Effects of Cold Storage and Post-cold Storage Duration on Several Fruit Quality Parameters and Shelf Life of "Golden Delicious" Apples

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Abstract

The study was conducted during 2011-2012 vintage-storage season. Freshly harvested apples were pre-cooled at 2°C for 24 h in a cold storage chamber to remove the field heat, then were dipped in five various concentrations of $CaCl_2$ solution (0-2.5%) for one hour and were exposed to hot air at 20°C and 90% RH for 24 hours. Three replications for treatment, with ninety uniform apples for each treatment on each replication, were used. Apples were placed on wooden crates and were stored under refrigerated conditions (0±2°C, 90% RH) for six months and up to 30 days post-cold storage, under normal environmental conditions (15±2°C, 75% RH). Apples were sampled for several quality parameters at intervals of 60 days during cold storage period and at intervals of five days during *post*-cold storage. Observed results showed that duration of cold storage and *post*-cold storage significantly affected fruit firmness, juice content, weight loss and shelf life of "Golden Delicious" apples. Post-harvest $CaCl_2$ dip treatments of 2.0% and 2.5% maintained the highest quality of "Golden Delicious" apples, with less negative effects on consumer acceptance, and, since there were not observed significant differences between them, $CaCl_2$ 2.0% was recommended for "Golden Delicious" apples grown under Korça's conditions.

KEYWORDS: apple, calcium chloride, cold storage, "Golden Delicious", parameters, quality.

INTRODUCTION

Apple is one of the most important fruit in the world which, due to its high nutritional value, ranks thirds in consumption, after citrus and banana (UIE, 2013). Among the commercially grown varieties in Albania, "Golden Delicious" is very popular and very important, due to its overall sensory quality, consumer acceptability and market returns (ProMali, 2012). According to Roy (1993), huge losses of 20–40% occur in the fresh produce during handling, packaging, transportation, marketing and storage, due to inappropriate postharvest management practices, lack of proper storage and prompt transportation facilities. Factors affecting the overall quality of apple after harvest and during storage include loss of water, respiration, metabolism and microbial spoilage (Balla and Holb, 2007; Alak & Goswami, 2006). In recent years,

there is an increased interest related to storage, shelf life and nutritional quality of postharvest fruits and vegetables. Quality is usually defined in terms of all of the characteristics of a food that lead a consumer to be satisfied with the product (Harker *et al.*, 2003). The concept of quality can be studied from different perspectives; that of the consumer, producer and fruit industry. In both cases, efforts mainly focus on establishing a reference system that is valid for measuring fruit quality, and, of course, for establishing the most appropriate methodologies and parameters for reliably predicting how consumers and the market are likely to react to the product in question. For the fruit industry it of great importance to be able to predict consumer tastes and requirements (Shewfelt, 1999). Postharvest treatment of fresh apple has become necessary to maintain the quality and provide longer shelf life of fruit. Jan and Rab (2012) have reported that storage duration affects significantly physico-chemical changes of apple fruit cultivars, but different cultivars remain with a better quality than some others. Fruits of different apple cultivars exhibit significant differences in physiological and anatomical parameters, such as ethylene production (Nilsson and Gustavsson, 2007; Khan and Ahmad, 2005), responsible for the changes in texture and fruit softening and water loss, time of harvest and picking maturity (Konopacka & Plocharski, 2002). Postharvest losses depend on external and internal conditions, which affect the fruit firmness, juice content, weight loss, pH, total soluble solids content, and other quality parameters (Song and Bangerth, 1993; Sams and Conway, 1993; Tu *et al.*, 2000). Significant advances have been made in fruit storage using different postharvest treatments and storage methods, in order to maintain or improve fruit quality attributes, without adverse effects on fruit appearance and consumer acceptability (Hussain *et al.*, 2012). Pre- and postharvest application of calcium has been reported to improve firmness, delay softening, decrease the incidence of physiological disorders and extend the postharvest shelf life of a wide range of fruits and vegetables (Gafir *et al.*, 2009; Poovaiah, 1986), with no detrimental effect on consumer acceptance (Kadir, 2005;). Chardonnet *et al.* (2003) have reported that the major chemical changes in the cortical tissue and cell walls of calcium-infiltrated “Golden Delicious” apples occur after six months cold storage, indicating that this stage is critical for quality maintenance. The maintenance of the quality parameters in apples differ with cultivar, maturity stage, environmental growing conditions, orchard characteristics, and storage conditions (Fan *et al.*, 2005; Juan *et al.*, 1999; Ploto *et al.*, 1995). Storage methods affect apple fruit shelf life and fruit quality (Nour & Ionica, 2002), while, Kvikliene *et al.* (2006) have reported that harvest time and storage conditions affect significantly fruit quality parameters and consumer acceptability of “Auksis” apples. Softening rate vary from cultivar to cultivar, depending on the presence and expression of genes which regulate the activity of hydrolytic enzymes (Ingle *et al.*, 2000; Konopacka and Plocharski, 2002; Johnston *et al.*, 2001).

