ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 8 September 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2021; 21(8): 18552-18573 https://doi.org/10.18697/ajfand.103.20350

EFFECTS OF MODE AND TIMING OF CALCIUM CHLORIDE APPLICATION ON TISSUE CALCIUM CONCENTRATION AND ACCEPTABILITY OF MANGO FRUITS

Bitange NM*[1], Chemining'wa GN[1], Ambuko JL[1] and WO Owino[2]

Naphis Mokaya Bitange

*Corresponding author email: mokayanaphis@gmail.com

[1]Department of Plant Science and Crop Protection, University of Nairobi, P.O. Box 29053-00625, Kangemi, Nairobi, Kenya

[2]Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology. P.O. Box 6200-00200, Nairobi, Kenya

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 8 September 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Mango (*Mangifera indica* L) production in Kenya directly supports approximately 200,000 farmers and many other beneficiaries. Despite this, its production suffers from post-harvest losses due to the fruits' short shelf life in ambient conditions. Calcium maintains cell integrity, strengthens the cell wall, membrane structure, and thus increases shelf life. A completely randomized block design with a split plot arrangement was used to compare the effect of spraying and immersion of 'Van Dyke' mango fruits at maturity or 15 days later in calcium chloride at different concentrations (0.5%, 1%, 1.5%, or 0%) and times on the fruit ripening rate and organoleptic acceptance. The peel firmness (N), total soluble solids (^{0}Brix), flesh color (H_o), beta carotene (mg/100ml), and carbon dioxide evolution (ml/kg/hr) of fruits were determined at time 0 and every two days for up to eight days in ambient conditions. Additionally, organoleptic characteristics, flesh firmness, calcium concentration (g/mg), and their correlations were determined. Fruits immersed in calcium chloride at maturity had higher retained peel firmness (10.6 N, 10.3 N), deeper flesh color (37.45, 36.78), lower total soluble solids (14, 13.8), a lower carbon dioxide evolution (30.7 ml/kg/hr), higher beta carotene and higher flesh calcium concentration than fruits exposed to other treatments. Fruits sprayed at maturity outperformed those sprayed 15 days later in the studied parameters. Flesh calcium content correlated positively with flesh firmness (r= 0.913, r= 0.852), flesh color (r= 0.828, r= 0.841), fruit aroma (r=0.8199, r=0.841), and negatively with skin shriveling (r=-0.778, r=-0.806) and fruit flavor (r=-0.811, r=-0.829). Flesh firmness correlated negatively with skin shriveling (r=-0.868, r=-0.788) and fruit flavor (r=-0.8869, r=-0.821), but positively with peel color (r=0.9115, r=0.856) and aroma (r=0.907, r=0.848). Skin shriveling was found to have a negative relationship with peel color (r=-0.944, r=-0.93) and aroma (r=-0.944, r=-0.938), but a positive relationship with fruit flavor (r=0.933, r=0.947). Peel color correlated positively with aroma (r=0.979, r=0.977) and negatively with fruit flavor (r=-0.962, r=-0.950), respectively. Despite the effectiveness of post-harvest calcium chloride immersion in extending fruit shelf life, optimal use is advised to avoid deteriorated pulp flavor and increased shriveling. More research is needed to determine how calcium chloride can be made available to the fruit while it is still attached to the tree.

Key words: Mango, shelf life, calcium, organoleptic, post-harvest losses, post-harvest immersion

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

INTRODUCTION

Mango (*Mangifera indica* L.) is an important fruit in Kenya and elsewhere in producing countries. Despite this, this fruit has a short shelf life in ambient conditions, affecting its production and commercialization due to high post-harvest losses. Farmers suffer high losses during peak seasons due to very low prices caused by gluts coupled with a shelf life of 7-10 days depending on harvesting stage, shipping, handling, and storage conditions [1]. Furthermore, because small-scale farmers lack modern storage facilities, they are forced to give away the fruits at low prices.

Polysaccharides found in the fruit cell wall include hemicelluloses, pectin, and cellulose [2]. Calcium is a critical component of pectin in the cell wall, where it reacts with the pectic to form calcium pectate, which forms cross links that contribute to the cell wall's rigidity and integrity. This inhibits the breakdown of the cell wall and the onset of senescence. Additionally, calcium inhibits the evolution of ethylene, resulting in a low rate of respiration and a slower rate of fruit weight loss [3, 4], both of which are signs of ripening. Calcium chloride has been demonstrated to retard fruit and vegetable ripening and decay [3, 5, 6, 7]. The frequency, mode of application, timing, rate and the calcium source used have varied effects on the shelf life and consumer acceptability of various fruits [8, 9]. Pre-harvest spraying as well as post- harvest immersion in calcium chloride for quality preservation has been well reported in mango [3, 9, 10] and guava [11] amongst other fruits and vegetables. Post-harvest immersion in calcium chloride preserves the quality of mango fruits by reducing the physiological weight loss and reduction of rapid soluble solids accumulation. Post-harvest spraying of apple [12] and lemon [13] fruits appears to be more effective than preharvest spraying, though there have been reports of fruit taste being affected [8, 14, 15]. However, farmers have limited experience with post-harvest immersion of fruits in calcium chloride.

Furthermore, some authors have reported that calcium is available to the fruit during the early stages of fruit development [16], whereas others have reported that calcium can be used effectively even after physiological maturity [3]. The purpose of this study was to determine the effect of calcium chloride applied by spraying or immersion at various concentrations and times on delaying fruit ripening and the overall effect on the organoleptic properties of the fruits.

MATERIALS AND METHODS

Experimental Site Description

The study was conducted during the 2017/2018 and 2018/2019 fruiting seasons at the Karurumo orchard in Embu County, Kenya, which is classified as lower midland 3 (LM3) and is located at an elevation of 1174 m asl at coordinates 0° 32 S 37° 41 E. This area receives 1206 millimeters of annual rainfall, with a bimodal pattern and an average annual temperature of 22.7 degrees Celsius. This area's soils are loamy sand and clay (ferralic arenosol).

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Experimental Material, Design and Treatments

The study used approximately ten-year-old "Van Dyke" mango cultivar trees. The treatments were laid out in a completely randomized block design with three trees per replication in a split plot arrangement. The main plots were determined by the timing, while the sub plots were determined by the application rates. The plots were maintained in accordance with Kenyan cultural norms [17]. Uniformity in sampling was ensured on the basis of size and shape of fruits.

Calcium chloride (0, 0.5, 1.0, and 1.5%) was sprayed onto the fruits when they reached maturity or 15 days later. Another sample of physiologically mature fruits was immersed in calcium chloride (0 %, 0.5 %, 1.0 %, and 1.5 %) for 10 minutes. The control fruits were either sprayed or immersed in water. Physiological maturity was calculated by counting 120 days after full bloom [17]. At this stage, the fruits' external color had changed from green to yellow, and the stone hardens; the pulp color changes from white to cream to deep yellow, beginning at the endocarp and progressing outward; and shoulders swell and rise above the stem with swollen cheeks. The fruits were transported to the Jomo Kenyatta University of Agriculture and Technology Post-harvest Laboratory in cartons lined with newspapers and stored for eight days under ambient room conditions (25±2^{0}C and 70% RH) for evaluation.

Data Collection and Analysis

During the storage period, data on peel firmness, total soluble solids (TSS), flesh color, beta carotene, and respiration rate were collected at two-day intervals. At the end of the storage period, the calcium concentration in the flesh, firmness, and organoleptic attributes, as well as their relationship, were determined.

