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Full Paper

Coating minimally processed Golden Nam Dok Mai mango with *Aloe vera* gel extract to maintain quality during storage

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Abstract: This study investigated the effects of varying concentrations of *Aloe vera* gel extract on the post-harvest quality and shelf life of minimally processed 'Golden Nam Dok Mai' mango chunks stored at 5 °C for 7 days. Although all mango chunks softened during storage, slower softening was observed with higher *Aloe vera* concentrations, except for those treated with 100% *A. vera*, which showed similar softening to the controls. Coating with *A. vera* gel reduced weight loss compared to untreated controls, although the concentration of *A. vera* did not significantly influence weight loss. Total soluble solids increased across all treatments, but 40% *A. vera* treatment led to the least increase, suggesting moderate metabolic activity. Titratable acidity decreased during storage, with higher *A. vera* concentrations (40% and 60%) preserving acidity better. Vitamin C content was better retained in mango chunks coated with 100% *A. vera*. Additionally, *A. vera* coatings led to a darker flesh over time, particularly with thicker coatings. Sensory evaluation revealed that mango chunks coated with 40% *A. vera* gel were most preferred. We concluded that coating minimally processed 'Golden Nam Dok Mai' mango chunks with *A. vera* gel would be beneficial in terms of a cost-effective natural preservative to enhance the shelf life and sensory qualities of fresh-cut mangoes.

Keywords: mango (minimally processed), *Aloe vera* gel, edible coating, mango preservation

INTRODUCTION

In 2023 Thailand was the eighth largest mango (*Mangifera indica* L.) producer, with approximately 1.6 million tons [1]. Thailand has more than 60 mango cultivars that are

commercially cultivated with 'Nam Dok Mai' being the most important cultivar, especially for export. It has a yellow skin and is sweet, fragrant and juicy with no fibre. Besides being marketed as fresh fruit, mangoes are sold as canned, dried, frozen and increasingly as minimally processed fruit, which is also called ready-to-use or fresh-cut and is marketed after being ripened, peeled and cut into small chunks, so that it is fully edible without any further preparation. Ranges of minimally processed fruit have been developed, mainly in response to a growing demand for convenient and healthy fresh fruit. These products provide a simple and attractive way of meeting the '5-a-day' common recommendation and can also allow consumers to reduce waste since only the edible part of the product is marketed [2]. Several factors affect the shelf life of minimally processed fruit, especially refrigeration. In some countries laws control the maximum display temperature for minimally processed fruit and supermarkets generally use 5ºC in order to maintain freshness and safety [3]. However, Corato [2] pointed out that at 5ºC most minimally processed fruit and vegetables have only a 1-2 days shelf life. In order to increase shelf life, minimally processed fruit are commonly packed in plastic film.

Therefore, in order to ensure an adequate and safe marketing period, preservation technologies that maintain freshness and safety have been developed. These include heat treatment, refrigeration, irradiation and changes in pressure as well as types of packaging and edible coatings [4]. The main goal of developing edible films or coatings is to create an environmentally friendly method of extending the shelf life of minimally processed fruit by reducing the gas exchange between the cells of the fruit and the external environment, which reduces the respiration rate. Edible coatings also facilitate the control of pathogens and be used as carriers of beneficial compounds such as vitamins, minerals and antioxidants [5]. Coating fresh fruit with non-phytotoxic, tasteless and odourless chemicals, usually waxes, has been practiced for many decades. The main purpose of coating is to improve the appearance and reduce desiccation in order to enhance market life, but it can also reduce the rate of physiological effects such as ripening and senescence, by slowing the rate of gas exchange between cells of the fruit and its immediate environment [6]. Mangoes have been specifically tested with coatings made from tapioca flour, sago flour, soy protein [7], chitosan and *A. vera* gel [8]. Also, combinations of different coating materials have been shown to enhance positive effects on mangoes [9-11]. Chitosan possesses strong antibacterial and antifungal properties and evidence suggests that coating mangoes with chitosan reduces the development of anthracnose disease caused by the fungus *Colletotrichum gloeosporioides* by triggering plant defense mechanisms [12]. Conversely, although gum arabic has been successfully applied to mangoes, it does not have antifungal properties [9, 13].

