RESEARCH ARTICLE

Effect of Post-Harvest Calcium Chloride Concentrations on Physio-Chemical Quality and Shelf Life of Mango (*Mangifera indica* L. cv. Calcuttia)

Nisha k. Shah[1], Umesh Timilsina[2], Abhishek Shrestha[2], Prabhakar shah[2]

[1]College of Natural Resource Management(CNRM), Agriculture and Forestry University(AFU) Bardibas, Mahottari, Nepal

[2]Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, Nepal

Corresponding Author: Nisha k. Shah. Email: shahnisha3334@gmail.com

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Abstract

Mango experiences substantial post-harvest losses in South Asia due to rapid ripening, which shortens shelf life and reduces fruit quality. Post-harvest calcium chloride ($CaCl_2$) treatment is a low-cost approach known to enhance cell wall stability, delay softening, and reduce decay; however, the optimum concentration for 'Calcuttia' mango has not been well established. A laboratory experiment was conducted at the Horticulture Laboratory, College of Natural Resource Management, from 20 June to 3 July 2024 to evaluate the effect of different $CaCl_2$ concentrations on post-harvest quality and shelf life of mango (*Mangifera indica* L. cv. Calcuttia). Mature-green fruits were immersed for 10 min in $CaCl_2$ solutions at 0, 200, 400, 600, 800, 1000, and 1200 ppm, arranged in a completely randomized design with three replications. During ambient storage, physiological weight loss, pulp colour development, decay incidence, firmness, titratable acidity, total soluble solids, and shelf life were assessed. Mangoes treated with 800 ppm $CaCl_2$ exhibited the lowest physiological weight loss, reduced decay, higher firmness, and extended shelf life of up to 13 days, compared with 9 days in untreated fruits. Higher concentrations did not provide additional benefits, while lower concentrations were less effective. Total soluble solids were not significantly affected by $CaCl_2$ treatments. The results indicate that a 10-min post-harvest dip in 800 ppm $CaCl_2$ effectively delays ripening and enhances storage life of 'Calcuttia' mango without adversely affecting sweetness. Further evaluation under commercial handling and distribution conditions is recommended to confirm its practical applicability and compatibility with other non-chemical post-harvest treatments.

Keywords: $CaCl_2$; Post-harvest treatment; Physio-chemical properties; Quality, Shelf life

Introduction

Mango (*Mangifera indica* L.), popularly known as the "King of fruits," is one of the most important tropical fruits cultivated and consumed worldwide due to its unique flavor, attractive appearance, high nutritional value, and medicinal properties (Prasad et al., 2019; Jabbar et al., 2011). It belongs to the family Anacardiaceae and is considered one of the most widely grown fruit crops after banana and papaya (Kumah & Appiah, 2011). Mango fruits are rich in carbohydrates, vitamins A and C, minerals, antioxidants, and dietary fiber, making them highly valued for fresh consumption as well as for processing into products such as juice, pulp, nectar, pickles, jams, and dried slices. Owing to its wide adaptability, diversity in taste, color, and cultivar types, mango has gained global acceptance and economic importance.

In Nepal, mango is one of the most commercially important fruit crops, particularly dominant in the Terai and inner Terai regions. According to MoALD (2022), mango occupies the largest fruit-growing area in the country with an area of 43,688 ha and a production of 466,266 tons, with an average productivity of 10.67 t/ha (Pandey et al., 2023). In Madhesh Province, mango cultivation contributes significantly to farmers' income and local markets. Among the locally grown varieties, 'Calcuttia' is a late-season cultivar widely available in the region. It is characterized by medium-sized trees and fruits, oblong shape, green peel, yellow pulp, relatively firm texture, high yield potential, and comparatively better storage capacity. Despite these favorable traits, the commercial potential of 'Calcuttia' mango remains constrained by post-harvest losses under ambient storage conditions.

Mango is a climacteric fruit that continues to respire actively after harvest, exhibiting a sharp rise in respiration rate and ethylene production during ripening (Nacional et al., 2024). These physiological processes accelerate softening, color development, sugar accumulation, organic acid degradation, and ultimately senescence. Under the warm ambient conditions prevalent in Nepal, mango fruits ripen rapidly, resulting in a very short shelf life, high susceptibility to mechanical injury, microbial infection, and substantial post-harvest decay (Agric, 2021; Prasad et al., 2019). Post-harvest losses are considered one of the major challenges limiting mango commercialization, market expansion, and profitability, particularly in developing countries like Nepal where cold-chain infrastructure and advanced storage technologies are limited (Pandey et al., 2023).

The primary causes of post-harvest deterioration in mango include high metabolic activity, moisture loss through transpiration, enzymatic breakdown of cell wall components, and increased vulnerability to pathogens (Shirzadeh et al., 2011). Post-harvest decay is widely recognized as the major factor restricting storage life in many fresh horticultural commodities (Irtwange, 2006). Therefore, delaying ripening, reducing respiration and ethylene production, maintaining membrane integrity, and minimizing oxidative metabolism are essential strategies for extending shelf life and preserving fruit quality under ambient storage conditions (Shahin et al., 2020). Various post-harvest treatments such as hot water dips, fungicides, growth regulators, edible coatings, and chemical retardants have been explored to slow ripening and reduce losses in mango (Jabbar et al., 2011; Kumah & Appiah, 2011). However, many chemical treatments raise concerns related to food safety, consumer acceptance, environmental impact, and cost. In this context, calcium-based treatments have emerged as a safer, cost-effective, and eco-friendly alternative for post-harvest management of fruits.