“Golden Delicious” is prone to fruit drop and to softening during storage, therefore, it is very important to systematically monitor changes in fruit quality to determine optimal storage duration. To ensure maximum storability, apples should be harvested at the right stage, because of physiological processes which complicate storage, even under optimal conditions (Ullah *et al.*, 2004; Braun *et al.*, 1995; Hatfield & Knee, 1988). Weight loss and decay during storage can greatly affect marketability. Weight loss during storage depends on fruit maturity at harvest time (Gafir *et al.*, 2009; Schrader et al., 2009; Ferguson *et al.*, 1999; Wills and Scot, 1972). Apples picked too early or too late lost more mass than apples picked at the optimum stage of ripeness. Apples which are picked earlier are less prone to rot, but are not as tasty and attractive

than apples which are picked later. Most fruit quality parameters are useful not only for gauging fruit maturity, but for evaluating the eating quality of the apple, as well (Hoehn *et al.,* 2003). Fruit firmness is a measure of texture; soluble solids content, acidity and sugar content are associated with taste; and volatile substances contribute to fruit aroma (Kvikliene *et al.,* 2006). Firmness, soluble solids content and acidity are usually considered the destructive variables that are best correlated with consumer acceptance and therefore serve as good indicators of texture, sweetness and tartness (Hoehn *et al.,* 2003; Harker *et al.,* 2003; Mehinagic *et al.,* 2004).

The aim of the study was to investigate changes in fruit quality parameters of "Golden Delicious" apples pre-treated with different $CaCl_2$ concentrations, during 180 days cold storage and up to 30 days after cold storage under normal environmental conditions, in order to determine the optimum storage duration and consumer acceptance.

MATERIAL AND METHODS

The study on effects of cold storage and *post*-cold storage duration on several fruit quality parameters and shelf life of "Golden Delicious" apples was conducted during 2011-2012 vintage-storage season.

Plant material. Ten apple trees of "Golden Delicious" cultivar with uniform vigor and size from a 10 years apple orchard, situated in Menkulas, Korça, in southeastern part of Albania, were selected for the collection of fruit samples. Apple fruits were harvested at the commercial maturity stage (180 days after full bloom). Apples were pre-cooled at 2°C for 24 h in a cold storage chamber in order to remove the field heat. Unhealthy, diseased and bruised fruits were discarded and apples with an equal size were selected for the study. After selection, apples were dipped in five various concentrations of $CaCl_2$ solution [T_1 = 0 – control (0% $CaCl_2$ - distilled water), T_2 = 1.0% $CaCl_2$, T_3 =1.5% $CaCl_2$, T_4 = 2.0% $CaCl_2$ and T_5 = 2.5% $CaCl_2$], for one hour, as floating and penetration under 250 mm Hg, and were exposed to hot air at 20^{o}C and a relative humidity of 90% for 24 hours. Thereafter, apples were placed on wooden crates (boxes) and were stored under refrigerated conditions at 0±2^{o}C and 90% relative humidity, up to 3 months. Three wooden crates (replications) with a plot size of ninety apples for each treatment ($CaCl_2$ concentration), were used. After six months cold storage period, apples were placed under normal environmental conditions (15±2°C, 75% RH) for a period up to 30 days *post*-cold storage (*post*-CS). Fruits were sampled for several physico-chemical parameters, such as fruit firmness (kg cm^{-2}), juice content (%), weight loss (%) and overall acceptability, at intervals of 60 days during cold storage and at intervals of 5 days during *post*-cold storage period.

Fruit quality analyses were carried out at the above specified intervals at the Microbiology Lab of the Agriculture Faculty at the University "Fan S. Noli" Korçë. Prior to the measurement of quality attributes, fruits were allowed to attain the room temperature.

Fruit firmness (kg/cm^2) was determined using a hand penetrometer model "FT-327" (Effegi, Italy) provided with a round plunger 11.2 mm diameter. Samples of five fruits for treatment were selected randomly and firmness was measured on both sides of each whole fruit, and average value was calculated. To avoid the interference of skin, fruits were peeled at the points where firmness was measured (Plocharski *et al*., 2002; Garner *et al*., 2013; Abbott *et al.,* 1992).