A. vera (L.) Burm.f. is a succulent plant that originated in the Arabian Peninsula, but now grows wild in numerous tropical, semi-tropical and arid regions worldwide [14]. Extracts of *A. vera* are used in the manufacture of medicinal products, cosmetics and hair treatments [15] as well as some food products, but its use as a food is limited because of its bitter taste [16]. *A. vera* leaf gel can be used as an ingredient in edible films for coating fresh fruits and vegetables. Coating whole fresh mangoes with *A. vera* gel was shown to significantly delay ripening, softening and weight loss [17]. Muangdech [18] coated 'Nam Dok Mai' mangoes with 20% *A. vera* gel and stored them for 12 days at 25ºC and 75±5% RH and found that weight loss and softening were slower and titratable acidity (TA) and total soluble solids significantly higher than the untreated control fruit while the quality of the fruit was not altered when ripe.

Other coatings and combinations have been tested on fresh cut mangoes [19, 20] but detailed study of different levels of *A. vera* gel has not been reported. The objective here is to test the effects

Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28

of coating minimally processed mangoes with different levels of *A. vera* extract on their quality and shelf life.

MATERIALS AND METHODS

Fruit

Mango fruit, *Mangifera indica* L. cv. 'Golden Nam Dok Mai', were harvested from Chachoengsao province, Thailand. The trees were monitored every day and as soon as any individual fruit had set, a label was tied to it so that it was possible to determine the age of the fruit as it developed. Individual fruit were harvested 105-115 days after the fruit set, and were selected for their uniform size (about 3 fruit per kg), colour, shape and lack of blemishes and disease symptoms. All the fruit were judged to be about 80% ripe, following Sirisomboon et al. [21] and Wichitkunanan et al. [22]. Each fruit was immediately laid on its side after harvesting to allow the latex to drain away. After that, it was carefully packed in cartons and transported to the laboratory, around 100 km away, where the fruit were put in a water-filled tank. Those that sank were subsequently transferred to another tank with 2% sodium chloride, and only the floating fruit were used in the experiment in order to ensure that every fruit in the experiment had the same stage of maturity. The fruit were then washed, allowed to dry and stored at ambient temperature (about 25ºC) for 4 days in plastic baskets until they were all judged to be fully ripe based on their skin colour, smell and texture (assessed by gently pressing each fruit).

Preparation of *A. vera* Gel and Coating

The *A. vera* leaves were washed to eliminate impurities, the thick epidermis was removed, and the gel was rinsed with warm water to remove the yellow sap. The gel was then blended and filtered through an 80 mesh sieve to separate the clear, finely blended jelly from the solid fraction. The gel was then heated at 70-80ºC for 5-10 min. in a cast iron pot on a stove. Then citric acid at 0.15% w/w of the gel was added to the filtered gel, which was then cooled to room temperature and stored in glass jars at 5ºC until required.

Fruit Coating and Storage

After ripening each mango fruit was peeled, cut in lengthwise pieces and cut further into chunks approximately 20 mm in size (Figure 1) and randomly divided into 7 groups with 60 chunks of fruit in each group, which was then dipped in *A. vera* gel whose concentrations in distilled water ranged between 0-100%, i.e. 0%, 20%, 40%, 60%, 80%, 100%.

After treatment the slices were placed on a wire mesh rack at ambient temperature (about 25ºC) for a few min. and allowed to dry. Directly after treatment and drying, the slices were placed in PET boxes (Figure 1) and stored at 5ºC and 70-80% RH in temperature-controlled refrigerator. Random samples (including control sample) of fruit chunks were removed for analysis directly after treatment and after 3, 5 and 7 days of storage.

Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28

Figure 1. Mango chunks coated with *A. vera* gel, dried and placed in PET box

Physical Analysis

Weight loss and colour

Weight loss was measured for 10 fruit chunks per treatment by weighing each chunk daily and expressed as a fraction of the initial mass. The colour of each chunk was measured using a Minolta Colourimeter (Chroma Metre CR 400, Japan), using the Commission Internationale de l'éclairage (*L**, *a**, *b**) scale at 3 different locations on different sides of each chunk (10 chunks per treatment) and the average colour value was recorded. Prior to measurement, the colourimeter was calibrated using a white standard calibration plate.

