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Estimation of Postharvest Quality of "Red Delicious" Apple Fruits Based on Fruit Nutrient Elements Composition

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Abstract

Fruit nutrient elements content during harvest could considerably effect on postharvest life of apples. In this study, apple fruits cultivar Red Delicious were harvested at the commercial maturity stage at 20 commercial orchards. Fruits were divided into three groups according to peel color; dark red, medium and light red. The mineral elements nutrient content such as nitrogen, phosphorus, potassium, calcium and magnesium and their ratios were measured in the harvested fruits. Thereafter, fruits were places in the cold storage at 0 °C and relative humidity of 90% for 4 months. The characteristics such as fruits weight loss, firmness, TSS, dry matter, total anthocyanin content, antioxidant activity, respiration rate and ethylene production were measured at the end of storage. The results showed a positive significant correlation between fruit firmness at the end of storage time with N+K:Ca, K+Mg:Ca, K:Ca and Mg:Ca ratios. Furthermore, a negative significant correlation was found between total anthocyanin with Nitrogen content, Mg:Ca and N:Ca ratios. The results also showed a positive significant correlation between fruit respiration rate and Nitrogen, N+K:Ca and N:Ca ratios. The analysis of regression based on mean values of three red apple groups showed a significant negative correlation between total anthocyanin with fruit ethylene production at the storage time and Mg:Ca ratio. The relationship between these two variables and Anthocyanin was expressed by the equation of regression: Anthocyanin = 100.22–1.651 Ethylene–43.963 Mg:Ca. Overall, the results confirm that measurement of fruit mineral composition during harvest time could be a strategy for predicting postharvest behaviors of apple fruits at the cold storage. Also the results showed that a relationship between mineral nutrient composition and the characteristics such as firmness, anthocyanin, respiratory rate in apple fruits.

Keywords: anthocyanin, keeping quality, nitrogen, respiration, ethylene

1. Introduction

Apple (*Malus domestica* (Borkh.) is a good source of soluble and insoluble fiber (Iqbal et al., 2012). Polyphenols are the main source of antioxidants in apple; furthermore, this fruit is a very important source of flavonoids in the U.S. and European diets (Telias, 2011). Several studies have linked apple consumption with reduced risk for cancer, especially lung cancer, cardiovascular disease, asthma, pulmonary problems, diabetes and obesity (Telias, 2011). These effects are due to the fruit's antioxidant activity, anti-proliferative activity, inhibition of lipid oxidation and cholesterol-lowering (Telias, 2011). The antioxidants compounds are mainly localized in the apple peel and the cultivars exhibit a wide variation in the distribution pattern (Telias, 2011).

Apple fruits have a long postharvest life in cold storage and their postharvest life is affected by many factors, such as growing condition, harvesting time and operation, and storage condition (Rabiei et al., 2011). Postharvest losses result in fruit softening is a limiting factor for storage life in many countries (Johnston et al., 2015). Fruit softening is generally considered an undesirable ripening process in apple fruit, as the firmer apples tend to be the juicier, crisper, crunchier, and less mealy than softer fruit (Johnson, 2000). Fruit softening is typically assessed using a puncture test, also known as a flesh firmness, fruit firmness, or fruit pressure test (Johnson, 2000).

Several studies have attempted to predict the post storage firmness of apples using pre harvest or at harvest measurements of meteorological variables, harvest indices, and mineral concentrations (Johnson, 2000). In general, the best predictions came from pre storage assessments of firmness, where fruit with higher firmness at harvest

were firmer after storage than fruit with lower firmness (Johnston et al., 2015). However, predictive accuracy of pre storage firmness measurements varied substantially between seasons and cultivars (Johnston et al., 2015). The different systems of irrigation and fertilization in the orchard resulted in variations of the nutrition status of apple and quality of the fruit (Milosevic & Milosevic, 2015).

