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Effectiveness of $CaCl_2$ treatment on quality attributes of banana fruit during storage

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Abstract

Banana is a delicious fruit with excellent nutrient components beneficial for human health. In post harvest, banana fruit is quickly ripe within few days at ambient temperature condition and its quality is seriously degraded afterwards. Extension of its stability during storage and distribution is very necessary to enhance its economic value. This research evaluated the effectiveness of $CaCl_2$ treatment on the physicochemical quality attributes, phytochemical and antioxidant activities and potential enzymes of banana fruit during storage. Banana fruits were dipped in 3% $CaCl_2$ solution for 5 min before draining on racks for 30 min at ambient temperature to remove excess calcium chloride solution. Another banana group is dipped in clean water, leaved on racks for 30 min as the control. Both these fruit groups were then stored at 4±0.5°C with 85-90% relative humidity for 28 days. In 7 day-interval, each group is taken to verify quality attributes such as decay index, firmness, extractable juice recovery, ascorbic acid, carotenoid, total soluble solid, phenolic content, total flavonoid content, DPPH radical scavenging rate, H_2O_2 content, catalase (CAT) activity, superoxide dismutase (SOD) activity of banana fruit during storage. Our findings demonstrated that $CaCl_2$ exerted a positive influence in limiting decay (2.24±0.11 mark); slowing down texture firmness reduction (7.25±0.10 N); enhancing the extractable juice recovery (85.49±1.12%); controlling ascorbic acid (12.79±0.13 mg/100 g), total soluble solid (16.40±0.13 °Brix), phenolic retention (161.35±1.19 mg GAE/100 g), flavonoid content (64.41±0.25 mg QE/100 g) and H_2O_2 accumulation (20.09±0.10 µmol/g); improving carotenoid (21.83±0.13 µg/100 g), catalase (15.28±0.12 U/g), superoxide dismutase activity (5.60±0.10 U/g), antioxidant capacity of banana fruit (46.20±0.15%) during chilling storage. $CaCl_2$ treatment would be an effective approach to extend shelf life of banana fruit in commercial distribution.

Keywords

banana fruit, calcium chloride treatment, chilling storage, quality attribute

Introduction

Calcium is an important mineral element in preserving post harvest quality of fruit and vegetable. It involved in forming the cell wall structure and cellular membrane by providing a linkage between calcium and pectin to form a complex of pectate-calcium (1). This application could delay senescence without any detrimental impact on consumer acceptance (2). Calcium treatment stabilized plant cell wall and membrane integrity, improved texture firmness, lowered membrane lipid catabolism, prolonged shelf-life of agricultural products (3). These functions of calcium effectively protected cell wall from catalyzing enzymes (4). Calcium is a vital secondary delivery in crop indication inspiration participating in physiological pathways and the interaction to different tension (5). In low-temperature disorders, sparked temporary accumulation of calcium ion is significant by various calcium capturing proteins, thus facilitating numerous physiological reactions in the cell (6). Calcium treatment is demonstrated to be effective on different kinds of fruits and vegetables such as chili pepper (7), loquat (8, 9), apple (10), peach (11, 12), persimmon (13), papaya (14, 15), gooseberry (16), strawberry (17), mango (18), purple shallot (19), soursop (20), tomato (21) and watermelon (22).

Banana (*Musa* spp.) belonged to Musaceae family which is widely cultivated in the tropical and subtropical locations like Africa, Asia, the Pacific, Latin America and the Caribbean. Banana is believed to have originated in Southeast Asia. Banana is highly preferred due to its unique favor, aroma, texture and attractive appearance. Banana is ranked 4th in the list of the most preferred foodstuffs. Banana is low in fat and protein but rich in carbohydrates, dietary fibers, vitamins, minerals with numerous therapeutic advantages (23). Banana is considered as a medicinal fruit against various ailments such as diarrhea, diabetes, cancer, ulcer, hypertension and infection (24). Banana belonged to climactic fruit exhibiting a respiratory peak in natural ripening at 20 °C. The quality of the green banana went down quickly during post harvest as a result of degradation in appearance, texture and taste. It is highly perishable within 2-3 days in hot humid condition (25); therefore a controlled ripening in the fresh state is very important in post harvest and distribution. Ripening is correlated to different biochemical modifications including texture softening, discoloration, off-aroma, astringent disappearance (26).

