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Effect of Post-Harvest Calcium Chloride Treatment on Quality and Shelf Life of Apple (*Malus domestica*)

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Abstract: In Ethiopia, apple production is estimated to be about 50 metric tons collected from 35,000 small apple fruit producers annually. But lack of appropriate post-harvest care has been influencing the quality and shelf life of apple. In view of this, the current study was initiated with the objective of investigating the effect of post-harvest calcium treatment on quality and shelf life of fresh apple fruit. The experiment was laid out in Completely Randomized Design (CRD) with four level of treatments and three replications. The levels of treatments involved in the experiment were four concentrations of calcium chloride (Control (0%), 1%, 2%, 3%). Data such as fruit firmness, juice yield, pH value, weight loss, Unmarketable (damaged) and marketable (undamaged) were measured at 1,5,10 and 15 days of post-harvest life. Collected data was subjected to analysis of variance (ANOVA), SAS version 9.4. Non-significant difference was observed in fruit pH, while a significant difference was observed in all the remaining studied parameters during storage days. The results showed that fruits treated with 3% $CaCl_2$ were found to be most acceptable. In general, maximum firmness, TA, TSS and marketability and reduced damage and weight loss was recorded by postharvest treatment of apple fruit by 3% concentration of $CaCl_2$. The final result of this research shown that calcium chloride can enhance quality and shelf of apple fruit. Therefore, it can be recommended that farmers and other grower to use 3% $CaCl_2$ treatment till the study is repeated over years and locations.

Keywords: Concentration, Damaged Percentage, Firmness, Local Cultivar, Total Soluble Solid, Weight Loss

1. Introduction

Apple (*Malus domestic*) it belongs to family Rosaceae and Genus Malus widely cultivated in temperate climate fruit tree. It is also a deciduous fruit (fruit which shed their leaves). The deciduous fruits are divided into pome, soft and stone fruits. Apple is among the pome fruits and rich in vitamins, calcium, phosphorus, potassium and organic acid. The introduction of apple tree to the tropical country, Ethiopian is traced back to 1950S. However, apple cultivation has local market as well as their high cost in international market. The apple fruits can be stay with a long post-harvest life in calcium treatment. The shelf-life of apple fruits are affected by many factors, such as growing condition, harvesting operations or storage conditions [24]. Losses in fruit quality are mostly due to its relatively high metabolic activity during storage [21].

Postharvest calcium solution applications have been used to extend post-harvest shelf life of fruits [18]. Post-harvest calcium dips can increase calcium content considerably without causing fruit injury; depending on salt type and calcium concentration [7, 12].

Surface treatments delay physiological decay in fruit tissues, stabilize the fruit surface and prevent degradation that affect the quality of the product. They also rinse the enzymes and substrates released from injured cells during cutting operations from the product surface. Infiltrated calcium in fresh apples has been shown to bind the cell wall and middle lamellae, where major influences on firmness are expected. Pre- and postharvest application of calcium may delay senescence in fruits with no detrimental effect on consumer acceptance [17]. Exogenously applied calcium stabilizes the plant cell wall and protects it from cell wall degrading enzymes.

Studies have shown that the rate of senescence often depends on the calcium status of the tissue and by increasing calcium levels, various parameters of senescence such as respiration, protein, chlorophyll content and membrane fluidity are altered [7, 12]. Post-harvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism, extending shelf life of fruits [21]. Post-harvest Ca treatments is used to increase Ca content of the cell wall were effective in delaying senescence, resulting in firmer, higher quality fruit [20] that were less susceptible to disease during storage [6]. Exogenously applied calcium stabilizes the plant cell wall and protects from cell wall degrading enzymes [21, 25]. Calcium (Ca^{2+}) has been extensively reviewed as both an essential element and its potential role in maintaining postharvest quality of fruit and vegetable crops [2] by contributing to the linkages between pectic substances within the cell-wall. The presence of Ca^{2+} ions increases the cohesion of cell-walls. It is also involved in reducing the rate of senescence and fruit ripening [13]. A 1% solution of $CaCl_2$ delayed fruit ripening, improved resistance to fungal attack and maintained structural integrity of cell walls of strawberry during a 10-day storage period at 3°C [13]. Moreover, softening was delayed and storage life was increased by 10–12 weeks in Kiwi fruits stored at 0°C by application of 1% $CaCl_2$ compared with untreated fruit [8].

