J Bangladesh Agril Univ 22(4): **547-557**, 2024 https://doi.org/10.3329/jbau.v22i4.78874

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Postharvest Quality of Calcium Chloride-Treated Strawberry (*Fragaria x ananassa* cv. Festival) in CoolBot Storage

Sheikh Nymur Rashid Lekhon[1], Shamim Ahmed Kamal Uddin Khan[2] and Md. Yamin Kabir[2]*

[1]Department of Agricultural Extension, Ministry of Agriculture, Bangladesh
[2]Agrotechnology Discipline, Khulna University, Khulna 9208, Bangladesh

ARTICLE INFO

Article history
Received: 20 October 2024
Accepted: 24 December 2024
Published: 31 December 2024

Keywords
Fruit physical attributes,
Firmness,
Total carbohydrate,
Anthocyanin,
Vitamin C,
Shelf life

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

Abstract

Though strawberry is a popular and nutritious fruit gladly accepted worldwide, its delicate nature and high perishability makes it highly susceptible to postharvest loss. The objective of this study was to evaluate the postharvest quality attributes including shelf life of 'Festival' strawberry as affected by calcium chloride in CoolBot storage system. The experiment was conducted with four calcium chloride concentrations [control (no calcium), 1%, 2%, and 3% calcium chloride] following Completely Randomized Design with three replications. Each replication consisted of 400 g freshly harvested strawberry fruits which were dipped into the respective calcium chloride solutions for two minutes followed by 10-minutes air drying. The findings showed that 3% calcium chloride resulted in the highest anthocyanin content (40.62 mg $100g^{-1}$) and shelf life (10.33 days) along with the lowest fruit weight loss (11.18%). The 3% calcium chloride also maintained the higher fruit diameters (polar and equatorial) and firmness along with high level of titratable acidity, vitamin C, and total carbohydrate and low level of total soluble solids compared to the control. However, the lowest fruit spoilage (11.59%) was reported from 2% calcium chloride. Overall, 3% calcium chloride performed better regarding physical and chemical quality attributes and shelf life of strawberry at postharvest and therefore, it can be suggested for postharvest strawberry fruit preservation. However, further research could be conducted with other strawberry varieties to have a better understanding of postharvest strawberry preservations with calcium chloride in the CoolBot storage facilities.

Introduction

Strawberry is an attractive, tasty, luscious and nutritious fruit with a distinct, pleasant aroma and delicate flavor. The strawberry (*Fragaria x ananassa* Duch.) cultivated in the present days is developed by crossing between *Fragaria chiloensis* and *Fragaria virginiana*, the two American native species. Strawberry is an aggregate non-climacteric fruit and is extensively cultivated in the temperate and subtropical regions in the world. They are grown throughout the Europe, the United States, as well as in Canada, China, Russia, South America and many other countries (Darnell et al., 2003). It is an exotic fruit in Bangladesh and our climate parameters like photoperiod, temperature and humidity are suitable for its cultivation.

The postharvest quality attributes of fruits include weight, dimensions (length, diameter), firmness, color index, TSS, p^H, anthocyanin, carotenoid, flavonoids, total phenol, carbohydrate, ascorbic acid, titratable acidity, decay (%), and shelf life (Kader, 2002). These quality parameters can be retained by refrigeration, precooling, edible coatings, water/ heat/ edible oil or chemical (such as calcium chloride) treatments and packaging (Azam et al., 2019). Strawberry is a highly perishable fruit due to their soft texture, extreme tenderness, high level of respiration, and high rate of softening and excess sensitivity to fungal attack (Hernández-Muñoz et al., 2006). Postharvest losses of strawberry range from 25% - 40% due to inappropriate management practices, poor handling, low quality packaging and poor storage condition (Aday and Caner, 2014). Quality of strawberry fruits declines rapidly—by less than a week—after harvest (Wills et al., 2001). Strawberries should be kept at 0-4 °C to retain fruit quality (Khreba et al., 2014).

Cite This Article
Lekhon, S.N.R., Khan, S.A.K.U., and Kabir, M.Y. 2024. Postharvest Quality of Calcium Chloride-Treated Strawberry (*Fragaria x ananassa* cv. Festival) in CoolBot Storage. *Journal of Bangladesh Agricultural University,* 22(4): 547-557. https://doi.org/10.3329/jbau.v22i4.78874

Among various chemical treatments, calcium chloride ($CaCl_2$) is widely used for postharvest preservation of strawberry, banana, papaya, mango, watermelon, apple, gooseberry, loquat, pomegranate, and sweet cherry. Calcium chloride dissociates readily into calcium and chloride ions—required for humans and other animals. Thus, calcium chloride is a very good combination that has been used for 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). It can maintain strawberry fruit quality (Astuti et al., 2013) through improving the rigidity of cell walls, retarding tissue softening, and hindering the accessibility of cell wall degrading enzymes (Lurie, 2009). Calcium is considered to be an important mineral element that regulates fruit quality such as maintenance of fruit firmness, retaining ascorbic acid, decreasing postharvest decay and fungal attack without affecting sensory quality (Garcia et al., 1998; Luna-Guzman and Barrett, 2010). Calcium chloride delays fruit weight loss and increases firmness in peach (Shalan, 2020). 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). Though $CaCl_2$ is used for postharvest management of different fruits, reports on strawberry particularly for the variety 'Festival' in CoolBot storage are limited. Therefore, this study evaluates postharvest quality attributes including shelf life of 'Festival' strawberry with different concentrations of calcium chloride.

Materials and Methods

Experimental materials, application of treatments and experimental design

The experiment was conducted in the CoolBot storage room, Khulna University, Khulna, during March 30 to April 12, 2021. The CoolBot room (internal dimensions: 6 ft× 8 ft × 9 ft, floor area= 48 ft^2) was developed according to the Horticulture Innovation Laboratory, USA. The room was concealed and insulated, and the temperature was adjusted by a CoolBot (Store It Cold, USA) panel. The developed CoolBot facility takes <2 hours to reach the lower limit of room temperature (6±2°C) and it maintained 90%-95 % relative humidity. The maximum and minimum temperatures of the CoolBot storage room were 8 °C and 4 °C, respectively. The temperature and relative humidity were recorded with a digital thermo-hygrometer.