Calcium is an essential plant nutrient known for its vital role in maintaining cell wall structure, membrane stability, and overall tissue integrity. Calcium ions (Ca^{2+}) form cross-links with pectic substances in the cell wall, thereby strengthening cell walls, delaying softening, and reducing membrane permeability (Shirzadeh et al., 2011). Numerous studies have demonstrated that calcium application reduces respiration rate and ethylene production, thereby slowing ripening and senescence in fruits such as mango, tomato, apple, peach, strawberry, and guava (Daundasekera, 2016; Rajkumar et al., 2019; Eroğul et al., 2024). Among different calcium salts, calcium chloride ($CaCl_2$) is the most commonly used due to its high solubility, effectiveness, low cost, and ease of application. Post-harvest calcium chloride treatments have been reported to improve firmness, reduce physiological weight loss, delay skin and pulp color development, maintain titratable acidity, suppress decay incidence, and extend shelf life without adversely affecting sweetness or consumer acceptability (Joyce et al., 2001; Karemera & Habimana, 2014; Chepngeno et al., 2016). Calcium chloride has also been shown to reduce post-harvest diseases and control microbial spoilage by maintaining fruit structural integrity and delaying tissue breakdown (Rajkumar et al., 2019). However, excessive concentrations of $CaCl_2$ may cause surface injury, shriveling, or quality deterioration, indicating the importance of optimizing concentration levels for specific fruit cultivars (Shirzadeh et al., 2011).

Although several studies have documented the beneficial effects of calcium chloride on mango and other fruits, information regarding the optimum concentration of $CaCl_2$ for post-harvest treatment of the locally important 'Calcuttia' mango under ambient Nepalese conditions remains limited. Most previous studies have focused on other mango cultivars or different agro-climatic regions, and the response of fruit quality parameters to varying $CaCl_2$ concentrations can differ significantly depending on cultivar, maturity stage, and storage environment. Therefore, a clear research gap exists in identifying an effective, safe, and economically feasible calcium chloride concentration for extending shelf life and maintaining the post-harvest quality of 'Calcuttia' mango in Madhesh Province. Addressing this gap is crucial for reducing post-harvest losses, improving fruit marketability, and enhancing farmers' income through improved post-harvest management practices.

Therefore, the present study was undertaken to evaluate the effect of different concentrations of calcium chloride as a post-harvest dip treatment on the physio-chemical characteristics and shelf life of mango (*Mangifera indica* L. cv. Calcuttia) under ambient storage conditions. The specific objectives of the study were to assess the influence of $CaCl_2$ concentrations on physiological weight loss, firmness, titratable acidity, total soluble solids, TSS:TA ratio, pulp color development, rotting percentage, organoleptic quality, and overall shelf life of mango fruits. We hypothesized that post-harvest application of calcium chloride would significantly delay ripening, reduce post-harvest losses, and extend shelf life of 'Calcuttia' mango, with an optimum concentration providing maximum benefit without negatively affecting fruit quality. The findings of this research are expected to provide practical recommendations for farmers, traders, and stakeholders for adopting an efficient and low-cost post-harvest treatment to improve mango quality and reduce losses in Nepal.

Materials And Methods

The investigation entitled Effect of different concentration of Calcium chloride ($CaCl_2$) as Postharvest treatment on quality and shelf-life of Mango (*Mangifera indica L.)*" was conducted from 2081/03/07 to 2081/03/21. The following were the details of the experimental materials, techniques and procedures employed during the study.

Experiment site (Location)

This research experiment was carried out in the Laboratory of College of Natural Resource Management, AFU, Bardibas(Mahottari). Mahottari district is one of the eight districts of province -2, which falls in the Terai region of Madhesh province in Nepal at latitude 26º 52' 22.08 "North, longitude 85º49 '42.96" East.

Selection of cultivar

The locally available variety of mango (Calcuttia) was selected for the experiment.

Design of experiment

The experiment was laid out in CRD (Completely Randomized Design) with 7 treatments and each were replicated thrice (3 times). Total there were 21 experimental units. Figure 1 shows the map of mahottari district. Figure 2 shows the map of Nepal showing the study area.

