

Physical and Biochemical Changes of Some Iranian Quince (*Cydonia oblonga* Mill) Genotypes during Cold Storage

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ABSTRACT

Quince fruit has many benefits to human health and is an excellent source of pectin for jellies and jam industry. The objective of the present research was to study fruit physio-chemical attributes of some quince genotypes at harvest and their changes during cold storage. The fruit of 15 genotypes were harvested at optimum maturity and stored for 0, 30, 60, 90 and 120 days in cold storage and some parameters were measured. The range of 13.00-18.76% for Soluble Solid Content (SSC), 0.38-0.95% for titratable acidity, 2.55-3.75 for pH, 52.16-91.00 N for firmness, 0.89-0.98 g cm⁻³ for density, 255.39-349.56 mg 100 g⁻¹ DM for carbohydrate, 7.28-23.02% for pectin and 11.66-33.30% for fruit fibers were observed across genotypes at harvest time. Negative correlations were found between weight loss and both firmness and density, while firmness had positive correlation with pectin and Ca content. Generally, significant changes (P ≤ 0.05) for measured characters were observed across genotypes and during cold storage, but the rate of changes varied according to genotypes. It was found that each studied genotype had one or more unique character such as lowest weight loss in 'Paveh 1', highest fruit firmness retaining in 'Marivan1', highest pectin in 'Marivan 1' and highest SSC in 'Marivan 2', that are promising for fruit breeding in future programs.

Keyword: Firmness, Fruit quality, Pectin, Postharvest.

INTRODUCTION

Quince (*Cydonia oblonga* Mill) fruit is very fragrant and has a balanced sweet-tart flavor that is excellent for jellies and preserves. Quince is a shrub or small tree (Sharma *et al.*, 2011), classified in *Rosaceae* family, pomoideae subfamily (Bell and Leitao, 2011), grows at cold temperate regions (Thomidis and Michailides, 2004) and cooler site in subtropical area (Razavi *et al.*, 2000), and needs cultural practices similar to that of apples and pears. Despite reports of quince benefits to human health (Legua *et al.*, 2013; Wojdyło *et al.*, 2013; Szychowski *et al.*, 2014) and increased demand in recent years, consumption remains low and few data are available

about cultivars and their behaviors in cold storage. Generally, low temperatures can substantially reduce the rate of many metabolic processes, which lead to fruit senescence, deterioration, and quality losses. Pome fruits, especially apples and pears, responses to cold storage are widely studied but have rarely been studied in quince fruit

According to available literature, quince fruit quality attributes, physiological changes, and postharvest losses have not been extensively studied, probably because quince is not a widely cultivated crop. However, the beneficial effects of quince as a source of pectin (Forni *et al.*, 1994; Thomas *et al.*, 2003, Moradi *et al.*, 2016) and bioactive compound (Alesiani *et al.*, 2010; Fiorentino *et al.*, 2008;

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Khoubnasabjafari and Jouyban, 2011; Wojdyło *et al.*, 2013) have been previously reported. In addition to bioactive compounds, some quince fruit quality attributes may affect consumers and food industry attitude including: Firmness, Soluble Solid Content (SSC), Titratable Acidity (TA), color, pectin, fiber and shrinkage (weight loss) (Tu *et al.*, 2000). Firmness and SSC are two important quality parameters in determining fruit maturity and harvest time, and they are also key parameters in assessing and grading the postharvest quality of pome fruit. Moisture loss during long-term storage of apples causes direct economic loss because of a decrease in saleable weight (Veraverbeke *et al.*, 2003). Excessive weight loss causes the surface to shrivel or the wax to change structure and become greasy or glossy (Maguire *et al.*, 1999). The storage life, quality, and susceptibility of fruit to disease and physiological disorders can be affected strongly by cultivars (Gautier, 1984). Development of cultivars with superior traits and tolerance to various postharvest environmental conditions would be beneficial. New cultivars or genotypes must be characterized by high fruit quality attributes which satisfy the consumers demand.

As one of the centers of origin of genus *Cydonia*, Iran is rich in quince germplasm resources, some quince genotypes are distributed in different areas of Iran. However, traditional cultivars have been threatened with extinction by the changes that have occurred in urbanization and modern fruit industry and just few cultivars are cultivated. The objective of our study was to evaluate and compare the fruit quality attributes of fifteen quince genotypes to figure out constituent and quality characterization of quince fruit of those available genotypes, and the postharvest fruit quality changes across genotypes during cold storage were also monitored. Furthermore, we aimed to determine which of the chemically analyzed compounds in

quince fruit correlate best with physical and chemical traits.

MATERIALS AND METHODS

Plant Source and Sampling

Fifteen quince fruit genotypes including: 'KVD1', 'KVD3', 'KVD4', 'NB2', 'PH2', 'Raghah Kordi', 'Esfahan', 'Tehran', 'Asgari', 'Paveh1', 'Paveh2', 'Torshah beh', 'Shakarah beh', 'Marivan1', and 'Marivan2' were harvested at commercial maturity stage in west part of Iran with temperate climate. In general, harvest begins when fruits change their ground color from deep-green to a lighter-green (Kader, 1996). After harvest, fruits were immediately transferred to postharvest lab and graded to ensure that fruits were of uniform size and free of blemishes. Fruits of each genotype were divided into five groups each containing 30 fruits, packed in boxes and stored in cold storage at $2\pm 1^{\circ}\text{C}$ with 80-90% relative humidity. Three replicates of 10 fruits per genotype were assessed at 0, 30, 60, 90 and 120 days.

