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ORIGINAL ARTICLE

The Effect of Pedicel Length and Post-Harvest Calcium Chloride Application on the Storage Life of Strawberry Fruit

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Abstract

This study was carried out to examine the effects of postharvest fruit pedicel length and calcium chloride ($CaCl_2$) treatments on quality changes during storage of 'Monterey' strawberry variety. After the fruits were harvested according to three different pedicel lengths (0-5-10 cm), they were immersed in three different doses (0%-2%-4%) of $CaCl_2$ solution for 5 min, then 1.0 ± 1.0 °C and. It was stored for 21 days in a cold storage at 90% relative humidity. During storage, measurements and analyses of fruit quality parameters were carried out on days 0, 7, 14 and 21. As a result of the study, it was observed that the amount of weight loss increased during storage and the lowest weight loss was in the fruits with a pedicel length of 5 cm. It was observed that the lowest values of rot in terms of fruit pedicel lengths were in 0 and 5 cm pedicel length fruits, and the best results were observed at the 2% $CaCl_2$ dose in $CaCl_2$ applications. The amount of SSC in the fruits decreased during the storage period. In terms of phytochemical content, increases and decreases were observed depending on fruit pedicel lengths and calcium doses during storage. As a result, it has been seen that 0–5 cm pedicel length and 2% $CaCl_2$ applications are effective in many parameters and can be recommended.

Keywords $CaCl_2$ · *Fragaria* × *ananassa* · Post-Harvest · Storage · Pedicel Length · Antioxidant

Introduction

Strawberry is a species of berry fruit with a unique taste and smell (Aybak 2000). While 8.8 million tons of strawberries are produced worldwide, Turkey ranks 4th with 546 thousand tons (FAO 2020). Strawberries are sensitive fruit and can spoil very quickly after harvest (softening, color change, taste/aroma losses and physiological/pathological losses). After harvest, fruit losses of between 10 and 30% occur until arrival from the producer to the consumer. The majority of these losses are due to transportation or lack of proper storage conditions. In order to prevent losses, first of all, it is necessary to ensure the storage in appropriate conditions by considering the physiological properties of the products, which are more sensitive to physical impacts and injuries that may occur during the harvest, and to control the undesirable situations that may occur after the harvest by making some applications (Bal 2016). These applications include controlled and modified atmosphere storage, storage at hypobaric pressure, pre-cooling, hot applications, radiofrequency, microwave applications, ultraviolet light (UV) and immersion applications (Erkan et al. 2008; Turtoi 2013; Usall et al. 2016). Therefore, many applications have been made to increase the post-harvest shelf life of strawberry fruit. Calcium (Ca), which is generally applied in different doses and ways in post-harvest preservation and shelf life studies, increases the fruit flesh firmness by adding to the cell wall of fruit and increases post-harvest storage period. In previous studies, $CaCl_2$ have been applied to fruit species such as strawberry (Chen et al. 2011; Qureshi et al. 2013; Nguyen et al. 2020; Shahzad et al. 2020), plum (Dursun 2019), loquat (Akhtar et al. 2010), cherry (Wang et al. 2014), persimmon (Bagheri et al. 2015), apple (Hussain et al. 2012; Ekinci and Sakaldas 2016). Pareek (2017) reported that calcium chloride ($CaCl_2$) applications control the turgor pressure in the fruit by participating in the structure of the cell wall in plants and prevent the softening of the fruit after the harvest. In addition, it has been reported that the physiological deterioration in fruits is reduced, the loss of taste and nutrients is prevented, and the

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antioxidant content is preserved. In the light of this information, it is seen that useful results can be obtained from different harvesting techniques and different doses of Ca applications in order to minimize post-harvest losses of the perishable strawberry fruit. In addition, the studies relationship to the preservation of post-harvest quality of fruit in different fruit species were conducted to examine the effects of the organs such as fruit pedicel and waxy layer on the fruit surface on preservation. In these studies, it has been reported that the waxy layer on the fruit surface reduces water permeability and loss, and plays an important role in minimizing susceptibility to infections and physiological disorders (Lara et al. 2014). In addition, Ozturk et al. (2020) stated that the quality losses are higher in pedicelless fruit, where different results are obtained on the postharvest shelf life of fruit harvested with or without pedicel s. In the study, it was aimed to examine the effects of different lengths fruit pedicel and different doses of $CaCl_2$ applications on the storage period and to determine the most suitable pedicel length for harvest in 'Monterey' strawberry cultivar.

Materials and Methods

The fruit used in the study were harvested at three different pedicel lengths (0-5-10 cm), which were homogeneously colored, unharmed, healthy and flawless. The fruit were immediately transported to Tokat Gaziosmanpaşa University Faculty of Agriculture, Department of Horticulture, Fruiting Laboratory, Turkey, and soaked in $CaCl_2$ solution at three different doses (0%-2%-4%) for 5 min. After the application, the fruit were dried at room temperature. Then, the fruit were transferred to the cold storage and kept at 1.0 ± 1.0 °C and 90% relative humidity conditions for 21 days. During cold storage, the measurements and analyses of fruit quality parameters were carried out on days 0, 7, 14 and 21 (Fig. 1).

