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The Effects of Calcium Chloride and Ascorbic Acid Treatment on Ready-to-use Carrot Shreds

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Abstract: This study aimed to evaluate the effect of calcium and ascorbic acid treatments on the quality of carrot shreds during storage. Towards this aim, carrot shreds were dipped into a 5 L solution of 2 g/L ascorbic acid containing 1%, 3%, or 5% $CaCl_2$ (Ca + AA) for 3 min at room temperature (~20 °C). In case of the control group (control, C), samples were dipped into distilled water for the same time interval. Subsequent to treatment, carrot shreds were stored in a cold room at 5 ± 1 °C, 85-90% RH for a period of 11 days. Color values (*L*, a* b**), whiteness index, saturation index, hue angle values, visual quality, firmness scores, bitterness scores, total soluble solids (TSS) and electrolyte leakage measurements were conducted at various sampling dates. The results from this study demonstrated that brightness of carrot shreds was augmented by calcium and ascorbic acid treatments irrespective of the dosage used. Whiteness index values for the 5% Ca + AA treated samples were observed to be low whereas saturation indices of 5% Ca + AA and 3% Ca + AA treated carrot shreds were higher as compared to other treatments. This study concludes that treatment with calcium at high doses improves the color quality of carrot shreds under storage conditions. Visual quality and firmness of carrot shreds was maintained till day 4 of storage, thereafter it declined as compared to the control group. Bitterness of carrot shreds was also observed to increase upon treatment with calcium and ascorbic acid. However, calcium treatment of the test carrot shreds was seen to decrease weight loss and cause an increase in the TSS under storage conditions.

Key words: Calcium, ascorbic acid, color, bitterness, quality.

1. Introduction

Fresh-cut vegetables are vegetables that are available in a ready-to-use format. They are minimally-processed plant products that are peeled, trimmed and/or cut prior to being packaged in a way that retains freshness whilst being convenient to the end user. Lettuce and pre-prepared salads are the most common types of fresh-cut vegetables available commercially, although fresh-cut carrots, tomatoes, broccoli, cauliflower, and cabbage can also be found [1].

In recent years, Turkey has witnessed an increase in the demand and availability of fresh-cut vegetables as well as fruits; the examples include pre-washed and trimmed spinach, sliced carrots, leeks, apples, etc.

The basic premise for obtaining high quality fresh-cut vegetables is minimal processing such that the produce retains fresh-like texture, color, flavor, and safe-to-use quality. However, injuries that occur during processes such as peeling, slicing, cutting, shredding, etc. result in stress at the tissue cellular, subcellular and biochemical levels leading to several undesirable changes in the vegetables during the course of storage and transportation [2].

In the case of fresh-cut carrots, the most significant problem faced is surface whitening. It is a phenomenon that arises as a result of dehydration and lignin synthesis. Several treatments, such as application of edible coatings [3], treatment with citric acid [4, 5] or ascorbic acid [6] are available to prevent the whitening.

Results from previous studies have indicated that treatment of carrot shreds with ascorbic acid is successful in preventing the appearance of surface whitening. However, as this treatment results in

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softening of the shreds, the application of a firming agent has been suggested for maintaining the crispness [6]. Calcium treatments that use either calcium chloride ($CaCl_2$) or calcium lactate have been shown to be effective in maintaining the firmness of several fresh-cut fruits and vegetables during storage [7]. It is also known that treatment with Ca^{2+} has the potential to maintain the textural qualities of carrot for as long as up to 10 days of storage [2]. As softening and other undesirable textural changes in fresh-cut products are related to their tissue calcium levels, application of calcium salts (calcium-chloride, -carbonate, -lactate, -propionate, -pectate, etc.) to fruits and vegetables, such as pears, strawberries, kiwis, shredded carrot, honeydew melon discs, nectarines, peaches and melons, helps in retaining tissue firmness [8]. Calcium, in a 1% $CaCl_2$ formulation, and ascorbic acid dips have been employed as firming agents that aid in extending the postharvest shelf life of sliced pears and strawberries that have been stored in a controlled atmosphere [9].