Weight Loss (%)

The weight of all fruits was measured before storage (W_0) and at each sampling time (W_t). Weight loss expressed as percentage of fresh weight using the following equation:

$$\text{Weight loss (\%)} = (W_0 - W_t) / (W_0) \times 100 \quad (1)$$

SSC, TA and pH Measurements

TA was measured using a bulked sample of all 10 fruit with $1/8^{\text{th}}$ of each fruit juiced together and analyzed. Aliquots of 10 mL were titrated to pH 8.1 with 0.1 N NaOH and expressed as % malic acid (Roussos *et al.*, 2011). The juice was also used to measure Soluble Solids Content (SSC) using an Atago digital refractometer (Brix 0–32%,

Atago, Tokyo, Japan) (Arzani and Koushesh-Saba, 2005).

Fruit Flesh Firmness and Density

Fruit flesh firmness was measured on opposite peeled sides of each fruit using a penetrometer (FDK, Vagner, USA) fitted with an 11.1 mm probe. Values were expressed as Newtons (N). The fruit density in each sampling time was measured based on water displacement method using the following equation and expressed as g cm^{-3} .

$$\text{Fruit density} = M/V \times 100 \quad (2)$$

Where, M is the mass of fruit and V is the volume of fruit.

Total Pectin

Total pectin content was determined as described previously (Ruck, 1969). Six g of fruit sample was boiled in 100 mL of distilled water for 1 hour. The volume of the sample was made up to 250 mL and filtered through Wathman No.4. Then, 125 mL of water and 2.5 mL NaOH were added to 100 mL of the aliquot while stirring constantly, and left to stand for one night. Also, 12.5 mL 1N acetic acid and 6.5 mL of 1.0N CaCl_2 solution were added while stirring, and allowed to stand for 1 hr, followed by heating to boiling for 5 minutes and, then, filtered through paper. The precipitates were washed with distilled water to make them free from chloride ion, then, few drops of silver nitrate solution was added. Remaining white materials were oven dried and weighted. Total pectin was calculated as in Equation (3):

$$\text{Pectin (\%)} = (W_t \text{ of Ca pectate}) / (W_t \text{ of the sample}) \times 100 \quad (3)$$

Total Carbohydrate and Fiber Assay

The total carbohydrate content was estimated using the Anthrone method

(Hedge and Hofreiter, 1962). Briefly, 100 mg of sample was hydrolyzed in pre-warmed HCl for 3 hours in boiling water bath, then neutralized with sodium carbohydrate. One mL of aliquots of the supernatant was added to 4 mL of freshly prepared Anthrone reagent, heated in water bath for 8 min, cooled, and reading for absorbance were taken at 630 nm. Fruit total fiber was measured as previously describe (Lee *et al.*, 1992).

Ca and Mg Measurement

To determine the calcium content, a wet oxidation procedure was applied (Emami, 1996). The wedges of fresh fruit were oven-dried at 70°C and then ground to a powder. Later, 0.3 g grounded fruit samples were digested in $\text{HNO}_3/\text{HClO}_4$, and the calcium and magnesium were measured by atomic absorption spectrophotometer (Shimadzu, Japan). The results were expressed as mg kg^{-1} dry weight (mg kg^{-1} DM).

Statistical Analysis

Data for the analytical determinations were subjected to Analysis Of Variance (ANOVA). Sources of variation were storage duration (days) and cultivars. Least Significant Difference (LSD) test at $P \leq 0.05$ was used to compare means between genotypes or cultivars at each sampling. Pearson correlation was used to evaluate relationship between measured parameters. All data from each sample individually was used for correlations. All analyses were performed with MSTATC software.

RESULTS AND DISCUSSION

Fruit Flesh Firmness

The fruit flesh firmness average varied among quince genotypes such that the highest (71 N) and lowest (42 N) firmness

