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Effect of Preharvest Spray of Different Calcium Sources on Quality Attributes and Storability of Strawberry Fruits

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ABSTRACT

This study was carried out on strawberry cv. Fortuna during the two successive winter seasons of 2023-2024 and 2024-2025 to study the effect of foliar spray of strawberry plants with different calcium sources (calcium nitrate, calcium lactate, and calcium citrate) at a concentration of 0.5% compared with untreated plants as control (sprayed with water only) on the quality and storability of strawberry fruits. The results revealed that strawberries obtained from plants treated with all used calcium sources resulted in significant increases in physical properties such as fruit length, average fruit weight, and firmness, and in chemical properties such as total soluble solids, ascorbic acid, total sugars content, and calcium concentration in the fruits compared to fruits obtained from untreated plants. However, there were no significant differences found among all treatments and the control regarding fruit diameter and titratable acidity. Additionally, all different calcium sources were effective in preserving fruit quality characteristics, which decreased weight loss, preserved fruit firmness, total soluble solids, titratable acidity, ascorbic acid, and total sugars content, reduced color development and preserving the overall appearance of strawberries throughout the storage periods and shelf life compared to untreated fruits. The study recommends that strawberries cv. Fortuna obtained from plants sprayed with calcium lactate improved fruit quality characteristics at harvest, enhanced storability, maintaining the quality characteristics of the fruits and gave an excellent appearance of fruits after 15 days of storage at 0 ºC plus 2 days at 10 ºC (shelf life) without any decay.

Keywords: Strawberry - Calcium nitrate - Calcium lactate - Calcium citrate - Storability.

INTRODUCTION

Strawberries (*Fragaria* x *ananassa* Duch.) are among the most important vegetable crops in Egypt, grown for fresh consumption, export, and processing (Mohamed et al., 2021). However, since strawberries are non-climacteric fruits, they must be harvested at full maturity to ensure optimal market quality in regards to appearance, texture, flavor, and nutritional value (Cordenusi et al., 2003). Also, it is highly perishable fruit, the most sensitive fruits, and has low mechanical resistance, which contributes significantly to their short postharvest shelf lives (Ansar et al., 2020), due to their high respiration rate, higher water content, and sensitivity to fungal attack (Neri et al., 2014). Fruits are also susceptible to mechanical injury, bruising, microbial decay, water loss, and physiological deterioration because of the soft texture of the fruits, the lack of a protective peel, and the high softening rate (Liu et al., 2018). Also, calcium deficiency reduces the firmness of fruit, making them more susceptible to bruising during transportation and increaseing their sensitivity to many physiological and pathological disorders, leading to a rapid loss of their marketable quality and a reduction in their shelf life after harvest (Bieniasz et al., 2012). Therefore, postharvest handling and storage of strawberry fruits are difficult (Shahat et al., 2020).

Enhancing the quality of strawberry fruits during cultivation, maintaining their quality after harvest and throughout storage, and extending their storability are important objectives that can be achieved by applying different calcium sources as a foliar spray on the plants. Several studies have investigated the beneficial effect of various calcium sources, including calcium nitrate, calcium lactate, and calcium citrate, in improving fruit quality at harvest, enhancing firmness, extending storability, and preserving fruit quality during storage in various horticultural crops (Hamail et al., 2018, Vani et al., 2020 and Ghahremani et al., 2021). This may be due to calcium being an important essential macronutrient for the growth and development of fruit and playing a vital role in preserving the structural integrity and stability of cell walls and membranes. Additionally, calcium enhances tissue firmness, improves the overall quality of fruits, and delays membrane lipid catabolism, thus preserving the quality attributes and prolonging the storability (Kadir, 2005 and Hepler and Winship, 2010).

Some investigators have demonstrated that calcium is vital for production and plays a key role in enhancing quality at harvest (Hamail et al., 2018 and Sidhu et al., 2020), increases fruit weight and fruit length, enhances fruit firmness and external color (Sidhu et al., 2020) has significant higher values of the total soluble solids percentage and ascorbic acid (Kazemi, 2015) and total sugars content (Hamail et al., 2018 and Sidhu et al., 2020) increases the concentration of calcium in fruit tissue (Gastol and Domagala, 2006 and Mahmoud, 2017) and decreases disease incidence (Sangeeta et al., 2019).

Moreover, many studies have shown that calcium can delay senescence, decrease respiration rates and fruit softening, minimize physiological disorders and postharvest decay, preserve quality attributes, and extend the storability of fruits and vegetables (Sinha et al., 2019 and Haleema et al., 2020) by contributing to the linkage between pectic substances in the cell walls, inhibiting germination of fungal spores, and suppressing enzymatic activities responsible for cell wall degradation, thus maintaining fruit firmness (Ghahremani et al., 2021). The rationale for applying calcium before harvest lies in its ability to maintain cell membrane stability, strengthen the cell wall structure, reduce membrane permeability, and increase the cell wall thickness by cross-linking pectin chains in the middle lamella (Prajapati et al., 2021). Calcium application as a foliar spray was effective in retaining fruit quality during postharvest storage (Wang and Long, 2015), decreasing the loss of firmness and weight loss percentage of strawberries (Harris et al., 2017), preventing softening of fruits, decreasing color development (Wang and Long, 2015), controlling postharvest decay, maintaining the general appearance of fruits, ascorbic acid, and titratable acidity (Akhtar and Rab, 2014), retaining total soluble solids and total sugars contents in fruits (Vani et al., 2020 and Amiri et al., 2022), and delaying anthocyanin accumulation in fruits (Correia et al., 2017).

This study aimed to evaluate the impact of foliar spraying with different calcium sources on the quality and storability of strawberries cv. Fortuna.