There were several notable studies mentioned to the application of calcium treatment on banana fruit. Banana (*Musa accuminata*) fruit is submerged in 50, 100 and 200 mg/l $CaCl_2$ to verify the impact of the divalent cation Ca^{2+} on organoleptic senescence, color change, fat content and moisture content. Calcium is effective in controlling the senescence in banana by slowing down the breakdown of chlorophyll. Moreover, this application also increased fat content of banana. Ca^{2+} participated in reinforcing cell membranes, retaining cell wall hardness, slowing down chlorophyll a decomposing enzyme, retarding respiration and decomposition of membrane lipid in banana (27). $CaCl_2$ treatment resulted to a higher pulp to peel ratio and an extended stability on banana fruit (28). Calcium treatment effectively increased in protein content while controlled the reduction of chlorophyll content and photosynthetic intensity in banana fruit (29). $CaCl_2$ treatment of 20 mM greatly inactivated proliferation of anthracnose disease caused by *Colletotrichum* (30).

Horticultural harvest encountered different physical injuries (mishandling, collision), inappropriate storage conditions (high storage temperature, fluctuation in relative humidity, high ethylene accumulation) and physiological disorders (ripening, microbial invasion) causing significant quality and quantity losses (31). Horticultural products were highly perishable throughout series of steps from harvesting, preservation, delivery, trading and consumption (32). Post-harvest losses were a big challenge in agricultural production because they directly affected to income of farmer, processor and distributor. The objective of our study investigated the influence of $CaCl_2$ treatment on the decay index, firmness, extractable juice recovery, ascorbic acid content, carotenoid content, total soluble solid content, total phenolic content, total flavonoid content, DPPH radical scavenging activity, H_2O_2 content, catalase (CAT) activity and superoxide dismutase (SOD) activity of banana fruit during storage.

Materials and Methods

Material

Banana fruits in maturity, uniformity and without defect were harvested in orchard in My Tu district, Soc Trang province, Vietnam.

Chemical reagents were all analytical grade. Standard β-carotene, hexane, Folin-Ciocalteu reagent, and 2, 6-dichlorophenol indophenols were purchased from Sigma Aldrich (USA). Thrichloracetic acid, methanol were supplied from Fisher Scientific (USA). Standard quercetin, gallic acid, aluminum chloride, sodium acetate, sodium carbonate, potassium phosphate, potassium iodine, nitroblue tetrazolium were purchased from Merck (Germany).

Methodology

Banana fruits (30 samples) were randomly separated into two different groups (control and $CaCl_2$ treatment). Control group (15 samples) is dipped in clean water for 5 min. Another group (15 samples) is dipped in 3% $CaCl_2$ solution for 5 min. 3 replications were prepared for each experiment. Both groups were drained on racks for 30 min at ambient temperature to remove excess water. They were then kept at 4±0.5°C with 85-90% relative humidity for 28 days. In 7 day-interval, samples were taken to define decay index, firmness, extractable juice recovery, ascorbic acid content, carotenoid content, total soluble solid content, total phenolic content, total flavonoid content, DPPH radical scavenging activity, H_2O_2 content, catalase (CAT) activity and superoxide dismutase (SOD) activity.