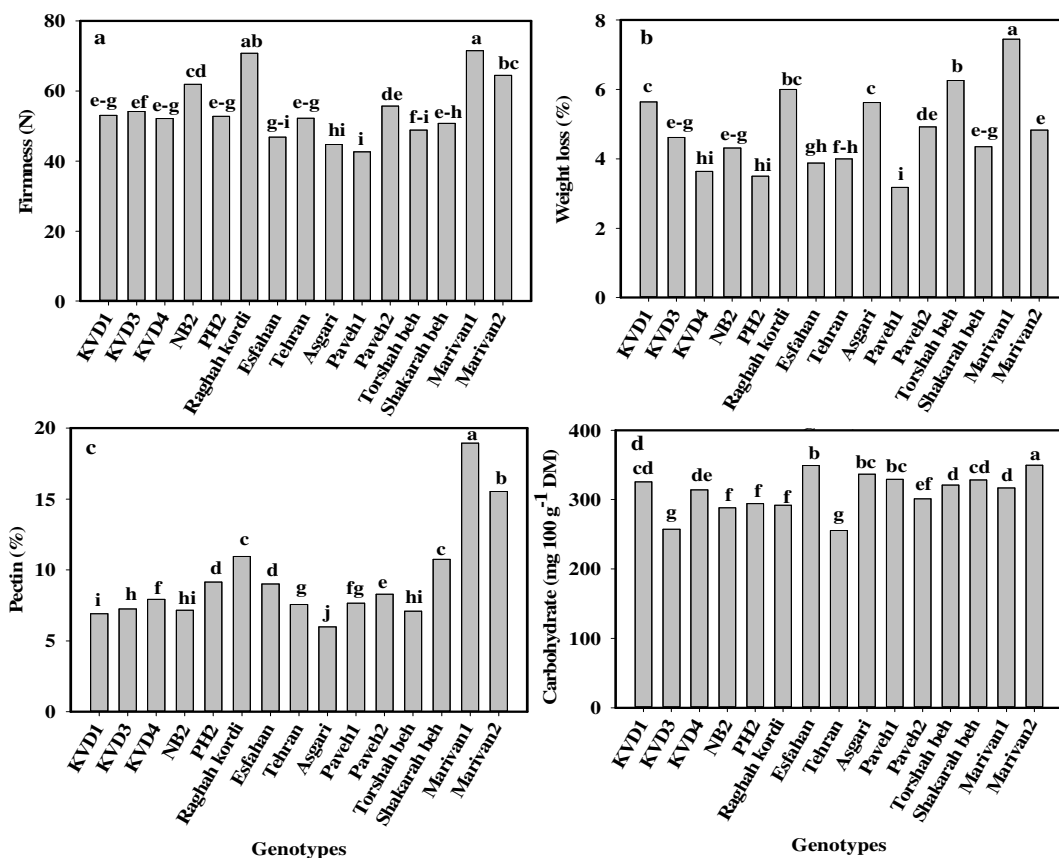


Figure 1 Fruit firmness (a), weight loss percent (b), pectin (c) and carbohydrate (d) of 15 quince genotypes during cold storage at 2°C. Different letters indicates significant difference among treatments according to LSD test ($P \leq 0.05$).

were observed in 'Marivan 1' and 'Paveh 1', respectively (Figure 1-a). For all the genotypes, there was a steady decrease in fruit firmness over storage time, however, the rate of this decrease differed according to the genotypes (Figure 2-a). It can be noted that 'Shakareh beh' showed a lower rate of loss of firmness (29.8%) compared to 'NB2' (58.8%) after 120 days of cold storage (Table 1). Fruit firmness is an important criterion for edible quality and market value of pome fruit (DeEll *et al.*, 2001) and loss of fruit firmness is a serious problem resulting in quality losses (Kovacs *et al.*, 2005). In the current study, fruit flesh firmness had a positive correlation with the density and pectin content, but a negative correlation with carbohydrate content (Table 2). It has been previously reported that fruit firmness

depends on their pectin composition, the rate of evapotranspiration, respiration, turgor pressure and water loss (Billy *et al.*, 2008; Cosgrove *et al.*, 1997; Ghafir *et al.*, 2009; Van den Berg, 1981). Genotypes like 'Shakareh' that retained firmness are more suitable for long-term cold storage, especially in areas that equipped storage system is unavailable.

Weight Loss

The value of weight loss, measured on the first month of cold storage, ranged from 1.9% for 'KVD4' to 7.2% for the 'Marivan1'. The overall average of fruit weight loss was different among quince genotypes and the range was from 3.2% in

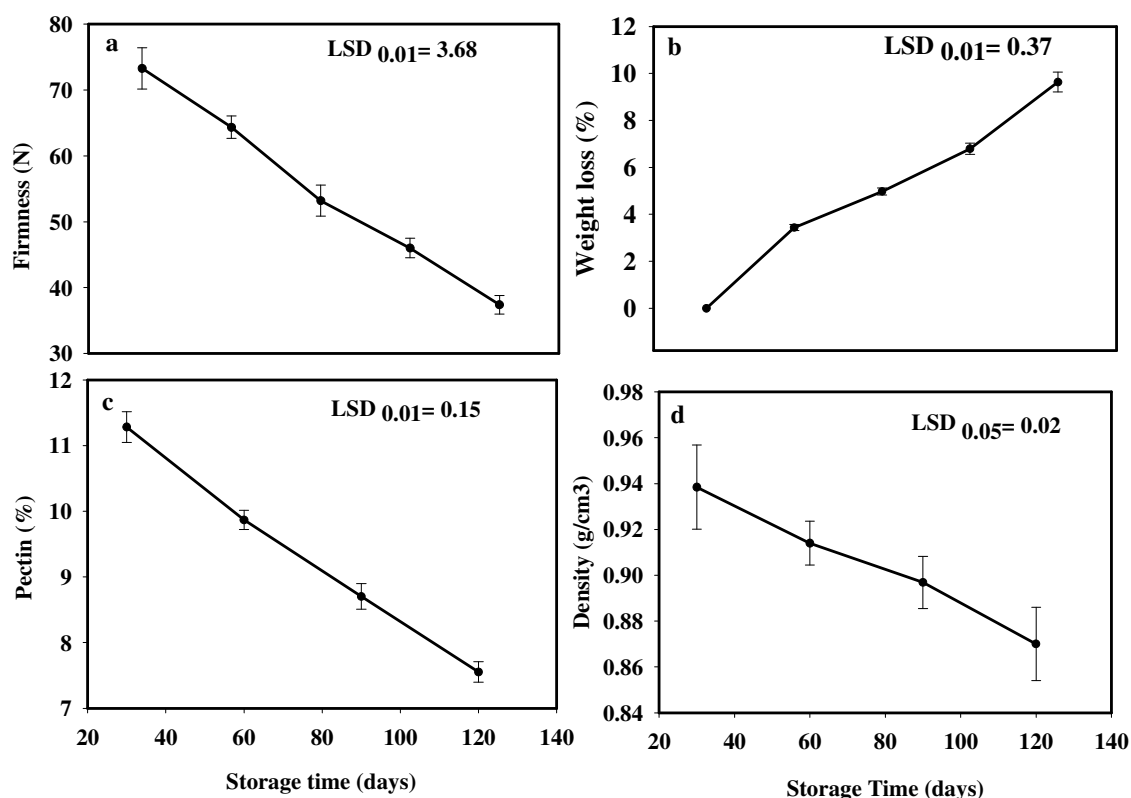


Figure 2. Mean value changes of firmness (a), weight loss (b), pectin (c) and fruit density (d) in 15 quince genotypes during cold storage at 2°C. Values represent means±standard error (n= 3).