Orchard nutrition is a pre-harvest and post-harvest practice that affects productivity and fruit quality and has to be performed very carefully since, after harvest, fruits quality cannot be improved (Milosevic & Milosevic, 2015). Nutrient content in apple leaves is a feature of a specific cultivar; it is influenced, within certain limits, by the rootstocks, by soil and climatic conditions (Blazek & Hlusickova, 2007), by the phase of vegetation (Holb et al., 2009), and particularly by the orchard management practices, i.e. irrigation and fertilization (Nagy & Holb, 2006; Jivan & Sal, 2014). Variations in mineral composition are widely recognized to affect fruit quality after harvest (Bramlage et al., 1980; Sharples, 1980). Mineral composition greatly influences postharvest quality retention and calcium is dominant in this respect (De Castro et al., 2007). Trees high in nitrogen are usually vigorous trees with low crop loads; as a consequence, fruit is large, high in nitrogen, and low in calcium (De Castro et al., 2007). And calcium is important in all cell membranes to stabilize phospholipids (De Castro et al., 2007). Bramlage et al., (1985) reported that Ca was the most variable element among samples within seasons and this element correlated negatively with breakdown, rot, and scald.

Although leaf analysis is a diagnostic tool for optimizing mineral nutrition in fruits trees, it correlates weakly with fruit quality; thus, fruit analysis is more useful in estimating quality (Fallahi et al., 1985; Sharples, 1980) and storage disorders (Bramlage et al., 1980; Sharples, 1980). Mineral analysis of leaf and fruit tissues have become more popular in recent years, because of advances in analytical equipment, allowing multi-element analysis at fraction of time and cost traditionally associated with mineral analyses (Sharples, 1980). Therefore, understanding relationships between postharvest quality and preharvest mineral nutrients and orchard practices makes various management decisions, such as storage strategies easier (Sharples, 1980). So, He demonstrated that mineral composition standards for Cox's Orang Pippin apples and expressed that fruit behavior in storage can be predicted based on the analysis of fruit before harvest. Therefore, the objectives of this study were to determine the relationship between calcium and another macronutrients elements and their ratios on postharvest behaviors of 'Red delicious' apple cultivar.

2. Materials and Methods

For this study, twenty commercial orchards of "Red Delicious" apple with the same rootstock and tree age were selected in the north of the Fars province, Iran. Fruits were harvested at commercial maturity stage (based on starch test), thereafter were put into three groups with dark red, medium, and light red peel color. Immediately, after harvest, fruits were transported to University of Guilan, Rasht, Iran for more evaluation. The first fruits mineral nutrient elements content including nitrogen, phosphorus, potassium, calcium and magnesium and their ratios were measured. Thereafter, about 60 fruits from each color group were placed in the cold storage with 0 °C and 90% relative humidity (RH) for 4 months. At the end of cold storage, the characteristics such as fruits weight loss, firmness, soluble solids content (SSC), dry matter, total anthocyanin, antioxidant activity, respiration rate and ethylene production were measured.

2.1 Fruit Weight Loss

The initial weight of fruits was noted with the help of electronic balance (Kalra, 1998). The weight loss (%) was calculated as under:

$$\text{Fruit weight loss (\%)} = (\text{Initial weight} - \text{Final weight})/\text{Initial weight} \times 100 \quad (1)$$

2.2 Fruit Firmness

The fruits firmness was measured using the firmness tester (Penetrometer) with the probe 8mm (Ferguson et al., 2003). Pressure units to influence the tissue were expressed in kilograms per square centimeter.

2.3 Total Soluble Solid (SSC)

Total soluble solid (SSC) were measured by using digital refract meter in laboratory temperature and were expressed as a percentage.

2.4 Dry Matter

To measure dry matter, 9 to 10 mm slices were prepared from a third midway part of fruit. These slices after weighing were placed into oven at 70-75 °C for 72 hours to obtain constant weight. The dry matter content was calculated with the following formula:

$$\text{Dry matter content} = (\text{Dry weight})/(\text{Wet weight}) \times 100 \quad (2)$$

2.5 Total Anthocyanin and Antioxidant Activity

One gram of fruit peel tissue was grinded by using liquid nitrogen in a mortar, and then 4 mL extraction buffer containing (85% methanol and 15% acetic acid) was added to it. The extract was used for measurement total anthocyanin and antioxidant activity.