Weight Loss

At the beginning of the cold storage, initial weights (Wi) of the fruit were determined by a digital scale with a precision of 0.01 g Radwag (PS 4500.R1 Model, Radwag Wagi Electronics, Poland (EU)). Then, on day 10, 20 and 30 of the

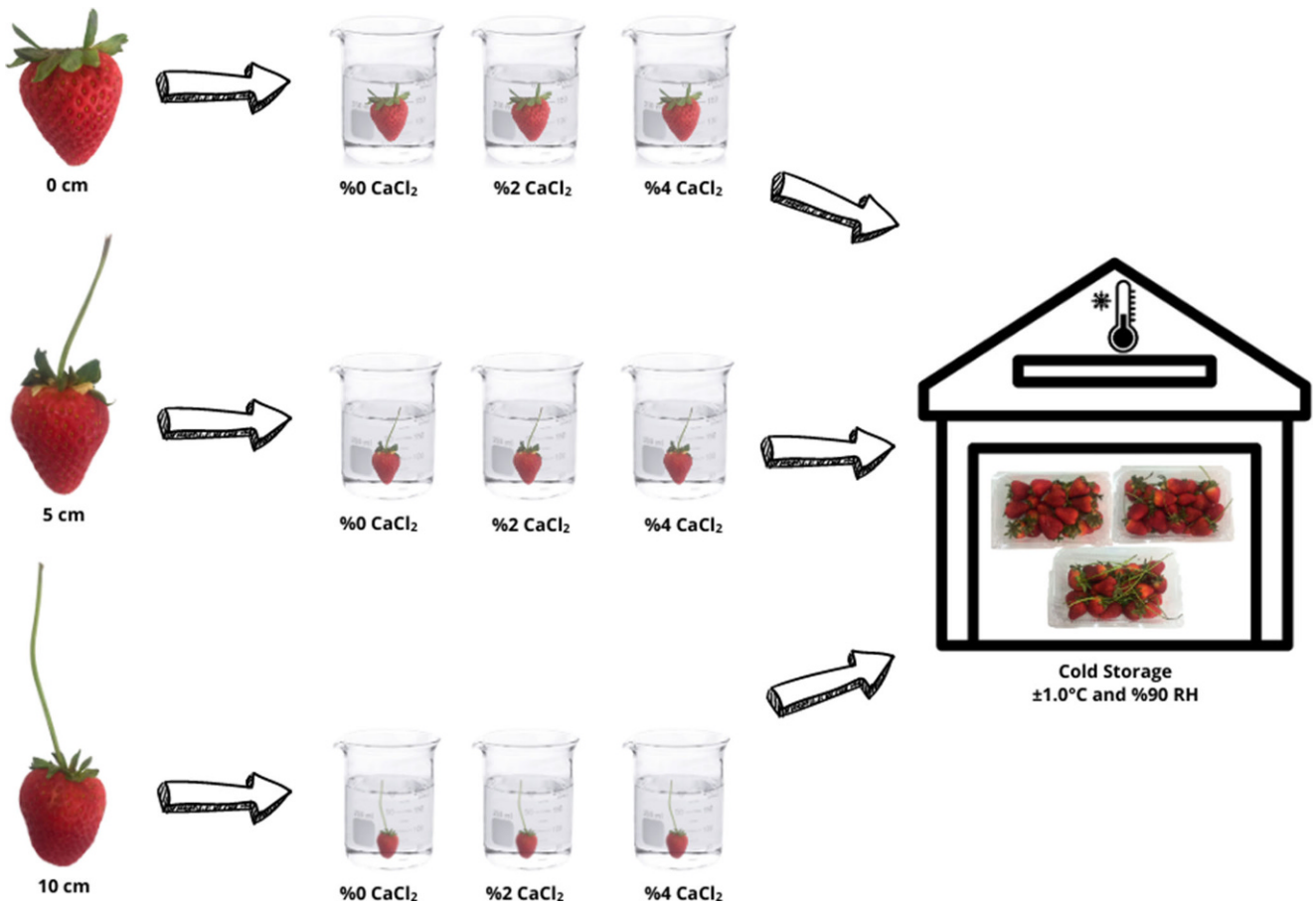


Fig. 1 Diagram and explanation of harvested pedicel length (0-5-10 cm), post-harvest application (0%-2%-4% calcium chloride [$CaCl_2$]) and storage conditions

storage, final weights (Wf) were determined. The weight loss that occurs in fruit was based on the weight at the beginning of each measurement period and determined as a percentage through the equation given below (Eq. 1).

$$WL = \frac{Wi - Wf}{Wi} \times 100 \quad (1)$$

Decay Rate

Before the cold storage, the fruit were counted in each replication and the total number of fruit (TF) was determined. Then, during each measurement period, the decayed fruit (DF) in each replication were determined. If the development of mycelium on shell occurred, the fruit were considered rotten. Finally, with the following equation (Eq. 2), the decay rate (DR, %) was detected.

$$DR = \frac{TF - DF}{TF} \times 100 \quad (2)$$

Fruit Color

The color determination of strawberry fruit was made with Minolta colorimeter (CR-400 model). Before measurement, the colorimeter was calibrated on a white standard plate and then the Hunter color measurement parameters L, a and b values were determined by measuring the skin color of the fruit. The fruit color measurements made on 10 randomly selected fruit from each replication was made to be one value from each vertical side of the fruit (McGuire 1992).

Fruit Flesh Firmness

In order to determine the fruit flesh firmness, the measurements were made with a digital firmness tester (Agrosta® 100, France) from both sides of 10 randomly selected fruit from each repetition. The firmness values in the measuring range of the device vary between 0 and 100. When the values approach 0 (zero), it means that the fruit are softened, but the values approaching 100 mean that the fruit firmness increases.

Soluble Solids Content (SSC, %)

The fruit were pureed with a homogenizer, and the juices were extracted by centrifugation. Then, the readings were made on a digital refractometer (Atago PAL-1, USA) calibrated according to pure water and the values were expressed as percent.

