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Research Article

Effects of Calcium Chloride on Shelf Life and Quality of Banana (*Musa sapientum* cv. Jin)

Susmita Dhali [1], Shamim Ahmed Kamal Uddin Khan[1], Juan C. Díaz-Pérez[2] and Md. Yamin Kabir[1]*

[1]Agrotechnology Discipline, Khulna University, Khulna 9208, Bangladesh
[2]Department of Horticulture, University of Georgia, Tifton, GA 31793, USA

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Correspondence
Md. Yamin Kabir
✉: yaminkabir@at.ku.ac.bd

ABSTRACT

Banana is a popular fruit that has been extensively cultivated in Bangladesh. However, high perishability along with very short shelf life of banana leads to immense fruit losses every year. An experiment was conducted to evaluate the effect of calcium chloride ($CaCl_2$) on the quality attributes and shelf life of bananas cv. Jin. The experiment was laid out in a completely randomized design with four treatments (3%, 5%, and 9% $CaCl_2$ concentrations and an untreated control) and three replications. The fingers of bananas were separated; randomly divided into four groups (10 fruits per group), and wetted with the $CaCl_2$ solution through spraying. The 5% $CaCl_2$ treatment resulted in decreased cumulative fruit weight loss (17.85%), disease severity (50%), disease incidence (70%), and extended shelf life (5.33 days) compared to the untreated control. Banana fruit treated with 5% $CaCl_2$ also delayed color development and maintained fruit quality (TSS, vitamin C). Therefore, a 5% $CaCl_2$ application could be recommended for extending fruit shelf life and decreasing the decay and water loss of bananas.

Introduction

Fruits are healthy food items for human consumption worldwide, rich in vitamins (A, B, and C) and minerals (iron, calcium, and iodine) (Pokhrel, 2021). However, they are highly susceptible to decay and have limited storability (Hu et al., 2017) which is decreased by faulty handling and preservation techniques along with microbial attack. Therefore, a vast quantity of fruits is lost due to faulty postharvest management.

Banana (*Musa sapientum* L.) is a popular and one of the most favoured fruits in the world. It is a key socioeconomically important crop in tropical and subtropical countries of Asia (Southeast), Africa (east, central, and west), South America and the Caribbean Islands and rich in carbohydrate, fibre, minerals (potassium, magnesium, phosphorous), and vitamins (vitamin B complex, vitamin C) (Ngoko Tchamba et al., 2024). It aids in digestion, weight loss, and cardiac health. However, banana is a climacteric fruit, thus highly perishable having very short shelf life (Ngoko Tchamba et al., 2024). Postharvest loss of banana varied based on variety, storage conditions, and handling and it can be 30% or higher in the developing countries due to poor storage, handling, and infrastructure (FAO, 2023).

In Bangladesh, banana is a popular and widely accepted fruit (Hossain and Iqbal, 2016) and ranks first in terms of area. Bangladesh produces 826,152 metric tons of bananas from an area of 49,470 ha in the fiscal year 2020-2021 (BBS, 2021). However, the postharvest loss of banana is 21.67% of total production in Bangladesh (Saha et al., 2021) primarily due to faulty postharvest management. Calcium chloride ($CaCl_2$) is widely used for postharvest preservation of various fruits including banana, papaya, mango, watermelon, apple, strawberry, gooseberry, loquat, pomegranate, and sweet cherry. $CaCl_2$—a non-hazardous agent—dissociates readily into calcium and chloride ions, which are required for all animals, including humans. Thus, $CaCl_2$ is a very good combination that has been used for