Peel firmness

The changes in peel firmness during the storage period were measured using a penetrometer fitted with a 5mm probe by selecting three fruits randomly from each treatment during the storage period. The corresponding average force used to penetrate the fruit peel was recorded in Newton (N) [18].

Total soluble solids

The changes in fruit TSS were determined using a hand refractometer (Model PAL-S, Atago, Tokyo, Japan) and recoded in ^{0} Brix [19].

Flesh color

Two fruits from each treatment were sampled and the changes in flesh color (hue angle H_o) were measured with a Minolta color meter (Model CR-200, Osaka, Japan). The color coordinates were obtained as follows [20].

$$\text{Hue angle } (H_o) = \arctan (b/a)$$

Beta carotene

This was determined using modified paper chromatographic procedure [21] and the beta carotene content determined as below:

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

$$\beta\_carotene\left(\frac{mg}{100ml}\right) = \frac{A \times volume\ (ml) \times 104}{A1\%1cm \times sample\ weight\ (g)}$$

Where:
A= Absorbance, Volume = Total volume of extract (25 ml)
A_1% 1cm = Absorption coefficient of β−carotene in Petroleum ether (2592).

Respiration rate
Three mangoes were randomly selected from each treatment group and stored in airtight plastic containers with a volume of (1450 ml-4500 ml) and a self-sealing rubber septum for 1(one) hour. A syringe was used to withdraw approximately 1(one) ml of headspace sample from the container and inject it into the gas chromatograph (Models GC-8A, Shimadzu Corp., Kyoto, Japan). The GC column (120^0C) was filled with porapak and helium as the carrier gas, and a thermal conductivity detector was installed. The following formula was used to calculate the rate of respiration:

CO_2 production rate ($mlkg^{-1}hr^{-1}$) =K x 1/R x H x (V-W)/t/w

K –calibration value, H-Peak height, R-volume of gas injected for sample, W –Weight of sample, V-Volume of incubation container (ml) and T- Incubation time.

Flesh calcium, firmness and organoleptic attributes determination
After eight days of storage in ambient conditions, 25 fruits from each replica were taken, sliced into equal sized slices, and flesh firmness was determined using a penotrometer fitted with a 5mm probe. The readings were collected from five different locations, and the average was calculated. The calcium concentration in the flesh was determined by drying slices in a furnace and grinding them to a fine powder, which was then dissolved in hydrochloric acid and calcium was measured using an atomic absorption spectrophotometer (Shimadzu-AA-670, Shimadzu, Kyoto, Japan).
Another sample of equal-sized slices from a representative sample of each treatment was placed on white paper and anonymously coded for the determination of organoleptic attributes. A panel of 100 individuals (70 males and 30 females) were instructed on how to rate pulp color, aroma, taste/flavor, and skin shriveling using a seven-point hedonic scale [18].

Data Analysis
Collected data were subjected to analysis of variance using Genstat, 14th edition. The differences in the treatment means were compared using Fisher's Protected LSD test at $p \leq 0.05$ probability level. A Pearson's product–moment was run to assess the relationship among flesh calcium concentrations, firmness and organoleptic attributes using Stata software 12th edition.

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

RESULTS AND DISCUSSION

Peel Firmness

The timing, rate, mode of calcium chloride application and their interactions had significant ($p \leq 0.05$) effects on the fruit firmness in both seasons (Table 1). Calcium treated fruits maintained a high peel firmness throughout the storage compared to control fruits. Application of calcium chloride (1.5%) by immersion had significantly higher peel firmness (10.6 N, 10.3N) than most of the other treatments at the end of the storage period in both seasons. Fruits immersed in calcium chloride had probably accumulated more calcium in their cells than those that were sprayed, which accumulated in the cell walls facilitating the cross linking of pectic substances that increased cell cohesion and strength, hence the high firmness as previously reported in tomatoes [24]. Calcium can easily penetrate through the fruit cuticle cracks and epidermis [25]. The contact time when spraying may have affected the penetration of calcium as compared to immersion which may have allowed more calcium in.

Fruits sprayed with calcium chloride (1.5%) at maturity had significantly greater peel firmness than those sprayed 15 days later. Peel firmness increased as calcium chloride concentration increased from 0.5 to 1.5%, regardless of mode or timing of application. Calcium binds, strengthens the cell wall, and maintains cell cohesion, preserving membrane structure and integrity [26, 27]. Calcium also inhibits the expression of enzymes and genes involved in cell wall degradation [28], causing the softening process to be delayed. Calcium treated fruits have been observed to maintain higher water insoluble protopectin and lower soluble pectin content [29], hence, the firmness. Calcium has also been reported to prevent physiological loss of weight and a reduced rate of ethylene evolution [4, 30], thus a reduced rate of ripening, hence a probable reason for firmness maintenance. Fruit firmness decreased during the storage period due to ripening and senescence [31]. Peel firmness was higher in mango fruits that were treated with higher calcium concentrations as observed previously [11, 15].

Total soluble solids

Calcium chloride application had significant ($p \leq 0.05$) effects on the changes in total soluble solids (TSS) during storage in both seasons (Table 2). There was a general increase in the fruits' total soluble solids followed by a decline irrespective of the treatment. The TSS for fruits that were treated with calcium chloride increased upto day six then declined gradually. After day four, control fruits experienced a rapid decline in TSS and had the lowest TSS at the end of the storage period. At the end of the storage period, fruits treated with calcium chloride by immersion had a significantly ($p<0.05$) higher TSS than most of the fruits from other treatments.

As fruits ripen, soluble solids accumulate. The initial increase in TSS during storage could be attributed to starch being hydrolyzed into sugars, after which no further hydrolysis occurs, resulting in a decline in TSS. This explains why the TSS levels of control fruits began to decline after day four, whereas the calcium-treated fruits declined gradually. A higher TSS in calcium chloride-treated fruits indicates that they can be stored longer than control fruits that have accumulated soluble solids to maximum levels and thus cannot be stored any longer due to being fully ripened [26].

CC BY NC ND

Calcium slows metabolic activity, resulting in a gradual accumulation of soluble solids in calcium-treated fruits. TSS levels were highest in fruits immersed in calcium chloride, most likely because a layer of calcium chloride formed on the fruits, delaying the degradation process and other metabolic activities. This has previously been observed in mango [3, 32] and guava fruits [11]. Because calcium is more available during the early stages of fruit development, spraying calcium chloride at maturity was more effective than spraying 15 days later in slowing soluble solids accumulation [3, 33].

Flesh color changes

Flesh color changes were expressed in hue angle, which decreased gradually for all the fruits irrespective of the treatment during the storage period (Table 3). Calcium chloride had a significant ($p \leq 0.05$) effect on the hue angle as the fruits changed from green to yellow. Generally, fruits treated by immersion in calcium chloride had high hue angle followed by those sprayed at maturity. Color development during ripening involves chlorophyll degradation and synthesis of anthocyanins and carotenoids among other pigments. Calcium could have retarded chlorophyll degradation and synthesis of the pigments. Fruits treated by immersion had probably more calcium penetration/uptake followed by those sprayed at maturity and 15 days later respectively, hence, the maintained color. The slow color changes exhibited by calcium treated fruits could be due to the suppressing effect of calcium on ethylene evolution [34], which retarded ripening and changes in color. The untreated fruits and those that were sprayed 15 days later in development had less or no chlorophyll degradation and anthocyanins synthesis representing full ripening. Similar results have been reported in mango [35] and papaya [36] in which infiltration of fruits by calcium chloride delayed color development. Additionally, post-harvest application of calcium chloride delayed ripening of sapodilla [37], tomatoes and African eggplant [38].