Total Phenolic Compounds (TPC)

Total phenol determination was made by using Folin–Ciocalteu's chemical as described by Singleton and Rossi (1965). A volume of 2 g pureed fruit samples were weighed in a homogenizer, and acetone, water and acetic acid (70:29.5:0.5) solution was added to it and the extraction process was applied for 24 h. The next day, 0.5 mL samples was taken, and 0.5 mL of Folin–Ciocalteu's chemical and 9 mL of distilled water were added, and after 8 min, 2.5 mL of 7% sodium carbonate was added. After 2 h of incubation, the solution, which has a bluish color, was read in the spectrophotometer at a wavelength of 750 nm. The values obtained were calculated as µg gallic acid equivalent/g fresh fruit in gallic acid (Saracoglu and Ozgen 2015).

Total Antioxidant Capacity (TAC)

The total antioxidant capacity of fruit was determined by using the Trolox equivalent antioxidant capacity (TEAC) method as described by Ozgen et al. (2006). For TEAC, 7 nm ABTS (2,2′-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) was mixed with 2.45 mM potassium bisulfate and kept in the dark at +4 °C for 12–16 h. Then, this solution was purified with 20 mM sodium acetate (pH 4.5) as 0.700 ± 0.01 absorbance at 734 nm wavelength in the spectrophotometer. The 30 µL sample was added 2.97 mL of the prepared TEAC solution and the readings were made at 734 nm wavelength in the spectrophotometer after 10 min incubation. The absorbance values after the measurement were calculated with the standard slope chart of Trolox (10–100 µmol/L) and presented as µmol Trolox equivalent/g wet weight (Saracoglu and Ozgen 2015).

Total Monomeric Anthocyanin (TMA)

Total monomeric anthocyanin (TMA) in fruit was determined using the pH difference method (Giusti et al. 1999). The extracts were prepared at pH 1.0 and 4.5 bafur and measured at wavelengths of 520 and 700 nm. Total anthocyanin amount absorbances ([A520–A700] pH 1.0–[A520–A700] pH 4.5) were as micrograms pelargonidin-3-glucoside/g fresh fruit (pelargonidin-3-glucoside: molecular weight 433.2, molar damping coefficient 31,600).

Statistical Analysis

After the data obtained as a result of the experiment were subjected to variance analysis by using the SAS package program, whether the difference between the application averages was significant or not was determined by using the Tukey multiple comparison test.

Results and Discussion

Weight Loss (%)

It is seen that the initial weight loss values continue to increase during the cold storage period. When the fruit pedicel lengths were compared at the end of the cold storage period, the lowest weight loss was observed with 4.06% in the samples with 5 cm fruit pedicel length. This was followed by samples with a pedicel length of 0 cm with 4.40%, while the highest weight loss was determined with samples with a pedicel length of 10 cm with 5.43%. When $CaCl_2$ doses were compared, no statistical difference could be detected. It was observed that the main reason for the weight loss was the difference in fruit pedicel lengths (Fig. 2).

In previous studies on $CaCl_2$ (Bal 2016; Rahîmi et al. 2018; Korkut 2019; Shahzad et al. 2020), it has been reported that an increase was observed during the cold storage period.

It is seen that our findings with the researchers are similar. It can be stated that the weight loss increased during the cold storage period may be due to the water loss of the products over time and the metabolites, which they spend in respiration. At the same time, with the progression of the cold storage period, the higher weight loss in long-pedicel med fruit may have been caused by the higher pedicel tissue and water losses in this tissue.

Decay Rate (%)

Generally, it is observed that decays start on the 14th day. When the fruit pedicel lengths were compared at the end of the cold storage period, it was determined that the lowest decay rate was observed in fruit with a pedicel length of 5 cm. When $CaCl_2$ doses were compared among themselves, it was determined that there was the least decay at 0% dose at the end of the cold storage (Fig. 3).

Bal (2016), reported that the first decays started as of the 10th day of the cold storage. Shahzad et al. (2020) determined that less decay was observed in the $CaCl_2$ and SA applications of strawberry compared to the control. In our study, the decay rate in $CaCl_2$ application was higher than control application. This difference may be due to the application of $CaCl_2$ together with SA in the study mentioned in the literature.

Fruit Color (L, a, b)

In general, there was a decrease in L values at the end of the cold storage period compared to the initial value (Table 1). When only fruit pedicel lengths were compared

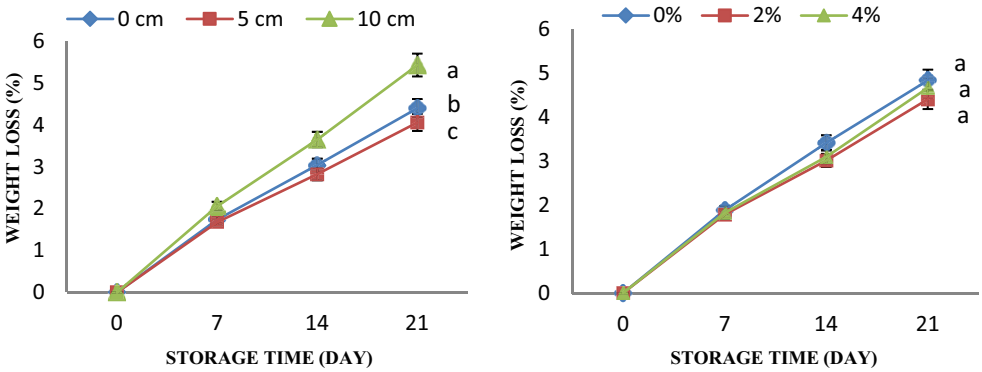


Fig. 2 The effect of different pedicel lengths and calcium chloride doses on weight loss (%) during the storage period in strawberry fruits