Juice content (%). The fruits initially used for firmness measurement were subject of juice extraction using an Omini mixer (Philips make). Juice content was determined

by extracting the juice from known weight of fruit sample and was calculated using the formula (1):

$$\text{Juice content (\%)} = \frac{\text{Weight of juice fruit}^{-1}}{\text{Average weight of fruit}} \times 100 \quad (1)$$

Weight loss (%) was determined by periodical weighing of samples. Five fruits in each treatment were separated for weight loss test. The initial weight of each fruit was noted with the help of an electronic balance. The weight loss (%) was calculated using the formula (2):

$$\text{Weight loss (\%)} = \frac{\text{Initial weight of fresh fruits} - \text{Weight after interval}}{\text{Initial weight}} \times 100 \quad (2)$$

Overall acceptability was evaluated during *post*-cold storage period by a panel of three specialists (judges), based on sensory attributes such as visual firmness, appearance and taste, using 4-point scale [4 = excellent (E), 3 = good (G), 2 = fair (F), and 1 = poor (P)]. Five fruits for each treatment were selected randomly, coded and served to judges (Oraguzie *et al.*, 2009; Molina *et al.*, 2006).

Statistical analyses. The obtained data were subject of ANOVA and differences between variants were tested using LSD test (0.05) (Papakroni, 2001).

RESULTS AND DISCUSSION

"Golden Delicious" apples were analyzed for several quality parameters, such as fruit firmness (kg cm^{-2}), juice content (%), weight loss (%) and overall acceptability. Results showed that fruit quality parameters of "Golden Delicious" apples, were significantly affected/decreased during cold storage (CS) and *post*-cold storage (*post*-CS) periods.

Fruit firmness (kg cm^{-2}). Fruit firmness is an important criterion for edible quality and market value of apples (De-Ell *et al.*, 2001). Initial fruit firmness (day 0) of "Golden Delicious" apples at harvest was 9.2 kg cm^{-2}. There was observed a significant gradual decrease on fruit firmness to all treatments as cold storage (CS) and *post*-cold storage (*post*-CS) period increased, but the rate of fruit firmness decrease was significantly different. After 60 days of cold storage, firmness of control samples and those treated with 1% $CaCl_2$ did not show any significant difference between each-other, but they showed a significantly lower firmness than 2.0 and 2.5% $CaCl_2$ treatments (10.9% and 8.7%, respectively). As the storage period advanced, firmness recorded a further decrease, which was significantly higher in control, 1.0% and 1.5% $CaCl_2$ treated apples. After 180 days of cold storage, for control fruits was measured a decrease of 30.4% in firmness, while in apples treated with 2.0 and 2.5% $CaCl_2$ the decrease in firmness was 16.3% and 15.2%, respectively. Firmness of 2% and 2.5% $CaCl_2$ treated apples was below detection level after 25 and 30 days of storage, respectively, but marketable and acceptable firmness was observed between 20–25 days of storage (Table 1).

Weight loss (%).Weight loss through transpiration is a major cause of quality deterioration in fresh horticultural crops after harvest. Weight loss not only results in direct quantitative losses, but also causes losses in appearance, textural quality (softening, loss of crispness and juiciness) and nutritional quality. If weight loss is

more than 10%, surface of the fruit show quality defects like wilting and shriveling and the commodity becomes unmarketable (Hussain *et al.*, 2012).

Table 1. Firmness (kg cm^{-2}) of "Golden Delicious" apples treated with different $CaCl_2$ solutions during cold and post-cold storage periods (mean values, different letters indicate significant difference at $p \leq 0.05$).