The strawberry variety 'Festival' was collected from the farmer's field of Jhikargacha of Jashore at the morning hours. Festival is a hybrid developed by crossing between 'Rosa Linda' (Chandler et al., 1997) and 'Oso Grande' (Voth and Bringhurst, 1989). The fruit of this variety is conical, deep red at maturity having firm textured with excellent flavor (Chandler et al., 2000). However, leaves of 'Festival' strawberry are superior to fruits regarding polyphenol and antioxidant activities (Salas-Arias et al., 2023). After harvesting, the fruits were precooled through a fan to remove the field heat and the fruits were transferred to the CoolBot storage room of Khulna University. Mature, uniform sized, and good quality fruits were sorted out and randomly selected 1.2 kg fruits of each were dipped in 1%, 2% and 3% $CaCl_2$ for two minutes and allowed to air dry for 10 minutes. The calcium chloride solutions were prepared by dissolving 10 g, 20 g or 30 g $CaCl_2$ in 750 ml of distilled water, stirred gently by a glass rod, and added more water to make the final volume 1000 ml. The fruits of each category (1%, 2%, 3% $CaCl_2$ treated) were divided into three equal amounts [400 g each, fresh weight (FW)], packed in a paper box, and transferred to the CoolBot storage room. About 1.2 kg non-treated fruit was also divided into three parts (400 g each), packed in the similar type of paper box, and transferred to the CoolBot storage facilities to be considered as the control. Therefore, the experimental plan was a Completely Randomized Design (CRD) which consisted of four treatments (control, 1% calcium chloride, 2% calcium chloride, and 3% calcium chloride) and three replications.

Physical attributes

Equatorial and polar diameter (cm)

The equatorial dimeter (D_e) and polar diameter (D_p) were measured using digital slide callipers. Polar diameter is the distance between the strawberry crown and the point of fruit attachment to the strawberry (Afrisal et al., 2013). Equatorial diameter is the maximum width of the strawberry in a plane perpendicular to the polar diameter.

Calculation of fruit weight loss (%)

The strawberry was selected randomly from each treatment and weighed with an electric balance to assess the weight every day during storage and the weight difference of the same fruit was compared day to day. Fruit weight loss (%) was calculated following Wang et al. (2005) and Kabir and Hossain (2024) with the formula as -

$$\text{Weight loss } (\%) = \frac{M_0 - M_1}{M_0} \times 100$$

Where, M_0 is the fresh weight of strawberry fruit on the first day, and M_1 is the measured weight on next day of storage.

Firmness measurement

Firmness was measured with Shimadzu EZ-SX, USA Texture Analyzer equipped with a cylindrical probe having 2-mm diameter. The probe was penetrated 5 mm with a crosshead speed of 2 mm/s. The maximum force firmness (N) was calculated from the force vs time curve.

Measurement of color attributes of fruit (L, a*, b* and h°)*

The skin color of sample fruit was recorded on color coordinates as L*, a* and b* from opposite positions of each fruit in Commission International de L'Eclairage (CIE) units using a chromameter (HunterLab ColorFlex, Hunter Associates Inc., Reston, VA, USA). Hue angle (h°) was calculated as $h° = \tan^{-1} b^*/a^*$ (McGuire, 1992). Chromaticity L* represents the lightness of the fruit color, which ranges from 0 (black) to 100 (white). Chromaticity a* indicates the redness (+a*) or greenness (-a*), and chromaticity b* indicates yellow (+b*) or blue (-b*) color of fruit skin. Hue angle (h°) indicates absorbance or reflection and the values refer to the intrinsic luminosity.

Chemical measurements

The chemical analyses of strawberry fruit were conducted according to Mazumdar and Majumdar (2001) and Saini et al. (2006).

Determination of p^H

The p^H of strawberry fruit was measured by a desktop p^H meter. In brief, 5 g fresh fruit was taken in a conical flask with 10 ml of distilled water, crushed by a blender and the extract was filtered. The pH meter was adjusted before measurement by using standard buffer solutions (p^H 7 and p^H 4) along with temperature corrections and the data were recorded.

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

To determine total soluble solids (TSS), a drop of juice was placed on the prism of the Digital Brix Meter (Digital/Brix/RI-Check Refractometer, Reichert Technologies Inc., Japan) to get the direct reading.

Titratable acidity (TA) was measured through titration as-

$$\text{TA (\%)} = 100 \times \frac{d \times 0.064 \times c}{a \times b}$$

Where,

a = sample weight, b = aliquot volume, c = final volume made with distilled water, d = mean burette reading. Titration factor: 0.064 (as 0.064 g citric acid is neutralized by 1 ml 0.1 N NaOH).

Determination of vitamin C (mg 100g^{-1}) content

Vitamin C (mg 100g^{-1} FW) was estimated using the dye (2,6-dichlorophenol indophenol) titration method as described by Nerdy (2018).

$$\text{Vitamin C (mg 100g}^{-1}\text{)} = \frac{e \times d \times b}{c \times a}$$

Where,

a= Fresh 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

Determination of total carbohydrate (g 100g^{-1} FW)

Total carbohydrate was measured according to Mazumdar and Majumdar (2001) following the formula as stated below:

$$\text{Total carbohydrate (100 mg sample)} = \frac{mg\ of\ glucose}{Volume\ of\ test\ sample} \times 100$$

Determination of anthocyanin content (mg 100g^{-1} FW)

Ethanolic-hydrochloride is used to extract anthocyanin and the color intensity is measured calorimetrically (Gordillo et al., 2018). From the reading, the amount of the pigment is determined according to formula as follows:

Total absorbance value of the sample (per 100 g)

$$= \frac{e \times b \times c}{d \times a} \times 100$$

Where,

a denotes sample weight, b is volume made for color measurement, c indicates total volume made, d is the volume of aliquot taken for estimation, and e is the volume for 535 nm.

Anthocyanin (mg 100g^{-1}) = *Total Absorbance ÷ 98.2*

98.2= Constant value for equation

Calculation of fruit spoilage (%)

Spoiled fruit was counted and the percent fruit spoilage was calculated according to Matar et al. (2018) as follows:

$$\text{Fruit spoilage (\%)} = \frac{No.of\ spoiled\ fruit}{Total\ no.of\ fruit} \times 100$$

Calculation of shelf life (days)

Shelf life was determined on the basis of the physical parameters such as weight loss, change in color, firmness and % spoiled fruit. These parameters were judged through eye observation and the judgement criteria were determined in a consumer perspective to consider the fruit as acceptable for buying or selling. In this light, the average days required for losing a cumulative weight of 25%, change in color from deep red to pale red, retaining at least eating softness and reasonably minimum spoiled fruit (maximum 5%) was noted as shelf life of the fruits (Tabassum et al., 2018).

Statistical analysis

The collected data were statistically analysed by One-way Analysis of Variance using IBM SPSS Statistics for Windows (Version 27.0.1.0) [IBM Corp. (2020), Armonk, NY, USA]. Treatment means were compared using the same software by the Tukey's Honestly Significance Difference (HSD) Test @ 5% level of significance.