The objective of this study was to determine the effect of calcium chloride and ascorbic acid treatments on the quality parameters of shredded carrots.

2. Materials and Methods

2.1 Plant Material and Sample Preparation

Carrots were obtained from the Kocaeli Wholesale Distribution Center. They were transported immediately to the laboratory, thoroughly washed, peeled, trimmed of tap root and stem plate prior to preparation. A grate was used to prepare carrot shreds (about 5 mm wide, 40 long, and 2 mm thick).

Processed carrots (100 g for each replicate) were dipped into the following calcium and ascorbic acid solutions:

(1) 1% Ca + AA: 5 L solution of 1% $CaCl_2$ containing 2 g/L ascorbic acid for 3 min.

(2) 3% Ca + AA: 5 L solution of 3% $CaCl_2$ containing 2 g/L ascorbic acid for 3 min.

(3) 5% Ca + AA: 5 L solution of 5% $CaCl_2$ containing 2 g/L ascorbic acid for 3 min.

(4) C: The control group samples were dipped in distilled water for 3 min.

All treatments were carried out at room temperature (~20 °C). Treated carrot shreds were dried by first using a salad spinner (2 min, room temperature) so as to remove excessive surface solution and then at room temperature (15 min).

2.2 Packaging and Storage Condition

The samples of shredded carrots (100 g) were placed in covered plastic boxes 110 × 110 × 50 mm in size. Triplicates of each treatment were stored for 11 days at 5 ± 1 °C with relative humidity of 85-90%.

2.3 Color Measurements

Color measurements (L*, a* and b* values) were performed using a chroma meter CR-400 (Konica Minolta Inc. Osaka, Japan) with an illuminant D65 with 8 mm aperture. The instrument was calibrated with a white reference tile (L* = 97.52, a* = -5.06, b* = 3.57) prior to measurements. The L* (0 = black, 100 = white), a* (+red, green) and b* (+yellow, –blue) color coordinates were determined as per the CIELAB coordinate color space system.

Whiteness index [WI, Eq. (1)], saturation index [SI, Eq. (2)] and hue angle [H, Eq. (3)] were calculated using L*, a* and b* values that were computed as described below; these values were used to compare the color changes of the test samples with that of the control (fresh-cut carrot shreds) [10].

$$WI = 100 - \sqrt{(100 - L*)^2 + a*^2 + b*^2} \quad (1)$$

$$SI = \sqrt{a*^2 + b*^2} \quad (2)$$

$$H = \arctan\left({}^{b*}/_{a*}\right) \quad (3)$$

2.4 Visual Quality, Firmness and Bitterness Assessments

Visual quality was evaluated by grading the freshness, appearance, color, uniformity and brightness of the test samples on a five-point Likert scale: 5, excellent; 4, good quality; 3, fair quality; 2, poor quality; 1,

extremely poor quality.

Firmness of the carrot shreds was scored as a subjective variable; the perceived hardness or softness experienced when carrot shreds were taken between two fingers and pressure was applied and was graded on a five-point Likert scale: 5, very firm; 4, firm; 3, partially firm/soft; 2, soft; 1, very soft (not usable).

Bitterness of the carrot shreds was also scored on a five-point Likert scale: 5, no bitterness; 4, slightly bitter; 3 bitter; 2, very bitter; 1, extremely bitter (not consumable).

The judging panel for sensory evaluation was composed of nine food-science students enrolled at the university. All the students had prior classroom training and experience in the sensory evaluation of food items.

2.5 Electrolyte Leakage Measurement

Electrolyte leakage (EL) was measured in the test carrot shreds. Distilled water was used for washing as well as immersion of test sample shreds and conductivity was measured 2 h after immersion. Total electrolyte conductivity of the carrot shreds was measured after they had been frozen and thawed. EL was calculated as percentage of the conductivity after 2 h [11].

2.6 Loss of Weight

The weight of the triplicate samples was recorded on the day of harvest and after the designated sampling dates. The loss in weight was calculated using the following formula:

weight loss (%) = $(W_i - W_s/W_i) \times 100$; where W_i = initial weight; W_s = weight at sampling period.