Samples were kept in the refrigerator at 4 °C over night for extraction. Thereafter, it was centrifuged (Ependorf 5417R Model) for 10 minutes in 10000 rpm. Total anthocyanin content in 180 apple fruits peel was determined spectrophotometrically by the pH differential method as described by Wrolstad (1976). The absorbance was measured at 510 and 700 nm in buffers at pH 1.0 and 4.5 using a UV-visible spectrophotometer, and then calculated according to following equation:

$$A = [(A510 - A700)\ pH1.0 - (A510 - A700)\ pH4.5] \quad (3)$$

Results were expressed as mg of cyanidin-3-glucoside per /100 g fresh weight, using a molar absorptive coefficient (ε) of 26,900 and a molecular weight of 449.2.

The antioxidant activity was measured according to the DPPH method reported by Brand-Williams et al. (1995) with some modifications. The absorbance was measured at 515 nm using a UV-visible spectrophotometer. For each sample, three separate determinations were recorded. Antioxidant activity was expressed as the percentage decline in absorbance relative to the control, corresponding to the percentage of DPPH scavenged %DPPHsc), which was calculated as:

$$\%DPPHsc = (1 - Asample/Acontrol) \times 100 \quad (4)$$

2.6 Respiration Rate and Ethylene Production

Respiration rate and Ethylene measurement was done by GC device model (Agilent 7890) for 180 samples and by placing one fruit in 1 L flask and capped with a rubber stopper for 24 h. Then, 1 mL gas samples were withdrawn from the headspace by syringe to determine carbon dioxide (CO_2) and ethylene The temperature for the injector column and detector were 90, 120 and100 °C respectively. Column temperature was kept constant for 3 minutes at 90 °C. Then temperature was reachedat130 °C with 8 °C speed per minute. Helium was used as the carrier gas with flow rate of 30 ml per minute. The volume of injected gas was 1 mL (Kim, 1999).

2.7 Determination of Mineral Nutrient Composition

Before assays of mineral nutrients, 180 fruit samples were washed thoroughly with tap water and subsequently rinsed with deionized water to remove all surface residues. After air drying, fruit flesh samples were taken from the equatorial section of each fruit quarter, oven-dried at 70 °C for 72 hand milled to fine powder passed through a forty-mesh sieve. Two grams fine powder was ashed in a furnace at 550 °C for 4 hours then the ash was dissolved in 10 mL hydrochloric acid (HCl) 2 M. The digested samples were filtered through Whatman No. 40 filter paper and used for phosphorus (P), potassium (K), Ca and magnesium (Mg) analyses.

The nitrogen (N) concentration in samples was determined according to the Kejeldahl method (Jones, 2001). Briefly, a 0.3 g sample was digested in concentrated H_2SO_4 and distilled with NaOH (40%), and ammonium N was fixed in H_3BO_3 (2%) and titrated with 0.1 N H_2SO_4. The P content of samples was determined by the vanadate-molybdate colorimetric method (Chapman & Pratt, 1982). The absorbance of samples was measured at 470 nm in a UV-visible spectrophotometer (model PG Instrument+80, Leicester, UK). K was determined by flame photometric method as described by (Jones, 2001). Digested extract was diluted by calcium chloride (CaCl) at a 1:9 ratio and the absorbance was measured at 766.5 nm (Jones, 2001).

Ca and Mg were measured using atomic absorption spectroscopy. Briefly, digested extracts were diluted with distilled water (1:9 v/v), then 4.75 mL lanthanum nitrate [$La(NO_3)_3$] was added to 250 mL of the diluted extract. Finally, the absorbance was measured at 422.7 nm for Ca and 285.2 nm for Mg (Jones, 2001). All macronutrients were expressed as mg per 100 g of fruit dry weight (mg 100 g^{-1} DW) and the ratios of N+K:Ca, K+Mg:Ca, K:Ca, Mg:Ca and N:Ca were determined.