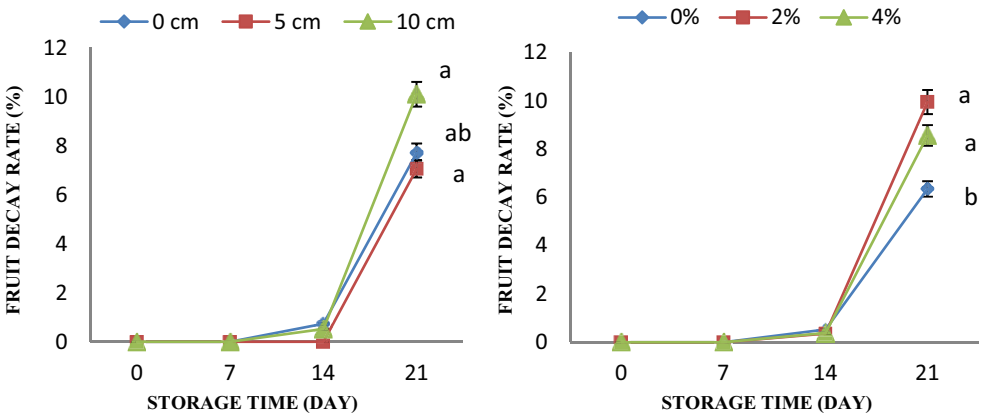


Fig. 3 The effect of different pedicel lengths and calcium chloride doses on the decay rate (%) in strawberry fruits during the storage period

Table 1 The effect of different pedicel lengths and calcium chloride ($CaCl_2$) doses on fruit outer color L value during storage period in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	38.66 Ab	32.46 Ba	30.74 Ca	30.53 Cb
5 cm	37.73 Ab	33.26 Ba	30.53 Ca	32.15 Ba
10 cm	40.18 Aa	33.46 Ba	30.45 Ca	32.50 Ba
$CaCl_2$				
0%	38.86 Aa	32.02 Ba	30.05 Ca	29.98 Cb
2%	38.86 Aa	35.06 Bb	31.32 Da	32.98 Ca
4%	38.86 Aa	32.11 Bb	30.35 Ca	32.22 Ba
0% $CaCl_2$				
0 cm	38.86 Aa	32.38 Ba	30.61 Ba	30.20 Ba
5 cm	37.73 Aa	31.24 Ba	29.73 Ba	29.93 Ba
10 cm	40.18 Aa	32.38 Ba	29.82 Ba	29.83 Ba
2% $CaCl_2$				
0 cm	38.86 Aa	34.01 Ba	31.94 BCa	30.73 Cb
5 cm	37.73 Aa	35.81 Aa	30.82 Ba	35.12 Aa
10 cm	40.18 Aa	35.38 Ba	31.18 Ca	33.10 BCab
4% $CaCl_2$				
0 cm	38.86 Aa	30.99 Ba	29.67 Ba	30.68 Bb
5 cm	37.73 Aa	32.74 Ba	31.04 Ba	31.42 Bb
10 cm	40.18 Aa	32.61 BCa	30.36 Ca	34.56 Ba

GO Overall average

*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

Table 2 The effect of different pedicel lengths and calcium chloride ($CaCl_2$) doses on fruit outer color a value during the storage period in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	31.57 Bab	33.62 Aa	34.73 Aa	33.50 Aa
5 cm	33.06 Ba	33.50 ABa	34.92 Aa	32.02 Bab
10 cm	31.09 Bb	33.78 Aa	34.48 Aa	31.66 Bb
$CaCl_2$				
0%	31.91 Ba	35.25 Aa	35.63 Aa	34.63 Aa
2%	31.91 Ba	31.24 Bb	35.51 Aa	31.39 Bb
4%	31.91 BCa	34.40 Aa	32.98 Ab	31.18 Cb
0% $CaCl_2$				
0 cm	31.57 Ba	35.67 Aa	34.25 ABa	35.52 Aa
5 cm	33.06 Ba	34.96 ABa	36.72 Aa	34.60 ABa
10 cm	31.09 Ba	35.14 Aa	35.93 Aa	33.78 ABa
2% $CaCl_2$				
0 cm	31.57 Ba	29.53 Ba	36.15 Aa	32.84 ABa
5 cm	33.06 ABa	31.37 BCa	35.35 Aa	29.33 Cb
10 cm	31.09 Ca	32.83 ABa	35.03 Aa	32.00 ABab
4% $CaCl_2$				
0 cm	31.57 Ba	35.65 Aa	33.80 ABa	32.17 Ba
5 cm	33.06 Aa	34.17 Aa	32.68 Aa	32.15 Aa
10 cm	31.09 ABa	33.36 Aa	32.47 ABa	29.22 Ba

GO Overall average

*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

among themselves, regardless of $CaCl_2$ doses, the lowest value at the end of the cold storage was found in fruit with a pedicel length of 30.53 and 0 cm. When only $CaCl_2$ doses were compared among themselves, no statistical difference was observed between the doses, regardless of fruit pedicel lengths. The lowest L value was determined at 0% dose application at the end of the storage. When $CaCl_2$ doses and fruit pedicel lengths were compared together, no statistically significant difference was found. At the end of the cold storage, the lowest L value was observed with the 2% $CaCl_2$ dose × 0 cm fruit pedicel length combination (Table 1).

