Journal of Horticultural Research 2017, vol. 25(1): 67–79
DOI: 10.1515/johr-2017-0008

DE GRUYTER
OPEN

IMPACT OF HARVESTING TIME AND LENGTH OF COLD STORAGE PERIOD ON PHYSIOLOGICAL AND QUALITY TRAITS OF FOUR QUINCE GENOTYPES (*CYDONIA OBLONGA* MILL.)

Maryam TATARI*[1], Asghar MOUSAVI[2]
[1]Horticulture Crops Research Department, Isfahan Agricultural and Natural Resources Research and Education Center. Agricultural Research, Education and Extension organization (AREEO) 8415865451 Isfahan, Iran
[2]Horticulture Crops Research Department, Agriculture and Natural Resources Research Center of Chahar-Mahal va Bakhtiari, Education and Extension Organization (AREEO), Shahrekord, Iran

Received: March 2017; Accepted: Mai 2017

ABSTRACT

The investigation was conducted to determine the best harvesting time and the storage period of some quince cultivars and promising genotypes from the collection of quince germplasm in the Horticultural Research Station of Isfahan, Iran. For this study, fruits of 'Vidoja' and 'Isfahan' cultivars as well as promising genotypes PH2 and NB4 were harvested on 6, 14 and 21 October 2015 and 2016 and then stored at 0 ± 1 °C with 90 ± 5% R.H. for five months. Weight loss, firmness, total soluble solids (TSS), titrable acids (TA), taste index, pectin, total phenols, and percent of decay and surface browning of fruits were measured immediately after harvest and one-month intervals after storage in a factorial experiment based on a completely randomized design with three replications and 10 fruits per each replication. The results showed that 'Isfahan' cultivar had the highest TSS (18.83%), total phenols and weight loss. The least weight loss was observed in the 'Vidoja' cultivar. NB4 genotype showed the least taste index and pectin, while the most pectin and firmness was related to PH2 genotype. Generally, the delay in harvesting and prolongation of storage led to increasing of TSS and weight loss and declining of firmness and phenols, TA, and pectins. Until the third month of storage, there was no surface browning. Browning symptoms were observed from the fourth month of storage and increased in the fifth month up to 1.72%. Generally, the best harvesting time for 'Vidoja' was 185 days and for the rest of the genotypes, it was 193 days after full bloom. Fruit storage for four months in cold is advisable for these cultivars and genotypes.

Key words: postharvest, surface browning, pectin, phenol content**,** fruit firmness, total soluble solids, titratable acidity

INTRODUCTION

Quince (*Cydonia oblonga* L.) is an economically third fruit from pome fruits category (Rasoulzadegan 1992). The total production of quinces in the world in 2014 was 649 364 tons. More than 66% of the quinces comes from Asia (FAO 2014). According to the Sabeti (1995), quince has been known to be native to Iran and its distribution centers are the northern forests of Iran. The most important cultivars of quince in the world are 'Orange', 'Champion', 'Pineapple', 'Smyrna', 'Van Deman', 'Rea', and 'Meach'. 'Isfahan', 'Gorton', 'Neishabour', and 'Torsh' cultivars are the main quince cultivars of Iran (Maniei 1995). Quince is a climacteric fruit (Angelov 1975), which should be harvested after physiological ripening to enable maximum storage life. If climacteric fruits were harvested before physiological ripening, they will have not unique taste and smell, as a result of small size and high firmness at harvest. On the other hand, if these fruits were harvested after full ripening, their storage life will be short (Franck et al. 2007). One of the main strategies is harvesting fruits at their maturity stage

*Corresponding author:
e-mail: mtatari1@gmail.com

(Kupferman et al. 1995). The measured factors for the determination of maturity stage and harvesting time of fruits included fruit firmness, skin and pulp color, total soluble solids (TSS), titrable acids (TA), chlorophyll, and carotene content. Days from full bloom to ripening and heat units during special periods of growth season are also used for this purpose (Rahemi & Akbari 2004).

Storage of fruits in low temperature is another important method to store horticultural crops that can reduce some metabolic reactions conducive to natural disintegration, loss of crop quality, respiration, ethylene production, senescence, and decay development (Brown 1986). The storage life of quince cultivars is more than three months (Gunes et al. 2012). Kuzucu and Sakaldas (2008) reported that quince cv. 'Esme' were stored in 0 ± 0.5 °C and 85–90% RH for six months.

Soska and Tomala (2006) reported that TSS and TA play an important role in assessing internal fruit quality because of the direct effect on the taste of the fruit. The most TSS in 'Gorton' quince was obtained 135 days after storage (Nikkhah & Ganji Moghadam 2006). In quince cv. 'Esme', TSS concentration at the third harvest was higher than at first and second harvests. The amounts of TA at the beginning of storage and after six months were 0.7% and 0.35%, respectively (Kuzucu & Sakaldas 2008).

Weight and water content in very early harvested fruits are low because of the incomplete physiological maturation process (Kvikliene & Valiuskaite 2009).

Fruit firmness depends on size, shape, thickness, and stability of cell structure, and composition of the cell wall and also how cells connect with each other. During ripening, these factors change and lead to more empty cellular spaces and less cellular connections. Tissues with smaller cells have more intercellular connections and lower intercellular species, so these tissues are firmer than tissues with larger cells and intercellular spaces (Harker et al. 1997). Fruit firmness and TSS declined with storage time for kiwifruit cv. 'Hivard' (Ashournezhad et al. 2013).

Firmness, water loss, and physiological dis-orders in the early stages of quince storage are lower than those in apple and pear. One of the important problems during the marketing of quince cultivars is enzymatic browning, which leads to physiol-ogical disorder occurring after storage. It is affected by the growing season, harvest term, and storage conditions (Kuzucu & Sakaldas 2008). Surface browning is caused by the polyphenoloxidase enzyme activity (Amiot et al. 1992). During enzym-atic browning, phenolic compounds such as chlorogenic acid are oxidized to *o*-quinone by polyphenoloxidase and then *o*-quinone is converted into melanin by nonenzymatic polymerization process, which leads to the destruction of fruit and develop-ment of yellow or brown pigments. In fact, the phenolic compounds are substrates for polyphenol-oxidase (Awad & De Jager 2000). Late harvest and long-term quince storage reduced fruit firmness and promoted surface browning (Nikkhah & Ganji Moghadam 2006).