Results and Discussion

Physical characteristics of strawberry fruits

Polar diameter (cm) and equatorial diameter (cm)

The polar diameter and equatorial diameter of 'Festival' strawberry were measured at 2, 5, 8, and 11 days after storage (DAS) and both the diameters varied statistically due to the effects of different concentrations of calcium chloride ($CaCl_2$) for all DAS except 2 for equatorial diameter (Table 1-2). At 2 DAS, the highest polar diameter (5.34 cm) was obtained from 1% calcium chloride treatment which was statistically similar to 3% calcium chloride and the lowest polar diameter was obtained from the control (3.69 cm). At 5 and 8 DAS, the highest polar diameters were obtained from 3% calcium chloride treatment and lowest was measured from the control. Similarly, at 11 DAS, the highest polar diameter (4.19 cm) was measured from 3% calcium chloride which was statistically similar to 1% and 2% calcium chloride treatments and the lowest polar diameter (2.86 cm) was measured from control (Table 1). Polar diameter decreased over the period of time and in general, higher diameter was obtained from calcium chloride treatments compared to the control (Table 1). The highest equatorial diameters were obtained from 1% and 2% calcium chloride treatments at 5 and 8 DAS, respectively. At 11 DAS, the highest equatorial diameter (3.42 cm) was obtained from 2% calcium chloride and the lowest from control (2.99 cm) (Table 2). Similar to the polar diameter, equatorial diameter showed a decreasing trend as the storage time increased. Diameter of fruit decreases day by day at storage due to moisture loss and shrinkage (Rolle, 2006) and calcium chloride treated apple fruit retains higher fruit dimensions (Ganai et al., 2018) as reported in this study. Calcium treated apple fruit also retains higher fruit length than control fruits due to less moisture loss and less shrinkage (Ajender and Chawla, 2019).

Table 1. Effects of calcium chloride on polar diameter (cm) of Festival strawberry at different days after storage (DAS)

	Polar diameter (cm) [a]			
Treatments	2 DAS	5 DAS	8 DAS	11 DAS
Control	3.69 c	3.45 b	2.89 b	2.86 b
1% Calcium chloride	5.34 a	3.97 b	3.86 ab	3.42 ab
2% Calcium chloride	4.15 bc	4.73 a	4.44 a	3.62 ab
3% Calcium chloride	4.96 ab	5.02 a	4.49 a	4.19 a
p	0.002	<0.001	0.003	0.005

[a] Values represent mean of three measurements. Treatment means in a column with dissimilar letter(s) are statistically significant according to the Tukey's Honestly Significant Difference Test at 5% level of probability (p<0.05).

Table 2. Effects of calcium chloride on equatorial diameter (cm) of Festival strawberry at different days after storage (DAS)

	Equatorial diameter (cm) [a]			
Treatments	2 DAS	5 DAS	8 DAS	11 DAS
Control	3.41	3.19 b	3.05 b	2.99 c
1% Calcium chloride	3.66	3.59 a	3.37 a	3.22 b
2% Calcium chloride	3.63	3.54 a	3.44 a	3.42 a
3% Calcium chloride	3.19	3.10 b	3.02 b	3.00 c
p	0.106	<0.001	<0.001	0.005

[a] Values represent mean of three measurements. Treatment means in a column with dissimilar letter(s) are statistically significant according to the Tukey's Honestly Significant Difference Test at 5% level of probability (p<0.05).

Fruit firmness (N)

Though the fruit firmness has been measured at 2, 5, 8 and 11 DAS, they did not vary among the treatments (Table 3). However, at 2 DAS, the maximum fruit firmness (8.16 N) was obtained from 3% calcium chloride treatment and the minimum from (7.59 N) 1% calcium chloride. Similarly, at 11 DAS, the maximum fruit firmness (7.77 N) was obtained from 3% calcium chloride and the minimum from control fruit (6.70 N). Calcium treated fruit shows higher fruit firmness (Guan et al., 2016). Calcium chloride treated strawberry is firmer than the non-treated fruit and it slows down the process of decreasing fruit firmness compared to the control (Bola et al., 2017). However, in the present study, though we had higher fruit firmness with the calcium treatment, it was not significant which might be due to varietal attributes. The variety Festival is a firm strawberry which may offset the treatment effect.

Table 3. Effects of calcium chloride on firmness (N) of Festival strawberry at different days after storage (DAS)

Treatments	Firmness (N) [a]			
	2 DAS	5 DAS	8 DAS	11 DAS
Control	7.81	7.52	7.10	6.70
1% Calcium chloride	7.59	7.53	7.08	6.76
2% Calcium chloride	7.96	7.77	7.67	7.07
3% Calcium chloride	8.16	8.00	7.81	7.77
p	0.643	0.665	0.068	0.056

[a] Values represent of three measurements. Treatment means in a column with dissimilar letter(s) are statistically significant according to the Tukey's Honestly Significant Difference Test at 5% level of probability ($p<0.05$).

Weight loss of fruit (%)

The fruit weight loss varied among the treatments. A 3% calcium chloride treatment resulted in the lowest weight loss (11.18%) which was statistically similar to 1% calcium chloride (18.02%) and the highest weight loss was recorded from control (23.18%) (Fig. 1). Fruit weight loss is the result of loss of water due to transpiration and loss of carbon dioxide through respiration. Calcium treated fruit may bind the water strongly by formation of calcium pectate hydrogel and delays the process of dehydration (Lester and Grusak, 1999). Similarly, application of $CaCl_2$ significantly reduces weight loss of peach compared to control (Rahman et al., 2016).

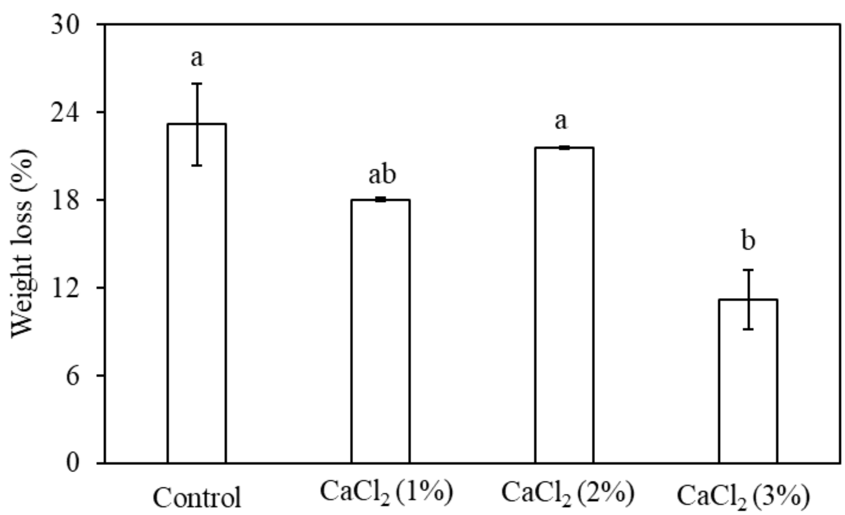

Fig. 1. Weight loss (%) of strawberry as affected by calcium chloride ($CaCl_2$) treatments. The error bar represents mean ± standard error (SE) of three measurements. Different letter(s) on a bar represent statistically significant difference at 5% level of probability according to Tukey's HSD Test.

