***Original Research Article***

**Development of Aloe Vera Gel and Ascorbic Acid Based Edible Coatings of Indian Jujube (*Ziziphus mauritiana*): Maintenance of Post-Harvest Quality**

Abstract

A significant amount of Indian Jujube is produced annually in Bangladesh. Although it is one of the most important seasonal fruits in the country, it is highly susceptible to post-harvest losses due to its short shelf life and lack of proper storage techniques. This study aimed to develop an edible coating and evaluate its effectiveness in preserving the post-harvest quality of the fruit during storage. Aloe Vera gel (AG) was diluted in a 1:3 ratio, and different concentrations of Ascorbic Acid (AA) (3% and 5%) were used to formulate three types of coatings: diluted AG+0% AA, diluted AG+3% AA, and diluted AG+5% AA. The treated fruits were assessed for pH, titratable acidity, total soluble solids, weight loss, ascorbic acid content, total antioxidant activity, and total phenolic content at intervals of 0, 3, 9, 12, and 15 days of storage. The results showed that coated fruits had delayed ripening and retained higher levels of quality parameters compared to untreated fruits. The combination of AG and AA as edible coatings demonstrated potential in reducing post-harvest losses by preserving the freshness and nutritional quality of Indian Jujube for an extended storage period. These findings suggest that Aloe Vera gel and Ascorbic Acid-based coatings can serve as an effective natural preservation method for freshly harvested fruits and vegetables, improving their shelf life and marketability.

**Keywords:** Indian Jujube, Aloe Vera Gel, Ascorbic Acid, Edible Coating, Physiochemical Properties

**1. Introduction**

*Ziziphus mauritiana*, commonly known as Indian jujube, is a highly nutritious fruit cultivated in various regions worldwide under different names, including Chinese date, Chinese apple, apple ber, Indian plum, and dunks (Sarkar et al., 2022). The fruit exhibits diverse shapes and sizes, ranging from oval to oblong and obovate, with lengths of 2.5–6.25 cm and an average weight of 9.6 g. It consists primarily of pulp (85.94%), mortar (15%), and juice (40%) by weight (Afroz *et al.*, 2014). When slightly underripe, the fruit is mildly succulent with a pleasant aroma, whereas the fully mature fruit develops a shiny red appearance, a juicy texture, and a sweet taste resembling apples.

Bangladesh is an agriculturally rich country where a vast quantity of fruits and vegetables is produced annually. In 2011–2012, the agricultural sector contributed 19.29% to the country's Gross Domestic Product (GDP) (Sikder & Islam, 2019). Indian jujube is a popular seasonal fruit in Bangladesh due to its high yield potential, nutritional value, and medicinal properties. It is a rich source of essential vitamins such as vitamin C, vitamin A, and B-complex vitamins, along with minerals including calcium (Ca), magnesium (Mg), potassium (K), bromine (Br), rubidium (Rb), and lanthanum (La) (Al-Reza *et al.*, 2010). The primary sugars present in the fruit include galactose, fructose, and glucose (Muchuweti *et al.*, 2005). Moreover, it contains several phenolic compounds, such as p-hydroxybenzoic acid, caffeine acid, ferulic acid, and p-coumaric acid, with vanillic acid being the least abundant at approximately 2.5 mg/kg. The Ziziphus species has been traditionally recognized in Asian countries, particularly in China and Taiwan, for its medicinal benefits in treating allergic reactions, gastrointestinal disorders, urinary dysfunction, respiratory problems, anxiety, depression, and liver diseases.

Despite its nutritional benefits and economic importance, post-harvest losses of fruits and vegetables in Bangladesh remain a major challenge. Indian jujube is highly perishable, with a storage life of less than ten days under ambient conditions. Post-harvest losses of fruits and vegetables in Bangladesh are estimated to range between 18% and 44%, amounting to an annual financial loss of approximately 3,392 crore Bangladeshi Taka (Hamim et al., 2014; Hossain et al., 2017). To mitigate these losses, the application of edible coatings has gained increasing attention as a promising post-harvest preservation strategy. Edible coatings have been utilized since the late 1940s for preserving fresh produce, including bananas, citrus fruits, pomegranates, apples, papayas, and cucumbers (Alam et al., 2020; Baldwin et al., 1999; Li & Barth, 1998). Among various bio-preservatives, Aloe Vera gel (AG) has emerged as a natural and effective coating material due to its antimicrobial properties and ability to retain moisture, thereby extending the shelf life of fruits and vegetables (Rodríguez *et al.*, 2010).

