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Effect of Calcium Concentration and Vacuum Pressure on Pulp Hardness and Ca Quantity of Post Harvest 'Golden Delicious' Apples

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Abstract: In this study, fruits of the apple cv. 'Golden Delicious' (Malus_/domestica Borkh.) were subjected to post-harvest calcium infiltration under vacuum. Research has been performed in two harvest years. In the first year, 'Golden Delicious' fruit were infiltrated with 0, 2, 4 or 5% $CaCl_2$ solutions and stored at 0 °C for up to 6 months. In the first year of harvest, apples were kept under -53.3 kPa and -66.6 kPa vacuum pressures for 2 and 2.5 minutes. In the second harvest year, 'Golden Delicious' apples were infiltrated with 0, 2, 4 $CaCl_2$ solutions and stored at 0 °C for up to 6 months. In that harvest year, apples were investigated under -26.6 kPa and -53.3 kPa vacuum pressure for 2.5 min. and submerged into solution for 1 min. Calcium chloride absorbed apples were investigated for surface hardness, water soluble matter criteria and compared with untreated apples.
The highest calcium infiltration was determined under -66.6 kPa vacuum pressure in 5% $CaCl_2$ solution but also the highest harm was also seen under the same conditions. The most suitable vacuum pressure for calcium infiltration and pulp hardness was found to be -53.3 kPa. The best Ca quantity and pulp hardness was obtained in 4% $CaCl_2$ solution so that the pulp hardness values after 6 months storage were nearly same or higher than control fruits.
Key words: Calcium, vacuum infiltration, 'Golden Delicious', fruit flesh firmness

INTRODUCTION

Vacuum infiltration with calcium chloride has been shown to reduce storage disorders of many fruit crops (Scott & Wills, 1977; 1979). Applying calcium to the fruit was determined to inhibit the occurrence of 'bitter pit' or suppress the disorder (Scott & Wills, 1977). Moreover, it was reported that calcium increased the firmness of fruit skin and the fruits could be stored for a longer time in the cold store (Sams et al., 1993). A large portion of the Ca in plant cells is located in the cell wall and plasma membrane where it plays a major role in senescence and ripening. Concentrations of 1-5 mm Ca^{2+} occur in the cell wall region(Poovaiah, 1986).

Many techniques to increase Ca content in the cell walls of fruit tissue after harvest have been developed. These include heat treatment (Klein et al., 1997), dipping (Conway & Sams, 1983), vacuum infiltration (Rajapakse et al., 1992), pressure infiltration (Conway & Sams, 1984), surfactants or coating agents (Saftner et al., 1998), or a combination of these techniques (Klein et al., 1990).

Low fruit calcium levels have been associated with reduced postharvest life and hysiological disorders (Wills et al., 1998). For example, low levels have been correlated with physiological disorders of avocados (Chaplin & Scott, 1980), papaya (Qiu et al., 1995), apples (Conway et al., 1992) and mangoes (Van Eeden, 1992). Delayed ripening in response to increased fruit calcium levels has been obtained with apples (Klein & Luire, 1994) and avocados (Wills & Tirmazi, 1982). Calcium treatment has been shown to decrease respiration, reduce ethylene production and to delay the onset of ripening in apples (Ferguson, 1984), avocados (Yuen et al., 1994) and mangoes (Tirmazi & Wills, 1981; Van Eeden, 1992).

Surface injury, however, is a negative effect sometimes observed when the calcium concentration of mango fruit is increased by postharvest infiltration with calcium salts (Tirmazi & Wills, 1981; Van Eeden, 1992).

Factors that influence calcium content include nutrient balance and fruit size (Van Eeden, 1992; Qiu et al., 1995). With regard to postharvest infiltration of calcium into mango fruit, Van Eeden (1992) found that there was little movement beyond the surface layer. On the other hand, Mootoo (1991) recorded increased levels in both skin and fresh layers. Fruit maturity can have a profound influence on calcium uptake. For instance, apples harvested 2 weeks before normal harvest time (maturity) and vacuum infiltrated with 8% calcium chloride had double the calcium levels of untreated fruits (Conway et al., 1992). In contrast, fruits treated in the same manner but at normal harvest time had calcium levels five times higher than untreated control fruits. With regard to the concentration of calcium, Yuen et al. (1994) reported that vacuum infiltration with 4% (w/v) calcium chloride of avocado fruits harvested 2 weeks prior to normal harvest time increased the time to ripen whilst causing negligible injury to the fruit.