Decay index is determined by visual appearance of fruit from completely fresh (1 mark), decay 5-10% (2 marks), decay 10-30% (3 marks), decay 30-50% (4 marks), decay surpass 50% (5 marks) (29). Firmness (N) is verified by texture penetrometer (Stable Micro Systems, model: TA.XT*plusC*). Extractable juice recovery (%) is estimated as the difference between the initial mass and the weight of the pellet after centrifugation divided by the initial mass (33). Ascorbic acid content (mg/100 g) is determined by using a 2,6-dichlorophenol indophenol visual titration method described by AOAC (34). Carotenoid content (µg/100 g) is examined by high-performance liquid chromatography method (Techno, model: HPLC 580) using a polymeric C30 column (22). Total soluble solid content (°Brix) is evaluated by hand-held refractometer (Atago, model: Master-53M) (26). Total phenolic content (mg

GAE/100 g) is quantified by using Folin–Ciocalteu assay (20). The optical density is read by the absorbance at 765 nm using a spectrophotometer (Mettler Toledo, model: UV5) (35). Total flavonoid content (mg GE/100 g) is quantified by the aluminium calorimetric method. The optical density is read by absorbance at 415 nm using a spectrophotometer (Mettler Toledo, model: UV5) (36). DPPH radical scavenging activity (%) is identified by the percentage of inactivation to radical DPPH of one prototype solution concentration (37). H_2O_2 content (µmol/g) is identified by homogenizing 5 g of banana pulp tissue in ice bath with 50 ml 0.1% thrichloracetic acid. The macerate paste is centrifuged at 10000×g for 20 min and 10 ml of the supernatant is added to 10 ml 10 mM potassium phosphate buffer (pH 7.5) and 20 ml 1 M KI. The supernatant absorbance is measured at wavelength 390 nm. The H_2O_2 content (µmol/g) is expressed on a standard curve (38). Catalase (CAT) activity (U/g) is determined as the amount of enzyme reacting with 1 µmol of H_2O_2 per min and absorbance is read at wavelength 240 nm (39). Superoxide dismutase (SOD) activity (U/g) is identified as the amount of enzyme inducing 50% inhibition of nitroblue tetrazolium reduction (39).

Statistical analysis

The experiments were run in triplicate with different groups of samples. The data were presented as mean ± standard deviation. Statistical analysis is performed by the Statgraphics Centurion version XVI. The mean value and standard deviation of a set of data obtained by analysis of random samples estimating the population statistics. 95% of results would be expected to lie within the range we described the lower and upper bounds of this range as the 95% confidence limits of the results. The differences between the pickling samples were analyzed using a one-way analysis of variance (ANOVA). A significant value is set at a 95% confidence interval (P⊠0.05). If significant differences were found, then post hoc analysis is performed using Duncan's multiple range tests.

Results and Discussion

Effect of $CaCl_2$ post harvest treatment on decay index, firmness, extractable juice recovery of banana fruit during storage

Decay significantly happened on banana fruit at the 21st day and accelerated afterwards. $CaCl_2$ treatment minimized decay better than control. At the 28th day of storage, the decay index in $CaCl_2$-dipped sample (2.24±0.11 mark) is lower than that in the control (3.71±0.13 mark) (Table 1).

Table 1. Decay index (mark) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	1.00±0.10^a	1.91± 0.12^a	2.45±0.13^a	3.03± 0.14^a	3.71±0.13^a
$CaCl_2$	1.00±0.10^a	1.24± 0.13^b	1.63±0.11^b	1.98± 0.13^b	2.24±0.11^b

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

Anthracnose originated from *Colletotrichum gloeosporioides* is a major rotten disease in bananas. On green fruit, the fungus only created latent contamination. At the ripening stage, anthracnose behaviors occurred, grew and fruit became decay immediately (30). Firmness in banana fruit revealed a decrease trend during storage. However, the $CaCl_2$-dipped sample showed a gradual decrease in texture firmness (7.25±0.11 N) while the control presented a sharp firmness reduction (5.48±0.12 N) at the 28th day of storage (Table 2). Extractable juice recovery of $CaCl_2$ dipped banana built up remarkably (85.49±1.12 %) while that of the control increased slightly (72.90±1.16) during storage (Table 3). These findings emphasized that $CaCl_2$ treatment effectively retarded decay, slowed down texture firmness reduction and improved the extractable juice recovery during chilling storage. We did not observe morphological or physiological changes.