Beta carotene

Beta carotene levels increased with increasing storage time in all fruits, regardless of treatment (Table 4). In both seasons, calcium chloride, its concentration, mode of application, and time of application had a significant ($p \leq 0.05$) effect on beta carotene. Control fruits contained the least beta carotene, whereas those immersed in calcium chloride contained the most at the end of the storage period.

The increase in beta carotene content during the storage period could be attributed to the breakdown of chlorophyll and increase in carotenoids content by chlorophyllase enzyme during storage [39]. Calcium inhibits the degradation of chlorophyll, resulting in a gradual increase in beta carotenes in calcium-treated fruits, and more in calcium-immersed fruits than in other treatments. Similar results on beta carotene increase with storage have been reported in mango [39], tomato [38], and passion fruit [40]. Jakhar and Pathak [41] reported similar results in higher beta carotene levels in calcium-treated fruits.

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Flesh calcium content

The mode and timing of calcium chloride application had a significant ($p<0.05$) effect on the calcium content of the flesh (Table 5). In seasons 1 and 2, fruits immersed in calcium chloride (1.5%) had the highest calcium content. Untreated fruits had the lowest calcium content in the flesh. Strawberry [42], peach [43], and apple [44] fruits have all shown increased calcium content as a result of calcium chloride application. Fruits sprayed with calcium chloride at maturity had higher calcium content than those sprayed 15 days later, confirming that calcium is more available early in the fruit development process, as reported in mango [3] and avocado [33] fruits.

Respiration rates of fruits

The respiration of fruits increased with storage time and then declined regardless of treatment as shown in Fig 1. Fruits treated at maturity reached their peak on day four, whereas those treated 15 days later reached their peak on day two, which was comparable to the control fruits. Calcium deactivates enzymes involved in the conversion of starch to sugars, therefore reducing transpiration, hence, a reduced rate of carbon dioxide evolution. Calcium has also been shown to reduce the activity of fruit softening enzymes in lemon and tomato [13, 38, 45] fruits because calcium delays the onset of the climacteric peak [46], the peak of calcium-treated fruits occurred later in the storage period.

CC BY NC ND
https://doi.org/10.18697/ajfand.103.20350

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 8 September 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

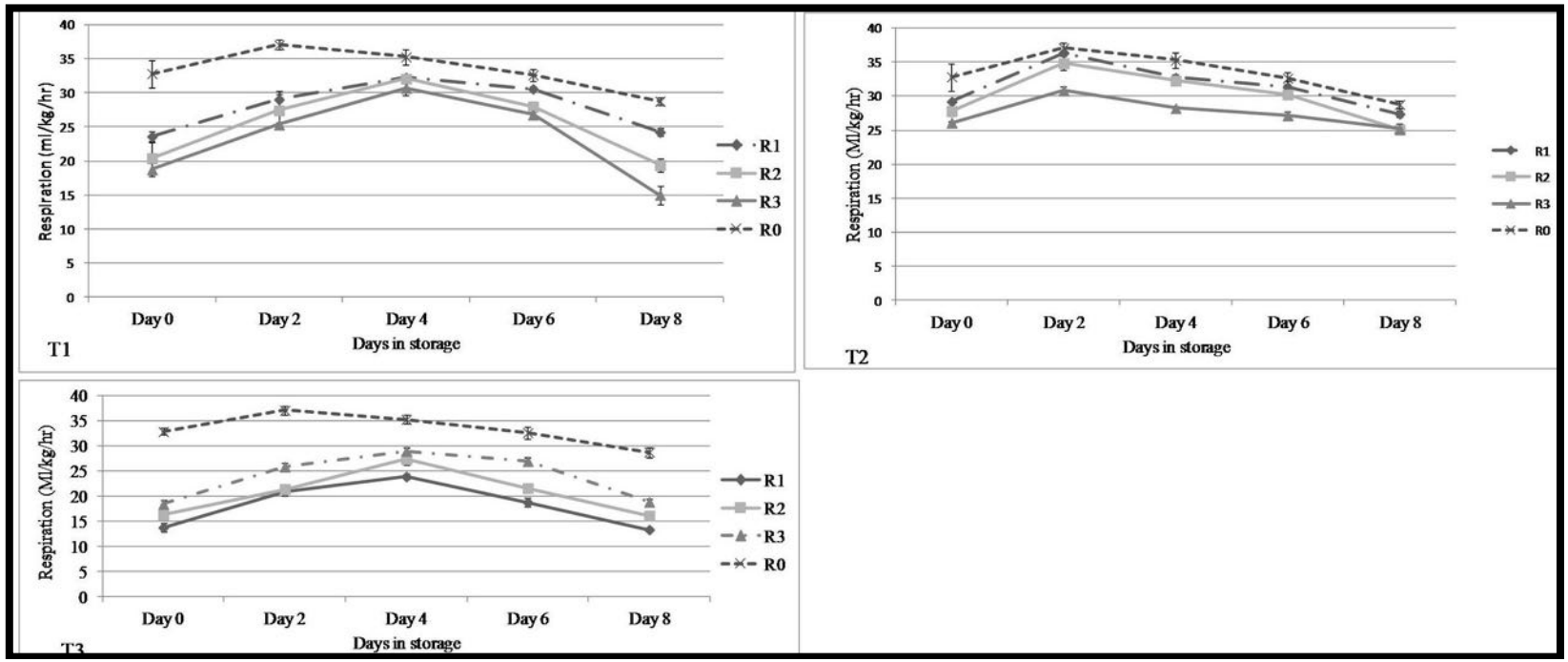

Figure 1: Effect of calcium chloride application at different times and rates on the respiration of mango fruits. Bars represent standard errors of the means at p ≤0.05

Key: R1-0.5%; R2-1.0%; R3-1.5%. TI-Spraying at maturity; T2-Spraying at 15 days after maturity; T3-Application at maturity by immersion

CC BY NC ND
https://doi.org/10.18697/ajfand.103.20350

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 8 September 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Sensory quality of fruits and relationship with flesh calcium concentration

The pulp color scores were significantly higher in fruits that had been immersed in calcium chloride, followed closely by those that had been sprayed at maturity (Fig. 2). Control fruits and those that were sprayed 15 days after maturity did not show any shriveling while fruits immersed in calcium chloride resulted to shriveled skin surface. Control fruits and those sprayed 15 after maturity had the lowest pulp color scores but higher pulp flavor and taste than other treatments. When the fruits were immersed in calcium chloride rather than spraying, the flavor was negatively affected, whereas the pulp color was favored by immersion. Control fruits and those sprayed 15 days after maturity showed no shriveling, whereas fruits immersed in calcium chloride showed shriveled skin surfaces. Additionally, skin shriveling increased as the calcium chloride concentration increased from 0.5% to 1.5%. Fruits immersed in calcium chloride may have shriveled more than those sprayed because the more calcium salts in the solution may have caused dehydration of the skin, hence, shriveling which may be as a result of osmotic effects [47]. Similar results on fruit skin shriveling due to application of calcium have been reported previously [8, 14, 48]. Immersion of fruits in calcium chloride and spraying of fruits at maturity scored higher in pulp color and aroma than other treatments perhaps due to increased calcium content. Similar results in good color appearance in calcium treated fruits have been reported previously [3, 8]. Calcium application led to a deteriorated flavor and taste probably due to reduced accumulation of soluble solids with the application of calcium as previously reported [8, 14, 15]. This has also been reported in peach [49], apricot [50] and jujube [51]. Additionally, the use of calcium chloride, a divalent cation, may have imparted bitterness and saltiness which results from residual calcium chloride on the surface of the fruit [52, 53], hence, the unfavorable taste scores.

