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INFLUENCE OF CALCIUM CHOLORIDE ON PHYSICAL CHARACTERISTICS AND SOFT ROT INCIDENCE ON FRUIT OF APPLE CULTIVARS

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ABSTRACT

The research on influence of calcium choloride on physical characteristics and soft rot incidence in apple cultivars was carried out at Horticulture Postharvest Laboratory, The University of Agriculture Peshawar-Pakistan during 2009-10. The fruits were harvested from apple cultivars: Royal Gala, Mondial Gala and Golden Delicious at commercial maturity stage at Matta, Swat. The experiment was laid out in completely randomized design (CRD) with factorial arrangement having twelve treatment combinations. The fruits were treated with 0 and 9 % $CaCl_2$ solution for the period of 12 minutes and stored for the period of 150 days at 5±1°C with 60-70 % relative humidity. Apple cultivar Royal Gala had the highest juice content (59.20 %) and firmness (5.46 kg/cm^2). Mondial Gala had the least weight loss (1.55 %). Percent weight loss and soft rot increase while, juice content, firmness and density of fruit declined during storage. The application of $CaCl_2$ significantly decreased percent weight loss (1.16 %) and soft rot (1.41 %), while juice content (57.58 %), firmness (5.62 kg/cm^2) and density of fruit (0.78 g/cm^3) increased with $CaCl_2$ solution.

Key words: Apple, cultivars, calcium chloride, physical characteristics, storage, soft rot

INTRODUCTION

The physical properties of apple fruit may also have significant influence on storage performance of apple because it influences water loss (Mauro *et al.,* 2004), gas exchange (Ho *et al.,* 2010) and subsequent storage life (Meisami *et al.,* 2009). Physical properties such as density of fruit and juice and porosity can be used to determine internal quality of produce (Jordan *et al.,* 2000). Fruit density has also been used as maturity index in many fruits and vegetables such as apricots, strawberries, tomato, pea, etc (Jordan *et al.,* 2000). According to Jordan *et al.* (2000), the fruit density is also related to the content of juice and dry matter (Jordan *et al.,* 2000) and may indicate the maturity as well as quality changes in fruit during storage (Mitropoulos and Lambrinos, 2000).

Calcium plays an important role in regulating the metabolism in apple fruit, and adequate concentration maintains fruit firmness, delays fruit ripening, lower the incidence of physiological disorders such as water core, bitter pit, and internal breakdown (Demuth and Sundrud, 2012; Matas *et al.,* 2009) and suppress *Erwinia carotovora* (Jones) incidence on apple fruits (Percival and Haynes, 2009). The apple fruit grown on soil having optimum calcium level, may experienced Ca deficiency symptoms (Neilsen and Neilsen, 2011) which may lead to several physiological disorders. The apple fruits having less than 50 mg kg^{-1} Ca content of fresh weight is sensitive to physiological disorders like bitter pit and internal breakdown (Duxbury, 2003). By contrast optimum level of calcium in apple fruit maintain fruit firmness and reduces the incidence of physiological disorders such as water core, bitter pit and internal breakdown and postharvest decay (Conway *et al*., 2002).

Soil treatments with calcium to increase fruit calcium content have often met with very little success but direct application of calcium to the fruit is the most effective method for increasing fruit calcium content, accomplished by pre-harvest sprays or postharvest dips or vacuum or pressure infiltration (Conway *et al*., 2002). Kadir (2005) reported that five to eight $CaCl_2$ applications to ‘Jonathan’ apple at fruits sizes of 0.9 and 1.6 cm average diameters increased the fruit firmness by 26% and the SSC/TA by 35% as compared to control but fewer $CaCl_2$ applications were required to sustain fruit skin colour during storage. The optimum level of Ca content may be different for various cultivars (Zheng *et al.,* 2006). The present experiment was, therefore, conducted to evaluate the influence of $CaCl_2$ concentration and dipping duration on physical changes and incidence of soft rot in apple cultivars.

MATERIALS AND METHODS

The experiment was conducted at Horticulture Postharvest Laboratory, The University of Agriculture, Peshawar-Pakistan during 2009-10. The fruits were harvested at commercial maturity stage from three apple cultivars: Royal Gala, Mondial Gala and Golden Delicious at Matta, Swat. Fruit trees of uniform vigour and size were selected for the collection of fruit samples.

