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Combination effects of calcium chloride and chitosan on the postharvest quality of okra (*Abelmoschus esculentus* L.) during storage

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ABSTRACT

Okra is a vegetable crop with high nutritional value that quickly loses its quality and decay after harvesting. This research aimed to investigate influences of calcium chloride concentrations combined with chitosan coating on the quality characteristics of okra pods during post-harvest. Okra pods were immersed in different concentrations of calcium chloride (0%, 1%, 2%, 4%) and then covered with chitosan (0, 0.5, 1 and 1.5%). Physicochemical analysis including: physiological weight loss, firmness, titratable acidity, total soluble solids, ascorbic acid content, total phenol content, and visual appearance and decay rate were performed at 4-day intervals for 16 days. The results showed that during storage, weight loss, soluble solids, and decay rate increased and firmness, ascorbic acid, total phenol content, titratable acidity and visual appearance showed a sharp decrease. Chitosan coating containing calcium chloride was significantly effective in maintaining the quality characteristics of okra. Among the investigated treatments, a combination of 2% calcium chloride and 1% chitosan was the most effective method to maintain the highest overall quality index score of okra pods stored at 4°C for up to 16 days. This treatment also significantly reduced weight loss and maintained ascorbic acid, total phenolic content, titratable acidity and visual appearance, and delayed increase in soluble solids and decay.

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1- Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is a popular vegetable worldwide due to its delicious and nutritious edible green pods [1]. This tropical vegetable is cultivated in many countries with hot climates, such as India, Pakistan, Turkey, Iran, Nigeria, Ghana, Greece, and the southern United States of America, making it one of the most important vegetables [2]. Okra is commonly consumed in the diets of people living in developing countries, where it is used as an important ingredient in stews, soups, or as steamed vegetables [1]. Okra pods have medicinal potential against inflammation, gastric irritation, colon cancer, and are also a good source of vitamin C, polyphenols, fats, carbohydrates, and mineral elements such as sodium, potassium, magnesium, calcium, zinc, iron, and manganese [2, 3, 4].

However, immature okra pods have a relatively short shelf life due to their high water content and respiration rate [1, 2]. This often leads to post-harvest losses of okra pods, sometimes exceeding 70% [4]. Post-harvest complications of okra include weight loss, reduction in tissue firmness and turgescence, color changes, loss of nutritional quality, pod discoloration (turning black and brown), rots, and unpleasant odor [3, 5].

One appropriate and practical method to extend the shelf life of fresh produce is the use of edible coatings. Edible coatings consist of thin layers of materials that act as barriers against the transfer of gases and water vapor, creating effects similar to modified atmospheres. These coatings can be used as an alternative to chemicals to enhance the shelf life of fresh fruits and vegetables. Moreover, they can be consumed together with the product by the consumer [6].

Chitosan (poly β-(1,4) N-acetyl-d-glucosamine) is a natural, high molecular weight polymer derived from the deacetylation of chitin. It is biologically safe and has a wide range of applications. Chitosan-based coatings are biocompatible, biodegradable, film-forming, antimicrobial, antioxidant, non-toxic, and edible. They can be used to create biologically safe preservative coatings for various types of food [7, 8].

Researchers have reported that the use of chitosan as an edible coating can effectively delay softening and maintain the texture properties of okra fruit, including hardness, phenrite, stickiness, gummy, chewy, and elastic properties [9]. Additionally, the edible coating of chitosan has been found to effectively preserve the physical properties and the amount of soluble solids in okra [10].

It has been suggested that the calcium present in the cell wall acts as an adhesive agent in calcium pectate, increasing the shelf life by maintaining the stiffness of the cell wall and reducing the activity of cell wall degrading enzymes [11 and 12]. Furthermore, calcium plays an important role in defense against plant pathogens, possibly due to its ability to inhibit the pectolytic enzyme activity of the pathogen [13]. The use of calcium chloride has been shown to increase tissue stiffness and antioxidant enzyme activity, preventing fruit weight loss and reducing frost damage in post-harvest conditions for persimmon fruit [14]. Calcium treatment has also proven effective in reducing physiological disorders, increasing fruit firmness, delaying the ripening process and ethylene production in tomatoes [15], improving acidity, soluble solids, pH, reducing the activity of cell wall degrading enzymes, and increasing antioxidants enzyme activity in pepper [16]. By reducing ethylene production and respiration, calcium increases the fruit basket residue of tomatoes [12]. Immersion treatment in calcium chloride has been found to increase the calcium content, maintain the firmness of fruit tissue, and control post-harvest decay of strawberry fruits [17]. While it has been stated that post-harvest calcium treatments have positive effects on fruit quality, excessive calcium concentration can lead to side effects on the fruit surface, such as color change and unpleasant sensory taste [13]. Previous studies have reported that combining calcium with other post-harvest treatments can yield significant improvements over calcium treatment alone [13, 18, 19]. Coating strawberries with a combination of calcium chloride and chitosan has been found to effectively maintain the post-harvest quality and increase the shelf life of strawberries during storage [13, 20, 21].

Reviewing the Literatures, it is evident that, refrigerators, modified atmosphere packages with preservatives are are mostly used to store okra. Recently, researchers have been exploring technical and hygienic methods to increase the shelf life and maintain the quality of okra after harvesting [9]. However, there is no information available regarding the use of calcium chloride with chitosan to maintain the quality and increase the shelf life of okra after harvesting. Therefore, the purpose of this research was to investigate the effects of calcium chloride and chitosan on the quantitative and qualitative characteristics of okra fruit after harvesting, particularly during storage.

2- Materials and methods

2-1- Experimental materials:

Local okra seeds were cultivated in a commercial farm located in Shushtar city (32°2′37″N; 48°51′25″E). Planting, cultivation (including fertilizing, irrigation, weeding, pest and disease control, etc.), and harvesting were conducted following the technical recommendations provided by the Ministry of Agriculture Jihad. The okra fruits were ready for harvesting within 4 to 7 days

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after the flowers had opened. Harvesting took place 15 weeks after planting, once the crop production had reached the desired commercial quantity. Okra pods with a length ranging from 50 to 70 mm and a diameter of 12 to 15 mm were harvested. Subsequently, the harvested okra pods were immediately transferred to the Physiology Laboratory of the Department of Horticultural Science at Agricultural Sciences and Natural Resources University of Khuzestan. There, they underwent visual grading to ensure uniformity in terms of size, shape, and color brightness. Only fruits with the same characteristics were selected for testing. Prior to treatment, the fruits were washed twice with distilled water to remove any surface impurities. Following this, the okra pods were dried and cooled at laboratory temperature to eliminate surface moisture.

2-2- Preparation of chitosan solution

Chitosan solutions with concentrations of 0.5%, 1%, and 1.5% were prepared by dissolving 5, 10, and 15 grams of pure chitosan (Low molecular weight chitosan, CAS No.: 48869, Sigma-Aldrich Co.) in one liter of glacial acetic acid solution (0.5% v/v), respectively. The mixtures were continuously stirred until the chitosan was completely dissolved, after which the pH was adjusted to 5.2 using a sodium hydroxide solution (1 N). The prepared solutions were sterilized at 121 °C for 20 minutes. For the control group (0% chitosan treatment), an acidic solution without chitosan (pH = 5.2) was used [22].