The fruit calcium content was positively correlated with flesh firmness, peel color and aroma but negatively correlated with skin shriveling and fruit flavor in both seasons (Table 6). Flesh firmness was positively correlated with peel color and aroma but negatively correlated with skin shriveling and flavor in both seasons. Skin shriveling on the other hand negatively correlated with peel color and aroma but positively correlated with flavor in both seasons. Peel color positively correlated with aroma but negatively with flavor in both seasons while aroma positively correlated with flavor in both seasons.

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 8 September 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

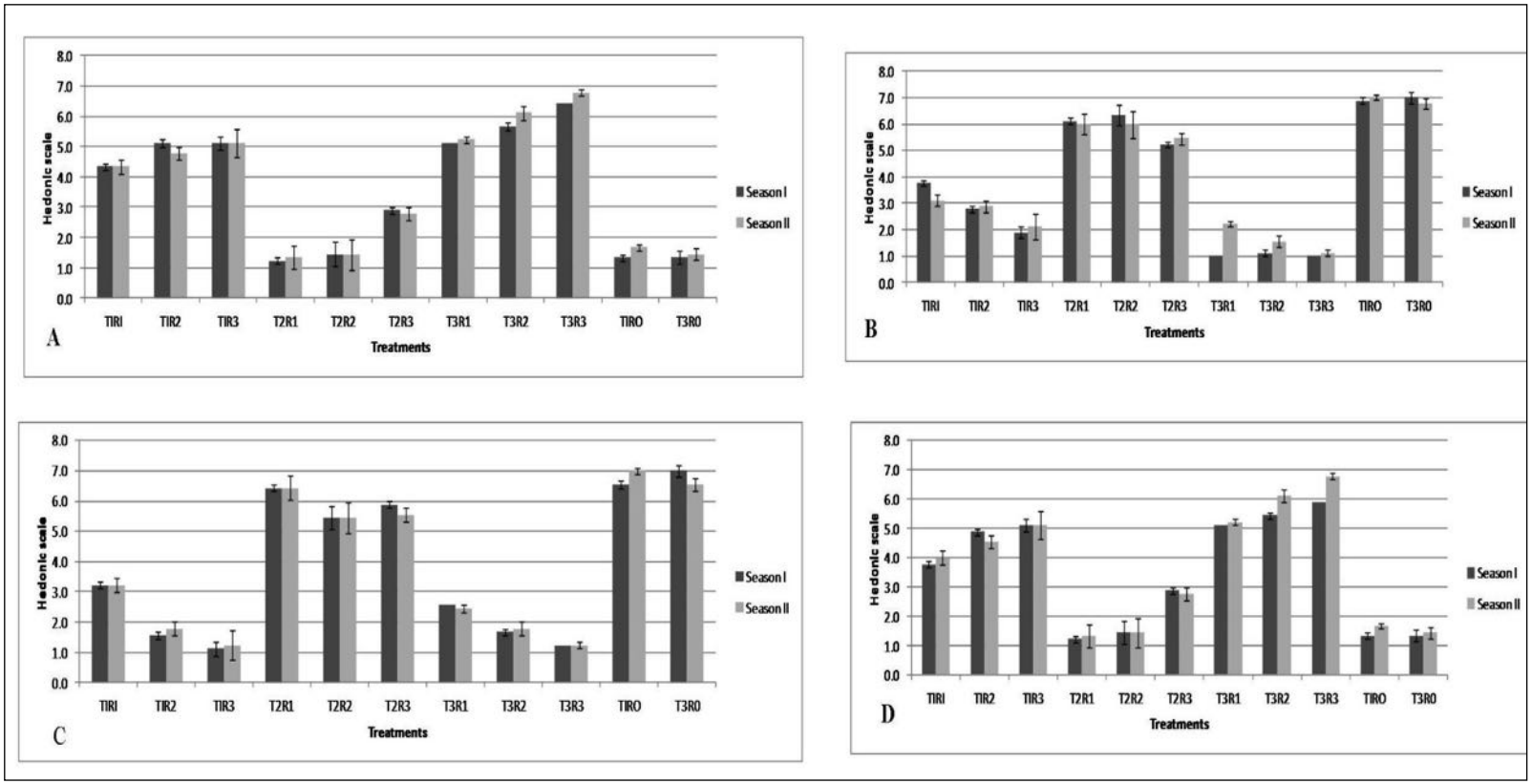

Figure 2: Effect of calcium chloride on the organoleptic acceptability of mango fruits. Bars represent standard errors of the means at p ≤0.05

Key A-Pulp color; B-Pulp flavor/taste; C-Shriveling; D-Aroma

T_1R_1-Calcium chloride (0.5%) sprayed at maturity; T_1R_2-Calcium chloride (1.0%) sprayed at maturity; T_1R_3-Calcium chloride (1.5%) sprayed at maturity; T_2R_1-Calcium chloride (0.5%) sprayed 15 days after maturity; T_2R_2-Calcium chloride (1.0%) sprayed 15 days after maturity; T_2R_3-Calcium chloride (1.5%) sprayed 15 days after maturity; T_3R_1-Calcium chloride (0.5%) immersion at maturity; T_3R_2- Calcium chloride (1.0%) immersion at maturity, T_3R_3- Calcium chloride (1.5%) immersion at maturity; T_1R_O-Sprayed with water at maturity; T_2R_0-Sprayed with water 15 days after maturity;T_3R_0-Immersed in water at maturity

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 8 September 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

CONCLUSION

The results of this study show that calcium chloride applied post-harvest improves fruit shelf life by increasing firmness, delaying skin color development, delaying soluble solids accumulation, decreasing carbon dioxide evolution, increasing fruit calcium concentration, and improving pulp color. However, higher concentrations (1.5%) resulted in a worsening of flavor and shriveling of the fruit, necessitating careful application. Additionally, this experiment demonstrates that spraying calcium chloride at maturity improves shelf life and fruit quality maintenance compared to 15 days later. Additional research can be conducted on multiple sites to increase the availability of calcium to mature fruits that are still attached to the tree, as this may increase calcium availability without impairing the fruit's organoleptic characteristics, as established in this study.

ACKNOWLEDGEMENTS

This Research was partly supported by the Rockefeller Foundation (Yield Wise Initiative), Grant Number 2016 YWS 328.