3. Experimental Design and Statistical Analysis

Correlation analysis was done using Pearson correlation coefficient. The relationship between macronutrient elements content and ratios with fruit postharvest characteristics at the end of storage such as weight loss, firmness, dry matter, total anthocyanin, antioxidant activity, and respiration rate and ethylene production were calculated. Comparison of means carried out by the least significant difference test (LSD) at $P < 0.05$. All statistical analysis was performed using SPSS 19 software.

4. Results and Discussion

4.1 The Means Evaluated Characteristics

One-way analysis of variance (ANOVA) or F-test was used to determine significant differences between three apple fruit groups, with dark red apple (Group 1), medium (Group 2) and light red (Group 3). The results showed a significant difference between apple fruits with different peel pigmentation for firmness, TSS, total anthocyanin, total antioxidant capacity, respiration rate, ethylene production, phosphorus, calcium, Mg:Ca and N:Ca (Table 1). Total anthocyanin content, TSS and calcium content have been decreased from dark red to medium and light red apple fruit groups respectively. On the other hand, ethylene production, respiration rate, phosphorus, N+K:Ca, K+Mg:Ca, K:Ca, Mg:Ca, N:Ca has increased from dark red apple groups to light red respectively (Table1). The highest and the lowest Nitrogen and Magnesium content were found in medium and light red apple groups. But the highest Potassium content was observed in apple fruits with medium red color (Table 1).

Overall, the apple fruit with dark red peel color (Group 1) have showed the highest antioxidant capacity, anthocyanin content, calcium concentration, and the lowest nitrogen and magnesium concentration, which followed by the best postharvest quality. In contrast, apple fruits with light red peel (Group 3) showed the lowest total anthocyanin content, calcium concentration, and the highest N+K:Ca, K+Mg:Ca, K:Ca, Mg:Ca, N:Ca ratios, and respiration rate and ethylene production. These have showed the lowest postharvest quality (Table 1).

Table 1. The F test analysis for comparing evaluated characteristics in three groups apple orchards with dark red (Group 1), medium (Group 2) and light red (Group 3) fruit

	Mean			MS			CV		
	Group 1	**Group 2**	**Group 3**	**Group 1&2**	**Group 2&3**	**Group 3&1**	**Group 1**	**Group 2**	**Group 3**
Weightloss (%)	2.35	2.27	2.15	0.086	0.112	0.198	0.268	0.521	0.334
Firmness (kg/cm^2)	4.03	4.41	4.85	0.382	0.445	0.828	0.656	1.09	0.707
TSS (%)	17.57	16.61	15.18	0.968	1.43	2.399	2.3	3.79	3.49
Dry matter (%)	79.93	75.76	81.5	4.17	5.73	1.559	2.5	16.16	3.93
Anthocyanin (mg/g) FW	58.73	27.45	14.69	31.27	12.75	44.03	14.18	8.93	4.23
Antioxidant (%)	47.07	40.27	40.31	6.79	0.043	6.75	8.39	7.8	9.88
CO_2 ($kg^{-1}h^{-1}$)	19.95	24.61	24.33	4.66	0.278	4.38	3.34	4.29	3.61
Ethylene (nl/g·h)	22.72	27.9	27.19	5.18	0.716	4.47	2.86	4.58	3.1
N (mg/100 g) DW	373.94	435.11	434.54	61.17	0.566	60.6	74.63	92.01	101.68
P (mg/100 g) DW	128.43	132.02	151.13	3.59	19.1	22.69	22.52	26.52	38.81
K (mg/100 g) DW	656.96	691.68	644.75	34.72	46.93	12.21	158.44	140.04	150.55
Ca (mg/100 g) DW	109.07	108.26	90.42	0.812	17.38	18.64	30.49	19.51	15.36
Mg (mg/100 g) DW	50.88	55.13	54.04	4.24	1.08	3.15	11.52	14.44	7.07
N+K:Ca	10.001	10.84	12.18	0.841	1.34	2.18	2.74	3.08	2.82
K+Mg:Ca	6.83	7.22	7.93	0.395	0.703	1.09	1.96	2.46	2.22
K:Ca	6.34	6.7	7.31	0.358	0.613	0.972	1.86	2.38	2.18
Mg:Ca	0.486	0.522	0.612	0.036	0.09	0.126	0.12	0.152	0.119
N:Ca	3.65	4.13	4.86	0.482	0.728	1.21	1.14	1.16	1.12