The demand for natural antioxidants is rising due to growing concerns over the long-term health risks associated with synthetic preservatives (Roy *et al.*, 2021; Sarkar, Ahmed, *et al.*, 2020; Sarkar, Rahman, *et al.*, 2020). Antioxidant-rich foods, including fruits, vegetables and legumes, contribute to maintaining cellular health by neutralizing free radicals and preventing oxidative stress. These compounds also stabilize essential nutrients, such as vitamins A, C, B-complex, folic acid, vitamin E, and thiamine, ensuring their bioavailability in the human body (Azam et al., 2023; Roy et al., 2022; Sarkar et al., 2024; Sarkar et al., 2025). Ascorbic acid (AA) is a potent antioxidant widely used in food preservation, particularly in meat products, to prevent oxidation and maintain nutritional quality. When incorporated into edible coatings, AA helps preserve vitamin C content and enhances the overall antioxidant capacity of coated fruits.

Despite the known benefits of edible coatings, limited research has been conducted on their application in maintaining the post-harvest quality of Indian jujube. This study aims to develop and evaluate the effectiveness of Aloe Vera gel and Ascorbic Acid-based edible coatings in preserving the physicochemical properties of fresh Indian jujube during storage. The research focuses on assessing the impact of these coatings on fruit ripening, weight loss, acidity, total soluble solids, ascorbic acid content, antioxidant activity, and phenolic content over a storage period.

**2. Materials and methods**

2.1 Sample preparation

Fresh Indian Jujube fruits were collected from a local market in Sylhet, a major division of Bangladesh. For the study, fruits of uniform size, shape, and color were selected. Only unripe, green-colored fruits were chosen, while any fruits with blemishes, diseases, or damage were discarded. The experiment included three treatment groups, with each group containing six fruits. Additionally, six untreated fruits were kept as a control group. In total, 24 uniform and unripe Indian Jujube fruits were used in the experiment (Sogvar *et al.*, 2016).

Before treatment, both the fruits and Aloe Vera leaves were washed under running tap water. The fruits were then left at room temperature for an hour to air dry. Aloe Vera gel was extracted from the leaves and collected in a container. The gel was blended using an electric mixer, and any remaining fibers were removed using filter paper. The extracted gel was then diluted in a 1:3 ratio with distilled water. The diluted Aloe Vera gel solution was divided into three batches. Two of these batches were mixed with 3% and 5% Ascorbic Acid (AA) to create edible coating solutions. The fruits were divided into four groups, with three groups dipped in the respective coating solutions for five minutes at room temperature. After coating, the fruits were air-dried and placed in baskets for storage.

**2.2 Physicochemical properties**

**2.2.1 Weight loss**

The weight loss of the samples was measured following the method described by Martínez-Romero *et al.* (2006). To determine the weight loss, the initial weight of each sample was recorded before storage. The weight was then measured again after 3, 6, 9, 12, and 15 days of storage. The difference between the initial and final weight was used to calculate the percentage of weight loss over time.

**2.2.2 Total soluble solid (TSS)**

The total soluble solids (TSS) of the samples were measured following the method of Hasan et al. (2022). Juice was extracted from the jujube fruits using a juice extractor machine, and the liquid was then filtered through filter paper to remove any solid particles. A hand refractometer was used to determine the TSS of the filtered juice, with the results expressed in degrees Brix.

**2.2.3 pH**

The pH of the samples was measured using a pH meter calibrated with a standard buffer solution at pH 7.0. The temperature was maintained at 28°C during the measurement. Before inserting the glass electrode into the sample solution, it was standardized with the buffer solution and thoroughly rinsed with distilled water to ensure accuracy (Hasan et al., 2025).

**2.2.4 Total acidity**

Titratable acidity was determined using the method described by Athmaselvi *et al.* (2013). First, 10 mL of extracted jujube juice was placed in a beaker and mixed with 25 mL of distilled water. The mixture was then titrated with 0.1 M sodium hydroxide (NaOH) solution using phenolphthalein as an indicator. The NaOH solution was added dropwise while continuously stirring until a persistent light pink color appeared, indicating the endpoint. The volume of NaOH used was recorded, and the total acidity was calculated based on the equivalent factor of the predominant acid in the fruit. The results were expressed as a percentage of citric acid.