MATERIALS AND METHODS

1. Field experiment

The field experiment was carried out on a private farm in Ismailia Governorate during the two successive growing seasons of 2023-2024 and 2024-2025. Fresh strawberry transplants (*Fragaria* x *ananassa* Duch. cv. Fortuna) were obtained from a local nursery and treated with 0.2% Rhizolex fungicide solution for 20 min. prior to planting and transplanted on September 10th and 13th for the two seasons, respectively. The experiment occupied three beds; each bed was divided into four plots. All treatments were distributed in a complete randomized block design with three replicates; each replicate consisted of one plot. The dimensions of each plot were 5 meters in length and 1.6 meters in width; the total area of each plot was 8 m^2. The transplants were distributed in four rows per plot, with a spacing of 25 cm between rows and 25 cm between plants, totaling 80 plants per plot. The beds were mulched with 40 micron double face (silver/ black) plastic mulch after one month from planting.

Soil application with calcium superphosphate (15% P_2O_5), ammonium nitrate (33% N) and potassium sulfate (48% K_2O) was done at 300, 250 and 100 kg per feddan, respectively. All agricultural practices, including irrigation, fertilization, and pest and disease control, were implemented in accordance with the recommendations of the Egyptian Ministry of Agriculture for commercial strawberry production. The physical and chemical characteristics of the sandy loam soil used in this study were analyzed at the Soil and Water Research Institute, Agricultural Research Center **(Table 1).**

Three different sources of calcium ions were used as foliar sprays: calcium nitrate (21.54 % Ca^{+2}) at 0.5%, calcium citrate (13.26 % Ca^{+2}) at 0.5% and calcium lactate (22.98 % Ca^{+2}) at 0.5%. In addition, untreated plants were sprayed with tap water (as a control). These treatments were applied four times during the strawberry growth cycle: before flowering, during flowering, at the beginning of fruit setting, and at the half-coloring stage of the fruits.

Table (1). Physical and chemical characteristics of the experimental soil as average of both seasons 2023/2024 and 2024/2025.

Physical properties								
Sand %		Silt %			Clay %		Texture	
54.80		25.7			17.5		Sandy loam	
Chemical properties								
EC ds/m	pH	Cations ($Meq.L^{-1}$)			Anions ($Meq.L^{-1}$)			
		Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-}
0.98	6.27	4.3	2.9	0.9	2.3	2.2	3.4	4.1

The following measurements were recorded:

Fruit quality parameters:

1. Physical properties:

A randomly selected sample of thirty fruits from each treatment at the 3/4 color stage was used to evaluate the following properties: the average weight of the fruit (g), length of the fruit (mm), and diameter (mm) were measured by a Vernier caliper, and the firmness of the fruit was determined using a digital force gauge (Model M4-200, MARK, Copiague, NY, USA) with an 8 mm diameter cylindrical probe. The firmness was measured in grams per square centimeter (g/cm^2) of force, as described by Del-Valle et al. (2005).

2. Chemical properties:

They were measured as follows: total soluble solids (%) was determined by a digital refractometer, as described by AOAC (2000), ascorbic acid (mg/100g F.W.) was measured using 2,6-dichlorophenol indophenol sodium salt and 3% oxalic acid as a substrate, as described by AOAC (2000), titratable acidity (mg/100g F.W.) was measured by titrating the fruit juice with a 0.1 N NaOH solution, using phenolphthalein as an indicator, as described by AOAC (2000), total sugars content (%) was measured by the method of Lane and Eynon using a spectrophotometer, as described by Krivorotova and Sereikaite (2014), and calcium concentration in fruits (%) was determined using atomic absorption spectrophotometer, according to AOAC (2005).

2. Storage experiment:

Strawberries obtained from the field experiment were harvested at the 3/4 color stage without any defect and packed directly in the field in plastic punnets (250 g) and placed in carton boxes in the first week of January at the 2024 and 2025 seasons, then transported to the laboratory of Handling of Vegetable Crops Research Department, Horticulture Research Institute, Agricultural Research Center, Giza Governorate, Egypt. All treatments were distributed in a randomized complete design with three replicates, each replicate consisted of three punnets. Fifty-four punnets were prepared for each treatment and then stored at 0˚C + 2 days at 10˚C (as a shelf life). Three replicates from each treatment were randomly selected and evaluated immediately after harvest, as well as after 3, 6, 9, 12 and 15 days of storage at 0˚C, followed by 2 days at 10˚C (shelf life) to assess the following properties:

1. Weight loss % was determined using the following equation: ((initial fruit weight – fruit weight at inspection date) / initial fruit weight) × 100.
2. The percentage of decay was determined through a visual inspection of fruits showing signs of injury or spoilage caused by fungal or microbial infections. It was calculated using the following equation: decay percentage % = (weight of decayed fruits / total weight of fruits at inspection date) × 100 (Rokaya et al., 2016).
3. The general appearance was evaluated based on factors such as fresh appearance, fresh calyx, color change, dryness, decay or any obvious signs of deterioration. The evaluation was conducted using the following scoring system: 9= excellent, 7= good, 5= fair, 3= poor, 1= unsalable (Shehata et al., 2020).
4. Firmness was measured as mentioned in the field experiment.
5. Color was assessed using a handheld tristimulus reflectance colorimeter (Model CR-400, Minolta Corp., Newburgh, NY, USA) to measure the L* value (lightness). Measurements were taken on three fruits per replicate, with readings recorded from three different positions on each fruit (Del-Valle et al., 2005).
6. Anthocyanins content (mg/100g F.W.) was determined using HCL (1.5 N) by a spectrophotometer as described by Tonu et al. (2014).
7. Ascorbic acid (mg/100g F.W.) was measured as mentioned in the field experiment.
8. Total soluble solids percentage was measured as mentioned in the field experiment.
9. Titratable acidity (mg/100g F.W.) was measured as mentioned in the field experiment.
10. The total sugars percentage was measured as mentioned in the field experiment.

Statistical analysis

All data were subjected to statistical analysis to calculate the means, variance, and standard error. Mean comparisons were conducted using the least significant difference (LSD) test at a 5% probability level, as described by Snedecor and Cochran (1980), with analyses performed using the MSTAT-C software.