Scott & Wills (1977), studied vacuum infiltration of calcium chloride. The treatment was realised by sampling four types of products from 22 orchards. Commercial $CaCl_2$ at 4% concentration was dissolved in water. Fruits were dipped into this solution and subjected to the reduced pressure for 3 minutes. The reduced pressure was initially applied for 90 s from 650 mmHg to 100 mmHg, and this reduced pressure was applied for an additional 30 seconds. Thereafter, the produce was dipped into $CaCl_2$ solution for 60 s. The fruits were held at 20°C for 3 weeks. Fruit firmness was measured with a penetrometer. It was observed that the fruit durability was improved and the disorder bitter pit was controlled *via* dipping the fruit into $CaCl_2$ solution under vacuum.

Abbott et al. (1989) studied the effect of post-harvest calcium chloride infiltration on the textural features of apples. The apples were subjected to infiltration in aqueous solutions of $CaCl_2$ at 0%, 1%, 2% and 4% concentration under 68.9 kPa pressure at least for 2 minutes. After that, the apples were ventilated on Kraft paper for 2 hours and then stored at 0°C for 2, 4 and 6 months. These apples were kept at 20°C for a week for tissue and Ca measurement after the completion of storage. Consequently, $CaCl_2$ infiltration increased the calcium quantity in the cell wall, as expected. This increase was between 1.6 and 32 fold. The highest increase was obtained with 4% $CaCl_2$ solution.

Sams et al. (1993) investigated the control of post-harvest decay of apples *via* pressurised calcium infiltration and heating method. Apples were dipped into regular distilled water for 3 minutes, thereafter; they were immersed in aqueous solution containing 4% $CaCl_2$ for 3 minutes under atmospheric pressure. Following this, the fruits were dipped into aqueous solution containing 4% $CaCl_2$ for 3 minutes under a pressure of 103 kPa. The apples were put in a clean place and dried *via* wrapping with white paper, before being put into the cold store. The fruits were put into polyethylene container and heated at 38°C for 4 days. Then they were kept at cold store at 0°C for 6 weeks after which they were subjected to measurements. It was observed that the disorder was reduced by 40% *via* pressurised infiltration. Calcium was determined to increase at significant rates under the fruit skin.

Del Valle et al. (1998) carried out a study on volumetric process by applying vacuum shock for the evaluation of infiltration kinetics and porosities of fruits. A volumetric process was developed in order to evaluate the fruit porosity using a hydrodynamic mechanism. In the study, it was suggested that the mass transfer operations comprising cellular interactions could accelerate the stage called hydrodynamic mechanism by forcing it to the intercellular zones. It was reported that a positive pressure differential should be provided between the liquid phase and intracellularly compressed gases. The trials were realised at the effective pressures of 80 kPa, 60 kPa, 40 kPa, 20 kPa and 10 kPa. The results obtained were then explained using a mathematical model.

Chardonnet et al. (2003) examined the chemical changes in the skin tissue and cell walls of calcium absorbed 'Golden Delicious' apples along the storage period. 'Golden Delicious' apples were stored at 0°C, for 6 months either without treatment or after absorbing 1%, 2%, 3% and 4% $CaCl_2$ solutions under pressure following the harvest. The chemical composition, skin tissue and cell walls of the layer 2-4

mm below the epidermis of apple fruits were examined. When Ca absorbed and untreated fruits were compared 6 months later, high levels of total P, Na and S were detected. An increase occurred in the tissue and cell walls of 2% $CaCl_2$ absorbed apple, during storage.

In this study, the objective was to develop a laboratory type system which would make the apples absorb calcium under vacuum, as well as to determine the quantity of calcium absorbed by fruits, firmness of apple fruits, quantities of water soluble solids and taste values.