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postharvest fruit management. Various concentrations of $CaCl_2$ such as 3%, 4%, 5%, 0-6% have been used for banana, and jabuticaba (Elbagoury et al., 2021; Garcia et al., 2019; Minh, 2022). Calcium of $CaCl_2$ strengthens cell wall and cell membrane, improves firmness, delays senescence, prolongs shelf life, and decreases spread of anthracnose in banana (Hocking et al., 2016; Le et al., 2018). While a 3% $CaCl_2$ increases fruit firmness, decreases fruit decay, and controls TSS and vitamin C content in banana (Minh, 2022), a 4% $CaCl_2$ decreases respiration, ethylene production, and chilling injury and increases fruit quality and shelf life of the fruit (Elbagoury et al., 2021). $CaCl_2$ delays fruit weight loss and increases firmness in peach (Shalan, 2020). It inhibits lightness decline in mature green and ripening banana at cold storage (Jiao et al., 2018). It delays browning, chilling injury, and physiological disorders of banana, loquat, pomegranate, sweet cherry, apple, and bell pepper (Kabir et al., 2024; Li et al., 2020; Ramezanian et al., 2010; Jiao et al., 2018; Wang et al., 2014; Luo et al., 2011). Combined application of 4% $CaCl_2$ and polyethylene bag increases total sugars, ascorbic acid, and shelf life of banana (Sahay et al., 2017). Though $CaCl_2$ has been used for postharvest management of bananas, reports on the cultivar Jin are scarce. Therefore, the present study was conducted to evaluate the effect of $CaCl_2$ on postharvest quality and shelf life of banana cv. Jin.

Materials and Methods

Experimental site and design

The lab experiment was carried out from 24 to 30 May 2023 at the Laboratory of Horticulture of Khulna University, Khulna 9208, Bangladesh, following a completely randomized design, and was replicated thrice, and each replication consisted of 10 fruits (fingers) of banana. Bananas were collected from Khulna and transported to the Horticulture Laboratory at the earliest convenience using an air-cooled vehicle. Sufficient care was taken to avoid any physical injury during transportation. On arrival in the lab, the bananas were cleaned, and field heat was removed with a cooling fan. Banana 'Jin' is a popular cultivar in Khulna region, having pendent bunches, 6-8 hands/bunch and 12-16 fruits (fingers)/ hand. The fruit is elongated with a curve in the middle. The pericarp is medium thick. Ripe bananas have an excellent texture and aroma.

Postharvest treatments

$CaCl_2$ (Merck KGaA, Billerica, USA) (100%) mixed with distilled water to prepare 3%, 5%, and 9%. The fingers of bananas were separated; randomly divided into four groups (10 fruits per group), and wetted with the $CaCl_2$.solution through spraying and the fruits were placed separately on the clean newspaper. Only high-quality fruits were used, and treatments were applied randomly; the control received no treatment.

Data collection

Fruits used in the experiment were observed regularly to collect data on physical attributes such as fresh weight (g), weight loss (%), firmness (score on a scale of 1-5), color, and shelf life (days); microbiological attributes like disease incidence and disease severity; chemical attributes like total soluble solids (TSS, %Brix), titratable acidity (TA, %), vitamin C (mg/100g) were measured following standard procedures as described below. Physical and microbial characteristics were recorded daily. Data on chemical attributes were recorded on alternate days. Collection of data continued up to 7 days after application of treatment.

Visual color assessment

The visual skin color of fruits was assessed according to a standard rating scale (scale 1 to 5) where 1 indicates 100% green skin, 2 means 1%-25% yellow, 3 means 26%-50% yellow, 4 means 51%-75% yellow, and 5 means 76%-100% yellow (Dang et al., 2008).

Assessing fruit color by using a Hunterlab Colourflex

The fruit skin color was also recorded for the color coordinates as L*, a*, and b* from the opposite positions. These values are also used to calculate chroma value (C*) and hue angle (h°), such as $C^* = (a^{*2} + b^{*2})^{1/2}$ and $h° = \tan^{-1} b^*/a^*$ (McGuire, 1992).

Subjective fruit firmness

Fruit firmness was recorded hedonically with a rating scale of 1 to 5 following Dang et al. (2008), where 1 = hard, 2 = sprung, 3 = slightly soft, 4 = eating soft, and 5 = over soft.

Determination of weight loss (%)

The fruit weight loss was calculated according to the following formula (Kabir and Hossain, 2024).

