THE EFFECTS OF HARVEST TIME DURING FRUIT DEVELOPMENT ON FRUIT QUALITY AND ANTIOXIDANT CAPACITY OF KAGIZMAN LONG APPLE

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***Abstract*— The long apple cultivar is in increasing demand in the markets thanks to its unique shape, aroma, and its endemic and delicious taste. This study aimed to determine the physical and chemical changes throughout the fruit development, which indicates its optimum harvest time. Fruit samples were collected every two weeks from the last week of May to the middle of October. The fruit harvest time was evaluated depending on different quality note attributes including physical, mechanical, chemical, physicochemical, and pomological properties. The weight, fruit size, sphericity, color, soluble solids content, pH, firmness, elasticity, phenolic content (gallic acid and catechin), and organic acids (citric acid and ascorbic acid) were analyzed. Throughout the ripening period, fruit weight, fruit size, sphericity, and SSC gradually increased. There was a negative correlation between organic and phenolic contents and harvest dates. The optimum harvest time of Kagizman long apple was approximately 18 weeks after the full bloom.**

***Keywords*— Fruit development, maturity, ripening, fruit quality properties**

I. INTRODUCTION

Apple grows in a temperate climate zone and is largely produced and consumed in the world thanks to its distinctive taste and aroma (Roshani *et al*., 2021). Apple has four different homelands: China, Central Asia, Near East, and North America. Turkey is one of the most important producers in the world. According to 2019 data, Turkey ranked third in apple production after China (42 425 400 tons) and the United States (4 997 680 tons) with a production of 3 618 752 tons (FAO, 2021).

Turkey, which is a very rich country in terms of apple genetic resources; has an important appellation in terms of production amount, the number of trees, and total economic value. In addition, Apple is the most important and popular fruit after citrus and bananas in point of economic added value (TUIK, 2021).

There are over 500 apple varieties in Turkey. However, new varieties have been added to this number by selection and breeding studies (Bostan, 2009). Among these varieties, the apple variety "long apple" called after its cylindrical shape grows only in the Kagizman district of Kars in Turkey. The Kagizman long apple cultivar was protected by a geographical indication registration certificate in 2017 (number 307) (Anonymous, 2021).

The long apple is a delicious variety that matures slowly, as well as endemic. It grows on lands at an altitude of 1300 m of the Kagizman region, and about 70 000 tons are produced annually (TUIK, 2021). The long apple tree usually has a narrow crown and grows vertically. Its fruit is cylindrical, longer than the egg, the lower and upper parts are yellowish-white, and the sun-exposed middle parts are red. This quite sweet apple variety is in increasing demand in the markets through attractive appearance, taste, and aroma (Anonymous, 2021).

Precisely determination of harvest maturity of apple is an important decision affecting quality note attributes that must meet the consumer high-quality fruit needs (Vanoli and Buccheri, 2012). Fruit growers should anticipate optimum harvest dates to allow time for labor planning. In addition, since the respiratory activities of agricultural products continue after harvest, they also affect the storage conditions (Kayısoglu, 2020). Therefore, harvest time is an important factor affecting apple quality after storage. In early harvest, harvesting becomes difficult because the rupturing layer between the stem and the branch is not fully formed. Additionally, fruits would not accumulate enough sugar, color, taste, and aroma compounds. At this point, fruits would not reach the full maturity of eating, and they are highly susceptible to physiological disorders such as blight and bitter spots, and wrinkling. On the other hand, in late harvest, due to the advancing maturity of the fruits, the sensitivity to physical injuries and diseases would increase, the storage life would shorten, and the taste-flavor balance would deteriorate. For these reasons, precise determination of the appropriate harvest time of fruit is of critical importance in terms of long and quality storage life (Delong *et al*., 1999; Skic *et al*., 2016).

The present study aimed to determine the optimum harvest time of Kagizman long apple according to the measurement of different quality parameters such as the physical, mechanical, chemical, physicochemical, pomological, and color properties.