Calcium (Ca^{2+}) in the apoplast exerts a binding effect in the complex of polysaccharides and proteins comprising the cell wall, and that cytoplasmic Calcium may regulate several enzyme activities [15]. Red Delicious has gained much popularity and commercial importance due to its overall sensory qualities, acceptability and market returns. Factors affecting the overall quality of apple during storage include loss of water, respiration, metabolism and microbial Spoilage [2, 24]. Postharvest infiltration of $CaCl_2$ solutions into apple fruit significantly reduced decay caused by *Penicillium expansum* Link, *Botrytis cinerea* Pers.: Fr., and *Glomerella cingulate* (Stoneman) Spauld. & Schrenk [8, 9]. The major problem is raising the Ca concentration of the fruit to a sufficient level to have the desired results. It has been postulated that calcium tissue concentrations should exceed 250 µg g-1 dry weight to control many calcium-related physiological disorders such as breakdown and bit \ter pit. Concentrations significantly higher than 1000 µg g-1 may cause surface injury to the fruit. Post-harvest treatment has all been tried in an effort to increase fruit tissue calcium ignored to have a positive effect on fruit quality in storage.

Statement of the problem

Apple is one of the major fruits in Ethiopia and world. It is superior fruits and has many health benefits but due to inappropriate post-harvest management practices, lack of proper storage and prompt transportation facilities, huge losses (20–40%) occur in the world fresh produce during handling, packaging, transportation, marketing and storage [21]. Many farmers and traders are complaining of difficult in post-harvest management activities why they obtain the less quality and shelf life.

Postharvest treatments like calcium chloride has been reported to reduce postharvest decay, aging and or ripening. Calcium controls the charge density in the cell wall thereby affecting ionic selectivity, which affects cell wall bound components and metabolism of the cell. Harvest treatments can help in increasing fruit shelf life, thus reducing commercial losses for packaging houses. Postharvest application of calcium may delay senescence in fruits with no detrimental effects on consumer acceptance. Exogenously applied calcium stabilizes the plant cell wall and protects it from cell wall degrading enzymes. It also reduces fruit softening and increases storage life as compared to untreated fruits.

Therefore, apple treatment is needed to maintain quality and extend shelf life which may contribute for national and international average yield. It may also facilitate international trade and overcome quarantine barriers by extending shelf life. So, this study initiated to minimize such a problem by postharvest treatment of apple fruits by $CaCl_2$ owing the following objectives.

Objective

1) To study effect of different concentration of calcium chloride on quality and shelf life of apple fruit in Jimma.
2) To determine the best calcium chloride concentration/rate for good quality and longest shelf life of apple fruit.

2. Material and Methods

2.1. Description of the Experimental Site

The study was conducted in Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), Food science and post-harvest technology research laboratory. JUCAVM is located at 356 Km south west of Addis Ababa at about 700330N latitude and 3600 570E longitude and altitude of 1710 meter above sea level (m.a.s.l). The mean maximum and minimum temperature were 26.8°C and 11.4°C, respectively and the mean maximum and minimum relative humidity is 91.4% and 39.92%, respectively.(http://www.ju.edu.et).

2.2. Experimental Material

The experimental material used was apple fruit (local cultivar). The fruit was bought from the local market.

2.3. Treatments and Experimental Design

The experiment was laid out in Completely Randomized Design (CRD) with three replications. The treatment involved in the experiment was four concentrations of calcium chloride of I.e Control, 1%, 2%, 3%. The data were recorded at 1, 5,10, and 15 days of post-harvest life.