Fruit showing the symptoms of surface damage or abnormalities were discarded while fruits of uniform size were selected for the study. Fruit samples of each cultivar were dipped in either 0 or 9 % $CaCl_2$ solution for 12 minutes and divided into two groups each containing 150 fruits. One lot was analysed for different quality attributes while the other was shifted to cold storage and stored for 150 days at 5±1 °C and 60-70% relative humidity. The data recorded on different parameters were analyzed by using completely randomized design with three factors having twelve treatment combinations replicated three times. In cases where the differences were significant, the means were further assessed for differences through Least Significant Difference (LSD) test. Statistical computer software, MSTATC (Michigan State University, USA), was applied for computing both the ANOVA and LSD (Steel *et al.*, 1997).

Extraction of Plant Samples: The sample was first grinded to a particle size of 1mm and 1 g of plant sample was taken in digestion flask. It was left over night after adding 10 ml HNO_3. Added 4 ml perchloric acid ($HClO_4$) and heated for 20 minutes and then solution become colourless. The sample was cooled and transferred to volumetric flask and the volume was made to the mark. This solution was used for recording the calcium content in fruits through atomic absorption spectrophotometer.

The data were recorded and statistically analyzed for the following post harvest quality parameters:

Weight loss (%): Five fruits in each treatment were separated for weight loss test. The initial weight of each fruit was noted with the help of electronic balance. The weight loss (%) was calculated as under:

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

Percent juice content: Juice was extracted from five randomly selected fruit from each treatment with the help of juice extracting machine, weighed and the percentage was computed as described by Rehman *et al.*, (1982).

$$\text{Percent Juice} = \frac{\text{Weight of juice fruit}^{-1}}{\text{Average weight of fruit}} \times 100$$

Fruit firmness (kg/cm^2): Data pertaining to fruit firmness was recorded with the help of penetrometer (Effigi, 11mm Prob.) for five fruits per treatment (Pocharski, *et al.,* 2000).

Density of fruit (g/cm^3): Density of fruit for each treatment in each replication was calculated by water displacement method (Meisami, *et al*., 2009).

$$\text{Density of fruit} = \frac{M}{V}$$

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

Soft rot (%): Percent soft rot in each replication of treatments was examined visually and counted during 150 days storage and their disease percentage of fruits was calculated by formula as under

$$\text{Percent disease incidence (\%)} = \frac{\text{Number of diseased fruits}}{\text{Total number of fruit}} \times 100$$

RESULTS AND DISCUSSION

Calcium content of the fruit: The data regarding Ca content of apple cultivars significantly affected. The Ca content of Royal Gala, Mondial Gala and Golden Delicious increased from 44, 41 and 38 mg/kg (Control) to 121, 115 and 105 mg/kg dipped in 9 % $CaCl_2$ respectively (Table 1). The results are in accordance with those of Moor *et al.* (2006), who observed that the $CaCl_2$ uptake is mainly through the lenticels.

Weight loss (%): The data presented in Table 2 indicates that there were significant differences in weight loss of different apple cultivars. The maximum weight lost (2.11 %) was recorded in cultivar Golden Delicious which was significantly higher than Royal Gala (1.61 %), and Mondial Gala (1.55 %), with the difference in weight loss in the later two cultivars being non significant. The mean percent weight loss increased significantly with storage for 150 days to the maximum of 3.52 % but a significant decreased was recorded with $CaCl_2$ application (1.16%) as compared to 2.36 % in control. The interaction of cultivars and storage duration was also significant. The highest weight loss (4.23 %) was recorded in cultivar Golden Delicious after 150 days storage, followed by Royal Gala and Mondial Gala with weight loss of 3.22 and 3.10 % respectively. However, the difference in the later two varieties was non significant (Figure 1). The interaction effect of storage and $CaCl_2$ application was significant. The greatest weight loss (4.71 %) recorded in fruit treated with 9 % $CaCl_2$ at 0 day storage, followed by apple fruits with 2.32 % treated with same application after 150 days storage (Figure 2). The moisture content of fruits is an important quality criteria (Xia *et al.,* 2007) and the loss of turgor pressure and subsequent softening is depends on moisture loss (Iwanami *et al.*, 2008). The weight loss depends on water present in the fruit and the structure of the skin and nature of waxes on the surface (Veravrbeke *et al*., 2003). Considerable variation has been observed in the skin thickness of different apple cultivars and even the same cultivar may show significant variation with in different years of production (Homutova and Blazek, 2006). The data on weight loss of different apple cultivars indicated that the maximum weight loss in cultivar Golden Delicious was 26.54% higher than Mondial Gala, though the difference in Mondial Gala and