‘Paveh 1’ to 7.5% in ‘Marivan1’ (Figure 1-b). The fruit weight loss increased after 120 days of cold storage (Figure 2-b) and the highest (13.0%) and lowest (6.8%) weight losses were observed in ‘Marivan1’ and ‘Esfahan’, respectively (Table 1). The weight loss in fruit increased linearly with increase in storage time due to water loss and respiration (Ghafir *et al.*, 2009). The apparent quality of the fruit is reduced by the loss of moisture, which leads to loss of turgidity and subsequently softening of the fruit (Tu *et al.*, 2000). Fruit weight loss varied among quince genotypes, which may be related to various factors including the skin structure, the suberization extent in periderm, and nature of the waxes on the surface of the fruit. Percentage of weight loss had a negative correlation with the firmness, density, and pectin, such that the high levels of weight loss were in low levels of fruit firmness, density, and pectin (Table 2). ‘Paveh 1’ had the lowest rate of weight

loss and can be used in breeding program and also for long-term cold storage.

Pectin

Fruit pectin content showed a wide variation across the studied genotypes: from 7.28% in ‘Asgari’ to 23.02% in ‘Marivan 1’ at harvest (Table 1). The overall pectin content decreased during fruit cold storage (Figure 2-c) and difference in the pectin among the genotypes at harvest persisted during storage, and ‘Marivan1’ had the highest pectin (14.26%) after 120 days cold storage (Figure 1-c). High pectin content may be beneficial for human health. However, few studies have been carried out on quince fruit and fruit derivatives (Silva *et al.*, 2000). Fruit pectin of 7.40% has been reported for ‘Kalecik’ quince genotype (Dumanoglu *et al.*, 2010) that is similar to the overall pectin content in all genotypes



Table 1. Soluble Solid Content (SSC), Titratable Acidity (TA), pH, density (g cm⁻³), weight loss (%), firmness (N), pectin (%) and carbohydrate (mg 100 g⁻¹ DM) of 15 quince genotypes at harvest (T1) and after 120 days cold storage at 2°C (T5).

Parameter	Time	Genotypes															LSD ^a
		KVD1	KVD3	KVD4	NB2	PH2	Raghah kordi	Esfahan	Tehran	Asgari	Paveh1	Paveh2	Torshah beh	Shakara beh	Marivan1	Marivan2	
SSC	T1	13.00	16.80	14.50	15.13	13.96	15.86	13.40	13.56	13.73	13.83	14.20	17.30	14.30	14.50	18.76	1.08
	T5	18.70	19.56	17.90	17.50	17.76	18.93	17.10	16.53	16.43	15.96	16.76	19.26	17.46	18.26	21.23	0.07
TA	T1	0.43	0.48	0.92	0.38	0.63	0.62	0.54	0.60	0.58	0.42	0.70	0.94	0.52	0.95	0.94	0.07
	T5	0.23	0.20	0.46	0.14	0.37	0.30	0.30	0.21	0.22	0.20	0.49	0.53	0.24	0.50	0.44	0.07
pH	T1	3.55	3.78	2.76	3.68	3.20	3.55	3.75	3.41	3.61	3.25	3.00	2.55	3.25	3.20	3.19	0.07
	T5	4.21	4.44	3.81	4.19	3.98	4.23	4.20	4.20	4.22	4.12	3.90	3.63	4.02	4.11	4.10	0.07
Density	T1	0.98	0.92	0.89	0.90	0.94	0.89	0.97	0.90	0.95	0.93	0.97	0.95	0.98	0.94	0.92	0.03
	T5	0.93	0.88	0.81	0.86	0.83	0.82	0.88	0.88	0.88	0.89	0.93	0.88	0.90	0.81	0.82	0.03
Weight loss	T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.45
	T5	8.90	9.33	7.87	8.03	10.62	10.8	6.77	9.12	9.63	7.69	10.32	11.60	9.37	12.96	11.37	1.45
Firmness	T1	76.66	72.66	72.33	85.00	72.00	91.00	64.33	72.00	61.66	58.00	73.66	68.66	52.16	90	89.00	10.82
	T5	33.33	38.33	33.00	35.00	36.66	52.00	30.66	32.66	30.66	30.66	38.66	31.66	36.66	52.66	48.33	10.82
Pectin	T1	8.50	8.50	9.58	8.70	10.76	12.67	11.06	8.30	7.28	9.98	10.36	8.64	14.29	23.02	17.57	0.77
	T5	5.15	5.90	6.08	5.76	7.86	9.43	7.70	6.43	4.76	5.49	6.39	5.95	8.68	14.26	13.40	0.77
Carbohydrate	T1	244.44	149.21	226.30	226.68	180.95	165.46	290.91	184.36	241.41	163.95	230.83	136.37	178.69	165.46	121.63	33.79
	T5	388.03	365.73	394.45	344.95	390.29	395.20	408.43	321.90	406.54	418.26	363.46	419.77	402.39	416.37	450.38	33.79

^a Least Significant Difference (LSD) value (P≤0.05) represents means differences in the same row.

Table 2. Pearson's simple correlation coefficient among the fruit characteristics of the 15 quince genotypes.

	Weight loss	Firmness	pH	TA	SSC	Carbohydrate	Density	Pectin	Mg	Ca
Weight loss	1									
Firmness	-0.61**	1								
pH	0.61**	-0.52**	1							
TA	-0.40**	0.58**	-0.83**	1						
SSC	0.59**	-0.25**	0.29**	-0.07	1					
Carbohydrate	0.77**	-0.65**	0.54**	-0.40**	0.52**	1				
Density	-0.47**	0.24*	-0.34**	0.17*	-0.43**	-0.38**	1			
Pectin	-0.22**	0.60**	-0.34**	0.60**	-0.20**	0.04	0.04	1		
Mg	-0.13	0.08	0.05	-0.11	-0.004	0.023	-0.13*	0.30**	1	
Ca	0.10	0.19**	-0.13	0.29**	0.03	0.14*	-0.002	0.68**	0.38**	1

after 120 days cold storage in this study. Pectin content in 'Marivan1' is higher than all of the other genotypes in the current study or previous reports, which is favorable for fruit processing as jam or jelly.