Table 1. *Deception of the treatments.*

Treatment number	Description
T1	Control
T2	1% solution of $CaCl_2$
T3	2% solution of $CaCl_2$
T4	3% solution of $CaCl_2$

2.4. Experimental Procedure

Before commencement of the experiment important materials including the apple fruit, were procured and made ready. The solutions of $CaCl_2$ were prepared according to the proposed rate of the treatments (1%, 2% and 3%). The fruit was sorted based on size and the absence of physical injuries or infections. Then, the fruit were partitioned and arranged as per treatment and replicated three times. Then, the fruits were dip for one hour, in their perspective treatments and the fruit was dried for about 6 hr., except control, which was left untreated. First day data collection was done just after treating with the solutions. The remaining fruits of each plot were stored in optimum storage condition till next data collection date and then stored at 25°c (room temperature) and 85 to 90% relative humidity. The data collection was continued till the last storage date.

2.5. Data Collected

Different data related to shelf life and quality were measured using manual of Food Science and Post–Harvest Technology department of Jimma University College of agriculture and veterinary Medicine. The collected data include: Weight loss, Fruit firmness, Total soluble solid in juice, pH value, Titrable acidity and Fruit decay index (%).

2.6. Data Analysis

The data recorded on different quality parameters of apple fruit emphasizing effect of $CaCl_2$ treatment and subjected to one-way analysis of variance (ANOVA) using SAS software version 9.4. All significant pairs of treatment means were compared using the Least Significant Difference (LSD) test at 5% level of probability.

3. Results and Discussion

3.1. Effect of Post-harvest Calcium Treatment on Firmness of Apple Fruit

As observed from analysis of variance, post-harvest calcium chloride treatment showed highly significant ($P<0.05$) effect on firmness of apple fruit at all the storage days.

All tested treatments have significant and highest effects on firmness during storage in compared with the control. At all the storage days, maximum firmness was recorded in 3% $CaCl_2$ and is statistically different from all the other $CaCl_2$ concentrations and control (Table 2). On the other hand, the minimum firmness was recorded from control treatment at all the storage days (Table 2). Exceptionally, the highest firmness (31.47) was recorded in 3% $CaCl_2$ at 5th day.

The retention of firmness in calcium treated fruits might be due its accumulation in the cell walls leading to facilitation in the cross linking of the pectic polymers which increases wall strength and cell cohesion [7, 25]. Application of calcium chloride helps in reducing the fruit respiration rate thus slows down the ripening process and maintained the fruits firmness [25]. Moreover, the retention of firmness in calcified samples is due to fact that calcium plays an important role in maintaining cell wall structure by interaction with pectin acids [6].

This current finding agrees with the report of Benavides *et al*. who suggested post-harvest application of apple by Ca decreased softening and kept firmness during storage. Similar results were obtained in 'Golden Smoothee' apple indicating that fruit firmness shows a positive correlation with fruit Ca content and bitter pit incidence correlates negatively with this nutrient concentration [5]. Furthermore, another research report indicated that Ca is known to stabilize cell membranes in 'fleshes fruit' and it may prevent physiological disorders attributed to Ca deficiency [21]. These results are also in accordance with those reported by Shuiliang *et al*. who indicated that postharvest dips with $CaCl_2$ maintained firmness and eating quality [23].

Table 2. *Firmness (score) of apple fruit as affected by postharvest treatments of CaCl2 at different storage days.*

Treatment	Day 1	Day 5	Day 10	Day 15
Control	23.3^{d}	18.68^{c}	17.05^{c}	15.2^{d}
%1	25.09^{c}	22.58^{b}	21.18^{b}	20.64^{c}
%2	27.44^{b}	23.16^{b}	21.8^{b}	21.61^{b}
%3	28.23^{a}	31.47^{a}	28.21^{a}	23.94^{a}
CV	1.33	2.45	6.56	2.22
LSD	0.69	1.17	2.89	0.9

Means followed by the same letter(s) within columns are not significantly different.