Storage period	T_1	T_2	T_3	T_4	T_5	LSD (0.05)
Initial firmness (kg cm^{-2})	9.2 ^{aA}	9.2 ^{aA}	9.2 ^{aA}	9.2 ^{aA}	9.2 ^{aA}	
60 days cold storage	8.2 ^{cB}	8.2 ^{cB}	8.4 ^{bB}	8.7 ^{aB}	8.7 ^{aB}	0.2
120 days cold storage	7.5 ^{bC}	7.6 ^{bC}	7.6 ^{bC}	8.1 ^{aC}	8.3 ^{aC}	0.3
180 days cold storage	6.4 ^{cD}	6.6 ^{bD}	6.6 ^{bD}	7.7 ^{aD}	7.8 ^{aD}	0.2
5 days post-CS	4.4 ^{cF}	4.7 ^{bE}	4.7 ^{bE}	5.4 ^{aE}	5.7 ^{aE}	0.4
10 days post-CS	3.6 ^{bF}	3.6 ^{bF}	3.8 ^{bF}	4.4 ^{aF}	4.6 ^{aF}	0.3
15 days post-CS	2.1 ^{cG}	2.2 ^{cG}	2.3 ^{cG}	3.6 ^{bG}	3.9 ^{aG}	0.3
20 days post-CS	BDL	BDL	BDL	2.4 ^{bH}	3.5 ^{aH}	0.2
25 days post-CS	–	–	–	BDL	2.4 ^{aI}	0.2
30 days post-CS	–	–	–	–	BDL	0.2
LSD 0.05	0.44	0.41	0.43	0.37	0.32	-

Note: BDL = Below Detection Level

Observed results showed that after 180 days of storage, weight loss increased to all treatments. It was significantly higher in control (6.8%) and 1.0% $CaCl_2$ treated apples (6.6%), while for apples treated with 2.0 and 2.5% $CaCl_2$ was 4.2% and 4.1%, respectively (Table 2). Maximum shelf life (at 15°C and RH 75%, following 180 days of cold storage) of control, 1.0 and 1.5% $CaCl_2$ treated apples was about 10 days, while for fruits treated with 2.0% and 2.5% $CaCl_2$ was 15 days and 20-25 days, respectively (Table 2).

Table 2. Weight loss (%) of "Golden Delicious" apples, treated with different $CaCl_2$ solutions, during cold storage and *post*-cold storage periods (mean values, different letters indicate significant difference at $p \leq 0.05$).

Storage period	T_1	T_2	T_3	T_4	T_5	LSD 0.05
Weight loss (%)						
60 days cold storage	1.6 ^{cA}	1.6 ^{cA}	1.5 ^{bA}	1.4 ^{aA}	1.3 ^{aA}	0.1
120 days cold storage	4.1 ^{cB}	4.1 ^{cB}	3.5 ^{bB}	3.2 ^{aB}	3.2 ^{aB}	0.2
180 days cold storage	6.8 ^{dC}	6.6 ^{cC}	4.9 ^{bC}	4.2 ^{aC}	4.1 ^{aC}	0.2
5 days *post*-CS	7.5 ^{dB}	7.6 ^{dA}	6.8 ^{cA}	6.2 ^{bA}	6.0 ^{aB}	0.2
10 days *post*-CS	10.4 ^{dC}	10.2 ^{dB}	9.5 ^{cB}	7.4 ^{bB}	7.2 ^{aC}	0.3
15 days *post*-CS	UM	UM	UM	9.6 ^{bC}	9.2 ^{aD}	0.4
20 days *post*-CS	–	–	–	UM	10.8 ^{aE}	0.3
25 days *post*-CS	–	–	–	–	UM	0.2
30 days *post*-CS	–	–	–	–	–	-
LSD 0.05	0.4	0.5	0.6	0.6	0.4	-

Note: UM = unmarketable

Juice content (%). Juice content of apple samples showed a declining trend during irrespective storage periods for all treatments (Table 3). After 60 days of storage, juice yield of control and 1% $CaCl_2$ samples were not significantly different to each

other. With progress of storage, juice content decreased significantly compared with the initial value. After 180 days of storage, juice content was decreased by 32.37% for control, 31.8% for samples treated with 1% $CaCl_2$. For samples treated with 2% and 2.5% $CaCl_2$, juice content was 14.5% and 14.0%, respectively, lower than initial value. There were observed not significant differences between 2% and 2.5% $CaCl_2$ treatments (Table 3).

Table 3. Juice content (%) of "Golden Delicious" apples, treated with different $CaCl_2$ solutions, during cold storage and post-cold storage periods (mean values, different letters indicate significant difference at $p \leq 0.05$).