When the general averages in Table 2 are examined, there are fluctuations in the a value. The decrease in a values was detected in all treatments after the 14th day of the cold storage. When only fruit pedicel lengths were compared, regardless of $CaCl_2$ doses, the lowest a value at the end of the cold storage was observed in fruit with 10 cm pedicel length. There was no statistical difference when only $CaCl_2$ doses were compared regardless of fruit pedicel lengths, the lowest a values at the end of the cold storage were detected at 2–4% $CaCl_2$ doses. When $CaCl_2$ doses and fruit pedicel lengths were compared together, these were not found to be statistically significant (Table 2).

The b values measured in the fruit peel during the cold storage period of different pedicel lengths and $CaCl_2$ doses in strawberry fruit are given in Table 3. When we look at the general averages in the table, it is seen that the b value generally decreases from the 14th day to the end of storage in all applications. No statistical difference was found when only fruit pedicel lengths were compared regardless of $CaCl_2$ doses. No statistical difference was found when $CaCl_2$ doses were compared regardless of fruit pedicel lengths. The highest b value was detected only at the 0% $CaCl_2$ dose on the 21st day. When $CaCl_2$ doses and pedicel lengths were compared together, b values were not found to be statistically significant (Table 3).

Demir (2014) reported that in strawberry, L values were found to be statistically significant, while a and b values were found to be statistically insignificant. In another study conducted on strawberries, it was reported that there was a decrease in fruit color parameters at the end of the cold storage (Akın 2014). In this study, especially decreases in L and b values were observed. The continuation of the

Table 3 The effect of different pedicel lengths and calcium chloride ($CaCl_2$) doses on fruit outer color b value during storage period in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	20.81 Ab	20.28 Aa	20.04 ABa	17.65 Ba
5 cm	23.57 Aa	20.22 Ba	19.26 Ba	15.96 Ca
10 cm	20.23 Ab	20.44 Aa	19.30 Aa	15.40 Ba
$CaCl_2$				
0%	21.54 Aa	21.50 Aa	19.93 ABab	18.32 Ba
2%	21.54 Aa	17.55 Bb	20.71 Aa	15.12 Bb
4%	21.54 Aa	21.89 Aa	17.97 Bb	15.57 Bb
0% $CaCl_2$				
0 cm	20.81 Aa	22.65 Aa	19.18 Aa	19.82 Aa
5 cm	23.57 Aa	20.04 Aa	19.62 ABa	18.15 Ba
10 cm	20.23 Aa	21.82 Aa	20.98 Aa	16.98 Aa
2% $CaCl_2$				
0 cm	20.81 ABa	16.36 Ba	22.17 Aa	16.52 Ba
5 cm	23.57 Aa	17.44 BCa	19.91 ABa	13.02 Ca
10 cm	20.23 Aa	18.84 Aa	20.06 Aa	15.81 Aa
4% $CaCl_2$				
0 cm	20.81 Aa	21.84 Aa	18.78 Aa	16.60 Aa
5 cm	23.57 Aa	23.19 Aa	18.26 ABa	16.70 Ba
10 cm	20.23 Aa	20.66 Aa	16.87 ABa	13.40 Ba

GO Overall average
*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

Table 4 The effect of different pedicel lengths and calcium chloride ($CaCl_2$) doses on fruit flesh firmness during storage period in strawberry fruits

Application	Storage ime (days)			
	0	7	14	21
Pedicel length				
0 cm	54.46 Ba	58.01 Aab	58.80 Aa	60.36 Aa
5 cm	56.30 Ba	56.35 Bb	56.31 Bab	60.00 Aa
10 cm	56.63 Ba	60.60 Aa	55.17 Bb	59.97 Aa
$CaCl_2$				
0%	55.80 Ba	55.21 Bb	59.31 Aa	61.88 Aa
2%	55.80 Ba	60.39 Aa	56.81 Bab	62.77 Aa
4%	55.80 Ba	59.38 Aa	54.16 Bb	55.67 Bb
0% $CaCl_2$				
0 cm	54.46 Ba	54.66 Ba	61.73 Aa	61.93 Aa
5 cm	56.30 Aa	55.96 Aa	60.73 Aa	62.10 Aa
10 cm	56.63 Aa	55.00 Aa	55.46 Aa	61.61 Aa
2% $CaCl_2$				
0 cm	54.46 Ba	56.96 Bb	57.46 Ba	64.66 Aa
5 cm	56.30 Aa	55.73 Ab	55.76 Aa	60.46 Aa
10 cm	56.63 Ba	68.40 Aa	57.20 Ba	63.20 Aba
4% $CaCl_2$				
0 cm	54.46 Ba	62.40 Aa	57.20 Aba	54.50 Ba
5 cm	56.30 Aa	57.36 Aa	52.43 Aa	57.43 Aa
10 cm	56.63 Aa	58.40 Aa	52.86 Aa	55.10 Aa

GO Overall average
*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

external color change at postharvest in strawberry caused darkening of the fruit, which resulted in a decrease in L values.

Fruit Flesh Firmness

Looking at Table 4, when only the fruit pedicel lengths are examined without considering the $CaCl_2$ doses, the lowest values among the fruit flesh firmness values were obtained for the fruit with 5 cm pedicel length on the 7th day and 10 cm pedicel length on the 14th day. However, no statistical difference was found at the end of the cold storage. When only $CaCl_2$ doses are compared without considering the fruit pedicel lengths, it is seen that the 4% $CaCl_2$ dose at the end of the cold storage has the lowest fruit flesh firmness value, and it can be said that the high concentration may have caused this. When $CaCl_2$ doses and fruit pedicel lengths were compared together, no statistically significant difference was found (Table 4).