Figure 1: Map of Mahottari District

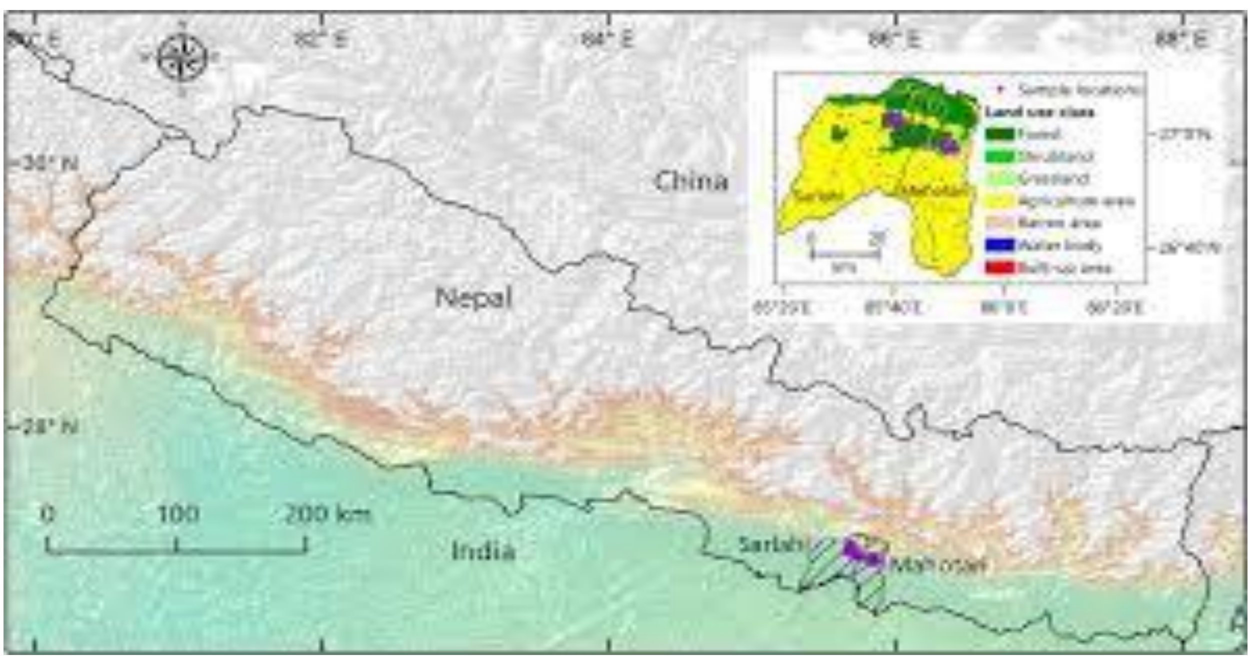

Figure 2: Map of Nepal showing the study area

Experimental (Treatment) details

Required concentration of Calcium chloride were weighed using a digital scale. Then it was dissolved in desired volume of distilled water to produce solutions containing 200 ppm, 400 ppm, 600ppm, 800ppm, 1000ppm and 1200 ppm of $CaCl_2$, respectively. After treatment imposition, the physiological and chemical parameters of fruits were observed in 2 days interval until their shelf life ended in order to determine the different physio-chemical changes in the fruits during storage. A total of 21 experimental units were made.

The treatment details along with their concentration were as follows.

T_1 = Distilled water (Control)

T_2 = Calcium Chloride ($CaCl_2$) @ 200 ppm

T_3 = Calcium Chloride ($CaCl_2$) @ 400 ppm

T_4 = Calcium Chloride ($CaCl_2$) @ 600 ppm

T_5 = Calcium Chloride ($CaCl_2$) @ 800 ppm

T_6= Calcium Chloride ($CaCl_2$) @ 1000 ppm

T_7= Calcium Chloride ($CaCl_2$) @ 1200 ppm

Generally, in the Nepalese market $CaCl_2$ is found in powdered form with 95%purity.

So, for 95% pure $CaCl_2$, the solution was prepared in the following ways. Table 1 shows treatment details showing $CaCl_2$ concentration required in 1-liter distilled water to make solution

Table 1: Treatment details showing $CaCl_2$ concentration required in 1-liter distilled water to make solution

Treatments	ppm	Amount of 95% pure powdered $CaCl_2$	Volume of distilled water
T1	Control	-	-
T2	200 ppm	210.53 mg	1 liter
T3	400 ppm	421.05 mg	1 liter
T4	600 ppm	631.58 mg	1 liter
T5	800 ppm	842.11mg	1 liter
T6	1000ppm	1052.63 mg	1 liter
T7	1200ppm	1263.16 mg	1 liter

Lab Experiment

Two parameters viz. physical and chemical were recorded for observation at an interval of 2 days from the starting day of research till the end of shelf life of the fruits.

Physical observation includes the record of Physiological loss in weight, colour change in mango pulp, rotting% and shelf life of Mango which were taken from the non-destructive sample of each treatment combination of every replication. Chemical observation includes the record of TSS, TA, Firmness and TSS:TA ratio which were taken from the destructive sample of every replication of each treatment combination.

- ***Physiological loss in weight (%)***

All treated fruits were weighed using electronic digital balance on alternate days and percentage weight loss calculated by using following formula

Weight loss (%) = $\frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100$

- ***Total soluble solids (º Brix)***

Total soluble solids (ºBrix) were be determined with the help of handheld Refractometer. The measurement was done by dripping the fruit juice on the prism of the refractometer with the help of clean pipette. The reading was recorded at room temperature. The instrument was cleaned with distilled water and muslin cloth after every use.

- ***Titratable acidity (%)***

Titratable acidity was determined by titrating pulp juice against 0.1N NaOH using phenolphthalein as an indicator. Titrable acidity was calculated by using the following formula (Saini et al., 2001)

Titratable acidity(%) = $\frac{Nb \times Vb \times Milliequivalent\ wt. of\ predominant\ acid}{Volume\ of\ the\ sample} \times 100 \times d.f$

Where, N_b= normality of base

V_b= Volume of the base

d.f.= dilution factor

Milliequivalent wt. of predominant acid i.e. Malic acid=0.067

- ***Percentage of Rotting***

Rotting was calculated as number of rotted fruits per total number of fruits. The fruits were observed visually for rotting and calculated using formula below while Table 2 shows ranking rotting percentage.

Rotting (%) = $\frac{No. of\ rotted\ fruit}{Total\ no.\ of\ fruit} \times 100$

Table 2: Ranking rotting percentage

Rotting%	Rank
0-20%	1
20-40%	2
40-60%	3
60-80%	4
80-100%	5

- ***TSS: TA ratio***

It was calculated by dividing TSS percentage with the percentage of titratable acidity.

TSS: TA=Total soluble solid/Titratable acidity

- ***Pulp color***

Color of pulp was observed and then ranked as below table 3;

Table 3: Rank

Color	Rank
Green	1
Light yellow	2
Yellow	3
Dark yellow	4

- ***Shelf life***

The stage where in more than 50% of stored fruits became unfit for consumption was considered as end of shelf life in that particular treatment. It was calculated by counting the period between the first day of storage after treatment to the end of the edible life of fruits.

- ***Organoleptic test***

The visual characteristics of mango appearance for pulp color, aroma, taste, texture, flavor, etc each marked 20 were scored in daylight by a panel of 5 trained judges and then final scoring were done as below table 4.