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 1: Effect of calcium chloride on changes in peel firmness (Newtons) during storage

		Season I					Season II				
Timing	Conc.	Day 0	Day 2	Day 4	Day 6	Day 8	Day 0	Day 2	Day 4	Day 6	Day 8
T_3	R3	14.3^{a}	13.8^{a}	12.6^{a}	11.8^{a}	10.6^{a}	14.1^{a}	13.2^{a}	12.2^{a}	11.5^{a}	10.3^{a}
	R2	13.9^{a}	13.2^{ab}	12.3^{a}	11.4^{ab}	10.0^{a}	13.4^{ab}	12.7^{a}	11.9^{a}	11.3^{ab}	9.8^{a}
	R1	13.1^{b}	12.7^{bc}	11.6^{a}	10.6^{b}	8.4^{b}	12.6^{b}	11.6^{b}	11.0^{ab}	10.4^{b}	8.4^{b}
	R0	4.1^{g}	3.5^{h}	3.1^{e}	2.6^{f}	2.1^{d}	4.0^{g}	3.1^{f}	2.9^{g}	2.6^{g}	$2.1d^{ef}$
T_1	R3	13.7^{ab}	12.1^{c}	9.4^{b}	7.7^{c}	4.4^{c}	12.9^{b}	11.8^{b}	10.2^{b}	8.1^{c}	4.1^{c}
	R2	11.6^{c}	9.7^{d}	8.6^{b}	6.2^{d}	3.1^{cd}	10.2^{c}	9.3^{c}	8.1^{c}	6.3^{d}	3.2^{cd}
	R1	9.2^{d}	7.1^{e}	6.0^{c}	4.3^{e}	2.7^{d}	8.1^{d}	6.4^{d}	5.8^{d}	4.6^{e}	3.0^{de}
	R0	3.8^{g}	3.6^{h}	2.9^{e}	2.5^{f}	2.0^{d}	3.4^{g}	3.5^{f}	2.5^{g}	2.1^{g}	1.8^{f}
T_2	R3	7.6^{e}	6.6^{ef}	5.8^{cd}	4.7^{e}	3.1^{cd}	7.4^{de}	6.3^{de}	5.6^{de}	4.5^{e}	2.9^{def}
	R2	6.9^{ef}	5.9^{fg}	4.9^{d}	4.2^{e}	2.8^{cd}	7.1^{e}	5.6^{de}	4.4^{ef}	3.7^{ef}	2.7^{def}
	R1	6.4^{f}	5.5^{g}	3.7^{e}	3.1^{f}	2.4^{d}	6.2^{f}	5.6^{e}	3.8^{fg}	3.0^{fg}	2.3^{def}
	R0	3.4^{g}	3.0^{h}	2.8^{e}	2.5^{f}	2.0^{d}	3.5^{g}	3.1^{f}	2.6^{g}	2.3^{gf}	2.0^{ef}
LSD	R	0.43	0.47	0.61	0.60	0.84	0.47	0.46	0.77	0.61	0.64
(P≤0.05)	T	0.37	0.41	0.53	0.52	0.73	0.41	0.40	0.67	0.53	0.56
	R*T	0.74	0.81	1.06	1.05	1.46	0.82	0.80	1.34	1.05	1.11
CV (%)		4.8	5.9	8.9	10.4	19.2	5.6	6.2	11.7	10.5	4.9

Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

**LSD-Least significant difference at p ≤0.05; CV (%)-Coefficient of variation T_1-Spraying at PM; T_2- Spraying 15 after PM; T_3-Immersion at PM; R1-$CaCl_2$ (0.5%); R2-$CaCl_2$ (1.0%); R3-$CaCl_2$ (1.5%); R-Rate; T-Time; PM-Physiological maturity

CC BY NC ND

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 2: Effect of calcium chloride on changes in total soluble solids (°Brix) during storage

		Season I					Season II				
Timing	Conc.	Day 0	Day 2	Day 4	Day 6	Day 8	Day 0	Day 2	Day 4	Day 6	Day 8
T3	R3	8.17^{a}	8.47^{a}	9.6^{a}	14.7^{ef}	14.0^{a}	7.7^{a}	8.6^{a}	10.5^{a}	13.17^{cde}	13.8^{d}
	R2	8.57^{ab}	9.0^{ab}	10.3^{ab}	11.7^{ab}	12.8^{bc}	8.0^{ef}	8.9^{a}	11.3^{ab}	13.07^{cdef}	12.7^{bcd}
	R1	9.6^{bcd}	9.6^{abc}	10.9^{ab}	13.1^{bcd}	12.1^{cd}	8.5^{e}	9.5^{a}	11.9^{b}	13.07^{cdef}	12.0^{bc}
	R0	12.37^{ef}	13.2^{f}	16.2^{gh}	11.2^{a}	8.4^{f}	12.6^{a}	13.0b^{cd}	16.9^{e}	11.23^{gh}	7.9^{a}
T1	R3	8.5^{ab}	9.1^{ab}	11.3^{bc}	13.3^{cde}	13.3^{ab}	8.0^{ef}	9.2^{a}	11.2^{ab}	12.43^{efg}	13.0^{cd}
	R2	9.03^{abc}	10.1^{bcd}	12.6^{cd}	12.8^{bcd}	12.2^{cd}	8.6^{e}	9.8^{a}	11.9^{b}	14.57^{b}	12.3^{bc}
	R1	10.23^{d}	11.4^{de}	13.2^{de}	12.9^{bcd}	11.7^{d}	10.1^{d}	11.4^{b}	13.2^{c}	13.5^{cd}	11.3^{b}
	R0	12.9^{f}	13.43^{f}	16.9^{h}	12.1^{abc}	8.0^{f}	12.6^{a}	14.4^{d}	17.6^{e}	12.1^{fgh}	8.9^{a}
T2	R3	9.87^{cd}	10.6^{cd}	12.9^{de}	12.8^{bcd}	10.5^{e}	10.9^{cd}	11.7^{b}	13.5^{c}	13.8^{bc}	11.3^{b}
	R2	11.7^{e}	12.7^{ef}	14.1^{ef}	13.6^{def}	10.2^{e}	11.2^{bc}	12.6^{bc}	14.1^{cd}	14.57^{b}	11.4^{b}
	R1	12.17^{ef}	13.3^{f}	15.0^{fg}	14.8^{f}	12.2^{cd}	11.9^{ab}	12.9^{bcd}	15.2^{d}	15.8^{a}	12.6^{bcd}
	R0	12.3^{ef}	13.8^{f}	17.3^{h}	11.9^{abc}	9.8^{e}	12.4^{a}	13.7^{cd}	17.5^{e}	11.87^{gh}	8.7^{a}
LSD	R	0.66	0.33	0.75	0.85	0.6	0.45	0.87	0.71	0.59	0.88
(P≤0.05)	T	0.58	0.38	0.65	0.73	0.5	0.39	0.76	0.61	0.52	0.77
	R*T	1.15	0.66	1.29	1.46	1.0	0.79	1.51	1.22	1.03	1.53
CV (%)		6.5	7.20	5.70	6.70	5.60	4.60	7.90	5.30	4.6	8

Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

**LSD-Least significant difference at p ≤0.05; CV (%)-Coefficient of variation T1-Spraying at PM; T2- Spraying at 15 after PM; T3-Immersion at PM; R1-$CaCl_2$ (0.5%); R2- $CaCl_2$ (1.0%); R3-$CaCl_2$ (1.5%); R-Rate; T-Time; PM-Physiological maturity

CC BY NC ND
https://doi.org/10.18697/ajfand.103.20350

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 3: **Effect of calcium chloride on changes in flesh colour (Ho) during storage**