RESULTS AND DISCUSSION

1. Field experiment:

Fruit quality parameters:

Physical properties:

Data in **Table (2)** demonstrate that foliar spray of different calcium sources increased both of fruit length and weight in comparison with untreated plants (control). However, calcium nitrate was more effective on both characters, followed by calcium lactate, with significant differences between them. In contrast, untreated plants exhibited the smallest fruit size in the two seasons. These findings concurred with Sidhu et al. (2020). Calcium is one of the most essential ions in the formation of the mitotic spindle, which has a direct impact on cell division (Hepler, 1994). Regarding fruit diameter, no significant differences were observed between control and the used treatments.

Regarding fruit firmness, the highest values were observed in plants treated with calcium lactate, followed by calcium nitrate with a significant difference between them. Calcium citrate treatment had a lesser impact on this concern, while the untreated plants exhibited the lowest fruit firmness values. These findings agreed with Sidhu et al. (2020). Calcium (Ca) plays a crucial role in providing thickness and strength to the cell wall of plants, verifying its importance in relation to fruit firmness (Easterwood, 2002). The gradual rise in fruit firmness could be explained by the thickening of the cell wall's middle lamella due to enhanced calcium pectate formation, deposition, and the stabilization of cell membranes by calcium ions (Singh et al., 2007).

Fruit firmness is increased by calcium ions, which stabilize the plasma membrane through binding with proteins and phospholipids on the membrane surface and maintaining cell turgor pressure and membrane integrity (Picchioni et al., 1996). The rise in Ca concentration in mesocarp cells due to pre-harvest Ca spray treatment was more likely to have improved tissue firmness at harvest (Naradison et al., 2006).

Table (2). Effect of preharvest spray of different calcium sources on physical properties of strawberry fruits during 2023/2024 and 2024/2025 seasons.

Treatments	2023/2024 season			
	Average fruit weight (g)	fruit length (mm)	fruit diameter (mm)	fruit firmness (g/cm^2)
Calcium nitrate	31.07 a	53.37 a	32.52 a	23.70 b
Calcium lactate	28.48 b	50.32 b	33.49 a	25.47 a
Calcium citrate	25.40 c	46.41 c	31.80 a	22.30 c
Control	22.46 d	44.59 d	31.55 a	21.10 d
	2024/2025 season			
Calcium nitrate	34.18 a	54.02 a	33.10 a	25.27 b
Calcium lactate	31.55 b	50.93 b	33.54 a	26.33 a
Calcium citrate	28.45 c	47.11 c	32.96 a	24.37 c
Control	25.48 d	45.13 d	32.80 a	22.33 d

The values that contain the same capital letters in the same columns indicate that there are no significant variations between each other at level 0.05.

Chemical properties:

Data in **Table (3)** indicate that all Ca treatments significantly increased total soluble solids (TSS %), ascorbic acid, and total sugars content in fruits compared to the untreated plants. However, the highest values of TSS% and ascorbic acid content were observed in strawberries from plants treated with calcium lactate or calcium nitrate, with significant differences between them in both seasons. In the meantime, the application of different calcium sources had a non-significant effect on the titratable acidity at harvest in both seasons. These findings agree with Kazemi (2015), Hamail et al. (2018) and Sidhu et al. (2020). These results could be attributed to the increased soluble matter in the juice by the penetrated calcium. Also, the higher content of ascorbic acid in fruits is primarily attributed to the effect of calcium on the content of vitamin C (Kadir, 2005).

Concerning the total sugars content, data in the same table reveal that fruits harvested from plants sprayed with calcium lactate or calcium nitrate exhibited the greatest total sugar content, with significant differences between them in the second season. In contrast, untreated plants recorded the lowest total sugar content.

These findings agreed with Hamail et al. (2018). This could be explained by a decrease in respiration due to calcium applications, which results in a decreased use of sugars in different metabolic processes (Sidhu et al., 2020).

Regarding calcium concentration in fruits, data in **Table (3)** show that all pre-harvest treatments significantly raised calcium content in fruits compared with untreated plants. However, calcium lactate or calcium nitrate treatments had the greatest value of calcium concentration in strawberry fruits with significant differences between them in both seasons. In contrast, untreated plants showed the least content of calcium at harvest. These findings were true in both seasons and were consistent with Wójcik and Lewandowski (2003) and Gastol and Domagala (2006).

Table (3). Effect of preharvest spray of different calcium sources on chemical properties of strawberry fruits during 2023/2024 and 2024/2025 seasons.

Treatments	Total soluble solids (%)	Ascorbic acid (mg/100g F.W.)	Titratable acidity (mg/100g F.W.)	Total sugar content (%)	Calcium content in fruits (%)
	2023/2024 season				
Calcium nitrate	9.40 b	95.33 b	0.79 a	6.69 a	0.37 b
Calcium lactate	9.96 a	96.80 a	0.81 a	7.06 a	0.44 a
Calcium citrate	8.85 c	93.17 c	0.75 a	6.25 b	0.30 c
Control	8.43 d	90.60 d	0.75 a	5.81 c	0.22 d
	2024/2025 season				
Calcium nitrate	9.70 b	96.23 b	0.83 a	6.79 b	0.37 b
Calcium lactate	10.20 a	97.73 a	0.85 a	7.17 a	0.47 a
Calcium citrate	9.20 c	94.10 c	0.81 a	6.33 c	0.30 c
Control	8.77 d	91.60 d	0.80 a	5.86 d	0.23 d

The values that contain the same capital letters in the same columns indicate that there are no significant variations between each other at level 0.05.

Storage experiment:

Weight loss percentage:

Data in **Table (4)** indicate that the weight loss percentage of strawberries increases significantly and continuously with the extension of the storage duration in both seasons. These findings align with those of Shehata et al. (2020). The main causes of weight loss are respiration and transpiration. Transpiration leads to moisture loss to the atmosphere, while respiration results in weight reduction as each lost carbon atom from the fruit forms a carbon dioxide molecule (Bhowmik and Pan, 1992).