Some quince genotypes were identified and collected from central areas of Iran by Ghasemi (2002). Some of them were introduced as new cultivars such as 'Vidoja' and the rest are promising genotypes, which are being introduced such as NB4 and PH2. The aims of this study were (a) to determine the best harvesting date of 'Vidoja' 'Isfahan' NB4, and PH2 quince genotypes based on effective harvest indexes such as TSS, TA, and taste index and (b) to investigate their suitable storage time because the supply on the market is high in October and it is essential that fruits can be stored and sold at the best time before they lose quality.

MATERIALS AND METHODS

Plant materials

Four Iranian quince cultivars and promising genotypes were separately harvested in three terms with weekly interval on October 6, 14, and 21 2015 and 2016 from an orchard collection located at the Horticultural Research Station in Esfahan, Iran. Flowering time of these cultivars and genotypes was registered in March and April and time of full bloom was separately recorded for each cultivar to predict harvesting time based on the number of days after full bloom.

Storage conditions

The harvested fruits in all the three terms were separately located in boxes in a factorial experiment based on a completely randomized design (CRD) with three replications and 10 fruits per each replication and stored for five months at 0 ± 1 °C and 90 ± 5% relative humidity (RH). Quantitative and qualitative characteristics of fruits were studied at harvest and in one-month intervals during cold storage.

Measurement of traits

Weight loss percentage was computed as the difference between the weight of individual fruit before transfer to the cold storage and after each month of storage.

Fruit firmness was measured by a penetrometer (model EFFEGI, Italy, plunger diameter 11.1 mm, depth 7.9 mm), at the opposite peeled sides and expressed as $kg \cdot cm^{-2}$.

Total soluble solids (TSS) were determined by extracting and mixing two drops of juice from the two cut ends of each fruit into a digital refractometer (ATAGO N-1α, Japan) at 22 °C.

Titrable acids were determined in 10 g of pulp samples by titration of extracted juice with sodium hydroxide (0.1 N) up to pH 8.1 and expressed as a percent of malic acid.

Taste index was calculated from TSS to TA ratio.

Pectin content was measured according to Thakur et al. (1996). Briefly, 100 g of fruit tissue was grated and 400 ml of distilled water was added and was boiled for an hour. After passing through the filter paper, 300 ml of distilled water and 10 ml NaOH were added and the resulting solution was kept overnight at room temperature. Then 50 ml of acetic acid (1 N) and 25 ml of calcium chloride was added to the solution. The resulting solution was kept for one hour at room temperature and then was boiled for an hour. Boiled solution was passed through filter paper. The difference between initial and secondary weight of filter paper was reported as pectin weight based on grams per 100 grams of fruit pulp.

Total phenols were measured in fruit juice using Folin-Ciocalteu (Singleton & Rossi 1965). Absorbance of the samples was determined at 765 nm wavelength using the spectrophotometer model T80 UV/Visible and then compared with the standard of gallic acid and expressed as mg gallic acid per 100 grams of fresh weight.

Decay percentage was recorded in each replication as resulting from fungal diseases.

The surface browning percentage was recorded three days after a cold storage after maintaining at 20 °C.

Statistics design

The results were compared using factorial experiment based on a completely randomized design with three replications and 10 fruits per replicate for different genotypes. Analysis of data was performed by ANOVA method using statistical software SAS (version 1.9) and mean comparisons using Tukey.

RESULTS

Flowering time

The results showed that ‘Vidoja’ cultivar was flowering earlier than ‘Isfahan’, NB4 and PH2. ‘Isfahan’, NB4, and PH2 genotypes had moderate flowering overlap with ‘Vidoja’ (Table 1). Due to higher temperature in 2016, flowering occurred earlier in all studied genotypes.

The weather course in 2015 and 2016 influenced weight loss, TSS percentage, and TSS/TA proportion (Table 2, 3).

Table 1. Flowering time of quince cultivars and promising genotypes in 2015 and 2016

	March – April																			
	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Vidoja (2015)																					
Vidoja (2016)																					
NB4 (2015)																					
NB4 (2016																					
PH2 (2015)																					
PH2 (2016)																					
Isfahan (2015)																					
Isfahan (2016)																					

Table 2. Synthetic results of ANOVA (mean squares and degrees of freedom) for tested effects