2-3- Preparation of calcium chloride solutions

Calcium chloride (Merck, Germany, CAS No.: 10043-52-4) was dissolved in sterile distilled water to obtain concentrations of 0%, 1%, 2%, and 4%. A surfactant, Tween 20 (0.5 ml/liter), was added to the solutions, and the solutions were brought to the final volume. These solutions were prepared fresh on the day of the treatments.

2-4- Preparing samples and performing treatments

Okra pods were immersed in the solutions for a duration of 5 minutes using the immersion method. After being removed from the solution, the pods were left to dry for 2 hours at a temperature of 25 °C until the fruit surface was no longer moist. The treated fruits were then transferred to a warehouse with a temperature of 10 °C and a relative humidity of 95±2% for a period of 16 days. This experiment followed a completely randomized design with 3 factorial replications, including factors such as calcium chloride (0%, 1%, 2%, and 4%) and chitosan (0%, 0.5%, 1%, and 1.5%), with five different storage times (0, 4, 8, 12, and 16 days), which were evaluated.

5-2- Assessed indicators and attributes

2-5-1- Physiological weight loss

The Physiological weight loss of okra pods during storage was measured using a digital scale with an accuracy of 0.01 grams as a percentage of the initial weight. It was calculated using the following formula:

Physiological weight loss (%) = {(initial weight - secondary weight)/ initial weight}×100

2-5-2- Fruit tissue firmness

The firmness of okra pods was measured using a penetrometric test and a tissue measuring device (model FT 011, made in Romania) with a needle diameter of 5 mm. The firmness of the pods were measured at the middle point of the okra pod and presented in kilograms per square centimeter. Four samples were evaluated for each repetition [23].

2-5-3- Total soluble solids

Some of the okra pods were dewatered using a manual grater, and the resulting extract was used to measure the amount of dissolved solids. The amount of total soluble solids was measured in Brix degrees (corrected for a temperature of 20 degrees Celsius) using a digital refractometer (Milwaukee model MA 871, made in Romania) [10].

2-5-4- Titratable acidity

To measure titratable acidity, 10 grams of okra pod tissue was completely homogenized and mixed with 50 ml of distilled water. The resulting mixture was filtered through filter paper. The resulting extract was titrated with 0.1 normal sodium hydroxide until a pH of 8.2 was reached. The amount of titratable acidity was calculated in grams of citric acid per 100 ml of extract [23].

2-5-5- Ascorbic acid

To extract ascorbic acid, five grams of okra pods were extracted with metaphosphoric acid (50 ml, 1% W/V). The resulting extract was then centrifuged at 3000 g for 15 minutes at 3 °C. Immediately, one ml of the supernatant was mixed with dichlorophenol-indophenol solution (9 ml, 0.05 mM), and the absorbance of the samples was measured at a wavelength of 515 nm. Different concentrations of L-ascorbic acid solution (ranging from zero to 500 mg/L) were used as standards. The amount of ascorbic acid was reported in mg per 100 g of fresh weight [24].

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2-5-6- Total phenol content

The total phenolic content was determined using the Folin-Ciocalteu reagent method. One gram of the sample was homogenized with 9 ml of distilled water. After centrifugation for 30 minutes at 9520 g, 0.5 ml of the supernatant was transferred to test tubes, and 2.5 ml of 10% Folin-Ciocalteu reagent was added. After stirring, it was left for 5 minutes, and then 2 ml of 4% (V:V) sodium carbonate was added. The samples were kept in the dark at room temperature for two hours, and the absorbance was recorded at a wavelength of 725 nm. The total phenol content was calculated using a standard curve with gallic acid [25].

2-5-7- Visual appearance

The visual appearance of okra pods was evaluated by 15 trained evaluators based on the color change of the fruit from green to yellow and darkening (brown and black). The color change was evaluated using a hedonic scale from 1 to 7, where 7 represents excellent (light green), 5 represents good (dull green), 3 represents acceptable (yellowing), and 1 represents unacceptable (dark) [26].

2-5-8- Decay

The decay percentage was calculated using the following formula:

Decay (%) = (number of rotten pods /total number of pods)×100

2-6- Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA) using statistical analysis software (SAS, version 9.1, SAS Institute Inc., USA). The LSD test was used to evaluate the significance of the difference between the mean values at a significance level of $p \leq 0.05$. The analyzed results were graphically represented using Excel 2016 software.

3. Results and Discussion

The results of the variance analysis showed that the simple effects of chitosan, calcium chloride, and storage time were significant for all studied traits ($p \leq 0.01$). The interaction effects of calcium chloride × chitosan oral coating were significant only for caries percentage ($p \leq 0.01$). The double effects of calcium chloride × storage time on weight loss percentage, ascorbic acid, soluble solids, soluble sugars, decay rate, visual appearance ($p \leq 0.01$), total chlorophyll, beta-carotene, pH, and total phenol ($p \leq 0.05$) were meaningful. The interaction effects of chitosan edible coating × storage time on weight loss percentage, total chlorophyll content, beta-carotene, ascorbic acid, titratable acidity, soluble sugar content, decay rate, visual appearance, total phenol content ($p \leq 0.01$), and pod firmness ($p \leq 0.05$) were significant. However, the interaction effects of calcium chloride × chitosan × storage time were not statistically significant for any of the traits.

3-1- Physiological weight loss (PWL)

The results of mean comparisons for the PWL of okra pods are presented in Figure 1. PWL increased significantly ($p \geq 0.01$) during the storage period for all treatments, and the difference between treatments became more apparent with the increase of storage time. Among the treatments, the combination of calcium chloride and chitosan coating had better effects in delaying the PWL of okra pods than the control and chitosan coating alone (Figure 1-a). During storage, the lowest PWL was observed in the 2% calcium chloride treatment, and no significant difference was recorded between the 4% and 1% treatments (Figure 1-b). All chitosan coating treatments significantly slowed down PWL, and the lowest PWL was recorded in the 1% chitosan treatment (Figure 1-c). At the end of storage time, calcium chloride 2% + chitosan 1% was the best treatment to prevent PWL of okra. It has been proven that weight loss in fruit is mainly due to water evaporation from transpiration and respiration processes and metabolic reactions [27, 28]. It has been suggested that post-harvest calcium treatments may alter tissue gas diffusion rates, thereby inhibiting respiratory metabolism [13]. On the other hand, the results of various researches have shown that the chitosan coating acts as a semi-permeable barrier against oxygen, carbon dioxide and moisture, thus reducing respiration, oxidation reactions and water loss [29]. Therefore, the combination of chitosan coating and calcium chloride treatment was more effective in PWL than control or chitosan coating alone, as shown in Figure 1. The results of this research are in accordance with the findings of other researchers about strawberries [13, 20] and kiwifruits [30].

