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# Combined effect of calcium chloride and aloe mucilage on postharvest quality of spine gourd (*Momordica dioica* Roxb.) fruits

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## ABSTRACT

**To observe the response of fruit coating by edible calcium chloride and aloe mucilage on the physico-chemical quality and storability of spine gourd fruits. The three levels of calcium chloride ($CaCl_2$) (10, 20 and 30%) and aloe mucilage (10, 20 and 30%) were possibly combined for experimentation in three replications with untreated fruits as control. Fresh spine gourd fruits, treated with 30% of $CaCl_2$ and aloe mucilage, showed significantly lower values of physiological loss in weight, fruit decay, colour development of fruits. In contrast, higher titratable acidity values and shelf-life duration were also in the same treatment. On the contrary, fruit firmness was retained at the higher side and total soluble solids at the lower level, when fruits were treated with 30% of $CaCl_2$ in combination with 20% aloe mucilage. In the same treatment, marketability of the fruits was highest (91.30, 68.48 and 10.06%) than those treated with other concentrates at the 3rd, 6th and 9th day of storage, respectively. Therefore, observations suggested that application of $CaCl_2$ (30%) in combination with aloe mucilage at 30%, the shelf-life of spine gourd fruit can be extended up to 6 days with retention of fruit quality under ambient conditions.**

**Key words:** Firmness, fruit decay, marketability, natural preservative, shelf-life.

## INTRODUCTION

Spine gourd (*Momordica dioica* Roxb.) is a less-known, healthful vegetable crop, naturally scattered in sub-tropical and tropical parts of India. Spine gourd is widely consumed and serves as a vital nutritional and economic security source for many tribal communities residing in remote natural forest areas (Nandal and Bhardwaj, 13). However, the availability of fresh spine gourd fruit is constrained by substantial postharvest losses (50–60%) due to its climacteric respiration rate and elevated ethylene production, which shorten its shelf life (Bhardwaj *et al.*, 3) and create marketing challenges. Various postharvest techniques, such as pre-cooling, PGR applications, wax coatings, intelligent and active packaging, and cold storage, have been employed to delay fruit ripening, seed hardening, and decay by reducing respiration and ethylene synthesis rates (Bhardwaj *et al.*, 3). Aloe mucilage, a natural hydrophilic polysaccharide with antimicrobial properties and semi-permeable characteristics, has the potential to reduce transpiration, control respiration rates, delay oxidative browning, and slow maturation. It positively impacts the extension of shelf life, firmness retention, and prevention of peel colour changes during storage (Hernalsteens, 6). Calcium ions further enhance cell wall integrity by binding with pectin, ensuring higher cohesion of cell wall structures and minimizing fruit senescence and ripening rates (Prajapati *et al.*, 15). Calcium ions also stabilize cell wall structures, influence acidic growth, regulate ion exchange properties, and control wall enzyme activities. These effects result from the close binding of calcium ions to pectins in the cell walls, maintaining the fruit's natural state for a longer duration without deterioration.

Previous studies have utilized *Aloe vera* gel (Singh *et al.,* 18) and calcium chloride (Sunila-Riaz *et al.,* 19) as coating materials to maintain physiological processes and textural attributes in fruits. While several researchers have reported the individual benefits of calcium chloride and aloe mucilage in fresh fruit storage, their combined use as a postharvest coating to extend the storage life and maintain the quality of fresh spine gourd fruits has not been explored. This study aims to evaluate a suitable method for extending the availability and reducing postharvest losses of spine gourd fruits.