**2.3 Antioxidant activities**

2.3.1 Ascorbic acid

Ascorbic acid content was determined by following the method mentioned in Vallespir *et al.* (2019). The equation used for the determination of vitamin C were followed:

mg of vitamin-C per 100 g sample$ =\frac{T×D×V1}{W×V2}×100$

where T represents the titre or volume of titrant used, D is the dye factor, V1 is the total volume of the prepared solution, V2 is the volume of the extract used for titration, and W is the weight of the sample in grams. The calibration curve was constructed using standard L-ascorbic acid, with the equation y = 9.94x + 0.2896 and an R² value of 0.9976.

2.3.2 Total phenolic content

Total phenolic content was determined by the method described by Sarkar *et al.* (2021) with slight modification. A 0.5 mL aliquot of the sample extract was mixed with 8.5 mL of distilled water and 0.5 mL of Folin-Ciocalteu reagent. The mixture was allowed to stand at room temperature for 5 minutes. Subsequently, 1 mL of a 35% sodium carbonate solution was added, and the solution was thoroughly mixed. The reaction mixture was then left undisturbed at ambient temperature for 20 minutes before measuring the absorbance at 765 nm using a spectrophotometer. A blank sample was prepared by replacing the extract with distilled water and was used to calibrate the instrument. The total phenolic content was quantified by comparing the absorbance values with a standard curve generated using different concentrations of Gallic acid. The results were expressed in milligrams of Gallic acid equivalent per gram of dry extract, using the equation y = 0.009x - 0.010 with an R² value of 0.999.

2.3.3 Total antioxidant activity

The antioxidant activity of the samples was assessed using the DPPH radical-scavenging method as described by Saikia *et al.* (2015). A 2 mL aliquot of 0.2 mg methanolic DPPH solution was added to 2 mL of the sample extract at different concentrations. The mixture was vigorously shaken for 15 seconds to ensure proper mixing. The solutions were then incubated in a dark environment for 10 minutes to allow the reaction to occur. After the incubation period, absorbance was measured at 517 nm using a UV-Visible spectrophotometer against a blank sample. The DPPH radical-scavenging activity of each sample extract was calculated using the following equation:

DPPH radical-scavenging activity = $\frac{A0-A}{A0}×100$

where A is the absorbance of the sample-containing DPPH solution, and A0 is the absorbance of the control solution without the sample extract.

2.4 Statistical analysis

All the parameters were examined in triplicate, and the findings were showed as Mean ± SD. Statistical analysis was executed applying one-way ANOVA analysis of variance, followed by Tukey’s multiple comparison test, using Graph Pad Prism 8 software to determine the significant difference among samples. The significant difference was evaluated at p < 0.05.

**3. Result and discussion**

**3.1 physicochemical properties**

Weight loss in the samples increased progressively over the storage period, with the highest loss occurring in the control samples and the lowest in the AG+5% AA-treated fruits. The application of coatings significantly reduced weight loss by acting as a protective barrier. On day 3, the maximum weight loss was recorded in the control samples (6.93%), while the AG+5% AA-coated fruits exhibited the lowest loss (3.47%). This trend continued throughout the storage period, with weight loss on day 15 reaching 27.35% in the control samples, compared to 14.69% in AG+5% AA-coated fruits (Table 1). The untreated samples lost moisture rapidly due to direct exposure to the surrounding environment, whereas the coated fruits retained moisture more effectively. Aloe Vera gel formed a water-resistant layer, minimizing dehydration by acting as a moisture barrier between the fruit and the atmosphere. This protective effect can be attributed to the hygroscopic nature of Aloe Vera gel, which reduces excessive water loss (Morillon & Lassalles, 2002)

Total soluble solids (TSS) were consistently higher in the control samples compared to the coated ones. On day 15, the highest TSS value was observed in the control samples (23.26° Brix), whereas the AG+5% AA-coated samples retained the lowest TSS levels (11.13° Brix). There was a minor difference in TSS between AG+3% AA (12.67° Brix) and AG+5% AA-coated samples (Table 1). The coated fruits exhibited lower TSS levels due to the reduced respiration rate, which slowed down sugar metabolism. During storage, TSS levels typically increase as a result of respiration, which converts complex carbohydrates into simple sugars. The application of AG and AA coatings effectively reduced respiration, thereby delaying sugar conversion and extending fruit freshness. A similar outcome was observed in Aloe Vera-coated nectarines, where respiration was significantly suppressed, preserving fruit quality for an extended period (Ahmed *et al.*, 2009).