2.7 Total Soluble Solids (TSS)

For each of the test replicates, TSS was determined for two parallel using an Atago DR-A1 digital refractometer (Atago Co. Ltd., Japan). The experiment was conducted at 20 °C and the results were expressed as percent value.

2.8 Statistical Analysis

Experiments were conducted in a completely randomized design with a minimum of three replications per treatment per sampling date. The resultant data were analyzed by application of the ANOVA test and differences between mean values were determined using Duncan's multiple range test. The results were regarded as significant when $P < 0.05$ and $P < 0.001$.

3. Results and Discussions

3.1 L values and Whiteness Index*

*L** values of treated carrot shreds were observed to have increased irrespective of the type of treatment applied. The highest value was observed on day 4 for shreds treated with 5% Ca + AA (59.757), which was followed by those treated with 3% Ca + AA (57.790), 1% Ca + AA (57.003) and C (control, 56.287). The difference between the treatments was statistically significant ($P < 0.05$). Post day 4, *L** values of samples were observed to be changing whilst in storage: Initially a decrease was observed (day 8) subsequent to which *L** values started increasing again (Fig. 1).

The whiteness index of carrot shreds stored after treatment with 3% Ca + AA and 5% Ca + AA was significantly lower than that of shreds treated with 1% Ca + AA as well as the control samples ($P < 0.05$). Previous studies have determined that treatment with ascorbic acid has a positive effect on the brightness of carrot shreds [6] as well as carrot cubes [10]. Congruent with these findings, the present study observed that during the first four days of storage, treatments that combined ascorbic acid with $CaCl_2$ (at all doses) were observed to increase the brightness of carrot shreds as compared to the control group. Although, *L** values of samples were observed to be decreasing by day 8, brightness of carrot shreds were maintained when treated with 3% Ca + AA as well as 5% Ca + AA. Therefore, it can be concluded that

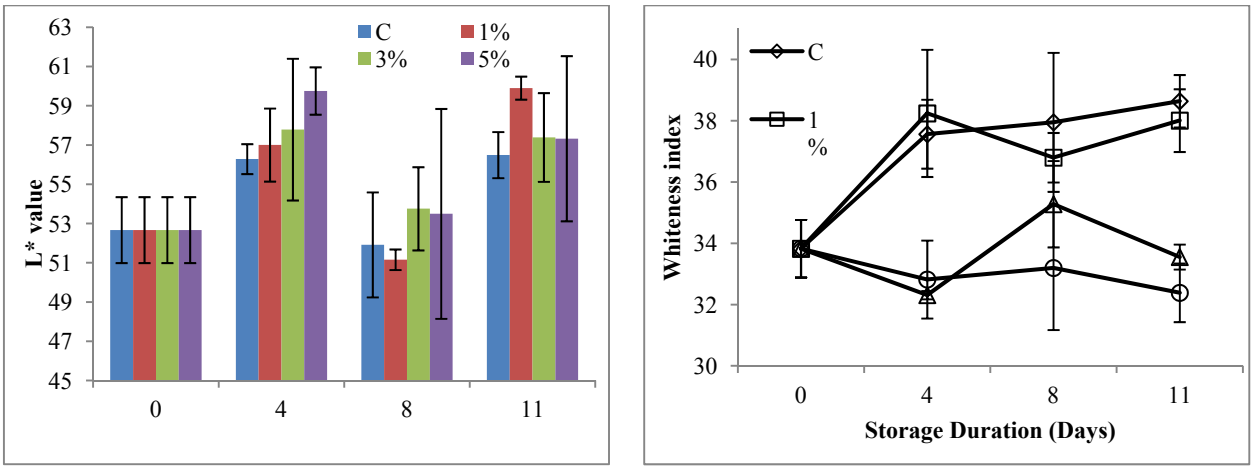

Fig. 1 ***L**** **and whiteness index (WI) values of carrot shreds. 1%: 1% $CaCl_2$ and 2 ppm ascorbic acid (AA); 3%: 3% $CaCl_2$ and 2 ppm AA; 5%: 5% $CaCl_2$ and 2 ppm AA; C: Control.**

treating carrot shreds with a combination of calcium chloride and ascorbic acid was effective in maintaining their brightness.