All pre-harvest treatments were shown to be significantly effective in decreasing the weight loss percentage of strawberries during storage and shelf life compared to untreated plants. However, calcium lactate and calcium nitrate proved to be the best treatments for decreasing the weight loss %, with significant differences observed between them in both seasons. Calcium citrate was comparatively less efficient in this regard. In contrast, control treatment exhibited the greatest percentage of weight loss in both seasons and concurred with Akhtar and Rab (2014), Harris et al. (2017) and Mahmoud (2017). Calcium treatments prevented weight loss by reducing respiration rate, maintaining cell integrity, and thereby reducing electrolyte leakage and water evaporation in fruit (Erbaş and Koyuncu, 2023). Additionally, they inhibited physiological processes, further contributing to reduced weight loss (Luna-Guzman and Barrett, 2000).

The combined effect of all pre-harvest treatments and storage durations had a significant effect on weight loss percentage throughout storage and shelf life in both seasons. After 15 days of storage at 0 ºC plus 2 days at 10 ºC, calcium lactate demonstrated the lowest value of weight loss when compared to the untreated plants and other treatments.

Table (4). Effect of preharvest spray of different calcium sources on weight loss (%) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	0.49 k	1.32 i	2.21 gh	2.95 f	3.75 e	4.47 d	**2.53 C**
Calcium lactate	0.40 k	1.09 ij	1.88 h	2.44 g	2.98 f	3.46 e	**2.04 D**
Calcium citrate	0.56 k	1.89 h	2.88 f	3.70 e	4.59 d	5.21 c	**3.14 B**
Control	0.76 jk	2.48 g	3.64 e	4.72 d	5.62 b	6.87 a	**4.02 A**
Mean	**0.55 F**	**1.69 E**	**2.65 D**	**3.45 C**	**4.23 B**	**5.00 A**	
	2024 / 2025						
Calcium nitrate	0.41 r	1.23 n	2.10 l	2.85 hi	3.66 f	4.39 e	2.44 C
Calcium lactate	0.34 r	1.01 o	1.79 m	2.36 j	2.91 h	3.40 g	1.97 D
Calcium citrate	0.49 q	1.81 m	2.79 i	3.63 f	4.51 d	5.14 c	3.06 B
Control	0.65 p	2.26 k	3.41 g	4.51 d	5.40 b	6.56 a	3.80 A
Mean	0.47 F	1.58 E	2.52 D	3.34 C	4.12 B	4.87 A	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Decay percentage:

Data in **Table (5)** indicated that the decay percentage of strawberries raised with the extension of storage periods and shelf life in both seasons. These findings concur with Shehata et al. (2020); this might result from continuous changes in the chemical and biochemical properties of the fruits, where complex compounds are converted into simpler forms, which are more susceptible to fungal infections (Wills et al., 1989).

However, different calcium source treatments didn't exhibit any signs of decay in fruits till the end of the storage duration and shelf life. However, decay began to be observed in the control treatment after 12 days of cold storage plus 2 days of shelf life, and then it raised until the end of the storage duration in both seasons. These findings coincide with those of Mahmoud (2017).

Calcium sources increase the activity of antioxidant enzymes and enhance resistance to fungal attack, accumulating H_2O_2 and defense-related metabolites such as polymethoxylated flavones, ornithine, and threonine, and the anti-senescent impact that maintains fruit firmness, which prevents the spread and penetration of pathogens in fruits, ultimately decreasing the spoilage percentage in fruits (Ghahremani et al., 2021). Calcium lactate has the ability to reduce intracellular pH or decrease the activity of water (Shelef, 1994), which creates an antimicrobial barrier that helps protect against foodborne pathogens in the product (Weaver and Shelef, 1993). Additionally, when pH is low, the microflora is generally limited to lactic acid bacteria and fungi (Luna-Guzman and Barrett, 2000).

Table (5). Effect of preharvest spray of different calcium sources on decay (%) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	**0.00 B**
Calcium lactate	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	**0.00 B**
Calcium citrate	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	**0.00 B**
Control	0.00 c	0.00 c	0.00 c	0.00 c	20.93 b	31.59 a	**8.75 A**
Mean	**0.00 C**	**0.00 C**	**0.00 C**	**0.00 C**	**5.23 B**	**7.90 A**	
	2024 / 2025						
Calcium nitrate	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	**0.00 B**
Calcium lactate	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	**0.00 B**
Calcium citrate	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c	**0.00 B**
Control	0.00 c	0.00 c	0.00 c	0.00 c	20.23 b	30.98 a	**8.53 A**
Mean	**0.00 C**	**0.00 C**	**0.00 C**	**0.00 C**	**5.06 B**	**7.74 A**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

General appearance (GA):

Data in **Table (6)** indicate a decrease in the general appearance score of strawberries as storage durations and shelf life were prolonged in both seasons. Comparable results were noted by Mahmoud (2017). Quality scores were based on appearance, dehydration, darkening, calyx dryness, and decay (Hernández-Muñoz et al., 2006). The reduction in GA throughout storage is possibly because of a little dryness of surface and calyx, rather than translucency or macroscopic decay and color changes (Shehata et al., 2009).

Strawberry fruits obtained from all treatments showed higher GA than the control during storage and shelf life. However, calcium lactate and calcium nitrate were the most efficient treatments in preserving GA, with significant differences observed between them in both seasons. Conversely, the untreated control had the lowest GA score. These findings were concurred with Akhtar and Rab (2014) and Harris et al. (2017). Foliar applications of Ca reduce respiration rates, increase the content of the total phenolic and antioxidant capacity in fruits, slow down softening, and delay ripening and senescence processes, which maintained GA throughout storage and increased the shelf life of strawberries (Lara et al., 2004 and Sharma et al., 2006).

The combined effect of all pre-harvest treatments and storage durations significantly affected GA in both seasons. Furthermore, calcium lactate gave the excellent appearance of fruits without any observed changes in appearance till the end of storage duration and shelf life (15 days at 0 ºC + 2 days at 10 ºC). Calcium nitrate treatment rated good appearance at the same time, while calcium citrate treatment exhibited good appearance for 12 days at 0 ºC + 2 days at 10 ºC (shelf life). Conversely, the untreated control indicated an unsalable appearance till the end of the storage period and shelf life in the two seasons.