Table 2. Firmness (N) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	8.32± 0.14^a	7.83± 0.15^b	7.14± 0.13^b	6.28± 0.14^b	5.48± 0.12^b
$CaCl_2$	8.32± 0.14^a	8.19± 0.13^a	8.02± 0.11^a	7.76± 0.13^a	7.25± 0.11^a

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

Table 3. Extractable juice recovery (%) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	47.53 ±0.13^a	50.06 ±0.20^b	58.72±0.17^b	70.25 ±0.14^b	72.90±0.16^b $x \pm 2s$
$CaCl_2$	47.53±0.13^a	54.79 ±0.18^a	69.18±0.15^a	83.71 ±0.10^a	85.49±0.12^a

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

$CaCl_2$ contributed to the control of the fruit respiration rate thus delayed the ripening and stabilized the texture firmness (4). Preservation at low temperature induced to the degradation of the center membrane and cellular depression causing a limitation in the tissue firmness (40). Calcium maintained texture firmness of fruit and vegetable by establishing the bridge between pectic components within the cell-wall (41). The application of calcium improved new ionic bridges among calcium and galacturonic acids, reinforced the cell wall and especially the center lamella accounted for combining cells together. From that, the durability of the cell wall structure and center lamella could be enhanced (42, 43). Texture firmness is also maintained when de-esterified pectic acid balance created cross -links between anionic carboxylic segments and divalent cations limiting pectin dissolution (44).

$CaCl_2$ treated strawberry had better firmness compared to the control (45). Firmness of kiwi fruit would be higher by dipping in 1% $CaCl_2$ (46). 2% $CaCl_2$ strongly retarded spore germination and proliferation of the pathogen *Rhizopus stolonifer* (47). 1% $CaCl_2$ submergence slowed down ripening, enhanced self-defense to decay and preserved cell wall integrity of strawberry (48). Calcium treatment is proven be effective in retarding fungus proliferation, lowering physiological disorder and respiration (49, 50). Mature-green banana dipped in 200 mg/l of calcium chloride induced a significant retention of weight with a better shelf life (27). Calcium treatment inhibited mycelial development of the fungus *Fusarium oxysporum* f. sp. *cepae* that causing decay on onion (51). 1.5% $CaCl_2$ strongly retarded spore germination and proliferation of apple anthracnose lesions caused by *Colletotrichum acutatum* (52). 2% $CaCl_2$ treatment increased persimmon fruit firmness during 4 month storage at 0 °C (13). Calcium treatment showed a possibility to minimize the loss of cell integrity on peach (12). Calcium chloride is beneficial to lessen the internal discoloration of pineapple in cold storage (53). Calcium treatment is effective in inhibition of fungal development on guava fruit caused by *Alternaria* sp., *Aspergillus niger, Botrytis cinerea*, *Fusarium solani* (54); proliferation of *Lasiodiplodia theobromae* on mango (55). Calcium is proven to effectively inhibit the chilling injury on pear fruit (56). An incorporation of 50 °C of water dipping and 0.64% calcium chloride is efficient to maintain texture firmness of purple shallot (19). 1.5% $CaCl_2$ treatment on green matured tomato resulted low decay rate during 20 days of storage (57).

Effect of $CaCl_2$ post harvest treatment on ascorbic acid, carotenoid, total soluble solid of banana fruit during storage

There is a slight reduction of ascorbic acid on the $CaCl_2$-treated banana (12.79±0.13 mg/100 g) while a remarkable decrease of ascorbic acid on the control (11.68±0.12 mg/100 g) from day 7th to the day 28th of storage (Table 4).