4.2 The Relationship between Fruit Mineral Composition with Weight Loss, Firmness, SSC, Dry Matter and Anthocyanin

As the results showed, there was a significant positive correlation between fruit firmness at the end of storage with N+K:Ca, K+Mg:Ca, K:Ca and Mg:Ca ratios ($P < 0.05$). The fruits with the lowest nitrogen content have the highest antocyanin and firmness (Table 2). Previous studies also showed that Nitrogen fertilizer reduced fruit firmness in strawberry (Abu-Zahra & Tahboub, 2008). Use of large amounts of nitrogen, in "Golden Delicious" apple, increased nitrogen of fruits and internal ethylene and reduced firmness (Nielsen et al., 1984).

The negative correlation was seen between anthocyanin with nitrogen ($P < 0.05$). These results are in agreement with finding of Delgado et al. (2006) in relation to the effect of nitrogen on reducing total anthocyaninin of grape. Furthermore, Hafiz Ibrahim et al. (2012) showed a negative correlation between concentrations of anthocyanin and nitrogen content in *Labisia pumila* plant. A well as, the results showed a negative significant correlation between anthocyanin content with Mg:Ca and N:Ca ratio at ($P < 0.01$).These results were in conflicting with those reported

by (Li et al., 2010) in relation to the positive correlation between anthocyanin and magnesiumin in peach fruit. Therefore, the high nitrogen content of fruit reduced calcium content and increase N:Ca ratio that has significant positive correlation with decreasing accumulation of anthocyanin in apple peel (Table 2).

Table 2. The correlation between mineral composition with weight loss, firmness, SSC, dry matter, and anthocyanin

	N:Ca	Mg:Ca	K:Ca	K+Mg:Ca	N+K:Ca	Mg	Ca	K	P	N	Anthocyanin	Drymatter	SSC	firmness	Weightloss
Weight loss	0.045	0.185	0.194	0.199	0.159	0.152	-0.083	0.2	-0.146	-0.014	0.107	0.102	0.053	-0.124	1
firmness	0.156	0.268*	0.273*	0.279*	0.261*	0.162	-0.154	0.226	0.152	0.106	-0.257*	-0.174	0.173	1	
SSC	-0.128	-0.042	0.208	0.198	0.098	-0.125	-0.044	0.173	-0.214	-0.249	0.273*	-0.207	1		
Dry matter	0.113	0.07	0.03	0.034	0.069	0.054	-0.019	0.015	-0.122	0.097	-0.063	1			
Anthocyanin	-0.348*	-0.333*	-0.142	-0.157	-0.246	0.218	0.195	-0.042	-0.201	-0.310*	1				
N	0.672**	0.143	0.031	0.038	0.299*	0.348**	0.099	0.206	0.247	1					
P	0.257*	-0.15	-0.041	-0.048	0.077	-0.270*	-0.061	-0.083	1						
K	0.094	0.152	0.661**	0.647**	0.517**	0.312*	0.111	1							
Ca	-0.633**	-0.638**	-0.632**	-0.649**	-0.718**	0.25	1								
Mg	0.058	0.560**	0.003	0.038	0.026	1									
N+K:Ca	0.785**	0.939**	0.935**	0.941**	1										
K+Mg:Ca	0.532**	0.605**	0.999**	1											
K:Ca	0.516**	0.563**	1												
Mg:Ca	0.653**	1													
N:Ca	1														

