International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 30 No. 1 December 2021, pp.388-402

Postharvest Treatments of Different Doses of Calcium Lactate in Combination with Chitosan Improves Biochemical Characters of Cucumis Sativus L. During Storage

Vedat Yılmaz[1], Rezzan KASIM[2*], Mehmet Ufuk KASIM[3],

[1]Graduate School of Natural and Applied Sciences, Kocaeli University, 41001 Kocaeli, Turkey
[2]Faculty of Agriculture and Natural Sciences, Kocaeli University, 41285 Kocaeli, Turkey
[3]Faculty of Agriculture and Natural Sciences, Kocaeli University, 41285 Kocaeli, Turkey

Abstract – This study aimed to determine the effects of the postharvest coating created with different doses of calcium compounds and chitosan on the quality of the cucumbers during storage. For this purpose, cucumber fruits were dipped into solutions containing the doses of 2, 4, and 6% calcium chloride ($CaCl_2$), calcium propionate ($C_6H_{10}CaO_4$), and calcium lactate ($C_6H_{10}CaO_6$) + 1.0% chitosan separately before storage. After the treatments, the cucumber fruits were dried and placed in boxes with plastic lids and stored at 7±1°C and 90-95% relative humidity for 20 days. Calcium change in fruits, flesh firmness (N), weight loss (%), fruit skin color (*L, *a**, *b**, hue angle, yellowness index), chlorophyll SPAD amount, total soluble solids (TSS), titratable acid (%), taste quality, electrolyte leakage (%), decay rate (%) observations and analyzes were evaluated at five-day intervals during storage. According to the results, it was found that especially the dose of 2% calcium lactate was more effective in preserving fruit firmness and green color, increasing the amount of TSS, and also delaying the decay, amongst calcium chloride, calcium propionate, and calcium lactate treatments. The KT and CaP4 treatments were successful in reducing weight loss, whereas CaL4 and CaL6 were found to be effective in maintaining chlorophyll content. Also, it observed that CaK4 and CaK6 treatments were increased electrolyte leakage due to causing damage to the cell wall, thus the shortened storage time of cucumber fruits in this study.**

Keywords – Cucumber, Calcium, Chitosan, Postharvest, Quality, Storage.

I. INTRODUCTION

Cucumber (Cucumis sativus L.) belongs to the Cucurbitaceae family, which includes the ninety genera and seven-hundred fifty species [1]. The cucumber production area in the world is 2.231.402 ha, and 87.805.086 tons of production is made in this area. Turkey has ranked second (1.9 million tons) in world cucumber production after China (70 million tons) [2]. Cucumber (1.120.742 tons), ranks second after tomato (4.099.129 tons) in greenhouse vegetable production in our country [3].

Since the water content of the cucumber fruits is high, the post-harvest life is short due to shrinkage, softening, and yellowing of the skin color due to water loss, and the shelf life is generally limited to 2-3 days. One of the main goals of post-harvest treatments is to extend the post-harvest life of the product via delaying the signs of senescence. The signs of senescence of cucumber fruit can be reduced by packaging and cold storage. However, since cucumber is a sensitive species to chilling injury, it cannot be stored for a long time at temperatures below 7-10°C. At these temperatures, shelf life decreases due to both weight loss and softening due to senescence [4].

Corresponding Author: Rezzan KASIM

It is tried to delay the tissue softening due to post-harvest senescence in various fruits and vegetables with pre-harvest and post-harvest calcium applications. Calcium is the third most used element after nitrogen and potassium amongst the nutrients that plants take from the soil, and it is used extensively in the formation of the cell wall in the plant [5] and in the regulation of its structure [6]. Calcium plays a very important role in cell wall structure by contributing to the adhesion and cohesion of non-crosslinked carboxyl groups in adjacent polygalacturonate chains in the middle lamella of the plant cell wall, thus leading to increased firmness of fruit tissues [7]. Also, increasing the calcium content of the cell wall prevents bacteria and fungi from damaging the cell wall of plants with the enzymes they extract. In addition, calcium reduces the fragility of growth points by allowing the cell wall to stretch and expand [8].

Besides, calcium plays a role in the formation of protein and the transfer of carbohydrates in the plant [6]. Again calcium is affected on the metabolic activities of the plant by increasing the enzyme activity [8] and also acts as a cofactor [5]. Reference [9] stated that calcium has a direct effect on enzyme synthesis and transport processes. When there is sufficient calcium in plant tissues, it prevents the outflow of substances from the cell and increases the resistance of plants against freeze-thaw stress and diseases [6]. Calcium interacts with the pectic acid in the cell walls to form calcium pectate and therefore strengthens the structure of the cell wall, therefore calcium, increases the quality of fresh fruits and vegetables and prolongs the storage period [10]. Depending on the type and concentration of calcium salts used, postharvest calcium applications significantly increase the calcium content of the fruit. [11, 12].

In a study, slices of cucumber (Cucumis sativus L. 'Beith Alpha') were dipped in solutions of 5% calcium lactate and 5% calcium lactate + 5% ascorbic acid and then stored in MAP packages at 4°C temperature for 7-10 days. MAP packaging reduced softening and increased shelf life of sliced cucumbers by 2-5 or 7 days at 4oC [13]. In a similar study, CaCl2 applications increased the lifespan of cucumber (cv. Cheongjang) fruits stored at 4oC by 4 days compared to the control (10 days) and increased it to 14 days. In addition, after 4 days at room temperature (20oC), weight loss was 15% in control fruits, while it was 9% in fruits treated with calcium chloride [14]. Reference [15] determined that the treatment of 1% CaCl2 to cucumber fruits in hot water at 55oC for 5 minutes (1%Ca+SHW) had a significant synergistic effect in inducing chilling tolerance, decreasing peroxidase activity, maximizing catalase activity, and reducing electrolyte leakage. In addition, it determined that the appearance, taste, and color of the cucumber fruits treated with 1% Ca+SHW were better, the weight loss was less, the firmness and total phenolic content of these fruits were higher in the study. Also, it found that TSS and sugar loss are maintained by delaying the maturation and senescence processes with this treatment. Latex coating that comprises polyvinyl acetate co-vinyl alcohol and 50, 100, and 150 mg/L CaO-nanoparticles had applied to the cucumber fruits. The fruits were then stored at 10oC. The coating treatment was maintained the visual quality, pigment, and antioxidant contents of the cucumber fruits and extended the shelf life up to 24 days [16].

Chitosan is a linear polysaccharide composed of randomly distributed b-(1-4)-linked D-glucosamine and N-acetyl-D-glucosamine units. The chitosan-based edible coating is produced from natural sources by deacetylation of chitin and is used to prevent rotting and extend the shelf life of fruits. Chitosan and its derivatives have been shown to inhibit the growth of a wide variety of fungi. It can also trigger defense mechanisms in plants and fruits against infections caused by some pathogens. Chitosan also delays ripening by changing the inner atmosphere in the fruit [17, 18]. Packing the cucumber coated with chitosan + limonene with active MAP containing 10% O2 + 5% CO2 were provided better quality preservation during storage [19]. Cucumber fruits show chilling injury when stored below 7oC. The 0.5% chitosan coating amongst 0.5, 1.0, or 1.5 was found to reduce chilling injury, maintain firmness, delay weight loss, and increase storability in cucumber fruits stored at 7°C and 90-95% relative humidity for 12 days [20]. Similarly, it found that the chitosan coating preserved the quality and reduced the CO2 production in fresh-cut cucumber fruits stored for 12 days at 5oC [21].