Density of Fruit

Fruit density decreased over storage periods (Figure 2-d). The average fruit density varied among quince genotypes and the maximum density was observed in genotypes 'KVD1' and 'Pavehe2' with 0.96 g cm^{-3} , while the minimum density of fruit was observed in genotype 'KVD4' with 0.85 g cm^{-3} (Table 3). The density of fruit can be used as a maturity index in many fruit and vegetables such as apricot, strawberry, tomato, and peas. It has been reported that fruit density decreases because of collapse of intercellular spaces and loss of moisture (Mitropoulos and Lambrinos, 2000). A negative correlation was observed between density and weight loss, SSC, pH and carbohydrate (Table 2). The decrease in fruit

density may be due to biochemical changes and water loss during storage.

SSC, TA and pH

SSC of the studied quince genotypes were significantly different. At harvest, 'Marivan2' had the highest SSC (18.8%) while 'KVD1' had the lowest (13.0%) (Table 1). The overall SSC increased during fruit cold storage (Figure 3a) and difference in the SSC among the genotypes at harvest persisted during storage. After 120 days cold storage, 'Marivan2' had the highest SSC (21.2%). 'Marivan1', 'Marivan2' and 'Torshah beh' had the highest TA percentage (0.94%), while 'NB2' had the lowest (0.38%) at harvest (Table 1). TA and pH were different in quince genotypes. TA decreased during fruit storage (Figure 3-b) while, inversely, pH increased (Figure 3-c).

The increase in SSC can be due to conversion of starch to sugar or the hydrolysis of cell wall polysaccharides (Jan and Rab, 2012). SSC of quince genotypes

Table 3. The overall mean value of density (g cm^{-3}), pH, SSC ($^{\circ}\text{Brix}$), titratable acidity (% malic acid), fiber (%), Ca (mg g^{-1} dry matter) and Mg (mg g^{-1} dry matter) of the 15 quince genotypes during cold storage at 2°C for 120 days.^a

	Density (g cm^{-3})	pH	SSC ($^{\circ}\text{Brix}$)	TA (%Malic acid)	Fiber (%)	Ca (mg g^{-1} DM)	Mg (mg g^{-1} DM)
KVD1	0.96 a	3.91 bc	15.67 e	0.33 i	25.43 bc	42.00 g	5.28 f
KVD3	0.90 c-e	4.11 a	18.41 b	0.34 i	25.83 bc	33.80 jk	5.97 e
KVD4	0.85 g	3.33 h	16.44 d	0.67 b	18.75 e-g	39.27 h	5.23 f
NB2	0.89 d-g	3.93 bc	16.48 d	0.27 j	22.08 c-e	37.90 i	6.04 e
PH2	0.88 e-g	3.60 f	15.86 e	0.50 e	25.42 bc	34.49 j	6.77 cd
Raghah kordi	0.86 fg	3.88 cd	17.19 c	0.46 f	22.08 c-e	38.59 hi	7.04 c
Esfahan	0.91 cd	3.97 b	15.12 fg	0.43 g	21.25 d-f	33.12 k	6.04 e
Tehran	0.89 c-f	3.83 d	14.53 h	0.43 g	22.92 cd	44.74 f	8.34 b
Asgari	0.92 b-d	3.94 bc	15.11 fg	0.40 gh	17.50 fg	39.27 h	2.48 h
Paveh1	0.91 c-e	3.72 e	14.76 gh	0.32 i	18.33 e-g	73.44 b	10.05 a
Paveh2	0.96 a	3.49 g	15.46 ef	0.57 d	23.75 b-d	52.25 e	5.95 e
Torshah beh	0.92 bc	3.11 i	18.39 b	0.75 a	15.00 g	42.00 g	4.39 g
Shakara beh	0.95 ab	3.66 ef	15.60 e	0.38 h	20.42 d-f	61.82 d	6.54 d
Marivan1	0.89 c-e	3.65 ef	16.62 d	0.74 a	30.00 a	113.08 a	6.52 d
Marivan2	0.89 c-f	3.64 f	20.08 a	0.63 c	27.50 ab	65.24 c	8.54 b
LSD	0.033	0.06	0.48	0.03	3.81	1.01	0.27

^a Different letters in each column indicates significant difference among genotypes according to LSD test ($P \leq 0.05$).