Royal Gala non significant. Storage for 150 days resulted in 3.52% mean percent weight loss which decreased significantly 50.85% with $CaCl_2$ application as compared to untreated control (Table 2). The weight loss in fruits increased linearly with increase in storage duration due to water loss and respiration (Gavlheiro *et al*., 2003; Erturk, 2003; Ghafir *et al*., 2009). The weight loss decreased significantly with increase in $CaCl_2$ concentration or dipping solution in $CaCl_2$ solution (Table 2). The decrease in weight loss with increase in $CaCl_2$ concentration or dipping duration is in accordance with Ashour, (2000) and Hayat *et al*., (2003).

Juice content (%): Significant variations were observed in juice content of different apple cultivars with the maximum juice content (59.20 %) recorded in Royal Gala. While, the minimum juice content (49.17 %) was recorded in Golden Delicious, followed by Mondial Gala with 57.65 % juice content (Table 2). The juice content significantly decreased from 63.44 % for fresh harvest fruit to 47.23 % for fruits stored for 150 days but was significantly high with $CaCl_2$ application (57.58 %) as compared to 53.10 % recorded in control. The juice content of apple fruit depends mainly on the water content of the fruit and decreasing the rate of water loss increases the juice content (Tu *et al*., 2000). Thus, cultivar Golden Delicious, characterized by more weight loss had 16.94 % lower juice content (Ekinci and Celik, 2006) as compared to Royal Gala. The decrease in percent juice decline is due to the water loss from the tissue which increases with storage duration (Allan *et al*., 2003). The $CaCl_2$ application resulted in significantly high juice content which was 8.10 % more than the untreated control (Table 2).

Firmness (kg/cm^2): There was significant difference in fruit firmness among apple cultivars. The maximum firmness of 5.46 kg/cm^2 was observed in Royal Gala, followed by Mondial Gala with the firmness of 5.43 kg/cm^2, however the difference in these cultivars was non significant. The minimum firmness (4.87 kg/cm^2) was recorded in Golden Delicious. The firmness significantly decreased from 6.34 kg/cm^2 for fresh fruits to 4.17 kg/cm^2 for fruits after 150 days storage (Table 2) but significantly increased from 4.89 kg/cm^2 recorded in non treated apple fruits to 5.62 kg/cm^2 in fruits dipped in 9 % $CaCl_2$ solution. The interaction effect of cultivars and storage durations on firmness was also significant. The maximum firmness (6.47 kg/cm^2) was recorded in cultivar Royal Gala, followed by Mondial Gala and Golden Delicious with 6.42 and 6.13 kg/cm^2 respectively after 0 day storage, however, these three cultivars was at par with each other. The minimum firmness (3.61 kg/cm^2) was observed with 150 days storage in cultivar Golden Delicious (Figure 3). The interaction effect of storage and $CaCl_2$ application was also significant. The maximum firmness (6.45 kg/cm^2) recorded in fruits dipped in 9 % $CaCl_2$ solution at 0 day storage while, the minimum firmness (3.55 kg/cm^2) observed in untreated fruits at 0 day storage (Figure 4). Fruit firmness is an important criteria for edible quality and market value of apples (De-Ell *et al*., 2001; Weibel *et al*., 2004; Peck *et al*., 2006) and loss of fruit firmness is a serious problems resulting in quality losses (Kov *et al*., 2005). The apple cultivars varied significantly in fruit firmness was recorded among apple cultivars. Cultivar Royal Gala had the maximum firmness, which was at par with Mondial Gala but 10.81% higher than Golden Delicious. The difference in firmness of different apple cultivars is attributed to differences in pectin composition of different cultivars (Billy *et al*., 2008). The firmness significantly decreased by 34.70% with 150 days storage and this trend was retarded by the treatment with $CaCl_2$ solution so that the fruit firmness 12.99 % higher as compared to the untreated control. The firmness of the apple fruit significantly decreased with increasing storage (Table 2). The firmness of the apple fruit is due to texture of the flesh and textural changes of fruits especially the cell wall breakdown (Fuller, 2008) due to enzymatic activities (Kittemann *et al.,* 2010) and pectin solubalization (Chang-Hai *et al*., 2006), reducing the mechanical strength of cell walls which decrease the firmness in apple fruits (Kov *et al*., 2003; Kov *et al*., 2005). The retention of firmness with increasing calcium concentration or dipping duration can be attributed to the formation of calcium pectates leading to increased rigidity of the cell wall and, thus, improved turgor pressure (Luna-Guzman and Barrett, 2000).