Source of variation	Degrees of freedom (df)	Traits								
		weight loss (%)	TSS (%)	TA (%)	TSS/TA	firmness ($kg \cdot cm^{-2}$)	pectin ($g \cdot 100\,g^{-1}$)	total phenol ($mg \cdot 100\,g^{-1}$ FW)	fruit decay (%)	fruit browning (%)
Year	1	164.72^{**}	984.03^{**}	0.02^{ns}	2367.61^{**}	0.46^{ns}	356.48^{ns}	11.42^{ns}	0.019^{ns}	0.00001^{ns}
Repetition (year)	4	52.83^{**}	8.23^{**}	0.03^{**}	196.29^{**}	1.77^{**}	358.72^{ns}	697.23^{**}	0.03^{**}	0.002^{**}
Harvesting term	2	160.64^{**}	98.26^{**}	1.03^{**}	7003.83^{**}	3.97^{**}	372.57^{ns}	12103.65^{**}	0.02^{*}	0.002^{**}
Cultivar	3	675.51^{**}	77.52^{**}	1.28^{**}	5229.96^{**}	28.17^{**}	360.38^{ns}	17502.37^{**}	0.02^{*}	0.0005^{ns}
Storage time	5	2181.77^{**}	92.14^{**}	1.42^{**}	6625.94^{**}	41.14^{**}	382.09^{ns}	28768.39^{**}	0.11^{**}	0.007^{**}
Cultivar×Harvesting term	6	3.02^{ns}	30.8^{**}	0.03^{**}	465.84^{**}	0.53^{**}	358.02^{ns}	362.95^{**}	0.001^{ns}	0.00007^{ns}
Storage time×Harvesting term	10	11.66^{*}	5.2^{**}	0.006^{ns}	293.21^{**}	0.11^{**}	360.65^{ns}	107.89^{**}	0.008^{ns}	0.001^{*}
Cultivar×Storage time	15	44.77^{**}	11.06^{**}	0.01^{**}	142.35^{**}	0.31^{**}	359.35^{ns}	1299.57^{**}	0.009^{ns}	0.0005^{ns}
Cultivar×Harvesting term×Storage time	30	36.59^{*}	4.15^{**}	0.008^{ns}	70.53^{**}	0.108^{**}	359.5^{ns}	138.64^{**}	0.001^{ns}	0.0003^{ns}
Year×Harvesting term	2	14.5^{ns}	0.22^{ns}	0.00009^{ns}	4.26^{ns}	0.001^{ns}	359.81^{ns}	1.15^{ns}	0.003^{ns}	0.0000002^{ns}
Year×Cultivar	3	18.9^{*}	0.56^{ns}	0.00009^{ns}	21.63^{ns}	0.001^{ns}	356.88^{ns}	2.62^{ns}	0.01^{ns}	0.00001^{ns}
Year×Storage time	5	103.64^{**}	0.19^{ns}	0.0008^{ns}	12.82^{ns}	0.001^{ns}	358.86^{ns}	4.26^{ns}	0.008^{ns}	0.00005^{ns}
Year×Harvesting term×Cultivar	6	10.19^{ns}	0.11^{ns}	0.0000^{ns}	2.47^{ns}	0.002^{ns}	359.65^{ns}	2.01^{ns}	0.009^{ns}	0.000008^{ns}
Year×Harvesting term×Storage time	10	16.33^{**}	0.07^{ns}	0.001^{ns}	2.64^{ns}	0.002^{ns}	358.57^{ns}	3.56^{ns}	0.002^{ns}	0.000005^{ns}
Year×Cultivar×Storage time	15	6.10^{ns}	0.18^{ns}	0.0006^{ns}	6.09^{ns}	0.002^{ns}	359.05^{ns}	2.08^{ns}	0.006^{ns}	0.00002^{ns}
Year×Harvesting term×Cultivar×Storage time	30	9.66^{ns}	0.21^{ns}	0.0004^{ns}	2.8^{ns}	0.001^{ns}	358.41^{ns}	2.64^{ns}	0.006^{ns}	0.00001^{ns}
Error	284	5.62	0.58	0.006	37.96	0.005	358.63	15.23	0.006	0.0004
Total	431	-	-	-	-	-	-	-	-	-
C.V.	-	15.77	5.06	13.58	14.13	2.19	18.93	9.3	14.44	4.11

**,* and ns: significant at the 1% and 5% probability level and non-significant difference respectively

Table 3. Mean comparison of cultivar, duration of storage and harvesting time on weight loss, TSS, firmness and total phenol

Cultivar	Harvesting time	Duration of storage (month)	Weight loss (%)	TSS (%)	TSS/TA	Firmness (kg/cm^2)	Total phenol (mg/100 g FW)
Vidoja	1	At the beginning of storage	-	15.66h-l	20.6rs	3.9fgh	45.94kl
Vidoja	1	1	1.55yz	15.33j-m	20.03rs	3.67hij	40.04lmn
Vidoja	1	2	2.94v-y	15.16klm	20.26rs	3.19n	31.14nop
Vidoja	1	3	4.57s-x	15.83h-k	23.93pqr	2.67rs	21.18pqr
Vidoja	1	4	6.59p-t	16g-k	34.54kl	1.98wx	16.43rst
Vidoja	1	5	7.65o-r	16.33e-i	36.05ijk	1.42z	9.13vw
NB4	1	At the beginning of storage	-	10.16v	9.5x	4.36d	56.71hij
NB4	1	1	2.73wxy	11.5tu	12.2uvw	4.06ef	40.25lmn
NB4	1	2	4.64s-x	12.83rs	15.2tu	3.21n	43.2klm
NB4	1	3	8.88nop	14.5mno	19.91rst	2.86pqr	23.09pq
NB4	1	4	14.01g-j	15.66h-l	22.36qr	2.52rst	17.74rs
NB4	1	5	17.18cde	15.83h-k	26.88nop	2.28u	3.51xy
PH2	1	At the beginning of storage	-	11.5tu	12.84uvw	4.95a	33.99no
PH2	1	1	4.23t-x	11.83t	14.76tuv	4.69b	35.82n
PH2	1	2	6.42p-u	13.16qr	19.35rst	4.47cd	25.52p
PH2	1	3	12.81h-k	15.16klm	23.26pqr	4.06ef	21.57pqr
PH2	1	4	16.06d-g	15.83h-k	27.54no	3.69hi	11.53u
PH2	1	5	16.65c-f	16.16f-j	30.5mn	3.27mn	2.68xyz
Isfahan	1	At the beginning of storage	-	13.5pqr	17.97st	4.56c	98.21b
Isfahan	1	1	3.78v-y	13.83opq	20.03rs	4.14e	73.02ef
Isfahan	1	2	6.38q-u	14.5mno	24.94pq	3.69hi	58.41ghi
Isfahan	1	3	9.91l-o	15.5i-l	33.41klm	3.3lmn	32.44no
Isfahan	1	4	12.84hij	15.83h-k	33.47klm	2.89pq	11.64u
Isfahan	1	5	18.77bc	16.33e-i	45.27fgh	2.46stu	5.37x
Vidoja	2	At the beginning of storage	-	15.66h-l	20.71rs	3.76gh	57.88g-j
Vidoja	2	1	3.12v-y	15.66h-l	22.61qr	3.33lm	61.82g
Vidoja	2	2	4.55s-x	15.66h-l	24.37pq	2.98op	51.19jk
Vidoja	2	3	6.51p-u	15.5i-l	32.25lm	2.52rst	47.05k
Vidoja	2	4	8.28n-q	15.83h-k	41.3f-i	2.16uv	32.43no
Vidoja	2	5	11.79j-m	16g-k	50.69e	1.72x	19.49qr
NB4	2	At the beginning of storage	-	10.83uv	11.25vw	4.3de	69.52f
NB4	2	1	2.68wxy	12.16st	16.27stu	3.7ghi	60.67gh
NB4	2	2	4.94s-x	13.83opq	21.18qrs	3.19n	54.73ij
NB4	2	3	12.36i-l	14.5mno	21.78qrs	2.89pq	46.49kl
NB4	2	4	14.05g-j	15.16klm	23.54pqr	2.71r	29.24op
NB4	2	5	19.005bc	16.16f-j	31.75lmn	2.53rst	10.98uv