Similar results were obtained by Awad and De Jager (2002) which showed a negative correlation between the N:Ca ratio and anthocyanins in 'Elestar' apple cultivar. Because, apple peel coloration reduced in the terms of increasing nitrogen application (Fallahi et al., 2001). This reduction in coloration with increasing nitrogen could be because of inhibition synthesis and accumulation of anthocyanin by nitrogen, as well as the delaying the chlorophyll decline (Wang & Cheng, 2011). In another study, when nitrogen percentage in apple leaves exceed 3%, for every 2.0% increase in the amount of nitrogen the apple color was declined to 5% (Jihoni, 2013). In consistent with this study, Awad and De Jager (2002) showed that increasing the rate of nitrogen, reduced anthocyanin in apple 'Elestar' cultivar. K+Mg:Ca ratio in apple fruit is important for storage life of fruits (Ferguson & Watkins, 1989). It means that when K+Mg increase and fruit calcium deficiency in fruits happen these fruit are susceptible to postharvest losses (Bramlage & Weis, 2004). Potassium and magnesium have antagonism relationship with calcium in plants due to the cationic competition (Kotze, 1996). The result of this study was in agreed with findings of Dilmaghani et al. (2004) in relation to the positive correlation between the concentration of calcium and fruit firmness, although they are in conflict in relation to the negative correlation between K:Ca ratio and firmness. In apple high levels of calcium compared to the low levels of potassium delay fruit ripening, decreased respiration rate and ethylene production and reduced fruit softening (Marcelle, 1990). These results confirmed those (Bizjak et al., 2013) stated the effect of calcium and phosphorus on increasing the concentration of anthocyanin in 'Braeburn' apples cultivar, actually low ratio of Mg:Ca is meant to increase the amount of calcium in fruits that showed a significant positive correlation with anthocyanin accumulation in fruit peel (Table 2). Furthermore, the results of this study are in consistent with those reported by Farag et al. (2012) which found that the use of magnesium chloride and magnesium sulfate increases the amount of anthocyanin in fruit.

4.3 The Relationship between Fruit Mineral Composition and Antioxidant Capacity, Respiration and Ethylene Production

The correlation between fruit mineral composition with antioxidant capacity, fruit respiration rate and ethylene production was summarized in table 3. A positive significant correlation was found between the respiration rate and nitrogen, N+K:Ca and N:Ca ratios ($P < 0.05$). Previous studies also showed that with increasing nitrogen application respiration rate and ethylene production increased in Red delicious' apple (Wang & Cheng, 2011). This observation is very importance to apple growers, because the high fruit nitrogen content retards peel pigmentation of apple fruits therefore, growers have to delay harvesting in order to improve the color, but the respiration rate and ethylene production, continue and this delay may lead to fruit decay in storage (Bramlage & Weis, 2004). The results also showed a positive correlation between fruit postharvest respiration rate and ethylene production. The highest fruit respiration rate was followed by the highest ethylene production.

Table 3. The correlation between fruits mineral composition with antioxidant capacity, ethylene production and respiration

	Antioxidan	Respiration	Ethylene	N	P	K	Ca	Mg	N+K:Ca	K+Mg:Ca	K:Ca	Mg:Ca	N:Ca
Antioxidan	1												
Respiration	-0.312*	1											
Ethylene	-0.198	0.782**	1										
N	-0.091	0.259*	0.211	1									
P	-0.48	0.035	0.181	0.247	1								
K	0.023	0.066	0.08	0.206	-0.083	1							
Ca	0.225	-0.228	-0.149	0.099	-0.061	0.111	1						
Mg	-0.074	0.098	0.003	0.348**	-0.270*	0.312*	0.25	1					
N+K:Ca	-0.141	0.257*	0.203	0.299*	0.077	0.517**	-0.718**	0.026	1				
K+Mg:Ca	-0.112	0.195	0.156	0.038	-0.048	0.672**	-0.649**	0.038	0.941**	1			
K:Ca	-0.102	0.186	0.154	0.031	-0.041	0.661**	-0.632**	0.003	0.935**	0.999**	1		
Mg:Ca	-0.214	0.25	0.122	0.143	-0.15	0.152	-0.638**	0.560**	0.939**	0.605**	0.563**	1	
N:Ca	-0.163	0.299*	0.222	0.672**	0.257*	0.094	-0.635**	0.058	0.785**	0.532**	0.516**	0.563**	1