Density of fruit (g/cm^3): A significant decrease in density of fruit was recorded with storage duration of 150 days. The density of fruit decreased from 0.79 g/cm^3 recorded in fresh harvested fruit to 0.74 g/cm3 observed in fruit stored for 150 days. The application of $CaCl_2$ solution retained significantly higher fruit density (0.78 g/cm^3) as compared to non treated apple fruits (0.76 g/cm^3). The density of the fruit is a physical characteristic that has been can as maturity (Mitropoulos and Lambrinos, 2000) and quality index. In Potato, the tuber's density is generally correlated with the starch content of tubers (Jordan *et al.,* 2000), dry matter (Jordan *et al.,* 2000), as well as the mechanical resistance of tubers (Johnson *et al.*, 2003). The density of the fruit may be influenced by rind thickness, juice content (Jordan *et al*., 2000), dry matter (Jordan *et al.,* 2000) total sugars and starch contents (Robert *et al.,* 2000). Thus, fruit density also been used as maturity and quality index in many fruits and vegetables such as apricots, strawberries, tomato, pea, etc (McGlone *et al.,* 2007). No significant decrease in density of fruit was recorded among different apple cultivars under study but the storage for 150 days decline fruit density by 6.33%. The treatment with $CaCl_2$ solution retained significantly higher fruit density. The fruit density in $CaCl_2$ treated fruits was 2.56 % higher the non treated control (Table 2). The changes in density of apple fruit is a function air spaces and solutes dissolved in the cell sap (Goula and Adamopoulos, 2011). Therefore, the specific gravity of apple fruit from different cultivars could be significantly different (Abubaker etal., 2011) due to differences in biochemical composition (Homutova and Blazek, 2006; Ghafir *et al*., 2009) and moisture loss during storage (Rivera, 2005). Therefore, the density of apple fruit is high in fresh fruits and decline during storage due to collapse of intercellular spaces and loss of moisture (Mitropoulos and Lambrinos, 2000). Both increasing the concentration of Calcium in dipping solution or duration of dipping in calcium solution decreased the loss of density in apple fruit. The calcium regulates the firmness by maintaining cell wall structure (Lara *et al*., 2004; Dimitrios and Pavlina, 2005) and delaying the natural ripening and senescence (Lara *et al*., 2004). Thus, the calcium may decrease the development of air spaces associated with ripening and responsible for the loss of specific gravity (Sarrwy *et al*., 2012).

Soft rot (%): The soft rot in apple fruit increased with increase in storage durations, it increased to 10.57 % during 150 days storage. The soft rot incidence significantly decreased from 9.16 % recorded in non treated apple fruits to 1.41 % in fruits dipped in 9 % $CaCl_2$ solution. The interaction of cultivars and storage duration showed significantly high soft rot incidence with increasing storage duration. After 150 days storage, the soft rot incidence was the maximum (12.54 %) in cultivar Golden Delicious followed by Royal Gala and Mondial Gala with 9.70 and 9.47 % respectively, however, all the three cultivars were at par with each other (Figure 5). The interaction of storage and $CaCl_2$ application significantly affected the incidence of soft rot. The maximum incidence of soft rot (18.32 %) observed in fresh fruits treated with 9 % $CaCl_2$ solution, followed by 2.82 % in fruits treated with the same application after 150 days storage (Figure 6). The soft rot in apple fruit increased with increase in storage durations, it increased to 10.57 % during 150 days storage but decreased significantly with dipped in $CaCl_2$ solution (Table 2). The bitter pit incidence on apple fruit depends on cultivar but generally increase during storage (Spotts *et al*., 1999). The incidence of soft rot was 84.61% more in untreated control as compared to the fruit treated with $CaCl_2$. The decreased soft rot incidence with increased calcium concentration may be due to the calcium-induced delay in natural ripening and senescence (Agar *et al*. 1999), which causes the fruit susceptible to pathogens.

