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Effects of Harvest Date on Apple Fruit Quality at Harvesting and after Cold Storage

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Abstract
Different dates for apples fruit harvest (*Malus domestica* Borkh. Cv. Fuji) were studied to determine physiochemical changes during the storage. Fuji apples were harvested from 9 September till 23 October, at five different times and stored at 0±0.5 °C and 95% relative humidity for 120 days. To determine the best harvest date for maximum quality and storability, physical and chemical parameters were measured at each harvesting time and after 40-day periods until the end of 120 days of storage. Results showed that, the fruit quality parameters at harvest and after storage, depends on the degree of the ripeness at which the apples were harvested. Fruits from the first harvest, were firmest before and after storage and had the lowest phenolic compounds at the end of storage. First, second and third harvest date samples, had a decrease in phenolic content and total antioxidants activity during storage, but the fourth and fifth harvested fruits were opposite. Total soluble solids and Titrable acidity were affected by the harvest date and duration of storage. First and second harvest date samples showed an increase in total soluble solids during 120 days of storage but it was opposite in third, fourth and fifth harvested samples. The fifth harvest date samples characterized with oblate fruit shape and high weight loss during storage.

Keywords: *Malus domestica*, quality parameters, total phenolic content, total antioxidant activity (TAA), storage, harvest date.

Abbreviations: TA, total acidity (titrable acidity); **TAA**, total antioxidant activity; **TSS,** total soluble solids.

Introduction

Apple (*Malus domestica* Borkh.) is an important and desired fruit for its taste and nutritive value (Bokhari, 2002). As a perishable commodity, apples are prone to qualitative and quantitative losses after harvest. The losses may occur during post-harvest handling or storage periods and can be as high as 17% of the harvest (Shah et al., 2002).

Fruits and vegetables are rich in bioactive compounds (Duda-Chodak and Tarko, 2007). Nowadays, the positive effects of secondary metabolites on human health is well documented (Scalbert et al., 2005; Kevers et al., 2011) and many efforts have been made to improve antioxidants contents of the fruits (Duda-Chodak and

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Tarko, 2007). Antioxidant capacity and phenolic compounds could be affected by some factors including harvest date (Mosel and Herman, 1974; Macheix et al., 1990; Renard et al., 2007; Kevers et al., 2011). In early harvest, fruits are small with reduced flavor, color and some unidentifiable characteristics such as non-uniform ripening that could have an inverse effect on fruit quality after storage. Kviklienė et al (2011) reported that in late harvest some of the physiological processes are underway that can complicate storage by making the fruits susceptible to scald, bitter rot and internal breakdown. However, an appropriate harvest date can improve fruit storage life, quality and productivity. Harvesting on optimal physiological conditions, ensures good quality at later stages by enhancing a number of quality characteristics, such as extended shelf life, slower rate of decline in firmness and acidity and formation of a suitable fruit color (Smith, 1987).

One of the main problems in apple post-harvest is the inappropriate harvest time, because full ripen apples are prone to mechanical injury (Hribar et al., 1996). The most important market for fruits (especially apples) in Iran is during the ‘Norooz’ celebration, started 21th of March. Usually huge numbers of apples fruits are stored for around 4 or 5 months, until they being sold during ‘Norooz’ period.

As a climacteric fruit, apples continue to ripen after harvest, so fruits can be harvested before full ripeness and stored to achieve a good price in markets (Kader et al., 2002). Kader and Barrett (1996) reported that, at the climacteric stage, synthesis rate of flavor components increases, and organic acids and starch are converted to sugars and other flavor components which will be used for respiration, thereby decreasing the overall sourness of the fruits. Reid and Kader (2002) offer some maturity indexes to estimate the optimum harvest date for various apple cultivars in different countries. These indices include firmness and percentage of soluble solids, in order to minimize losses during storage (Skrzynski, 1996; DeLong et al., 1999). This study aimed to investigate the changes in apple fruit quality during cold storage to determine the optimum harvest date for ‘Fuji’ cultivar in Alborz region of Iran.