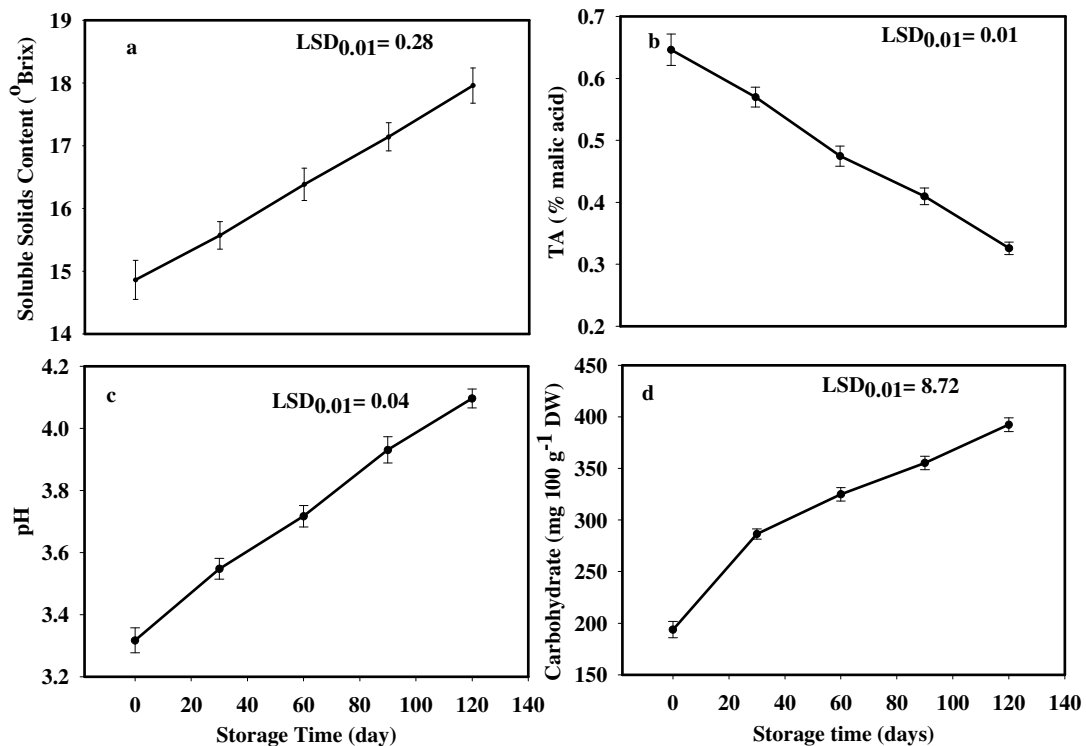


Figure 3 Mean value changes of pH (a), soluble solid content (b), titratable acidity (c), and fruit carbohydrate (d) in 15 quince genotypes during cold storage at 2°C. Values represent means±standard error (n= 3).

increased during cold storage as previously reported by others (Rivera-Lopez *et al.*, 2005). SSC had a positive correlation with weight loss and carbohydrate, in contrast, it had a negative correlation with firmness and density. SSC in quince ranging from 13.6 to 14.6% has been reported by Gunes (2008) while SSC in 'Marivan2' is higher than the other genotypes in the current study or previous reports. Genotypes with higher SSC are promising and potentially can be used for both processing and desert fruit. The pH of the fruit depends mainly on organic acid in the fruit and the rate of TA changes that are affected by metabolism (Clark *et al.*, 2003). Organic acids are consumed in respiration, resulting in lower acidity and higher pH with increasing storage duration (Ghafir *et al.*, 2009; Rivera-Lopez *et al.*, 2005). In the current study, TA of 'Torshah beh' was twofold that of 'NB2'

and had a sour taste that is more suitable for fresh use than processed forms like jam.

Total Carbohydrate (TC) and Fiber

The highest TC was observed in 'Marivan2' and 'Esfahan' with 349.6 and 348.9 mg g⁻¹ dry matter, respectively, whereas the lowest fruit carbohydrate was in genotype 'KVD3' and 'Tehran' with 257.2 and 255.4 mg g⁻¹ dry matter, respectively (Figure 1-d). TC content significantly increased during storage times such that the overall TC was twofold that of harvest time after 120 days cold storage (Figure 3-d). Fruit fiber content was significantly different across genotypes and the highest and lowest was in 'Marivan1' and 'Torshah beh', respectively (Table 3).

Mineral Content

Calcium and magnesium content had significant differences among genotypes. The highest Mg and Ca were in 'Paveh 1' and 'Marivan 1', respectively (Table 3). A positive correlation was found between fruit Ca and pectin content with firmness (Table 2). 'Marivan 1' and 'Paveh 1' with highest Ca level were firmer than the other genotypes. Fruit firmness at harvest was related to fruit Ca but not to the rate of softening, after 120 days of cold storage. The involvement of Ca in the regulation of fruit maturation and ripening process has been well established (Ferguson, 1984). Ca interacts with pectin compounds and forms cross-linked polymer network which makes cell wall constituents firmer.

CONCLUSIONS

A wide range of variation in fruit quality and biochemical composition exists in quince genotypes in Iran, but just a few commercial cultivars are available. Fruit weight loss, pH, SSC, and carbohydrate increased, while firmness, density, pectin, and TA decreased during quince fruit storage; but the rate of changes varied according to genotypes. 'Marivan 1', 'Ragha', and 'Marivan 2' genotypes had the highest firmness during storage. The lowest percentage weight loss was observed in 'Paveh 1', 'KVD4' and 'Esfahan' genotypes. The highest pectin was observed in 'Marivan 1', 'Marivan2', 'Ragha kordi' and 'Shakara beh' genotypes. In this study, firmness had positive correlation with pectin and Ca content and negative correlation was found between weight losses and both firmness and density. This finding indicates that fruit constituents can affect quality changes during storage. Finally, more research is needed to evaluate the quince germplasm to find out the genotypes which can be considered as promising for further evaluation in breeding programs

for releasing new cultivars to satisfy consumers' demand and provide valuable samples in processing industry.