## MATERIALS AND METHODS

Spine gourd fruits were harvested at the horticultural maturity from naturally grown plants at the College of Agriculture, Sumerpur-Pali, Rajasthan (73° 05' East longitude and 25° 09' North latitude) in August 2022 and 2023. Qualitatively graded spine gourd fruits were randomly divided into ten treatment lots with three

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replications containing 750 g of fruits in each replicate. A group of 250 g of fruits per treatment was used for weight loss and fruit decay percentage assessment. Double-coated postharvest fruit dipping treatments with all nine combinations (Table 1) were applied as 10%, 20% and 30% $CaCl_2$ solutions for 5 min then, air-dried for 30 min at room temperature, followed by another dipping in 10%, 20% and 30% aloe mucilage for 5 min and air-dried for 30 min. For control, three lots of uncoated fruits were kept after 5 min of dipping them in distilled water. Treated fruits were placed in 2% perforated polyethylene film bags and stored in ambient conditions at 30 ± 2 °C temperature with 65% ± 5 relative humidity for 9 days. The details of the treatment combinations are as below;

Fruit physico-chemical quality parameters, such as physiological loss in weight (PLW), fruit firmness, total soluble solids (TSS), and titratable acidity (TA) were evaluated on the date of the experiment (0 day) before treatments and at 3rd, 6th, and 9th days after storage. PLW was measured with the help of an electronic weighing balance and the difference in weight loss was expressed in percentage on a fresh weight basis. Fruit decay was determined by visual observation of the degree of infection and data were expressed as the percentage. Colour development in fruits was determined by visual observation and weighing of yellow and reddish colour fruits, data were expressed as percentages. Fruit firmness was measured by a digital penetrometer device with a 6 mm steel tip head to compute the average force needed to puncture the fruit flesh. The total soluble solid was measured by hand refractometer (ATAGO TC-1E) with a range of 0 to 32 °Brix and resolutions of 0.2 °Brix. TA in spine gourd fruit juice samples was quantified by titration using 0.1 mol $L^{-1}$ NaOH and the end point was pH 8.1. To determine the organoleptic score of the fruits based on taste, aroma, bitterness, texture, and overall acceptability of fruits was done by semi-trained judges using 7-point hedonic scales. The marketability of fruits was recorded as the weight of fresh and saleable fruits during storage, based on descriptive quality attributes.

**Table 1.** Detail of treatment combinations.

| S. No. | | Treatment Combinations |
|---|---|---|
| 1 | $T_1$- | Control (without any coating treatment) |
| 2 | $T_2$- | 10% aloe mucilage + 10% $CaCl_2$ solution |
| 3 | $T_3$- | 10% aloe mucilage + 20% $CaCl_2$ solution |
| 4 | $T_4$- | 10% aloe mucilage + 30% $CaCl_2$ solution |
| 5 | $T_5$- | 20% aloe mucilage + 10% $CaCl_2$ solution |
| 6 | $T_6$- | 20% aloe mucilage + 20% $CaCl_2$ solution |
| 7 | $T_7$- | 20% aloe mucilage + 30% $CaCl_2$ solution |
| 8 | $T_8$- | 30% aloe mucilage + 10% $CaCl_2$ solution |
| 9 | $T_9$- | 30% aloe mucilage + 20% $CaCl_2$ solution |
| 10 | $T_{10}$- | 30% aloe mucilage + 30% $CaCl_2$ solution |

The analysis of variance (ANOVA) was performed using the '*AOV*' function under the 'STATs' package in R under Completely Randomized Design. Tukey's HSD (honestly significant difference) was used for evaluating pooled mean separation at a 5% level of significance.