MATERIALS AND METHODS

Materials

Sample Preparation For Infiltration Treatments

'Golden Delicious'(a_w = 0.99; and pH 3.49–3.88), types of apples were Golden delicious apples used in the experiments were obtained from gardens of Atatürk Garden Culture Researh Institute of Yalova,Turkey. The harvested fruits were classified with dividing into 7 groups according to their weights(140-160 g).

Vacuum Infiltration Treatments

An infiltration system was established in order to make the apples absorbe calcium under vacuum. The system has a capacity of 20 liters. The system consisted of electrical motor, vacuum pump, vacuum chamber in which the apples were placed, manometers, valves hoses and the container with the calcium solution inside. Schematic representation of laboratory type calcium infiltration system with vacuum is given in Figure 1.

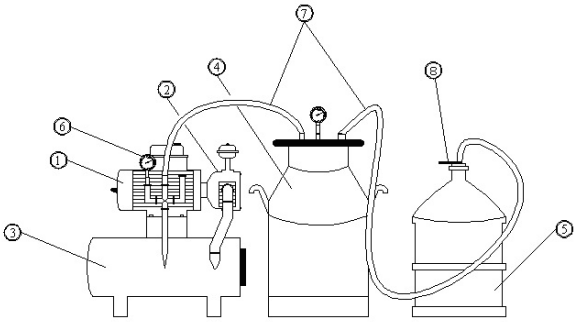

Figure 1. Schematic representation of loboratory type calcium impregnation system: (1) single-phase electrical motor; (2) vacuum pump; (3) vacuum store; (4) vacuum chamber in which the apples were placed; (5) container for $CaCl_2$ solution; (6) manometer; (7) transparent plastic hose; (8) spherical valve

The operating principle of calcium infiltration system is given in Figure 2(a-d).

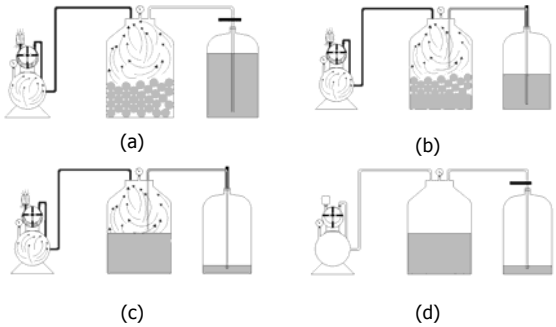

Figure 2. The operation of vacuum calcium infiltration system: (a) the desired infiltration pressure is obtained on the apples in the vacuum chamber; (b) and (c) the desired pressure(vacuum) value is reached in 4 to 8 seconds; apples are kept at this vacuum value for 2-2.5 minutes after the desired value is reached; thereafter, the valve on the calcium solution container is opened and the solution is pulverised onto the apples under vacuum in vacuum chamber; (d) then the valve and vacuum system on the calcium solution container is closed and the apples are held in the solution for 60 s

Calcium infiltration under the vacuum has been occurred one day after with respect to harvest date. Apples were stored in the storage room for one day.

An electronic balance with 1 mg precision, chronometer, graduated container, three-staged fan, water container, and powdered calcium chloride were used in the experiment. Before beginning with the trials, a starch test was carried out in order to determine whether the apples were at the proper harvest stage. A refractometer was used for measuring the water soluble solids and a penetrometer (Fruit Pressure Tester FT 327, measurement point diameter 11 mm, length 24 mm) was utilised for measuring the fruit flesh firmness. (Acican et al, 2007). All of the calcium analyses in the apples were realised in the laboratory.

Calcium absorbed and untreated fruits are placed in the storage room at 0-1 ^oC, 90-95% humidity until for 0, 2, 4 and 6 month, when they were used for the Calcium analysis, firmness and water soluble solids tests.