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REFERENCES

1. Alesiani, D., Canini, A., Abrosca, B. D., Dellagrecia, M., Fiorentino, A., Mastellone, C. and Pacifico, S. 2010. Antioxidant and Antiproliferative Activities of Phytochemicals from Quince (*Cydonia vulgaris*) Peels. *Food Chem.* **118**: 199–207.
2. Arzani, K. and Koushesh-Saba, M. 2005. Enhancement of Sultana Grape (*Vitis vinifera* L.) Maturity by Pre-veraison Ethanol and Methanol Spray. *Indian J Agric. Sci.*, **75**: 670–672.
3. Bell, L. R. and Leitao, M. J. 2011. *Cydonia*. In: "Wild Crop Relatives: Genomic and Breeding Resources, Temperate Fruits", (Ed.): Kole, C. Springer-Verlag, Berlin, Heidelberg, Germany, PP. 1–16.
4. Billy, L., Mehinagic, E., Royer, G., Renard, C. M. G. C., Arvisenet, G., Prost, C. and Jourjon, F. 2008. Relationship between Texture and Pectin Composition of Two Apple Cultivars during Storage. *Postharvest Biol. Technol.*, **47**: 315–324.
5. Clark, C. J., McGlone, V. A. and Jordan, R. B. 2003. Detection of Brownheart in "Braeburn" Apple by Transmission NIR Spectroscopy. *Postharvest Biol. Technol.*, **28**: 87–96.
6. Cosgrove, D. J., Bedinger, P. and Durachko, D. M. 1997. Group I Allergens of Grass Pollen as Cell Wall-Loosening Agents. *Proc. Natl. Acad. Sci.*, **94**: 6559–6564.
7. DeEll, J. R., Khanizadeh, S., Saad, F. and Ferree, D. C. 2001. Factors Affecting Apple Fruit Firmness: A Review. *J. Am. Pomol. Soc.*, **55**: 8–26.
8. Dumanoglu, H., Gunes, N. T. and Aygun, A. 2010. Analysis of Clonal Variations in Cultivated Quince (*Cydonia oblonga* "Kalecik") Based on Fruit Characteristics and SSR Markers. *New Zeal. J. Crop Hortic. Sci.*, **37**: 113–120.



9. Emami, A. 1996. *Plant Analysis Methods*. Iraninan Soil and Water Research Institute. Publication No. 928. (in Farsi)
10. Ferguson, I. B. 1984. Calcium in Plant Senescence and Fruit Ripening. *Plant Cell Environ.*, **7**: 477–489.
11. Fiorentino, A., D'Abrosca, B., Pacifico, S., Mastellone, C., Piscopo, V., Caputo, R. and Monaco, P. 2008. Isolation and Structure Elucidation of Antioxidant Polyphenols from Quince (*Cydonia vulgaris*) Peels. *J. Agric. Food Chem.*, **56**: 2660–2667.
12. Forni, E., Penci, M. and Polesello, A. 1994. A Preliminary Characterization of Some Pectins from Quince Fruit (*Cydonia oblonga* Mill.) and Prickly Pear (*Opuntia ficus indica*) Peel. *Carbohydr. Polym.*, **23**: 231–234.
13. Gautier, M. 1984. Pear and Apple Storage: Practical Advice. *Arboric. Fruit.*, **31**: 34–38.
14. Ghafir, S. A., Gadalla, S. O., Murajei, B. N. and El-Nady, M. F. 2009. Physiological and Anatomical Comparison between Four Different Apple Cultivars under Cold-storage Conditions. *Afr. J. plant Sci.*, **3**: 133–138.
15. Gunes, N.T., 2008. Ripening Regulation during Storage in Quince (*cydonia oblonga mill.*) fruit. *Acta Horti* **796**: 191–196.
16. Hedge, J. E. and Hofreiter, B. T. 1962. In: "*Carbohydrate Chemistry*" 17, (Eds.): Whistler, R. L. and Be Miller, J. N. Academic Press, New York.
17. Jan, I. and Rab, A. 2012. Influence of Storage duration on Physico-chemical Changes in Fruit of Apple Cultivars. *J. Anim. Plant Sci.*, **22**: 708–714.
18. Kader, A. A. 1996. Quince Recommendation for Maintaining Postharvest Quality. Dep. Pomol., Postharvest Technol. Res. Inf. Cent., Univ. California.
19. Khoubnasabjafari, M. and Jouyban, A. 2011. A Review of Phytochemistry and Bioactivity of Quince (*Cydonia oblonga* Mill.). *J. Med. Plants Res.* **5**: 3577–3594.
20. Kovacs, E., Róth, E., Hertog, M. L. A. T. M., Vanstreels, E. and Nicolai, B. 2005. Relationship between Physical and Biochemical Parameters in Apple Softening. *Acta Horti*, **682**: 573–578.
21. Legua, P., M. Serrano, P. Melgarejo, D. Valero, J. J. Martinez, R. Martinez, and F. Hernandez, 2013. Quality Parameters, Biocompounds and Antioxidant Activity in Fruits of Nine Quince (*Cydonia oblonga* Miller) Accessions. *Sci Horti*, **154**: 61–65.
22. Lee, S. C., Prosky, L. and DeVries, J. W. 1992. Determination of Total, Soluble and Insoluble Fiber Foods. Enzymatic-Gravimetric Method, Mes-Tris Buffer. *Collaborative Study. J. AOAC*, **75**: 395–416.
23. Maguire, K. M., Lang, A., Banks, N. H., Hall, A., Hopcroft, D. and Bennett, R. 1999. Relationship between Water Vapour Permeance of Apples and Micro-cracking of the Cuticle. *Postharvest Biol. Technol.*, **17**: 89–96.
24. Mitropoulos, D. and Lambrinos, G. 2000. Dehydration of "Delicious Pilafa" and Granny Smith Apple during Storage. *Proc. 2nd Agric. Engg. Natl. Cong.*, Giaxoudi-Giapouli, Volos, Greece, **1**: 433–440.
25. Moradi, S., Koushesh Saba, M., Mozafari, A.A and Abdollahi, H. 2016. Antioxidant Bioactive Compounds Changes in Fruit of Quince Genotypes Over Cold Storage. *J. Food Sci.*, **81**(7), H1833-H1839.
26. Razavi, F., Arzani, K. and Vezvaei, A., 2000. Identification of local quince (*Cydonia oblonga* L.) genotypes in some parts of Isfahan province. *Seed Plant*, **15**: 354–374.
27. Rivera-Lopez, J., Vazques-Ortiz, F. a., Ayala-Zavala, J. F., Sotelo-Mundo, R. R. and Gonzalez-Aguilar, G. A., 2005. Cutting Shape and Storage Temperature Affect overall Quality of Fresh-Cut Papaya Cv. "Maradol". *J. Food Sci.*, **70**: 482–489.
28. Roussos, P.A., Sefferou, V., Denaxa, N.K., Tsantili, E. and Stathis, V. 2011. Apricot (*Prunus arm eniaca* L.) Fruit Quality Attributes and Phytochemicals under Different Crop Load. *Sci. Horti*, **129**: 472–478.
29. Ruck, J. A. 1969. *Chemical Method of Analysis of Fruit and Vegetable Products*. Research Station, Summerland BC, PP. 14–16.
30. Sharma, R., Joshi, V. K. and Rana, J. C. 2011. Nutritional Composition and Processed Products of Quince (*Cydonia oblonga* Mill.). *Indian. J. Nat. Prod. Resour.*, **2**: 354–357.
31. Silva, B. M., Andrade, P. B., Valentão, P., Mendes, G. C., Seabra, R. M. and Ferreira, M. A. 2000. Phenolic Profile in the Evaluation of Commercial Quince Jellies Authenticity. *Food Chem.*, **71**: 281–285.