## RESULTS AND DISCUSSION

The combination of higher levels of aloe mucilage (30%) and $CaCl_2$ (30%) ($T_{10}$) significantly minimized weight loss (30.46%) followed by $T_9$ treatment (31.92%) and $T_7$ treatment (32.19%) on 9th day of storage compared to control (42.64%). Calcium ion with aloe mucilage plays an important role in preserving fruit physiology by stabilizing the cell membrane, the slower rate of transpiration, respiration, and maintaining the turgor pressure of the spine gourd fruits. The results are in agreement with Hassan *et al.* (4) in strawberries; Prajapati *et al.* (15) in bitter gourd; Sunila-Riaz *et al.* (19) in sweet oranges. Among all treatments, the highest fruit decay was reported in $T_1$ (13.13%, 25%, and 68.75%), followed by $T_2$ treatment (9%, 15%, and 50%) on the 3rd, 6th, and 9th days of storage, respectively (Table 2). On 3rd day of storage, fruit decay initiated in all coating treatments and gradually increased with the advancement of the storage period, but a minimum decay of 39.13% was observed in fruits coated with $T_7$ combination (aloe mucilage 20% + $CaCl_2$ 30%), whereas the maximum fruit decay 68.75% was observed in control ($T_1$ treatment) on 9th day of storage. Fruit decay in treatments $T_7$ (39.13%), $T_{10}$ (40%), $T_{11}$ (41.30%), $T_8$ (41.67%) and $T_6$ (41.69%) showed no significant difference at the end of the experiment. This indicates that a higher concentration of aloe mucilage and $CaCl_2$ treatments effectively reduced the fruit decay rate during storage in comparison to lower concentration and control fruits. Aloe mucilage significantly reduces microbial infection due to antimicrobial properties (Singh *et al.*, 18), whereas calcium chloride strengthens and thickens the middle lamella of the cell wall (Prajapati *et al.*, 15), it can efficiently reduce the occurrence of diseases, slow down ethylene production, delayed softening and ripening hence maintaining shelf life for longer duration (Bhardwaj *et al.*, 3). The current results agree with Rasouli *et al.* (17) in oranges; Mazumder *et al.* (10); Mani *et al.* (9) in tomatoes.

**Table 2.** Effect of calcium chloride in combination with aloe mucilage on physiological loss in weight (PLW), fruit decay, and colour development of spine gourd fruits during storage.

| Treatments | PLW (%) | | | Fruit decay per cent | | | Colour development in fruits (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| DAS* | 3rd | 6th | 9th | 3rd | 6th | 9th | 3rd | 6th | 9th |
| $T_1$ | 7.69 | 22.29 | 42.64 | 13.13 | 25.00 | 68.75 | 18.75 | 38.75 | 68.75 |
| $T_2$ | 6.77 | 20.95 | 40.48 | 9.00 | 15.00 | 50.00 | 9.50 | 27.50 | 50.00 |
| $T_3$ | 6.45 | 19.43 | 37.37 | 6.47 | 14.71 | 47.06 | 8.82 | 20.00 | 47.06 |
| $T_4$ | 6.23 | 19.18 | 36.82 | 4.55 | 13.64 | 45.45 | 8.18 | 17.27 | 45.45 |
| $T_5$ | 5.55 | 18.40 | 35.32 | 6.82 | 14.09 | 42.73 | 5.45 | 16.82 | 41.36 |
| $T_6$ | 5.35 | 18.02 | 33.87 | 5.83 | 12.96 | 41.69 | 5.00 | 15.75 | 39.58 |
| $T_7$ | 5.27 | 17.85 | 32.19 | 3.70 | 12.09 | 39.13 | 4.78 | 15.26 | 38.70 |
| $T_8$ | 4.89 | 17.50 | 33.44 | 4.17 | 13.75 | 41.67 | 5.22 | 15.48 | 38.26 |
| $T_9$ | 4.86 | 17.35 | 31.92 | 3.87 | 12.57 | 41.30 | 4.58 | 15.25 | 35.42 |
| $T_{10}$ | 4.75 | 17.18 | 30.46 | 4.40 | 11.80 | 40.00 | 4.35 | 15.22 | 35.22 |
| | 5.78± 0.30 | 18.81± 0.53 | 35.45± 1.23 | 6.19± 0.93 | 14.56± 1.20 | 45.77± 2.76 | 7.46± 1.39 | 19.73± 2.42 | 43.98± 3.15 |
| C. D. (p=0.05) | 0.68 | 1.20 | 2.78 | 2.10 | 2.71 | 6.24 | 3.14 | 5.47 | 7.13 |