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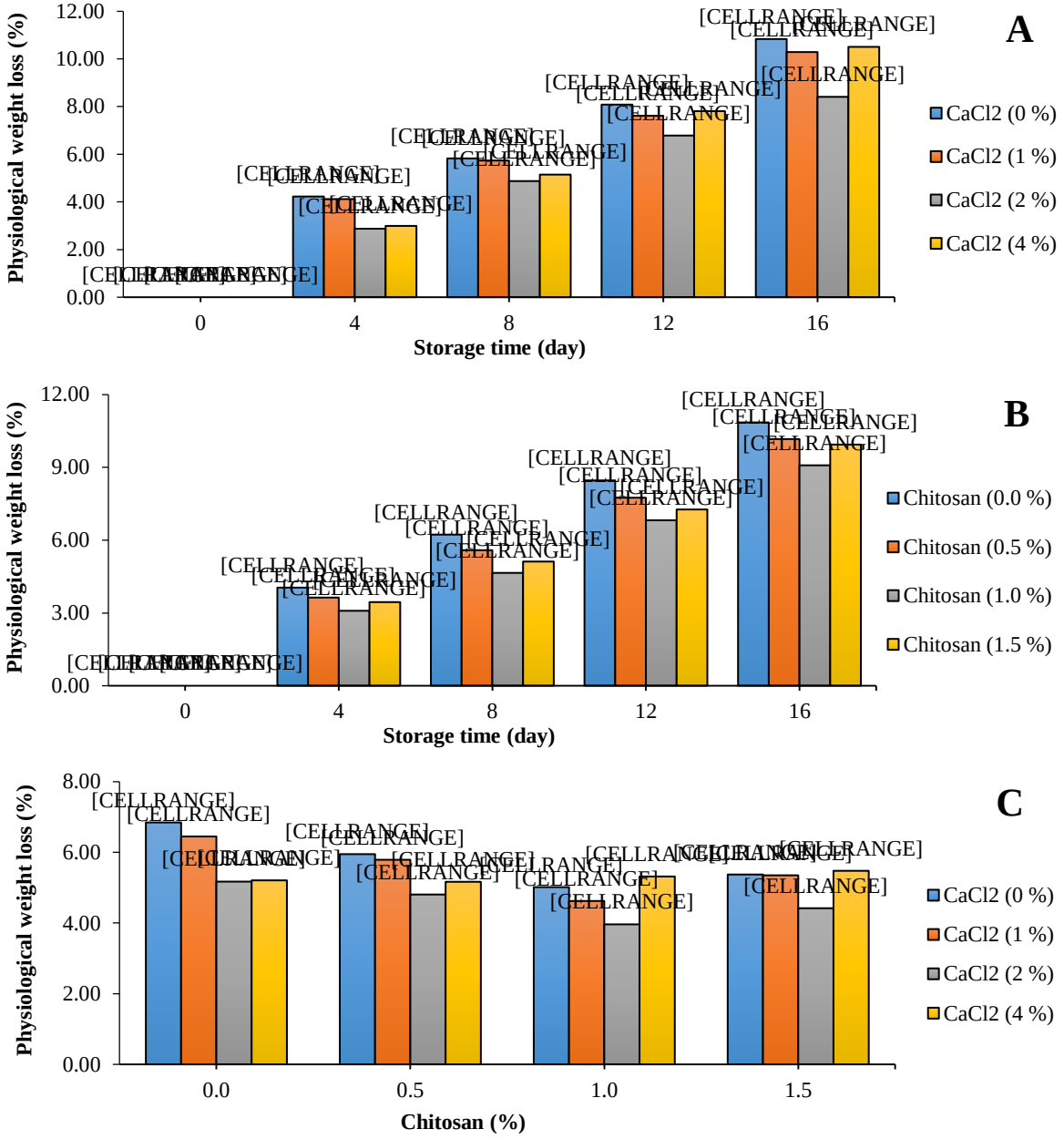

Figure 1- Interaction effects of calcium chlorides × storage time (A), chitosan × storage times (B) and calcium chlorides × chitosan (C) on physiological weight loss of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different ($p \geq 0.05$).

3-2- Firmness

The changes in the tissue firmness of control and treated okra pods in different treatments of a combination of calcium chloride and chitosan and calcium chloride in time are shown in Figure 2. The interaction of calcium and chitosan treatment showed that the highest level of firmness of okra pods was obtained in the combined treatment of 1% chitosan with 2% calcium (Figure 2-a). The initial firmness of the fruit was 5.41 $kgcm^{-2}$ and decreased during storage so that it reached 2.90 $kgcm^{-2}$ at the end of storage, but this decrease was effectively delayed by calcium treatment. After the first 4 days of storage, the stiffness of all the samples decreased, but the samples treated with 2 or 4% calcium concentrations did not show any significant difference with the day of the beginning of storage (Figure 2-b). 2% calcium (3.57 $kgcm^{-2}$ on average) was significantly different from other treatments. Loss of firmness is one of the destructive factors that limit the post-harvest life and quality of okra. The use of calcium treatment preserves the cell wall and the structure of the middle layer, both of which contribute to the firmness of the fruit [13]. Under the effect of the

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pectin methyl-esterase in the ripening stage, more carboxyl groups of pectin are produced, which leads to the stimulation of calcium ion binding to pectin [31 and 32]. Creating a cross bond with carboxyl groups in pectin is enough. On the other hand, water loss is responsible for the reduction of cell turgor and changes in cell structure and cell wall composition, leading to loss of fruit firmness [30]. Chitosan coating allows better retention of fruit juice [9], which can lead to an increase in the force required to break the fruit flesh [33]. As seen, the combination of 1% chitosan coating and 2% calcium chloride treatment was more effective than chitosan coating alone in maintaining the firmness of okra pods (Figure 2-a). The results of this research are in accordance with the findings of other researchers about strawberries [13, 20] and kiwifruits [30].