The aim of this study is to determine the effects of chitosan coating application containing different doses of different calcium salts on the preservation of postharvest quality in cucumber fruits.

II. Material And Methods

2.1. Plant Materials

In this study, PTK 40 F1 silor type cucumber (Cucumis sativus L. cv. Silor) cultivar grown in Çandır village of Serik district of Antalya used as plant material. Cucumber fruits used in the study were brought to Kocaeli University Arslanbey Vocational

School cold storage within 24 hours after being harvested. Cucumbers had been evaluated after cooling treatment, according to size, uniformity, crushing/injured, and the fruits that were of non-standard size, deformity, crushed, or injured were excluded from the experiment.

2.2. Calcium and Chitosan Treatments

For applying calcium and chitosan firstly, calcium chloride (CaCl2), calcium propionate (C6H10CaO4), and calcium lactate (C6H10CaO6) solutions were prepared in doses of 2, 4, and 6%. Then 0.5% acetic acid and 1.0% acetic acid and chitosan were added to each solution. Treatments used in this study are given in Table 1. To homogenize the prepared solutions, the solution temperature was increased to 60°C and then cooled to 25°C. Cucumber fruits were dipped in these solutions for 5 minutes, then dried and packaged.

Table 1. Treatments made to cucumber fruits before storage

KK	: The fruits were stored directly by packaging, without being immersed in any solution.
SK	: The fruits were immersed in tap water for 5 minutes, then dried and packaged..
KT	: Cucumbers were dipped in a solution containing 1% chitosan + 0.5% acetic acid, kept for 5 min, then removed, dried, and packed.
CaP2	: Cucumbers were dipped in a solution containing 2% calcium propionate + 1% chitosan + 0.5% acetic acid, kept for 5 min, then removed, dried, and packed.
CaP4	: Cucumbers were dipped in a solution containing 4% calcium propionate + 1% chitosan + 0.5% acetic acid, kept for 5 min, then removed, dried, and packed.
CaP6	: Cucumbers were dipped in a solution containing 6% calcium propionate + 1% chitosan + 0.5% acetic acid, kept for 5 min, then removed, dried, and packed..
CaL2	: Cucumbers were dipped in a solution containing 2% calcium lactate + 1% chitosan + 0.5% acetic acid, kept for 5 min, then removed, dried, and packed.
CaL4	: Cucumbers were dipped in a solution containing 4% calcium lactate + 1% chitosan + 0.5% acetic acid, left for 5 min, then removed, dried, and packed.
CaL6	: Cucumbers were dipped in a solution containing 6% calcium lactate + 1% chitosan + 0.5% acetic acid, left for 5 min, then removed, dried, and packed.
CaK2	: Cucumbers were dipped in a solution containing 2% calcium chloride + 1% chitosan + 0.5% acetic acid, left for 5 min, then removed, dried, and packed.
CaK4	: Cucumbers were dipped in a solution containing 4% calcium chloride + 1% chitosan + 0.5% acetic acid, left for 5 min, then removed, dried, and packed.
CaK6	: Cucumbers were dipped in a solution containing 6% calcium chloride + 1% chitosan + 0.5% acetic acid, left for 5 min, then removed, dried, and packed.

2.3. Packaging and Storage

Following the treatments, cucumber fruits were stored for 20 days in a cold room with a temperature of 7±1°C and relative humidity of 90-95%. Due to the high water content of cucumber fruits, the fruits were placed in boxes with polyvinylchloride (PVC) lids to prevent water loss, and holes of equal size were drilled on the lids to prevent CO_2 gas accumulation in the boxes.

2.4. Determination of the amount of calcium in cucumbers

5 mm thick discs were taken from the middle of each cucumber fruit and the juice was extracted, to determine the amount of calcium in the cucumber fruits. The amount of calcium in the fruit juice was measured in ppm with a calcium meter (LAQUAtwin CA-11).

2.5. Fruit firmness

Flesh firmness was measured from the flower stalk, middle part and tip of three fruits taken from each replication, using a texture analyzer (Shimadzu EZ-LX) and a 6 mm diameter needle (piercing) tip and expressed as Newton (N).

2.6. Weight loss

Three packages of samples were separated in each application and these samples were used during storage, to calculate weight losses. Weight measurements were made at the beginning of the experiment and in each analysis period, and the weight losses were calculated using following equation, and expressed as (%), as follows [22].

A.K.(%)=((initial weight-weight at the analysis period x 100)/initial weight

2.7. Fruit skin color

Minolta CR 400 Chroma portable colorimeter (Minolta Co., Osaka, Japan) was used to determine the skin color of cucumber fruits. D65 illumination was used as a light source in the device, and at the beginning of the measurement, the device was calibrated with a white standard calibration plate (L^*=97.52; a^*= -5.06; b^*=3.57) [23, 24]. In addition, using the data obtained, when a<0 and b> 0, the hue angle calculated according to the formula ho= 90+(-1x(tan-1 a^*/b^*)) [22] and the yellowing index according to the formula SI= 142.86 b*/L* [25]. Color measurements were done at three points on each cucumber, and a total of 12 measurements was applied for each treatment. From the measured color values, the color change ratios by initial color were calculated and shown as (%).

2.8. Chlorophyll SPAD measurement

The skin of four cucumber fruits in each replicate was cut into thin strips for chlorophyll SPAD measurements. Chlorophyll content was measured from three different points of each strip, namely the beginning, middle, and end of each strip, using SPAD-502 Plus (Konica Minolta, Inc. Osaka, Japan) chlorophyll meter.

2.9. Total soluble solids (TSS)

TSS of cucumbers was measured in fruit juice with a digital refractometer (Atago Pal-3) and the results were given as (%).

2.10. Titratable acidity

Titratable acidity amount of fruits was determined according to [26].

2.11. Taste scores

Taste scoring was done by the panelists using a 1-5 scale. Scores used in the scale; 1: very bad, 2: bad, 3: moderate, 4: good, and 5: very good.

2.12. Electrolyte leakage (EL)

To determine EL, 5 mm thick discs were cut from the cucumber fruits, cut in half, and washed twice with 50 mL distilled water. Then, 50 ml of distilled water was added to the samples, and the electrical conductivity (EC) was measured after they were kept at room temperature for 2 hours. After this, these samples were frozen and thawed, and when the temperatures reached 18^{o}C, EC measurements were made again. The amount of electrolyte leakage from cucumber fruits was determined by proportioning the initial EC values with the final EC values and expressed as (%) [22].

2.13. Decay rate (%)

For this purpose, the fruits in each replication were examined, and the decay rate was calculated as a percentage (%) by proportioning infected fruits to the total fruit number.

2.14. Experimental Design

The experiment was established, conducted, and evaluated in a randomized plot design with three replications. Four fruits (one package) were used in each replication. Data were analyzed with SPSS 16 program, and the Duncan comparison test was used to compare the differences among the means.