Bal (2016), Oz and Kafkas (2015), Rahimi et al. (2018) and Ocalan et al. (2022) reported that the fruit flesh firmness decreased during the cold storage period. However, it is said that calcium applications in many fruit species slow down the softening of the fruit flesh (Guldas and Daglıoglu 2008). In addition, Nguyen et al. (2020) stated that the fruit firmness decreased at the first day of the cold storage, while the fruit firmness increased to the end of storage from the 3rd day of the cold storage, and this was due to the effect of calcium applications. Our study supports that fruit flesh firmness increased at the end of the cold storage compared to the beginning of storage.

pH

When Table 5 is examined, it is observed that there was an increase in pH values at the end of the cold storage in all applications. No statistical difference was found between pH values when fruit pedicel lengths were compared without considering $CaCl_2$ doses. Only on the 14th day, higher pH values at 0 cm pedicel length and lower pH values at 10 cm pedicel length were obtained. It was observed that there was no statistical difference when $CaCl_2$ doses were compared regardless of fruit pedicel lengths. It was observed that the 0% $CaCl_2$ application dose only on the 7th day had a lower

Table 5 The effect of different pedicel lengths and calcium chloride ($CaCl_2$) doses on pH during storage period in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	3.10 Ba	3.19 Aa	3.26 Aa	3.23 Aa
5 cm	3.11 Ba	3.18 ABa	3.21 Aab	3.18 Aa
10 cm	3.04 Ba	3.23 Aa	3.18 Ab	3.17 Aa
$CaCl_2$				
0%	3.08 Ba	3.13 ABb	3.18 Aa	3.18 Aa
2%	3.08 Ba	3.22 Aa	3.25 Aa	3.20 Aa
4%	3.08 Ba	3.25 Aa	3.23 Aa	3.21 Aa
0% $CaCl_2$				
0 cm	3.10 Aa	3.08 Aa	3.23 Aa	3.23 Aa
5 cm	3.11 Aa	3.15 Aa	3.16 Aa	3.16 Aa
10 cm	3.04 Aa	3.16 Aa	3.16 Aa	3.15 Aa
2% $CaCl_2$				
0 cm	3.10 Ba	3.24 Aa	3.28Aa	3.23 ABa
5 cm	3.11 Aa	3.20 Aa	3.24 Aa	3.17 Ab
10 cm	3.04 Ba	3.23 Aa	3.22 Ab	3.20 Aa
4% $CaCl_2$				
0 cm	3.10 Ba	3.27 Aa	3.28 Aa	3.22 ABa
5 cm	3.11 Aa	3.19 Aa	3.24 Aa	3.23 Aa
10 cm	3.04 Ba	3.28 Aa	3.16 ABa	3.17 ABa

GO Overall average
*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

Table 6 The SSC effect of different pedicel lengths and calcium chloride ($CaCl_2$) doses during storage in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	9.06 Ba	9.33 Aa	9.35 Aa	8.93 Ba
5 cm	9.06 Ba	9.04 Bb	9.44 Aa	8.82 Ca
10 cm	8.93 BCa	9.28 Aa	9.11 ABb	8.73 Ca
$CaCl_2$				
0%	9.02 Aa	9.13 Ab	9.04 Ab	8.55 Bc
2%	9.02 Ba	9.06 Bb	9.75 Aa	9.08 Ba
4%	9.02 BCa	9.46 Aa	9.11 Bb	8.84 Cb
0% $CaCl_2$				
0 cm	9.06 Aa	8.73 Ab	8.86 Ab	9.06 Aa
5 cm	9.06 Aa	9.40 Aa	9.33 Aa	8.40 Bb
10 cm	8.93 Aa	9.26 Aa	8.93 Aab	8.20 Bb
2% $CaCl_2$				
0 cm	9.06 Ba	9 Ba	9.93 Aa	8.80 Bb
5 cm	9.06 Ba	9.20 Ba	10.06 Aa	9.46 Ba
10 cm	8.93 Aa	9 Aa	9.26 Aa	9.00 Ab
4% $CaCl_2$				
0 cm	9.06 Ba	10.26 Aa	9.26 Ba	8.93 Ba
5 cm	9.06 Aa	8.53 Bc	8.93 ABa	8.60 Ba
10 cm	8.93 Ba	9.60 Ab	9.13 Ba	9.00 Ba

GO Overall average
*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

pH value. When $CaCl_2$ doses were compared according to pedicel length, no statistical difference was found in 0 and 4% $CaCl_2$ doses. In the 2% $CaCl_2$ dose, a statistical difference was detected only on the 7th and 14th days (Table 5).

Oz and Kafkas (2015) determined that pH values decreased during the cold storage period, while Rahimi et al. (2018) stated that there was an increase in pH values during the cold storage period. It is previously known that organic acids consumed by respiration cause an increase in pH value (Hosseinifarahi et al. 2020). This explains the increase in pH value at the end of the cold storage in our study.

Soluble Solids Content (SSC)

SSC values decreased during cold storage in all applications. When only fruit pedicel lengths were compared without considering $CaCl_2$ doses, no statistical difference was found between SSC values. The lower SSC values were obtained with 5 cm pedicel length on the 7th day and with 10 cm pedicel length on the 14th day. Regardless of fruit pedicel length, the difference between $CaCl_2$ doses was found to be statistically significant. On the 7th day, the highest SSC value was observed in the samples of 4% $CaCl_2$ dose application, but on the 14th day, the highest SSC value was determined at the 2% $CaCl_2$ dose. At the end of the cold storage, the highest SSC value was observed in the samples at 2% $CaCl_2$ dose. When the $CaCl_2$ doses were compared according to the pedicel length, at 0% $CaCl_2$ dose, the lowest value on the 7th day and 14th day was detected with a pedicel length of 0 cm. At the end of the cold storage, the lowest value was obtained from samples with 5–10 cm pedicel length. There was no statistically significant difference at the 2% $CaCl_2$ dose. The highest value at the end of cold storage was determined in samples with 5 cm pedicel length. The difference was not statistically significant in the samples at the 4% $CaCl_2$ dose. Only on the 7th day, the highest SSC value was observed in fruit with 0 cm pedicel length, followed by sample groups with 5 and 10 cm pedicel length, respectively (Table 6).