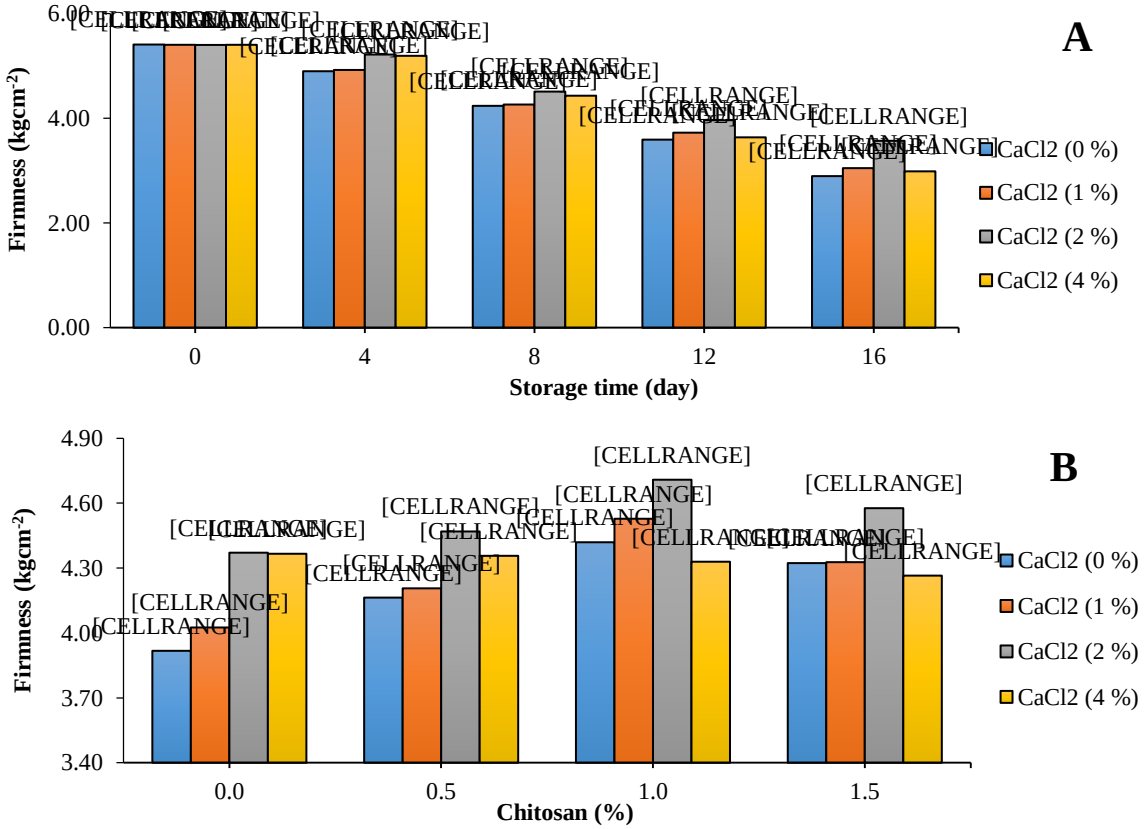

Figure 2- Interaction effects of calcium chlorides × storage time (A) and calcium chlorides × chitosan (B) on firmness ($kgcm^{-2}$) of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different ($p \geq 0.05$).

3-3- Soluble solids (TSS)

TSS of samples treated with different concentrations of calcium and chitosan are presented in Figure 3. The lowest amount of TSS was observed in the treatment of 2% calcium chloride in combination with 1% chitosan, which statistically had no significant difference with the same treatments of 2% calcium chloride in combination with 1.5% or 0.5% chitosan (Figure 3-A). The level of TSS at the beginning of storage in all treatments with or without calcium chloride was 6.50 ± 0.50 °Brix, which reached 11.82 °Brix at the end of storage in the treatment without calcium chloride, but this increasing trend was less in treatments with calcium chloride. So that during storage, the least increase was observed in the 2% calcium chloride treatment (Figure 2-b). During storage, the TSS of fruits increases, which is probably due to the dissolution of polyuronides and hemicelluloses in the cell wall, as well as water loss due to transpiration [13]. It has been reported that calcium treatment may delay the process of cell wall degradation by binding to pectic substances present in the cell wall and interlayer [34]. As a result, it prevents the increase of TSS compared to calcium-free treatments to some extent. In addition, the presence of edible chitosan coating by creating a barrier against gas exchange and preventing the decrease of humidity can prevent the increase of TSS by slowing down the metabolic activities and the aging process [20]. Other researchers have also shown that the treatment of calcium chloride in combination with chitosan effectively delays the

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increase of soluble solids in fruits [13, 20, 30, 35], which is consistent with the results of the present study.

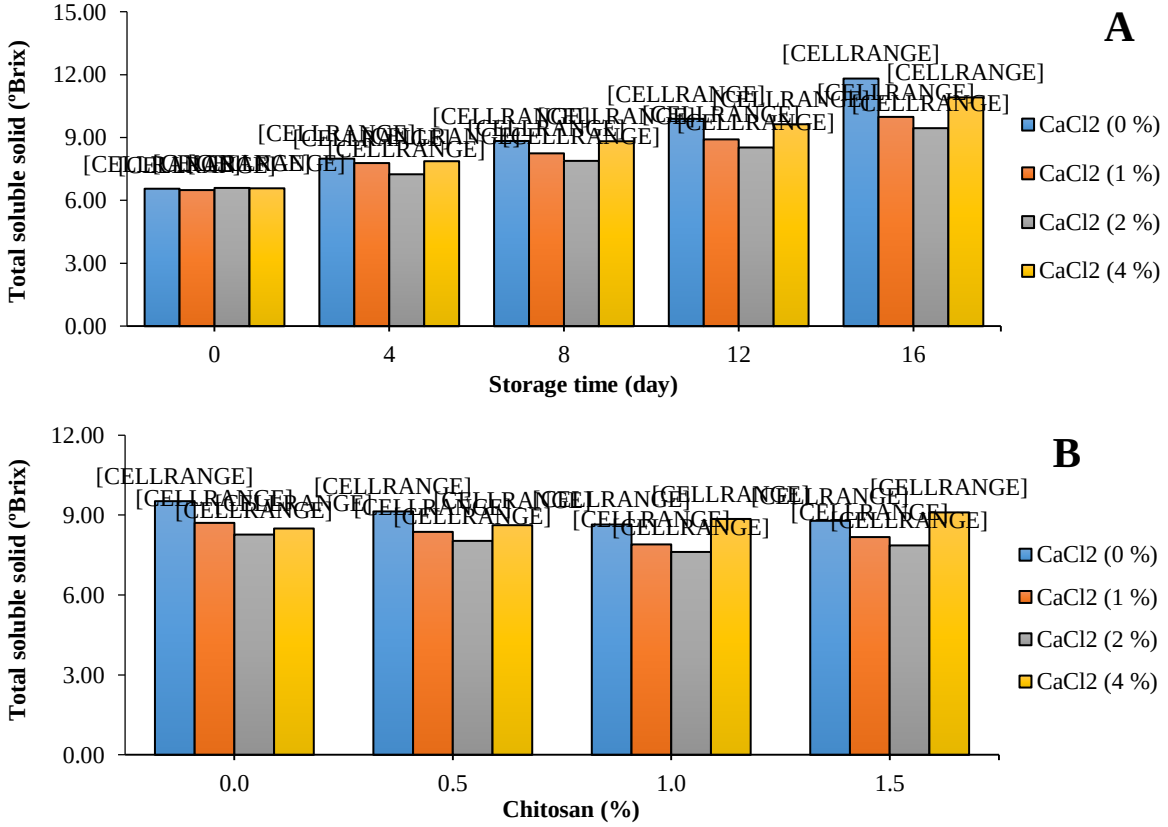

Figure 3- Interaction effects of calcium chlorides × storage time (A) and calcium chlorides × chitosan (B) on total soluble solid (°Brix) of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different ($p \geq 0.05$).

3-4- titratable acidity (TA)

The changes of TA of okra pods in the combined treatments of calcium and chitosan and calcium in time are shown in Figure 4. The highest amount of TA was observed in the samples treated with 2% calcium chloride in combination with 1% chitosan, which is statistically significantly different from the combined treatment of 0.5 calcium chloride with 1% chitosan and the treatment of 2% calcium chloride in combination with 1.5% chitosan did not have a statistically significant difference (Figure 4-a). A significant decrease in TA was observed in all calcium treatments during storage, but this decrease in calcium chloride treatment was 2% less than other treatments and this difference increased with increasing storage time (Figure 4-b). The results of the researchers have shown that the organic acids of the okra fruit are consumed during storage due to metabolic changes in the fruit caused by the use of organic acids in the respiratory process and thus decrease [10]. The use of combined treatment of calcium chloride with chitosan may create a thin layer on the surface of the fruit, and the formation of such a layer helps to reduce oxygen, increase carbon dioxide, reduce respiration and suppress ethylene production and metabolic activities, which ultimately leads to TA is better preserved [30]. Our results are consistent with other studies that show the effects of combined application of calcium and chitosan on the fruit of mango [35], strawberry [13, 20], kiwifruits [30] and peach [36] on preventing TA reduction.