**Table 1: Weight loss and TSS of samples.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Coating Condition** | **Day 0** | **Day 3** | **Day 6** | **Day 9** | **Day 12** | **Day 15** |
| Weight loss (%) | Control | 0 | 6.93±0.003a | 11.25±0.006a | 15.23±0.025a | 20.11±0.029a | 23.26±0.050a |
| AG | - | 6.61±0.023b | 9.41±0.230b | 13.30±0.176b | 16.28±0.126b | 18.80±0.138b |
| AG+3%AA | - | 4.84±0.006c | 8.82±0.050c | 10.55±0.0115c | 13.74±0.132c | 16.80±0.015c |
| AG+5%AA | - | 3.47±0.006d | 7.90±0.006d | 9.54±0.004d | 12.22±0.116d | 14.72±0.025d |
| TSS (o Brix) | Control | 9.02±0.190a | 10.03±0.152a | 11.4±0.010a | 13.60±0.100a | 14.46±0.015a | 15.16±0.057a |
| AG | - | 9.70±0.010b | 10.26±0.057b | 11.46±0.057b | 12.73±0.058b | 13.46±0.016b |
| AG+3%AA | - | 9.40±0.010c | 9.73±0.058c | 10.13±0.057c | 10.86±0.057c | 11.26±0.104c |
| AG+5%AA | - | 9.27±0.006c | 9.40±0.010d | 9.67±0.050d | 10.73±0.050c | 11.13±0.076c |

All the data is presented as a mean value with a standard deviation. Values in a column within each parameter with distinct letters are significantly different at p < 0.05.

The values of pH of treated and untreated samples are significantly different. A significantly higher pH value was found for the untreated samples (5.045) on day 15. In contrast, the lowest pH value was noticed in the samples layered with AG+5% AA coating (4.72) at day 15. The pH of samples coated with AG+3% AA and AG+0% AA coatings differed significantly (Table 2). The pH levels of both treated and untreated samples showed significant differences throughout storage. By day 15, the control samples exhibited the highest pH value (5.045), while the AG+5% AA-coated fruits maintained the lowest pH (4.72). The pH values of AG+3% AA (4.89) and AG+0% AA (4.94) were also significantly lower than the control (Table 2). The lower increase in pH in coated fruits suggests that the edible coatings helped maintain acidity for a longer period. The rise in pH during storage is commonly linked to acid degradation through respiration. Additionally, ascorbic acid, being naturally acidic, contributed to maintaining a lower pH in coated samples. The protective effect of edible coatings delayed acid oxidation, slowing down ripening and extending the fruit’s shelf life. Similar results were reported for Aloe-pectin treated jujube, where coatings played a role in reducing pH fluctuations over time (Padmaja & Bosco, 2014). The semipermeable nature of the coating may have influenced internal gas composition, particularly CO2 and O2 levels, thereby regulating respiration and delaying senescence (Athmaselvi et al., 2013; Morillon et al., 2002).

**Table 2: pH and TA of samples.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Coating Condition** | **Day 0** | **Day 3** | **Day 6** | **Day 9** | **Day 12** | **Day 15** |
| pH | Control | 4.31±0.025a | 4.62±0.025a | 4.71±0.0152a | 4.75±0.0057a | 4.88±0.0404a | 5.045±0.005a |
| AG | - | 4.53±0.010b | 4.63±0.0153b | 4.66±0.0153b | 4.74±0.01b | 4.89±0.015b |
| AG+3%AA | - | 4.45±0.020c | 4.59±0.0153c | 4.65±0.0152bc | 4.71±0.0057bc | 4.84±0.012c |
| AG+5%AA | - | 4.42±0.026c | 4.56±0.015c | 4.62±0.0153c | 4.65±0.0057c | 4.72±0.015d |
| TA (%) | Control | 0.65±0.005a | 0.61±0.0105a | 0.58±0.002a | 0.57±0.003a | 0.54±0.002a | 0.52±0.001a |
| AG | - | 0.63±0.007b | 0.59±0.002b | 0.58±0.004b | 0.56±0.004b | 0.53±0.002ab |
| AG+3%AA | - | 0.65±0.003bc | 0.62±0.003c | 0.61±0.001c | 0.58±0.005c | 0.55±0.001ab |
| AG+5%AA | - | 0.64±0.004c | 0.63±0.020d | 0.62±0.004d | 0.59±0.0052d | 0.58±0.011b |

All the data is presented as a mean value with a standard deviation. Values in a column within each parameter with a distinct letter are significantly different at p < 0.05.