Materials and methods

Study site and Plant material

This experiment was carried out at the facilities of the horticulture research station of University of Tehran, Alborz, Iran in 2013. For this experiment, eight-years-old apple trees (*Malus Domestica* Borkh .cv. Fuji) that were grafted on M9 rootstock with uniform size and shape were used.

Fruit harvest and sampling

Harvest and measurements of fruit quality parameters were performed 2 to 3 weeks before and after the date of commercial harvest for this cultivar. Apple fruits were harvested from uniform trees at five different dates: 9 September, 19 September, 30 September, 12 October and 23 October. Within 2 hours after harvesting, uniform-sized and -shaped fruits without any disorders and infections were selected.

Storage and quality measurements

Fruits were stored at 0±0.5 °C and 95% relative humidity for 120 days. For each harvesting date and for 40-day periods of storage, 50 fruits were randomly selected with four replicates for each treatment and four replicates for determination of dry matter, firmness, soluble solids content, pH, TA, fruit shape, TAA and total phenolic compounds.

Soluble solids content in expressed juice from fresh fruit was measured with a hand refractometer (% Brix). Firmness was measured with a penetrometer (model FT-327) with 0.8cm diameter probe (Pocharski et al., 2000). Ten fruits in each treatment were used for determining weight loss. The initial weight of each fruit was recorded in harvesting time and the average of weight loss in all the treatments was calculated every 40 days. The weight loss (%) was calculated through the following equation:

Fruit weight loss (%) = (fruit initial weight – fruit final weight / fruit initial weight) × 100

Fruit juice was extracted by juicers and the pH was determined with an electronic pH meter on 10 ml of fruit juice in 40 mL of stirred deionizer water. Fruits length and width were measured by digital calipers and fruit shape was measured by the length to width ratio. TA was measured on juice extracted from composite sample of segments by titration to an end point of pH 8.1 with 0.1 M NaOH.

Total Antioxidant activity and Phenolic contents measurements

The total phenolic content in the apple samples were measured by a modified colorimetric Folin-Ciocalteu method (Ough and Amerine, 1988). Around 0.5 g of fruit flesh and 0.5 mL Folin reagent were added to the test tube separately, 8 mL deionized water and 1 mL sodium carbonate was added to the Folin. Then 0.5 g fruit sample was homogenized with 4 mL methanol and the mixture was centrifuged at 9500 for 20 min and 0.5 mL of this methanol extract was added to Folin solution and allowed to react for 90 min. The absorbance was read at 765 nm with a spectrophotometer (SHIMADZU, model UV-1700, Japan). The measurement was compared to the standard curve of Gallic acid solution and expressed in mg of Gallic acid equivalents (GAE/100g) of samples.

Total antioxidant activity was measured by using the method of Faniadis et al. (2010). 0.5 g of fruit tissue homogenized with 4 mL of 80% methanol. The mixture was centrifuged at 9500 rpm for 20 min. Then, 3.4 mL of solution DPPH (1-diphenyl-2-picrylhydrazyl) was added to 100 µL methanol extract and after two hours exposure to darkness, the absorbance was read at 520 nm by the spectrophotometer. The capability of TAA was calculated using the following equation:

Antioxidant activity % = (A520 sample/A520 blank) * 100

Statistical Analysis

The data was analyzed as a factorial experiment with based on a completely randomized design on five harvesting time and four storage time with four replicates for each treatment and four replicates for sampling. Mean of interactions were assessed for differences by Duncan and SPSS (Statistical Package for the Social Sciences) testing statistical computer software was used for statistical analysis.

Results

TSS content of apple fruit was significantly affected by storage duration and harvest date interactions (Table 1). First, second and third harvested fruits showed increase in TSS during storage. But in fourth and fifth harvested samples, fruits in the first 40 days had highest TSS (TSS decreased during storage) (Table 2).

Table 1. Results of two-way analysis of variance (ANOVA) for the effects of harvest date and duration of cold storage on apple fruit quality parameters.