Table 4. Ascorbic acid (mg/100 g) of banana fruit by the control and 3% CaCl2 treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	14.28± 0.17[a]	13.64± 0.14[b]	13.09± 0.13[b]	12.45± 0.14[b]	11.68± 0.12[b]
$CaCl_2$	14.28± 0.17[a]	14.03± 0.13[a]	13.86± 0.11[a]	13.17± 0.12[a]	12.79± 0.13[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

This might be due to $CaCl_2$ limited the oxidative degradation of ascorbic acid. Ascorbic acid participated in the respiration circle as well as photo-degradation therefore there is a downtrend of this content during storage (58). Ascorbic acid is one of the most vital vitamins available in fruit and vegetable. However it is very sensitive to oxidative decomposition (59). Carotenoid content built up on $CaCl_2$-treated banana (21.83±0.13 µg/100 g) higher than that on the control (19.07±0.12 µg/100 g) (Table 5). Extended storage induced to a higher loss of carotenoid content, followed by the evolution of ripening (60). The total soluble solid content increased during storage with a lower accumulation on the $CaCl_2$-treated banana (16.40±0.13 °Brix) compared to the control (19.23±0.12 °Brix) (Table 6). During storage, polysaccharides such as starches and pectins were metabolized into simple sugar (61). Our findings proved that $CaCl_2$ treatment significantly controlled ascorbic acid degradation; improved carotenoid content; and inhibited total soluble solid increment during cool storage.

Table 5. Carotenoid (µg/100 g) of banana fruit by the control and 3% CaCl2 treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	11.3±0.15[a]	13.82±0.14[b]	15.5±0.13[b]	18.20±0.14[b]	19.0±0.12[b]
$CaCl_2$	11.3±0.15[a]	14.54±0.13[a]	17.9±0.11[a]	20.46±0.12[a]	21.8±0.13[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

Table 6. Total soluble solid (oBrix) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	8.32± 0.12[a]	11.24± 0.14[a]	14.92± 0.12[a]	17.04± 0.10[a]	19.23± 0.12[a]
$CaCl_2$	8.32± 0.12[a]	9.67± 0.15[b]	12.51± 0.14[b]	14.75± 0.13[b]	16.40± 0.13[b]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

High ascorbic acid content in tomato is noticed by $CaCl_2$ treatment compared to the control (62). Calcium treatment effectively retained firmness of chili pepper (7). $CaCl_2$ treatment preserved the highest ascorbic acid, lycopene content on tomato during 14 days of ambient storage (63). 6% $CaCl_2$ remarkably minimized decay, while retained higher firmness and ascorbic acid of tomato fruit in a prolonged shelf life (64). 1.5% $CaCl_2$ treatment effectively preserved firmness and reduced decay severity on papaya fruit caused by anthracnose incidence (15). 2% $CaCl_2$ treatment significantly maintained the ascorbic acid content in raspberry and strawberry fruits (17). $CaCl_2$ treatment induced to a great reduction of anthracnose lesion circles in the infected papaya (65). 4 % $CaCl_2$ pre-harvest treatment resulted to higher total ascorbic acid content on citrus (66). Calcium treatment increased carotenoid content while maintained chlorophyll content, photosynthetic intensity in banana fruit (29). Tomato fruit treated by 6% $CaCl_2$ had an improvement of physicochemical attributes (67). An incorporation of 2.5% $CaCl_2$ and 0.6 ppm 1-MCP created a synergistic effect to prolong watermelon stability with minimal weight loss and decay rate while firmness, total soluble solid, carotenoid and ascorbic acid contents could be retained in an efficient manner (22).

Effect of $CaCl_2$ post harvest treatment on total phenolic content, total flavonoid content, DPPH radical scavenging rate of banana fruit during storage

There is a trend of reduction total phenolic content during storage with a remarkable decrease on the control (140.19±1.37 mg GAE/100 g) and slight falling on the $CaCl_2$-treated banana (161.35±1.19 mg GAE/100 g) at the 28th day of storage (Table 7). Similarly, the total flavonoid content also decreased during storage with a sharp reduction on the control (57.63±0.33 mg QE/100 g) while the $CaCl_2$-treated banana showed a better value (64.41±0.25 mg QE/100 g) (Table 8). DPPH of both the control and $CaCl_2$-treated banana fruit showed a minor improvement (44.39±0.12% and 46.20±0.15%, respectively) during stor-