Color attributes (L, a*, b* and h°)*

Among the color attributes, though L*, b* and h° did not differ due to the effects of treatments, a* differed significantly at 3 and 11 DAS (Table 4). The highest a* (17.87) was recorded from 1% calcium chloride which was statistically similar to 3% calcium chloride (14.29) and the lowest value of a* was recorded from control (11.19) at 3 DAS. At 11 DAS, the highest value of a* was obtained from 2% calcium chloride (14.59) which was statistically similar to other two calcium treatments and the lowest a* was obtained from control (11.31). Though the values of color attributes (L*, a*, b* and h°)

fluctuated, they generally showed a decreasing trend as the time elapsed (Table 4). Slow development of color may indicate lower respiration rate along with reduced ethylene production resulting in slow down the process of ripening and senescence (Ali et al., 2011). A gradual decrease in color L* means dark color with ripening of fruits and beginning to spoil (Ngo et al., 2021). Decreasing trend of color L* is reported in strawberry stored at cold storage (Pelayo et al., 2002) and mango coated with pectin/nano-chitosan (Ngo et al., 2021). A decreasing trend of color a* and color b* were reported for the coated fruit compared to uncoated one (Ngo et al., 2021). However, h° increased in strawberry in the cold storage (Koyuncu, 2004) indicating that cold storage can enhance development of color attributes of fruits. However, in the present study we did not have any definite effect of treatments on color attributes which might be due to storage condition (CoolBot).

Table 4. Fruit color (L*, a*, b*, and h°) attributes of strawberry at as affected by calcium chloride at different days after storage (DAS) [a]

Treatments	3 DAS	7 DAS	11 DAS
		L*	
Control	39.22	37.56	32.58
1% Calcium chloride	34.97	32.31	33.50
2% Calcium chloride	40.88	39.71	38.13
3% Calcium chloride	38.64	35.57	35.11
p	0.148	0.091	0.075
		a*	
Control	11.19 b	14.43	11.31 b
1% Calcium chloride	17.83 a	13.75	13.26 ab
2% Calcium chloride	12.11 1b	11.68	14.59 a
3% Calcium chloride	14.29 ab	11.66	12.25 ab
p	0.045	0.079	0.020
		b*	
Control	14.13	13.15	13.34
1% Calcium chloride	14.69	13.21	15.04
2% Calcium chloride	15.99	13.09	14.46
3% Calcium chloride	13.59	11.15	13.33
p	0.880	0.364	0.217
		Hue (h°)	
Control	45.65	32.22	34.68
1% Calcium chloride	44.44	36.35	29.91
2% Calcium chloride	40.17	32.16	32.61
3% Calcium chloride	41.06	33.36	33.33
p	0.418	0.058	0.051

[a] Values represent average of three measurements where an L* is lightness (0 = black and 100 = white); a* (negative = greener and positive = redder); b* (negative = bluer, positive = more yellow), and h° represents hue angle. Treatment means with similar letter(s) are statistically non-significant at 5% level of probability ($p<0.05$).

Chemical attributes

Chemical attributes such as total soluble solids (TSS, %), titratable acidity (TA, %), pH, vitamin C ($mg100g^{-1}$), total carbohydrate ($g100g^{-1}$), and anthocyanin ($mg100g^{-1}$) content of strawberry as affected by the treatments were measured at different days after storage (DAS) and described here.

TSS (%)

TSS content varied at 5 and 8 DAS. For both the dates, the highest TSSs (6.40% and 6.33%) were recorded from the control treatment and the lowest TSS was obtained from 1% or 2% calcium chloride (Table 5). However, TSS content did not vary at 2 and 11 DAS. An increase in TSS of untreated fruits was probably due to hydrolysis of polysaccharides and concentrated juice content as a result of dehydration as the storage time increased (Akhtar et al., 2010). High concentration of calcium chloride application increases the metabolic actions which eventually reduces the TSS of apple (Sajid et al., 2019). TSS content varied from variety to variety (Aziz et al., 2018) and the highest TSS (12.6%) was reported for the variety 'Festival' (Ahsan et al., 2014).

Table 5. Effects of calcium chloride on TSS, TA, and pH of Festival strawberry at different days after storage (DAS) [a]

Treatments	2 DAS	5 DAS	8 DAS	11 DAS
	TSS (%)			
Control	5.33	6.40 a	6.33 a	5.33
1% Calcium chloride	5.90	5.63 b	5.10 c	5.03
2% Calcium chloride	5.93	5.57 b	5.17 c	4.97
3% Calcium chloride	6.10	5.87 ab	5.63 b	5.27
p	0.067	0.024	<0.001	0.303
	TA (%)			
Control	0.61 c	0.60 d	0.59 c	0.58 c
1% Calcium chloride	0.74 a	0.71 a	0.70 a	0.69 a
2% Calcium chloride	0.69 b	0.67 c	0.66 b	0.65 b
3% Calcium chloride	0.70 b	0.69 b	0.68 ab	0.65 b
p	<0.001	<0.001	<0.001	<0.001
	pH			
Control	3.56	3.49	3.57	3.26
1% Calcium chloride	3.47	3.68	3.37	3.43
2% Calcium chloride	3.65	3.38	3.36	3.49
3% Calcium chloride	3.46	3.62	3.24	3.35
p	0.906	0.716	0.699	0.469

[a] Values represent mean of three measurements. Treatment means in a column with dissimilar letter(s) are statistically significant according to the Tukey's Honestly Significant Difference Test at 5% level of probability ($p<0.05$).

Titratable acidity (TA) (%)

TA varied due to the effects of treatments. The highest TA (0.74%) was obtained from 1% calcium chloride and the lowest (0.61%) from control at 2 DAS. Similarly, at 11 DAS, the highest TA (0.69%) was obtained from 1% calcium chloride and the lowest from control (0.58%) (Table 5). TA content decreased over the period of storage. Similarly, decreasing trend of TA was observed for strawberry varieties in a study of 10 day-storage (Koyunch, 2014). Decreasing in acidity demonstrates maturation of fruits (Garcia et al., 1998). Similarly, calcium chloride (0, 1% and 2%) showed a declining pattern of TA in strawberry (Turmanidze et al., 2016). However, TA content of fruit may not differ due to calcium treatment (Mozhdehi et al., 2012).

p^H

The pH of strawberry did not vary due to calcium treatments and it fluctuated without following any pattern (Table 5). At 11 DAS, the pH was 3.49, 3.43, 3.35, and 3.26 for 2% calcium chloride, 1% calcium chloride, 3% calcium chloride and control, respectively. The non-significant pH along with no pattern of increasing or decreasing was also reported by other studies (Turmanidze et al., 2016; Wan Mahfuzah et al., 2012).