Previously Rico et al., (2007) have reported that in instances of a colorimeter being used to analyze color, increases in luminosity can be correlated with the development of whiteness in the test samples. In this study, however, the whiteness index (WI, Fig. 1) values of high calcium treated samples (3% and 5% Ca + AA) were lower than those of control and 1% Ca + AA treatments. Therefore, on account of the decrease in WI values of the samples, it can be concluded that treatment with a high dose of calcium prevented the whitening of samples. Similar results were reported for ascorbic acid treatments of carrots [6, 10]. Interestingly, in case of carrot shreds calcium treatments alone did not impact white tissue formation and WI values were observed to increase [2]. However, ascorbic acid alone was effective in inhibiting white color formation on surface of carrots [6]. Therefore, as a result of this study, it can be concluded that the combined use of calcium and ascorbic acid enhances the color quality and also prevents whitening of carrot shreds. Similar results were found [12] in case of nectarine halves.

3.2 Hue Angle and Saturation Index Values

Fig. 2 shows the hue angle (*h**) values measured at day 1 and day 11 of storage. During storage, it was seen that treatment with a combination of ascorbic acid and calcium, irrespective of dose, resulted in a reduction in *h** values. This conclusion was arrived at because significantly higher values were found in control samples compared to those that were treated with Ca + AA ($P < 0.05$). Saturation index (SI) values of samples subjected to 3% Ca + AA and 5% Ca + AA were higher than those treated with 1% Ca + AA and control (Fig. 2; $P < 0.05$). On day 4, the highest value of SI (53.756) was found in fruits treated with 3% Ca + AA. By contrast, the lowest value was observed in carrot shreds treated with 1% Ca + AA (44.303). However, from 4th day of storage till the conclusion of the study, carrot shreds in the control group had the lowest measures of SI values.

The main physiological effect of fresh-cut processing in the case of carrots is surface whitening which results from a combination of dehydration and lignin formation. This leads to significant loss of quality. In this study, the orange color of carrot shreds was observed to be maintained by treatment with calcium and ascorbic acid. This was especially true when samples of the control group were compared with those that received high dose treatments. In the case of minimally processed cabbage, results clearly demonstrated that while treatment with ascorbic acid did not lead to significant differences between test and

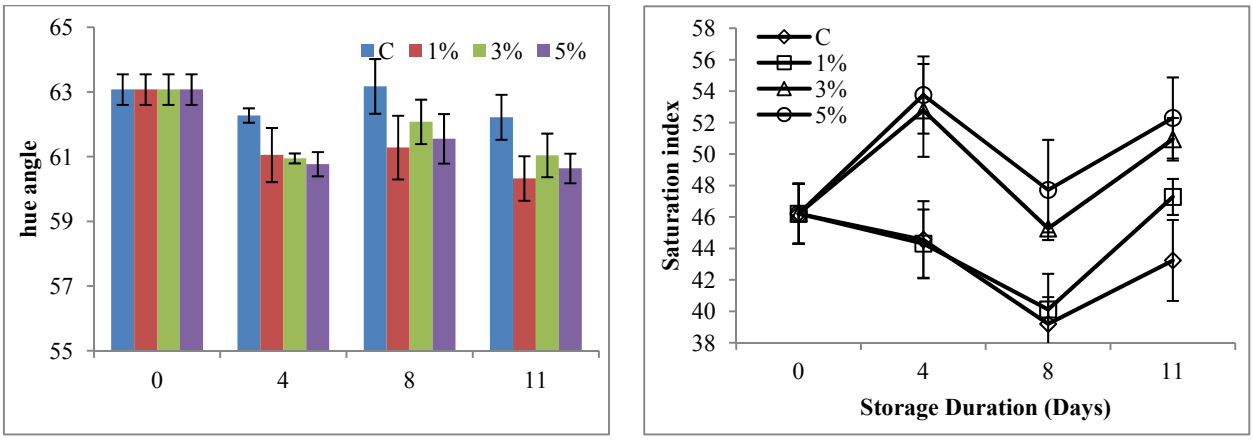

Fig. 2 Hue angle (h^*) and saturation index (SI) values of carrot shreds. 1%: 1% $CaCl_2$ and 2 ppm ascorbic acid (AA); 3%: 3% $CaCl_2$ and 2 ppm AA; 5%: 5% $CaCl_2$ and 2 ppm AA; C: Control.