Methods

Prepared fruits, was put in impregnation vacuum system at the temperature of 25 degrees. In the first harvest year, trials were carried out using calcium

chloride at (20 g commercial $CaCl_2$ in 1 liters of water)2%, 4% and 5% (Abbott et al. (1989) purity with the immersion times of 60 s under -53.3 kPa and -66.6 kPa.(Del Valle et al. 1998,) pressure with 2 and 2.5 minute (Scott & Wills, 1977, 1979) reduced pressure time. Twenty four trials were carried out in total, in the first year, and 20 apples were used in each trial. Also 20 apples were used for controls. Calcium analysis, firmness and water soluble solids quantity were determined for each replicate after the periods of 0, 2, 4 and 6 months. The trials were conducted with fruits harvested at the proper maturity stage.

In second harvest year, -66.6 kPa vacuum pressure was not used, all measurements were performed under -53.3 kPa and -26.6 kPa vacuum pressures. The aim of this is lowering the energy consumption to minimum levels.

In the second year of harvest, the trials were carried out with calcium chloride at 2% and 4% (Abbott, et al. (1989) purity under -26.6 kPa and -53.3 kPa absolute pressures with an immersion time of 60 s. and reduced pressure time of 2.5 minutes(Scott & Wills 1977, 1979).

When choosing these values, the minimisation of infiltration energy and the values obtained in the first harvest year were taken into consideration. In total, four trials were carried out and 30 apples were used in each one of the trials. Also 30 apples were used for controls. Calcium analysis, firmness and water soluble solids quantity were determined for all replicates at the beginning of the 0, 2, 4 and 6 month periods.

Analysis of calcium was made according to NMKL (Nordic Committee on Food Analysis) 161(1998) method. Product was made a pulp mixture and homogenised. 0.2 g – 0.5 g example vessel (combustion unit) was inserted into tubes. 8 ml aqua fortis and 2 ml hydrogen peroxide was added and cap was closed. After tubes was put in micro wave, the temperature was increased to 150, 170 and 190 °C and after waiting 5 minutes the temperature was dropped to 100 °C the tubes was cooled and infiltrated into 5 ml volumetric flask. In order to make quantitative analysis diluted samples was given to device. Ependorf Elex 6361 Flame Emission Spectrophotometry has been used for Ca analyses (Horneck ve Hanson, 1998). Calcium values are given in fresh weight basis.

Data Analysis, The research was conducted using randomized plots factorial experimental design. Determination of the investigated components was carried out in three replicates. Analysis of variance (ANOVA) was used to detect treatment effect. Mean seperation were performed by using least significance difference(LSD) at the $p \leq 0.01$. The statistical analysis was performed using Statistical Analysis System (SAS) JMP 7.

RESULTS AND DISCUSSION

First harvest year

Values for firmness, water soluble solids and findings of Ca analysis for 12 trials that were measured in treated and untreated apples during the periods of 0, 2, 4 or 6 months are given in Table 1.

When Ca quantities and pulp hardness values of treated apples and untreated apples were compared after 6 months storing period, serious differencies were determined. In untreated apples under -66.6 kPa vacuum pressure, the increase of Ca quantities of apples were determined to be 2.8 times in 2% $CaCl_2$ solution, 2.85 times in 4 % $CaCl_2$ solution and 3.25 times in 5 % $CaCl_2$ solution. Same results were obtained in infiltration experiments which were performed under -53.3 kPa vacuum pressure. For treated apples, increase in Ca quantity was found to be 2.1 times in 2% $CaCl_2$ solution, 2.5 times in 4 % $CaCl_2$ solution and 2.9 times in 5 % $CaCl_2$ solution. Same results were obtained in infiltration experiments which were performed under -53.3 kPa vacuum pressure. Pulp hardness values of untreated apples after 6 months was 44.6 N whether Pulp hardness values of

untreated apples after 6 months under, -66.6 kPa vacuum pressure in 4 % $CaCl_2$ solution was 54.7 N. In consideration, pulp hardness values of treated apples after 6 months storing period was found to be similar or a little bit higher than pulp hardness values of untreated apples at the beginning of experiments.