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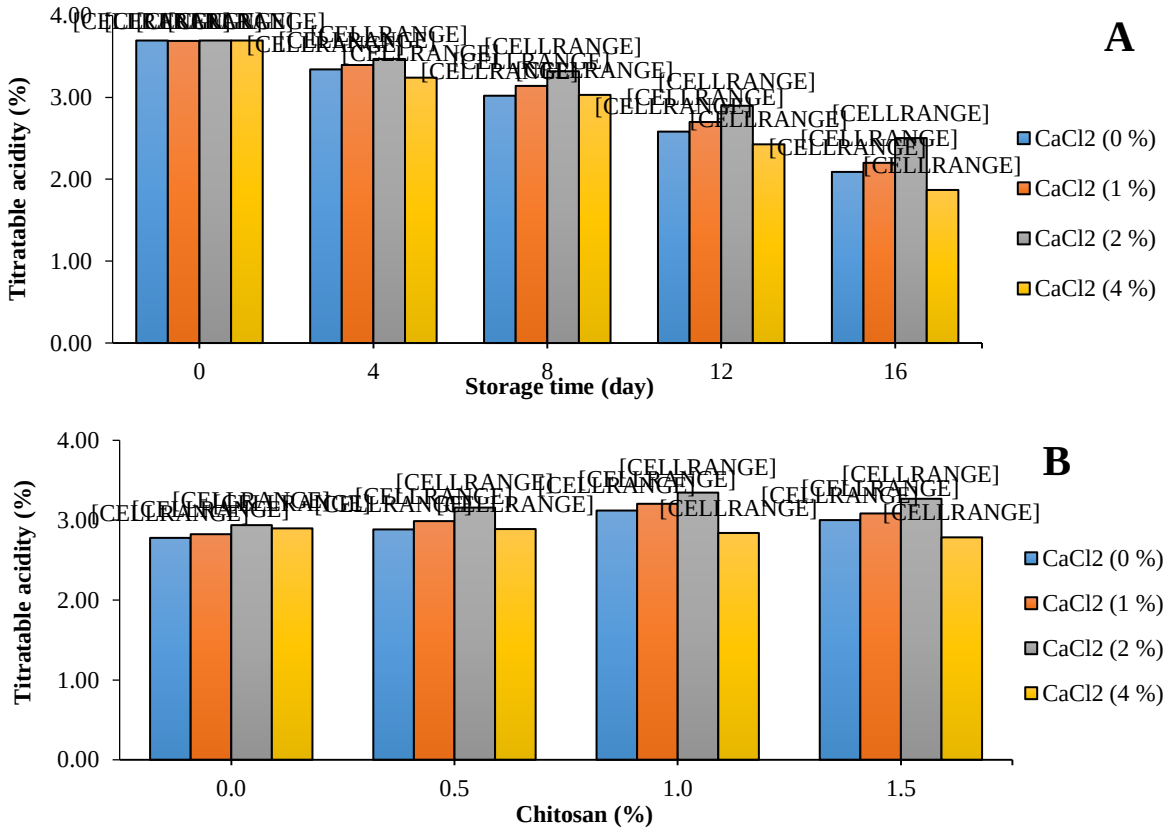

Figure 4- Interaction effects of calcium chlorides × storage time (A) and calcium chlorides × chitosan (BA) on titratable acidity (%) of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different ($p \geq 0.05$).

3-5- Ascorbic acid (AsA)

The change in the content of ascorbic acid (AsA) under the influence of different treatments of calcium chloride and chitosan during storage and the combined treatments of calcium chloride and chitosan are shown in Figure 5. A. Decreasing trend of AsA was observed during storage for all calcium chloride treatments. The initial AsA of the fruit was 14.65 mg $100g^{-1}$ FW and decreased during storage so that it reached 6.23 mg $100g^{-1}$ FW at the end of storage, but this decrease was effectively delayed by calcium treatment. During storage, the lowest and highest decrease in AsA was related to 2% and 4% calcium chloride treatment, respectively. At the end of storage, the highest AsA was related to the 2% calcium treatment (on average 61.7 mg $100g^{-1}$ FW), which had a significant difference with other treatments (Figure 5-a). Also, the decreasing trend of AsA during storage was observed for all chitosan treatments. The lowest amount of AsA reduction during storage was related to 1% chitosan treatment (Figure 5-b). The interaction of the combined treatments of calcium chloride and chitosan showed that the treatment of 2% calcium chloride together with 1% chitosan had the greatest effect in maintaining the AsA of okra pods during storage (Figure 5-c).

Ascorbic acid is sensitive to oxidation during the processing and storage process, and it decreases with increasing storage time and aging of fruits [37]. The decrease in the loss of vitamin C in the calcium chloride and chitosan treatments can be attributed to the low oxygen exchange and the slower fruit aging process. Because preventing aging and keeping oxygen away from the product delays the oxidation reaction of ascorbic acid [38]. The positive role of the combined treatment of calcium chloride and chitosan in preserving the ascorbic acid of strawberry [13, 20], peach [36] and mango [35] has also been reported, which is consistent with the results of our research.