Continued Table 3

Cultivar	Harvesting time	Duration of storage (month)	Weight loss (%)	TSS (%)	TSS/TA	Firmness (kg/cm^2)	Total phenol (mg/100 gFW)
PH2	2	At the beginning of storage	-	12.83rs	14.88tuv	4.87a	46.76kl
PH2	2	1	4.51t-x	14.16nop	19.08rst	4.47cd	42.5lm
PH2	2	2	10.33k-n	15.5i-l	22.83qr	3.94fg	30.79nop
PH2	2	3	14.12g-j	15.5i-l	23.5pqr	3.64j	24.11p
PH2	2	4	17.01cde	15.83h-k	28.22n	3.33lm	15.73rst
PH2	2	5	19.12bc	16.33e-i	36.66ijk	2.98op	14.62rst
Isfahan	2	At the beginning of storage	-	13.16qr	21.53qrs	4.51c	103.32a
Isfahan	2	1	4.06u-x	13.5pqr	24.75pq	4.09ef	80.61d
Isfahan	2	2	6.64p-t	15.16klm	28.72n	3.55k	73.01ef
Isfahan	2	3	11.94j-m	16.16f-j	37.66ij	2.88pq	59.37gh
Isfahan	2	4	15.64efg	16.83d-g	37.83ij	2.35tu	40.59lmn
Isfahan	2	5	18.09bcd	10.83uv	33.19klm	2.11uvw	12.69t
Vidoja	3	At the beginning of storage	-	14.5mno	23.09pqr	3.94fg	59.6gh
Vidoja	3	1	2.49xy	14.5mno	26.38nop	3.4l	63.07g
Vidoja	3	2	3.5v-y	15.16klm	35.33jk	2.91opq	52.16j
Vidoja	3	3	7.66o-r	15.83h-k	38.69i	2.44stu	47.29kl
Vidoja	3	4	10.2lmn	16.33e-i	64.44c	2.05vw	33.27no
Vidoja	3	5	12.8h-k	16.33e-i	67.22b	1.54y	20.82qr
NB4	3	At the beginning of storage	-	11.83t	13.68uv	3.72ghi	84.36cd
NB4	3	1	5.02s-w	12.83rs	17.26st	3.1o	69.25f
NB4	3	2	7.01p-s	13.83opq	21.53qrs	2.8qr	62g
NB4	3	3	11.77j-m	14.83lmn	24.66pq	2.55rs	45.99kl
NB4	3	4	15.06e-h	15.83h-k	33.77klm	2.34tu	32.45no
NB4	3	5	20.2ab	16.5e-h	41.25f-i	2.1vw	21.81pqr
PH2	3	At the beginning of storage	-	15.83h-k	20.77rs	4.57c	47k
PH2	3	1	5.36r-v	16.16f-j	22.76qr	4.39d	45.97kl
PH2	3	2	9.63mno	16.83d-g	25.43op	4.005efg	32.24no
PH2	3	3	14.49f-i	17c-f	28.37n	3.73ghi	25.76p
PH2	3	4	18.22bcd	17.83bc	38.74i	3.34lm	19.98qr
PH2	3	5	20.54ab	17.5bcd	48.19f	2.88pq	15.54rst
Isfahan	3	At the beginning of storage	-	16.5e-h	30.22mn	3.92fgh	101.64ab
Isfahan	3	1	3.56v-y	16.83d-g	39.16hi	3.72ghi	85.79c
Isfahan	3	2	4.5t-x	17.16cde	46.19fg	3.39l	74.17e
Isfahan	3	3	11.67j-m	17.5bcd	50.83e	2.89pq	57.63g-j
Isfahan	3	4	18.68bc	18.16ab	55.55d	2.47r-u	44.22klm
Isfahan	3	5	21.71a	18.83a	73.33a	2.1vw	36.12n

Means in each column have significant difference at the 5% level of Tukey test

General results of storage

All the studied factors – cultivar, year of cultivation, harvesting term, and length of storage – significantly influenced weight loss, TSS, TA concentration, and taste index (Table 2). Firmness, total phenols, browning, TA concentration, and decay % were not influenced by the year of the experiment. None of the studied factors influenced pectin concentration. Year of the experiment and cultivar did not cause browning of fruits. A significant correlation in weight loss was found for the harvesting term × storage time, storage time × cultivar, and year of growing × storage time × harvesting term. Similarly, a significant correlation for TSS and total phenols concentrations, taste index, and firmness was recorded for harvesting term × cultivar, harvesting term × storage time, storage time × cultivar, and storage time × harvesting term × cultivar (Table 2).

Weight loss

In all cultivars and terms of harvest, weight loss gradually increased with time of storage (Table 3). The least loss was recorded in 'Vidoja'. Between the remaining genotypes losses were similar. The weight loss increased also with term of harvest. During the first term, after five months of storage, a loss of 'Vidoja' was 7.7%, whereas fruits harvested in the third term lost 12.8% of weight. The same values in 'Isfahan' were 18.8% and 21.7% respectively.

TSS, TA, and pectin concentration

The lowest TSS concentration was recorded in NB4 genotype (10.2–16.5%) and the highest in 'Vidoja' (14.5–16.3%) (Table 3). TSS concentration increased slightly with time of storage, but much less with harvest term.

TA concentration decreased gradually with the time of storage (Fig. 1). The highest concentration of TA was recorded in NB4 and PH2 genotypes and it was typical in each length of storage, but decreased with term of harvest being the lowest at the third term (Fig. 3).

The values of taste index resulted from above proportions were higher in 'Vidoja' and 'Isfahan' than in NB4 and PH2 (Table 3). They increased with time of storage more in 'Vidoja' and 'Isfahan' than NB4 and PH2.

Pectin concentration was highest at the beginning of storage and gradually decreased with time of storage up to 4–5× (Fig. 2). At this time, there were significant differences between genotypes, so in PH2 pectin concentration was the highest, followed by 'Vidoja' and the lowest was in 'Isfahan'.