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

Determination of titratable acidity (TA, %) and total soluble solid (TSS, %Brix)

TA was estimated by titration of 5.0 mL aliquot (10 mL of fresh juice mixed with 20 ml distilled water,) against 0.1 N NaOH and phenolphthalein as the indicator endpoint and expressed as malic acid percentage as follows (Nerdy, 2018).

$$\text{Malic acid (\%)} = \frac{0.0067 \times Vol.\ of\ NaOH \times 3\ 0 \times 100}{5 \times 10}$$

Where,
0.0067 = Milli-equivalent weight of malic acid
30 = Total volume (mL)
5 = Extract juice sample (mL)
10 = Volume of aliquot (mL)

To measure TSS, a drop of juice was placed on the prism of Digital Brix Meter (Digital/Brix/RI-Check Refractometer, Reichert Technologies Inc., Japan) and the readings were recorded. The TA:TSS ratio was computed by dividing TA by the corresponding TSS.

Determination of vitamin C (mg per 100g)

Vitamin C was determined by the dye (2,6-dichlorophenol indophenols dye) titration method (Nerdy, 2018).

$$\text{Vitamin C (mg per 100g)} = \frac{e \times d \times b}{c \times a}$$

Where,
a= Weight of sample
b= Volume made with metaphosphoric acid
c= Volume of aliquot taken for estimation
d= Dye factor
e= Average burette reading for sample

Assessment of disease incidence (%) and disease severity (%)

Disease incidence represents the percentage of fruits with disease symptoms such as black spots and strips. The disease incidence was calculated as follows –

$$\% \text{ Disease incidence} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits}} \times 100$$

The percentage of infected fruit area is considered as disease severity and measured through eye estimation (Kabir and Hossain, 2024).

Shelf life (days)

The shelf life is the required days to ripen a banana fully and retain its edibility and marketability. Shelf life was determined on the basis of physical attributes such as fruit weight loss, change in color, firmness, and disease severity. These attributes were evaluated visually with criteria based on a consumer perspective, grading the fruit as acceptable for buying or selling. The fruits are considered acceptable until the score for disease severity is less than 12%, color change is less than 5, firmness score is 3, and cumulative weight loss is less than 15%.

Statistical analysis

The data were analysed following a one-way analysis of variance and F-test with the MSTAT-C program. The mean differences were evaluated by Tukey's HSD Test at a 5% level of significance.

Results

Climate of the experimental room

The average day temperature (24-30 May 2023) of the experimental room ranged from 29-30 °C, and the afternoon relative humidity (RH) ranged from 82%-85% with an average of 84%, indicating prevalence of hot and humid weather of the experimental room (Fig. 1).

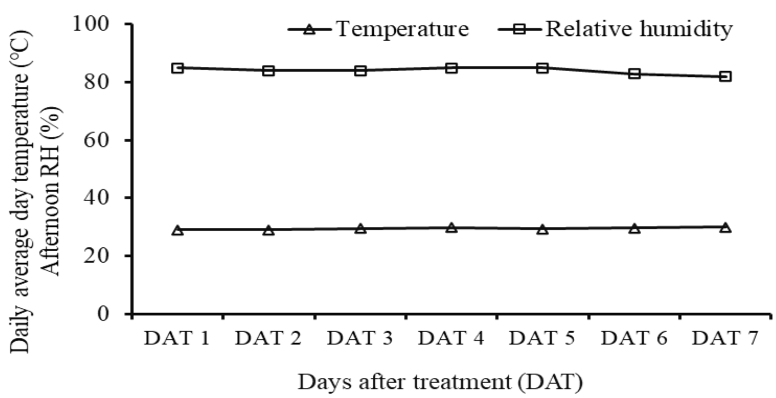

Fig.1. Daily average day temperature (°) and afternoon relative humidity (RH, %) during the experimental period. Khulna, Bangladesh.

Fruit weight loss and firmness

Cumulative weight loss (%) of banana fruit was inconsistent due to $CaCl_2$ application and it was not significant except at DAT 3 and DAT 7 (Fig. 2). At DAT 3 and DAT 7, 5% $CaCl_2$ reduced the cumulative weight loss of banana significantly (Fig. 2). At DAT 7, the minimum cumulative weight loss (17.85%) was observed from the 5% $CaCl_2$ coated banana fruits, and the maximum weight loss from the control treatment. $CaCl_2$ treated bananas were significantly more firm than untreated fruits at DATs 3, 4, and 5 (Fig. 3).