Table 1.Results of firmness, water soluble solid and Ca amount quantities after 0, 2, 4, 6 months for the first harvest year (immersion period 60 s)

$CaCl_2$ concentration (%)	Vacuum Pressure (kPa)	Vacuum period (min)	Firmness, (N)				Water soluble solid,(%)				Ca amount, (mg/100g)			
			2 week	2 month	4 month	6 month	2 week	2 month	4 month	6 month	2 week	2 month	4 month	6 month
Untreated(Control)			50.4^{h} (±0.27)	47.1^{f} (±0.29)	46.1^{h} (±0.5)	44.6^{g} (±0.41)	13.2^{c} (±0.24)	13.2^{d} (±0.35)	13.5^{c} (±0.28)	13.7^{gh} (±0.31)	4.46^{i} (±0.12)	4.46^{h} (±0.05)	4.42^{i} (±0.09)	4.41^{k} (±0.19)
2	-53.3	2	50.9^{gh} (±0.30)	48,8^{ef} (±0.13)	47.1^{h} (±0.42)	46.4^{efg} (±0.59)	13.2^{c} (±0.32)	13.4^{d} (±0.49)	13.5^{c} (±0.26)	14.1^{ef} (±0.25)	9.06^{g} (±0.16)	9.16^{f} (±0.42)	9.19^{h} (±0.18)	9.45^{h} (±0.33)
		2.5	50.2^{h} (±0.22)	46.9^{f} (±0.24)	47.3^{gh} (±0.23)	48.1^{de} (±0.13)	11.9^{d} (±0.21)	11.8^{f} (±0.30)	12.0^{e} (±0.56)	12.5^{i} (±0.31)	9.13^{g} (±0.11)	9.01^{f} (±0.56)	9.20^{h} (±0.15)	9.15^{i} (±0.35)
	-66.6	2	55.1^{ef} (±0.23)	55.2^{cd} (±0.36)	52.4^{de} (±0.37)	50.4^{c} (±0.19)	14.2^{ab} (±0.42)	15.1^{ab} (±0.24)	14.8^{a} (±0.32)	14.3^{de} (±0.42)	8.26^{h} (±0.03)	8.00^{g} (±0.16)	8.00^{i} (±0.31)	8.20^{j} (±0.35)
		2.5	53.2^{fg} (±0.34)	52.6^{cde} (±0.39)	51.2^{ef} (±0.20)	52.2^{bc} (±0.50)	14.0^{b} (±0.33)	14.3^{c} (±0.40)	14.7^{a} (±0.56)	15.3^{ab} (±0.29)	10.86^{e} (±0.32)	11.20^{de} (±0.56)	12.10^{cd} (±0.27)	12.30^{d} (±0.37)
4	-53.3	2	54.1^{f} (±0.20)	53.5^{cde} (±0.48)	50.9^{ef} (±0.30)	44.8^{fg} (±0.17)	14.6^{a} (±0.43)	15.3^{a} (±0.16)	15.0^{a} (±0.19)	14.4^{d} (±0.25)	11.36^{de} (±0.21)	11.80^{c} (±0.29)	11.30^{ef} (±0.27)	11.20^{e} (±0.26)
		2.5	50.7^{h} (±0.22)	50.6^{def} (±0.31)	51.5^{ef} (±0.40)	51.5^{bc} (±0.45)	13.2^{c} (±0.12)	13.6^{d} (±0.37)	14.3^{b} (±0.20)	15.4^{a} (±0.10)	10.0^{f} (±0.37)	10.90^{e} (±0.53)	10.50^{g} (±0.50)	10.10^{g} (±0.40)
	-66.6	2	66.8^{a} (±0.16)	60.4^{b} (±0.46)	57.0^{ab} (±0.52)	51.1^{c} (±0.62)	14.7^{a} (±0.28)	15.1^{a} (±0.31)	15.0^{a} (±0.35)	14.8^{c} (±0.56)	13.06^{b} (±0.20)	13.00^{b} (±0.14)	12.80^{b} (±0.25)	12.60^{c} (±0.26)
		2.5	60.4^{c} (±0.25)	60.6^{b} (±0.43)	58.8^{a} (±0.51)	54.7^{a} (±0.38)	14.3^{ab} (±0.30)	14.6^{bc} (±0.28)	14.8^{a} (±0.15)	15.2^{ab} (±0.14)	11.26^{e} (±0.32)	11.50^{cd} (±0.26)	11.00^{fg} (±0.26)	10.90^{f} (±0.55)
5	-53.3	2	63.7^{b} (±0.27)	67.7^{a} (±0.44)	56.1^{bc} (±0.24)	50.2^{cd} (±0.21)	14.2^{ab} (±0.51)	14,5^{c} (±0,418)	14.8^{a} (±0.22)	15.0^{bc} (±0.50)	12.02^{c} (±0.16)	12.00^{c} (±0.28)	11.70^{de} (±0.13)	11.00^{ef} (±0.21)
		2.5	54.8^{ef} (±0.22)	56,1^{bc} (±0,34)	53.2^{de} (±0.58)	53.8^{ab} (±0.22)	12.1^{d} (±0.23)	12,5^{e} (±0,253)	12.8^{d} (±0.37)	13.2^{i} (±0.35)	13.43^{ab} (±0.41)	13.70^{a} (±0.46)	13.00^{b} (±0.45)	12.85^{c} (±0.46)
	-66.6	2	56.8^{de} (±0.21)	56,9^{bc} (±0,25)	49.6^{fg} (±0.54)	47.0^{ef} (±0.69)	13.4^{c} (±0.41)	13,6^{d} (±0,123)	13.5^{c} (±0.24)	13.4^{hi} (±0.28)	11.96^{cd} (±0.33)	11.50^{cd} (±0.46)	12.50^{bc} (±0.13)	13.20^{b} (±0.11)
		2.5	59.1^{cd} (±0.20)	56,4^{bc} (±0.19)	54.3^{cd} (±0.16)	50.7^{c} (±0.17)	13.4^{c} (±0.46)	13,6^{d} (±0,161)	13.5^{c} (±0.68)	13.8^{fg} (±0.25)	13.73^{a} (±0.28)	13.30^{ab} (±0.08)	13.80^{a} (±0.15)	14.28^{a} (±0.54)