Vitamin C (mg100g^{-1})

The vitamin C content varied due to treatments. At 2 DAS, the highest vitamin C (46.19 mg100g^{-1}) was obtained from 2% calcium chloride followed by 1% and 3% calcium chloride and the lowest level of vitamin C (40.44 mg100g^{-1}) was obtained from control (Table 6). Similarly, the highest level of vitamin C (42.1 mg100g^{-1}) was obtained from 2% calcium chloride which was statistically similar to 1% and 3% calcium chloride and the lowest vitamin C (35.73 mg100g^{-1}) was obtained from control. Calcium chloride treated fruits retained more ascorbic acid after 15 days of storage compared to the untreated fruits (Shahzad et al., 2020) which might be due to delayed oxidation of vitamin C. Calcium chloride with chlorine also retained more vitamin C in strawberry than untreated fruits (Mozhdehi et al., 2012).

Total carbohydrates (g100g^{-1})

The total carbohydrate content also varied among the treatment. At 3 DAS, the highest total carbohydrate (8.30 g100g^{-1}) was recorded from 2% calcium chloride and the lowest from control (7.96 g100g^{-1}) (Table 6). Similarly, the highest total carbohydrate (8.22 g100g^{-1}) was obtained from 2% calcium chloride and lowest (7.13 g100g^{-1}) from control at 11 DAS. Total carbohydrate content of strawberry varieties varied (Saied et al., 2005) and the maximum total carbohydrates (6.81%) was obtained from the variety Camarosa (Ahmed et al., 2018). Calcium chloride treated guava retained more total carbohydrate than the control (Chawla et al., 2018) which is in agreement with the findings of the present study.

Table 6. Effects of calcium chloride on vitamin C (mg 100g^{-1}) and total carbohydrates (g 100g^{-1}) content of Festival strawberry at different days after storage (DAS) [a]

Treatments	2 DAS	5 DAS	8 DAS	11 DAS
	Vitamin C (mg100g^{-1})			
Control	40.44 d	38.49 c	37.27 c	35.73 b
1% Calcium chloride	44.95 b	44.03 a	43.29 ab	41.21 a
2% Calcium chloride	46.19 a	45.33 a	44.01 a	42.10 a
3% Calcium chloride	42.50 c	41.90 b	41.25 b	40.66 a
p	<0.001	<0.001	<0.001	<0.001
	Total carbohydrates (g100g^{-1})			
Control	8.47 a	7.96 b	7.47 c	7.13 c
1% Calcium chloride	7.45 b	7.40 c	7.28 c	7.18 c
2% Calcium chloride	8.38 a	8.30 a	8.26 a	8.22 a
3% Calcium chloride	7.99 ab	7.97 b	7.96 b	7.92 b
p	0.002	<0.001	<0.001	<0.001

[a] Values represent mean of three measurements. Treatment means in a column with dissimilar letter(s) are statistically significant according to the Tukey's Honestly Significant Difference Test at 5% level of probability ($p<0.05$).

Anthocyanin (mg100g^{-1})

Anthocyanin content of strawberry fruit differed based on calcium treatments. At 3 DAS, the highest level of anthocyanin (40.05mg 100g^{-1}) was measured from 3% calcium chloride treatment which was statistically similar to 1% calcium chloride treatment and the lowest anthocyanin (37.66mg 100g^{-1}) was obtained from control (Table 7). Similarly, at 11 DAS, the highest anthocyanin (40.33 mg 100g^{-1}) was obtained from 3% calcium chloride and lowest (35.90 mg 100g^{-1}) from control. Calcium treatment has been reported to enhance color formation of strawberry fruits by affecting phenylalanine ammonia lyase and tyrosine ammonia lyase activities (Kumar et al., 2020) thus affect fruit anthocyanin content. Calcium chloride in combination with chitosan also retained more anthocyanin than untreated control (Rahimi et al., 2018).

Table 7. Effects of calcium chloride on anthocyanin (mg100g^{-1}) content of Festival strawberry at different days after storage (DAS)

	Anthocyanin (mg 100g^{-1}) [a]		
Treatments	3 DAS	7 DAS	11 DAS
Control	37.66 b	37.73 b	35.90 d
1% Calcium chloride	39.43 a	40.03 a	38.42 b
2% Calcium chloride	37.99 b	38.25 b	37.33 c
3% Calcium chloride	40.05 a	40.62 a	40.33 a
p	<0.001	<0.001	<0.001

[a] Values represent mean of three measurements. Treatment means in a column with dissimilar letter(s) are statistically significant according to the Tukey's Honestly Significant Difference Test at 5% level of probability ($p<0.05$).

Fruit spoilage (%)

The proportion of fruit spoilage (%) significantly differed among the treatments. The minimum fruit spoilage (11.59%) was recorded for 2% calcium chloride which was statistically similar to 1% calcium chloride and control treatments (Fig. 2). However, the highest proportion (17.39%) of strawberry fruit is lost from 3% calcium chloride. Calcium treated strawberry resulted in the minimum fruit spoilage compared to the untreated fruits (Amal et al. 2020; Zhao et al., 2013; Kumar et al., 2021) through formation of an edible coating that triggers defence responses against fungal attack (Zhao et al., 2013). Surprisingly, the highest concentration of calcium chloride (3%) showed the significant fruit spoilage which might be due to effect of high calcium chloride as a high concentration of calcium chloride may result in rotting of fruit and core as reported in apple (Ullah et al., 2007).