Storage period	T_1	T_2	T_3	T_4	T_5	LSD 0.05
Initial juice content (%)	69.2 ^{aA}	69.2 ^{aA}	69.2 ^{aA}	69.2 ^{aA}	69.2 ^{aA}	
60 days cold storage	56.2 ^{aB}	58.3 ^{bB}	60.2 ^{cB}	63.4 ^{dB}	64.6 ^{dB}	1.4
120 days cold storage	51.5 ^{cC}	52.1 ^{cC}	54.3 ^{bC}	58.6 ^{aC}	59.3 ^{aC}	1.3
180 days cold storage	46.8 ^{cD}	47.2 ^{cD}	50.2 ^{bD}	54.7 ^{aD}	55.2 ^{aD}	1.6
5 days *post*-CS	37.5 ^{dE}	37.6 ^{dE}	46.8 ^{cE}	50.2 ^{bE}	51.6 ^{aE}	1.4
10 days *post*-CS	30.4 ^{cF}	31.2 ^{cF}	37.5 ^{bF}	47.4 ^{aF}	48.2 ^{aF}	1.4
15 days *post*-CS	UM	UM	UM	39.6 ^{bG}	42.5 ^{aG}	1.3
20 days *post*-CS	–	–	–	UM	36.8 ^{aH}	-
25 days *post*-CS	–	–	–	–	UM	-
30 days *post*-CS	–	–	–	–	–	-
LSD 0.05	1.1	1.3	1.5	1.2	1.3	-

Note: UM = Unmarketable

Overall acceptability assessment was based on fruit texture, taste and visual appearance during *post*-cold storage period. It was significantly ($p \leq 0.05$) lower in control, 1.0 and 1.5% $CaCl_2$ treated samples after first 5 days of ambient storage following refrigeration. The overall acceptability of all other treatments was significantly different over the same storage period. After 15 days of ambient storage, overall acceptability was significantly higher in samples treated with 2.0 and 2.5% $CaCl_2$. Beyond 25 days of storage, overall acceptability of all the samples was rated poor (Table 4).

Table 4. Overall acceptability of "Golden Delicious" apples during ambient storage (at 15°C, RH 75%), following 180 days cold storage (mean values, different letters indicate significant difference at ($p \leq 0.05$).

Storage period	T_1	T_2	T_3	T_4	T_5	LSD 0.05
Overall acceptability (OAA)						
5 days *post*-CS	3.3 ^{bA}	3.4 ^{bA}	3.5 ^{bA}	3.8 ^{aA}	3.8 ^{aA}	0.2
10 days *post*-CS	2.7 ^{cB}	2.9 ^{cB}	3.0 ^{bB}	3.3 ^{aB}	3.4 ^{aB}	0.3
15 days *post*-CS	2.0 ^{cC}	2.2 ^{cC}	2.3 ^{bC}	2.7 ^{aC}	2.8 ^{aC}	0.2
20 days *post*-CS	P	P	P	2.1 ^{aD}	2.2 ^{aD}	0.2
25 days *post*-CS	–	–	–	P	P	0.2
30 days *post*-CS	–	–	–	–	–	-
LSD 0.05	0.44	0.41	0.43	0.37	0.32	-

Note: P = Poor

Values with different superscript uppercase letters (A–I) within a column and superscript lowercase letters (a–d) within a row differ significantly ($p \leq 0.05$).

CONCLUSIONS

The observed results showed that cold storage (at 0±2°C, 90% RH for six months) and *post*-cold storage under environmental conditions (at 15±2°C, 75% RH for 30 days) significantly affected the quality parameters and shelf life of "Golden Delicious" apples. After 180 days of cold storage, for control fruits was measured a decrease of 30.4% in firmness, 6.8% weight loss, and 32.37% juice content, while in apples treated with 2.0 and 2.5% $CaCl_2$ the decrease in firmness was 16.3% and 15.2%, weight loss was 4.2% and 4.1%, while juice content was 14.5% and 14.1%, respectively. Maximum shelf life (at 15°C and RH 75%, following 180 days of cold storage) of control, 1.0 and 1.5% $CaCl_2$ treated apples was about 10 days, while for fruits treated with 2.0% and 2.5% $CaCl_2$ was 15 days and 20-25 days, respectively. Overall acceptability of apples, based on fruit texture, taste and visual appearance during *post*-cold storage period for control, 1.0% and 1.5% $CaCl_2$ treatments was 10 days, and after 15 days of ambient storage, overall acceptability was significantly higher in samples treated with 2.0 and 2.5% $CaCl_2$. Calcium chloride dip treatments of 2.0 and 2.5% were significantly effective in maintaining the quality parameters (firmness, weight loss, juice content) and were helpful in extending the shelf-life of "Golden Delicious" apples up to 20–25 days at 15±2°C and RH 75%, following 180 days of cold storage. Since there were not observed significant differences between 2.0 and 2.5% $CaCl_2$ dip treatments, the recommended $CaCl_2$ concentration solution for "Golden Delicious" apples was 2%.

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