control samples with respect to color or general appearance, treatment with 2% $CaCl_2$ at 20 °C resulted in consistent maintenance of high quality with less intense browning and the best general appearance [13]. These results were also confirmed in the present study.

3.3 Visual Quality, Firmness and Bitterness Scores of Carrot Shreds

Visual quality scores of test samples, regardless of type of treatment, were observed to be decreased by day 4. Subsequently, scores increased until the 8th day of storage after which they continued decreasing till the end of the storage (Fig. 3). However, the appearance of samples treated with calcium and ascorbic acid was superior as compared to control during the first eight days of storage with the difference between treatments assuming statistical significance at day 4 ($P < 0.05$). Therefore it can be said that as compared to the control samples, the visual quality scores of test carrot shreds were highest during the first 4 days of the storage, but subsequent to that the effectiveness of the treatments decreased such that by the end of the storage period the visual quality scores of the Ca + AA treated samples were much below that of the control group.

According to the firmness scores, the texture of the shredded carrots was retained best in the control group followed by samples treated with 1% Ca + AA, 3% Ca + AA and 5% Ca + AA (Fig. 3). Also, statistically significant differences amongst the treatments were observed at day 4 and 11 of storage ($P < 0.05$ and $P < 0.001$). Fresh-cut vegetables that maintain a firm, crunchy texture are highly desirable because consumers associate such textures with freshness and wholesomeness of produce [14]. The development of such undesirable textural changes in minimally processed products can be reduced by the application of calcium salts (calcium-chloride, -carbonate, -lactate, -propionate, -pectate, etc) because the rate of softening was directly related to the reduction of calcium levels in fruit tissues [11]. Studies have shown that application of Ca salts to pears, strawberries, kiwifruits, shredded carrots, honeydew discs, nectarines, peaches and melons helps in retaining tissue firmness [15]. Firmness scores of treated carrot shreds across all Ca + AA doses were lower than that obtained for control samples during storage, and differences amongst the different treatments were observed to be statistically significant at day 4 ($P < 0.05$) and day 11 ($P < 0.001$). Also, results clearly showed that the firmness scores of samples treated with 1% $CaCl_2$ were higher than that of other calcium treatments leading to the conclusion that $CaCl_2$ treatments were not effective in improving the texture of carrot shreds during storage. But, as per the weight loss results obtained in this study (Fig. 4), the recorded weight loss of the 3% Ca + AA and 5% Ca + AA treatments were lower than those obtained