Browning index

The browning index (BI), defined as the 'brown colour purity,' is one of the most prevalent markers of browning in sugar-containing food products. A higher BI corresponds to a darker fruit [23]. BI was calculated as BI = (100 (x – 0.31)) / 0.172, where x = (a + 1.75L) / (5.645L + a – 0.3012b) [24]. Here x is the chromaticity coordinate calculated from the La*b* scale, where L measures lightness, a is the red/green coordinate and b is the yellow/blue coordinate.

Firmness

Firmness was determined using a texture analyser HD Plus (Stable Micro Systems, UK) with a 100-kg load cell, calibrated at 5 kg and equipped with a 2-mm diameter probe held perpendicular to the mango chunk, at a speed of 10 mm/min. to penetrate to a depth of 5 mm into the mango section. Readings were recorded at 3 points selected at random on each chunk and results were expressed in terms of force in Newtons (N).

Chemical Analysis

All chemicals used were of analytical grade (except where stated) as follows: citric acid (food grade, Merck), L-ascorbic acid (Merck), N-acetylcysteine (Merck), oxalic acid (Merck),

Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28

phenolphthalein (Merck), sodium hydroxide (Carlo Erba) and 2,6-dichlorophenolindophenol sodium salt hydrate (Fluka).

Total soluble solids (TSS)

TSS were determined by extracting a juice sample and directly placing it into a portable digital refractometer (Atago Co., Japan). The findings were expressed as a percentage of TSS. Prior to measurement, the refractometer was calibrated with pure water to register 0% TSS.

TA, pH and vitamin C

The acidity of each sample was assessed using a Mettler Toledo auto-titration analyser (Switzerland). The pH of the mango juice was measured and TA was calculated based on 5 mL of filtered juice by titrating it with 0.1N sodium hydroxide to pH 8.1. TA was expressed as per cent citric acid per 100 g of each chunk, representing acidity on a fresh weight basis.

The titrimetric method (AOAC 967.21) using 2,6-dichloroindophenol was used to determine the level of vitamin C in each fruit sample [25].

Statistical Analysis

The experiment used a completely randomised design, analysed using one-way analysis of variance. Differences between means were determined at $p \leqslant 0.05$ using Duncan's multiple range test with the SPSS statistic version 29 software (IBM Corporation, USA).

RESULTS AND DISCUSSION

Even though the mango samples were subjectively judged to be of edible ripeness when prepared for the *A. vera* gel treatment, the slices continued to significantly soften ($p \leqslant 0.05$) during the 7-day storage at 5ºC, although softening was slowed with higher *A. vera* concentration gel used, except for samples coated with 100% gel, which were similar to the controls (Table 1). As would be expected, weight losses occurred for all treatments during storage. Also, there was a general trend for the coated fruit to lose less mass than the controls. However, the concentration of *A. vera* extract used had no significant effect ($p \leqslant 0.05$) on mass loss (Table 1). In terms of firmness, the fruit progressively softened during storage, again as would be expected, but the effect of the coating was variable and inconsistent.

The effects of different concentrations of *A. vera* gel extract on TSS, TA and vitamin C content of mango flesh during storage at 5°C over a 7-day period (Table 2) show that the TSS increases for all treatments over the storage period, with 40% *A. vera* treatment showing the least increase, indicating a moderation of metabolic activity. The TA generally decreases as expected during storage, but higher concentrations of *A. vera* (40% and 60%) help maintain higher acidity levels, suggesting a protective effect against respiration-driven acid loss. Additionally, the control and 20% *A. vera* treatment retain more vitamin C compared to other treatments, though the 100% *A. vera* treatment is particularly effective in preserving vitamin C levels by day 7.

Overall, our results suggest that *A. vera* gel, especially at higher concentrations, can act as a natural preservative to extend the shelf life of mango flesh by slowing down changes in TSS, TA and vitamin C content. The potential antioxidative properties of *A. vera* may also contribute to this effect, making it a promising candidate for post-harvest treatment to maintain the nutritional quality of processed mangoes during storage.

Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28

The changes in colour parameters (*L**, *a**, *b**) and BI of mango flesh next to the seed during cold storage at 5ºC and 70-80% RH for 7 days (Figure 2) show that all treatments exhibit a decrease in *L** over time, indicating increased browning, but the control group showing the highest decline. The *a** values slightly decrease, indicating a subtle shift towards green colour while *b** values show a slight increase, suggesting a shift towards yellow colour. The BI increases across all treatments, confirming browning development with the control group displaying the highest BI values. Water immersion treatments result in lower BI values compared to the control, indicating reduced browning. The changes in the colour parameters (*L**, *a**, *b**) and BI of mango flesh below the peel during cold storage at the same conditions (Figure 3) are somewhat similar to those for mango flesh next to the seed.

Table 1. Effects of concentration of *A. vera* gel extract (0-100%) in water on firmness and fresh weight loss of fresh mango chunks during storage at 5ºC

Treatment	No. of storage days			
	0	3	5	7
Firmness below peel (Newton)				
Control	293.21±7.97	175.13±12.15^{bc}	147.96±0.90^{ab}	123.64±1.93^{b}
0%	293.21±7.97	179.58±13.53^{bc}	124.06±4.34^{c}	110.50±6.32^{d}
20%	293.21±7.97	198.67±7.16^{b}	147.92±1.90^{ab}	111.20±5.92^{cd}
40%	293.21±7.97	156.87±10.47^{c}	143.39±14.16^{b}	141.52±4.88^{a}
60%	293.21±7.97	259.61±26.27^{a}	153.64±2.90^{ab}	112.02±3.12^{cd}
80%	293.21±7.97	251.36±20.92^{a}	159.49±7.48^{a}	118.64±1.37^{bc}
100%	293.21±7.97	151.29±4.15^{c}	149.64±6.23^{ab}	142.84±2.16^{a}
Firmness next to pulp (Newton)				
Control	229.74±5.68	152.23±6.74^{cd}	158.24±2.36^{a}	129.81±3.92^{a}
0%	229.74±5.68	124.28±2.52^{e}	122.23±1.19^{c}	119.16±6.83^{b}
20%	229.74±5.68	179.90±2.73^{a}	109.33±5.70^{d}	92.43±3.45^{d}
40%	229.74±5.68	144.16±6.76^{d}	146.60±4.25^{b}	136.70±4.54^{a}
60%	229.74±5.68	166.77±1.71^{b}	165.70±2.69^{a}	129.24±6.06^{a}
80%	229.74±5.68	158.05±3.66^{c}	123.99±1.21^{c}	115.63±2.95^{b}
100%	229.74±5.68	128.14±6.35^{e}	125.26±10.14^{c}	105.99±0.64^{c}
Fresh weight loss (%)				
Control	0	1.39±0.47^{a}	1.87±0.09^{a}	2.36±0.22^{a}
0%	0	1.20±0.25^{a}	1.16±0.36^{ab}	1.93±0.23^{ab}
20%	0	1.59±0.55^{a}	1.49±0.06^{ab}	1.73±0.22^{ab}
40%	0	1.68±0.87^{a}	0.99±0.47^{b}	1.40±0.08^{b}
60%	0	1.52±0.72^{a}	0.86±0.56^{b}	1.56±0.32^{b}
80%	0	1.56±0.67^{a}	1.04±0.30^{ab}	1.60±0.48^{ab}
100%	0	2.03±0.01^{a}	1.32±0.01^{ab}	1.73±0.36^{ab}

Note: Differing superscript letters within a column for each day represent statistical differences ($p<0.05$).