III. Results And Discussion

3.1. Calcium content

While the calcium content of the cucumbers was 86.33 ppm at the initial, it decreased in KT, CaP2, CaP4, CaP6, CaK6 treatments on the fifth day and increased in other applications. The highest increase in calcium content determined 42.85% in CaK4 (123.33 ppm) treatment, and the difference between this and the others was found to be statistically significant at the $p<0.05$ level. While the amount of calcium was found to be higher than the initial, in the 10th day of storage in KK (87.00 ppm), it has preserved close to the beginning in SK (83.67 ppm) and KT (81.33 ppm), and it had fallen below the initial concentration in all other calcium-treated fruits. In addition the calcium content of cucumber in all treatment groups decreased at the end of storage (Fig. 1).

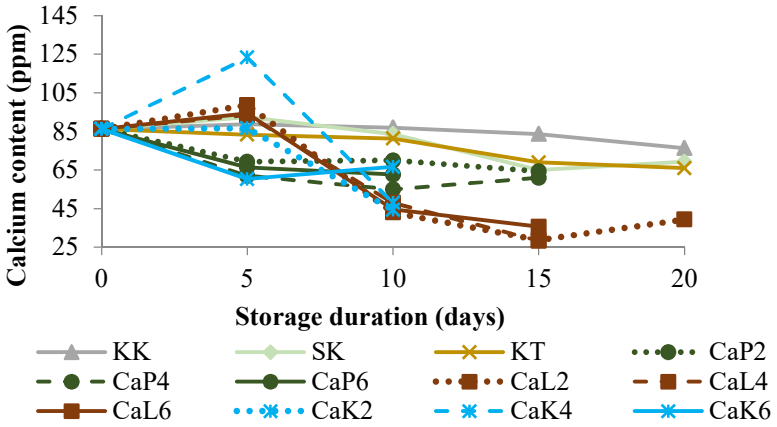

Fig. 1. The change in the amount of calcium in the juice of cucumber treated with a combination of different calcium compounds and chitosan (ppm).

Calcium plays an important role in the structure of the cell wall, as it contributes to cell-cell adhesion and cohesion by causing cross-linking of free carboxyl groups on the linked polygalacturonase chains in the middle lamella of the plant cell wall, which causes an increase in the hardness of fruit tissues [27]. Therefore, it is important to increase the amount of calcium in the cell. Hence, this study aimed to increase the calcium content of the fruits by applying different calcium compounds to the cucumber fruits, thereby increasing the storage time and fruit quality. In the experiment, the calcium content of cucumbers treated in all doses of calcium propionate and two doses of calcium chloride (CaK2 and CaK6) decreased below the initial amount on the fifth day of storage. On the other hand, it exceeded the baseline level in fruits treated with calcium lactate (all doses) and in CaK4 (123.33 ppm). It was found by reference [11] and reference [12] depending on the type and concentration of calcium salts used, postharvest calcium applications significantly increase the calcium content of the fruit. Since the tenth day of storage, the calcium content of the calcium-treated fruits remained below the control groups, suggesting that the applied doses might have damaged the fruit peel.

3.2. Fruit firmness

All calcium treatments increased the flesh firmness of the cucumbers until the fifth day of storage. On the other hand, calcium lactate treatments were more successful than the others. As a matter of fact, on the 5th day of storage, the highest fruit firmness was measured 30.34 N in CaL4 and was followed by CaL2 (30.14 N) and CaL6 (29.49 N) treatments. Although the difference amongst these three applications was statistically insignificant ($p>0.05$), the difference between CaL4 and CaL2 and other

calcium treatments, chitosan, and control groups was significant. Besides, calcium lactate treatments continued this activity until the 15th day (Fig. 2).

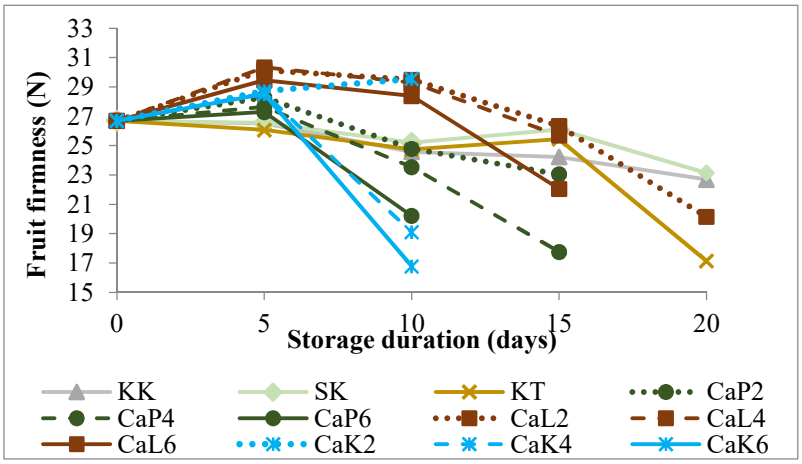

Fig. 2. The changes in fruit firmness (N) in cucumber treated with a combination of different calcium compounds and chitosan

Fruit firmness is decreasing during storage due to the breakdown of Ca-pectate molecules in the plant cell wall [26]. In addition, it has been stated that calcium applications can increase the amount of calcium in the fruit and delay ethylene production, thus delaying softening and color change. Besides, high calcium applications help maintain fruit quality was expressed [7]. In the present study, all calcium and chitosan combinations, especially CaL2 and CaL4, increased flesh firmness compared to the initial. Fruit firmness remained above the initial value in the CaL2, CaL4, CaL6, and CaK2 treatments on the tenth day of storage, but as expected, it began to decrease towards the end of storage. Therefore it can be said that calcium lactate treatments are the most effective on fruit firmness, compared to calcium chloride and calcium propionate during ten days of storage. Reference [13] found that softening of cucumber slices is reduced by 5% calcium lactate and 5% calcium lactate + 5% ascorbic acid+MAP combination. Similarly, reference [15] determined that the treatment of 1% CaCl2 to cucumber fruits in hot water at 55^{o}C for 5 minutes (1%Ca+SHW) maintained the firmness was higher than control. In the present study, also, it was observed that calcium chloride treatments maintained the fruit firmness in the first ten days, while calcium lactate and calcium propionate (except for CaP4) for fifteen days. Reference [28] stated that calcium chloride maintained fruit flesh firmness due to reducing aging by protecting the cellular organization and regulating enzyme activity. However, in the current study, cucumbers treated with calcium chloride could be stored for a maximum of ten days, and this was due to the damage to the skin of the fruit by calcium chloride was thought.

3.3. Weight loss

In general, weight losses increased during storage in all treatments (Fig.3). However, on the fifth and tenth days of storage, the highest weight loss (0.36% and 0.72%, respectively) occurred in the CaK6 treatment. Also, the differences between the CaK6 and others are found to be statistically significant ($p<0.05$). On the 15th day of storage, the highest weight loss was in the CaL4 with 1.08%, whereas the least weight loss occurred in the KT treatment.