Source Of Variation	Mean square								
	TSS	Firmness	pH	TA	Dry matter	Weight loss	L/W	Total phenolic	TAA
Harvest time	6.582 ns	5.540 *	0.307 **	0.060 *	19.748 ns	2.134 **	0.005 *	140.1671 ns	1760.892 *
Storage	9.726 ns	33.037 **	0.183 **	0.005 *	59.023 **	9.143 *		1794.492 **	318.485 *
H * S	6.722 *	1.509 *	0.026 **	0.025 ns	25.253 *	0.485 ns		584.867 *	2676.810 *
Error	2.683	0.245	0.007	0.002	7.423	0.252	0.004	60.081	414.071

* and ** are significant in 0.05 and 0.01 respectively. ns is non-significant.

Table 2. Effects of harvest date and duration of cold storage on fruit TSS, Firmness and pH of Fuji apple. The means were compared by Duncan multiple range test at p ≤ 0.05.

Harvest Date	Storage	TSS (% Brix)	Firmness (kg/cm3)	pH
1 (9 September)	0 day	9.15 d-g	9.25 a	4.15 i
	40 days	8.8 e-g	4.97 b-d	4.23 g
	80 days	10.5 b-g	5.7 b	4.29 f
	120 days	12.5 ab	5.15 b-d	4.2 h
2 (19 September)	0 day	9.78 c-g	8.55 a	4.24 g
	40 days	11.56 a-d	5.14 b-d	4.23 g
	80 days	11 a-e	4.53 cf	4.45 d
	120 days	12 a-c	4.06 f	4.5 c
3 (30 September)	0 day	9.2 d-g	8.37 a	4.4 e
	40 days	13 a	4.95 b-e	4.13 i
	80 days	13 a	5.28 bc	4.5 c
	120 days	11 a-e	4.13 f	4.55 b
4 (12 October)	0 day	9.3 d-g	8.15 a	4.42 e
	40 days	8.2 g	4.71 c-f	4.55 b
	80 days	8.91 e-g	4.87 b-e	4.56 b
	120 days	8.5 f-g	4.6 c-f	4.73 a
5 (23 October)	0 day	10.6 b-f	7 b	4.42 de
	40 days	9.46 d-g	4.4 d-f	4.55 b
	80 days	9.45 d-g	4.02 f	4.74 a
	120 days	9.5 d-g	4.14 e-f	4.72 a

Table 3. The effects of harvest date and duration of cold storage on fruit TA, Dry matter, weight loss, Total phenolic contents and TAA of Fuji apple cultivar. The means were compared by Duncan multiple range test at p ≤ 0.05.

Harvest Date	TA (mg/100mL)	Dry mattar (%)	Weight loss (%)	Total phenols (mg/100g FW)	TAA (%)
1 (9 September)	2.76 a	11.08 bc		52 b	8 b
	2.6 b	10.78 bc	0.91 fg	51.29 b	8.05 b
	2.46 c	11 bc	1.5 c-g	49.46 b	7.95 b
	2.2 ef	11.96 a-c	1.3 d-g	40.35 c	6.5 c
2 (19 September)	2.6 b	14.4 ab		43 bc	10.55 a
	2.46 c	14 ab	0.87 g	39.91 c	11.56 a
	2.36 d	14.33 ab	1.13 e-g	40 c	9.5 b
	2.16 fg	11.44 a-c	1.12 e-g	50.44 b	8.6 b
3 (30 September)	2.56 b	9.78 c		52 b	9.5 ab
	2.43 c	12 a-c	1.8 c-e	44.26 bc	9.55 ab
	2.26 ef	11.62 a-c	1.9 b-d	38.8 c	9.63 ab
	2.03 h	11 bc	1.65 c-e	45.02 bc	9.36 ab
4 (12 October)	2.33 d	14 ab		60 b	8 b
	2.43 c	13 a-c	1.55 c-g	80 a	8.2 b
	2.33 d	12.79 a-c	1.61 c-f	87 a	8.91 b
	2.23 e	12.08 a-c	1.18 e-g	85 a	9 b
5 (23 October)	2.26 e	15.16 a		63 b	10.6 a
	2.13 g	13 a-c	2.6 ab	78.17 a	9.46 ab
	2.03 h	10.66 bc	2.68 a	75 a	11.1 a
	1.86 i	10 c	2.2 abc	80 a	12.23 a

Harvest date and storage periods and their interactions had significant effect on fruit firmness (Table 1). The highest fruit firmness was recorded in the first and second harvest dates and the softest fruits were observed in fifth harvest date (in zero day of storage). Changes in fruit firmness during 120 days of storage at 0±0.5 °C are shown in Table 2. After 40 days in cold storage, the firmness of apple fruits from all harvested times was significantly declined and after 80 days of storage it was again slightly decreased.