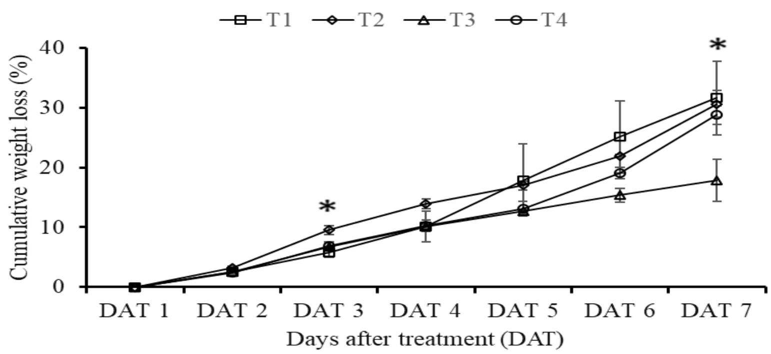

Fig. 2. Effect of calcium chloride on cumulative weight loss (%) of banana fruit. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. * represents significance at a 5% level of probability. Khulna, Bangladesh.

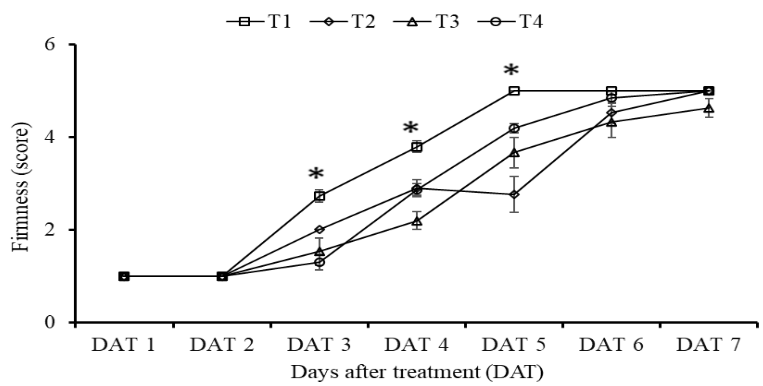

Fig. 3. Effect of calcium chloride on fruit firmness of banana. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. Firmness was measured hedonically using a rating scale of 1 to 5 (1 = hard, 2 = sprung, 3 = slightly soft, 4 = eating soft, and 5 = over soft). The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. * represents significance at a 5% level of probability. Khulna, Bangladesh.

Fruit color

The L* values were significantly different at DATs 1, 5, 6, and 7 and $CaCl_2$ resulted in increased L* values of banana skin compared to untreated control. The maximum L* value (51.74) was obtained at DAT 7 with 9% $CaCl_2$ (Fig. 4). The a* value varied among the treatments at DAT 1 and DAT 7, and it was more positive (5.82) with 5% $CaCl_2$ treatments at DAT 7 (Fig. 4). Hue angle (h°) showed a decreasing trend from DAT 1 to DAT 7, and it was significant at DATs 1, 5, and 7 (Fig. 4). The maximum hue angle was 80.92 for 3% $CaCl_2$ at DAT 7, and the minimum was 42.75 for the control. The visual color evaluation indicated that untreated bananas developed yellow color significantly faster than $CaCl_2$ treated fruits at DATs 2-5 (Fig. 5).