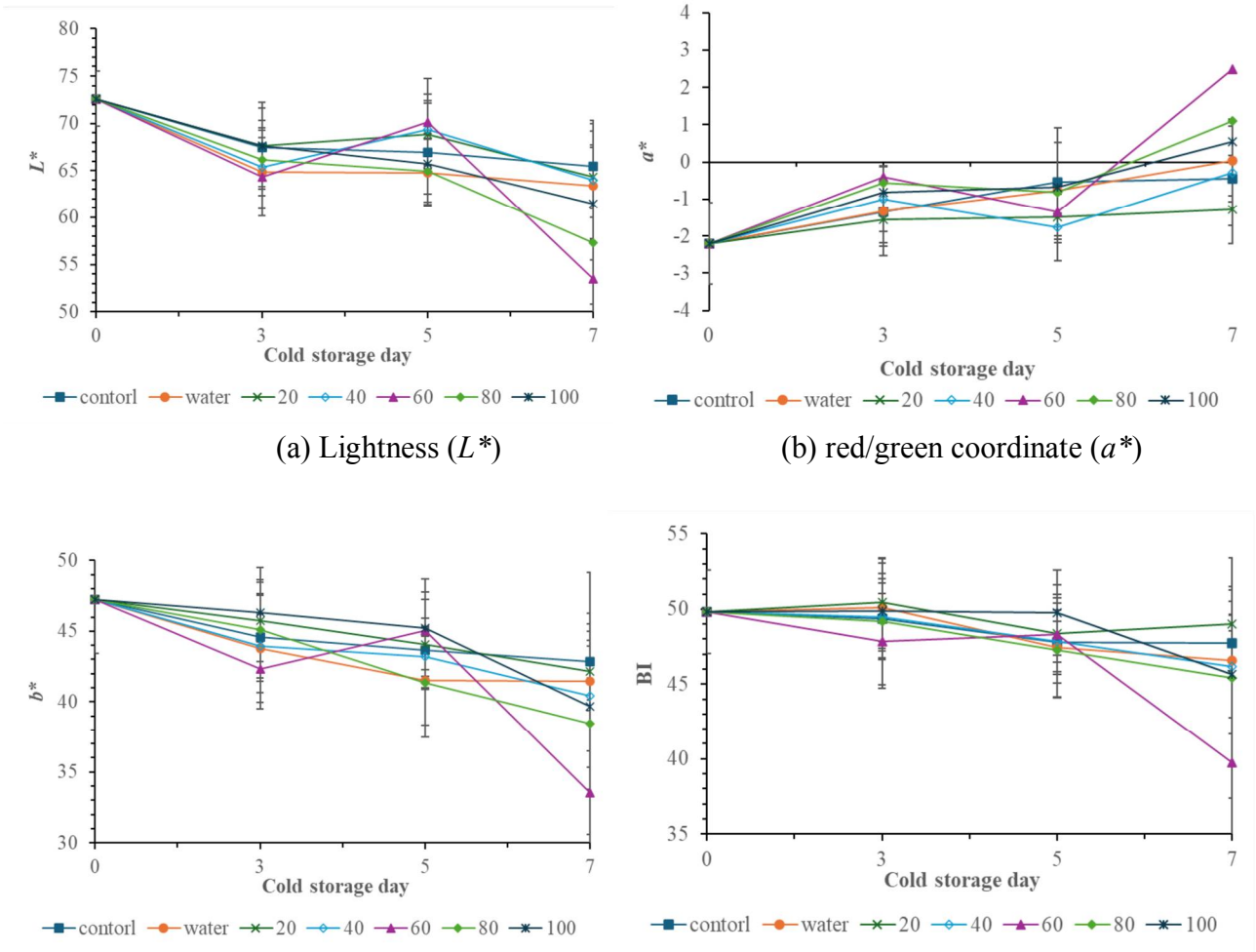
Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28

Table 2. Effects of concentration of *A. vera* gel extract (0-100%) in water on TTS, TA and vitamin C of mango flesh during storage at 5°C