Table (6). Effect of preharvest spray of different calcium sources on general appearance (score) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days) 0+2	3+2	6+2	9+2	12+2	15+2	Mean
	2023 / 2024						
Calcium nitrate	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	7.00 c	**8.33 B**
Calcium lactate	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	**8.89 A**
Calcium citrate	9.00 a	9.00 a	8.33 ab	7.67 bc	7.00 c	5.67 d	**7.78 C**
Control	9.00 a	8.33 ab	7.00 c	5.67 d	3.00 e	1.67 f	**5.78 D**
Mean	**9.00 A**	**8.83 AB**	**8.33 B**	**7.67 C**	**6.67 D**	**5.67 E**	
	2024 / 2025						
Calcium nitrate	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 ab	7.00 bc	**8.33 B**
Calcium lactate	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	**9.00 A**
Calcium citrate	9.00 a	9.00 a	9.00 a	7.67 ab	7.00 bc	4.33 de	**7.67 C**
Control	9.00 a	8.33 ab	7.67 ab	5.67 cd	3.67 e	1.67 f	**6.00 D**
Mean	**9.00 A**	**8.83 A**	**8.67 A**	**7.67 B**	**6.83 C**	**5.50 D**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Fruit firmness:

Firmness is a critical factor influencing the physiology of fruits and the postharvest quality (Bal, 2013). Data in **Table (7)** demonstrate that the firmness of strawberry fruits reduced continuously with extending the storage periods and shelf life in both seasons. These findings concurred with those of Shehata et al. (2020). The degradation of the middle lamella in the cortical parenchyma cell wall leads to strawberry softness during storage (Hernández-Muñoz et al., 2008), or a rise in pectin solubilization, with limited changes in the weight of pectin molecules and a slight reduction in the content of hemicelluloses (Koh and Melton, 2002). Also, fruit softening is caused by cell membrane breakdown and cell wall hydrolases such as b-galactosidase, xylanase, pectin methylesterases, and polygalactosidases along with the cell membrane deterioration (Ghahremani et al., 2021).

All treatments gave significantly larger fruit firmness in comparison to untreated control. However, calcium lactate was the best successful treatment in decreasing the loss of firmness, followed by calcium nitrate, with significant differences observed between them throughout the storage periods and shelf life. Calcium citrate was less successful in this regard. In contrast, the control treatment had the greatest reduction in fruit firmness in both seasons. The findings are consistent with Wójcik and Lewandowski (2003) and Harris et al. (2017).

The beneficial role of calcium compounds in inhibiting fruit-softening enzymes may be attributed to their ability to strengthen cell structure by preserving the fibrillar arrangement in the cell wall. This enhances cell-to-cell contact, promoting the formation of calcium pectate and counteracting the action of pectin methylesterase (Alandes et al., 2009). Also, calcium applied externally increases the cell wall rigidity, which could result in increased resistance to the cellulase enzyme's activities (Sinha et al., 2019) and delays the softening of tissue and also lowers the activity of the pectinase enzyme, which causes cell wall deterioration (Vicente et al., 2009).

The combined effect of all pre-harvest treatments and storage periods significantly affect the firmness of fruits. Calcium lactate was more efficient in preserving the firmness of the strawberries till the end of the storage periods and shelf life in both seasons, while the untreated fruits had the lowest values of firmness.

Table (7). Effect of preharvest spray of different calcium sources on firmness (g/cm^2) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	23.50 ab	23.00 a-c	22.33 b-d	20.67 e-g	18.83 ij	16.50 k	**20.81 B**
Calcium lactate	24.17 a	23.83 a	23.33 a-c	22.17 b-d	20.50 f-h	19.17 h-j	**22.19 A**
Calcium citrate	22.00 c-e	21.17 d-f	20.17 f-i	18.17 j	16.00 k	13.33 l	**18.47 C**
Control	20.67 e-g	19.33 g-j	18.17 j	15.83 k	13.17 l	11.00 m	**16.36 D**
Mean	**22.58 A**	**21.83 B**	**21.00 C**	**19.21 D**	**17.13 E**	**15.00 F**	
	2024 / 2025						
Calcium nitrate	24.93 b	24.13 d	23.43 e	21.80 g	19.93 j	17.60 l	**21.97 B**
Calcium lactate	25.33 a	25.03 ab	24.47 c	23.33 e	21.63 g	20.33 i	**23.36 A**
Calcium citrate	23.47 e	22.37 f	21.30 h	19.33 k	17.10 m	14.57 n	**19.69 C**
Control	21.87 g	20.57 i	19.37 k	17.07 m	14.37 n	12.20 o	**17.57 D**
Mean	**23.90 A**	**23.02 B**	**22.14 C**	**20.38 D**	**18.26 E**	**16.17 F**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Color (L* value):

Data in **Table (8)** show that the lightness (L* value) of strawberry fruits was influenced by the storage durations. A significant decrease in the L* value was observed as storage time increased, resulting in darker fruits in both seasons, which aligns with the findings of Shehata et al. (2020). This may be related to water loss in fruit (Ardakani and Mostofi, 2019).

All treatments significantly maintained L* values of strawberry fruits in comparison to untreated fruits. With the end of the storage duration and shelf life, calcium lactate treatment had a significantly lighter color of fruits (high L* value), followed by calcium nitrate treatment, with significant differences observed between them. While the untreated fruits had a darker color (low L* value) in both seasons and are concurred with Singh et al. (2007) and Harris et al. (2017), who found that strawberries harvested from plants treated with calcium were better and brighter, while fruits harvested from control treatment turned darker sharply. The color development happened significantly more quickly in control fruits. However, pre-harvest spray with calcium revealed a significantly slower color development rate, showing a delayed ripening of persimmon fruits (Agustí et al., 2004).