Table 4: Ranking pulp colour

Quality	Rating(%)
Excellent	90-100
Good	80-89
Fair	70-79
Poor	<70

Statistical methods

All collected data were entered into MS-Excel for statistical analysis and subjected to Analysis of Variance (ANOVA) using the Gen-Stat 15th edition. Duncan's Multiple Range Test at a 5% level of Significance (DMRT) was used to separate the means of treatments that were significantly different.

Result and Discussion

Physiological Weight Loss

Physiological weight loss of mango fruits increased progressively during storage in all treatments; however, the magnitude of loss differed significantly among calcium chloride concentrations. The untreated control fruits exhibited the highest cumulative weight loss throughout the storage period, while mangoes treated with 800 ppm $CaCl_2$ consistently showed the lowest weight loss. Other calcium-treated fruits also showed reduced weight loss compared to the control, though the effect was less pronounced than at 800 ppm. The reduction in weight loss in $CaCl_2$-treated fruits can be attributed to the role of calcium ions in strengthening cell wall structure and stabilizing membrane integrity, which reduces moisture loss through transpiration and lowers respiration rate. Calcium-mediated suppression of ethylene production further slows metabolic activity, thereby minimizing water loss and CO_2 evolution during storage. The superior performance of the 800 ppm concentration suggests that this level supplied adequate calcium to reinforce cell wall pectates without impairing gas exchange through surface deposits. These findings are in close agreement with Ferreira (2004), who reported significantly lower weight loss in calcium chloride–treated mangoes stored under ambient conditions. Similar reductions in post-harvest weight loss following calcium treatment have also been reported in pears and other climacteric fruits, emphasizing the effectiveness of calcium dips in reducing post-harvest desiccation (Mahajan and Dhatt, 2004). Table 5 shows effect of different concentration of Calcium chloride on titratable acidity of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081.

Table 5: Effect of different concentration of Calcium chloride on titratable acidity of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081

Treatment	Titratable acidity					
	Initial	3DAT	6DAT	9DAT	12DAT	Avg.
Control	0.97	0.335^{a}	0.2479^{a}	0.188^{a}	0.1362^{a}	0.3753^{a}
200ppm CaCl2	0.97	0.395^{ab}	0.2993^{ab}	0.261^{ab}	0.1787^{ab}	0.4209^{abc}
400ppm CaCl2	0.97	0.581^{c}	0.3685^{bc}	0.27^{ab}	0.2032^{b}	0.4785^{cd}
600ppm CaCl2	0.97	0.402^{ab}	0.2836^{ab}	0.255^{ab}	0.1653^{ab}	0.4151^{ab}
800ppm CaCl2	0.97	0.632^{c}	0.4355^{c}	0.295^{b}	0.2546^{c}	0.5174^{d}
1000ppm CaCl2	0.97	0.462^{b}	0.3395^{b}	0.295^{b}	0.1809^{ab}	0.4495^{bc}
1200ppm CaCl2	0.97	0.431^{ab}	0.2903^{ab}	0.234^{ab}	0.1876^{ab}	0.4227^{abc}
Grand mean	0.97	0.463	0.3235	0.257	0.1866	0.4399
CV%	-	12.8	13.9	17.9	14.4	7.3
Sem (±)	-	0.0343	0.026	0.0265	0.0155	0.01852
LSD	-	0.104	0.07887	0.0804	0.047	0.05616
F-value	-	***	**	NS	**	**

Note: Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV=Coefficient of Variation, LSD= Least Significant Difference, SEm(±)=Standard Errors of Means, *=Significantly different at (p<0.05), **=highly significant different at (p<0.01), ***=very significantly different at (p=<0.001), NS=Non-significant., DAT= Days after treatment.

Titratable Acidity

Titratable acidity of mango fruits declined steadily during storage across all treatments; however, calcium chloride–treated fruits retained significantly higher acidity compared to the untreated control. Among the treatments, mangoes treated with 800 ppm $CaCl_2$ maintained the highest titratable acidity throughout the storage period, whereas the control fruits showed the most rapid decline. The slower reduction in acidity in calcium-treated fruits indicates delayed ripening and reduced metabolic activity. Organic acids such as malic and citric acid are utilized as respiratory substrates during ripening, and calcium treatments are known to suppress respiration by stabilizing cellular membranes and slowing ethylene-mediated physiological processes. As a result, the rate of acid degradation is reduced, allowing calcium-treated fruits to retain higher acidity and better flavor balance. These results are consistent with the findings of Singh et al. (2017), who observed higher titratable acidity retention in calcium-treated peach fruits during both ambient and cold storage. Similar trends were also reported by Shirzadeh et al. (2011) in apple fruits, where calcium chloride treatment delayed acid depletion by reducing respiratory metabolism. Table 6 shows the effect of different concentration of Calcium chloride on firmness of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas, Mahottari, 2081.

Table 6: Effect of different concentration of Calcium chloride on firmness of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas, Mahottari, 2081

Treatment	Firmness					
	Initial	3DAT	6DAT	9DAT	12DAT	Avg.
Control	9	5.433^{a}	4.067^{a}	3.27^{a}	2.5^{a}	4.853^{a}
200ppm CaCl2	9	5.433^{a}	4.067^{a}	3.67^{ab}	3.067^{ab}	5.047^{ab}
400ppm CaCl2	9	6.567^{b}	5.8^{bc}	4.63^{ab}	3.933^{b}	5.987^{cd}
600ppm CaCl2	9	5.933^{ab}	4.6^{ab}	3.83^{ab}	3.067^{ab}	5.287^{abc}
800ppm CaCl2	9	8.4^{c}	6.567^{c}	5^{b}	3.8^{b}	6.553^{d}
1000ppm CaCl2	9	6.667^{b}	5.7^{bc}	4.97^{b}	3.867^{b}	6.04^{cd}
1200ppm CaCl2	9	6.333^{ab}	5.5^{bc}	4.53^{ab}	3.067^{ab}	5.687^{bc}
Grand mean	9	6.395	5.186	4.27	3.329	5.636
CV%	-	4.8	8.6	12.3	11.5	4.8
Sem (±)	-	0.1759	0.2582	0.302	0.2211	0.1554
LSD	-	0.5336	0.7832	0.917	0.6707	0.4714
F-value	-	***	***	**	**	***

Note: Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV=Coefficient of Variation, LSD= Least Significant Difference, SEm(±)=Standard Errors of Means, *=Significantly different at (p<0.05), **=highly significant different at (p<0.01), ***=very significantly different at (p=<0.001), NS=Non-significant.