Titratable acidity (TA) gradually increased with the application of coatings, with AG+5% AA-coated samples exhibiting significantly higher acidity (0.58%) compared to the control samples (0.52%) by day 15 (Table 2). Similar findings were observed in AG-coated table grapes, where coatings helped retain acidity over extended storage (Serrano *et al.*, 2006). The higher acidity in coated samples may be due to the gel layer acting as an oxygen barrier, reducing the oxidation of organic acids. The protective nature of the coating helped maintain acidity levels, preserving the fruit’s freshness and delaying metabolic changes that contribute to ripening (Guillén *et al.*, 2013). Overall, the application of Aloe Vera gel and Ascorbic Acid coatings significantly influenced weight loss, TSS, pH, and titratable acidity, demonstrating their effectiveness in extending the post-harvest shelf life of Indian Jujube. The coatings not only minimized weight loss but also helped maintain fruit acidity, slow down sugar metabolism, and delay ripening, thereby improving the overall quality during storage.

**3.2 Antioxidant activities**

The total phenolic content decreases as the storage time gets longer. The maximum TPC was found in AG+5% AA samples (224.3 mg/100g samples), and the lowest was for control (212.33 mg/100g samples) at day 3. A similar trend was observed for all the samples from day 3 to day 1. After 15 days, the TPC of the untreated samples was lower than that of the treated samples. The untreated samples lost the highest number of phenolic contents (Fig. 1). Edible coatings helped in the preservation of phenolic contents by affecting the metabolism of treated fruits.

**Fig. 1:** Total phenolic content of samples. Values in a column within each period with a distinct letter are significantly different at p < 0.05.

Total antioxidant activity in Indian Jujube showed a drastic change in the untreated samples. However, there was a gradual increase in the treated samples. The highest amount of the antioxidant was found to be 88.32% in AG+5% AA samples, and the lowest amount was found to be 86.29% in control fruits on day 3. With the rise in storage time, a similar pattern observed in all the samples (Fig. 2). Our results were congruous with the results found in AG+AA coated strawberry fruits in storage temperature and humidity (Sogvar *et al.*, 2016).

**Fig. 2:** Total antioxidant activity of samples. Values in a column within each period with a distinct letter are significantly different at p < 0.05.

The ascorbic acid content of treated and untreated samples was significantly different. The ascorbic acid value of the untreated ones diminished drastically while the ascorbic acid content of treated samples was reserved better. The control samples had the lowest level of Ascorbic Acid in all storage times, and the samples treated with AG+5% AA coating had the most enormous amount. On day 15, it was 5.29 mg/100g for AG+5% AA coated sample and 2.81 mg/100g for the control sample (Fig. 3).

**Fig. 3:** Ascorbic acid value of samples. Values in a column within each period with a distinct letter are significantly different at p < 0.05.

Ascorbic acid decreased rapidly in the uncoated fruits, whereas AA content in the coated ones decreased at a much slower rate. The Ascorbic acid used in the coatings could have incorporated in the coated fruits, and as a result, AA content decreased less. This may be attributed to the coating's low oxygen permeability, which protects the product from oxygen exposure and slows the AA's deteriorative oxidation process (Ayranci & Tunc, 2003).

**5. Conclusion**

The experiment done on Indian Jujube (*Ziziphus mauritiana)* by applying lab-made edible coatings, figured significant differences in post-harvest properties and storage period of the treated and non-treated samples. The experiment results suggest that edible coatings made of AG and AA are recommended to maintain post-harvest qualities, visual properties, and extended storage periods of fruits. The samples coated with edible coatings maintained the physio-chemical properties better than the untreated ones. The untreated samples lost their post-harvest qualities rapidly and showed signs of deterioration much sooner than the treated ones. According to the experiment, edible coatings made from AG and AA were used as a preservative; it extended the harvested fruits shelf life, reduced water, and moisture loss, delays the ripening process, and prevent microbial growth, specifically in fresh fruits and vegetables.

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