Table (8). Effect of preharvest spray of different calcium sources on color (L* value) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	43.35 a-c	42.94 a-f	42.42 b-g	41.76 d-i	40.95 g-k	40.31 i-l	**41.95 B**
Calcium lactate	44.11 a	43.85 ab	43.50 a-c	43.17 a-d	42.65 a-f	42.26 c-h	**43.26 A**
Calcium citrate	43.00 a-e	42.25 c-h	41.55 e-i	40.59 i-k	39.59 k-m	38.65 mn	**40.94 C**
Control	41.41 f-j	40.78 h-k	39.89 j-m	38.84 l-n	37.53 n	35.88 o	**39.05 D**
Mean	**42.97 A**	**42.45 AB**	**41.84 BC**	**41.09 C**	**40.18 D**	**39.28 E**	
	2024 / 2025						
Calcium nitrate	45.68 a-d	45.29 a-e	44.76 c-g	44.09 e-h	43.29 h-j	42.64 i-k	**44.29 B**
Calcium lactate	46.43 a	46.19 ab	45.83 a-c	45.51 a-d	44.98 b-f	44.58 d-g	**45.59 A**
Calcium citrate	45.09 b-f	44.58 d-g	43.89 f-h	42.91 h-k	41.93 k-m	40.97 mn	**43.23 C**
Control	43.72 g-i	43.10 h-k	42.22 j-l	41.15 lm	39.86 n	38.19 o	**41.37 D**
Mean	**45.23 A**	**44.79 AB**	**44.17 B**	**43.42 C**	**42.52 D**	**41.60 E**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Anthocyanins content:

Data in **Table (9)** show a significant increase in the anthocyanin content of strawberries throughout the storage periods and shelf life in both seasons. These results align with those of Shehata et al. (2020), and possibly as a result of the chlorophyll content degrading and the production of anthocyanin pigment, which contributes to the red coloration of strawberries (Afifi, 2016).

All pre-harvest treatments resulted in significantly lower total anthocyanin levels in strawberries compared to the control treatment throughout the storage periods and shelf life. Calcium lactate gave the lowest values of anthocyanins in fruits, followed by calcium nitrate, with significant differences observed between them, indicating a reduction in the development of color as the fruits become less red. While calcium citrate was observed to be less efficient in this regard. The untreated control had the greatest anthocyanin values, which developed more redness. These findings confirm those of Wang and Long (2015) and Sinha et al. (2019).

Correia et al. (2017) found that Ca treatments slowed down the accumulation of the contents of the total anthocyanin and the total phenolic by inhibiting the ripening process and slowing down senescence processes and the respiration rate of cherries throughout storage.

Regarding the effect of the combination between all pre-harvest applications and storage durations, data show that calcium lactate gave significantly lower anthocyanin concentrations of fruits compared to other applications and control treatment till the end of storage duration and shelf life in both seasons.

Table (9). Effect of preharvest spray of different calcium sources on anthocyanin (mg/100 g F. W.) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	53.41 o	55.73 lm	58.20 k	61.18 i	64.50 h	69.21 f	**60.37 C**
Calcium lactate	51.27 p	52.94 o	54.79 mn	56.65 l	58.28 k	59.79 j	**55.62 D**
Calcium citrate	54.04 no	57.99 k	61.96 i	67.82 g	72.88 e	80.79 c	**65.91 B**
Control	56.39 l	64.77 h	69.81 f	77.25 d	86.47 b	95.89 a	**75.10 A**
Mean	**53.78 F**	**57.86 E**	**61.19 D**	**65.73 C**	**70.53 B**	**76.42 A**	
	2024 / 2025						
Calcium nitrate	48.30 op	50.60 m	53.09 k	56.03 i	59.37 h	64.10 f	**55.25 C**
Calcium lactate	46.19 q	47.83 p	49.70 n	51.57 l	53.18 k	54.71 j	**50.53 D**
Calcium citrate	48.96 no	52.90 k	56.88 i	62.72 g	67.79 e	75.71 c	**60.83 B**
Control	51.19 lm	59.56 h	64.61 f	72.02 d	81.25 b	90.69 a	**69.89 A**
Mean	**48.66 F**	**52.72 E**	**56.07 D**	**60.58 C**	**65.40 B**	**71.30 A**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Ascorbic acid content:

Data in **Table (10)** show that the ascorbic acid content of strawberry fruits significantly reduced as storage periods and shelf life were extended in both seasons. The same finding was observed with Shehata et al. (2020). The loss of ascorbic acid during storage may be due to its antioxidant activity, particularly under postharvest storage conditions (Davey et al., 2000). In addition, it might result from a decrease in the enzymatic activity of ascorbate peroxidase (Kadir, 2005).

All treatments had significant greater ascorbic acid content in comparison with the untreated fruits throughout storage duration and shelf life. Furthermore, calcium lactate and calcium nitrate showed the greatest effectiveness as treatments for preserving the content of ascorbic acid, with significant differences observed between them in both seasons. Untreated control exhibited the least content of ascorbic acid. These findings were true in both seasons and agree with Akhtar and Rab (2014) and Harris et al. (2017) and may be attributed to calcium regulation of the oxidative process in the cytosol (Haleema et al., 2020). Also, calcium slowed down the rapid oxidation of the ascorbic acid content in fruits (Turmanidze et al., 2017). Calcium keeps horticultural commodities from losing antioxidants like ascorbic acid (Luna-Guzman and Barrett, 2000), reducing the rate of respiration and moisture loss (Goodarzi, 2009) and delaying the overall ripening and senescence (Asrey and Jain, 2004); thus, it retains ascorbic acid content. Also, applying calcium increased the activity of a number of catalytic enzymes, which were crucial for the biosynthesis of vitamin C (Kadir, 2005).

The interaction between all pre-harvest applications and storage durations significantly affected the ascorbic acid content of strawberry fruits in both seasons.