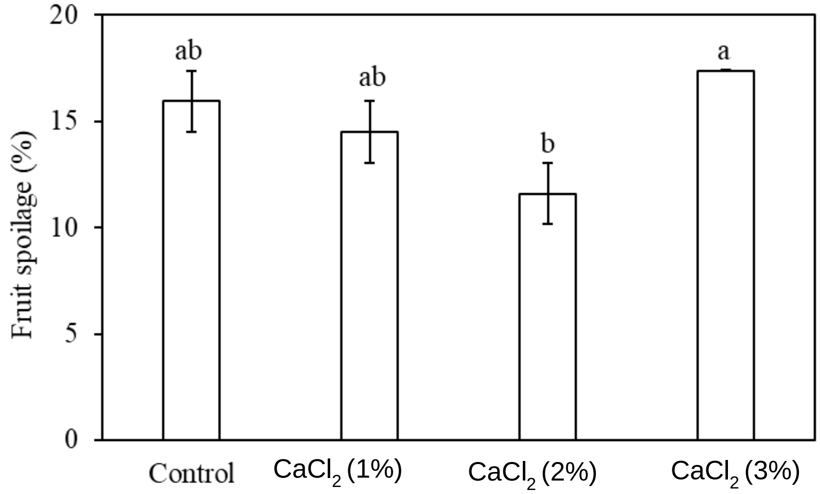

Fig. 2. Fruit spoilage (%) of strawberry as affected by calcium chloride ($CaCl_2$) treatments. The error bar represents mean ± standard error (SE) of three measurements. Different letter(s) on a bar represent statistically significant difference at 5% level of probability according to Tukey's HSD Test.

Shelf life (days)

The shelf life of strawberry fruit differed among the treatments. The maximum shelf life (10.33 days) was recorded from 3% calcium chloride followed by 2% (9.25 days) and 1% calcium chloride (8.25 days) and the minimum shelf life (7.17 days) was recorded from untreated control (Fig. 3). Shelf life of strawberry fruit increased by 44% (> 3 days) with 3% calcium chloride treatment compared to the control. Calcium treated fruits exhibited higher shelf life due to low weight loss (%) and high fruit firmness (Wan Mahfuzah et al., 2012). Calcium chloride treatments may also protect the fungal attack and thus, increases shelf life of strawberry (Zhao et al., 2013).

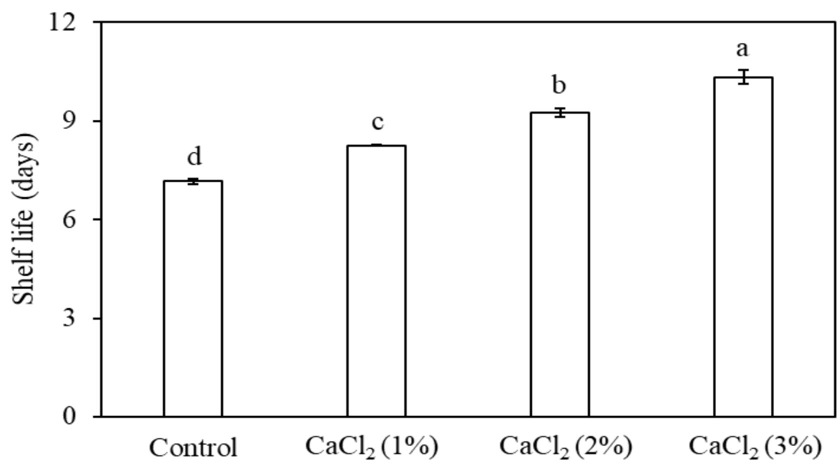

Fig. 3. Shelf life of strawberry as affected by calcium chloride ($CaCl_2$) treatments. The error bar represents mean ± standard error (SE) of three measurements. Different letter(s) on a bar represent statistically significant difference at 5% level of probability according to Tukey's HSD Test.

Conclusion

Though strawberries are highly nutritious, they perish quickly. A 3% calcium chloride solution increases the shelf life of strawberry cv. Festival by more than three days by increasing fruit firmness and decreasing fruit weight loss. The 3% calcium chloride also increases the anthocyanin content of the fruit. Therefore, 3% calcium chloride can be used for strawberry storage in the CoolBot. However, further research is suggested before the final recommendation.

Funding Statement

This research was supported by the National Science and Technology Fellowship 2020 from the Government of Bangladesh in favor of the first author.

Acknowledgement

The authors are grateful to the Ministry of Science and Technology of the Government of Bangladesh for funding the research. The authors express their sincere gratitude to Prof. Dr. Prosanta Kumar Das of Agrotechnology Discipline for providing CoolBot facilities as well as Agrotechnology Discipline, Khulna University, Bangladesh for their supports during the experimental period.

Competing Interest

The authors report that there are no competing interests to declare.

References

Aday, M. S., and Caner, C. (2014). Individual and combined effects of ultrasound, ozone and chlorine dioxide on strawberry storage life. *LWT-Food Science and Technology*, 57(1), 344-351. https://doi.org/10.1016/j.lwt.2014.01.006

Afrisal, H., Faris, M., Grezelda, L., and Soesanti, I. (2013). Portable smart sorting and grading machine for fruits using computer vision. *In* International Conference on Computer, Control, Informatics and Its Applications (IC3INA) (pp. 71-75). IEEE.

Ahmad, M., Banday, F. A., Bhat, M. Y., Sharma, M. K., Dar, M. A., Khalil, A., and Nazir, N. (2018). Performance of exotic strawberry varieties under temperate conditions of north-western Himalayas. *Indian Journal of Horticulture*, 75(4), 698-702. DOI: 10.5958/0974-0112.2018.00116.0

Ahsan, M. K., Mehraj, H., Hussain, M. S., Rahman, M. M., and Jamal Uddin, A. F. M. (2014). Study on growth and yield of three promising strawberry cultivars in Bangladesh. *International Journal of Business, Social and Scientific Research*, 1(3), 205-208.

Ajender, T. B., and Chawla, W. (2019). Effect of calcium chloride on growth, fruit quality and production of apple. *Journal of Pharmacognosy and Phytochemistry*, *8*(1S), 588-593.

Akter, M. M., Hossain, M. M., Hoque, M. A., Ivy, N. A., and Roni, M. S. (2018). Evaluating nutritional quality and shelf life of strawberry genotypes under field condition. *Journal of Agricultural Science and Food Technology*, 4 (6): 112-119.

Astuti, N. K., Maghfoer, M. D., and Soelistyono, R. (2013). Calcium chloride applications to improve fruit quality on bruised and diseased of pineapple (*Ananas comosos* (L) Merr). *Applied Chemistry*, 5, 30-34.

Azam, M., Ejaz, S., Rehman, R. N. U., Khan, M., and Qadri, R. (2019). Postharvest quality management of strawberries. *In*: Strawberry - Pre- and Post-Harvest Management Techniques for Higher Fruit Quality. *Intechopen*. DOI: 10.5772/intechopen.82341

Aziz, M. M., Alvi, A., Rashid, S., Abbas, M. M., and Riaz, S. (2018). Evaluation of strawberry (*Fragaria× ananassa* Duch.) cultivars for morphological and physico-chemical parameters in subtropical climate. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, 34(2), 126-129.

Bola, P.K., Jain S.K., and Anupama. (2017). Efficacy of calcium chloride, carboxymethyl cellulose and chitosan on the shelf-life of strawberry (*Fragaria* x *ananassa* D.). *Green Farming*, 8 (4): 995-998.