II. MATERIALS AND METHODS

A. Plant material

This study was carried out on long apple fruit of the veg-

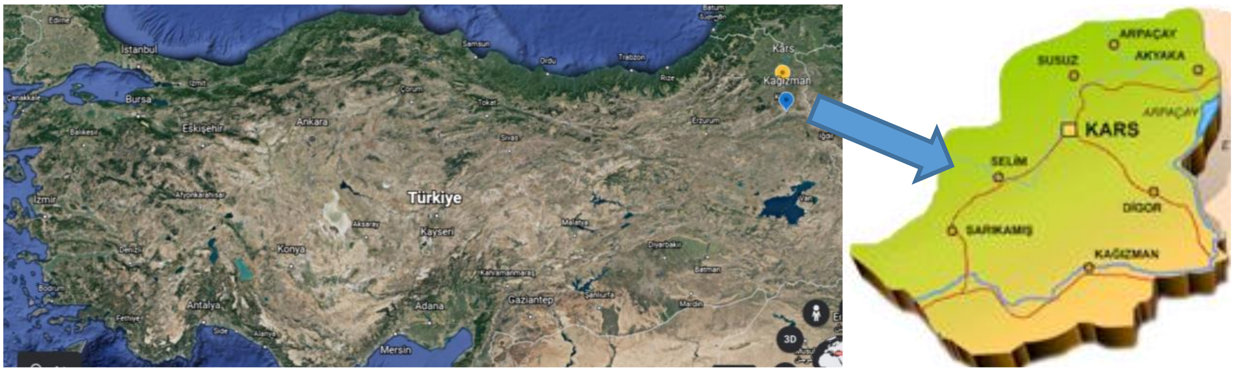

Figure 1: Location of the study region

Figure 2: The different development stages of long apple fruit

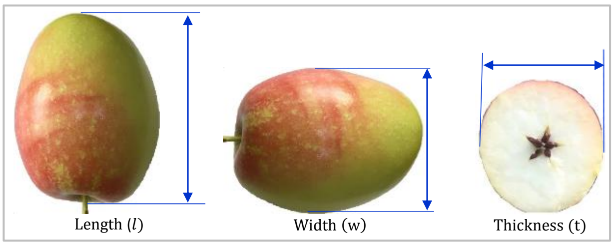

Figure 3: Sizes of Kagizman long apple

etation period of 2017. This study was carried out on long apple fruit of the vegetation period of 2017. The long apple fruit samples were obtained from orchard of a local producer in the region of Kagizman (Kars, Turkey). The experimental area was at latitude 40˚ 07' 15" North and longitude 43˚ 04' 08" East and an altitude of 1350 m (Fig. 1). Throughout the experimental period, cultural processes such as irrigation, fertilization, plant protection, and pruning were applied regularly. In the year of the study, the annual average temperature and total precipitation values were 9.1°C and 423.5 mm, respectively.

The study was set as a completely randomized design with three replications. First fruit samples were picked at last week of May after two week of full bloom, and fruits were harvested at two weeks' intervals until the second week of October (Fig. 2). Samples were randomly taken from three different trees and kept in plastic bags. 30 fruits were harvested randomly from different trees (10 fruits from different sides of each tree) once in every two weeks. The fruits were then immediately analyzed for their physical, pomological, and color properties. The fruit samples were then stored at -18°C for further.

B. Physical and pomological analyses

The size of fruit samples (i.e. length, width, and thickness) was measured by a digital caliper. The geometric mean diameter and sphericity values of fruits were calculated by Eq 2 and 3 (Mohsenin, 1970). The fruit weight (g) was measured with a scale of 0.01 g accuracy. All measurements were performed on 10 apples for each replicate.

$$Dg = (lwt)^{1/3}. \tag{1}$$

$$s = (((lwt)^{1/3})/l) * 100. \tag{2}$$

where: Dg is the geometric mean diameter (mm), and s (%) is the sphericity, l (mm), w (mm), and t (mm) are the length, width, and thickness, respectively (Fig. 3).

C. Physicochemical analyses

The total soluble solids content (SSC%) of filtered apple juice was determined using a digital refractometer (Boeco Digital Abbe Refractometer BOE 32400, Germany). The pH value was measured using a multiparameter analyzer (Consort, C3040, Belgium) and a pH electrode (Consort, SP10B, Belgium).