P<0.01, Column mean values with different superscripts are significantly different

Table 2. Results of firmness, water soluble solid and Ca amount quantities after beginning 0, 2, 4, 6 monts for the second harvest year (vacuuming period 2,5 min, immersion period 60 s in all treatment)

$CaCl_2$ Concentration (%)	Pressure (kPa)	Firmness, (N)				Water soluble solid, (%)				Ca amount, (mg/100g)			
		2 week	2 month	4 month	6 month	2 week	2 month	4 month	6 month	2 week	2 month	4 month	6 month
Untreated		51.21 ^{d} ±0.42	50.03 ^{d} ±0.34	47.09 ^{c} ±0.60	46.11 ^{b} ±0.50	15.1 ^{b} ±0.46	16.1 ^{c} ±0.41	17.0 ^{b} ±0.39	17.2 ^{a} ±0.28	3.88)^{c} ±0.16	3.78 ^{c} ±0.23	4.26 ^{d} ±0.23	3.63 ^{c} ±0.20
2	-26.6	55.62 ^{e} ±0.57	52.48 ^{c} ±0.73	50.03 ^{b} ±0.58	54.45 ^{a} ±0.74	15.7 ^{a} ±0.43	16.4 ^{bc} ±0.87	16.7 ^{b} ±0.91	16.9 ^{a} ±0.37	8.33 ^{b} ±0.32	7.47 ^{b} ±0.26	7.57 ^{c} ±0.40	6.29 ^{b} ±0.19
	-53.3	61.12 ^{b} ±0.44	55.43 ^{b} ±0.71	54.25 ^{a} ±0.55	54.45 ^{a} ±0.36	14.8 ^{b} ±0.43	16.5 ^{ab} ±0.13	16.9 ^{b} ±0.13	16.5 ^{b} ±0.15	10.81 ^{a} ±0.46	8.40 ^{b} ±0.35	8.20 ^{bc} ±0.18	8.49 ^{a} ±0.49
4	-26.6	61.7 ^{ab} ±0.43	57.09 ^{ab} ±0.20	54.54 ^{a} ±0.23	53.37 ^{a} ±0.89	14.9 ^{b} ±0.77	16.8 ^{a} ±0.86	17.5 ^{a} ±0.29	17.1 ^{a} ±0.23	9.37 ^{b} ±0.12	9.90 ^{a} ±0.33	9.11 ^{b} ±0.49	9.09 ^{a} ±0.33
	-53.3	63.27 ^{a} ±0.56	57.98 ^{a} ±0.48	54.94 ^{a} ±0.32	54.74 ^{a} ±0.35	15.2 ^{b} ±0.61	16.4 ^{bc} ±0.22	16.8 ^{b} ±0.34	16.2 ^{b} ±0.21	9.17 ^{b} ±0.21	9.84 ^{a} ±0.47	11.20 ^{a} ±0.34	9.89 ^{a} ±0.49