Fruit juice pH was significantly affected by both treatments and their interactions (Table 1). At the beginning and end of the 120 days of storage in fourth and fifth harvest dates, higher pH levels were detected in fruits (Table 2). During the storage periods, the pH was increased and in the last period of storage (80 to 120 days) it reached to its highest level. Fruits from the first harvest date, showed the lowest changes in pH during storage.

Fruit juice TA was declined during cold storage in all treatments (Table 1). As shown in Table 3, TA content of late harvested fruits were lower than those who harvested at earlier date.

Table 3 shows the change in dry matter of apple fruits throughout the harvest dates with storage duration of 120 days. The dry matter content was gradually increased during the different harvest dates, starting from the 9th of September. Meanwhile during storage, dry matter content was decreased, except for first harvested fruits. After 40 days maintaining in cold storage the dry matter content for the fourth and fifth harvest dates was significantly decreased, 13.71% and 34.04% respectively.

The highest weight loss was detected for the fifth harvested date and the second harvest had the least. During storage from 40 to 80 days, the first, second and third harvests, showed an significant increase in weight loss. In all harvest dates except for the first and second harvest samples, it decreased after 80 days (Table 3).

The total phenolic content showed dispersion in the fourth and fifth harvests relative to earlier harvests. At harvest (zero day of storage), fourth and fifth harvested fruits showed higher total phenolic compounds (Table 3). Total phenolic compounds were increased by storage only in the fourth and fifth harvests. Total phenolic content, in first, second and third harvests showed a significant decreased during the storage.

The fifth harvest had the highest antioxidant activity at the beginning and at the end of storage period (Table 3). Except for the fourth and fifth harvests, the remaining harvested samples showed decrease in the TAA during storage and this decrease was significant in the first and second harvests.

The effect of harvest date on the fruit shape (length to width ratio) was significant (Table 1). As shown in Fig 1, fourth and fifth harvested fruits were more oblate than the three earlier harvests (high length to width ratio).

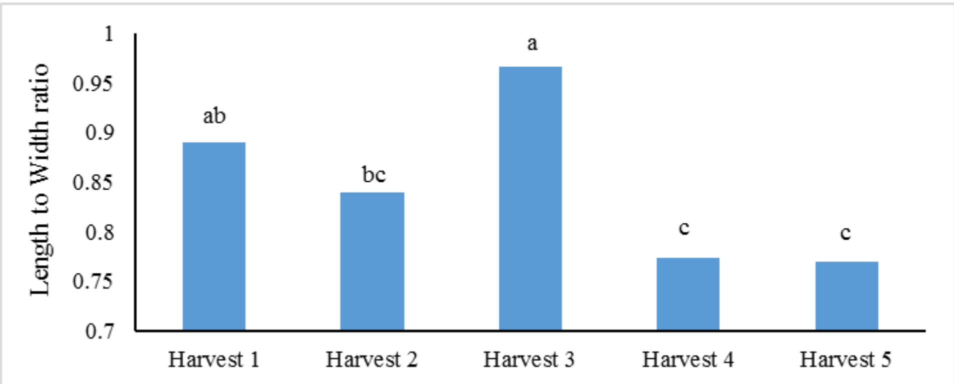

Fig. 1. Effects of harvest date on fruit shape (length to width ratio) of Fuji apple cultivar. The means were compared by Duncan multiple range test at $p \leq 0.05$.