Total Soluble Solids

Total soluble solids (TSS) content increased gradually during storage in all treatments as ripening progressed; however, the differences among treatments were statistically non-significant. This indicates that calcium chloride treatment did not markedly influence sugar accumulation in mango fruits. The increase in TSS during storage is mainly associated with the enzymatic conversion of starch into soluble sugars, a process that continues during ripening irrespective of calcium treatment. Although $CaCl_2$ delays ripening by reducing respiration and ethylene production, it does not significantly interfere with carbohydrate metabolism pathways responsible for sugar formation. Consequently, calcium-treated fruits followed a ripening pattern similar to that of the control with respect to TSS accumulation, albeit at a slightly slower rate. These observations corroborate the findings of Shirzadeh et al. (2011), who reported no significant effect of calcium chloride treatment on TSS content in apples during storage. Similar results have also been documented in mango and other fruits, indicating that calcium treatments preserve sweetness while primarily influencing textural and physiological attributes.

Firmness

Fruit firmness decreased progressively during storage in all treatments, but calcium chloride–treated mangoes retained significantly higher firmness than untreated fruits. The highest firmness values throughout the storage period were recorded in mangoes treated with 800 ppm $CaCl_2$, while the control fruits exhibited the greatest softening. The retention of firmness in calcium-treated fruits is closely associated with calcium's role in maintaining cell wall integrity. Calcium ions bind with pectic substances in the middle lamella to form calcium pectate, which strengthens intercellular adhesion and reduces the activity of cell wall–degrading enzymes such as polygalacturonase. This delays the breakdown of cell wall components, resulting in slower softening and extended textural quality during storage. The present findings are in agreement with Shirzadeh et al. (2011), who reported significantly higher firmness in apples treated with calcium chloride during extended storage. Similar firmness retention due to calcium application has also been reported in mango (Joyce et al., 2001) and strawberry fruits (Eroğul et al., 2024), confirming the role of calcium in delaying fruit softening.

TSS: TA Ratio

The TSS:TA ratio increased during storage in all treatments as ripening progressed; however, untreated fruits exhibited the highest ratio, while mangoes treated with 800 ppm $CaCl_2$ recorded the lowest values. The lower TSS:TA ratio in calcium-treated fruits reflects delayed ripening and improved retention of organic acids rather than changes in sugar content. Since TSS levels were not significantly affected by calcium chloride, the reduced ratio is primarily attributed to the higher titratable acidity maintained in treated fruits. A lower TSS:TA ratio is generally associated with better flavor balance and slower maturity progression. These results are consistent with the findings of Karemera and Habimana (2014), who observed delayed ripening and improved quality indices in $CaCl_2$-treated mango fruits. Similar reductions in TSS:TA ratio following calcium treatments have been reported in other climacteric fruits, indicating prolonged shelf life and enhanced eating quality.

Rotting Percentage and Pulp Color

Significant differences were observed in rotting percentage and pulp color development among the treatments. Mangoes treated with calcium chloride, particularly at 800 ppm, exhibited the lowest rotting incidence, while the untreated control fruits showed the highest decay. Pulp color development was also significantly delayed in calcium-treated fruits, with the control fruits showing faster transition from greenish-yellow to deep yellow. The reduced decay in calcium-treated fruits can be attributed to enhanced firmness and delayed senescence, which limit tissue breakdown and reduce susceptibility to pathogen invasion. Calcium-mediated stabilization of cell walls and membranes also restricts enzymatic activity and microbial proliferation. Delayed pulp color development further reflects reduced metabolic activity and slower pigment synthesis associated with suppressed ethylene action. These findings are in agreement with Karemera and Habimana (2014), who reported improved pulp color and reduced decay in $CaCl_2$-treated mango fruits. Similar reductions in post-harvest decay have also been observed in strawberry and other fruits following calcium treatments (Eroğul et al., 2024; Rajkumar et al., 2019).

Shelf Life

Shelf life of mango fruits varied significantly among treatments, ranging from 9 days in the untreated control to 13 days in mangoes treated with 800 ppm $CaCl_2$. Calcium-treated fruits remained marketable for a longer period under ambient storage conditions. The extension of shelf life can be attributed to delayed ripening, reduced respiration rate, improved firmness retention, and lower decay incidence in calcium-treated fruits. By strengthening cell walls and stabilizing membranes, calcium chloride slows senescence and preserves overall fruit quality. These results are consistent with Ferreira (2004), who reported delayed ripening and extended shelf life of mangoes following post-harvest calcium chloride treatments. Similar shelf-life enhancement due to calcium application has been documented in mango and other fruits (Joyce et al., 2001; Shirzadeh et al., 2011).