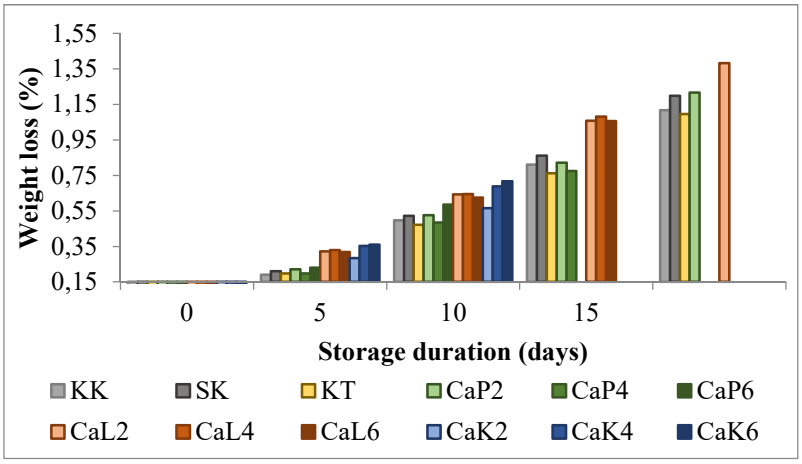

Fig. 3. Change of weight loss (%) in cucumbers treated with combination of different calcium compounds and chitosan

Although the weight loss of cucumber fruits increased during the storage period, it reached a maximum of 1.38%. However, it can be said that even this maximum value does not affect the visual quality of the product. Because the weight loss limit that affects the sales quality of horticultural products is stated as 3-10% [29]. Reference [30] found that the weight losses of cucumber fruits dipped in calcium chloride for 5 and 10 minutes on the 16th day of storage were 10.37% and 10.01%, respectively. However, in the present study, weight losses never reached these levels in all treatments and remained below 3%. Besides, it found that both chitosan alone and in combination with calcium propionate were more successful than calcium chloride in reducing weight loss.

3.4. Change rate of L, hue (h^o) and yellowing index (YI)*

In the study, the *L** value of cucumber fruits generally increased compared to the initial value in all treatments during the storage period (Fig. 4). On the other hand, on the fifth day of storage, while the *L** value was the highest with -4.29% in the CaK4 treatment, it was the lowest was in the CaP4 (0.04%) treatment. On the tenth day of storage, the color *L** value decreased in KT, CaL2, and CaL4 treatments, whereas it increased in others, and the highest increase occurred in CaP2 with a value of -7.34%. The *L** value increased in all applications from this period to the end of the storage period.

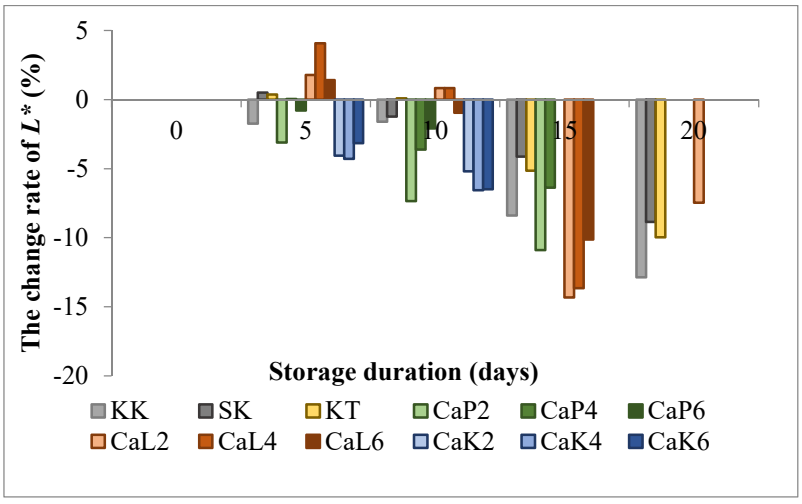

Fig. 4. L* color value change of cucumber fruits treated with different calcium compounds and chitosan combination

In the study, the highest hue angle change was 1.37% in CaL4 treatment compared to the initial of the experiment on the fifth day of storage (Fig. 5). This treatment was followed by CaL6 and CaK6 applications. The hue angle of cucumbers continued to decrease in all treatments as the storage period progressed. The greatest decrease in hue angle occurred in CaL6 treatment (3.99%) on the 15th day of storage, whereas it was the lowest (5.25%) in CaL2 at the end of the storage period.

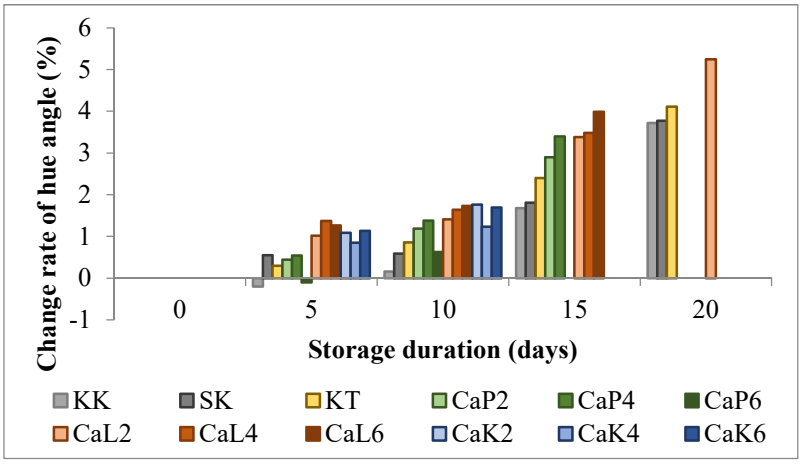

Fig. 5. Changes in the hue angle value of cucumbers treated with a combination of different calcium compounds and chitosan.

YI values increased in SK, CaP4, CaL2, CaL4, and CaL6 treatments on the fifth day of storage, while decreasing in others (Fig. 6). However, while the highest decrease in YI values was detected in CaK4 with 8.21%, the highest increase has occurred in CaL4 treatment with -8.09%, and the difference between these two treatments is statistically significant. The yellowing of cucumbers was less in all calcium chloride treatments, while it continued to increase in others on the tenth day of storage, similar to the fifth day. Also, the difference between CaK4 and CaK6 and the other treatments was statistically significant. In the study, yellowing increased in cucumbers in all application groups with the progression of storage time, and the highest SI change rate was measured in SK application with -25.70% on the twentieth day.