Discussion

These results demonstrated that harvest time and duration that Fuji apples stored in cold storage, significantly affected quality and storability. The TSS of apples and other fruits is an important quality factor which determine fruit taste (TSS/TA ratio) (Weibel et al., 2004). The increase in TSS could be attributed to the breakdown of starch into sugars (Kvikliene and Valiuskaite, 2009). Since, TSS percentage was a function of total dissolved solids and moisture content of the fruit, the increase in TSS could be also due to accumulation of soluble solids and moisture loss (Farooq et al., 2012). Decrease in fruit firmness after 40 days of storage may be due to the high activity of enzymes involved in the cell wall collapse as fruits ripeness and therefore will affect storability (Kviklienė et al., 2011). TA of the fruit depends on the rate of metabolism, especially respiration which consumes organic acids (Ghafir et al., 2009). Apples continue to lose water following their harvest, which results in weight loss (Al-Obeed and Horhash 2006). It has been earlier reported that increasing storage duration will result in increase in the percentage of fruit weight loss (Kader et al., 2002). The weight loss in fruit depends on the nature and amount of wax on their surface and fruit respiration rate (Veravrbeke et al., 2003). Therefore, the relative low rate of weight loss for up to 90 days of storage indicates that the wax layer may have been undamaged for 90 days. Damage to this layer after this time of harvest, could be the major reason for high weight loss of the fruits (Gavlheiro et al., 2003). The loss of moisture and subsequent weight loss also depends on the water content of the fruit (Banarus et al., 1994). Second harvested fruits, had lowest weight loss during storage that may be due to appropriate formation of wax layer (as compared with the first harvested fruits) and low respiration rate as compared with the full ripen fruits (compared with the fourth and fifth harvested fruits).

Increase in fruit size, TSS and reduction in fruit firmness indicates advanced maturity and improves fresh eating quality of the late harvested apples, but decreases their storability (Farooq et al., 2012). Another aim of this study was to improve antioxidants efficiency and preserving them in fruits and prevent their dysfunctioning. High content of phenolic compounds and TAA in late harvested fruits suggest that a late harvest time could have beneficial effects on the phytochemical content of Fuji apples. In this respect it can be said that the fifth and fourth harvested fruits (harvested at 12 and 23 October) have a high activity of total antioxidant and total phenols contents at the beginning and at the end of 120 days of storage. Unripe apples (harvested at 9 and 19 September) together constitute a lower source of total phenolic content and total antioxidant activity and more decrease in storage duration. Therefore, storage of ripen apple fruits (rather than unripe fruits) could keep fruit pro-health values.

References

1. Al- Obeed R, Harhash M. 2006. Impact of postharvest treatments on storage life and quality of "Mixican" Lime. International Journal of Advance Agricultural Research 11, 533-549.
2. Banarus M, Lownds N.K, Bosland P.W. 1994. Relationship of physical properties to postharvest water loss in pepper fruit (*Capsicum annuum* L.). Pakistan Journal of Botany 26, 321 -26.
3. Bokhari S. 2002. Apple the sweet gold of Pakistan. Export Promotion Bureau of Pakistan 5, 2- 15.
4. Defilippi B, Dandekar A.M, Kader A. 2004. Impact of suppression of ethylene action or biosynthesis on flavor metabolites in apple (Malus domestica Borkh) fruits. Journal of agricultural and food chemistry 52, 5694-5701.
5. DeLong J.M, Prange R.K, Harison P.A, Shofild R.A, DeEll R.J. 1999. Using the Streif index as a fial harvest window for controlled-atmosphere storage apples. Horticultural Science 34, 1251-1255.
6. Duda-Chodak A, Tarko T. 2007. Antioxidant properties of different fruit seeds and peels. Acta Scientiarum Polonorum Technologia Alimentaria 6, 29-36.
7. Faniadis D, Drogoudi P.D, Vasilakakis M. 2010.

Effects of cultivar, orchard elevation and storage on fruit quality characters of sweet cherry (*Prunus avium* L.). Scientia horticulturae 125, 301-304.

8. Farooq R.A, Khan I. 2012. Physico- Chemical Quality Of Apple cv. Gala fruit Stored At Low Temprature. FUUAST Journal of Biology 2, 103-107.

9. Gavalheiro O.J, Santos A, Recasens I, Larrigancliere C, Silvestre A. 2003. Quality of the postuguese "Bravo de Esmolfe" apple after normal cold storage or controlled atmosphere and two shelf life periods. Acta Horticulture 1, 395-400.