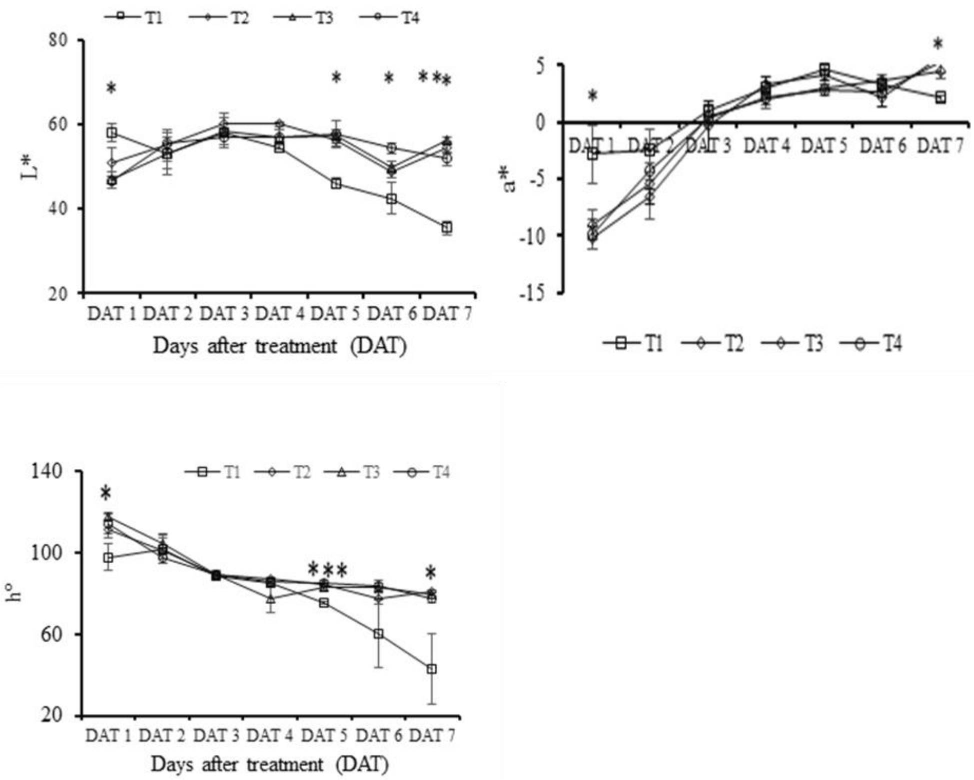

Fig. 4. Effect of calcium chloride on color L*, a*, h° of banana. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. *, ** represent significance at 5% and 1% levels of probability, respectively. Khulna, Bangladesh.

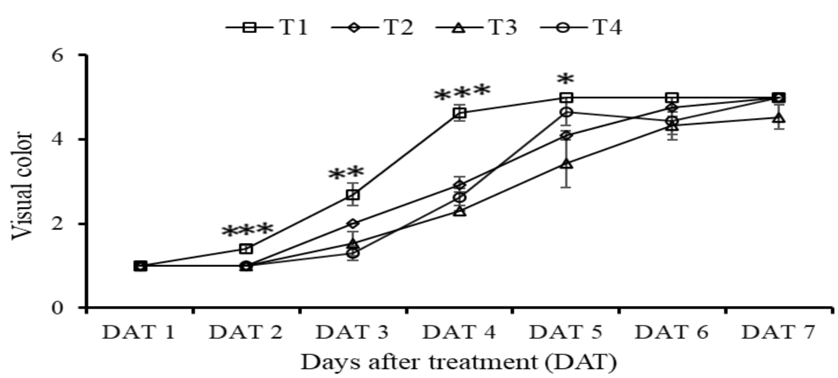

Fig. 5. Effect of calcium chloride on the visual color of banana fruit. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. *, **, *** represent significant at 5%, 1%, and 0.1% levels of probability, respectively. Khulna, Bangladesh.

Fruit quality attributes

Fruit attributes like TSS, TA, TA: TSS ratio, and vitamin C content were affected by $CaCl_2$ treatment. Generally, TSS increased and TA and vitamin C decreased during storage irrespective of treatments. The maximum TSS (22.67%) was recorded from the control treatment at DAT 7 and 5% $CaCl_2$ resulted in the lowest TA (0.27 %) on the same date (Fig. 6). The TA: TSS ratio was significantly highest with the control treatment for all DATs (Fig. 6). At DAT 7, 9% $CaCl_2$ treated fruits retained the highest vitamin C (3.76 mg $100g^{-1}$) which was statistically similar to the control treatment (Fig. 7).