Timing	Conc.	Day 0	Day 2	Day 4	Day 6	Day 8	Day 0	Day 2	Day 4	Day 6	Day 8
T_3	R3	50.9^{a}	46.5^{a}	42.2^{a}	39.6^{a}	37.5^{a}	48.7^{a}	44.4^{a}	41.05^{a}	38.1^{a}	36.8^{a}
	R2	48.03^{a}	43.5^{ab}	38.4^{b}	36.9^{b}	35.5^{a}	44.46^{b}	41.16^{ab}	38.24^{b}	35.79^{ab}	33.18^{b}
	R1	42.34^{b}	40.1^{b}	36.9^{b}	33.0^{c}	29.2^{b}	42.1^{bc}	38.7^{b}	36.0^{bc}	33.4^{b}	30.6^{b}
	R0	24.8^{fg}	22.2^{e}	19.3^{f}	17.2^{h}	16.3^{f}	22.7^{g}	21.08^{e}	19.19^{f}	17.92^{e}	17.02^{e}
T_2	R3	33.5^{de}	31.2^{c}	28.7^{c}	25.8^{d}	22.81^{c}	32.8^{de}	30.4^{c}	28.5^{d}	25.7^{c}	23.4^{c}
	R2	32.2^{de}	26.0^{d}	24.8^{de}	22.6ef	19.9^{cde}	30.3^{ef}	28.9^{cd}	26.63^{d}	24.19^{c}	22.18^{cd}
	R1	29.09^{ef}	25.93^{d}	22.3^{ef}	20.3^{fg}	19.3^{def}	29.23^{f}	26.28^{d}	23.28^{e}	20.88^{de}	19.62^{de}
	R0	24.23^{g}	22.2^{e}	20.13^{f}	19.1^{gh}	18.5^{def}	23.8^{g}	21.4^{e}	19.1^{f}	18.2^{e}	17.3^{e}
T_1	R3	42.2^{b}	40.1^{b}	37.1^{b}	35.7^{b}	30.9^{b}	41.0^{c}	38.1^{b}	35.1^{c}	33.3^{b}	30.1^{b}
	R2	38.6^{bc}	31.7^{c}	27.1^{cd}	25.6^{d}	21.8^{cd}	35.1^{d}	31.51^{c}	27.59^{d}	25.33^{c}	23.3^{c}
	R1	35.19^{cd}	31.1^{c}	26.8^{cd}	23.61^{de}	21.07^{cd}	34.25^{d}	30.15^{c}	27.67^{d}	24.06^{cd}	20.68^{cd}
	R0	22.53^{g}	20.64^{e}	19.4^{f}	18.43^{gh}	17.53^{ef}	22.51^{g}	20.51^{e}	19.06^{f}	17.75^{e}	16.8^{e}
$LSD_{(P\leq0.05)}$											
R		2.77	2.03	1.91	1.55	1.87	1.93	1.89	1.61	1.91	1.87
T		2.40	1.76	1.66	1.34	1.62	1.67	1.64	1.39	1.65	1.62
R*T		4.80	3.51	3.31	2.68	3.2	3.33	3.27	2.79	3.31	3.24
Cv (%)		8.0	6.50	6.80	6.00	7.90	5.80	6.20	5.80	7.50	7.90

Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

**LSD-Least significant difference at p ≤0.05; CV (%)-Coefficient of variation T1-Spraying at PM; T2- Spraying 15 days after PM; T3-Immersion at PM; R1- $CaCl_2$ (0.5%); R2- $CaCl_2$ (1.0%); R3-$CaCl_2$ (1.5%); R-Rate; T-Time; PM-Physiological maturity

CC BY NC ND
https://doi.org/10.18697/ajfand.103.20350

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 4: Effect of calcium chloride on changes in fruit beta carotene (mg 100ml^{-1}) during storage

		Season I					Season II				
Timing	Conc.	Day 0	Day 2	Day 4	Day 6	Day 8	Day 0	Day 2	day 4	Day 6	Day 8
T_3	R3	0.42^{a}	0.49^{a}	0.60^{a}	0.72^{a}	0.87^{a}	0.45^{a}	0.54^{a}	0.66^{a}	0.76^{a}	0.94a
	R2	0.32^{b}	0.40^{b}	0.48^{b}	0.57^{b}	0.68^{b}	0.39^{ab}	0.44^{b}	0.52^{b}	0.59b	0.66b
	R1	0.26^{c}	0.32^{c}	0.43^{b}	0.45^{cd}	0.52^{c}	0.33^{bc}	0.38^{b}	0.42^{c}	0.49cd	0.57c
	R0	0.12^{f}	0.16^{f}	0.20^{g}	0.22^{h}	0.27^{e}	0.13^{fgh}	0.16^{e}	0.22^{f}	0.25gh	0.28fg
T_2	R3	0.22^{cd}	0.31^{cd}	0.36^{cd}	0.41^{de}	0.48^{c}	0.22^{de}	0.28^{c}	0.35^{d}	0.40def	0.45d
	R2	0.18^{de}	0.21^{ef}	0.28^{ef}	0.31^{fgh}	0.36^{d}	0.18^{defg}	0.25^{cd}	0.30^{de}	0.33efg	0.37e
	R1	0.14^{ef}	0.20^{ef}	0.24^{fg}	0.30^{fgh}	0.34^{de}	0.14^{efgh}	0.19^{de}	0.27^{ef}	0.32fgh	0.35ef
	R0	0.11^{f}	0.18^{ef}	0.24^{fg}	0.30^{fgh}	0.31^{de}	0.10^{gh}	0.17^{e}	0.23^{f}	0.26gh	0.30fg
T_1	R3	0.26^{c}	0.35^{bc}	0.42^{bc}	0.51^{bc}	0.61^{b}	0.32^{bc}	0.38^{b}	0.43^{c}	0.53bc	0.61bc
	R2	0.22^{cd}	0.31^{cd}	0.34^{de}	0.39^{def}	0.51^{c}	0.25^{cd}	0.30^{c}	0.34^{d}	0.42de	0.56c
	R1	0.18^{de}	0.24^{de}	0.30^{def}	0.36^{efg}	0.48^{c}	0.20^{def}	0.25^{cd}	0.29^{de}	0.38ef	0.46d
	R0	0.1^{0f}	0.18^{ef}	0.22^{g}	0.27^{gh}	0.31^{de}	0.10^{gh}	0.18^{de}	0.22^{f}	0.24h	0.28g
LSD (P ≤0.05)											
R		0.03	0.04	0.04	0.05	0.05	0.05	0.04	0.04	0.05	0.04
T		0.02	0.04	0.03	0.05	0.04	0.04	0.04	0.03	0.04	0.03
R*T		0.04	0.07	0.07	0.09	0.09	0.08	0.07	0.06	0.09	0.07
CV (%)		12.60	15	11.80	13.40	10.7	20.60	14.1	10.3	12.7	8.4

Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

**LSD-Least significant difference at p ≤0.05; CV (%)-Coefficient of variation T1-Spraying at PM; T2- Spraying 15 after PM; T3-Immersion at PM; R1-$CaCl_2$ (0.5%); R2-$CaCl_2$ (1.0%); R3-$CaCl_2$ (1.5%); R-Rate; T-Time; PM-Physiological maturity

CC BY NC ND
https://doi.org/10.18697/ajfand.103.20350

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 8 September 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 5: **Effect of calcium chloride on the fruit flesh calcium content (µg/mg)**

Conc.		**Season I**			**Season II**	
Rate	T1	T2	T3	T1	T2	T3
R0	0.26g	0.22g	0.16g	0.22e	0.26e	0.26e
R1	0.64de	0.48f	0.77cd	0.64cd	0.52d	0.80bc
R2	0.66de	0.60ef	0.98b	0.75bc	0.61cd	0.87b
R3	0.87bc	0.67cd	1.43a	0.87b	0.69bcd	1.23a
LSD (P≤0.05)						
R		0.09			0.11	
T		0.08			0.09	
R*T		0.15			0.19	
CV (%)		13.7			17.2	