D. Color analysis

The skin color measurements of fruits were determined using the CIE system and L^* a^* b^* values for each fruit by performing three different measurements for each fruit skin using a colorimeter (Minolta, CR 410, Osaka, Japan). L^* defines the lightness of color (0=black, 100=white), $-a^*/+a^*$, greenness/redness, and $-b^*/+b^*$ blueness/yellowness. ΔE (total color difference), C^* (chroma), and k^o (hue angle) were calculated by Eqs. 3, 4, and 5.

$$\Delta E = \left[\left(L_i^* - L_f^*\right)^2 + \left(a_i^* - a_f^*\right)^2 + \left(b_i^* - b_f^*\right)^2\right]^{1/2}. \tag{3}$$

$$C^* = \sqrt{a^2 + b^2}. \tag{4}$$

$$h^o = \arctan b^*/a^*. \tag{5}$$

E. Mechanical analysis

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 and with a 30 kg load cell. The test parameters were; pre-speed and post-speed 5 mm s^{-1}, test speed 1 mm s^{-1}, penetration distance 3 mm (Cui *et al*., 2008).

F. Chemical analyses

Organic acid content:

The extraction of apple samples was applied according to Reddy *et al.* (2010) with some modifications. To prepare the liquid samples, 5 g of fruit sample was extracted using 10 ml of 50/50 methanol-water (%, v/v) containing 0.1% HCl, and the samples were homogenized at 1300 rpm for 1 min (IKA Ultra Turrax, T18 model, Korea). The homogenate was kept in the dark for 2 h at 25°C, followed by centrifugation at 10.000 ×g (10°C for 15 min). The supernatants were filtered through Whatman No. 4 filters and 0.45-µm. The filtrate was stored at -80°C until analysis.

Organic acids analysis was carried out isocratically according to Akin *et al*. (2008) with slight modification by using 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 Na2HP4 (pH 2.4 adjusted with H3PO4) and the flow rate of the mobile phase was 1 mL min^{-1}. The chromatograms were detected at 210 nm and 400 nm for citric acid and ascorbic acid, respectively.

Phenolic content:

Determination of phenolics (gallic acid and catechin) was performed according to the method described by Hussain *et al*. (2013) with slight modification using 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-1, with an injection volume of 20 µL. The following gradient was used: 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, 210 and 300 nm; injection volume, 20 µL; column temperature, 20°C.

G. Statistical analysis

The SPSS statistical software program (IBM SPSS Statistics 22) was used to analyze the data. Analysis of variance (ANOVA) was applied to determine the effects of apple harvest dates (picking dates) on the quality parameters of fruit. Additionally, Duncan multiple comparison (Post-Hoc) tests were used to determine the significant differences and similarities, according to the significance levels of 0.01 and 0.05, between the groups of the experiments. In addition, correlation analysis was performed and regression graphs were created to determine the relationship between organic acids and phenolic contents of fruits and fruit picking dates.

III. RESULTS AND DISCUSSION

A. Physical and pomological properties

The full bloom time of Kagizman long apple generally varies between 1-15 May, depending on the weather conditions. In our study, the full blooming took place in the second week of May. The changes in the physical characteristics of the long apple variety during the ripening period were given in Fig 3. There were significant differences in fruit physical properties among long apple samples picked on consecutive dates ($p<0.05$). Between the first and last fruit picking dates, fruit weight increased from 2.35 g to 84.28 g, fruit length from 23.46 mm to 64.46 mm, fruit width from 14.04 mm to 53.58 mm, and fruit thickness from 13.50 mm to 53.19 mm. The width increased by 281%, the thickness by 294% the length by 175% during the fruit development period. Nevertheless, the length was still prominent visually. It assumed that this was due to the unique structural characteristics of the long apple variety.