P<0.01, Column mean values with different superscripts are significantly different

Second Harvest Year

Measurement of firmness, water soluble solids and Findings of Ca analysis for 4 trials that were done in calcium absorbed or non-absorbed apples for the periods of Beginning 0, 2, 4 or 6 months are given in Table 2.

According to Table 2, after 6 months under -26.6 kPa vacuum pressure, Ca analysis and pulp hardness datas were increased significantly with respect to datas found in control fruits. The values of Ca analysis was increased 1.75 times in 2% $CaCl_2$ solution, however they were increased 2.4 times in %4 $CaCl_2$ solution. Calcium analysis values, 1.75 fold increased in a solution of 2%, 4% solution was 2.4 fold. After 6 months protection, pulp hardness values were determined as 46.11 N for control fruit, 54.45 N in 2% $CaCl_2$ solution and 53.37 N in 4 %$CaCl_2$ solution. The increase in the quantity of Ca with respect to control fruit after 6 months was higher under -53.3 kPa vacuum pressure. According to analysis products, the increase in 2% $CaCl_2$ solution was 2.35 times and 2.7 times in 4 %$CaCl_2$ solution. However, pulp hardness hasnot changed significantly depending on vacuum pressure ($p<0.01$).

GALLERANI *et al.*(1990) treated apples with 4 and 8% calcium chloride solution through dip and vacuum dip methods. After the treatment the apples were stored at ambient temperature (20°C). The 4% CaCl2 vacuum infiltration treatment was better in controlling bitter pit and in keeping fruit firm. They also found that calcium infiltration at pressure is beter than simple immersion.

Vacuum Pressure infiltration of 2% calcium chloride was optimal for maintaining the texture of 'Golden Delicious' apples during 6 months storage (ABBOTT et al., 1989), especially by maintaining fruit water relations (by decreasing air space volume) while minimizing the risk of salt-related injuries (Saftner et al., 1998).

Results of second harvest period were given as 3D graphs of water soluble solid(%), firmness(N) ve calcium content(mg/100 g) values under -26.6 kPa and -53.3 kPa vacuum pressures in Figure 3.

CONCLUSION

The importance of calcium in apple fruit is its role in contributing to the maintenance of optimum quality during postharvest storage and fruit ripening. This role is seen directly in the prevention of specific disorders such as bitter pit, and in relationships between calcium and more general quality properties such as flesh firmness. This work suggests that postharvest vacuum infiltration of 'Golden Delicious' fruits in 2 and 4% $CaCl_2$ benefits storage life capacity and maintains quality characteristics, shows better effects than with other concentrations and with calcium dip treatments.

In observations performed in two harvest year period, different vacuum presuures were applied to fruits and affirmative results were obtained. However, under -66.6 kPa vacuum pressure, serious harmness was observed on fruits. According to results obtained in this study, the relevant vacuum pressure for these fruits was found to be -53.3 kPa, but also -26.6 kPa vacuum pressure can be suggested for these experiments. Besides, the most suitable $CaCl_2$ solution rate was found to be 4% for these fruits in two year harvest period.