*Days after storage

Among different treatments, $T_{10}$ was found effective in maintaining the natural green colour with the minimum changes (35.22%), followed by $T_9$ (35.42%) and $T_8$ (38.26%), whereas significantly higher colour change was reported in $T_1$ treatment (68.75%) at the end of storage period. The modified atmosphere created by the aloe mucilage coating retarded the ethylene production rate, therefore, delaying ripening, chlorophyll degradation, anthocyanin accumulation, and carotenoid synthesis; thereby, ultimately delaying the colour change of fruits compared to uncoated fruits (Bhardwaj *et al.*, 3). Similar results were also reported, indicating that $CaCl_2$ delayed skin browning in strawberry fruits, following the same pattern (Singh *et al.*, 18). Previous studies demonstrated retardation of fruit colour changes by aloe mucilage coating in cucumber (Ajiboye and Gboyinde, 1), and in lime (Pimsorn *et al.*, 14). Both the control and the coating treatments exhibited a decreasing trend in fruit firmness during storage. Among storage days, the highest firmness (42.70 N) was recorded on the initial day and the lowest (8.29 N) on the 9th day of storage in untreated fruits. Throughout the storage period, the $T_8$ (23.05N), $T_7$ (22.99N), and $T_9$ (22.47N) consistently demonstrated significantly higher fruit firmness than all other treatments and control (8.29 N). Diminish in the firmness of cherries during the storage period has been reported (Hu and Feng, 7), which could be associated with the activity of cell wall degrading enzymes, dehydration due to water loss, and pathogen infection. Furthermore, similar findings on the positive effects of aloe mucilage and $CaCl_2$ on fruit firmness have been obtained for tomatoes (Mazumder *et al.*, 10), and duke cherry (ValizadehKaji and Fakhri, 20).

In general, the total soluble solid content before storage was about 3.5 °Brix and increased to 5.67 °Brix, 7.10 °Brix, and 8.19 °Brix after 3, 6, and 9 days of storage in untreated fruits (Table 3). Throughout storage, an increasing trend in TSS was reported, which can be attributed to fruit dehydration, ripening, and breakdown of polysaccharide substances such as starch, pectin, and cellulose into soluble sugars (Bhardwaj *et al.*, 3). At the end of storage, the highest PLW (42.64%) was experienced in untreated fruits ($T_1$), whereas $T_{10}$ and $T_9$ had lower rates of 30.46% and 31.92%, respectively, resulting in corresponding TSS values of 8.19%, 5.67%, and 5.32%, respectively. Coating with aloe mucilage can reduce the respiration rate and may slow down the synthesis and use of metabolites, resulting in lower TSS (Ali *et al.*, 2), which may explain the higher concentration of TSS in non-treated fruits. Analogous to the presented TSS, similar change pattern was found in oranges treated with 30% *Aloe vera* gel (Rasouli *et al.*, 17), as well as mandarin treated with 60% *Aloe vera* gel (Rashid *et al.*, 16). Calcium chloride helps maintain TSS, possibly due to its inhibitory effect on turgor pressure failure and its role in maintaining membrane integrity (Sunila-Riaz *et al.*, 19). Similar results were also reported by Mazumder *et al.* (10) and Parjapati *et al.* (15).

TA decreased progressively with the advancement of the storage period, which was noticed in all the

**Table 3.** Effect of calcium chloride in combination with aloe mucilage on fruit firmness, total soluble solid (TSS), and TA of spine gourd fruits during storage.