Treatment	No. of storage day			
	0	3	5	7
TTS (%)				
Control	17.13±0.12	18.17±0.06^{a}	18.53±0.12^{a}	19.67±0.12^{a}
0%	17.13±0.12	17.47±0.12^{b}	17.23±0.06^{b}	18.33±0.12^{d}
20%	17.13±0.12	17.40±0.20^{b}	17.33±0.23^{b}	18.73±0.23^{c}
40%	17.13±0.12	17.40±0.20A^{b}	17.27±0.12^{b}	17.47±0.12^{e}
60%	17.13±0.12	17.27±0.31^{b}	17.27±0.12^{b}	18.67±0.31^{cd}
80%	17.13±0.12	17.47±0.23^{b}	17.47±0.31^{b}	19.27±0.12^{b}
100%	17.13±0.12	17.23±0.06^{b}	18.33±0.12^{a}	19.27±0.31^{b}
TA (g/L)				
Control	0.59±0.02	0.53±0.03^{a}	0.34±0.06^{ab}	0.034±0.004^{b}
0%	0.59±0.02	0.48±0.03^{a}	0.18±0.03^{c}	0.035±0.003^{b}
20%	0.59±0.02	0.48±0.02^{a}	0.29±0.05^{b}	0.035±0.005^{b}
40%	0.59±0.02	0.40±0.09^{b}	0.36±0.06^{a}	0.041±0.003^{a}
60%	0.59±0.02	0.52±0.05^{a}	0.35±0.03^{ab}	0.033±0.002^{b}
80%	0.59±0.02	0.47±0.04^{a}	0.35±0.04^{ab}	0.028±0.001^{c}
100%	0.59±0.02	0.50±0.04^{a}	0.34±0.02^{ab}	0.029±0.002^{c}
Vitamin C (μmol/L)				
Control	3.47±0.55	3.27±0.73^{Aab}	3.20±0.76^{a}	2.87±0.39^{Ab}
0%	3.47±0.55	3.40±0.49^{Aa}	3.53±0.39^{a}	3.27±0.53^{Ab}
20%	3.47±0.55	3.07±0.41^{Babc}	3.67±0.47^{a}	4.13±0.83^{Aa}
40%	3.47±0.55	2.73±0.16^{Bbc}	3.93±0.47^{a}	3.47±0.33^{Ab}
60%	3.47±0.55	3.13±0.53^{Aabc}	3.27±0.53^{a}	3.40±0.49^{Ab}
80%	3.47±0.55	3.13±0.69^{Aabc}	3.80±0.90^{a}	3.07±0.41^{Ab}
100%	3.47±0.55	2.60±0.22^{Bc}	3.60±0.76^{a}	3.53±0.59^{Aab}

Note: Different uppercase superscripts within the same row show significant differences ($p<0.05$). Lowercase supercripts within the same column of each day show significant differences ($p<0.05$).

Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28

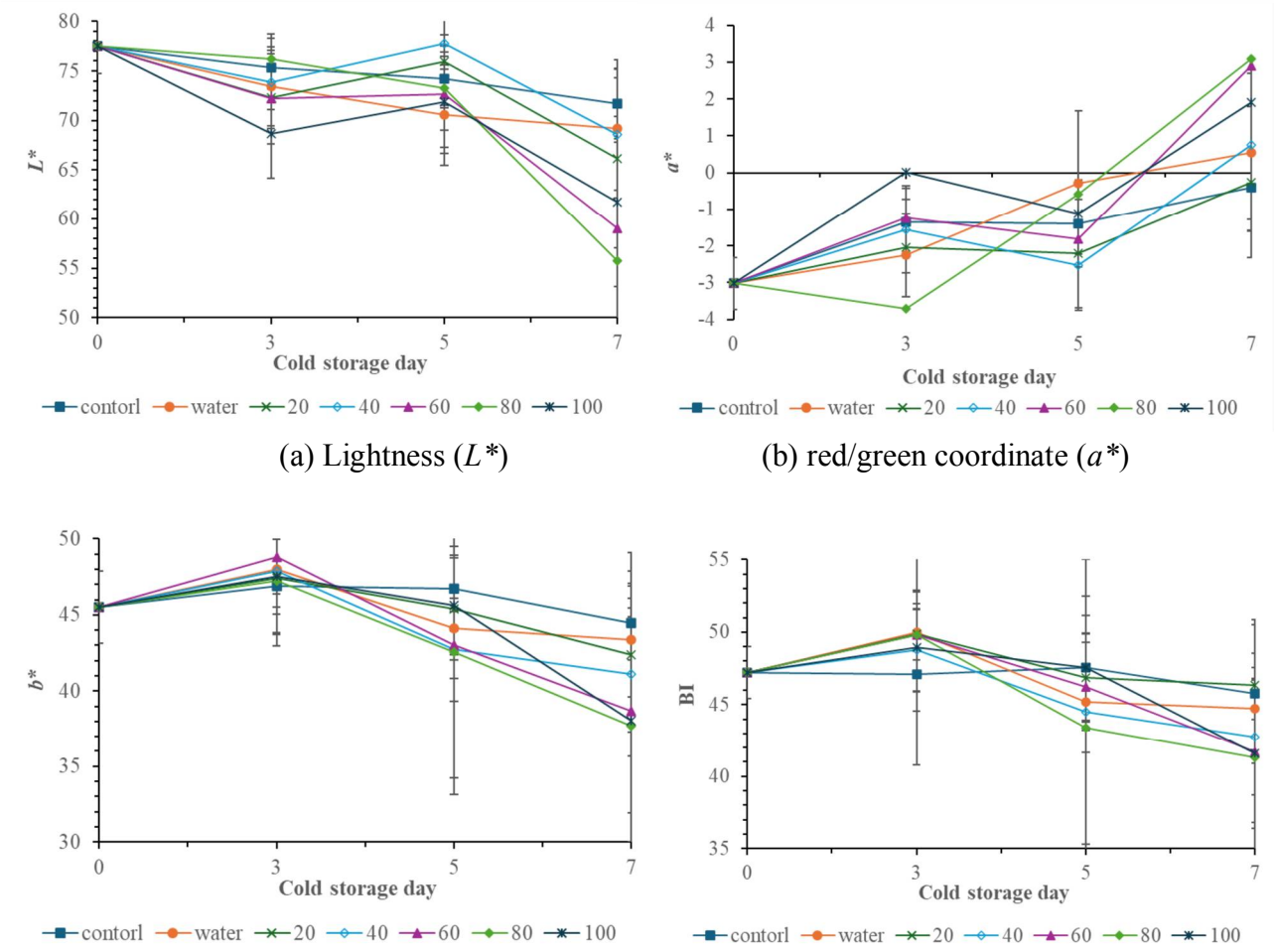


(a) Lightness (*L**) (b) red/green coordinate (*a**)

(c) yellow/blue coordinate (*b**) (d) Browning Index (BI)

Figure 2. Changes in *L**, *a**, *b** and browning of mango flesh next to the seed during storage at 5ºC, RH 70-80%
Note: *L** black = 0, white = 100; initial reading for day 0 = 72.60±2.91 (a)
*a** (red/green coordinate); - = green, + = red; reading at day 0 = -2.20±1.10 (b)
*b** (yellow/blue coordinate); - = blue, + = yellow; reading at day 0 = 47.23±3.79 (c)
Reading for BI on day 0 = 49.79±2.77 (d)

Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28



(a) Lightness (*L**) (b) red/green coordinate (*a**)

(c) yellow/blue coordinate (*b**) (d) Browning Index (BI)

Figure 3. Changes in *L**, *a**, *b** and browning of mango flesh below the peel during storage at 5ºC, RH 70-80%
Note: *L** black = 0, white = 100; initial reading for day 0 = 77.53±2.82 (a)
*a** (red/green coordinate); - = green, + = red; reading at day 0 = -3.03±0.70 (b)
*b** (yellow/blue coordinate); - = blue, + = yellow; reading at day 0 = 45.50±2.38 (c)
Reading for BI on day 0 = 47.20±1.78 (d)

The results indicate that cold storage at 5°C, 70-80% RH promotes browning in mango flesh, as evidenced by the decrease in *L** and increase in BI, attributed to complex enzymatic and non-enzymatic reactions. Water immersion treatment can mitigate browning to some extent, possibly by reducing oxygen availability, inactivating polyphenol oxidase, or leaching substrates needed for browning. Duration longer than 3 days generally leads to lower BI values, suggesting a dose-dependent effect. The coating of the mango slices with *A. vera* extract results in significant ($p \leqslant 0.05$) overall preference by the consumer (Table 3). Sensory evaluation involved twenty untrained subjects (7 males and 13 females, aged 19-22 years). A hedonic scale score evaluated sensory quality, with scores from 1 to 5 (1–dislike extremely; 2–dislike slightly; 3–neither like nor dislike; 4–like slightly; 5–like extremely). The participants were asked to evaluate the samples in accordance with their preferences related to colour, aroma, taste, texture and overall preference.