The fruit weight increased with the development of fruit with a linear tendance. Indeed, it was reported that there is a linear relationship between harvest time and fruit weight and that the fruit weight of apples depends on cell number, size, and intercellular spaces. However, the largest increase in the fruit weight was found between the 9th date (66.83 g) and the 10th one (81.33 g). The fruit length reached more than 50% of its harvest size at the 2nd date (34.85 mm). The sphericity value increased depending on the ripening of the fruit. This can be explained by the convergence of fruit physical size values (Fig. 4). Genetic factors, cultural practices, and environmental conditions can affect the size of an apple (Stern and Flaishman, 2004). Yang et al. (2021) reported that fruit weight changed from 44.49 g at 60 DAFB [days after full bloom] to 292.80 g at 180 DAFB on Orin apple cultivar collected at different ripening stages (60 DAFB, 90 DAFB, 120 DAFB, 150 DAFB). Also, fruit size increased and reached the largest value (height: 76.70 mm, diameter: 85.58 mm) at the full ripening stage of 180 DAFB.

B. Color properties

Skin color is a crucial indicator for the ripeness of fruit, as well as an important criterion for deciding the harvest time (Ninio *et al*., 2003). The mean values of measurements performed to determine color parameters (L^*, a^*, b^*, C^*, h and ΔE) of long apples picked 11 times after full bloom throughout the developing period are presented in Table 1. The values of L^* (lightness), a^* (red-green), and b^* (yellow-blue) showed significant differences between the 1st and 11th dates. The L value, which expresses the lightness, generally tended to increase (except for the picking on 21 August), with its maximum value of 71.0 reached on 4 September. The a^* value was negative throughout fruit development. In other words, the rate of green color in the fruit was higher than red. However, the redness ratio increased as the fruit ripened. The largest increase in b^* value occurred in the first three dates, while the variation between the remaining other dates was generally either insignificant or had minor differences. As the long apple ripens, the side of the fruit which is subjected to the sunlight turns red, while the other side turns yellow. Generally, the redness of fruit starts in August in long apples. It is estimated that the high a^* and high standard deviation values in the 6th date (see 7 August) were due to this. Because there were both positive and negative a^* values in the replications of

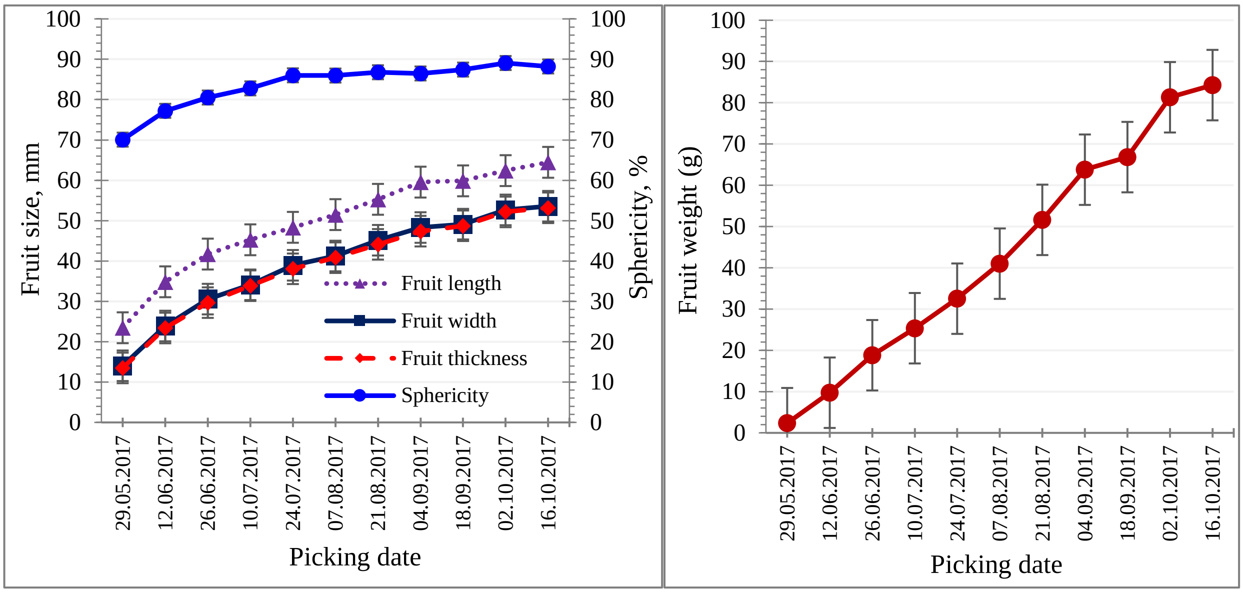

Figure 4: The changes in length, weight, thickness, and sphericity values of long apples were picked at different dates. The vertical bars represent the standard error and the results are the mean of thirty different fruit sample experiments (n=30).