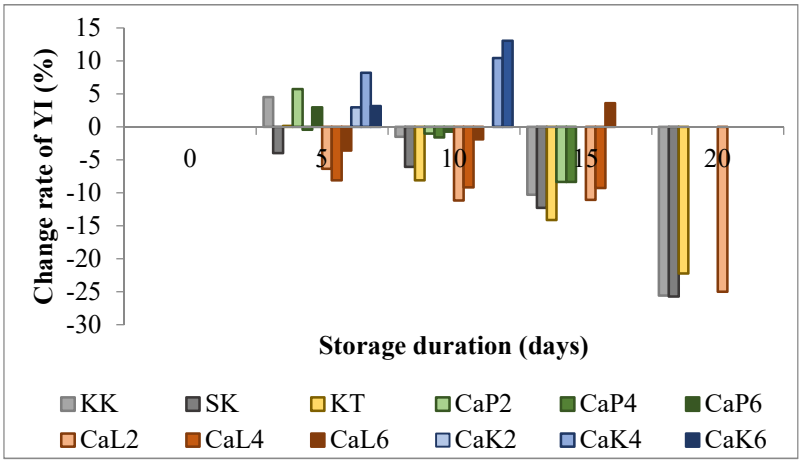

Fig. 6. Changes in the YI of cucumbers treated with a combination of different calcium compounds and chitosan (%)

Color is one of the most important quality criteria of fresh fruits and vegetables and gives information about the changes in the ripening, texture, flavor, and aroma of the fruit [31]. For this reason, it stated that color, that is, the visual quality of the products, is the most important sensory quality feature for the consumer [32, 33]. It also accepted that visual quality gives information about many features such as size, shape, texture, mass, brightness, and color of fresh fruits and vegetables [34, 35, 36]. In the present study, the L* value increased in all treatments during storage, indicating that the brightness of cucumber fruits increased in all applications during storage. However, while the brightness of the fruits in calcium propionate applications was higher than in other applications, it was the lowest in two doses of calcium chloride treatment (CaK4 and CaK6). Therefore, the damage caused by high doses of calcium chloride on the peel of the cucumber fruit affected the brightness of the fruits was thought. In the study, it was determined that the hue angle values decreased during storage in all treatments. However, the highest hue angle value was obtained in the KT, followed by CaP6, KK, SK, and CaL2 applications. Hence it could be said that chitosan coating is the most effective treatment for preserving the green color, and in this sense, CaP6 and CaL2 are better than the other calcium applications. Yellowing is the color change that occurs in the product as a result of exposure to light, chemicals, and various post-harvest

processes. The yellowing index (YI) is mainly used to measure these deterioration types with a single value and shows the degree of yellowness of the product [37]. In the current study, the change rate of YI values decreased in all applications during storage, except for in CaK4 and CaK6 treatments. So it was seen that the calcium treatments effectively maintain green color except for the higher calcium chloride doses.

3.5. Chlorophyll SPAD content of fruit skin

Chlorophyll-SPAD values measured from fruit peel decreased regularly in all treatments during storage (Fig. 7). However, while the chlorophyll SPAD values in CaL6 were the highest (34.88), the lowest was in KT treatment with 29.59. Also the differences between these two treatments were found to be significant statistically. Similar changes were detected on the tenth day of storage. In general, the amount of chlorophyll SPAD of the cucumbers treated with calcium lactate and calcium chloride was higher than those treated with calcium propionate, KK, SK, and KT. The chlorophyll SPAD content of fruit continued to decrease until the last day of storage, and changed between 20.95-23.28 at the end of the storage period.

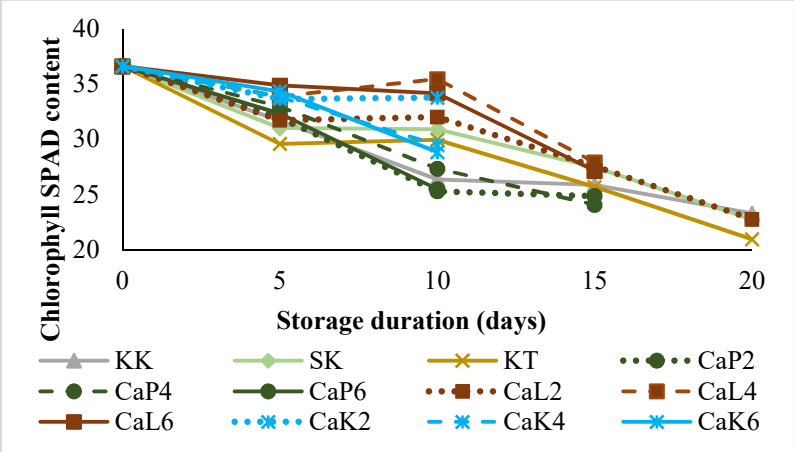

Fig. 7. Changes in the amount of chlorophyll SPAD in cucumbers treated with the combination of different calcium compounds and chitosan

The Chlorophyll-SPAD content of fruit peel was high at the beginning, whereas decreased as the storage duration extent reference [38] found that there is a strong correlation (R2 ~ 0.9) between chlorophyll SPAD measurements and the amount of chlorophyll in vitro. Therefore, according to SPAD data, it can also be said that the amount of chlorophyll in the fruit peel has decreased. However, the highest decrease in the chlorophyll SPAD content occurred in CaP2 application, followed by KK and CaP4. On the other hand, the chlorophyll content of the cucumbers in CaL6 and CaL4 was highly preserved. The chlorophyll SPAD content, which was high at the beginning of storage, decreased towards the end of the storage due to chlorophyll degradation due to senescence. On the other hand, it determined that calcium lactate applications slowed down the degradation rate of chlorophyll compared to other calcium applications.

3.6. Total soluble solids (TSS) content (%)

As shown in Fig. 8, the TSS content of KK, CaL2, CaK2, SK, Cal4, CaK4, and CaK6 increased, whereas decreased in KT, CaL6, CaP2, CaP4, and CaP6 compared to the initial level (3.10%) on the fifth day of storage. However, it was found that there were no statistically significant differences between the treatments. On the tenth day of storage, the TSS content decreased in all treatments, but the least decrease was found to be in SK (3.0%). In the experiment, the amount of TSS continued to decrease in all treatments on the fifteenth and twentieth days of storage, but again, no significant difference was detected between the applications (Fig. 8).

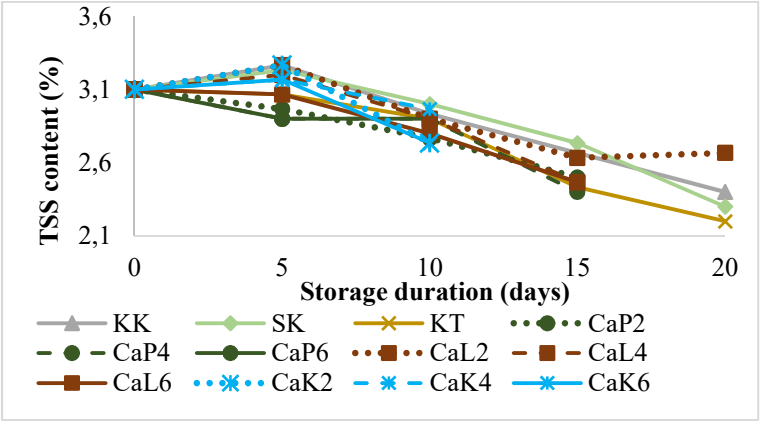

Fig. 8. Changes in the amount of TSS in cucumbers treated with a combination of different calcium compounds and chitosan

In the study, the TSS content of cucumbers decreased during the storage period in all applications due to senescence. However, it is seen that the decreased TSS content of cucumbers in KK, SK, and CaK4 treatments is slow compared to others. Reference [15] determined that the treatment of 1% $CaCl_2$ in hot water at 55°C for 5 minutes (1%Ca+SHW) to cucumber fruits provided the maintenance of TSS content. It determined that CaL2 and CaL4 treatments increased the TSS content on the fifth day of storage, but it decreased in all treatments until the end of storage in the present study.