3.2. Effect of Post-harvest Calcium Treatment on pH of Apple Fruit

Output from the analysis of variance indicated that different concentration of $CaCl_2$ showed no significant difference ($p>0.05$) on pH of apple fruit. Even if, some numerical difference was observed it is statistically non-significant. This means postharvest treatment of apple fruit with $CaCl_2$ solution didn't affected pH of the fruit.

3.3. Effect of Post-harvest Calcium Treatment on Titratable Acidity of Apple Fruit

Analysis of variance indicated that the effect of different concentration of $CaCl_2$ showed high significant differences ($P<0.05$) on titratable acidity of the apple fruit.

All $CaCl_2$ treated treatments have significant and highest effects on titratable acidity during storage in compared with the control. Increasing concentration of $CaCl_2$, increased titratable acidity exponentially. At all the storage days, maximum titratable acidity was recorded in 3% $CaCl_2$ and is statistically different from all the other $CaCl_2$ concentrations and control (Table 3). On the other hand, the minimum titratable acidity was recorded from control treatment at all the storage days (Table 3). Furthermore, the highest titratable acidity (14.53) was recorded in 3% $CaCl_2$ at 1^{rst} da, while the lowest (7.94) was at control on the 15th day.

Titratable acidity is directly related to the concentration of organic acids present in the fruit, which are an important parameter in maintaining the quality of fruits. The present study is in line with that of Rabiei *et al*. who indicated that the highest statistical values of TA were recorded by higher concentration of calcium [19].

These results were against with those reported by Ashour who reported the acidity decrease in "Anna "apple fruit; during storage which was treated with Calcium chloride spray or spray plus dipping [3]. Unlike the present study result, Manganaris *et al*. has reported that postharvest calcium chloride dips did not affect TA in peaches during storage [15]. Acidity decreases due to fermentation or break up of acids to sugars in fruits during respiration [13].

Table 3. *Titratable acidity and total soluble solids of apple fruit as affected by postharvest treatments of $CaCl_2$ at different storage days.*

Parameters	Treatment	Day 1	Day 5	Day 10	Day 15
TA	Control	11.57^c	10.38^d	8.95^d	7.94^d
	%1	13^b	12.33^c	9.95^c	8.79^c
	%2	14^a	13.5^b	10.64^b	9.38^b
	%3	14.53^a	13.7^a	11.94^a	10.71^a
	CV	2.56	0.74	1.12	1.22
	LSD	0.68	0.18	0.23	0.22
TSS	Control	8.2^d	9.1^d	10^d	11.23^d
	%1	9.8^c	10^c	10.37^c	11.7^c
	%2	10.2^b	11^b	11.67^b	12.3^b
	%3	11^a	11.6^a	12.27^a	13^a
	CV	0.83	0.48	1.63	0.99
	LSD	0.16	0. 1	0.36	0.24

Means followed by the same letter(s) within columns are not significantly different.

3.4. Effect of Post-harvest Calcium Treatment on TSS of Apple Fruit

Analysis of variance indicated that different concentration of $CaCl_2$ highly significantly affected ($P<0.05$) total soluble solid of the apple fruit.

Increasing concentration of $CaCl_2$, increased total soluble solid linearly. All $CaCl_2$ treated treatments have significant and highest effects on titratable acidity during the storage in compared with the control. At all the storage days, maximum total soluble solid was recorded in 3% $CaCl_2$ and is statistically different from all the other $CaCl_2$ concentrations and control (Table 3). On the other hand, the minimum total soluble solid was recorded from control treatment at all the storage days (Table 3). Furthermore, the highest total soluble solid (13) was recorded in 3% $CaCl_2$ at 15^{rst} day, while the lowest (7.94) was at control on the 1^{rst} day.