Organoleptic Quality

Organoleptic evaluation revealed that calcium chloride–treated mangoes received higher sensory scores compared to untreated fruits. Among the treatments, mangoes treated with 800 ppm $CaCl_2$ achieved the highest overall acceptability scores, while the control fruits recorded the lowest scores. The improved sensory quality of calcium-treated fruits is associated with better firmness, delayed ripening, reduced decay, and a more balanced sugar–acid ratio. Calcium treatments preserve desirable textural and flavor attributes without negatively affecting sweetness, resulting in enhanced consumer acceptability. These findings are in line with previous studies reporting improved sensory quality in mango and other fruits following calcium chloride application (Karemera & Habimana, 2014). Table 7 and table 8 are presented below. Figure 3 shows the effect of different concentration of calcium chloride on physiological loss in weight of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081. Figure 4 shows the effect of different concentration of Calcium chloride on total soluble solid of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081. Figure 5 shows the effect of different concentration of Calcium chloride on shelf life of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081. Figure 6 shows the effect of different concentration of Calcium chloride on organoleptic test of taste of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas, Mahottari, 2081.

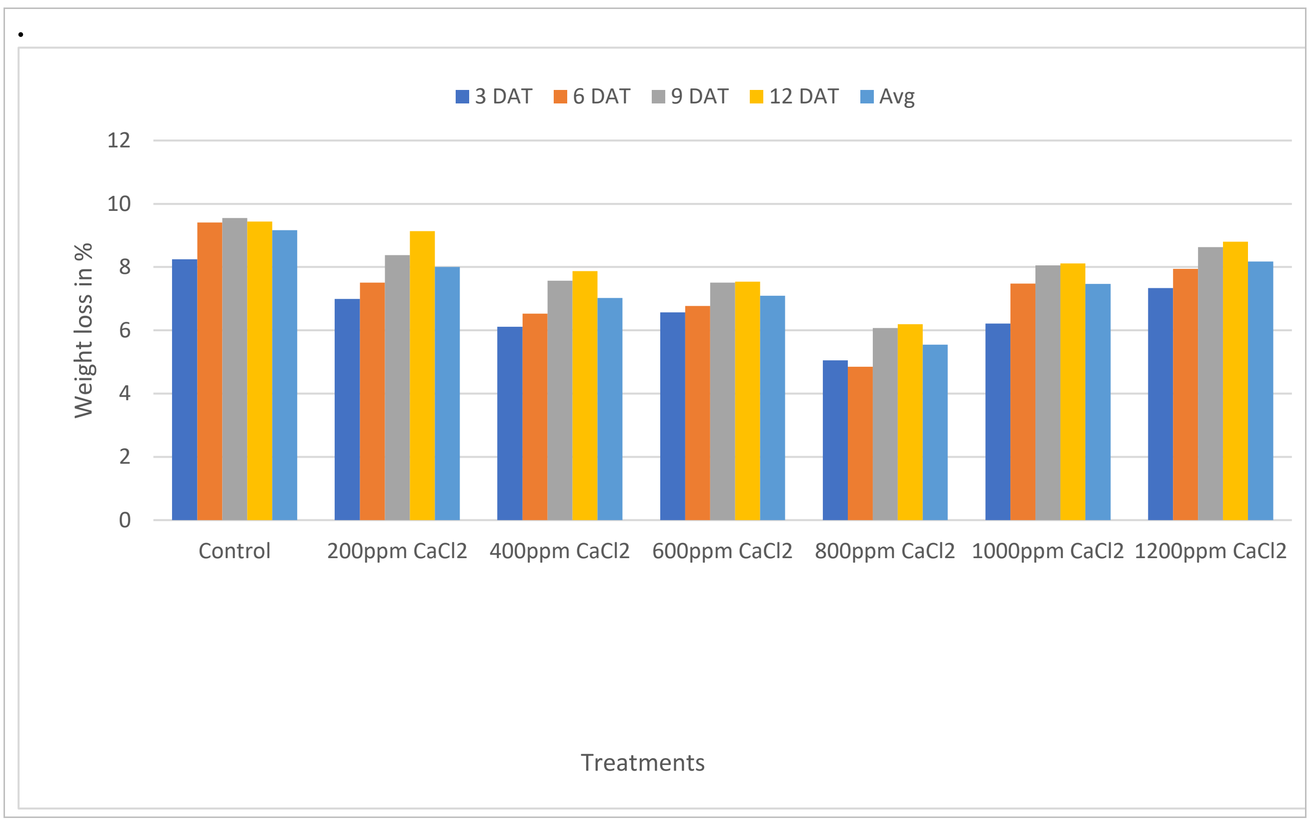

Figure 3: Effect of different concentration of calcium chloride on physiological loss in weight of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081