3.7. Titratable acidity (TA, %)

It has been found that the amount of TA decreased during storage in all treatments (Fig.9) in the study. On the fifth day of storage, the decrease in the amount of TA was lowest in the CaK6 (0.12%) application, while it was highest in the control application with 0.22%. Besides, the difference between these two applications was statistically significant at the $p<0.05$ level. The amount of TA showed a similar change on the tenth day of storage, and the lowest amount of TA was found in the CaL6 (0.09%) application in this period. The amount of TA continued to decrease on the 15th and 20th days of storage and decreased to approximately 1/3 and 1/2 of the initial value at the end of storage and changed between 0.11% and 0.14%.

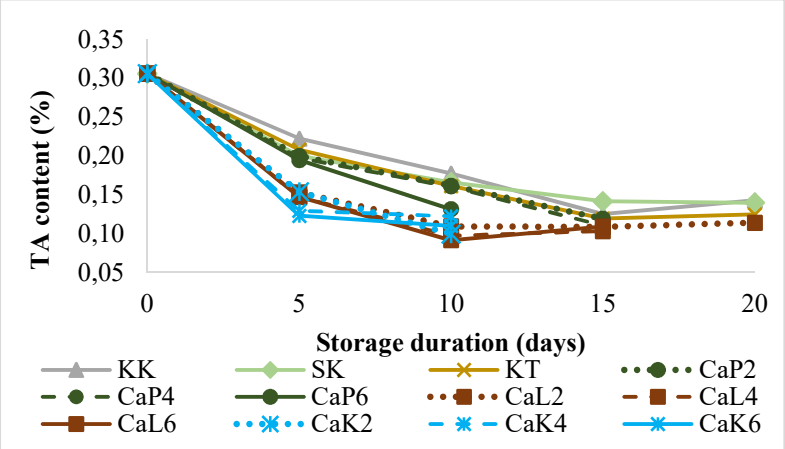

Fig. 9. Changes in the amount of TA during storage of cucumbers treated with a combination of different calcium compounds and chitosan (%)

In the study, the TA content of cucumber fruits showed a more stable slope until the twentieth day after rapidly decreasing until the tenth day of storage. However, it was observed that the amount of TA in the samples treated with calcium chloride was less than in the other calcium treatments.

3.8. Taste scores

Although there is a decrease in fruit flavor during storage, it determined that the flavor qualities of the fruits in KK, SK, KT treatments are preserved until the 10th day of storage, and after this, decreases (Fig. 10). On the 5th day of storage, while the taste

quality of the fruits in KK, SK, KT, CaP4 and CaP6 treatments preserved their initial value, it decreased in the others, and the highest decrease was in CaK6 application with a value of 3.7 ($p<0.05$). The taste scores were decreased, especially in CaP6, CaK4, and CaK6 significantly ($p<0.05$) compared to other treatments on the 10th day, and this decrease continued until the end of the storage period.

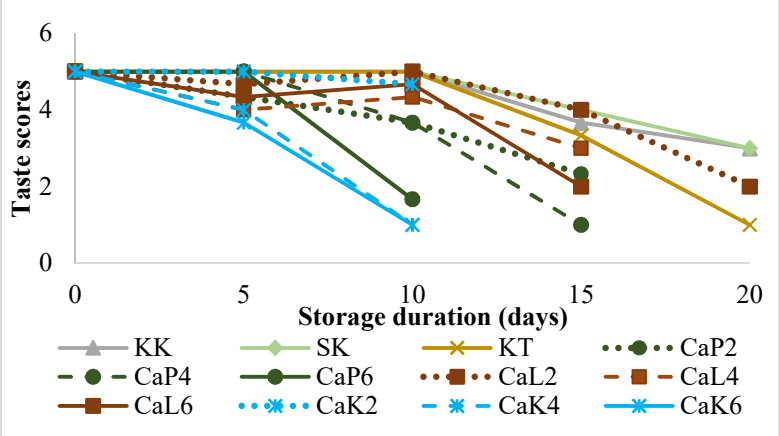

Fig. 10. Changes in taste scores of cucumbers treated with a combination of different calcium compounds and chitosan

The taste, flavor, and aroma of the product are the important quality criteria in fruits and vegetables. Cucumber contains an average of thirty volatile compounds, among which aliphatic alcohols and carbonaceous compounds are abundant. The taste of fresh cucumber fruit emerges as a result of the enzymatic breakdown of linoleic and linolenic acid [39]. In the study, it determined that taste scores decreased during storage, the taste was preserved at a high level in KK, SK, KT, and CaL2 until the 15th day of storage, and it decreased to unacceptable levels in CaP6, CaK4, and CaK6 on the tenth day of storage. It is thought that the loss of taste in these applications was caused by the high doses damaging the fruits.

3.9. Electrolyte leakage (EL)

The amount of EL, which was 14% at the beginning of storage in the experiment, increased in all applications except KK, SK, and KT, on the fifth day of storage (Fig. 11). In this period, the highest EL occurred in CaK6 (29.30%) and followed by CaK4 (25.96%) treatment, while EL was significantly lower ($p<0.05$) (11.53%) in KK application. Although electrolyte leakage increased in all applications from the tenth day of storage, the highest increase was detected in the CaK6 application. The increase in EL continued on days 15 and 20 of storage.

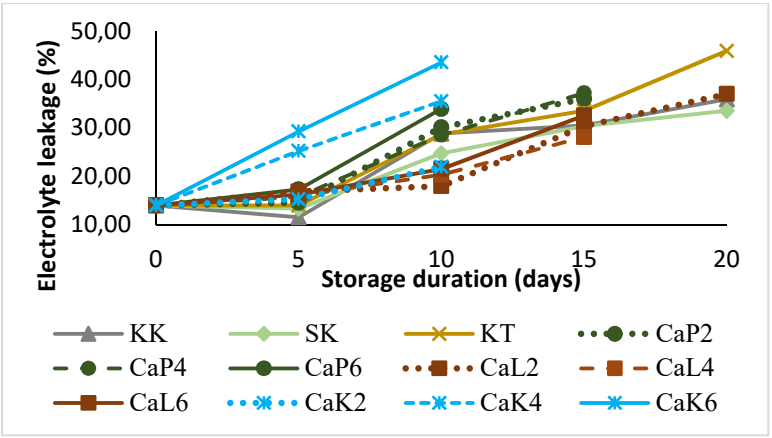

Fig. 11. Changes in electrolyte leakage of cucumbers treated with a combination of different calcium compounds and chitosan (%)

Post-harvest treatments can cause damage to the cell wall of fruits and vegetables, and the amount of this damage has best determined by electrolyte leakage [22]. In the study, EL of cucumbers in CaK4 and CaK6 treatments was quite high. Reference [40] reported that severe stress conditions such as low temperature, which cause the integrity of fruit tissue to deteriorate, increase EL. Similarly, in the current study, it is seen that high doses of calcium chloride damaged the fruit peel. As a matter of fact that, EL increased two times in the CaK4 compared to the KK and also 2.5 times in the CaK6 application on the fifth day of storage. This increase caused the storage life of the calcium chloride-treated cucumbers to be limited to 10 days. CaP6 application had a similar effect and increased EL, and the storage period of this group was only 10 days. However, calcium lactate caused less cell damage compared to other calcium salts. For example, the EL of cucumber treated with CaL2 was lower than in the control group until the 15th day of storage.