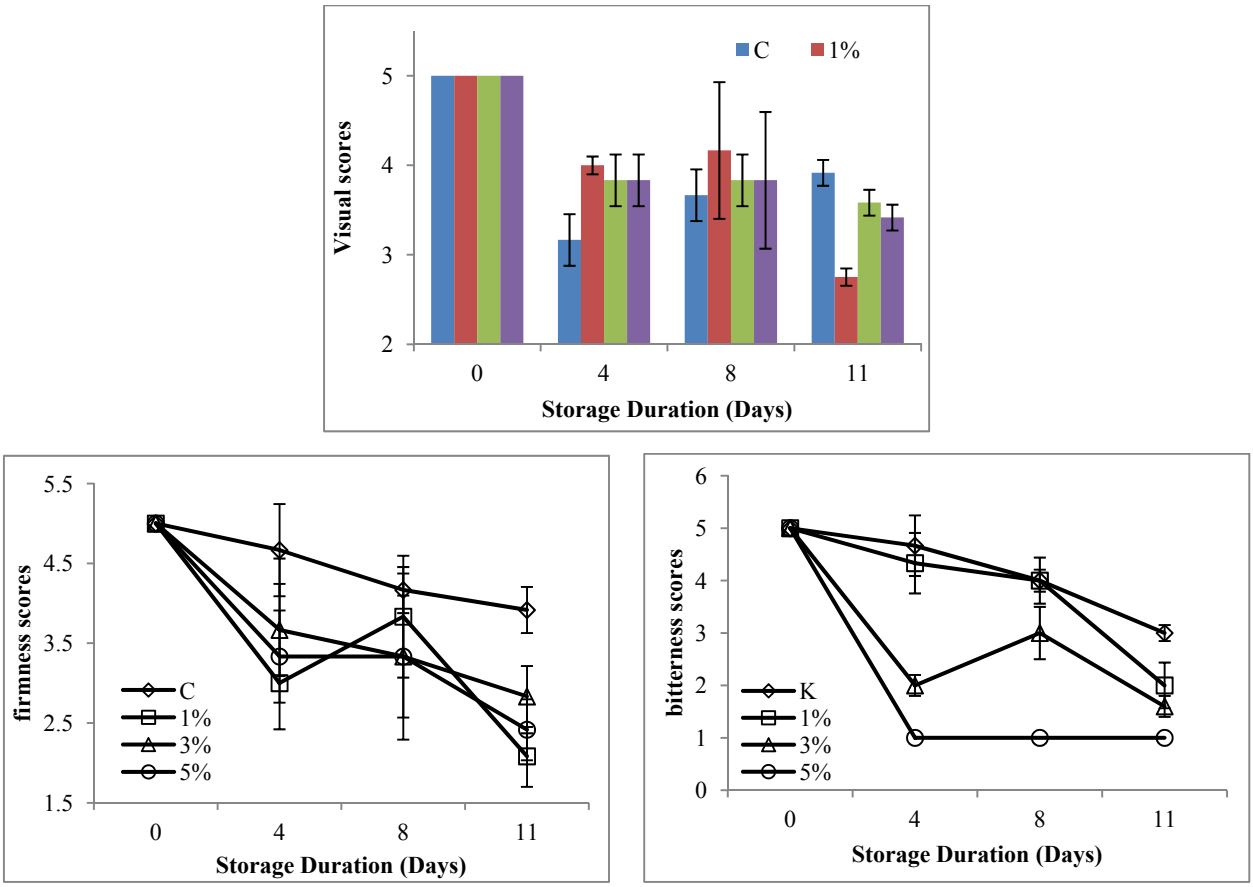

Fig. 3 Visual quality, firmness and bitterness scores of carrot shreds. 1%: 1% $CaCl_2$ and 2 ppm ascorbic acid (AA); 3%: 3% $CaCl_2$ and 2 ppm AA; 5%: 5% $CaCl_2$ and 2 ppm AA; C: Control.

for 1% Ca + AA and control. Hence, the high firmness values of samples in control and 1% Ca + AA treatments can be potentially explained as a byproduct of water loss.

Bitterness of carrot shreds increased upon increasing $CaCl_2$ dose (Fig.3) with the highest (least bitter) values being obtained by 1% Ca + AA treatment (4.33) followed by 3% Ca + AA (2.0) and 5% Ca + AA as recorded on day 4, and these results continued during the storage. Differences amongst the treatments were statistically significant at the level of $P < 0.001$ (4 and 8 days of storage) and $P < 0.05$ (11th day of storage). Studies [16] determined that exogenous administration of $CaCl_2$ in form of a solution can reduce browning as well flesh softening in case of zucchini squash slices. However, $CaCl_2$, when used in high concentrations (> 0.5%), has been known to cause a detectable off-flavor. The results of present study corroborate the above mentioned results.