Highest TSS in 3% $CaCl_2$ might be due to the fact that more concentration of $CaCl_2$ (3%) formed a thin layer on the surface of fruit which delayed degradation process. It was probably due to hydrolysis of polysaccharides and concentrated juice content as a result of [1]. In addition, the increase in TSS is attributed to the enzymatic conversion of higher polysaccharides such as starches and pectins into simple sugars during ripening [11]. Therefore, the $CaCl_2$ dip resulted in delaying the increase in TSS in samples subjected to higher concentration of $CaCl_2$ even after 24 days of cold storage. However, in inconsistent with the current finding it is reported that postharvest application of $CaCl_2$ solution have no significant effect of TSS of different fruits [19, 22].

3.5. Effect of Post-harvest Calcium Treatment on Weight Loss of Apple Fruit

Application of $CaCl_2$ on apple fruit showed a highly significant effect ($P<0.05$) in percent of weight loss.

No apparent difference among postharvest treatments was observed on relative weight loss in all the treatments initially (day 1). The weight loss is zero on this day. On the 5^{th} day the lowest weight loss (0.84) was recorded by 3% $CaCl_2$, even if it has statistical Varity with 2% $CaCl_2$, while the highest (1.26) was recorded by control, but statistically similar with 1% $CaCl_2$ (Table 4). In the remaining days all the treated treatments were significantly different from control. The lowest and significant weight loss was observed in 3% $CaCl_2$, while the highest weight loss was recorded by control on these days. Overall highest weight loss (1.5) occurred in control during the 15^{th} day and the lowest was in 3% $CaCl_2$ during 5^{th} day.

Calcium applications have known to be effective in terms of membrane functionality and integrity maintenance which may be the reason for the lower weight loss found in Calcium treated fruits [9]. Calcium might have delayed senescence and reduced the rate of respiration and transpiration. Furthermore, it may be due to the fact that application of calcium chloride acts as a barrier, thereby restricting water transfer and thus delaying dehydration. Besides, the lower weight loss in samples treated with $CaCl_2$ dip may also be due to the effect of $CaCl_2$ on the delaying of natural physiological processes like respiration, onset of the climacteric, ripening process and senescence [12].

These results in line with those recorded by Ashour who found that spraying "Anna "apple fruits with 0.5% Calcium chloride reduced fruit weight losses percentages [3]. Mahajan and Dhatt reported that pear fruit treated with $CaCl_2$ proved to be most effective in reducing weight loss compared to non-treated fruit during a 75 days storage period [14]. The current investigation is also concord with Naveena and Immanuel who reported that pear fruit treated with calcium chloride proved to be most effective in reducing weight loss compared to non-treated fruit [17].

Table 4. *Effect of postharvest treatments of $CaCl_2$ on Weight loss, Percentage of damaged and undamaged of apple fruit at different storage days.*

Parameters	Treatment	Day 1	Day 5	Day 10	Day 15
WL	Control	0	1.26^a	1.39^a	1.5^a
	%1	0	1.19^a	1.2^b	1.31^b
	%2	0	0.88^b	0.91^c	1.13^c
	%3	0	0.84^b	0.87^d	1.05^d

Parameters	Treatment	Day 1	Day 5	Day 10	Day 15
	CV	0	3.75	1.23	1.9
	LSD	0	0.08	0.03	0.05
%Dam	Control	0	33.15[a]	60.5[a]	73.15[a]
	%1	0	26.07[b]	39[b]	60.5[b]
	%2	0	20.25[c]	26.35[c]	39.5[c]
	%3	0	6.35[d]	19.75[d]	26.35[d]
	CV	0	1.76	1.69	0.88
	LSD	0	0.75	1.23	0.88
%UnDam	Control	100	73.93[c]	39.5[d]	26.85[d]
	%1	100	66.85[d]	61[c]	39.5[c]
	%2	100	79.5[b]	73.65[b]	60.5[b]
	%3	100	93.65[a]	80.25[a]	73.65[a]
	CV	0	0.55	0.97	0.88
	LSD	0	0.87	1.23	0.88

Means followed by the same letter(s) within columns are not significantly different.

3.6. Effect of Post-harvest Calcium Treatment on Damaged Percentage of Apple Fruit

Application of $CaCl_2$ showed a highly significant effect ($P<0.05$) in damaged percentage of apple fruit as analysis of variance indicated.