3.10. Decay rate (%)

In the first 10 days of the storage period, while no decay occurred in SK, KT, CaL2, CaL4, and CaL6, the decay rate in other treatments was ranged from 0.02% (KT) to 0.33% (CaK4) (Fig. 13). The decay rate increased in all applications except the SK treatment on the fifteenth day of the experiment. In this period, while the highest decay occurred in CaP4 (0.67%) treatment, the least decay (0.05%) formed in K, KT, and CaL2. At the end of the storage period, the highest decay was found in the application of KT (0.42%), while the lowest infection was in the application of SK (0.05%). The fruits decayed in the calcium chloride treatments were shown in Fig. 14.

Fig. 12. Fruits of calcium chloride treatment on the tenth day of storage

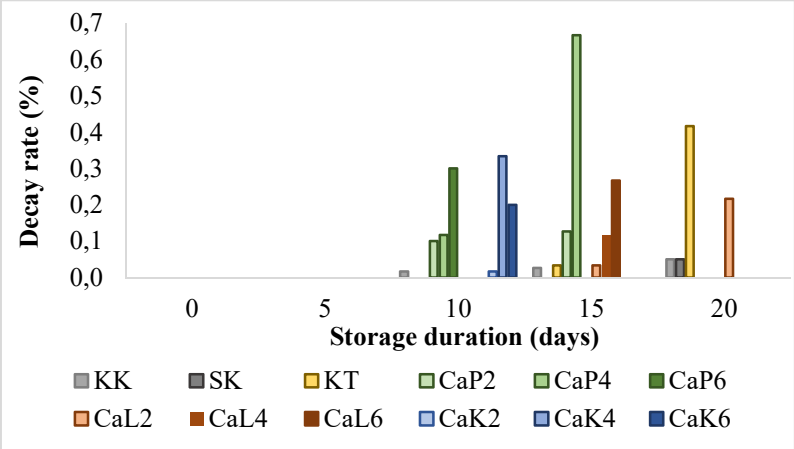

Fig. 13. Variation in decay rate of cucumbers treated with different calcium compounds and chitosan combination

Cucumber harvest before it is ripe, and very susceptible to post-harvest infections due to its high water content and respiratory rate. Therefore, to reduce the infection rate some post-harvest treatments are used. Increasing the amount of calcium in the plant

cell wall increases the firmness of the cell wall by thickening the middle lamella. Therefore, it was also stated that fruits and vegetables treated with exogenous calcium were less susceptible to spoilage [41]. In the study, while calcium propionate and calcium chloride applications were ineffective in preventin On the other hand, the decay of fruits stored after immersion in the water started only on the twentieth day decay, calcium lactate application lost its effect after being effective until the tenth day. The calcium content of the cucumbers changed between 60.33-123.33 pm on the fifth day of storage, and no decay was observed in any treatment group during this period. The increased decay rate of fruit treated with calcium propionate and chloride applications is because these applications damage the fruit peel. As a matter of fact, during this period, the electrolyte leakage of fruits in these applications is also high.

IV. Conclusion

In this study, the effects of different calcium salts and chitosan combinations on the storage duration and quality of cucumbers were investigated. As a result, it was revealed that the combination of calcium lactate and chitosan gave better results than the calcium propionate and calcium chloride with chitosan combinations in preserving the biochemical quality of the product, especially the CaL2 treatment was successful in this regard. It has been determined that 4% and 6% doses of calcium chloride in particular cause damage to the product and reduce its quality. Therefore, as a result of the study, although CaL2 treatment is recommended for maintaining the storage quality of cucumber, it has been seen that the KT application is also usable. In addition, it concluded that the combination of chitosan with lower doses of calcium lactate should also be tried.

V. Acknowledgement

We would like to thank Kocaeli University BAP Coordination Unit (Project No: 2019/014) for supporting this master's thesis study.

References

[1] Anonymous, 2018. Nutritional Recommendations for Cucumber in Open Fields, Tunnels and Greenhouses.http://www.haifa-group.com/files/Guides/Cucumber.pdf adresinden alınmıştır. (Ziyaret tarihi:07.01.2018)

[2] FAOSTAT, 2019. Cucumber.www.fao.org: http://www.fao.org/faostat/en/#data/QC/ visualize adresinden alınmıştır.(Ziyaret tarihi: 16.12.2021)

[3] TUIK, 2020. “Protected cucumber cultivation” “Örtüaltı, hıyar üretimi. http://www.tuik.gov.tr/PreTablo Arama.do?araType=vt&metod=search:https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr, Accessed date: 03.01.2019

[4] Y. Funamoto, N. Yamauchi, T. Shigenaga and M. Shigyo, “Effects Of Heat Treatment On Chlorophyll Degrading Enzymes İn Stored Broccoli (*Brassica Oleraceae* L.)”. Postharvest Biol. Technol., vol. 24, pp.163-170, 2002.

[5] M. Olle M. and I. Bender, “Causes And Control Of Calcium Deficiency Disorders, In Vegetables: A Review”, The Journal of Horticultural Science and Biotechnology vol.84, pp.577-584, 2009.

[6] İ. Bolat and Ö. Kara, “Plant Nutrient, Bitki Besin Elementleri: Kaynakları, İşlevleri, Eksik Ve Fazlalıkları” Bartın Orman Fakultesi Dergisi, vol. 19(1), pp. 218-228, 2017.

[7] M.K. Saba, K. Arzani and M. Barzegar, “Impact of Postharvest Calcium Treatments on Storage Life, Biochemical Attributes and Chilling Injury of Apricot”, J. Agr. Sci. Tech., vol.18, pp.1355-1366, 2016.

[8] M.R.Kahraman, “Plant Nutrition, Bitki Besleme”, 1rd ed. ,Gübretaş ,Ankara, 2012.

[9] D.S. Bush, M.J. Cornejo, N.H. Chun and J. Russell, “Ca2 -Stimulated Secretion of a-Amylase During Development in Barley Aleurone Protoplasts”, American Society of Plants biologists, vol.82, pp.566-574, 1986.

[10] M.Y. Bhak, H. Ahsan, F.A. Banday, M.A. Dar, A.I. Wani and G.I. Hassan, “Effect of Harvest Dates, Pre Harvest Calcium Sprays And Storage Period On Physico-Chemical Characteristics of Pear cv.Bartlett”. J Agric Res Dev, vol.2, pp.101-106, 2012.

[11]T.M.M. Mahmud, A. Al Eryani-Raqeeb, S.R. Syed Omar, A.R. Mohamed Zaki and A.E. Abdul-Rahman, "Effects of Different Concentrations and Applications of Calcium on Storage Life and Physicochemical Characteristics of Papaya (*Carica Papaya* L.)", Am J Agric Biol Sci, vol.3, pp.526-53, 2012.

[12]P.P.S. Gill, S.K. Jawandha, A.K. Sangwan, N.P. Singh and N. Kaur, "Postharvest calcium treatments extend the storage life of pear fruits under low temperature storage", Vegetos-An Intaernational Journal of Plant Research, vol.30, pp.180-184, 2017.