Table 1. Color values (L^*, a^*, b^*, C^*, b^* and ΔE) and different color indices of long apple variety

No.	Picking Date	L^*	a^*	b^*	C^*	b^*	ΔE
1	29.05.2017	$^+$37.7 ± 0.7 e	-5.9 ± 0.8 ab	9.5 ± 1.4 e	11.2 ± 1.6 c	121.8 ± 0.6 a	-
2	12.06.2017	51.2 ± 2.9 d	-15.3 ± 1.6 cd	26.4 ± 3.2 d	30.5 ± 3.6 b	120.1 ± 0.6 ab	23.6
3	26.06.2017	61.7 ± 1.9 c	-16.3 ± 1.4 d	37.5 ± 1.8 bc	41.4 ± 1.9 a	116.9 ± 1.7 bc	38.3
4	10.07.2017	65.5 ± 2.3 b	-18.2 ± 0.4 d	36.9 ± 1.3 bc	41.2 ± 1.3 a	116.2 ± 0.4 bc	40.9
5	24.07.2017	65.9 ± 1.2 b	-17.5 ± 0.2 d	36.3 ± 1.2 c	40.3 ± 1.0 a	115.8 ± 0.9 bc	40.6
6	07.08.2017	67.7 ± 1.7 b	-8.1 ± 13.7 abc	36.2 ± 0.3 c	39.5 ± 1.3 a	113.2 ± 4.1 cd	31.7
7	21.08.2017	65.6 ± 2.0 b	-16.4 ± 0.9 d	36.8 ± 1.1 c	40.3 ± 0.8 a	114.0 ± 1.7 cd	40.5
8	04.09.2017	71.0 ± 1.7 a	-14.3 ± 2.5 cd	38.9 ± 1.0 abc	41.5 ± 1.3 a	110.2 ± 3.3 de	45.3
9	18.09.2017	70.7 ± 1.8 a	-11.6 ± 0.9 bcd	38.3 ± 0.7 abc	40.0 ± 0.5 a	106.9 ± 1.5 e	45.5
10	02.10.2017	71.0 ± 1.6 a	-3.7 ± 5.3 a	41.1 ± 4.3 a	41.6 ± 4.5 a	94.5 ± 7.4 f	27.3
11	16.10.2017	71.0 ± 2.1 a	-1.8 ± 5.5 a	40.2 ± 4.6 ab	40.6 ± 4.8 a	91.7 ± 7.5 f	17.5
Significance^{++}		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). $^{++}$ P < 0.001

measurements in the 6th picking date. The fact that the situation in the 6th picking date did not occur especially in the 7th, 8th, and 9th picking dates indicates that the analyzed samples were taken from the non-red side. However, it is thought that the reason for the higher a* values in the 10th and 11th picking dates is due to the increase in the redness ratio in the fruit surface area.

The chroma indicates the purity of color in visual color perception and describes the vividness or opacity of a color. That is, it shows how far the color is from gray or pure color (Lopez *et al.*, 2013). In the current study, the change in chroma values between the 1st and 3rd picking dates was approximately 270%, while the change in measurements performed between the 4th and 11th picking dates was approximately 5%. In addition, only the change between the first three measurements was significant. However, the lowest and highest values of Chroma were obtained in the 1st and 10th dates, respectively. The high chroma values represent the high color intensity of samples perceived by humans (Pathare *et al.*, 2013). While the long apple samples collected in the early harvest dates were generally dark green, a variety of colors including light green, yellow and red were observed in the lately harvested samples.