Chandler, C. K., Legard, D. E., Dunigan, D. D., Crocker, T. E., and Sims, C. A. (2000). 'Strawberry Festival' Strawberry. *HortScience*, 35(7), 1366-1367.

Chawla, S., Devi, R., and Jain, V. (2018). Changes in physicochemical characteristics of guava fruits due to chitosan and calcium chloride treatments during storage. *Journal of Pharmacognosy and Phytochemistry*, 7(3), 1035-1044.

Darnell, R.L., Cantliffe, D.J., Kirschbaum, D.S., and Chandlar, C.K. (2003). The physiology of flowering in strawberry. *Hort. Rev*. 28 (6): 325-332.

Elbagoury, M. M., Turoop, L., Runo, S., & Sila, D. N. (2021). Regulatory influences of methyl jasmonate and calcium chloride on chilling injury of banana fruit during cold storage and ripening. *Food Science & Nutrition*, *9*(2), 929-942. https://doi.org/10.1002/fsn3.2058

Ganai, S. A., Ahsan, H., Tak, A., Mir, M. A., Rather, A. H., and Wani, S. M. (2018). Effect of maturity stages and postharvest treatments on physical properties of apple during storage. *Journal of the Saudi Society of Agricultural Sciences*, 17(3), 310-316.

Garcia, L. G. C., Silva, E. P. D., Silva, C. D. M. E., Vilas Boas, E. V. D. B., Asquieri, E. R., Damiani, C., & Silva, F. A. D. (2019). Effect of the addition of calcium chloride and different storage temperatures on the post-harvest of jabuticaba variety Pingo de Mel. *Food Science and Technology*, 39(Suppl. 1), 261-269.

García, M. A., Martino, M. N., and Zaritzky, N. E. (1998). Plasticized starch-based coatings to improve strawberry (*Fragaria× ananassa*) quality and stability. *Journal of Agricultural and Food Chemistry*, 46(9), 3758-3767.

Gordillo, B., Sigurdson, G. T., Lao, F., González-Miret, M. L., Heredia, F. J., & Giusti, M. M. (2018). Assessment of the color modulation and stability of naturally copigmented anthocyanin-grape colorants with different levels of purification. *Food research international*, *106*, 791-799. https://doi.org/10.1016/j.foodres.2018.01.057

Guan, J., Park, H. W., Kim, Y. H., Kim, S. H., and Park, H. R. (2006). Effects on quality of strawberry fruit by dipping of calcium solution and MA packaging. *Korean Journal of Food Preservation*, 13(1), 13-17.

Hernández-Muñoz, P., Almenar, E., Ocio, M. J., and Gavara, R. (2006). Effect of calcium dips and chitosan coatings on postharvest life of strawberries (*Fragaria x ananassa*). *Postharvest Biology and Technology*, 39(3), 247-253.

Jiao, W., Xi, Y., Cao, J., Fan, X., & Jiang, W. (2018). Regulatory effects of $CaCl_2$, sodium isoascorbate, and 1-methylcyclopropene on chilling injury of banana fruit at two ripening stages and the mechanisms involved. *Journal of Food Processing and Preservation*, *42*(2), e13442. https://doi.org/10.1111/jfpp.13442

Kabir, M. Y., & Hossain, S. K. (2024). Botanical extracts improve postharvest quality and extend the shelf life of papaya (*Carica papaya* L. cv. Shahi). *New Zealand Journal of Crop and Horticultural Science*, 1-17. https://doi.org/10.1080/01140671.2024.2348137

Kabir, M. Y., Nambeesan, S. U., & Díaz-Pérez, J. C. (2024). Shade nets improve vegetable performance. *Scientia Horticulturae*, *334*, 113326. https://doi.org/10.1016/j.scienta.2024.113326

Kader, A. A. (2002). Quality parameters of fresh-cut fruit and vegetable products. *Fresh-cut fruits and vegetables. Science, technology and market*, 11-20.

Khreba, A. H., Hassan, A. H., Emam, M. S., and Atala, S. A. (2014). Effect of some pre and post-harvest treatments on quality and storability of strawberry fruits. *The Journal of American Science*, 10(11), 239-248.

Koyuncu, M. A. (2004). Quality changes of three strawberry cultivars during the cold storage. *European Journal of Horticultural Science*, 69(5).

Kumar, A., Karuna, K., Mankar, A., Mandal, S. K., and Kumari, N. (2020). Pre-harvest spray of chitosan, calcium chloride and low temperature storage (7 °C) effect on biochemical attributes of strawberry cv. Camarosa. *Journal of Pharmacognosy and Phytochemistry*, 9(3), 1097-1102.

Kumar, R., Antil, R. S., and Ali, A. (2021). Effect of packaging material and postharvest calcium treatment on weight loss, decay and biochemical quality of strawberry fruits during storage. *Journal of Applied and Natural Science*, 13(4), 1158-1165. https://doi.org/10.31018/jans.v13i4.2981

Lester, G. E., and Grusak, M. A. (1999). Postharvest application of calcium and magnesium to honeydew and netted muskmelons: effects on tissue ion concentrations, quality, and senescence. *Journal of the American Society for Horticultural Science*, 124(5), 545-552.

Li, Z., Wang, L., Xie, B., Hu, S., Zheng, Y., & Jin, P. (2020). Effects of exogenous calcium and calcium chelant on cold tolerance of postharvest loquat fruit. *Scientia Horticulturae*, *269*, 109391. https://doi.org/10.1016/j.scienta.2020.109391

Luna-Guzmán, I., and Barrett, D. M. (2000). Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes. *Postharvest Biology and Technology*, 19(1), 61-72.

Luo, Y., Lu, S., Zhou, B., & Feng, H. (2011). Dual effectiveness of sodium chlorite for enzymatic browning inhibition and microbial inactivation on fresh-cut apples. *LWT-Food Science and Technology*, *44*(7), 1621-1625. https://doi.org/10.1016/j.lwt.2011.02.015

Lurie, S. (2009). Stress physiology and latent damage. *Postharvest handling: A systems approach*, 2, 443-459.

Matar, C., Gaucel, S., Gontard, N., Guilbert, S., and Guillard, V. (2018). A global visual method for measuring the deterioration of strawberries in MAP. *MethodsX*, 5, 944-949. https://doi.org/10.1016/j.mex.2018.07.012

Mazumdar, D. B. C. and Majumdar, K. (2001). Methods of physico-chemical analysis of fruits. Daya Publishing House, India. pp. 112-115.

McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience*, 27(12), 1254-1255.

