fruits have an acidic taste until fully mature [Shiratake and Martinoia 2007]. Contrary to citric acid, a significant decrease of ascorbic acid from 682.62 (1st week) to 81.05 mg 100 g^{-1} fw (10th week) was observed (Fig. 5A). In the flesh of apricots and peaches both malic and citric acids can be abundant [Famiani et al. 2016], whereas in the flesh of cherries and plums, malic acid is much more abundant [Moscatello et al. 2019]. Stone fruit such as apricot and peach usually have a high ascorbic acid content in the fruit flesh. Ascorbic acid is necessary for several essential metabolic activities in living organism by protecting effect against oxidative stress and acting as a cofactor in different enzymes [Hussain et al. 2013]. Fan et al. [2017] investigated organic acid content in seven apricot cultivars collected at two different maturities (commercial and tree ripe stage) and reported that ascorbic acid content of both commercial ripe and tree ripe apricots was 18–7 mg 100 g^{-1} and 7.1–15.3 mg 100 g^{-1} fruit, respectively. A study performed on some apricot cultivars by Akin et al. [2008] estimated ascorbic acid content of cv. Shalakh at 68.4 mg 100 g^{-1} d.w.

While gallic acid content of cv. Shalakh decreased during the fruit growth (1737.14–85.24 mg 100 g^{-1} f.w.), catechin content (max. 62.53 mg 100 g^{-1} f.w.) decreased in the first two weeks, but then a regular increase or decrease was not observed (Fig. 5B). Gündoğdu et al. [2013] found that gallic acid and catechin content of cv. aprikoz (Shalakh) was 868.25 µg g^{-1} d.w. and 3250.19 µg g^{-1} d.w., respectively. In a previous study conducted on different 8 apricot cultivars showed that gallic acid levels were between 127.76 µg g^{-1} d.w. and 9.68 µg g^{-1} d.w. and catechin levels changed between 220.12 µg g^{-1} d.w. and 8.84 µg g^{-1} d.w. [Gündoğdu

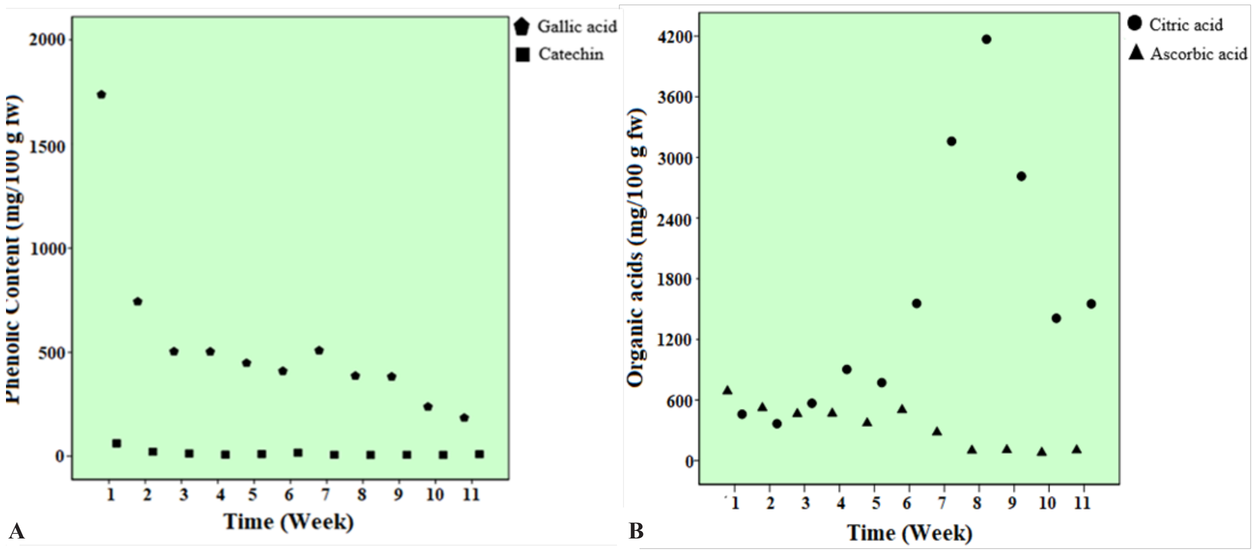

Fig. 5. Changes in phenolic content and organic acids of Shalakh (Aprikoz) apricot cultivar during ripening period

et al. 2013, Gundogdu et al. 2017]. Differences of amounts of these bioactive compounds were mostly related to different parameters such as climate, soil condition, cultivar and ripening level of fruit [Çuhacı et al. 2021].

CONCLUSION

This study was performed to establish optimal harvest time of Shalakh apricot cultivar which is the most common cultivar grown in Iğdır region using physical and chemical properties. Weight, length, width, thickness and sphericity traits increased gradually and reached the highest levels at 10th week of the after the full bloom. The results showed that all color values (L*, a*, b*, C*, h° and ΔE), color indices [a*/b*, (a*/b*)^2, 2000a*/L*C*, 180-h/L* + C*, 1000a*/L*b*], firmness, elasticity and organic acids are good harvest criteria to determine optimal harvest time of cv. Shalakh. But contrary to previous studies, soluble solids content (SSC) and pH didn't give clear information. Quality of apricot fruit is closely contributed to ripening stage. Therefore, harvesters or producers have to know the suitable harvest time where the fruits reach their optimal quality attributes such as color, appearance texture, taste and flavor. When the results are evaluated together, it can be said that the optimum harvest date for cv. Shalakh is approximately 10th after the full bloom.