The hue angle (h*) indicates the dominant color wavelength and is angularly expressed in degrees: 0-60˚ (red), 60-120˚ (yellow), 120-180˚ (green), 180-240˚ (cyan), and 240-300˚ (blue) (Manamohana *et al.*, 2020). The highest and lowest values for the Hue angle were reached in the first and last dates, respectively. However, if the 7th date is not taken into account, a regular decrease has occurred in these values. The higher hue angle value demonstrates a lesser yellow color according to Pathare *et al.* (2013). Accordingly, as the long apple variety ripens, the decrease in the hue angle values shows an increase in yellow color. Differences in perceivable color (ΔE) are analytically expressed as 1.5<ΔE (small difference), 1.5<ΔE<3.0 (distinct), and ΔE>3.0 (very distinct) (Pathare *et al.*, 2013). Since all ΔE values between consecutive dates of long apple were greater than 3.0, it can be said that the difference between dates is very distinct. However, the minimum and maximum color changes occurred at the 11th (17.5) and 9th (45.5) dates, respectively.

Table 2. Changes in SSC, pH, firmness, and elasticity values of long apple cultivar during the ripening period

No.	Picking Date	SSC (%)	pH	Firmness (g)	Elasticity (mm)
1	29.05.2017	[+]10.6 ± 0.28 g	3.3 ± 0.10 ef	898.8 ± 130 b	1.8 ± 0.89
2	12.06.2017	9.9 ± 0.22 h	3.4 ± 0.09 de	1141.4 ± 115 a	1.4 ± 0.11
3	26.06.2017	11.5 ± 0.24 f	3.2 ± 0.02 fg	1219.3 ± 143 a	1.5 ± 0.12
4	10.07.2017	13.4 ± 0.24 d	3.1 ± 0.06 g	1215.7 ± 100 a	1.7 ± 0.13
5	24.07.2017	11.7 ± 0.42 ef	3.4 ± 0.04 cde	1201.3 ± 147 a	1.5 ± 0.13
6	07.08.2017	12.1 ± 0.09 e	3.5 ± 0.10 bcd	1221.8 ± 175 a	1.9 ± 0.23
7	21.08.2017	13.5 ± 0.12 d	3.5 ± 0.09 bcd	1201.2 ± 109 a	1.6 ± 0.22
8	04.09.2017	14.5 ± 0.29 c	3.6 ± 0.09 b	1104.5 ± 127 a	1.5 ± 0.19
9	18.09.2017	15.1 ± 0.12 b	3.6 ± 0.09 bc	1128.8 ± 122 a	1.5 ± 0.17
10	02.10.2017	15.6 ± 0.14 a	3.8 ± 0.06 a	946.1 ± 75 b	1.4 ± 0.18
11	16.10.2017	15.6 ± 0.30 a	3.6 ± 0.08 bc	743.9 ± 124 c	1.6 ± 0.49
	Significance[++]	0.000[***]	0.000	0.000	NS

[+]: The values are the mean of three replicate experiments with three samples analyzed per replicate (n=9).
[++]: NS, ***; Nonsignificant at P≤0.05, significant at 0.001, respectively.

C. Physicochemical properties

The variance analysis results of the data for SSC (soluble solids content) and pH were statistically significant ($p<0.001$). However, multiple range test results showed that both SSC and pH values were not different on all dates (Table 2). The pH values varied between 3.1-3.8, and the pH value reached the highest value in the 10th picking date; and although this value was statistically different, it was close to the values of the 8th, 9th, and 11th picking dates.

Soluble solids content (SSC) is one of the most important internal quality parameters affecting consumer preference and product price of fresh fruit (Lu, 2004; Li *et al*., 2016). SSC is also an important indicator in determining fruit maturity and harvest time and is commonly used for evaluating and grading the postharvest quality of fruits (Rajkumar *et al*., 2012; Hirsch *et al*., 2012). SSC value showed a gradual increase after the 5th picking date and ranged between 11.70-15.62% in the last 7 picking dates (24.07.2017-16.10.2017). However, no significant difference was found for the last two fruit picking dates. An increment in SSC could be associated with the hydrolysis of starch and polysaccharides in the cell wall into simple sugar (Gull *et al*., 2021).