As in weight loss the same trend was observed in damaged fruit percentage. No seeming difference among postharvest treatments was observed on damaged fruit percentage in all the treatments on the first day. In the rest of the days all the treated treatments were significantly different from control. The lowest and significant damaged fruit percentage was observed in 3% $CaCl_2$, while the highest was recorded by control on these days. In general, the highest damaged fruit percentage (73.15) was occurred in control during the 15th day and the lowest (6.35) was in 3% $CaCl_2$ during 5th day.

The lower damaged fruit percentage in higher concentration of $CaCl_2$ may be due to the fact that Ca is the major ingredient of middle lamella in cell walls and modifies cell wall rigidity by thickening the middle lamella of cell wall owing to increased formation and deposition of Ca-pectate. This intern reduces the rate of decay. In addition, the incorporation of calcium ions in fruit tissue promotes new cross-links between anionic homogalacturonans, strengthening the cell wall and particularly the middle lamella which is responsible for holding cells together. Thus, increasing the stability of the cell wall and middle lamella of the fruits [16]. Calcium dips raise the possibility of producing fruit less susceptible to decay during storage. While the higher decay content in untreated fruits was the result of lesser tissue strength and cellular disorganization. The current finding is also parallel with investigation of Naveena and Immanuel who observed significant decrease in damaged fruit percentage by applied $CaCl_2$ and its increased rate [17]. High calcium concentrations result in decreased flesh browning symptoms which are directly associated with calcium content in fruits [10].

3.7. Effect of Post-harvest Calcium Treatment on Undamaged (Marketability) Percentage of Apple Fruit

Analysis of variance indicated that the different concentration of $CaCl_2$ showed a highly significant effect ($P<0.05$) in undamaged percentage of apple fruit.

All of the treatments including the control was 100% undamaged (marketable) during the first day. In the rest of the days all the treated treatments were significantly different from control (Table 4). The highest and significant damaged fruit percentage was observed in 3% $CaCl_2$, while the highest was recorded by control on these days. As the concentration of the $CaCl_2$ increased, the marketability of the apple fruit is also increased (Table 4). In general, the highest undamaged fruit percentage (93.65) was occurred in 3% $CaCl_2$ during the 5th day and the lowest (26.85) was in control during 15th day (Table 4).

The highest marketability (undamaged) at higher rates of $CaCl_2$ might be due the fact that $CaCl_2$ have ability to reduce respiration, ethylene production of climatic fruits, translation and reduce infestation of mold, fungus and another microorganisms' population.

4. Conclusion

On the basis of the obtained results it is concluded that $CaCl_2$ reduces moisture amount, transpiration, respiration and delay senescence and also increase cell turgidity, member integrity and reduce catabolism reaction. Calcium dips retarded metabolism as indicated by the lower respiration rates of calcium treated samples.

This study, clearly shown that different concentrations of $CaCl_2$ have significant effect on the studied parameters, except pH which did not respond to the treatment. Postharvest treatment of $CaCl_2$ at 3% concentration is gave maximum firmness, TSS, TA and marketability and reduced damage and weight loss as compared to lower rates and control treatments. Generally, from this study result postharvest $CaCl_2$ treatment maintain quality and extend shelf life of apple fruit. And 3% $CaCl_2$ application was effective on Post-harvest quality and shelf life of apple. So, 3% $CaCl_2$ can be recommended temporally for treatment of apple fruit for apple grower of surrounding Jimma.

5. Recommendation

1) In future the current finding needs confirmation. So

over year study is paramount important.

2) In addition, there is a need to do further research on other quality parameters, such as Acidity, ascorbic acid, ethylene, prelim and thibautindexe, water soluble pectin, juice yield and etc.
3) Most of the studied parameters are showing increasing trend I.e with the highest concentration (3%), constant curve couldn't reached on, thus there is a probability of obtaining more higher record of the parameters. Therefore, higher $CaCl_2$ should be studied.

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