SOURCE OF FUNDING

This study was financially supported by Administration System of Scientific Research Project (BAP) of Iğdır University (Project no: 2019-FBE-A29).

REFERENCES

Akin, E.B., Karabulut, I., Topcu, A. (2008). Some compositional properties of main Malatya apricot (*Prunus armeniaca* L.) varieties. Food Chem., 107(2), 939–948. https://doi.org/10.1016/j.foodchem.2007.08.052

Alwazeer, D., Örs, B. (2019). Reducing atmosphere drying as a novel drying technique for preserving the sensorial and nutritional notes of foods. J. Food Sci. Technol., 1–11. 800 https://doi.org/10.1007/s13197-019-03850-2

Asma, B.M., Ozturk, K. (2005). Analysis of morphological, pomological and yield characteristics of some apricot germplasm in Turkey. Gen. Res. Crop Evol., 52(3), 305–313.

Ayour, J., Alahyane, A., Harrak, H., Neffa, M., Taourirte, M., Benichou, M. (2021). Assessment of nutritional, technological, and commercial apricot quality criteria of the Moroccan cultivar "maoui" compared to introduced spanish cultivars "canino" and "delpatriarca" towards suitable valorization. J. Food Qual., 6679128. https://doi.org/10.1155/2021/6679128.

Bae, H., Yun, S.K., Jun, J.H., Yoon, I.K., Nam, E.Y., Kwon, J.H. (2014). Assessment of organic acid and sugar composition in apricot, plumcot, plum, and peach during fruit development. J. Appl. Bot. Food Qual., 87, 24–29. DOI:10.5073/ JABFQ.2014.087.004

Balaguera-López, H.E, Arévalo, A.H. (2012). Determining optimal harvest point for champa (*Campomanesia lineatifolia* R. and P.) fruit based on skin color. Ing. Inv., 32(1), 88–93.

Chira, L., Chira, A., Delian, E., Alexe, C., Săvulescu, E. (2012). Researches regarding the determination of optimal time for apricot harvesting by using the colour code. Sci. Pap., Ser. B, Horticulture, (56), 443–445.

Çuhacı, Ç., Karaat, F.E., Uğur, Y., Erdoğan, S., Asma, B.M. (2021). Fruit quality and biochemical characteristics of new early ripening apricots of Turkey. J. Food Meas. Charac., 15(1), 841–850. https://doi.org/10.1007/s11694-020-00685-w

Cui, Z.W., Li, C.Y., Song, C.F., Song, Y. (2008). Combined microwave-vacuum and freeze drying of carrot and apple chips. Dry. Technol., 26(12), 1517–1523. https://doi.org/10.1080/07373930802463960

Ella Missang, C., Maingonnat, J.F., Renard, C.M.G.C., Audergon, J.M. (2012). Apricot cell wall composition: relation with the intra-fruit texture heterogeneity and impact of cooking. Food Chem., 133(1), 45–54. https://doi.org/10.1016/j.foodchem. 2011.12.059

Ercisli, S. (2009). Apricot culture in Turkey. Sci. Res. Essays, 4(8), 715–719.

FAO. (2022). http://fenix.fao.org/faostat/internal/en/#data/QCL/visualize [date of access: 06.03.2022].

Famiani, F., Farinelli, D., Moscatello, S., Battistelli, A., Leegood, R.C., Walker, R.P. (2016). The contribution of stored malate and citrate to the substrate requirements of metabolism of ripening peach (*Prunus persica* L. Batsch) flesh is negligible. Implications for the occurrence of phosphoenolpyruvate carboxykinase and gluconeogenesis. Plant Physiol. Biochem., 101, 33–42. http://dx.doi.org/ 10.1016 /j.plaphy.2016.01.007

Fan, X., Zhao, H., Wang, X., Cao, J., Jiang, W. (2017). Sugar and organic acid composition of apricot and their contribution to sensory quality and consumer satisfaction. Sci. Hortic., 225, 553–560. https://doi.org/10.1016/j.scienta.2017.07.016

Gecer, M.K., Kan, T., Gundogdu, M., Ercisli, S., Ilhan, G., Sagbas, H.I. (2020). Physicochemical characteristics of wild and cultivated apricots (*Prunus armeniaca* L.) from Aras valley in Turkey. Gen. Res. Crop Evol., 67(4), 935–945. https://doi.org/10.1007/s10722-020-00893-9

Granato, D., Masson, M.L. (2010). Instrumental color and sensory acceptance of soy-based emulsions: a response surface approach. Ciên. Tecnol. Aliment., 30(4). https://doi.org/10.1590/S0101-20612010000400039

Güleryüz, M., Ercişli, S., Eşitken, A. (1999). A study on characteristic features of apricot grown in Erzincan, Malatya and Iğdır Provinces. Acta Hort., 488, 165–169.