D. Mechanical properties

The fruit texture is a crucial characteristic for maintaining the taste and shelf life of the fruit. As a major quality parameter, fruit firmness affects postharvest physiology and eventually consumer preferences (Vicente *et al*., 2007). Analysis of variance results showed that the fruit firmness was statistically significant ($p<0.001$) for different dates, while elasticity was insignificant ($p>0.05$).

According to Table 2, the firmness value of long apple showed a fluctuating behavior (increasing-decreasing) until the 5th picking date. In general, a gradual decrease occurred between the 6th and 11th picking dates (except the 9th picking date) with the improvement of ripening. However, while there was no significant difference in the measurements performed from the 2nd to the 9th picking dates, the difference in the last three harvest dates was found to be significant. On the other hand, the highest elasticity was recorded at the 6th picking date (1.9 mm) and the lowest at the 10th picking date (1.4 mm). While the elasticity value decreased gradually between the 6th and 10th picking dates, an increase was observed again at the 11th picking date. Softening of fruit flesh is mainly associated with the breakdown of the main components of the cell wall namely insoluble protopectines into soluble pectic compounds. During the softening process of the fruit, protopectin is transformed into water-soluble pectin, and the chains of pectin, cellulose, and hemicellulose are depolymerized leading to the softness of fruit (Zhongfeng *et al*., 2009).

E. Chemical properties

Organic acid content:

The mean data for the ascorbic acid and citric acid are shown in Fig. 5. The correlation between the content of ascorbic acid and citric acid of the long apple variety and the fruit picking date was significant (Fig. 5) ($p<0.001$). The Figure shows that the acid content decreases almost linearly with the progress of fruit ripening. However, citric acid was detected at the highest level in the 2nd picking date and the lowest level in the 11th picking date. The content of ascorbic acid was at the highest level in the 2nd picking date and then decreased until the 11th picking date (excluding the 9th picking date). During the first stages of fruit development, organic acids accumulate to be used as substrates for the maintenance of respiration processes. As maturation progresses, stored carbohydrates breakdown to sugars and a clear reduction is observed in organic acids (Batista –Silva *et al*., 2018). The decrease in the citric and ascorbic acid content of long apple over time can be explained by this phenomenon.

Ascorbic acid is necessary for plants as well as animals. It controls cell division and cell expansion, acts as a cofactor of many enzymes, plays an important role in photosynthesis, hormone biosynthesis, and the renewal of antioxidants (Lisko *et al*., 2014). Ascorbic acid acts as an antioxidant to protect cellular components from free radical damage and regulates cell division and growth (Mescic Macan *et al*., 2019). Gazdik *et al*. (2008)