Treatments with different letters in the same column are significantly different according to LSD at p ≤0.05

**LSD-Least significant difference at p ≤0.05; CV (%)-Coefficient of variation T1-Spraying at PM; T2- Spraying 15 after PM; T3-Immersion at PM; $CaCl_2$ (0.5%); R2-$CaCl_2$ (1.0%); R3-$CaCl_2$ (1.5%); R-Rate; T-Time; PM-Physiological maturity

Table 6: Pearson correlation among firmness, flesh calcium content and organoleptic attributes

	Season 1					**Season II**				
	FC	FF	S	PC	A	FC	FF	S	PC	A
FC	1					1				
FF	0.9127*	1				0.852*	1			
SS	-0.778	-0.868	1			-0.806	-0.788	1		
PC	0.8282*	0.9115*	-0.944	1		0.841*	0.856*	-0.931	1	
A	0.8199*	0.9068*	-0.944	0.9792*	1	0.841*	0.848*	-0.938	0.977*	1
F	-0.811	-0.8869	0.9335*	-0.962	-0.959	-0.829	-0.821	0.947*	-0.95	-0.95

FC: Flesh calcium; **FF**-Flesh firmness; **PC**; Peel color; **A**-Aroma **SS**: Skin shriveling

CC BY NC ND
https://doi.org/10.18697/ajfand.103.20350

REFERENCES

1. **Baloch MK F and MK Bibi** Effect of harvesting and storage conditions on the post harvest quality and shelf life of mango (*Mangifera indica* L.) fruit. *South African Journal of Botany*, 2012; **83**: 109-116.

2. **Owino WO, Ambuko JL and FM Mathooko** Molecular basis of cell wall degradation during fruit ripening and senescence. *Stewart Postharvest,2005;* **1(3)**: 1-10.

3. **Karemera NJU and S Habimana** Performance of calcium chloride sprays on ripening, shelf life and physical chemical properties of mango fruits (*Mangifera indica* L) Cv. Alphonso. *Universal Journal of Agricultural Research, 2014;* **2(3)**: 119-125. https://doi.org/10.13189/ujar.2014.020307

4. **Zhang Q, Dai W, Jin X and J Li** Calcium chloride and 1-methylcyclopropene treatments delay postharvest and reduce decay of New Queen melon. *Scientific reports,* 2019; **9**: 1-10.

5. **Gangle A, Kirar SK and CS Pandey** Effect of post-harvest treatments on shelf life and quality of guava (*Psidium guajava* L.) cv. Allahabad Safeda. *International Journal of Current Microbiology and Applied Sciences, 2019*;**8(10)**: 2104-2114.

6. **Hussain Z, Alam M, Asif M, Shah MA, Khan J, Zeb I, Mumtaz O, Siyab A and A Jalal** Dipping of pear fruit (*pyruscommunis* L) in calcium chloride may help prolong its storability. *Acta Scientific Agriculture,* 2019; **3(8)**: 31-35.

7. **Thakur RJ, Shaikh M, Yogesh Y and RB Waghmare** Effect of calcium chloride extracted from eggshell in maintaining quality of selected fresh cut fruits. *International Journal of Recycling of Organic Waste in Agriculture,* 2019; **8 (1)**: 27–36.

8. **Anjum MA and H Ali** Effect of various calcium salts on ripening of mango fruits. *Journal of Research* (*Science),* 2004 *;***15 (1)**: 45-52.

9. **Singh V, Pandey G, Sarolia DK, Kaushik RA and JS Gora** Influence of pre harvest application of calcium on shelf life and fruit quality of mango (*Mangifera indica* L.) cultivars. *International Journal of Current Microbiology and Applied Sciences,* 2017; **6 (4):** 1366-1372.

10. **Dhillon BS and K Sukhjit** Effect of post harvest application of calcium chloride on storage life of mango var. Dashehari fruit. *HortFlora Research Spectrum*, 2013; **2 (3)**: 265-267.

11. **Mahajan BVC, Brar KS, Ghuran BS and RS Boora** Effect of pre-storage treatments of calcium chloride and Gibberellic acid on storage behavior and quality of guava fruits. *Fresh produce,* 2011 ;**5(1):** 22-25.

CC BY NC ND

12. **Conway WS, Sams CE and KD Hickey** Pre- and postharvest calcium treatment of apple fruit and its effect on quality. *Acta Horticulturae*, 2002; **594**: 413-419.

13. **Tsantili E, Konstantinidis K, Athanasopoulos PE and C Pontikis** Effects of post harvest calcium treatments on respiration and quality attributes in lemon fruit during storage. *Journal of Horticultural Science and Biotechnology*, 2002; **77**: 479–484.

14. **Mahmud S, Shibly AZ, Hossain MM, Islam SM and R Islam** The effect of calcium carbide and different calcium salts on mango fruits ripening in Bangladesh. *Journal of Pharmacology and Phytochemistry*, 2015 ;**4(1)**: 210-215.

15. **Ngamchuachit P, Sivertsen KH, Mitchan JE and MD Barrett** Effectiveness of calcium chloride and calcium lactate on maintenance of textural and sensory qualities of fresh cut mangoes. *Journal of Food Science,* 2014; 1-9.

16. **Stino GR, Abd El, Wahab SM, Habashy SA and RA Kelani** Productivity and fruit quality of three mango cultivars in relation to foliar spray of calcium, zinc, boron or potassium. *Journal of Horticultural Sciences and Horticultural Plants* 2011;**3(2)**:91-98.

17. **Griesbach J** Mango growing in Kenya. 2003 ICRAF, Nairobi, Kenya.

18. **Jiang Y M, Joyce DC and LA Terry** 1-methylcyclopropene treatment affects strawberry fruit decay. *Postharvest Biology and Technology*, 2001; **23**:227–232.

19. **Dong Li, Zhou HW, Sonega L, Lers A and S Lurie** Ripening of "Red Rosa" plums: effect of ethylene and 1-methylcyclopropene. *Australian Journal of plant physiology,* 2001; **28**:1039-1045.

20. P**athare PB, Opara UL and FAJ Al-Said** Color measurement and analysis in fresh and processed foods: A review. *Food and Bioprocess Technology*, 2013; **6(1)**: 36–60. https://doi.org/10.10 07/s11947-012-0867-9

21. **Heionen MI** Carotene and Pro-vitamin (A) activity of carrot (Daucas) cultivars. *Journal of Agriculture and Food Chemistry,* 1990; **38**: 609-612.

22. **Karithi E M** Evaluation of the efficacy of coolbot™ cold storage technology to preserve quality and extend shelf life of mango fruits" 2016. M.Sc. (Agri.) Thesis, UoN, Nairobi.

23. **Galan SV**, **Fernandez GD and R Calvo** Incidence of softnose on mangoes in the Canary Islands. *Proceedings of the Fla State Horticulture Society*, 1984 ;**97:**358-360.

CC BY NC ND

24. **Arthur E, Oduro I and P Kumah** Postharvest quality response of tomato (*lycopersicon esculentum*, mill) fruits to different concentrations of calcium chloride at different dip times. *Journal of Food and Nutrition* 2015; **5(1)**:1-8 https://doi.org/10.5251/ajfn.2015.5.1.1.8

25. **Conway W S, Sams CE, Mcguire RG and A Kelman** Calcium treatment of apples and potatoes to reduce postharvest decay. *Plant Disease*, 1992; **76(4)**: 329-334. https://doi.org/10.1094/PD-76-0329

26. **Kazemi M, Aran M and S Zamani** Effect of calcium and salicylic acid on quality characteristics of kiwifruit (*Actinidia deliciosa* Cv. Hayward) during storage. *Journal of plant physiology* 2011; **6 (3)**:183-189.