[13]M. Ergün and N. Ergün. "Dilimlenmiş Hiyarin Raf Ömrünün Modifiye Atmosfer Paketlemesi ve Kalsiyum Laktat Uygulamasi ile Uzatilmasi", KSU Journal of Science and Engineering, vol.10(2), pp.94-99, 2007.

[14]K. Hearyoung, P. Kuenwoo and K. Homin, "Effects of postharvest heat treatment and calcium application on the storability of cucumber (*Cucumis sativus* L.)". Journal of the Korean Society for Horticultural Science, vol.40(2), pp.183-187, 2019.

[15]I.N. Nasef, "Quality Maintaining of Stored Cucumbers Under Cold Stress and Shelf Life at Room Conditions by Integrating Calcium Chloride and Short Hot Water", Egyptian Journal of Horticulture vol.46(1), pp.63-82, 2019.

[16]M.L. Cid-López, L.A.A Soriano-Melgar, A. García-González, G. Cortéz-Mazatán, E. Mendoza-Mendoza, F. Rivera-Cabrera, R.D. Peralta-Rodríguez, "The benefits of adding calcium oxide nanoparticles to biocompatible polymeric coatings during cucumber fruits postharvest storage". Scientia Horticulturae, vol.287, pp.110285, 2021.

[17]E.I. Rabea and M.E.T. Badawy, C.V. Stevens, G. Smagghe and W, Steurbaut, "Chitosan As Antimicrobial Agent: Applications and Mode of Action". Biomacromolecules, vol. 4(6), pp.1457-1465, 2003.

[18]E. Arrebola, "Advances in Postharvest Diseases Management in Fruits" Postharvest Biology and Technology of Horticultural Crops, vol.7, pp.244-282, 2015.

[19]G. Maleki, N. Sedaghat, E.J. Woltering, M. Farhoodi and M. Mohebbi, "Chitosan-limonene coating in combination with modified atmosphere packaging preserve postharvest quality of cucumber during storage". Journal of Food Measurement and Characterization vol.12, pp.1610–1621, 2018.

[20]Hashim, N.F.A., Ahmad, A., Bordoh P.K., 2018. Effect of chitosan coating on chilling injury, antioxidant status and postharvest quality of Japanese cucumber during cold storage. Sains Malaysiana 47(2):287-294.

[21]I.F. Olawuyi, J.J. Park, J.J. Lee and W.Y. Lee, "Combined effect of chitosan coating and modified atmosphere packaging on fresh-cut cucumber". Food Sci Nutr. Vol.7(3), pp.1043–1052, 2019.

[22]M.U. Kasım and R. Kasım, "Taze Kesilmiş Ispanaklarda Farklı Dalga Boyundaki Ultraviyole Işınlarının Hasat Sonrası Kaliteye Etkisi". YYÜ Tar.Bil.Dergisi, vol.26(3), pp.348-359, 2016.

[23]R.G.Mcguire, "Reporting Of Objective Color Measurements. U.S. Department Of Agriculture-Agricultural Research Service", Subtropical Horticulture Research Station, 1992

[24]J.E. Lancaster, C.E. Lister, P.F. Reay and C.M Triggs, "Influence of Pigment Composition on Skin Color Wide Range of Fruit and Vegetables". J. Amer. Soc. Hort. Sci., vol.122(4), pp.594-598, 1997.

[25]R.Hirschler, "Whiteness, Yellowness, and Browning in Food Colorimetry". Color in Food: Technological and Psychophysical Aspects, pp.93-104, 2012.

[26]İ. Karaçalı, "Bahçe Ürünlerinin Muhafazası ve Pazarlanması", İzmir ,2014.

[27]J. Burns and R. Pressey, "Ca^{2+} in Cell Walls of Ripening Tomato and Peach". J. Amer. Soc. Hort. Sci., vol.112, pp.782–787, 1987.

[28]B.V.C. Mahajan and A.S. Dhatt, "Studies on Postharvest Calcium Chloride Application on Storage Behaviour And Quality of Asian Pear During Cold Storage", Journal of Food, Agriculture & Environment, vol.2 (3&4), pp.157-159, 2004.

[29]C.N. Nunes and J.P. Emond, "Relationship between weight loss and visual quality of fruits and vegetables", Proc.Fla.State Hort.Soc., vol.120, pp.235-245, 2007.

[30]B. Naveena and G. Immanuel, "Effect of calcium chloride, sodium chloride cnd lime juice on physico-chemical properties of cucumber", International Journal of Agricultural Science and Research, vol.7(4), pp.765-77, 2017.

[31]Z. Pék, L. Helyes and A. Lugasi, "Color changes and antioxidant aontent of vine and postharvest-ripened tomato fruits". HortScience, vol.45(3), pp.466–468, 2010.

[32]C. Costa, F. Antonucci, F. Pallottino, J. Aguzzi, D. Sun and P. Menesatti, "Shape analysis of agricultural products: A Review Of Recent Research Advances And Potential Application To Computer Vision". Food and Bioprocess Technology, vol.4(5), pp.673–692, 2011.

[33]R.L.Grossman and J.Z. Wisenblit, "What We Know About Consumers' Color Choices". Journal Of Marketing Practice: Applied Marketing Science, vol.5(3), pp.78–88, 1999.

[34]K. Leon, D. Mery, F. Pedreschi and J. Leon, "Color measurement in *L* a* b** units from RGB digital images", Food Research International, vol.39(10), pp.1084–1091, 2006.

[35]P. Nisha, R.S. Singhal and A.B. Pandit A, "Kinetic Modelling Of Colour Degradation İn Tomato Puree (*Lycopersicon esculentum* L.)". Food and Bioprocess Technology, vol.4, pp.781–787, 2011.

[36]A.C. Pereira, M.S. Reis and P.M. Saraiva, "Quality control of food products using image analysis and multivariate statistical tools". Industrial and Engineering Chemistry Research, vol.48(2), pp.988–998, 2009.

[37]J. Rhim, Y. Wu, C. Weller and M. Schnepf, "Physical characteristics of a composite film of soy protein isolate and propyleneglycol alginate", Journal of Food Science, vol.64(1), pp.149–152, 1999.

[38]L. Limantara, M. Dettling, R. Indrawati and T.H.P. Brotosudarmo, "Analysis on the chlorophyll content of commercial green leafy vegetables", Proc Chem, vol.14, pp.225-23, 2015.

[39]Q. Husain, "Chemistry and Biochemistry of Some Vegetable Flavors". Handbook of Fruit and Vegetable, vol.32, pp.575-627, 2010.

[40]M. Bagheri, M. Esna-Ashari and A. Ershadi, "Effect of postharvest calcium chloride treatment on the storage life and quality of persimmon fruits (*Diospyros kaki* Thunb.) cv. 'Karaj'". International Journal of Horticultural Science and Technology, vol.2(1), pp.15-26, 2015.

[41]M. Sohail, M. Ayub, S.A. Khalil, A. Zeb, F. Ullah, S.R. Afridi and R. Ullah, "Effect of calcium chloride treatment on postharvest quality of peach fruit during cold storage", International Food Research Journal, vol.22(6), pp.2225-2229, 2015.