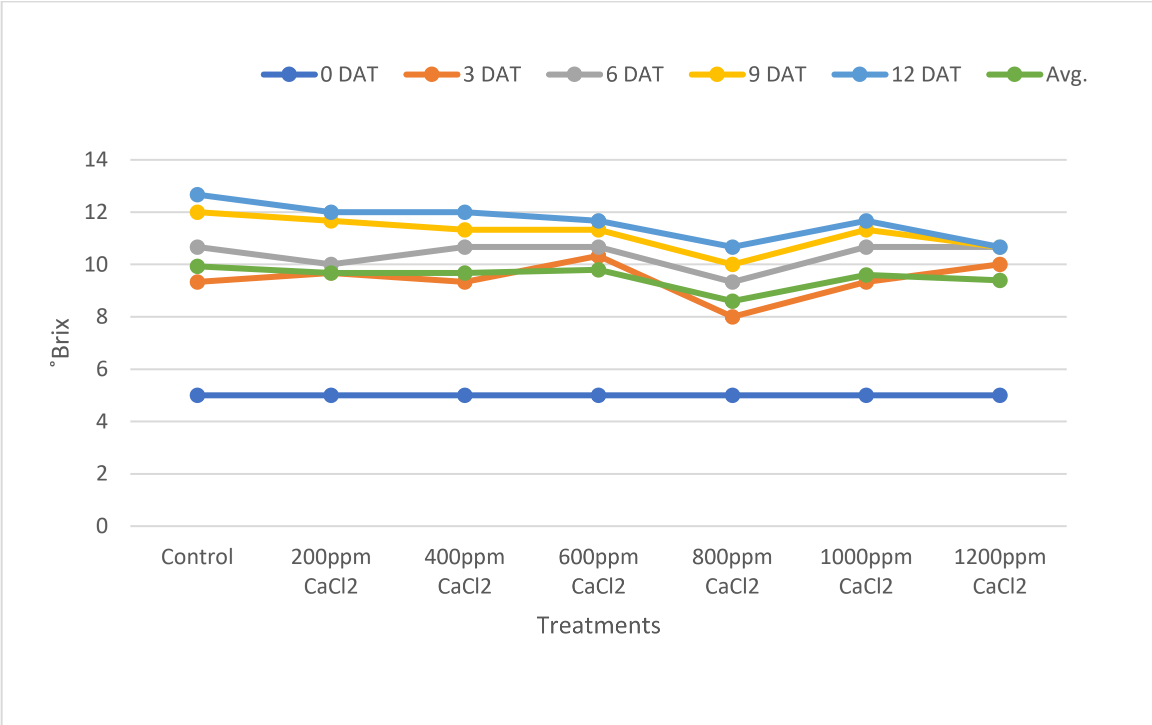

Figure 4: Effect of different concentration of Calcium chloride on total soluble solid of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081

Table 7: Effect of different concentration of Calcium chloride on TSS:TA ratio of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081

Treatment	TSS: TA Ratio					
	Initial	3DAT	6DAT	9DAT	12DAT	Avg.
Control	5.155	27.88^{d}	43^{c}	65^{b}	93^{c}	46.8^{c}
200ppm CaCl2	5.155	26.11^{cd}	35.7^{bc}	47.9^{a}	69.7^{b}	36.9^{b}
400ppm CaCl2	5.155	16.13^{ab}	28.9^{ab}	42^{a}	59.3^{ab}	30.3^{ab}
600ppm CaCl2	5.155	25.76^{cd}	37.7^{bc}	44.6^{a}	70.9^{b}	36.8^{b}
800ppm CaCl2	5.155	12.64^{a}	21.4^{a}	34.2^{a}	41.9^{a}	23.1^{a}
1000ppm CaCl2	5.155	20.18^{bc}	32.5^{bc}	39.4^{a}	66.5^{b}	32.8^{b}
1200ppm CaCl2	5.155	23.18^{cd}	36.8^{bc}	45.5^{a}	57.9^{ab}	33.7^{b}
Grand mean	5.155	21.7	33.7	45.5	65.6	34.3
CV%	-	17.1	16.9	16.9	15	14
SEm(±)	-	2.143	3.29	4.45	5.66	2.78
LSD	-	6.499	9.99	13.5	17.18	8.42
F-value	-	***	**	**	***	**

Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV=Coefficient of Variation, LSD= Least Significant Difference, SEm(±)=Standard Errors of Means, *=Significantly different at (p<0.05), **=highly significant different at (p<0.01), ***=very significantly different at (p=<0.001), NS=Non-significant.

Table 8: Effect of different concentration of Calcium chloride on rotting % and pulp color of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas, Mahottari, 2081

Treatment	Rotting %	Pulp color
Control	2.4^{c}	2.33^{ab}
200ppm CaCl2	1.933^{bc}	2.2^{a}
400ppm CaCl2	1.667^{ab}	2.333^{a}
600ppm CaCl2	2.333^{c}	2.2^{a}
800ppm CaCl2	1.2^{a}	2.667^{b}
1000ppm CaCl2	1.933^{bc}	2.2^{a}
1200ppm CaCl2	2.133^{bc}	2.333^{a}
Grand mean	1.943	2.324
CV%	13.8	5.9
SEm(±)	0.1553	0.0797
LSD	0.4711	0.2417
F-value	***	**

Mean in a column with same letters are not significantly different (p=0.05) according to DMRT, CV=Coefficient of Variation, LSD= Least Significant Difference, Sem (±)=Standard Errors of Means, *=Significantly different at (p<0.05), **=highly significant different at (p<0.01), ***=very significantly different at (p=<0.001), NS=Non-significant.