27. **White PJ and MR Broadley** Calcium in plants. Annals of Botany, 2003; **92**: 487- 511.

28. **Gao Q, Tan Q, Song Z, Chen W, Li X and X Zhu** Calcium chloride postharvest treatment delays the ripening and softening of papaya fruit, 2020. https://doi.org/10.1111/jfpp.14604

29. **Lv J, Han X, Bai L, Xu D, Ding S, Ge Y, Li C and J Li** Effects of calcium chloride treatment on softening in red raspberry fruit during low-temperature storage. J*ournal of Food Biochemistry,* 2020 Aug 9:e13419. https://doi.org/10.1111/jfbc.13419 Epub ahead of print. PMID: 32776337.

30. **Hussain PR, Meena RS, Dar MA and AM Wani** Effect of post-harvest calcium chloride dip treatment and gamma irradiation on storage quality and shelf-life extension of Red delicious apple. *Journal of Food Science and Technology,* 2012*;* ***49***: 415-426.

31. **Bagheri M, Esna-Ashar M and A Ershadi** Effect of postharvest calcium chloride treatment on the storage and quality of persimmon fruits (Diospros kaki thumb.) cv.'Karaj'. *International Journal of Horticultural Science and Technology*, 2015; **2(1):**15-26.

32. **Pooja P and CP Singh** Response of pre harvest spray of chemicals on shelf life and quality of mango (*Mangifera indica* L.) Cv. Dashehari. *International Journal of Basic and Applied Agricultural Research,*2014;**12 (3**): 374-378.

33. **Penter MG and PJC Stassen** The effect of pre-and post- harvest calcium application on the post-harvest quality of Pinkerton avocados. South Africa Avocado Growers' Association Yearbook, 2000; **23**:1-7.

34. **Ishaq S, Rathore HA, Masud T and S Ali** Influence of post-harvest calcium chloride application, ethylene absorbent and modified atmosphere on quality characteristics and shelf life of Apricot (*Prunus armeniaca* L.) fruit during storage. *Pakistan Journal of Nutrition*, 2009;**8(6)**: 861-865.

CC BY NC ND

35. **Mounika T, Reddy NN, Jyothi L N and V Joshi** Studies on the effect of postharvest treatments on shelf life and quality of mango [*Mangifera indica* l.] cv. Amrapali. *Journal of Applied and Natural Science,* 2017;**9 (4**): 2055— 2061.

36. **Eryani-Raqeeb AAl, Mahmud TMM, Syed OSR, Mohamed AR Zaki and Al Eryani** Effects of calcium and chitosan treatments on controlling anthracnose and postharvest quality of papaya (*Carica papaya* L.). *International Journal of Agricultural Research*, 2009; **4:** 53-68.

37. **Poonsawat PH, Nimitkeatkai A, Uthairatanakij S, Kanlayanarat and C Wongs-Aree** Calcium chloride affecting quality and aroma volatiles of fresh cut Malay sapodilla. *Acta Horticulture*, 2007; **746**: 309-315.

38. **Chepngeno J, Owino W, Kinyuru J and N Nenguwo** Effect of calcium chloride and hydro cooling on postharvest quality of selected vegetables. *Journal of Food Research*, 2016; **5 (2**): 23-40.

39. **Maina B, Ambuko J, Hutchinson MJ and WO Owino** The effect of waxing options on shelf life and postharvest quality of "ngowe" mango fruits under different storage conditions, 2019 *Advances in Agriculture* 1-9.

40. **Yumbya P, Ambuko J, Shibairo S and WO Owino** Effect of modified atmosphere packaging (MAP) on the shelf life and post harvest quality of purple passion fruit (*Passiflora eddlis sims*). *Journal of Postharvest Technology*, 2014 ;**2(1):** 25-36.

41. **Jakhar MS and S Pathak** Effect of pre-harvest nutrients application and bagging on quality and shelf life of mango (*Mangifera indica* L.) fruits cv. Amrapali *Journal of Agriculture, Science and Technology,* 2016; **18**:717-729.

42. **Garcia JM, Herrera S and A Morilla** Effect of postharvest dips in calcium chloride on strawberry. *J. Agric. Food Chem.,* 1996; **44**: 30-33**.**

43. **Manganaris GA, Vasilakakis M, Diamantidis G and I Mignani** The effect of postharvest calcium application on tissue calcium concentration, quality attributes, incidence of flesh browning and cell wall physico chemical aspects of peach fruits. *Food Chemistry,* 2005 ;**100 (4**): 1385-1392.

44. **Shirzadeh E, Rabiei V and Y Sharafi** Effect of calcium chloride (CaCl2) on postharvest quality of apple fruits African Journal of Agricultural Research, 2011; **6 (22**): 5139-5143.

45. **Pinzón-Gómez LP, Deaquiz YA and JG Álvarez-Herrera** Postharvest behavior of tamarillo (*Solanum betaceum* Cav.) treated with CaCl2 under different storage temperatures. Agronomía Colombiana, 2014; **32 (2**): 1-10.

CC BY NC ND

46. **Ben-Arie R, Mignani I, Greve LC, Huysamer M and JM Labavitch** Regulation of the ripening of tomato pericarp discs by GA_3 and divalent cations. *Physiology of plant*,1995; **93**: 99-107.

47. **Saftner R A, Conway WS and CE Sams** Effects of postharvest calcium and fruit coating treatments on postharvest life, quality maintenance, and fruit-surface injury in 'Golden Delicious' apples. **Journal of the American Society for Horticultural Science**, 1998; **123**: 294–298.

48. **Yuen CMC, Tan SC, Joyce D and P Chettri** Effect of post harvest calcium and polymeric fils– on ripening and ripening injury in 'Kensington Pride' Mango. *Asian Food Journal*, 1993; **8**:110-113.

49. **Hamzehzad K, Rabiei V, Naseri L and S Hemati** Effect of UV-C irradiation and CaCl2 treatment on the quality and storage life of peach fruit, cv. Zafarany. *Iranian Journal of Horticultural Sciences,* 2010; **40** (**4**): 53– 59.

50. **Antunes MDC, Correia MP, Miguel MG, Martins MA and MA Neves** The effect of calcium chloride postharvest application on fruit storage ability and quality of 'Beliana' and 'Lindo' apricot (Prunus armeniaca L.) cultivars. *Acta Horticulturae*, 2003; **604**: 721–726. https://doi.org/10.17660/actahortic.2003.604.91

51. **Moradinezhad F, Ghesmati M and M Khayyat** Postharvest calcium salt treatment of fresh jujube fruit and its effects on biochemical characteristics and quality after cold storage. *Journal of Horticultural Research* 2019; **27 (2):** 39–46 https://doi.org/10.2478/johr-2019-0009

52. **Lovera N, Ramallo L and V Salvadori** Effect of processing conditions on calcium content, firmness, and color of papaya in syrup. *Journal of Food Processing* 2014; 1-8.

53. **Luna-Guzmán I and D M Barrett** "Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cutcantaloupes" *Postharvest Biology and Technology*, 2000; **19 (1**): 61–70.

CC BY NC ND