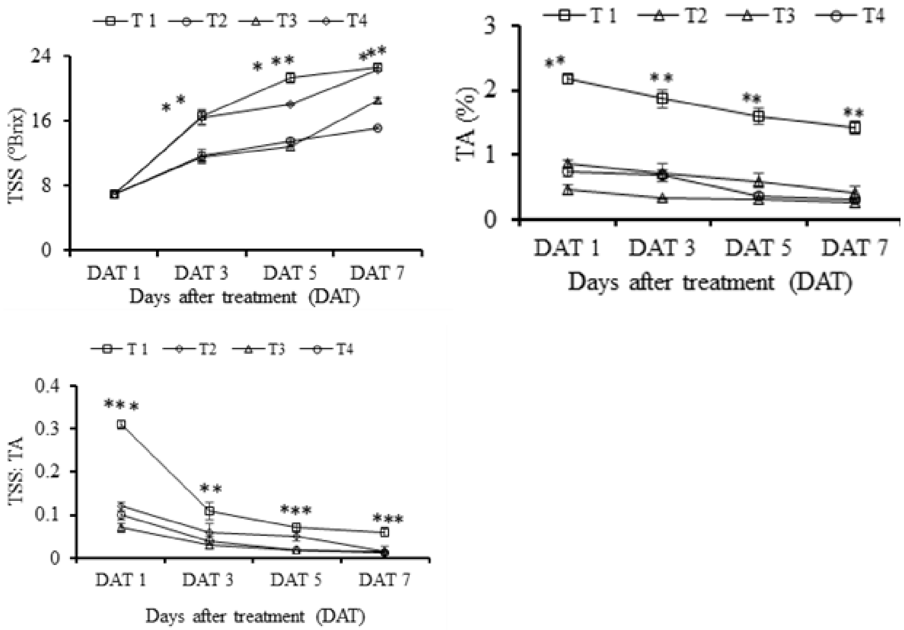

Fig. 6. Effect of calcium chloride on TSS (total soluble solids) and TA (titratable acidity) of banana fruit. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. **, *** represent significant at 1% and 0.1% levels of probability, respectively. Khulna, Bangladesh.

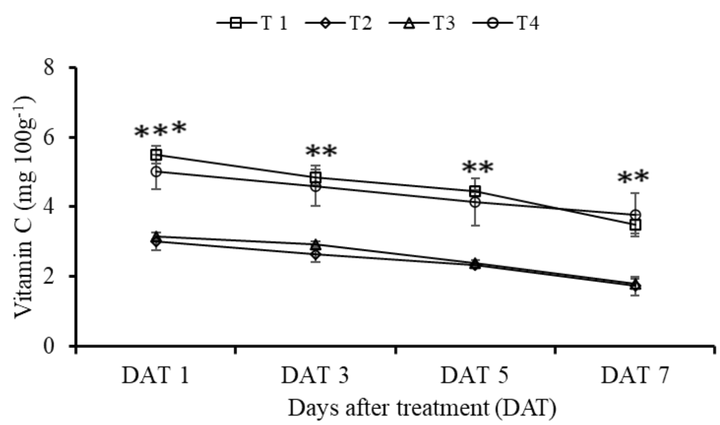

Fig. 7. Effect of calcium chloride on vitamin C content of banana fruit. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. **, *** represent significant at 1% and 0.1% levels of probability, respectively. Khulna, Bangladesh.

Disease incidence and severity

The disease incidence varied statistically among the treatments at DATs 5 and 6 (Fig. 8). The highest disease incidence (80%) was recorded from the control treatment and the lowest (56.7%) from 9% $CaCl_2$ at DAT 7. Disease severity also varied significantly at DATs 6 and 7. At DAT 7, the disease grew 80% of the fruit surface in untreated fruits which reduced to 50% fruit surface with 5% $CaCl_2$ (Fig. 9).

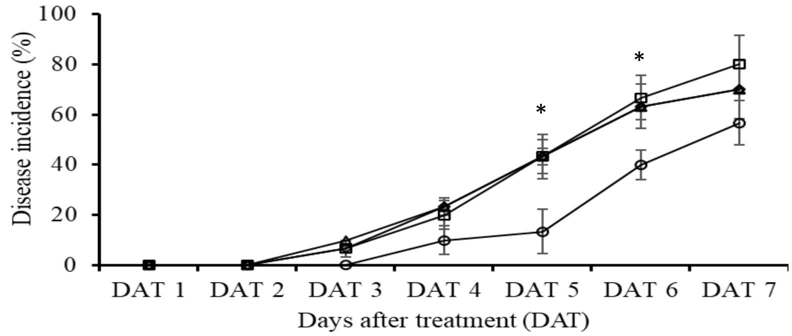

Fig. 8. Effect of calcium chloride on disease incidence of banana fruit. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. * represents significance at a 5% level of probability. Khulna, Bangladesh.