Table 1. Effect of $CaCl_2$ dipping on calcium content (mg/kg) of apple fruit.

Cultivars	$CaCl_2$ concentration (%)	
	0	9
Royal Gala	44	121
Mondial Gala	41	115
Golden Delicious	38	105

Table 2. The effect of cultivars, storage and $CaCl_2$ application on weight lost, percent juice, firmness (kg/cm^2), fruit density (g/cm^3) and soft rot (%) of apple cultivars

Cultivars	Weight loss (%)	Juice content (%)	Firmness (kg/cm^2)	Fruit density (g/cm^3)	Soft rot (%)
Royal Gala	1.61 b	59.20 a	5.46 a	0.78	4.85
Mondial Gala	1.55 b	57.65 ab	5.43 a	0.79	4.74
Golden Delicious	2.11 a	49.17 b	4.87 b	0.73	6.27
LSD value	0.33	9.40	0.43	NS	NS
Storage (days)					
0	0.00	63.44	6.34	0.79	0.00
150	3.52	47.23	4.17	0.74	10.57
Significance level	*	*	*	*	*
$CaCl_2$ (%)					
0	2.36	53.10	4.89	0.76	9.16
9	1.16	57.58	5.62	0.78	1.41
Significance level	*	*	*	*	*
Interactions			Significance Level		
C × S	*	NS	*	NS	*
C × Ca	NS	NS	NS	NS	NS
S × Ca	*	NS	*	NS	*
C × S × Ca	NS	NS	NS	NS	NS

Mean followed by similar letter(s) in column do not differ significantly from one another,
NS = Non Significant and * = Significant at 5 % level of probability. C × S = Interaction of cultivar and storage duration
C × Ca = Interaction of cultivar and $CaCl_2$ concentration S × Ca = Interaction of storage duration and $CaCl_2$ concentration
C × S × Ca = Interaction of cultivar, storage duration and $CaCl_2$ concentration.

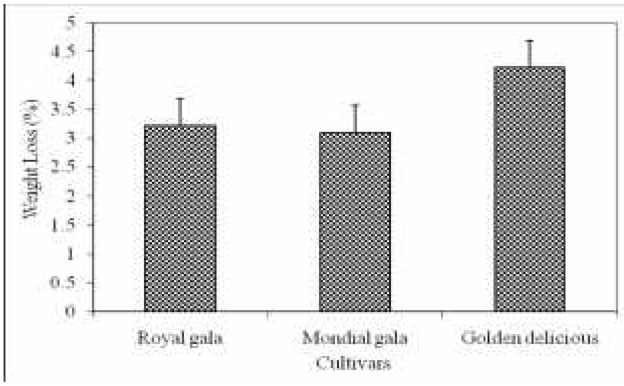

Figure 1. Variation in weight loss (%) in apple fruits among different cultivars

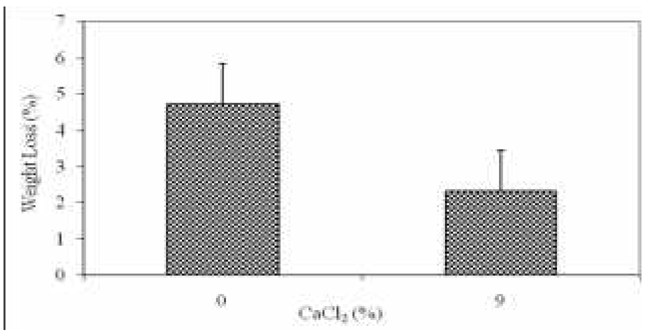

Figure 2. Effect of $CaCl_2$ concentrations on weight loss (%) in apple fruits stored for 150 days