4.4 The Analysis of Regression

The analysis of regression based on the mean values of three apple peel color groups (Table 4) showed a significant negative correlation between ethylene production and total anthocyanin ($R^2 = -0.367^{**}$; $P < 0.01$) and

Mg:Ca ratio with total anthocyanin content (R^2 = -0.333**; P < 0.01). The relationship between these two variables and Anthocyanin was expressed by the equation of regression (Table 4):

$$\text{Anthocyanin} = 100.22 - 1.651\ \text{Ethylene} - 43.963\ \text{Mg:Ca} \quad (5)$$

It means that with increasing Mg:Ca ratio the anthocyanin content will be decreased. Because it may be antagonism relationship with ca reduce ca uptake so the anthocyanin content will be decreased. These results were in conflicting with those reported by (Li et al., 2010) in relation to the positive correlation between anthocyanin and magnesium in in peach fruit. Also this result shows that ethylene has negative effect on anthocyanin accumulation in apple skin. This result is against those has been reported that endogenous ethylene is closely associated with red color development and anthocyanin accumulation in fruit skin (Blankenship & Unrath, 1988). Positive and significant correlations have been reported between ethylene and color development and between ethylene and total anthocyanin, but not the other flavonoid compounds. Ethylene therefore appears to be a key factor regulating anthocyanin biosynthesis and color development in 'Pink Lady' apple (Whale & Singh, 2007).

Table 4. Relationship of causality of ethylene and Mg:Ca with anthocyanin

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	81.077	15.997		5.068	.000	49.055	113.099			
	Ethylene	-1.829	.609	-.367	-3.005	.004	-3.048	-.611	-.367	-.367	-.367
2	(Constant)	100.220	17.166		5.838	.000	65.846	134.593			
	Ethylene	-1.651	.588	-.331	-2.808	.007	-2.828	-.474	-.367	-.349	-.329
	Mg:Ca	-43.963	17.731	-.292	-2.479	.016	-79.470	-8.457	-.333	-.312	-.290

Note. Dependent variable: Anthocyanin.

5. Conclusion

The results showed that fruit mineral composition especially Ca can be used as a guide to predict postharvest behavior of "Red Delicious" apples during cold storage. Calcium is especially important for apples because they are stored for long periods of time, and other factors cannot substitute for the effects of Ca on storage quality. Apple fruits that contain low Ca concentrations are sensitive to many physiological disorders (von Bennewitz et al., 2011).

Several disorders are related to the ratio of Ca to other nutrients in the tree. The Ca/N ratio is more closely related to the occurrence of bitter pit than the level of Ca alone .Also it has been demonstrated the importance of Ca/K and Ca/Mg ratios in postharvest quality. The evidence supporting the role of ratios of Ca:Mg+K in bitter pit development is further strengthened by the findings that K and Mg foliar sprays increased the incidence of bitter pit in apple. In the field, the only practical methods of reducing the risks of bitter pit development are by managing tree nutrition and vigor, and maximizing Ca levels in the fruit (Terblanche et al., 1980). The fruit Ca threshold for bitter pit is nevertheless known to vary from season to season, over the range from 2 to 7 mg 100 g^{-1} fresh mass (Terblanche, 1985). The latter is however very difficult to achieve because of the restricted uptake and movement of Ca to the fruit and within fruit. In this study, a significant positive correlation was observed between fruit firmness at the end of storage with N+K:Ca, K+Mg:Ca, K:Ca and Mg:Ca ratios (P < 0.05). Furthermore, a negative correlation was observed between total anthocyanin and nitrogen content (P < 0.05). There was a significant negative correlation between anthocyanin and Mg:Ca and N:Ca ratios (P < 0.01). A significant positive correlation was observed between fruit respiration rate and the fruit nitrogen content, N+K:Ca and N:Ca ratios. Therefore, the results of this study demonstrated that fruits from which have a good nutrient elements balance at harvest time have higher keeping quality at cold storage. Overall, the results confirm that measurement of fruit mineral composition during harvest time could be a strategy for predicting postharvest behaviors of apple fruits at the cold storage.

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