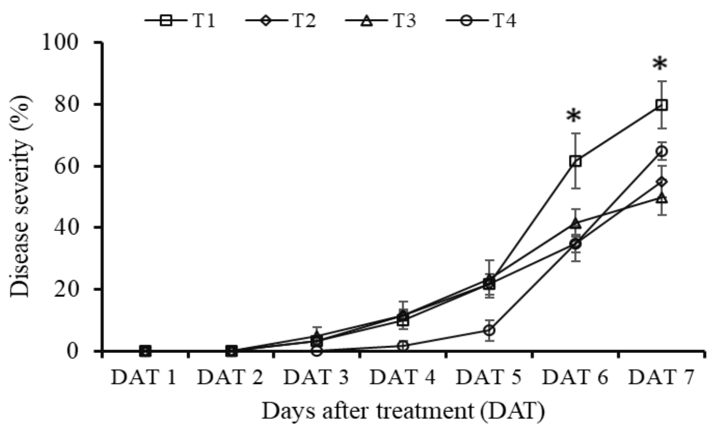

Fig. 9. Effect of calcium chloride on disease severity of banana. T_1= Control, T_2= 3% $CaCl_2$, T_3= 5% $CaCl_2$, T_4= 9% $CaCl_2$. The error bar represents mean ± SE (standard error). The means were compared at 5% level of probability. * represents significance at a 5% level of probability. Khulna, Bangladesh.

Shelf life

The shelf life of banana varied significantly among the treatments (Fig. 10). The highest shelf life (5.33 days) was recorded for the treatment 5% $CaCl_2$ which was statistically similar to 9% $CaCl_2$ (5 days) and 3% $CaCl_2$ (4.58 days). The lowest shelf life (3.38 days) was obtained from the control (without $CaCl_2$) treatment suggesting that 5% $CaCl_2$ treatment can increase the banana shelf life by couple of days (Fig. 10).

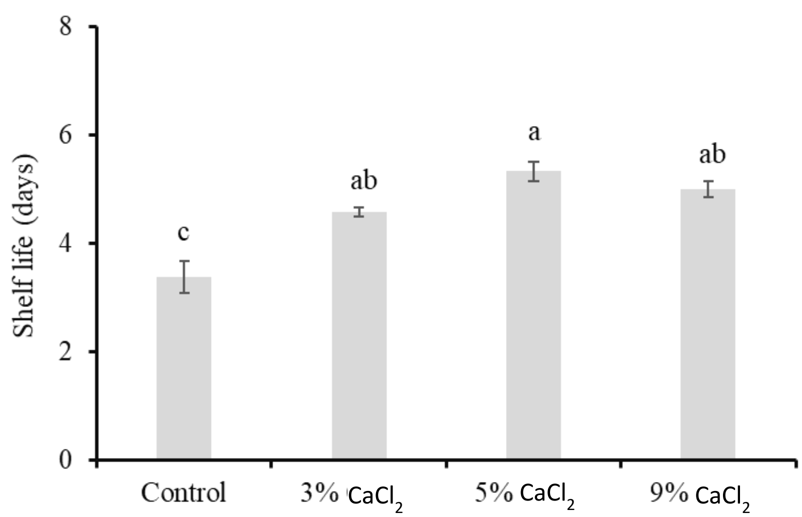

Fig. 10. Effect of calcium chloride ($CaCl_2$) on the shelf life of Banana. The error bar represents mean ± SE (standard error). The treatment means (average of three measurements) are separated by Tukey's HSD Test at a 5% (p < 0.05) level of probability. Khulna, Bangladesh.

Discussion

Storage conditions

Storage conditions such as air temperature and RH are the critical determinants of fresh fruit-keeping quality (Rodrigues et al., 2021). Prevalence of high temperature (>30 °C) and high RH (> 80%) during the experiment accelerate the ripening process through increasing respiration. Again, the edibility and marketability of fresh fruits diminish quickly due to the prevailing high temperature and RH. Such a hot and humid condition leads to a loss of considerable proportion of bananas at postharvest in Bangladesh (Saha et al., 2021).