Table 7. Total phenolic content (mg GAE/100 g) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	184.5±1.21[a]	174.18±1.30[b]	163.27±1.25[b]	151.34±1.41[b]	140.19±1.37[b]
$CaCl_2$	184.5±1.21[a]	179.32±1.17[a]	172.56±1.09[a]	167.20±1.20[a]	161.35±1.19[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

Table 8. Total flavonoid content (mg QE/100 g) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	75.19± 0.49[a]	71.38± 0.37[b]	68.51± 0.40[b]	63.17± 0.29[b]	57.63± 0.33[b]
$CaCl_2$	75.19± 0.49[a]	73.57± 0.28[a]	71.63± 0.31[a]	68.94± 0.27[a]	64.41± 0.25[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

age (Table 9). These findings expressed that $CaCl_2$ treatment efficiently minimized the reduction of phenolic constituents as well as better retention of antioxidant capacity on banana fruit during preservation.

Table 9. DPPH (%) of banana fruit by the control and 3% CaCl2 treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	42.3±0.15[a]	42.81±0.13[b]	43.3±0.16[b]	43.91±0.14[b]	44.3±0.12[b]
$CaCl_2$	42.3±0.15[a]	43.25±0.10[a]	44.0±0.12[a]	45.18±0.13[a]	46.2±0.15[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

2% $CaCl_2$ continuously maintained DPPH radical scavenging capacity until the last day (68). 0.2 M $CaCl_2$ treatment caused a reduction of tocopherol content and an accumulation of total phenolic content in lettuce (69). 80 mM $CaCl_2$ treatment retained high total phenol on cherry fruit (70). 2% $CaCl_2$ treatment increased antioxidant activities of persimmon fruit during 4 month storage at 0°C (13). 2% calcium chloride treatment showed high total antioxidant activity and total phenolic content on papaya fruit during storage (15). The raspberry and strawberry fruits treated with 2% $CaCl_2$ showed a positive retention of the total phenolic content during 8 days of storage at 0°C and relative humidity of 95% (17). 4% $CaCl_2$ pre-harvest treatment resulted to higher total phenol, total flavonoid and antioxidant capacity on citrus (65). Hydrothermal-calcium chloride treatment resulted in higher *L*-ascorbic acid, total phenol content and powerful antioxidant ability on pepper (71). A combination of 50 °C of water dipping and 0.64% of calcium chloride is useful to retain bioactive components such as total phenolic, total flavonoid and quercetin of purple shallot (19).

Effect of $CaCl_2$ post harvest treatment on H_2O_2 content, catalase (CAT) activity, superoxide dismutase (SOD) activity of banana fruit during storage

H_2O_2 content of banana fruit increased on both the control and treated sample with a sharp increase on the control (25.24±0.16 μmol/g) and a minor accumulation on the $CaCl_2$ -treated one (20.09±0.10 μmol/g) (Table 10). Hydrogen peroxide production during storage at high level is a negative symptom of membrane damage and quality deterioration (72). Catalase activity significantly accumulated on the $CaCl_2$-treated banana (15.28±0.12 U/g) higher than that on the control (13.91±0.13 U/g) (Table 11). Catalase activity is correlated to oxidative resistance and delayed ripening (73). High catalase activity is beneficial to eliminate reactive oxygen species, particularly O^{2-} released by biotransformation. Overload O^{2-} could speed up the membrane oxidative rancidity and senescence (74). Superoxide dismutase activity is increased during storage. $CaCl_2$-treated banana had a high SOD value (5.60±0.10 U/g) compared to the control (4.97±0.13 U/g) (Table 12). These results expressed that $CaCl_2$ treatment effectively controlled H_2O_2 accumulation while improved catalase and superoxide dismutase activity during cool storage.