The level of *A. vera* gel in the coating has little or no influence on overall preference except the coating with 40% gel, which is preferred. These findings are also observed in the other sensory

Maejo Int. J. Sci. Technol. **2025**, *19*(01), 17-28

characteristic assessments, in which gel-coated fruit are given higher scores than those that are not coated, and those coated with 40% gel have consistently higher results (Table 3).

Table 3. Mean sensory preference after 7 days storage at 5°C

Concentration of *A. vera* gel extract	Mean sensory evaluation score				
	colour	aroma	taste	texture	overall preference
Not treated	1.50 ± 0.58^{c}	1.75 ± 0.96^{bc}	1.25 ± 0.50^{d}	1.75 ± 0.96^{cd}	1.50 ± 0.58^{d}
0%	1.50 ± 0.58^{c}	1.50 ± 0.58^{c}	1.25 ± 0.50^{d}	1.50 ± 0.58^{d}	1.50 ± 0.58^{d}
20%	2.50 ± 0.58^{b}	1.75 ± 0.96^{bc}	2.00 ± 0.00^{c}	2.25 ± 0.50^{bcd}	2.25 ± 0.50^{cd}
40%	3.50 ± 0.58^{a}	3.00 ± 0.00^{a}	3.50 ± 0.58^{a}	4.25 ± 0.96^{a}	3.75 ± 0.50^{a}
60%	2.50 ± 0.58^{b}	2.50 ± 0.58^{ab}	3.00 ± 0.00^{ab}	3.00 ± 0.82^{abc}	2.75 ± 0.50^{bc}
80%	3.00 ± 0.00^{ab}	3.00 ± 0.00^{a}	2.75 ± 0.50^{b}	3.00 ± 0.82^{abc}	2.75 ± 0.50^{bc}
100%	3.25 ± 0.50^{ab}	2.75 ± 0.50^{a}	3.25 ± 0.50^{ab}	3.25 ± 0.96^{ab}	3.25 ± 0.96^{ab}

Note: Different superscript letters in the same column indicate statistical difference ($p < 0.05$).

It was difficult to interpret why coating the mango with 40% gel should consistently give the highest scores among the coated fruit compared to the other concentrations. However, these results support the findings of Perez et al. [26] who found that minimally processed 'Tommy Atkins' mango coated with 50% *A. vera* gel had an increased shelf life compared to uncoated samples and of Suriati et al. [27] working on minimally processed ‘Arumanis’ mangoes. However, in the current work the mango chunks were kept for only 7 days as discussions with those involved in retailing fruit suggested that this is the maximum time they would require for distribution and marketing.

CONCLUSIONS

The application of *A. vera* gel as a coating on mango slices demonstrates its potential in extending the shelf life and preserving the quality of the fruit during cold storage at 5°C over a 7-day period. The gel effectively slows the softening, moderates changes in TSS and helps maintain higher levels of TA and vitamin C content, particularly at concentrations of 40-60%. This suggests that *A. vera* gel possesses antioxidative properties that contribute to the preservation of the nutritional quality of mangoes during storage.

In terms of sensory characteristics, mango chunks coated with *A. vera* gel, especially at 40% concentration, are consistently preferred by the sensory evaluation panel over uncoated or water-dipped mangoes, indicating that the coating enhances the overall sensory appeal of the fruit. Despite some inconsistencies in firmness and colour changes, particularly browning, the *A. vera* coating generally helps reduce browning compared to controls, although higher concentrations lead to darker flesh, which may be undesirable.

However, the study identifies several limitations, including its focus on a single mango variety ('Golden Nam Dok Mai'). The results may not be directly applicable to other varieties or different fruits, limiting the scope of the findings. Also, the study did not examine the effects of *A. vera* gel on microbial growth during storage. Given the importance of microbiological safety in fresh-cut fruit products, this represents a significant gap in the evaluation of *A. vera*'s preservative capabilities. Future research should address this gap to provide a more comprehensive understanding of the commercial feasibility and safety of using *A. vera* gel as a natural preservative

for fresh-cut fruit. Overall, the findings suggest that *A. vera* gel, particularly at an optimal concentration, is a viable option for extending the shelf life of minimally processed mango chunks while maintaining their nutritional and sensory qualities.

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