10. Ghafir S, Gadalla S, Murajei B, El-Nady M. 2009. Physiological and anatomical comparison between four different apple cultivars under cold-storage conditions. African Journal of Plant Science 3, 133-138.

11. Hribar J, Johnson D.S, Bohling H. 1996. The Post-harvest Treatment of Fruit and Vegetables: Quality Criteria. Proceedings of Workshop, Commission of the European Communities.

12. Kader A, Barrett D.M. 1996. Classification, composition of fruitsand postharvest maintenance of quality. Processing fruits. Science and technology 1, 1-24.

13. Kader A.A. 2002. Postharvest Technology Of Horticultural Crops, UCANR Publications 3311.

14. Kevers C, Pincemail J, Tabart J, Defraigne J, Dommes J. 2011. Influence of cultivar, harvest time, storage conditionsand peeling on the antioxidant capacity and phenolic and ascorbic acid contents of apples and pears. Journal of agricultural and food chemistry 59, 6165-6171.

15. Kviklienė N, Kviklys D, Valiuškaitė A, Viskelis P, Uselis N, Lanauskas J, Buskiene L. 2011. Effect of harvest date on fruit maturity, quality and storability of 'Lodel'apples. Journal of Food, Agriculture & Environment 9, 210-213.

16. Kviklienė N, Valiuškaitė A. 2009. Influence of maturity stage on fruit quality during storage of 'Shampion' apples. Scientific Works of the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture Sodininkystė Ir Daržininkystė 28, 117-123.

17. Macheix J, Fleuriet A. 1990. Fruit phenolics. CRC press.

18. Meisami E, Rafiee S, Keyhani A, Tabatabaeefar A. 2009. Some physical properties of apple cv.'Golab'. Agricultural Engineering International, CIGR Journal. Manuscript 1124.

19. Mosel H.D, Herrmann K. 1974. Phenolics of fruits. 4. Phenolics of blackberries and raspberries and Their changes during development and ripness of fruits. Zeitschrift fur Lebensmittel- U. Untersuchung und-Forschung 154, 324- 327.

20. Ough C.S, Amerine M.A. (ed). 1988. Phenolic compounds. Methods for analysis of musts and wines. John, Wiley and Sons, Inc., New York, USA.

21. Pocharski W, Konopacka D, Zwierz J. 2000. Comparison of Magness -Taylor pressure test with mechanical, nondestructive methods of apple and pear firmness measurements. International Agrophysics 14, 311-331.

22. Reid M, Kader A. 2002. Maturation and maturity indices. Postharvest technology of horticultural crops. University of California, Agricultural and Natural Resources, Publication 3311.

23. Renard C, Dupont N, Guillermin P. 2007. Concentrations and characteristics of procyanidins and other phenolics in apples during fruit growth. Phytochemistry 68, 1128-1138.

24. Shah N, Khan M, Kasi A, Khair M. 2002. Post harvest and cold storage losses in apple of Balochistan. Asian Journal of Plant Sciences 1, 65-66.

25. Scalbert A, Johnson I.T, Saltmarsh M. 2005. Polyphenols: antioxidants and beyond. The American Journal of Clinical Nutrition 81, 2155-2175.

26. Skrzynski J. 1996. Optimum harvest date study of 4 apple cultivars in southern Poland. The Postharvest Treatment of Fruit and Vegetables. Determination and Prediction of Optimum Harvest Date of Apples and Pears 94, 61-66.

27. Smith S.M, Geeson J.D, Martin B.K, Genge P.M, Everson H.P. 1987. Modified-atmosphere retail packaging of discovery apples. Journal of the Science of Food and Agriculture 40, 165-178.

28. Veravrbeke E.A, Verboven P, Oostveldt P, Nicolai B.M. 2003. Predication of moisture loss across the cuticle of apple (*Malus sylvestris* supsp). Mitis (Wallr.) during storage: part 2. Model simulations and practical applications. Postharvest Biology and Technology 30, 89-97.

29. Weibel F, Widmer F, Husistein A. 2004. Comparison of production systems: integrated and organic apple production. Part III: Inner quality: composition and sensory. Schweizer Zeitschrift für Obst- und Weinbau 140, 10-13.