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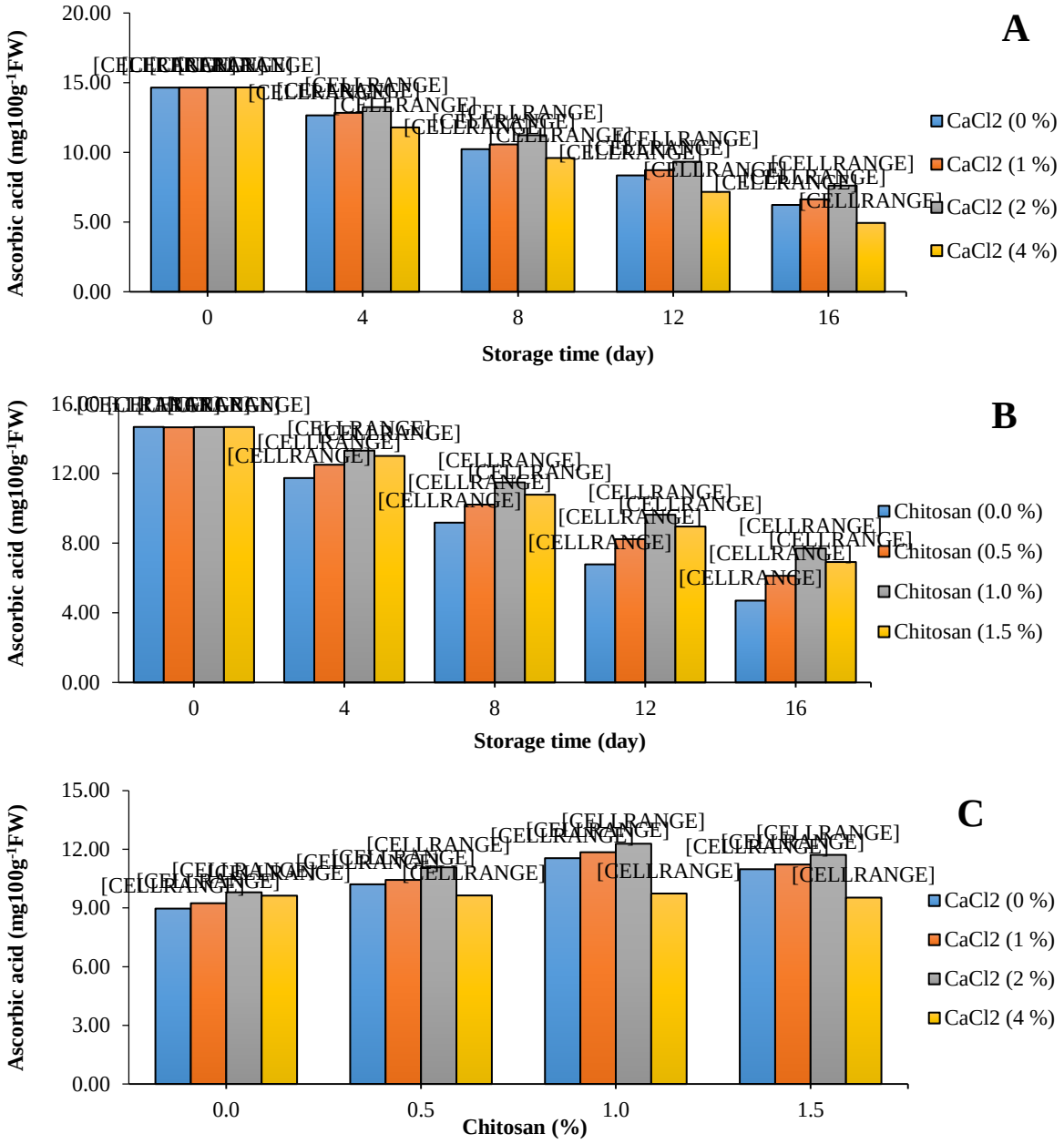

Figure 5- Interaction effects of calcium chlorides × storage time (A), chitosan × storage times (B) and calcium chlorides × chitosan (C) on ascorbic acid (mg100g^{-1}FW) of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different (p ≥0.05).

3-6- Total phenol content (TPC)

There was a decrease in TPC throughout the storage period (Figure 6). Calcium treatments were effective in maintaining TPC in okra pods, and the lowest reduction in TPC during storage was observed in the 2% calcium chloride treatment. On the 16th day of storage, the lowest and highest reduction in TPC was recorded in okra pods treated with 2% calcium chloride (25.6%) and without calcium chloride (44.6%), respectively (Figure 6-a). Chitosan treatments were also effective in maintaining the TPC of okra pods, and the lowest decrease in TPC content during storage was observed in fruits treated with 1% chitosan (Figure 6-b). Calcium chloride and chitosan treatments showed that the combination of 2% calcium chloride with 1% chitosan had the greatest effect in maintaining the TPC of okra pods (Figure 6-c). Nguyen and Nguyen (2021) reported that the decrease in TPC could be due to the ripening process and increased activity of polyphenol oxidase (PPO) enzymes that degrade phenolic compounds in fruit [21]. Also, the reduction of TPC can be due to the destruction of the cell structure in the aging stage of the fruit [29]. In

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addition, the use of a combined coating of calcium chloride and chitosan may form a selective barrier to reduce oxygen supply for the enzymatic oxidation of phenolic compounds [13] and also delay the aging process and reduce the activity of the PPO enzyme [20]. The results obtained from this research are consistent with previous reports on strawberry fruit [13, 20 and 21].

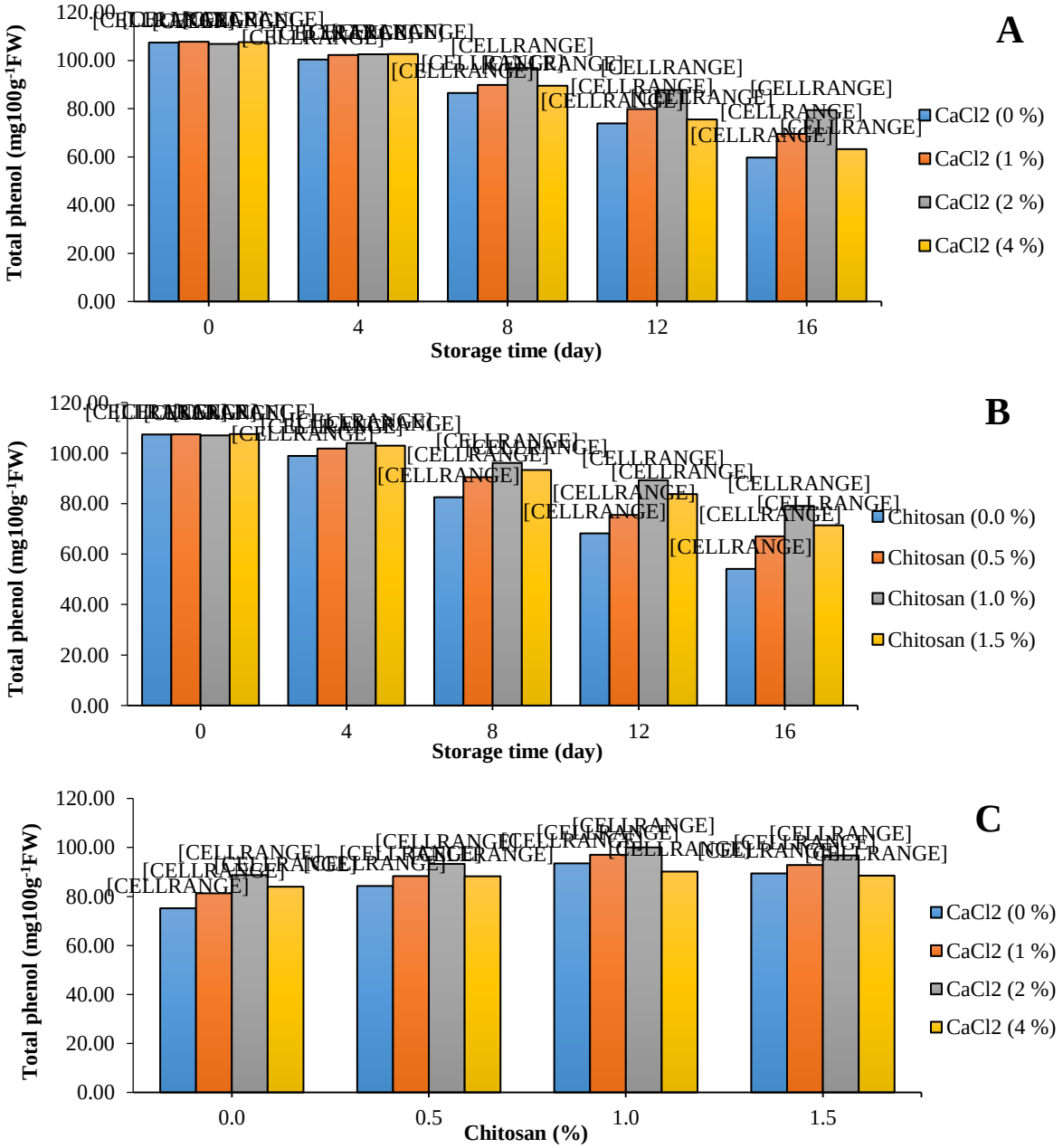

Figure 6- Interaction effects of calcium chlorides × storage time (A), chitosan × storage times (B) and calcium chlorides × chitosan (C) on total phenol (mg100g^{-1}FW) of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different (p ≥0.05).