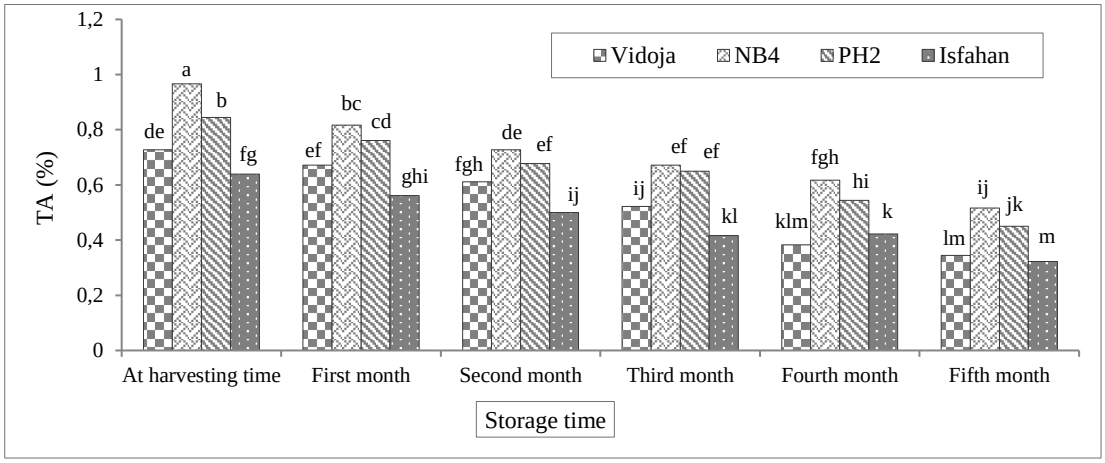

Fig. 1. Effects of cultivar and storage time on TA percentage

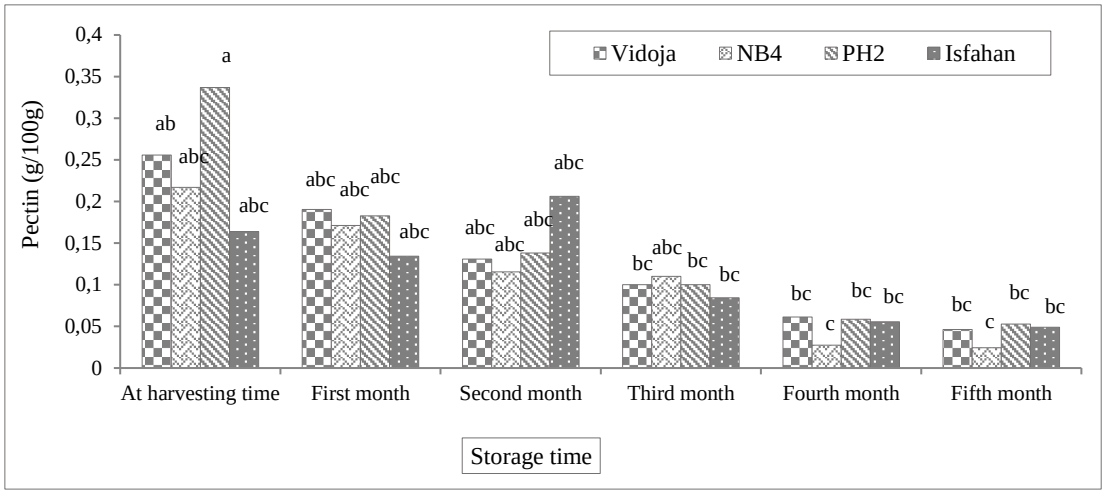

Fig. 2. Effects of cultivar and storage time on pectin content

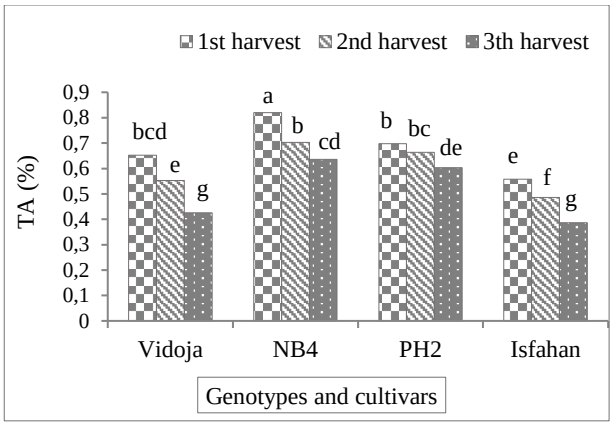

Fig. 3. Effects of cultivar and harvesting time on TA percentage

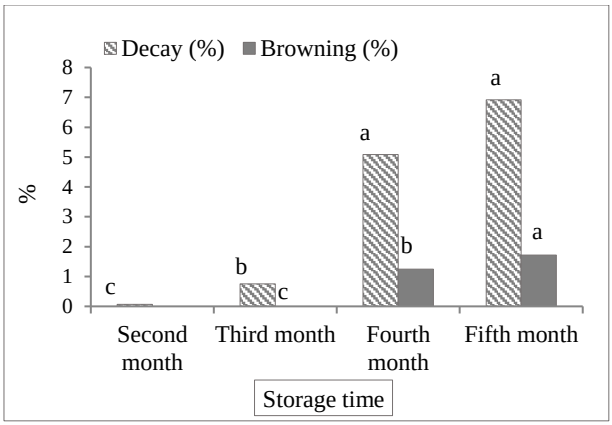

Fig. 4. Effects of storage time on decay and browning percentage

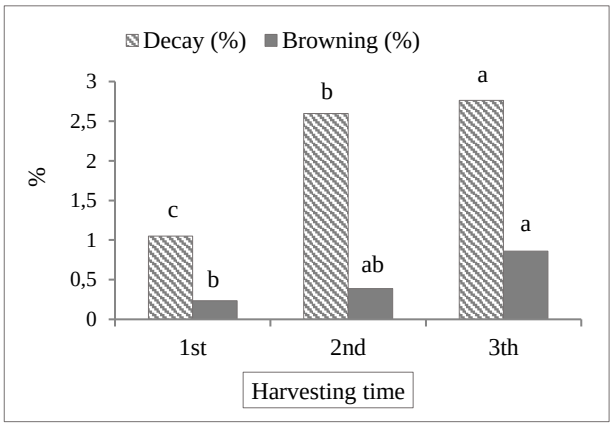

Fig. 5. Effect of harvesting time on decay and browning percentage

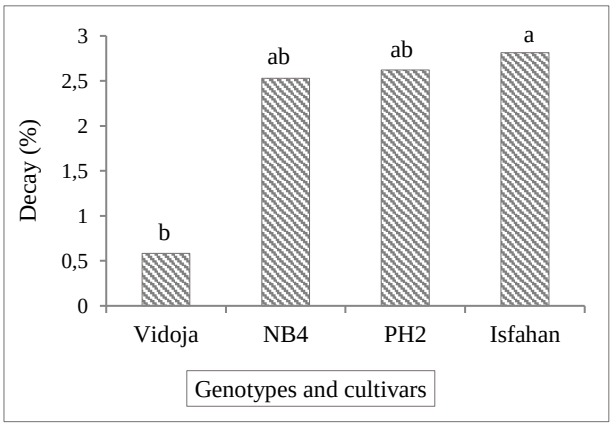

Fig. 6. Effect of cultivar on decay percentage

Total phenols, decay, and browning

There were big differences between genotypes in the total phenols concentration. The 2× higher phenols concentration than in 'Vidoja' and 3× higher than in PH2 was recorded in 'Isfahan'. The concentration increased with term of harvest and decreased with time of storage (Table 3).