Cordenunsi et al. (2005) reported that there was an increase in SSC values at the end of the cold storage. Oz and Kafkas (2015) and Korkut (2019) stated that the SSC values decreased at the end of the cold storage. In our study, the decreases are observed at the end of the cold storage. It is thought that the decrease in the amount of SSC during the

Table 7 The effect of different pedicel lengths and calcium chloride ($CaCl_2$) doses on total phenolic substance determination during storage period in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	3198.89 Aa	3034.44 Aa	2942.78 Aa	2795.56 Aa
5 cm	3018.89 Aa	3161.67 Aa	2387.22 Bb	2746.67 ABa
10 cm	2885.56 ABa	3045.56 Aa	2752.78 ABab	2470.56 Ba
$CaCl_2$				
0%	3034.44 Aa	3025.56 Aa	2801.11 Aa	2807.22 Aa
2%	3034.44 Aa	2914.44 Aa	2713.89 Aa	2827.78 Aa
4%	3034.44 ABa	3301.67 Aa	2567.78 BCa	2327.78 Ca
0% $CaCl_2$				
0 cm	3198.89 Aa	2953.89 Aa	3193.89 Aa	3143.89 Aa
5 cm	3018.89 Aa	3140.56 Aa	2223.89 Ab	2927.22 Aa
10 cm	2885.56 Aa	2982.22 Aa	2985.56 Aab	2350.56 Aa
2% $CaCl_2$				
0 cm	3198.89 Aa	2962.22 Aa	3143.89 Aa	2685.56 Aa
5 cm	3018.89 Aa	3048.89 Aa	2535.56 Aa	2965.56 Aa
10 cm	2885.56 Aa	2732.22 Aa	2462.22Aa	2832.22 Aa
4% $CaCl_2$				
0 cm	3198.89 Aa	3187.22 Aa	2490.56 Aa	2557.22 Aa
5 cm	3018.89 Aa	3295.56 Aa	2402.22 Aa	2347.22 Aa
10 cm	2885.56 Aa	3422.22 Aa	2810.56 ABa	2228.89 Ba

GO Overall average

*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

cold storage period is due to the increased respiration rate in fruit.

Total Phenolics Compounds (TPC)

In all applications, it was observed that the total phenolic compounds decreased at the end of the cold storage (Table 7). It was determined that when only the fruit pedicel lengths were compared without considering the $CaCl_2$ doses, there was no the statistical difference total phenolic compounds. Only on the 14th day, the value at 0 cm fruit pedicel length was found to be higher than 5 cm fruit pedicel length. When $CaCl_2$ doses were compared without considering fruit pedicel lengths, no statistical difference was found within three doses. When the application doses were compared according to the individual pedicel lengths, there was no statistical difference. At the only 0% $CaCl_2$ dose, the highest total phenolic content on the 14th day was obtained in the samples with 0 cm pedicel length, followed by the sample groups taken from the 5 and 10 cm pedicel length, respectively (Table 7).

When the studies in the literature are examined, it can be stated that there were fluctuations in the phenolic content during the cold storage period in the study by Bal (2016). Dursun (2019) and Celer et al. (2019) reported that there was a decrease in the total phenolic compounds during cold storage. In our study, it was determined that phenolic compounds showed a decreasing tendency.

Total Antioxidant Capacity (TAC)

When the total antioxidant capacity values are examined, a general trend was not observed (Table 8). When only fruit pedicel lengths were compared without considering $CaCl_2$ doses, no statistical difference was found in the total antioxidant capacity values. When only the $CaCl_2$ doses were compared without considering the fruit pedicel lengths, the differences were found to be statistically significant. On the 7th day, the highest results were found at 2–4% $CaCl_2$ doses, while the lowest was found in 0% $CaCl_2$ dose. On the 14th day, the highest results were seen at the 4% $CaCl_2$ dose, while the lowest results were observed in the samples at the 0–2% $CaCl_2$ dose. When the doses were compared according to the individual pedicel lengths, no statistical difference was observed. On the 7th day, in 2% $CaCl_2$ dose, the highest results were seen in the samples with 5 cm pedicel length, while the lowest antioxidant values were obtained from the sample groups with 10 cm pedicel length (Table 8).