3-7- Visual Appearance (VA)

The results of the VA test are shown in Figure 5. In summary, the VA quality score of okra pods decreased after 16 days of storage (p≥0.05). The lowest reduction in VA during storage was obtained with 2% calcium chloride treatment (Figure 7-a). Chitosan treatments also caused a better preservation of the VA of okra pods during storage, and the lowest reduction was obtained with 1% chitosan coating treatment (Figure 7-b). The highest amount of VA was observed in the combined treatment of 2% calcium chloride with 1% chitosan (Figure 7-c). The obtained results

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support the data presented in the previous sections and the reasons could be the loss of water during storage and the activity of endogenous enzymes [13]. In addition, researchers found that polyphenol oxidase enzymes produce undesirable brown or black pigments that negatively affect fruit surface color [39]. 2% calcium chloride treatment with 1% chitosan coating was significantly effective in maintaining the VA. The results of other researchers' research have also shown that the combined treatment of calcium chloride and chitosan has been effective in maintaining shelf life, nutritional composition and appearance quality of products such as strawberry [13, 20 and 21], kiwi [30] and mango [35], which The results of the present research are consistent.

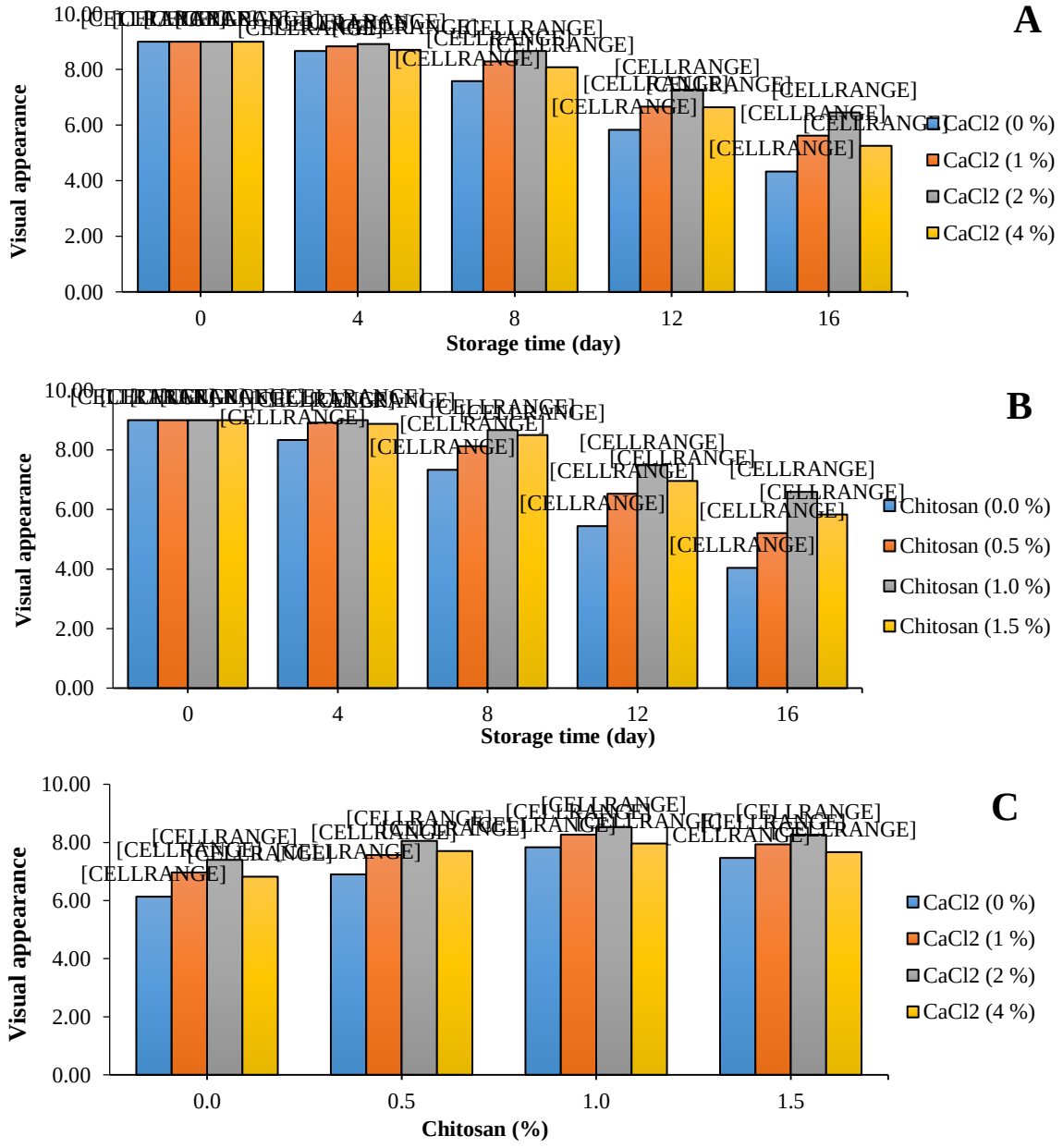

Figure 7- Interaction effects of calcium chlorides × storage time (A), chitosan × storage times (B) and calcium chlorides × chitosan (C) on physiological weight loss of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different ($p \geq 0.05$).

3-8- Incidence of decay (ID)

The data presented in Figure 3 show that the percentage of ID of okra pods increased gradually and significantly with the prolongation of the storage period in all treatments. Also, the data showed that all calcium chloride treatments

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significantly reduced the ID of fruit during storage compared to untreated fruits in this study, and the lowest amount of ID was observed in the 2% calcium treatment during storage (Figure 7-a). Chitosan coating treatments also effectively reduced the ID rate of okra pods and the lowest ID rate was obtained with 1% chitosan treatment (Figure 7-b). Also, post-harvest combined treatments had the greatest effect in this field. Treatment with 2% calcium chloride along with 1% chitosan coating showed the greatest effect in reducing the ID of okra pods (Figure 7-c). The reduction in ID in okra pods during storage due to chitosan and calcium chloride coatings, especially in combined treatments, may be due to low respiration rate and delayed senescence, which can increase resistance to infection and lesion formation [35]. . Chitosan inhibits the growth of caries and induces a defense response in the host tissue [40, 41]. Chitosan treatment has shown positive effects in maintaining membrane integrity and increasing the activity of antioxidant enzymes and phenolic compounds [41, 42, 43 and 44]. In addition, the NH^{3+} group of chitosan may also inhibit the proliferation of harmful microbes and thus effectively control fruit rot [45]. Also, calcium is an important component of plant tissues and by increasing membrane stability, cell wall strength and maintaining cell-to-cell contact by reducing the destruction of the middle layer and increasing tissue resistance, it plays an important role against decay [46]. These results are consistent with the results of other researchers about mango [35], strawberry [13].