| Treatments | Fruit firmness (N) | | | TSS (°Brix) | | | Titratable acidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| DAS* | 3rd | 6th | 9th | 3rd | 6th | 9th | 3rd | 6th | 9th |
| $T_1$ | 28.15 | 16.83 | 8.29 | 5.67 | 7.10 | 8.19 | 1.84 | 1.16 | 0.49 |
| $T_2$ | 31.09 | 20.77 | 10.20 | 4.59 | 5.54 | 6.25 | 2.52 | 2.14 | 1.71 |
| $T_3$ | 33.08 | 26.86 | 15.41 | 3.98 | 4.65 | 5.16 | 2.53 | 2.16 | 1.73 |
| $T_4$ | 34.01 | 28.99 | 18.76 | 3.96 | 4.62 | 5.12 | 2.65 | 2.33 | 1.94 |
| $T_5$ | 33.42 | 28.50 | 18.37 | 4.55 | 5.52 | 6.22 | 2.56 | 2.19 | 1.77 |
| $T_6$ | 32.39 | 26.97 | 16.34 | 4.37 | 5.15 | 5.70 | 2.74 | 2.49 | 2.15 |
| $T_7$ | 34.69 | 31.47 | 22.99 | 3.88 | 4.50 | 4.95 | 2.87 | 2.65 | 2.35 |
| $T_8$ | 34.97 | 31.65 | 23.05 | 4.32 | 5.14 | 5.60 | 2.75 | 2.48 | 2.18 |
| $T_9$ | 34.53 | 31.13 | 22.47 | 4.27 | 4.95 | 5.32 | 2.84 | 2.64 | 2.39 |
| $T_{10}$ | 33.40 | 27.93 | 20.24 | 4.57 | 5.28 | 5.67 | 2.94 | 2.80 | 2.57 |
| | 32.97± 0.64 | 27.11± 1.51 | 16.312± 2.43 | 4.416± 0.16 | 5.24± 0.23 | 5.81± 0.29 | 2.62± 0.09 | 2.30± 0.14 | 1.92± 0.18 |
| C. D. (p=0.05) | 1.45 | 3.42 | 5.50 | 0.36 | 0.52 | 0.66 | 0.20 | 0.32 | 0.41 |

*Days after storage; Initial average firmness value of the fruits = 40.5N; Initial average TSS value of the fruits 3.5°Brix; Initial average TA 3.35%.

treatments, including control fruits, and the decline rate was significantly affected by the coating treatments. At the end of storage (9 days), the highest titrable acidity (2.57%) was found in $T_{10}$ treatment, which was followed by $T_9$ (2.39%) and $T_7$ (2.35%), whereas the lowest (0.49%) was reported in control (Table 3). A decrease in TA of fruits during the storage period has been described for strawberries (Hassan *et al.*, 4), which could be due to the increase in respiration rate resulting use of organic acids (Sunila-Riaz *et al.*, 19), water losses, breakdown of glycoside into sub-units, and the catabolism of polysaccharides into simple sugars (ValizadehKaji *et al.*, 20). Furthermore, the positive effects of *Aloe vera* gel have been reported for strawberries (Hassan *et al.*, 4). Before the application of treatments, fruits were highly acceptable for consumption but at the end of the study period, fruits in $T_1$ treatment were neither acceptable nor unacceptable with a score of 4.14 due to their poor organoleptic quality (Fig. 1). The highest mean value of organoleptic was observed in $T_4$ (7.96, 5.52) followed by $T_3$ (7.70, 5.48), while the minimum organoleptic score was noted in $T_1$ (7.08, 4.14) and $T_8$ (6.02, 4.14) followed by $T_9$ treatment (6.19, 4.31) on the 6th and 9th day of storage, respectively. The higher retention of organoleptic scores in fruits treated with aloe mucilage and calcium chloride could be attributed to the activation of biosynthetic pathways that promote the accumulation of phenols and other bioactive compounds, which help maintain good taste and overall organoleptic quality during storage. Similar

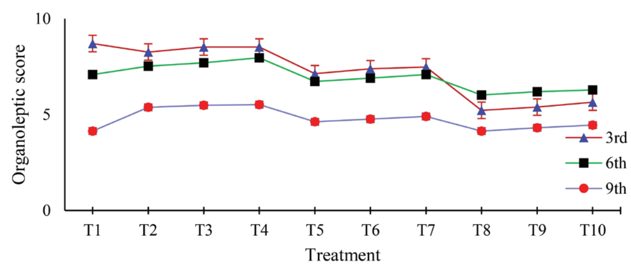


**Fig. 1.** Organoleptic score (out of 10 marks) of spine gourd fruits as affected by aloe mucilage and $CaCl_2$ coating treatments during storage.

results were also reported by Sunila-Riaz *et al.* (19) in sweet oranges and Prajapati *et al.* (15) in bitter gourd.