Table (10). Effect of preharvest spray of different calcium sources on ascorbic acid (mg/100 g F. W.) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	94.50 bc	93.37 cd	91.30 e	86.60 g	83.53 i	79.33 j	**88.11 B**
Calcium lactate	95.93 a	94.93 ab	92.97 d	89.10 f	86.90 g	83.03 i	**90.48 A**
Calcium citrate	92.33 de	91.20 e	87.50 g	83.07 i	79.20 j	73.60 l	**84.48 C**
Control	85.23 h	83.40 i	76.33 k	69.57 m	61.50 n	52.50 o	**71.42 D**
Mean	**92.00 A**	**90.72 B**	**87.03 C**	**82.08 D**	**77.78 E**	**72.12 F**	
	2024 / 2025						
Calcium nitrate	95.60 ab	94.50 bc	92.40 d	87.67 fg	84.63 h	80.43 i	**89.21 B**
Calcium lactate	96.83 a	95.87 a	93.90 c	90.00 e	87.80 fg	83.93 h	**91.39 A**
Calcium citrate	93.57 cd	92.47 d	88.73 ef	84.33 h	80.43 i	74.83 k	**85.73 C**
Control	86.67 g	84.90 h	77.80 j	71.03 l	63.03 m	53.90 n	**72.89 D**
Mean	**93.17 A**	**91.93 B**	**88.21 C**	**83.26 D**	**78.97 E**	**73.28 F**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Total soluble solids (TSS) percentage:

Data in **Table (11)** demonstrate that the TSS content in strawberries were significantly reduced with extension of the storage periods and shelf life in both seasons. The same findings were found with Shehata et al. (2020). TSS may have decreased during storage because loss of sugar through respiration is more rapid than loss of water through transpiration (Wills et al., 1989).

Calcium lactate was the most successful treatment in maintaining TSS of the fruits, followed by calcium nitrate, with significant differences observed between them during storage duration and shelf life. In contrast, the untreated control had the least TSS value. These findings were true in both seasons and concur with Vani et al. (2020). This could be as a result of the ability of calcium to reduce respiration rate and vital processes and slow down fruit ripening and senescence (Sharma et al., 2006), thus decreasing the loss of TSS throughout storage. Also, increasing the total soluble matter in the juice by the penetrated calcium (Kazemi, 2015).

Table (11). Effect of preharvest spray of different calcium sources on total soluble solids (%) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	9.33 bc	9.07 c-e	8.87 d-g	8.53 f-i	8.23 i-l	7.87 kl	**8.65 B**
Calcium lactate	9.87 a	9.58 ab	9.23 b-d	8.97 c-f	8.77 e-h	8.50 g-i	**9.15 A**
Calcium citrate	8.75 e-h	8.41 h-j	8.27 i-k	7.80 l	7.30 m	6.87 mn	**7.90 C**
Control	8.30 i-k	8.00 j-l	7.80 l	7.23 m	6.53 n	5.70 o	**7.26 D**
Mean	**9.06 A**	**8.76 B**	**8.54 C**	**8.13 D**	**7.71 E**	**7.23 F**	
	2024 / 2025						
Calcium nitrate	9.50 bc	9.23 c-e	9.03 d-f	8.70 f-h	8.40 h-j	8.03 jk	**8.82 B**
Calcium lactate	10.10 a	9.80 ab	9.47 b-d	9.23 c-e	9.00 e-g	8.73 f-h	**9.39 A**
Calcium citrate	9.07 c-f	8.57 g-i	8.40 h-j	7.90 k	7.43 l	7.00 lm	**8.06 C**
Control	8.63 f-h	8.17 i-k	8.00 jk	7.40 l	6.67 m	5.83 n	**7.45 D**
Mean	**9.33 A**	**8.94 B**	**8.73 B**	**8.31 C**	**7.88 D**	**7.40 E**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Titratable acidity (TA):

Results in **Table (12)** show that the TA content in strawberries reduced with the extension of storage periods and shelf life in both seasons. The same findings were observed with Shehata et al. (2020). One possible explanation for the decrease in fruit acidity during storage is the conversion of pyruvic acid and other organic acids into carbon dioxide through oxidation (Wills et al., 1989). Also, Toivonen and Brummell (2008) reported a drop in acid level in storage because fruit uses these acids.

Calcium lactate and calcium nitrate proved to be the most efficient applications for reducing the loss of TA content, with significant differences observed between them throughout storage and shelf life. Calcium citrate treatment had a lower effectiveness in this regard, while the control treatment had the smallest TA value. These findings were true in both seasons and consistent with Akhtar and Rab (2014).

EL-Sayed et al. (2023) recorded that calcium application before harvest maintained the acidity of strawberry fruits. This could be a result of the ability of calcium to slow down fruit ripening and senescence. The highest titratable acidity resulting in calcium treatment may be due to a reduction in the loss of organic acids and hence a decline in titratable acidity (Han et al., 2004). Additionally, the beneficial effect of calcium treatments on delaying the loss of TA can be attributed to calcium's ability to reduce the impact on fruit metabolic processes, such as the rate of respiration. Organic acids are known to play an important role in these respiration processes (Kays and Paull, 2004).

Table (12). Effect of preharvest spray of different calcium sources on titratable acidity (mg/100 g F.W.) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	0.77 a-c	0.65 e	0.53 fg	0.52 g	0.49 gh	0.46 hi	**0.57 B**
Calcium lactate	0.80 a	0.78 ab	0.76 a-c	0.73 b-d	0.72 cd	0.71 d	**0.75 A**
Calcium citrate	0.72 cd	0.58 f	0.43 ij	0.37 kl	0.32 lm	0.31 m	**0.45 C**
Control	0.65 e	0.53 fg	0.39 jk	0.30 mn	0.25 no	0.21 o	**0.39 D**
Mean	**0.73 A**	**0.64 B**	**0.53 C**	**0.48 D**	**0.44 E**	**0.42 E**	
	2024 / 2025						
Calcium nitrate	0.81 ab	0.71 d	0.60 ef	0.56 e-g	0.51 gh	0.49 hi	**0.61 B**
Calcium lactate	0.84 a	0.83 a	0.82 ab	0.77 bc	0.75 cd	0.74 cd	**0.79 A**
Calcium citrate	0.76 cd	0.61 e	0.45 ij	0.41 jk	0.37 kl	0.35 l	**0.49 C**
Control	0.71 d	0.55 fg	0.40 jk	0.33 lm	0.29 mn	0.24 n	**0.42 D**
Mean	**0.78 A**	**0.68 B**	**0.57 C**	**0.52 D**	**0.48 E**	**0.45 E**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

Total sugars content:

The results in **Table (13)** report that the total sugars in strawberries significantly reduced as storage periods and shelf life were extended in both seasons. These findings concur with Mahmoud (2017). This reduction could be attributed to loss of sugar through the respiration process (Wills et al., 1989).