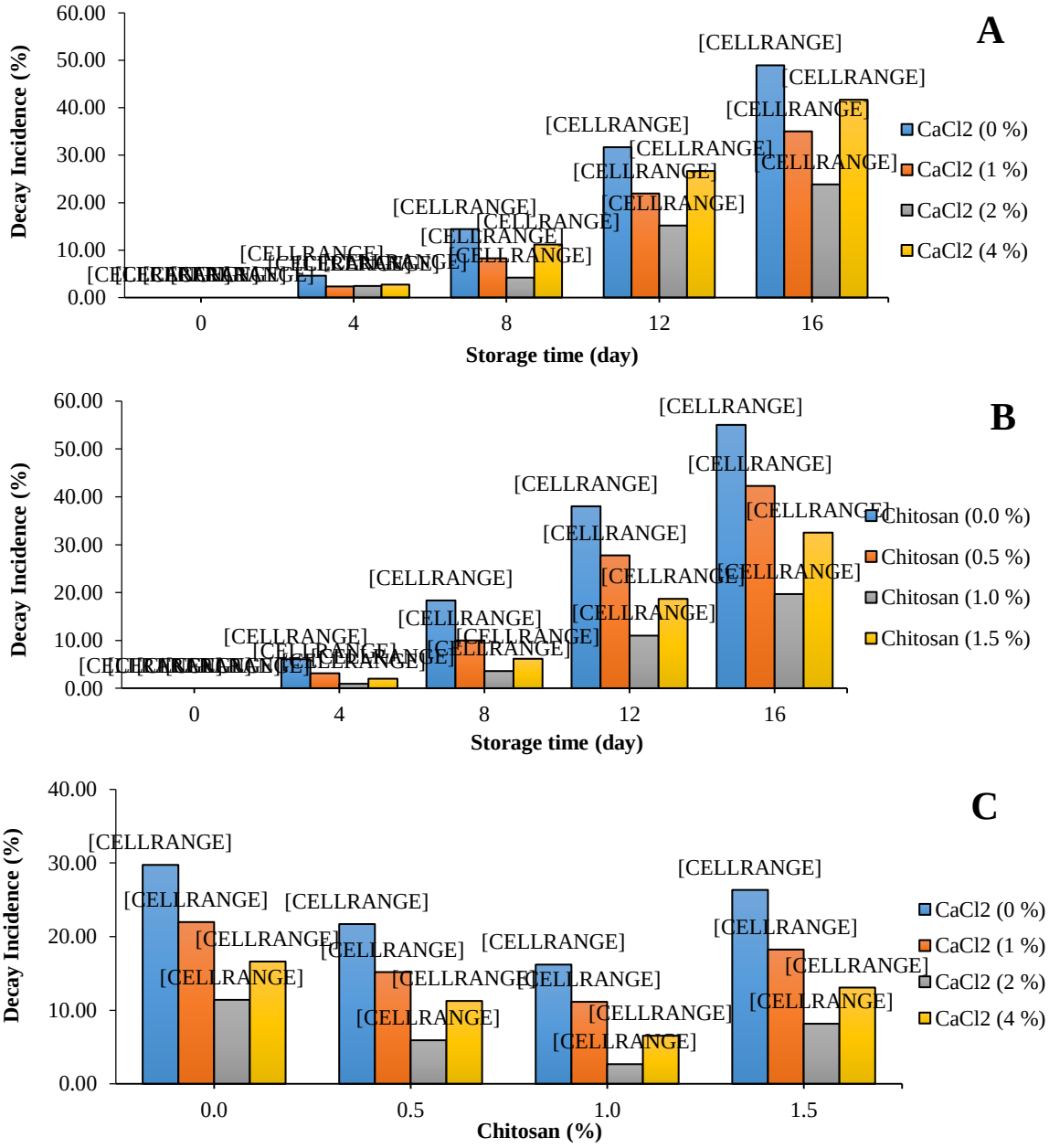

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Figure 8- Interaction effects of calcium chlorides × storage time (A), chitosan × storage times (B) and calcium chlorides × chitosan (C) on physiological weight loss of okra pods stored at 9±1 °C for 16 days. Values with different letters are significantly different ($p \geq 0.05$).

4- Conclusion

The present study showed that the coating of chitosan and calcium chloride, especially the combined treatments, is a promising strategy for the management of fruit quality after harvesting okra pods. The results of this study show that the combination of 2% calcium chloride and 1% chitosan coating has a higher overall quality index and a better positive effect than other treatments on physical properties such as weight loss, fruit firmness and chemical properties in the case of ascorbic acid, Total phenol content, total soluble solids and titratable acidity. Meanwhile, coating with 2% calcium chloride and 1% chitosan significantly maintained the Visual appearance quality of okra pods and greatly reduced the decay rate.

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اثرات ترکیبی کلرید کلسیم و کیتوسان بر کیفیت پس از برداشت بامیه (*Abelmoschus esculentus* L.) در طی انبارمانی

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چکیده

بامیه یک محصول سبزی باارزش غذایی بالا است که پس از برداشت به‌سرعت کیفیت خود را ازدست‌داده و دچار فساد می‌شود. این پژوهش باهدف بررسی تأثیر غلظت‌های مختلف کلرید کلسیم همراه با پوشش کیتوسان بر خصوصیات کیفی غلاف‌های بامیه در طول پس از برداشت انجام شد. غلاف‌های بامیه در غلظت‌های مختلف کلرید کلسیم (۰٪، ۱٪، ۲٪، ۴٪) غوطه‌ور و سپس با کیتوسان (۰، ۰/۵، ۱ و ۱/۵ ٪) پوشانده شد. آنالیز فیزیکوشیمیایی شامل: کاهش وزن، سفتی، اسیدیته قابل تیتراسیون، مواد جامد محلول کل، محتوای اسید آسکوربیک، محتوای فنل کل، و جذابیت ظاهری و میزان پوسیدگی در فواصل زمانی ۴ روزه به مدت ۱۶ روز انجام شد. نتایج نشان داد که در طی انبارمانی کاهش وزن، مواد جامد محلول، میزان پوسیدگی بامیه افزایش و میزان سفتی بافت، اسید آسکوربیک، محتوای فنل کل، اسیدیته قابل تیتر و جذابیت ظاهری افت شدیدی نشان داد. پوشش کیتوسان حاوی کلرید کلسیم به‌طور معنی‌دار در حفظ خصوصیات کیفی بامیه مؤثر بود. در بین تیمارهای موردبررسی، ترکیبی از کلرید کلسیم ۲ درصد و کیتوسان ۱٪ مؤثرترین روش برای حفظ بالاترین امتیاز شاخص کلی کیفیت غلاف‌های بامیه ذخیره‌شده در دمای ۴ درجه سلسیوس تا ۱۶ روز بود. این تیمار همچنین کاهش وزن را به میزان قابل‌توجهی کاهش داد و اسید آسکوربیک، محتوای فنل کل، اسیدیته قابل تیتر و جذابیت ظاهری را حفظ کرد و افزایش مواد جامد محلول و پوسیدگی را به تأخیر انداخت.

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