Fruit weight loss and firmness

Untreated banana fruit generally lost more weight and became soft quickly compared to $CaCl_2$ treated fruits. Fruit firmness is required for consumer acceptance, marketability, storability, and fruit quality. Calcium can increase fruit firmness through decreasing cell wall hydrolysis and maintaining cell wall rigidity (Elbagoury et al., 2021). It also maintains membrane integrity though delaying lipid breakdown and thus, increases fruit firmness (Jiao et al., 2018). Calcium strengthens cell wall and cell membrane and improves firmness in banana (Hocking et al., 2016; Le et al., 2018). $CaCl_2$ delays fruit weight loss and increases firmness in peach too (Shalan, 2020).

Fruit color

$CaCl_2$ resulted in higher values of color L* and a* and lower values of h°, i.e., during storage, $CaCl_2$ delayed color development, thus delayed the ripening process. $CaCl_2$ inhibits lightness decline in mature green and ripening banana at cold storage (Jiao et al., 2018). Similarly, $CaCl_2$ delayed the color development of mature green tomato (Mazumder et al., 2021). The slow color development in banana fruit might be linked to a reduced rate of respiration and ethylene production that decelerates the processes of ripening and senescence of banana fruits.

Fruit chemical attributes

Though the application of calcium influences sugars, acids, anthocyanins, and fruit texture at postharvest, there is a lack of consistency in the effect of $CaCl_2$ on total soluble solids (TSS) and titratable acidity (TA), and thus TA: TSS ratio and vitamin C content of banana fruits. However, $CaCl_2$ significantly increases the TSS in papaya (Gao et al., 2020), apple, and persimmon (Bagheri et al., 2015). A 3% $CaCl_2$ controls TSS and vitamin C content in banana (Minh, 2022) and a combination of 4% $CaCl_2$ and polyethylene bag increases total sugars and ascorbic acid in the fruit (Sahay et al., 2017). Though 3% and 5% $CaCl_2$ showed a decrease in TSS and vitamin C, the control and the 9% $CaCl_2$ resulted in the highest TSS and vitamin C, and the similar results were reported by the other researchers.

Disease incidence and severity

Calcium slowed down the incidence and severity of diseases compared to the control. Though the treated and untreated fruits had similar trend of infection, the rate of disease incidence and severity were higher in untreated fruits than in treated ones. Similarly, calcium decreases spread of anthracnose in banana (Le et al., 2018) probably by changing phenolics and antioxidants in the fruit (Elbagoury et al., 2021).

Shelf life

Calcium delays senescence and ripening and thus, prolongs shelf life in banana (Le et al., 2018; Elbagoury et al., 2021). Calcium increases banana shelf life by slowing down the processes, such as fruit weight loss, softening, ripening, and senescence (Jiao et al. 2018). $CaCl_2$ also extends the shelf life of apple, tomato, persimmon, papaya and peach (Bagheri et al., 2015; Gao et al., 2020; Sohail et al., 2015). $CaCl_2$ also increases quality and shelf life of nectarine presumably by delaying softening, ripening, and senescence of fruit (Hajiesmaeili and Danaee, 2024). However, another study reported that $CaCl_2$ had no satisfactory effect on banana shelf life. In the present study, 5% $CaCl_2$ increases shelf life of banana by two days compared to the control suggesting that $CaCl_2$ can be used for extending postharvest shelf life of bananas.

Conclusion

Banana fruit treated with $CaCl_2$ (5%) resulted in lower cumulative fruit weight loss (17.8% vs. 31.6%), disease severity (50% vs. 80%), disease incidence (70% *vs.* 80%), and increased shelf life (5.33 *vs.* 3.38 days) compared to the control. Fruit treated with 5% $CaCl_2$ maintained the acceptable fruit quality (TSS, vitamin C) as well. Therefore, application of 5% $CaCl_2$ may maintain fruit quality and prolong the shelf life of bananas at postharvest storage.

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