Calcium lactate proved to be the most efficient treatment in preserving the total sugars in fruits throughout the storage and shelf life conditions, followed by calcium nitrate and calcium citrate, with significant differences observed between them in the first season. The control treatment exhibited the smallest value of total sugars. These findings were concurred with Amiri et al. (2022), who reported that calcium treatment preserved total sugars in strawberry fruits during cold storage. Tantawy et al. (2014) revealed that the effect of Ca was more striking at the end of storage. Calcium-treated strawberries present sugar concentrations in the ionically-bound pectin, showing a gradual breakdown of cell walls and an increase in the treated fruit's commercial life (Lara et al., 2004).

The combined effect of all pre-harvest applications and storage durations significantly affects the total sugars in strawberry fruits in the two seasons. In this concern, with the end of storage and shelf life conditions, calcium lactate treatment showed the greatest value of total sugar content, while the untreated control had the lowest ones.

Table (13). Effect of preharvest spray of different calcium sources on total sugars (%) of strawberry fruits during storage at 0°C, with an additional 2 days at 10°C in 2023/2024 and 2024/2025 seasons.

Treatments	Storage period (days)						Mean
	0+2	3+2	6+2	9+2	12+2	15+2	
	2023 / 2024						
Calcium nitrate	6.34 bc	6.07 cd	5.68 d-f	5.31 f-i	4.96 h-j	4.63 j-l	**5.50 B**
Calcium lactate	6.83 a	6.64 ab	6.33 bc	6.01 cd	5.75 d-f	5.51 ef	**6.18 A**
Calcium citrate	6.01 cd	5.87 de	5.45 e-g	5.03 g-j	4.65 j-l	4.29 lm	**5.22 C**
Control	5.64 d-f	5.39 f-h	4.93 i-k	4.49 k-m	4.09 mn	3.66 n	**4.70 D**
Mean	**6.21 A**	**5.99 A**	**5.60 B**	**5.21 C**	**4.86 D**	**4.52 E**	
	2024 / 2025						
Calcium nitrate	6.51 a-c	6.26 a-d	5.88 c-e	5.48 d-g	5.16 e-h	4.80 f-i	**5.68 B**
Calcium lactate	6.92 a	6.75 ab	6.45 a-c	6.11 a-d	5.84 c-e	5.60 d-f	**6.28 A**
Calcium citrate	6.28 a-d	6.00 b-d	5.56 d-f	5.15 e-h	4.79 f-i	4.41 h-j	**5.36 B**
Control	5.81 c-e	5.57 d-f	5.09 e-i	4.68 g-j	4.29 ij	3.94 j	**4.90 C**
Mean	**6.38 A**	**6.15 AB**	**5.75 BC**	**5.36 CD**	**5.02 DE**	**4.69 E**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05.

CONCLUSION

According to the obtained results, it can be concluded that strawberries cv. Fortuna obtained from plants sprayed with calcium lactate improve fruit quality at harvest, exhibited increased firmness, total soluble solids, ascorbic acid, total sugars, and calcium concentration in the fruits at harvest. Additionally, it preserved fruit quality characteristics and enhanced storability and gave an excellent appearance of fruits after 15 days of storage at 0 ºC plus 2 days at 10 ºC of shelf life without any decay.

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الملخص العربى

تاثير الرش قبل الحصاد بمصادر مختلفة من الكالسيوم على صفات الجودة والقدرة التخزينية لثمار الفراولة

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أجريت هذه الدراسة على الفراولة صنف فورتونا خلال الموسم الشتوى 2023-2024 و 2024-2025 لدراسة تأثير الرش الورقي لنباتات الفراولة بمصادر مختلفة من الكالسيوم (نترات الكالسيوم ، لاكتات الكالسيوم وسترات الكالسيوم) بتركيز 0.5 ٪ مقارنة بالنباتات غير المعاملة (الرش بالماء فقط) على الجودة والقدرة التخزينية لثمار الفراولة. أشارت النتائج إلى أن ثمار الفراولة التي تم الحصول عليها من النباتات التي تم معاملتها بجميع مصادر الكالسيوم المستخدمة أدت الى زيادة الصفات الطبيعية معنويا مثل طول الثمرة، ومتوسط وزن الثمرة وصلابة الثمار، والصفات الكيميائية مثل نسبة المواد الصلبة الذائبة الكلية ، حمض الأسكوربيك، محتوى السكريات الكلية وتركيز الكالسيوم في الثمار عند القطف مقارنة بالثمار التي تم الحصول عليها من النباتات غير المعاملة. ومع ذلك، لم يكن هناك اى فرق معنوي بين جميع المعاملات والكنترول فيما يتعلق بقطر الثمرة والحموضة. بالاضافة الى ذلك، جميع مصادر الكالسيوم المختلفة كانت فعالة في الحفاظ على صفات جودة الثمار حيث قللت الفقد فى الوزن، والمحافظة على صلابة الثمار، ونسبة المواد الصلبة الذائبة الكلية، والحموضة، وحمض الأسكوربيك، والمحتوى من السكريات الكلية، وتقليل التغير فى اللون، والمحافظة على المظهر العام لثمار الفراولة خلال فترات التخزين و فترة العرض مقارنة بالثمار غير المعاملة. توصي الدراسة بأن ثمارالفراولة صنف فورتونا التي تم الحصول عليها من النباتات التى تم رشها بلاكتات الكالسيوم حسنت من صفات جودة الثمار عند الحصاد، و حسنت القدرة التخزيينة، والمحافظة على صفات الجودة للثمار، كما أعطت مظهرًا ممتازًا للثمار بعد 15 يوم من التخزين على صفر درجة مئوية بالإضافة إلى يومين على 10 درجة مئوية (فترة العرض) بدون أي تلف.