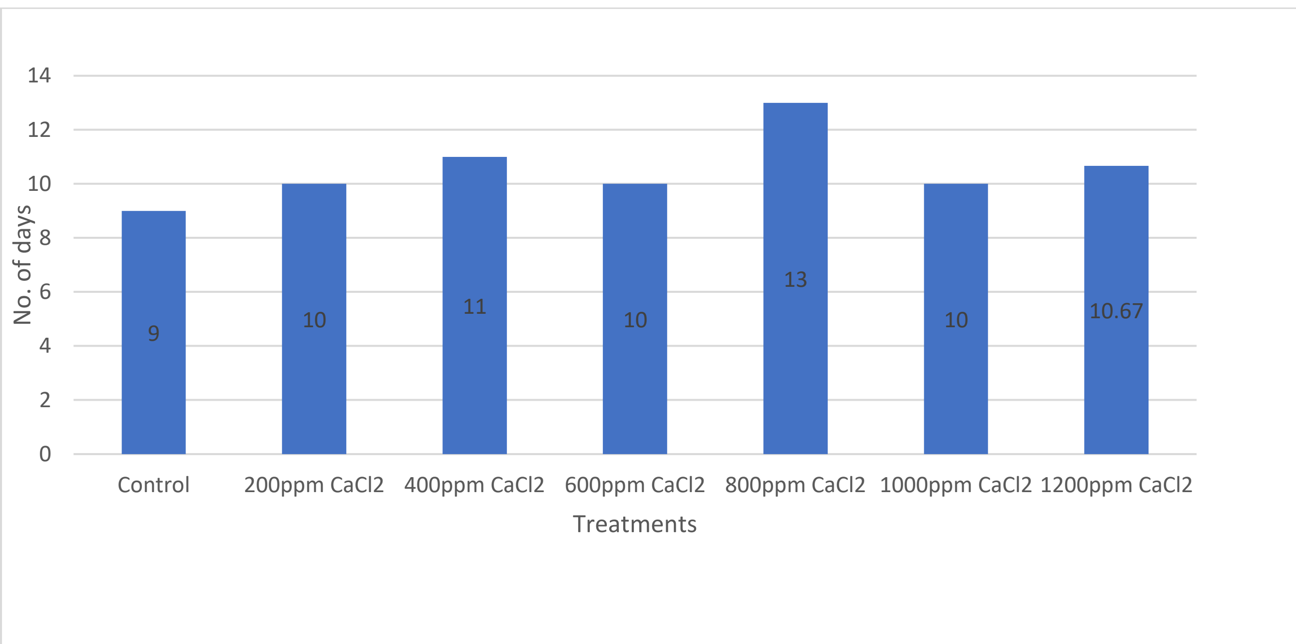

Figure 5: Effect of different concentration of Calcium chloride on shelf life of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas,Mahottari, 2081

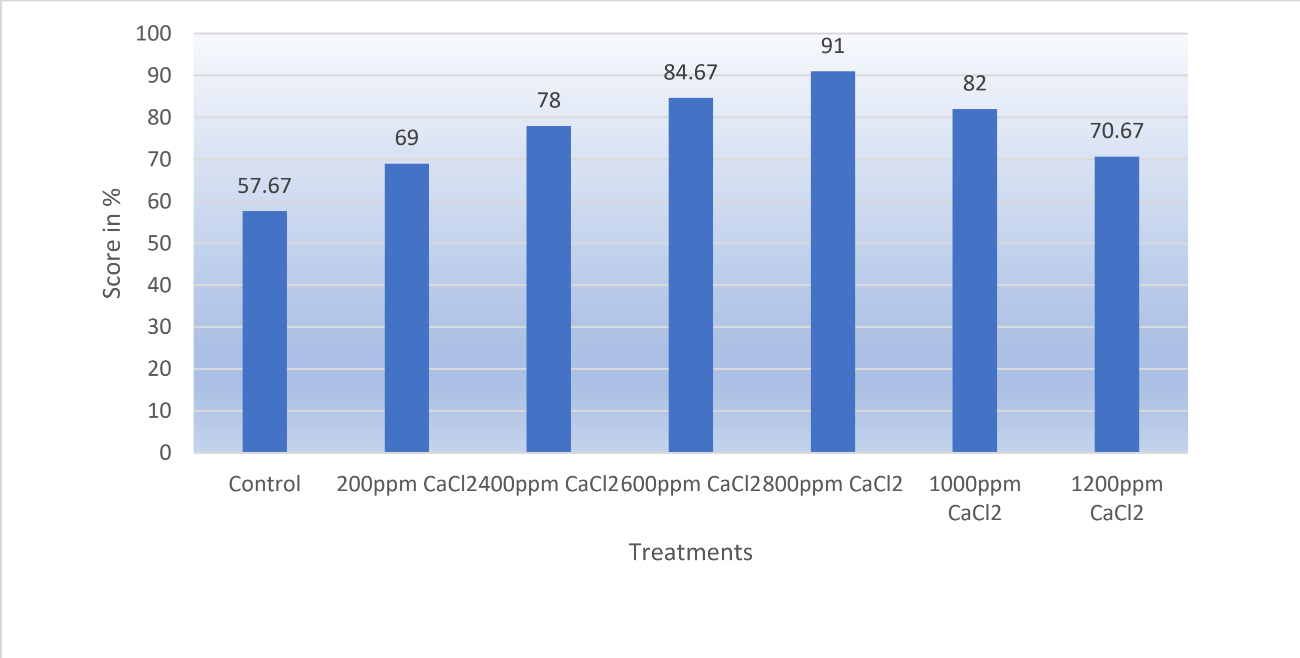

Figure 6: Effect of different concentration of Calcium chloride on organoleptic test of taste of Mango (*Mangifera indica L.cv.* Calcuttia) in Bardibas, Mahottari, 2081

Conclusion

This study demonstrates that post-harvest treatment with calcium chloride significantly affects the physio-chemical quality and storage behavior of mango (Mangifera indica L. cv. Calcuttia) under ambient conditions. Calcium chloride application reduced physiological weight loss, decay incidence, pulp color progression, and TSS:TA ratio, while maintaining higher firmness, titratable acidity, sensory acceptability, and extended shelf life. Total soluble solids were not significantly influenced, indicating that calcium treatment delayed ripening without adversely affecting sweetness. Among the tested concentrations, a 10-minute dip in 800 ppm $CaCl_2$ was the most effective, extending shelf life to 13 days compared with 9 days in untreated fruit. The beneficial effects are attributed to calcium-mediated stabilization of cell walls and membranes, suppression of respiration and ethylene production, and delayed enzymatic degradation associated with fruit softening and senescence. Higher concentrations did not result in additional quality improvements. These findings suggest that an optimized calcium chloride dip represents an effective post-harvest strategy for maintaining quality and extending shelf life of ‘Calcuttia’ mango. Further studies under commercial handling and distribution conditions are required to validate its broader applicability and to assess potential integration with other non-chemical post-harvest technologies.

Declaration

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