32. Thomas, M., Guillemain, F., Guillon, F. and Thibault, J. F. 2003. Pectins in the Fruits of Japanese Quince (*Chaenomeles japonica*). *Carbohydr. Polym.*, **53**: 361–372.
33. Thomidis, T. and Michailides, Z. 2004. Documentation of Field and Postharvest Performance for a Mature Collection of Quince (*Cydonia oblonga*) Varieties in Imathia, Greece. *New Zeal. J. Crop Hortic. Sci.*, **32**: 243–247.
34. Tu, K., Nicolaï, B. and De Baerdemaeker, J. 2000. Effects of Relative Humidity on Apple Quality under Simulated Shelf Temperature Storage. *Sci. Hortic.*, **85**: 217–229.
35. Van den Berg, L. 1981. The Role of Humidity, Temperature, and Atmospheric Composition in Maintaining Vegetable Quality during Storage. *ACS Symp. Ser.*, **170**: 95.
36. Veraverbeke, E.A., Verboven, P., Van Oostveldt, P. and Nicolaï, B. M. 2003. Prediction of Moisture Loss across the Cuticle of Apple (*Malus sylvestris* subsp. *mitis* (Wallr.) during Storage. Part 2. Model Simulations and Practical Applications. *Postharvest. Biol. Technol.*, **30**: 89–97.
37. Szychowski P. J., Munera-Picazo, S., Szumny, A., Carbonell-Barrachina, Á.A. and Hernández, F. 2014. Quality Parameters, Bio-compounds, Antioxidant Activity and Sensory Attributes of Spanish Quinces (*Cydonia oblonga* Miller). *Sci. Hortic.*, **165**: 163–170.
38. Wojdyło, A., Oszmiański, J. and Bielicki, P. 2013. Polyphenolic Composition, Antioxidant Activity, and Polyphenol Oxidase (PPO) Activity of Quince (*Cydonia oblonga miller*) Varieties. *J. Agric. Food Chem.*, **61**: 2762–2772.

تغییرات فیزیکی و بیوشیمیایی میوه برخی ژنوتیپ های به (*Cydonia oblonga* Mill) ایران در طول نگهداری در سردخانه

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چکیده

میوه به اثرات سودمند بسیاری برای انسان داشته و منبع بسیار خوبی برای پکتین جهت تولید ژله و صنعت مربا می باشد. تحقیق حاضر با هدف مطالعه ویژگیهای فیزیکی و شیمیایی برخی ژنوتیپ های به در زمان برداشت و در طول نگهداری در سردخانه صورت گرفت. برای این منظور میوه های ۱۵ ژنوتیپ به در زمان بلوغ برداشت شده و ارزیابی ها در زمان برداشت، ۳۰، ۶۰، ۹۰ و ۱۲۰ روز بعد از نگهداری در دمای ۲ درجه سانتیگراد انجام شد. در زمان برداشت میزان املاح محلول از ۱۳ تا ۱۸/۷۶ درجه بریکس، اسیدیته قابل تیتراسیون از ۰/۳۸ تا ۰/۹۵ اسید مالیک، پ. هاش از ۲/۵۵ تا ۳/۷۵، میزان سفتی بافت از ۵۲/۱۶ تا ۹۱ نیوتن، چگالی از ۰/۸۹ تا ۰/۹۸ گرم در سانتی متر مکعب، میزان کربوهیدرات از ۲۵۵/۳۹ تا ۳۴۹/۵۶ میلی گرم در ۱۰۰ گرم وزن خشک، میزان پکتین از ۷/۲۸ تا ۲۳/۰۲ درصد و میزان فیبر میوه از ۱۱/۶۶ تا ۳۳/۳ در بین ژنوتیپ ها متفاوت بود. همبستگی منفی بین کاهش وزن و دو صفت سفتی و چگالی مشاهده شد در حالیکه سفتی میوه با محتوای کلسیم و پکتین میوه همبستگی مثبت داشت. به طور کلی تغییرات معنی داری در صفات مورد ارزیابی در طول نگهداری در سردخانه مشاهده شد اما میزان تغییرات در ارقام متفاوت بود. برخی ژنوتیپ ها دارای ویژگی منحصر بودند به طوریکه کمترین کاهش



وزن در طول نگهداری در ژنوتیپ "پاوه ۱"، بیشترین میزان حفظ سفتی بافت و پکتین میوه در ژنوتیپ "مریوان ۱" و بیشترین میزان قند در ژنوتیپ "مریوان ۲" مشاهده شد که این ژنوتیپ ها به عنوان نمونه های امید بخش در برنامه های اصلاحی قابل استفاده خواهد بود.