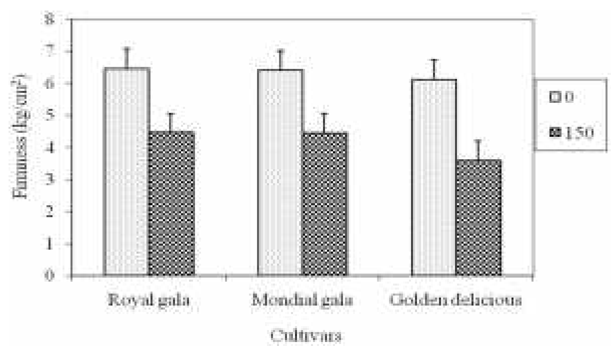

Figure 3. Influence of storage durations on fruit firmness (kg/cm^2) of apple cultivars

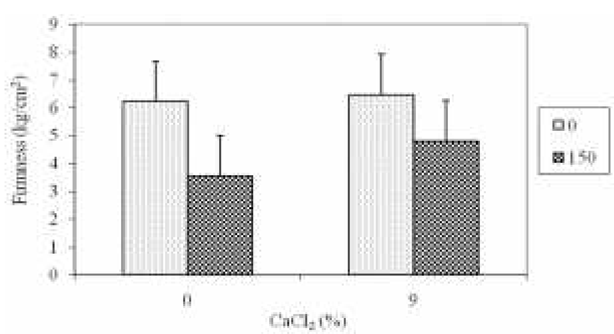

Figure 4. Influence of $CaCl_2$ concentrations and storage durations on fruit firmness (kg/cm^2) of apple

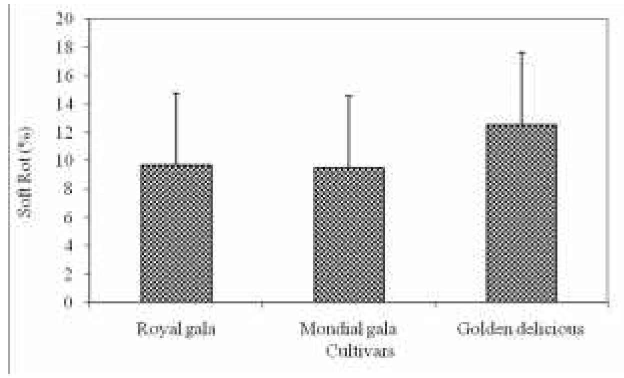

Figure 5. Influence of storage durations on soft rot (%) incidence in apple cultivars

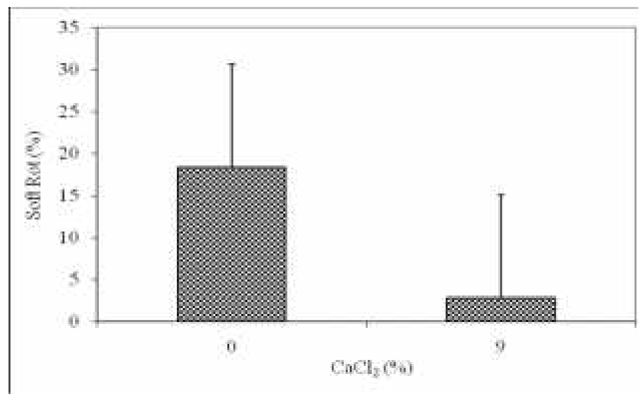

Figure 6. Effect of $CaCl_2$ concentrations on soft rot (%) incidence in apple fruits stored for 150 days

Conclusions: $CaCl_2$ application has significantly retained high juice content and firmness in cultivar Royal Gala. Apple cultivar Mondial Gala is characterized by least weight loss thus can be stored for long term storage. Cultivar Golden Delicious has relatively poor quality as well as the least fruit firmness, thus cannot be recommended for prolong storage**.** $CaCl_2$ application has not only improved the quality of apple fruit but also decreased the incidence of soft rot, therefore $CaCl_2$ application is strongly recommended for better storage performance of apple fruits.

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