The decay of fruit depended mostly on storage time and to a lesser extent on cultivar and year of growing (Table 2). It was 2.5 higher in the second and third terms of harvest and five and seven times higher after four and five months of storage. Moreover, decayed was only 0.5% of 'Vidoja' but 2.5–3% of the other genotypes (Figs. 5 & 6).

Higher browning was recorded in the second and third harvest terms and after four and five months of storage, but no more than 1.5% of the fruit was affected.

DISCUSSION

Water loss during storage resulting in weight reduction had a negative effect on fruit appearance (Pasquariello et al. 2013) and it correlated with storage length (Nikkhah & Ganji Moghadam 2006). Decreases of weight loss in quince cv. 'Esme' after six months of storage were 9.0%, 10.5%, and 11.5% at first, second, and third harvest terms, respectively (Kuzucu & Sakaldas 2008). This trait differs with cultivars. According to Burdon and Clark (2001), weight loss of kivi fruit depends on storage conditions, mineral elements, and surface-to-volume ratio of fruits. Fruits harvested at proper ripeness had less weight loss compared to fruit harvested too early or too late (Elgar et al. 1999). In this research, 'Isfahan', PH2 and NB4 in the third harvest term after five months of storage had the highest weight loss. The lowest loss of weight was observed in the first harvesting term after one month of storage in 'Vidoja'.

The soluble sugar (sucrose, fructose, and glucose) contents resulting from the hydrolysis of starch during ripening are determined by evaluation of TSS concentration (Etienne et al. 2013). Khoush Ghalb et al. (2008) showed that Asian pear at harvesting had large amounts of sucrose that was converted into simple sugars during prolonged storage, which leads to increase of TSS. These metabolic processes coincide with an increase or decrease other compounds, such as acids, soluble pectins, and phenolics (Amodio et al. 2007). In current research, TSS values differ among genotypes. Gorji et al. (2010) reported that the average value of the TSS differed between apple cultivars from 8.75% to 11.1%, which is based on both genetic characteristics and environmental conditions during growth. Our results showed that differences among cultivars and genotypes can be caused by different origins of these plants. Mosharraf and Ghasemi (2004) reported that TSS in the late harvested fruits of 'Isfahan' quince was 16.2% and 14.75% after five months of storage and at the beginning of storage, respectively, which was less than that reported in this study. The reason for these differences can be related to water deficits leading to an increase in cell sap concentration.

The highest value of taste index was recorded in 'Isfahan' and 'Vidoja' in the third harvest term and after five months of storage. Values of this trait increased with prolonged storage. Similar information was reported for Kiwi fruit cv. 'Hivard' (Ashournezhad et al. 2013). In the study of Eshghi et al. (2011) on apples, the proportion TSS/TA was similar to those in 'Isfahan' and 'Vidoja'.

In this research, the most and the least fruit firmness had PH2 and 'Vidoja', respectively. Generally, late harvest and longer storage reduced fruit firmness, which was determined, for example, in pear fruit cv. 'Yali' (Chen et al. 2006). In quince fruits cv. 'Esme', firmness in the third harvest term quickly reduced and after six months reached 3 $kg \cdot cm^{-2}$. The highest fruit firmness, 12.5 $kg \cdot cm^{-2}$, was observed at first harvest term (Kuzucu & Sakaldas 2008). Fruit firmness depends on the structure and composition of the cell walls (Valero & Serrano 2010). Progress in ripening, maturation, and senescence of fruit leads to dissolving of middle lamella, loss of integrity of the cell wall, and loss of firmness. In this case, the fruit sensitivity to postharvest disorders depends on the maturity stage of the fruit at harvest time (Raese & Drake 2000). On the other hand, polysaccharide property of sucrose cause fruit firmness. During cold storage of climacteric fruits ripening continues, during which time enzymes in the cell wall convert polysaccharides

and sucrose into simple sugars. The firmness and amount of sucrose are reduced with fruit ripening (Halinska & Frenkel 1991). The fruits of the evaluated genotypes here had different levels of firmness. The effect of harvesting term on apple firmness after cold storage has also been reported by Konopacka and Płocharski (2002).

In our experiment, the concentration of total phenols depended on genotype, harvest term, and length of storage, which was in accordance with other reports on apricots and kiwi fruits (Ashournezhad et al. 2013; Ardekani et al. 2013). After fruit harvesting, phenol content is reduced but that decrease is modified by the harvest term and storage conditions (Kalt 2005).

As mentioned in this paper, the TA concentration at harvesting time depended on genotype. Generally, TA decreased with prolongation of harvesting term and the storage period (Gorji et al. 2010; Mosharraf & Ghasemi 2004). There is a large amount of organic acids in the fruits at the beginning of fruit growth and development; therefore, the fruits have high acidity before ripening, but in the process of fruit ripening, organic acids decompose or convert to other organic acids or sugars and increasing fruit sweetness (Hudina & Stampar 2000).

Pectin content in quince fruit in our experiment had a maximum value at harvesting time, which then was reduced during storage, but concentration differs between genotypes. Mosharraf and Ghasemi (2004) observed decrease in pectin content by 50% with lengthy storage. In a report by this author, the values were higher than those observed in the present study, which could be the result of differences in growing conditions. In the study on apple cv. 'Idared', the total pectin content did not differ at various harvesting dates, but little change occurred during five months of storage. The pectin content decreased in 'Idared' apple during storage to about 10.12%, which was much less than in other cultivars, 'Jonica', 'Jonagold', 'Mutsu', 'Golden Delicious', and 'Kovelit' (Kovács & Merész 2004). In the current study, the range of decrease in pectin content during storage of quince genotypes was 9–16%.