3.4 Weight Loss

Weight loss of all the treated samples was observed to increase during storage (Fig. 4). The highest weight

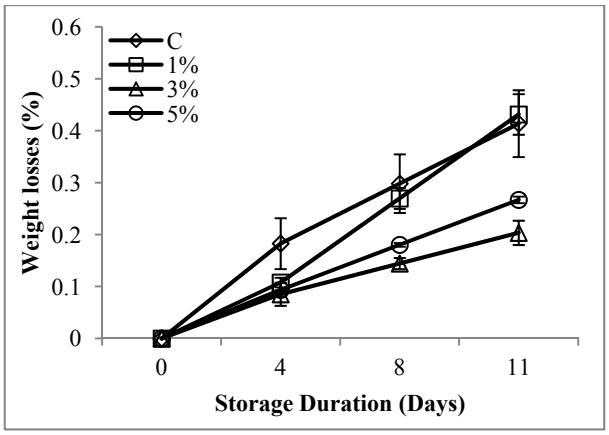

Fig. 4 Weight losses of carrot shreds. 1%: 1% $CaCl_2$ and 2 ppm ascorbic acid (AA); 3%: 3% $CaCl_2$ and 2 ppm AA; 5%: 5% $CaCl_2$ and 2 ppm AA; C: Control.

loss was observed in the control group (0.18 and 0.29) and followed by the 1% Ca + AA (0.10 and 0.26), 5% Ca + AA (0.09 and 0.18) and 3% Ca + AA (0.008 and 0.14) groups as noted on day 4 and 8. Also, statistically significant differences were observed between the various treatment groups while in storage. Therefore it can be concluded that $CaCl_2$—ascorbic acid treatments have a significant effect on weight loss especially at higher doses.

Peel or skin is a very important barrier against desiccation and loss of turgor. Several fruits and vegetables have a protective waxy coating that makes them highly resistant to water loss. Mechanical injury to the skin brought about by peeling, cutting, slicing, shredding, etc. makes fresh cut products highly susceptible to weight loss as the protective peel is no longer intact [11, 15]. In the present study, water lost by carrot shreds was reduced when treated with a combination of calcium and ascorbic acid. Izumi and Watada [2] have previously reported that Ca has no observable effect on weight loss in case of carrot slices and sticks but is effective in preventing the same in case of carrot shreds. Their results also proved that carrot shreds have almost two and three times more Ca content as compared to sticks and slices respectively. Additionally, Ca has widely been reported to play an important role in preserving the structural integrity and mechanical strength of cell walls [9]. The basis for the reduced weight loss observed in case of carrots shreds treated with Ca + AA in the present study, can be accounted for by the Ca absorbed by the samples under test.

3.5 Total Soluble Solids

Fig. 5 shows total soluble solid (TSS) values for carrot shreds subjected to different treatments. TSS of carrot shreds was observed to be decreased on day 4 but this decrease was higher in the control group as compared to the calcium and ascorbic acid treated samples. In quantitative terms, TSS of the control group was 1.2%; for the Ca treated carrot shreds it

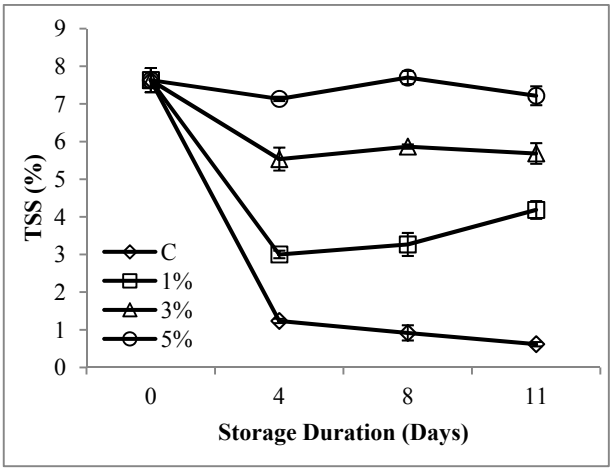

Fig. 5 Total soluble solids (TSS) of carrot shreds. 1%: 1% $CaCl_2$ and 2 ppm ascorbic acid (AA); 3%: 3% $CaCl_2$ and 2 ppm AA; 5%: 5% $CaCl_2$ and 2 ppm AA; C: Control.

ranged from 3% to 7%. Subsequent to day 4, TSS of the control group was observed to steadily decrease till the end of the storage period whereas in case of the Ca treated carrots it was observed to increase. It was also seen that TSS of samples treated with a combination of Ca and AA was higher than that of control and that the higher values were observed in correlation with high doses of $CaCl_2$ treatment during storage. Differences in TSS values amongst the various treatments were statistically significant ($P < 0.001$).