Fruits coated with higher concentrations of aloe mucilage and $CaCl_2$ under treatments $T_{10}$ (93.52%, 69.84%) and $T_9$ (93.24%, 69.66%) showed the highest fruits shelf life up to 3rd and 6th day of storage, respectively which was significantly greater than the other treatments, whereas uncoated fruits had the lowest shelf life (77.80%, 49.94%) on 3rd and 6th day and all fruits were spoiled on 9th day of storage (Fig. 2). Moreover, aloe mucilage and $CaCl_2$ treatments may modify the internal atmosphere, creating conditions such as elevated $CO_2$ and reduced $O_2$ levels, which help delay fruit ripening and senescence by lowering respiration and ethylene production rates. Previous studies on cauliflower Mu *et al.* (11) and sweet cherry Mujtaba *et al.* (12) align with these experimental findings.

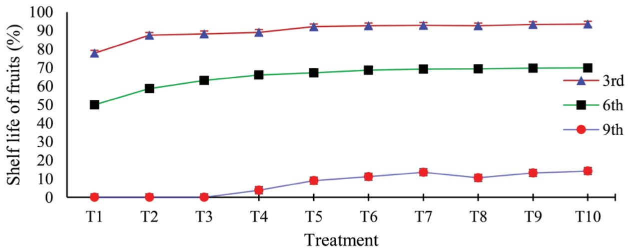


**Fig. 2.** Shelf life (%) of spine gourd fruits as affected by aloe mucilage and $CaCl_2$ coating treatments during storage.

The highest marketability of the fruits was reported in the $T_{10}$ (92.72% and 68.40%), which was closely followed by the $T_9$ (92.61% and 68.17%) and $T_7$ (91.30% and 68.48%) treatments, whereas the lowest marketability of the fruits (72.78% and 41.87%) was observed in control on 3$^{rd}$ and 6$^{th}$ day of storage, respectively (Fig. 3). On the 9$^{th}$ day of storage, the maximum fruits were discoloured, spoiled, and unmarketable in all treatments. Calcium ions ($Ca^{2+}$) and aloe mucilage-based coatings have been shown to prevent moisture loss and firmness, control respiratory rate and maturation development, delay oxidative browning, and reduce fruit microorganism proliferation (Hazarika *et al.*, 5). Increased marketability in spine gourd fruits, as observed in this study, is in line with the findings of Jaiswal *et al.* (8) in tomato fruits.

Postharvest fruit coating with aloe mucilage and calcium chloride significantly reduces physiological weight loss, delays fruit decay, preserves the natural green colour and firmness, and maintains total soluble solids, TA, and organoleptic quality during storage. Notably, fruits treated with a higher concentration of aloe mucilage (30%) combined with $CaCl_2$ under treatments $T_7$, $T_8$, $T_9$, and $T_{10}$ exhibit extended shelf life and enhanced marketability, lasting up to six days in storage. Despite these promising findings, further research is needed to explore combinations of other natural coating materials and essential minerals for preserving the quality of spine gourd fruits.

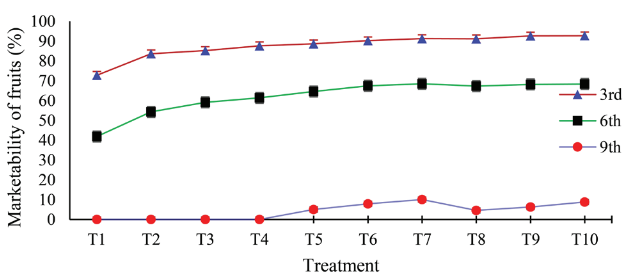


**Fig. 3.** Marketability (%) of spine gourd fruits as affected by aloe mucilage and $CaCl_2$ coating treatments during storage.

## AUTHORS' CONTRIBUTION

The Conceptualization of research (RLB, KC, P,); Designing of the experiments (KH, AS); Contribution of experimental materials (RLB, JM, AS); Execution of the experiments and data collection (RLB, KC); Analysis of data and interpretation (KC, JM); Preparation of the manuscript (RLB, KC).

## DECLARATION

The authors declare that they do not have any conflict of interest.

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