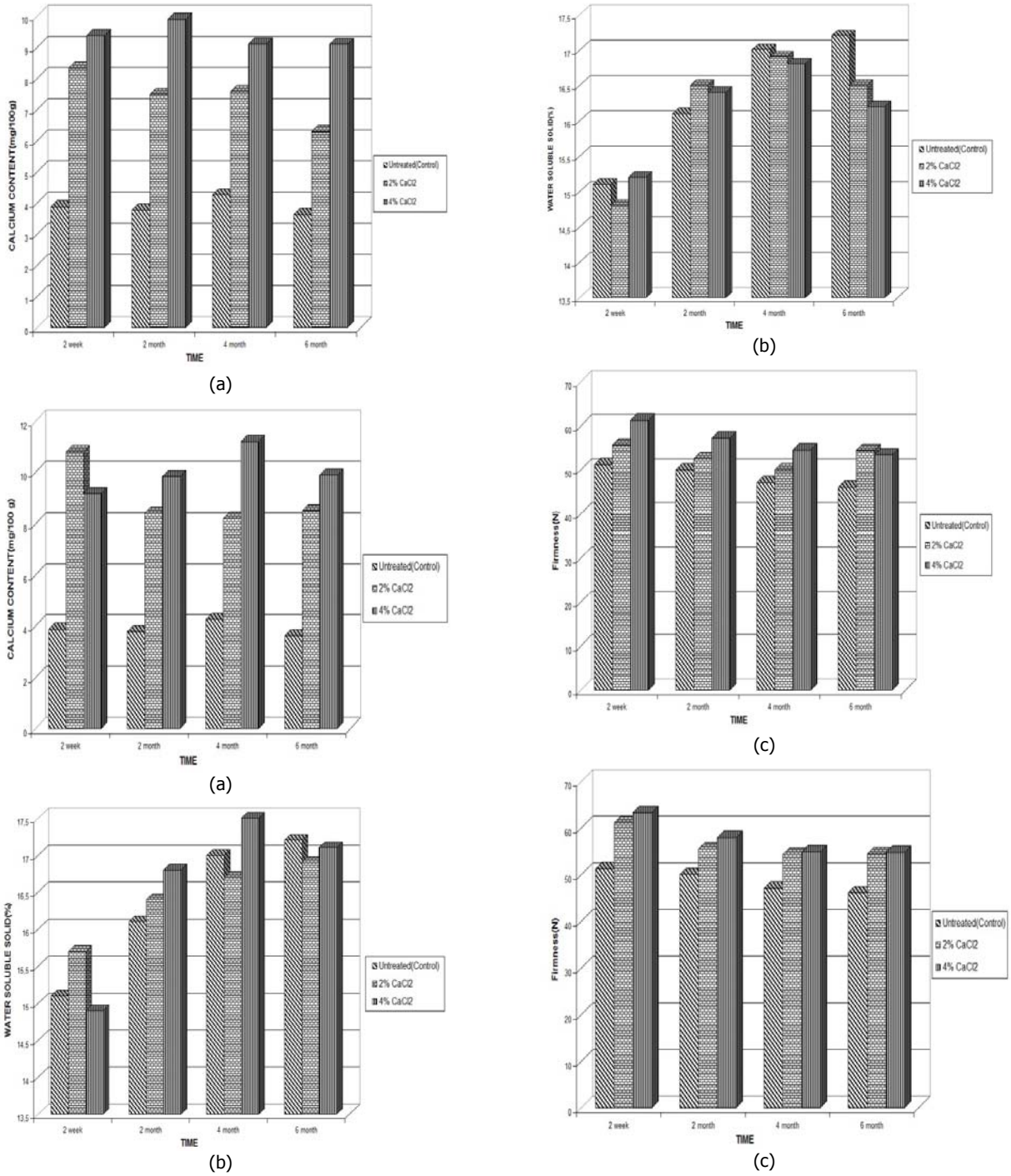

Figure 3. Variation of calcium content(mg/100 g)(a), water soluble(%)(b) ve firmness(N)(c) values under -26.6 kPa and -53.3 kPa vacuum pressures in second harvest year

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