Our results showed that storage period and decay were correlated. Studying of quince geno-types in different regions of Iran, Abdollahi (2012) has shown that fruits that grow in more humid areas have more symptoms of decay and fruit deformities than fruits produced in more arid areas.

It has been reported that prolonged storage and temperatures lower than 1 ± 2 °C increase surface browning and produce a decline product quality (Ayfer et al. 1983). In this study, surface browning was influenced by the duration of storage, so that in the fifth month, it reached 1.7%. Unlike the findings of this research, in the study of quince collection carried by Abdollahi (2012), surface browning was observed already in some fruits after two months of storage and a few months later, browning was observed in more than 70% of the fruits.

The delay in harvesting time led to increase in decay and surface browning. Khoush Ghalb et al. (2008) reported that increasing concentration of sugars and organic acids delayed fruit browning. Surface browning in the second harvest of quince cv. 'Esme' was more intensive than in the earlier harvest and reached 70% (Kuzucu & Sakaldas 2008). In this study, browning percentage was much lower than above. It is possible that higher levels of TSS in the present study led to a reduction in browning. Although it is believed that decay percentage is influenced by the genotype (Abdollahi 2012), our study didn't confirm this. Presumably, conditions of growing trees and storage procedure may be the reason. Amiot et al. (1992) suggested that it depends on the amount of phenolic compounds in fruits.

More TSS, TSS/TA, and less weight loss were observed in the second year of cultivation. Due to the annual decrease in rainfall and less irrigation water in the second year, the content of fruit juice was higher in the first year and weight and water loss becomes more visible. Less fruit juice in the second year increased concentration of cell sap and fruit sweetness and firmness compared to the first year.

According to the results, the first harvest term for 'Vidoja' (about 185 days after full bloom) is the most optimal for both desirable total soluble solids and for fresh consumption. For other genotypes, the third harvest term was more favorable than others (193 days after full bloom). Flowering time may change each year depending on environmental conditions, especially temperature, but the fruit development period (number of days from full bloom to

maturity) is almost unchanged with the cultivar. One of the main differences among cultivars is their fruit growing period (Mounzer et al. 2008). Other researchers have used the number of days from full bloom to harvest time for determination of appropriate harvesting term for different cultivars of quince. For example, Nikkhah and Ganji Moghadam (2006) reported that the most appropriate harvesting time for quince cv. 'Gorton' was 191 days after full bloom. Mosharraf and Ghasemi (2004) also reported that the best harvesting time for 'Isfahan' cultivar was 180 days after flowering and the most favorable storage period for this cultivar was five months after storage. Despite of cultivar, with prolonged storage higher TSS/TA value was recorded, but in the last month of storage, the fruits of all cultivars were soft and had an undesirable taste. So, storage of these genotypes for more than four months is not recommended. After this time, antioxidant properties and total phenolics content will reduce as well as surface browning and decay will increase.

CONCLUSIONS

The best harvesting time for 'Vidoja' was 185 days and in the 'Isfahan' and NB4 and PH2 genotypes was 193 days after full bloom. Fruit storage in at 0 ± 1^{o}C and $90 \pm 5\%$ relative humidity for four months is advisable for these genotypes.

REFERENCES

Abdollahi H. 2012. Evaluation of productive and vegetative traits a compatibility of new cultivars and genotypes of quince. Final Report of Research Project. Seed and Plant Improvement Institute, Karaj, Iran, 165 p. [in Persian with English abstract]

Amiot M.J., Tacchini M., Aubert S., Nicolas J. 1992. Phenolic composition and browning susceptibility of various apple cultivars at maturity. Journal of Food Science 57(4): 958–962. DOI: 10.1111/j.1365-2621.1992.tb14333.x.

Amodio M.L., Colelli G., Hasey J.K., Kader A.A. 2007. A comparative study of composition and postharvest performance of organically and conventionally grown kiwifruits. Journal of the Science of Food and Agriculture 87: 1228–1236. DOI: 10.1002/jsfa.2820.

Angelov T. 1975. Studies on fruit respiration in some quince cultivars with reference to determining the optimal harvesting date. Gradinarska i Lozarska Nauka 12: 11–18.

Ardekani E., Davari Nezhad G.H., Azizi M. 2013. Effect of foliar application of salicylic acid before harvest in shelf life, quality in post-harvest and antioxidant activity in apricot cv. Nouri. Journal of Horticultural Science 26: 448–459. [in Persian with English abstract]

Ashournezhad M., Ghasemnezhad M., Aghajanzadeh S., Fattahi Moghadam J., Bakhshi D. 2013. Evaluation of storage life and post-harvest quality of kiwifruit cv 'Hayward' fruits produced in conventional and organic agricultural systems. Journal of Agricultural Science and Sustainable Production 22: 1–12. [in Persian with English abstract]

Awad M.A., De Jager A. 2000. Flavonoid and chlorogenic acid concentrations in skin of 'Jonagold' and 'Elstar' apples during and after regular and ultra-low oxygen storage. Postharvest Biology and Technology 20: 15–24. DOI: 10.1016/S0925-5214(00)00116-2.

Ayfer M., Koksal A., Celik M., Kaynak L., Turk R. 1983. Researches on the cold storage conditions of the quince. Turkiye'de Bahce Urunlerinin Depolanması, Pazara Hazirlanması ve Tasınması Simpozyumu. Tubitak, pp. 48–57.

Brown B.I. 1986. Temperature management and chilling injury of tropical and subtropical fruit. Acta Horticulturae 175: 339–342. DOI: 10.17660/ActaHortic.1986.175.50.

Burdon J., Clark C. 2001. Effect of post-harvest water loss on 'Hayward' kiwifruit water status. Postharvest Biology and Technology 22: 215–225. DOI: 10.1016/s0925-5214(01)00095-3.

Chen J.L., Yan S., Feng Z., Xiao L., Hu X.S. 2006. Changes in the volatile compounds and chemical and physical properties of 'Yali' pear (*Pyrus bertschneideri* Rehd) during storage. Food Chemistry 97: 248–255. DOI: 10.1016/j.foodchem.2005.03.044.

Elgar H.J., Watkins C.B., Lalu N. 1999. Harvest date and crop load effects on a carbon dioxide-related storage injury of 'Braeburn' apple. HortScience 34(2): 305–309.