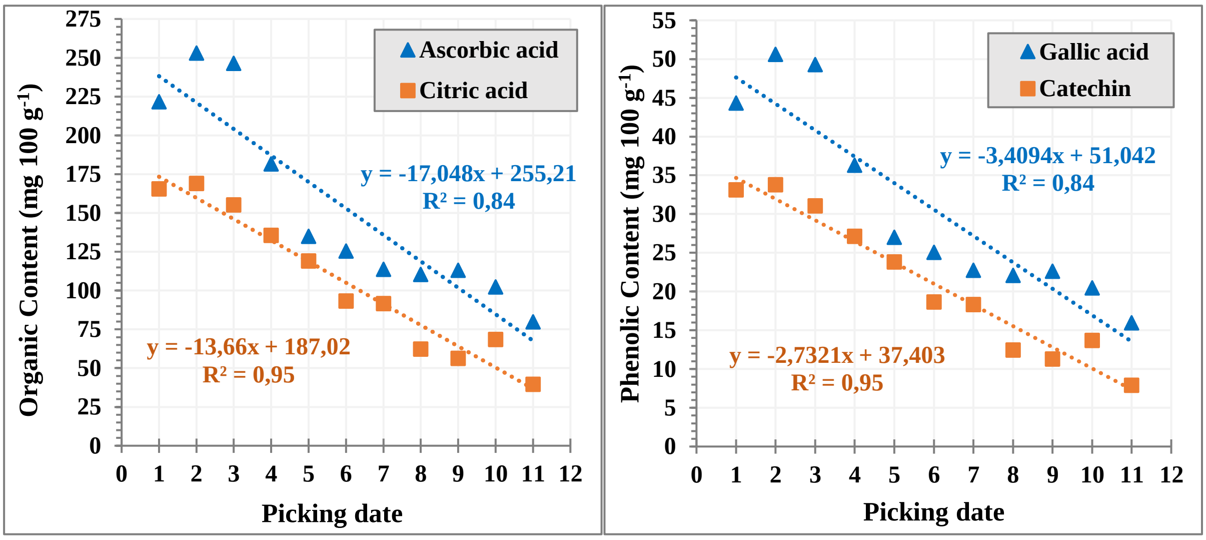

Figure 5: The correlation between organic and phenolic contents and picking dates of long apple

reported that ascorbic acid in ripe apples ranged from 11 to 19 mg 100 g^{-1}. Jan *et al.* (2012) investigated quality parameters of apple cultivars harvested at different stages of maturity (early, mid, late) and reported that ascorbic acid content of apple cultivars at early, mid and late maturity stages were 10.11, 11.68, 12.50 mg 100 g^{-1}, respectively. Akpomie *et al.* (2021) reported ascorbic acid in ripened fruits of Golden Delicious, Granny Smith, and Red Delicious apple cultivars as 22.83, 29.26, and 38.63 mg 100 g^{-1}, respectively. The ascorbic acid content in a cultivar of long apple investigated in this study was higher than the values reported by Gazdik *et al.* (2008), Jan *et al*. (2012), and Akpomie *et al*. (2021).

Phenolic content:

The content of gallic acid and catechin of the long apple cultivar gradually decreased from the 2nd picking date. The highest gallic acid and catechin amounts were found for the 2nd picking date. Figure 5 shows the similarity between the ascorbic acid and citric acid trendlines from one side, and gallic acid and catechine trendlines from another side. Podsedek *et al*. (2000) stated that catechin concentration in 10 apple cultivars ranged from 4 to 21 mg kg^{-1}. Similar to our study, Awad *et al*. (2001) reported that catechin concentration in Elstar and Jonagold apple cultivars initially increased, but then gradually decreased until harvest time during the ripening period. Vieira *et al.* (2009) found the content of gallic acid in Fuji and two new apple selections (Epagri COOP24 and Epagri F5P283) as 167.11, 180.39, 233.57 mg 100g^{-1}, respectively; while catechin contents were found as 24.59, 27.39, 24.89 mg 100g^{-1} respectively. Shafi *et al*. (2019) reported that the amount of catechin in 60 apple genotypes ranged from 109.98-5290.47 µg g^{-1}. Catechins are the predominant phytochemicals in apples. They give apples their color and flavor. These compounds vary greatly between cultivars and genotypes depending on location, season, light, and altitude (Lata *et al*., 2009).

IV. CONCLUSIONS

Determination of the optimum harvest date in fruit harvest may build up the confidence of fruit producers and affect consumer preferences, and eventually encourage its use. This paper showed the changes in physical, chemical, mechanical, color, and pomological properties of Kagizman long apple during the growing period. Some of the results to be highlighted in the study are summarized below:

1. As the Kagizman long apple cultivar developed, the length, width, and thickness values (or sphericity values) increased. However, this increase did not change the long appearance of the Kagizman apple. Although the percentage increase in width and thickness was large, the change in length was visually more prominent.
2. Changes in L*, a*, and b* values depending on fruit development were compatible with visual color. As the long apple ripens, its lightness increased, the sun-exposed side turned red, and the other side turned yellow. Optimum lightness, redness, and yellowness values were reached in the 8th, 11th, and 10th fruit picking dates, respectively. In addition, the hue angle (h*) values supported these results.
3. The highest SSC and pH values were reached at the 10th picking date and the lowest firmness value was reached at the 11th one. However, the elasticity did not give clear information. In other words, SSC, pH, and firmness indicated that the fruit should be harvested in October.
4. There was a strong negative correlation (R2>80) between acid content and harvest.

When the results are evaluated together, it can be said that the optimum harvest date for Kagizman long apple is approximately 18 weeks after the full bloom.

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