Gundogdu, M., Ercisli, S., Berk, S., Kan, T., Canan, I., Gecer, M.K. (2017). Diversity on color and phenolic compounds in apricot fruits. J. Food Meas. Charact., 11(4), 2087–2093. https://doi.org/10.1007/s11694-017-9592-4

Gündoğdu, M., Kan, T., Gecer, M.K. (2013). Vitamins, flavonoids, and phenolic acid levels in early-and late-ripening apricot (*Prunus armeniaca* L.) cultivars from Turkey. HortScience, 48(6), 696–700. https://doi.org/10.21273/HORTSCI.48.6.696

Hakgüder Taze, B. (2017). Investigation of the effect of different processing techniques on the overall quality and shelf life of local apricot variety of Iğdir (*Prunus armeniaca* L., cv. Şalak). İzmir Institute of Technology. Availabe: http://hdl.handle.net/11147/5717

Hashemi, S., Khadivi, A. (2020). Morphological and pomological characteristics of white mulberry (*Morus alba* L.) accessions. Sci. Hortic. 259(1),108827. httpx:doi.org/10.1016/j.scienta.2019.108827

Hirsch, G.E., Facco, E.M.P., Rodrigues, D.B., Vizzotto, M., Emanuelli, T. (2012). Physicochemical characterization of blackberry from the Southern Region of Brazil. Ciênc. Rural, 42(5), 942–947.

Hussain, P.R., Chatterjee, S., Variyar, P.S., Sharma, A., Dar, M.A., Wani, A.M. (2013). Bioactive compounds and antioxidant activity of gamma irradiated sun dried apricots (*Prunus armeniaca* L.). J. Food Compos. Anal., 30(2), 59–66. https://doi.org/10.1016/j.jfca.2013.02.001

Kamal, A., Mohammed, I., Emad, H., Mohammed, A. (2014). Segmentation framework on digital microscope images for acute lymphoblastic leukemia diagnosis based on. HSV color space. Int. J. Comp. Appl., 975, 8887.

Karaat, F.E, Serçe, S. (2019). Total phenolics, antioxidant capacities and pomological characteristics of 12 apricot cultivars grown in Turkey. J. Adyütayam, 7(1), 46–60.

Karabulut, I., Topcu, A., Duran, A., Turan, S. (2007). Effect of hot air drying and sun drying on color values and β-carotene content of apricot (*Prunus armenica* L.). Lebensm.-Wiss. Technol., 40, 753–758. https://doi.org/10.1016/j.lwt.2006.05.001

Khursheed, A., Rasool, A., Nazir, R., Rather, M.A., Shalla, A.H. (2020). Apricot. In: Antioxidants in fruits: properties and health benefits, Nayik, G.A., Gull, A. (eds.), Springer, Singapore, pp. 523–545. DOI: 10.1007/978-981-15-7285-2_27

Moscatello, S., Frioni, T., Blasi, F., Proietti, S., Pollini, L., Verducci, G. (2019). Changes in absolute contents of compounds affecting the taste and nutritional properties of the flesh of three plum species. Foods, 8, 486. https://doi.org/10.3390/foods8100486

Moustafa, K., Cross, J. (2019). Production, pomological and nutraceutical properties of apricot. J. Food Sci. Technol., 56(1), 12–23. https://doi.org/10.1007/s13197-018-3481-7

Ninio, R., Lewinsohn, E., Mizrahi, Y., Sitrit, Y. (2003). Changes in sugars, acids, and volatiles during ripening of koubo [*Cereus peruvianus* (L.) Miller] fruits. J. Agric. Food Chem., 51(3), 797–801. https://doi.org/10.1021/jf020840s

Pathare, P.B., Opara, U.L., Al-Said, F.A.J. (2013). Colour measurement and analysis in fresh and processed foods: a review. Food Bioproc. Technol., 6(1), 36–60. https://doi.org/10.1007/s11947-012-0867-9

Petrisor, C., Balan, V., Lazar, V., Tudor, V. (2006). Evolution of colour during maturation of different Romanian apricot cultivars. Acta Hortic., 717, 369–372. https://doi.org/10.17660/ActaHortic.2006.717.74

Shiratake, K., Martinoia, E. (2007). Transporters in fruit vacuoles. Plant Biotechnol., 24(1), 127–133.

Singh, M.P., Dimri, D.C., Nautiyal, M.C. (2001). Determination of fruit maturity indices in apricot (*Prunus armeniaca* L.) cv. New Castle. J. Appl. Hortic., 3(2), 108–110.

Su, C., Zheng, X., Zhang, D., Chen, Y., Xiao, J., He, Y., He, J., Wang, B., Shi, X. (2020). Investigation of sugars, organic acids, phenolic compounds, antioxidant activity and the aroma fingerprint of small white apricots grown in Xinjiang. J. Food Sci., 85(12), 4300–4311. https://doi.org/10.1111/1750-3841.15523