Eshghi M., Hajnajari H., Kalantari S., Damyar S., Rasuli V. 2011. Changes in physical and biochemical traits in native summer-ripening apple cultivars during cold storage. Journal of Agricultural Engineering Research 12: 59–70. [in Persian with English abstract]

Etienne A., Génard M., Lobit P., Mbeguié-A-Mbéguié D., Bugaud C. 2013. What controls fleshy fruit acidity? A review of malate and citrate accumulation in fruit cells. Journal of Experimental Botany 64: 1451–1469. DOI: 10.1093/jxb/ert035.

FAO 2014. Food and Agriculture Organization of the United Nations. http://www.fao.org./

Franck C., Lammertyn J., Ho Q.T., Verboven P., Verlinden B., Nicolai B.M. 2007. Browning disorders in pear fruit. Postharvest Biology and Technology 43: 1–13. DOI: 10.1016/j.postharvbio.2006.08.008.

Ghasemi A. 2002. Collection and identification of different quince genotype (Cydonia oblonga Mill.) in Isfahan province. Final Report of Research Project. Agriculture and Natural Resources Research Center of Isfahan, Iran, 123 p. [in Persian with English abstract]

Gorji C.A., Rajabipour A., Mobli H. 2010. Post-harvest physical and nutritional properties of two apple varieties. Journal of Agricultural Science 2(3): 61–68. DOI: 10.5539/jas.v2n3p61.

Gunes N.T., Dumanoglu H., Poyrazoglu E.S. 2012. Use of 1-MCP for keeping postharvest quality of 'Ekmek' quince fruit. Acta Horticulturae 934: 297–302. DOI: 10.17660/ActaHortic.2012.934.37.

Halinska A., Frenkel C. 1991. Acetaldehyde stimulation of net gluconeogenic carbon movement from applied malic acid in tomato fruit pericarp tissue. Plant Physiology 95(3): 954–960. DOI: https://doi.org/10.1104/pp.95.3.954.

Harker F.R., Redgwell R.J., Hallett I.C., Murray S.H., Carter G. 1997. Texture of fresh fruit. (ed J. Janick), Horticultural Reviews 20: 212–224. DOI: 10.1002/9780470650646.ch2.

Hudina M., Stampar F. 2000. Free sugar and sorbitol content in pear (Pyrus communis L.) cv. 'Williams' during fruit development using different treatments. Acta Horticulturae 514: 269–274. DOI: 10.17660/ActaHortic.2000.514.32.

Kalt W. 2005. Effects of production and processing factors on major fruit and vegetable antioxidants. Journal of Food Science 70: 11–19. DOI: 10.1111/j.1365-2621.2005.tb09053.x

Khoush Ghalb H., Arzani K., Malakouti M.J., Barzegar M. 2008. Changes of sugars and organic acids contents in two Asian pear cultivars (Pyrus serotina Rehd.) during fruit development and postharvest storage and its effect on fruit shelf life, quality and internal browning disorder. Journal Water and Soil Science 12(45A): 193–204. [in Persian with English abstract]

Konopacka D., Płocharski W.J. 2002. Effect of picking maturity, storage technology and shelf-life on changes of apple firmness of 'Elstar', 'Jonagold' and 'Gloster' cultivars. Journal of Fruit and Ornamental Plant Research 10: 15–26.

Kovács E., Merész P. 2004. The effect of harvesting time on the biochemical and ultrastructural changes in Idared apple. Acta Alimentaria 33(3): 285–296. DOI: 10.1556/AAlim.33.2004.3.9.

Kupferman E., Spotts R., Sugar D. 1995. Practices to reduce postharvest pear diseases. Tree Fruit Postharvest Journal 6(2): 18–23.

Kuzucu C.F., Sakaldaş M. 2008. The effects of different harvest times and packaging types on fruit quality of Cydonia oblongo cv. Eşme. Journal of the Faculty of Agriculture of Harran University 12 (3): 33–39.

Kvikliene N., Valiuskaite 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(3): 117–123.

Maniei A. 1995. Planting to harvest of pear and quince. Technical publication Iran, 113 p. [in Persian with English abstract]

Mosharraf L., Ghasemi A. 2004. Effect of harvesting time to increase the storage life of the Isfahan quince cultivar. J. Sci. Technol. Agric. Nat. Resour. 2: 181–189 [in Persian with English abstract].

Mounzer O.H., Conejero W., Nicolas E., Abrisqueta I., Garcia-Orellana Y.V., Tapia L.M., et al. 2008. Growth pattern and phenological stages of early-maturing peach trees under a Mediterranean climate. HortScience 43: 1813–1818.

Nikkhah S.H., Ghanji Moghadam E. 2006. Maintenance of qualitative and quantitative characteristics of the Gorton quince cultivar using Thiabendazole fungicide. 4th Congress of Horticultural Science, Mashhad, Iran.

Pasquariello M.S., Rega P., Migliozzi T., Capuano L.R., Scortichini M., Petriccione M. 2013. Effect of cold storage and shelf life on physiological and quality traits of early ripening pear cultivars. Scientia Horticulturae 162: 341–350. DOI: 10.1016/j.scienta.2013.08.034.

Raese J.T., Drake S.R. 2000. Effect of calcium sprays, time of harvest, cold storage and ripeness on fruit quality of 'Anjou' pears. Journal of Plant Nutrition 23: 843–853. DOI: 10.1080/01904160009382065.

Rasoulzadegan Y. 1992. Tree growing in temperate regions. Publication of Isfahan University of Technology, 756 p. [in Persian with English abstract].

Rahemi M., Akbari H. 2004. The effects of thermal treatment and type of packaging on quality and storage period of quince fruit. Journal of Horticultural Science and Technology 4: 72–83. [in Persian with English abstract]

Sabeti H. 1995. Iran's forests, trees and shrubs. Publication of Yazd University, 81 p. [in Persian with English abstract]

Singleton V.L., Rossi J.A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture 16(3): 144–158.

Soska A., Tomala K. 2006. Internal quality of apples during storage. Agronomijas Vēstis (Latvian Journal of Agronomy) 9: 146–151.

Thakur B.R., Singh R.K., Nelson P.E. 1996. Quality attributes of processed tomato products: a review. Food Reviews International 12(3): 357–401. DOI: 10.1080/87559129609541085.

Valero D., Serrano M. 2010. Postharvest biology and technology for preserving fruit quality. CRC Press. Taylor and Francis Group, Boca Raton, USA, 264 p.