The edible portion of carrot contains about 10% carbohydrate with the soluble carbohydrate composition ranging from 6.6 to 7.7 g per 100 g [14]. In the present study, the initial TSS content of carrot shreds was observed to be 8%. This value was seen to decrease across treatments under storage conditions. Interestingly, the maximum decrease in TSS values was observed in case of the control group where values fell from 1% on day 4 to below 1% on days 8 and 11. In contrast, TSS of calcium treated carrot shreds maintained constant high values especially in the case of shreds treated with 5% calcium where values ranged from 7.1% to 7.7%. TSS of samples in 1% Ca + AA and 3% Ca + AA treatment groups was also found to be high as compared to the control. Therefore it can be concluded that calcium and ascorbic acid

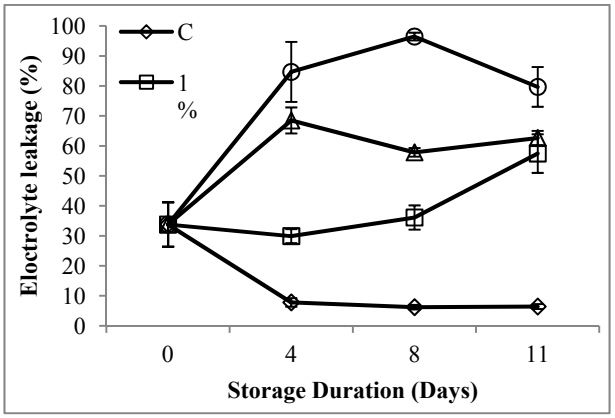

Fig. 6 Electrolyte leakage of carrot shreds. 1%: 1% $CaCl_2$ and 2 ppm ascorbic acid (AA); 3%: 3% $CaCl_2$ and 2 ppm AA; 5%: 5% $CaCl_2$ and 2 ppm AA; C: Control.

treatments prevent loss of TSS in case of carrot shreds especially when used in high doses.

3.6 Electrolyte Leakage

On day 4, it was observed that electrolyte leakage (EL) from carrot shreds in the control group and 1% Ca + AA treated group decreased, whereas in the 3% Ca + AA and 5% Ca + AA treated samples it was increased (Fig. 6). The EL values of the control samples continued to decline but an increase was noted in the 1% Ca + AA and 3% Ca + AA treated groups. Moreover, it showed variations between decrease and increase in 3% Ca + AA treatments during the storage. Differences in EL values among the treatments were statistically significant ($P < 0.001$). Leakage of electrolytes or cellular content is commonly used as an index for evaluating changes in membrane integrity arising due to ripening, stress damage or mechanical injury [7]. Electrolyte leakage is considered as an indirect measure of plant cell membrane damage [17]. In the present study, EL values for calcium and ascorbic acid treated samples were observed to be higher than that of the control group. Therefore, it can be concluded that $CaCl_2$ treatments have no membrane stabilizing effect conferred by exogenous calcium ions.

4. Conclusions

This study aimed to determine the impact of calcium and ascorbic acid on the quality of carrot shreds during storage. For this purpose, carrots were grated and treated with solutions containing varying doses of calcium along with 2 g/L ascorbic acid. The carrots were then stored for 11 days in a cold room at 5 ± 1 °C and 85-90% RH. According to the results obtained from this study, calcium was found to improve color quality and brightness while decreasing the development of whiteness on carrot shreds. As a cautionary note, however, it was observed that calcium, especially at higher doses, could cause bitterness of carrot shreds. Weight losses of carrot shreds treated with calcium and ascorbic acid was found to be higher than that of the control group; also firmness values of these test samples were low compared with the control. While calcium treatment was observed to improve the visual quality of the produce during the first eight days of storage, it was found to lose its efficacy after that. In addition, the calcium treatments showed no membrane stabilizing effect.

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