In the study conducted by Korkut (2019), there was no statistical difference between the total antioxidant values in

Table 8 The effect of different pedicel lengths and $CaCl_2$ doses on total antioxidant capacity during storage period in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	15.41 Aa	16.36 Aa	15.39 Aa	15.39 Aa
5 cm	16.49 ABa	17.64 Aa	15.23 Ba	16.84 Aa
10 cm	15.32 Aa	16.62 Aa	15.66 Aa	16.19 Aa
$CaCl_2$				
0%	15.74 Aa	15.4 Ab	14.45 Ab	14.78 Ab
2%	15.74 BCa	18.05 Aa	14.84 Cb	17.13 ABa
4%	15.74 Aa	17.17 Aa	17.00 Aa	16.50 Aa
0% $CaCl_2$				
0 cm	15.41 Aa	15.05 Aa	15.20 Aa	13.79 Aa
5 cm	16.49 Aa	15.43 Aa	13.87 Aa	16.87 Aa
10 cm	15.32 Aa	15.72 Aa	14.29 Aa	13.67 Aa
2% $CaCl_2$				
0 cm	15.41 ABa	18.31 Aab	14.69 Ba	16.83 ABa
5 cm	16.49 Ba	19.90 Aa	14.44 Ba	16.20 Ba
10 cm	15.32 Aa	15.95 Ab	15.39 Aa	18.38 Aa
4% $CaCl_2$				
0 cm	15.41 Aa	15.73 Aa	16.29 Aa	15.55 Aa
5 cm	16.49 Aa	17.57 Aa	17.40 Aa	17.44 Aa
10 cm	15.32 Aa	18.20 Aa	17.31 Aa	16.52 Aa

GO Overall average
*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

Table 9 The effect of different pedicel lengths and $CaCl_2$ doses on total monomeric anthocyanin determination during storage period in strawberry fruits

Application	Storage time (days)			
	0	7	14	21
Pedicel length				
0 cm	70.78 Ca	123.16 Ba	125.14 Ba	166.44 Aa
5 cm	67.81 Da	96.17 Cb	133.44 Ba	155.44 Aa
10 cm	64.72 Da	105.33 Cb	142.59 Ba	167.90 Aa
$CaCl_2$				
0%	67.77 Da	98.37 Cb	137.22 Bab	184.15 Aa
2%	67.77 Ca	105.72 Bab	120.50 Bb	152.09 Ab
4%	67.77 Ca	120.59 Ba	143.45 Aa	153.55 Ab
0% $CaCl_2$				
0 cm	70.78 Ca	100.56 BCa	131.12 Ba	182.30 Aa
5 cm	67.81 Ba	96.69 Ba	143.24 Aa	178.30 Aa
10 cm	64.72 Ca	97.85 Ca	137.31 Ba	191.84 Aa
2% $CaCl_2$				
0 cm	70.78 Ba	99.40 Ba	99.40 Ba	150.07 Aa
5 cm	67.81 Ca	108.68 Ba	129.83 ABa	144.27 Aa
10 cm	64.72 Ca	109.07 Ba	132.28 ABa	161.93 Aa
4% $CaCl_2$				
0 cm	70.78 Ba	169.54 Aa	144.91 Aa	166.96 Aa
5 cm	67.81 Ba	83.15 Bb	127.25 Aa	143.75 Aa
10 cm	64.72 Ca	109.07 Bb	158.19 Aa	149.94 Aa

GO Overall average
*Containment averages in the same row, shown with the same capital letter, the differences between the averages shown between the application averages shown with the same lowercase letter in the same column are not significant ($P < 0.05$)

fruit during cold storage. Nguyen et al. (2020) reported that the total antioxidant values in fruit decreased during cold storage.

Total Monomeric Anthocyanin (TMA)

There was an increase in total monomeric anthocyanin values during cold storage in all applications (Table 9). There was no statistical difference in total monomeric anthocyanin values when only fruit pedicel lengths were compared without considering $CaCl_2$ doses. On 7th day of the cold storage, the highest values were obtained in samples with 0 cm pedicel length. When $CaCl_2$ doses were compared without considering the fruit pedicel lengths, the values were found to be statistically significant. On the 7th day of the cold storage, the highest results were found at 4% $CaCl_2$ doses, while the lowest values was found at 0% $CaCl_2$ dose. On the 14th day, the highest result was seen at the 4% $CaCl_2$ dose, while the lowest results were observed in the samples at the 2% $CaCl_2$ dose. At the end of the cold storage, the best value was seen at 0% $CaCl_2$ dose. When the doses were compared according to the individual pedicel lengths, no statistical difference was observed. On the 7th day of the cold storage, with 4% $CaCl_2$ dose, the highest result was seen in samples with 0 cm pedicel length, while the lowest anthocyanin values were obtained from sample groups with 5 and 10 cm pedicel length (Table 9).

There are different research results regarding the increase or decrease in anthocyanin content during cold storage. Rahimi et al. (2018) and Ocalan et al. (2022) stated that the amount of anthocyanins in fruit increased at the end of the cold storage. In our study, the increases are seen at the end of the cold storage. The reason for this can be explained by the continuation of anthocyanin synthesis in strawberry fruits at postharvest. In a study conducted by Korkut (2019), the decreases in total monomeric anthocyanin values in fruit were detected during cold storage. This may be due to the modified atmosphere packages they used in the study.

Conclusion

In this study, one of the most important quality criteria that causes tissue disorders over time is weight loss. The

weight loss was less in fruit with 5 cm pedicel length, and calcium chloride doses did not make any difference. The lowest decay rates were in 0 and 5 cm pedicel length fruits and 2% calcium chloride applications. The fruit flesh firmness values increased towards the end of the cold storage. Although there is no clear distinction in terms of pedicel length, it can be said that the appropriate doses for calcium chloride applications are 0–2%. During cold storage, the increases and decreases were observed in fruit color values in all applications, but there was no obvious trend. A decrease was detected in the amount of SSC in fruit at the end of the cold storage. As a result, no clear effect of both pedicel length and calcium applications was found in terms of all quality parameters. However, 0–5 cm pedicel length and 2% calcium chloride applications are effective in many parameters and they can be recommended. In order to obtain better results, it will be useful to carry out detailed studies using different fruit pedicel lengths and different doses.

Conflict of interest F. Çezik and O. Saraçoğlu declare that they have no competing interests.

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