Table 10. H_2O_2 content (μmol/g) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	17.04± 0.15[a]	20.49± 0.13[a]	38.26± 0.14[a]	31.17± 0.12[a]	25.24± 0.16[a]
$CaCl_2$	17.04± 0.15[a]	18.87± 0.12[b]	27.30± 0.12[b]	23.41± 0.13[b]	20.09± 0.10[b]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

Table 11. Catalase activity (U/g) of banana fruit by the control and 3% CaCl2 treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	13.2±0.12[a]	13.57±0.12[a]	14.6±0.12[a]	14.29±0.10[a]	13.9±0.13[a]
$CaCl_2$	13.2±0.12[a]	14.10±0.11[b]	19.4±0.13[b]	17.72±0.10[b]	15.2±0.12[b]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

Table 12. Superoxide dismutase activity (U/g) of banana fruit by the control and 3% $CaCl_2$ treatment during 28 days of storage

Storage (days)	0	7	14	21	28
Control	3.65± 0.13[a]	4.01± 0.13[b]	6.28± 0.10[b]	5.61± 0.12[b]	4.97± 0.13[b]
$CaCl_2$	3.65± 0.13[a]	4.43± 0.12[a]	7.51± 0.11[a]	6.39± 0.13[a]	5.60± 0.11[a]

Figures are the mean of three replications; Figures in row followed by the same letter/s are not differed significantly (α = P=0.05)

$CaCl_2$ treatment efficiently suppressed chilling injury and H_2O_2 production; maintained firmness and extractable juice recovery; improved DPPH radical scavenging activity, catalase activity, superoxide dismutase activity of loquat fruit (9). Destabilization of the cell membrane is the main factor correlated to decay on fruit. Moreover, over production of hydrogen peroxide also induced fruit quality degradation (75). Superoxide dismutase and catalase were responsible for alleviation of fruit decay (76). Superoxide dismutase altered the redundant $O_2^{\cdot-}$ into hydrogen peroxide, while catalase triggered the hydrogen peroxide into water and oxygen (77). Calcium chloride treatment showed a significant influence on ripening physiology of banana fruit (78). Calcium treatment could retain a higher catalase activity in loquat (79) and apricot (80) during cold storage. Calcium treatment enhanced firmness and catalase activity of apple during 5 months of cold storage (81). Calcium chloride treatment enhanced superoxide dismutase and catalase activities contributing to better resistance to decay (82). Apricot treated by 0.5% $CaCl_2$ at 20 °C for 5 min showed an increase in catalase activity (83). 2% $CaCl_2$ treatment increased catalase activity of persimmon fruit during 4 month storage at 0°C (13). Hydrothermal-calcium chloride treatment showed lower peroxidase, polyphenol oxidase, and phenylalanine ammonia lyase activities with exception of higher catalase activity in the pepper during 32 days of storage at 8 °C (70).

Conclusion

Banana is one of the most available, delicious and nutritional fruits. Calcium chloride is used as a firming agent to extend shelf-life, physicochemical attributes such as decay rate, firmness, extractable juice recovery, ascorbic acid, carotenoid, total soluble solid of banana fruit. 3% $CaCl_2$ post-harvest treatment is especially efficient to control the degradation of bioactive components (total phenolic and flavonoid contents) and antioxidant power (DPPH). $CaCl_2$ treatment significantly retarded H_2O_2 accumulation while improved catalase and superoxide dismutase activity of banana fruit during storage. $CaCl_2$ submergence is a practical method to prolong the stability and nutritional quality of banana fruit. High retention of total phenolic and flavonoid contents contributed to better antioxidant power for banana fruit. Low H_2O_2 content while high and superoxide dismutase activity would be beneficial for banana fruit during storage. Findings of this research greatly contributed to the income improvement for farmer, processor and distributor to market banana fruit on trade.

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Authors' contributions

Nguyen Phuoc Minh arranged the experiments and also wrote the manuscript.

Compliance with ethical standards

Conflict of interest: The author strongly confirmed that this research is conducted with no conflict of interest.

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