Minh, N. P. (2022). Effectiveness of $CaCl_2$ treatment on quality attributes of banana fruit during storage. *Plant Science Today*, *9*(1), 206-214. https://doi.org/10.14719/pst.1458

Mozhdehi, F., Abdossi, V., and Kalatejari, S. (2012). Effect of packing system, calcium chloride and chlorine on the storage life of strawberry fruits (*Fragaria ananassa* cv. Kordistan). *Journal of Basic and Applied Sciences*, 8(2), 393-398.

Nerdy, N. 2018. Determination of vitamin C in various colours of bell pepper (*Capsicum annuum* L.) by titration method. *ALCHEMY Journal Penelitian Kimia*, 14(1), 164-177. DOI:10.20961/ALCHEMY.14.1.15738.164-178.

Ngo, T. M. P., Nguyen, T. H., Dang, T. M. Q., Do, T. V. T., Reungsang, A., Chaiwong, N., and Rachtanapun, P. (2021). Effect of pectin/nanochitosan-based coatings and storage temperature on shelf-life extension of "Elephant" Mango (*Mangifera indica* L.) *Fruit. Polymers*, 13(19), 3430.

Pelayo, C., Ebeler, S. E., and Kader, A. A. (2003). Postharvest life and flavor quality of three strawberry cultivars kept at 5°Cin air or air+ 20 kPa CO_2. *Postharvest Biology and Technology*, 27(2), 171-183. https://doi.org/10.1016/S0925-5214(02)00059-5

Rahimi, B. A., Shankarappa, T. H., Krishna, H. C., Mushrif, S. K., Vasudeva, K. R., Sadananda, G. K., and Masoumi, A. (2018). Chitosan and $CaCl_2$ coatings on physicochemical and shelf life of strawberry fruits (*Fragaria x ananassa* Duch.). *Int. J. Curr. Microbiol. App. Sci*, 7(7), 3293-3300.

Rahman, M. U., Sajid, M., Rab, A., Ali, S., Shahid, M. O., Alam, A., and Ahmad, I. (2016). Impact of calcium chloride concentrations and storage duration on quality attributes of peach (*Prunus persica*). *Russian Agricultural Sciences*, 42(2), 130-136. https://doi.org/10.3103/S1068367416020099

Ramezanian, A., Rahemi, M., Maftoun, M., Bahman, K., Eshghi, S., Safizadeh, M. R., & Tavallali, V. (2010). The ameliorative effects of spermidine and calcium chloride on chilling injury in pomegranate fruits after long-term storage. *Fruits*, *65*(3), 169-178. https://doi.org/10.1051/fruits/2010011.

Rolle, R. S. (2006). Improving postharvest management and marketing in the Asia-Pacific region: issues and challenges. *Postharvest management of fruit and vegetables in the Asia-Pacific region*, 1(1), 23-31.

Saini, R. S., Sharma, K. D., Dhankhar, O. P. and Kaushik, R.A. 2006. Laboratory manuals for analytical techniques in horticulture. *Agrobios Publishing* Co. Ltd., India. pp. 5-16.

Sajid, M., Basit, A., Ullah, I., Tareen, J., Asif, M., Khan, S., and Nawaz, M. K. (2019). Efficiency of calcium chloride ($CaCl_2$) treatment on post-harvest performance of pear (*Pyrus communis* L.). *Pure and Applied Biology* (PAB), 8(2), 1111-1125. http://dx.doi.org/10.19045/bspab.2019.80053

Salas-Arias, K., Irías-Mata, A., Sánchez-Kopper, A., Hernández-Moncada, R., Salas-Morgan, B., Villalta-Romero, F., & Calvo-Castro, L. A. (2023). Strawberry Fragaria x ananassa cv. Festival: A polyphenol-based phytochemical characterization in fruit and leaf extracts. *Molecules*, *28*(4), 1865. https://doi.org/10.3390/molecules28041865

Shahzad, S., Ahmad, S., Anwar, R., and Ahmad, R. (2020). Pre-storage application of calcium chloride and salicylic acid maintain the quality and extend the shelf life of strawberry. *Pakistan Journal of Agricultural Sciences*, 57(2). DOI: 10.21162/PAKJAS/20.8953

Shalan, A. M. 2020. Post-harvest applications by calcium chloride and ascorbic acid enhanced storage ability of peach fruits cv. Floridaprince. *Journal of Plant Production*, 11(2), 179-188.

Tabassum, P., Khan, S. A. K. U., Siddiqua, M., and Sultana, S. (2018). Effect of guava leaf and lemon extracts on postharvest quality and shelf life of banana cv. Sabri (*Musa sapientum* L.): Effect of plant extract on banana shelf life. *Journal of the Bangladesh Agricultural University*, 16(3), 337-342. https://doi.org/10.3329/jbau.v16i3.39489

Turmanidze, T., Gulua, L., Jgenti, M., and Wicker, L. (2016). Effect of calcium chloride treatments on quality characteristics of blackberry, raspberry and strawberry fruits after cold storage. *Turkish Journal of Agriculture-Food Science and Technology*, 4(12), 1127-1133. https://doi.org/10.24925/turjaf.v4i12.1127-1133.907

Ullah, J., Alam, S., Ahmad, T., and Qazi, I. M. (2007). Effect of $CaCl_2$ coating on the sensory quality and storage disorders of apple cv. Kingstar stored at ambient conditions. *Sarhad Journal of Agriculture*, 23(3), 775.

Voth, V., and Bringhurst, R. S. (1989). Strawberry plant called 'Oso Grande'. Plant patent-United States Patent and Trademark Office (USA). no. 6578.

Wan Mahfuzah, W. I., Zulkifli, M. S., Latifah, M. N., and Fauziah, O. (2012). Evaluations for effectiveness of calcium chloride treatment on the postharvest quality of strawberry. *In* VII International Postharvest Symposium 1012 (pp. 515-520).

Wang, Y. S., Tian, S. P., and Xu, Y. (2005). Effects of high oxygen concentration on pro-and anti-oxidant enzymes in peach fruits during postharvest periods. *Food Chemistry*, 91(1), 99-104.

Wang, Y., Xie, X., & Long, L. E. (2014). The effect of postharvest calcium application in hydro-cooling water on tissue calcium content, biochemical changes, and quality attributes of sweet cherry fruit. *Food Chemistry*, *160*, 22-30. https://doi.org/10.1016/j.foodchem.2014.03.073

Wills, R. B. H., Warton, M. A., Mussa, D. M. D. N., and Chew, L. P. (2001). Ripening of climacteric fruits initiated at low ethylene levels. *Australian Journal of Experimental Agriculture*, 41(1), 89-92.

Zhao, Y., Yang, C., Wang, R., and Song, Y. L. (2013). Influence of $CaCl_2$ on quality and gray mold rot in postharvest strawberry fruit. *Science and Technology of Food Industry*, 35, 313-316.