



Natural Preservative Potential of Chitosan-Aratiles (*Muntingia calabura*) Leaf Extract on Postharvest Quality of Eggplant

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ABSTRACT

Eggplant is a highly perishable crop prone to rapid deterioration under tropical conditions, leading to substantial postharvest losses in the Philippines. This study evaluated a chitosan-based edible coating enriched with *Muntingia calabura* (aratiles) leaf extract (ALE) as a natural preservative to prolong eggplant shelf life. Fruits coated with chitosan containing different ALE concentrations were stored at ambient temperature for six days, and changes in weight loss, firmness, total soluble solids, pH, and titratable acidity were monitored. The 1% ALE formulation showed the best performance, minimizing weight loss and maintaining firmness without adversely affecting other quality attributes. Results highlight the potential of chitosan-ALE coatings as an eco-friendly strategy to delay postharvest degradation. This approach offers a promising, sustainable solution for improving storage stability, reducing food waste, and supporting postharvest management in perishable crops.

Keywords: *Muntingia calabura*, Natural preservative, Eggplant, Postharvest, Chitosan, Aratiles.

INTRODUCTION

Eggplant (*Solanum melongena L.*) is a staple crop of global importance, but its commercial lifespan is severely limited by its extreme perishability.¹ In tropical environments like the Philippines, the postharvest quality of eggplant rapidly declines leading to significant economic losses and contributing heavily to food waste.² This accelerated senescence is primarily driven by high respiration rates related to enzymatic activities and excessive moisture loss.³ Consequently, there is an urgent and sustained global need for cost-effective

and sustainable preservation technologies to mitigate these losses.⁴

Traditional postharvest treatments, such as chemical fungicides^{5,6} or controlled-environment storage^{7,8,9}, are often inaccessible to small-scale farmers. Health concerns regarding chemical residues are also being raised by consumers. This has driven research toward natural, biodegradable edible coatings as a superior alternative. Chitosan, a non-toxic biopolymer, is a well-established matrix in food preservation¹⁰ due to its exceptional film-forming¹¹, gas-barrier¹², and intrinsic antimicrobial



properties¹³. However, the standalone efficacy of chitosan can be enhanced by incorporating natural plant bioactives to elevate its antioxidant¹⁴ and antimicrobial¹⁵ defense systems.

This study pioneers a novel composite coating utilizing *Muntingia calabura* (aratiles) leaf extract (ALE). *Muntingia calabura* is a locally abundant resource whose leaves are rich in beneficial phytochemicals, including flavonoids and phenolic acids, recognized for their potent biological activities.¹⁶ This research aimed to investigate the potential of chitosan-based coatings infused with varying concentrations of ALE as a natural preservative. The primary objective was to determine the optimal ALE concentration required to effectively extend the postharvest shelf life of eggplant under simulated ambient storage conditions. Key parameters considered were the control of weight loss and the management of key quality parameters, including firmness, total soluble solids, pH, and titratable acidity. The findings will contribute foundational data for the development of sustainable postharvest management strategies.

MATERIALS AND METHODS

Chemicals and Equipment

Chemical reagents such as chitosan, acetic acid (CH₃COOH), glycerol, sodium hydroxide (NaOH), and phenolphthalein were used without further purification. Solutions were prepared in distilled water. Fourier transform infrared spectrometer (FTIR), IRSpirit, using the attenuated total reflectance (ATR) accessory (Shimadzu, Japan), was used for the IR spectral characterization. A digital fruit penetrometer (GY-3) was used to evaluate the firmness of eggplants subjected to different treatments. A digital refractometer was used to assess the total soluble solids (TSS) content of eggplant and the reading was recorded in degrees Brix (°Brix).

Preparation of Aratiles Leaf Extract (ALE)

Aratiles leaf extract (ALE) was prepared following an extraction technique with slight modifications.¹⁷ In brief, air-dried and powdered leaves were extracted in 95% ethanol by maceration for 72 h at room temperature. Extracts were filtered and concentrated in vacuo at 40°C to obtain the crude extract. Collected crude extract was stored at 4°C in sterile vials for characterization and further use.

Preparation and Application of Chitosan-ALE Coating

The preparation of chitosan coatings was conducted following the published methods with slight modifications.^{18,19} Initially, 15 g chitosan was dissolved in 0.1 M acetic acid aqueous solution with constant stirring. Then 10 mL of glycerol was added, followed by the integration of varying amounts of ALE (1%, 2%, 3%) for each treatment. A control group consisting of chitosan coating prepared without ALE was also used for comparative analysis. Lastly, all solutions were centrifuged at 5,000 rpm for five min and stored at room temperature. Shortly after the preparation, chitosan-ALE coating was applied to plant samples. Long violet eggplants were harvested at the horticultural maturity stage from Dalangin farm. Samples were washed and immersed separately in different treatments with three varying ALE concentrations for three minutes, with replicates. Chitosan-ALE-coated samples and control group were dried at room temperature and stored for six days prior to postharvest quality assessment.

Evaluation of the Preservation Effect of Chitosan-ALE Coating

Postharvest quality parameters, including weight loss, firmness, total soluble solids (TSS), pH, and titratable acidity (TA), were evaluated to assess the preservation potential of ALE. Each parameter used chitosan-ALE-coated samples and experiments were conducted as follows, with replication.

Weight Loss

Weight loss of samples during 6 days of storage in each treatment was determined by monitoring the initial (W_i) and final (W_f) weights after the storage period, following the formula,

$$\text{Weight loss (\%)} = [(W_i - W_f) / W_i] * 100$$

Firmness

The firmness of eggplant samples was evaluated using a digital fruit penetrometer (GY-3). The penetration force was measured by gently inserting the probe into three equatorial regions of each sample. The resulting readings from the samples were averaged to provide an accurate representation of the firmness of the samples expressed in kilogram per square centimeter (kg/cm²).

Total Soluble Solid

Total soluble solids content of each sample was measured following a published method.²⁰ In brief, samples were juiced, and the supernatant was used for the TSS measurement was recorded in Brix at 20°C using a digital refractometer.

pH and Titratable Acidity

The pH level and total acidity of stored eggplants were measured following a method with slight modifications.²¹ A portable pH meter was used to check the acidity of the eggplant juice. The juice was titrated with 0.1N NaOH and 1% phenolphthalein as an indicator to determine the titratable acidity.

RESULTS AND DISCUSSIONS

Preparation of Aratiles Leaf Extract

Crude extracts of aratiles leaves were

successfully prepared and characterized using Fourier Transform Infrared (FTIR) to identify the functional groups present. FTIR spectral scan in Fig. 1 shows a broad band around 3307–3412 cm^{-1} corresponding to the stretching vibration of hydroxyl (-OH) and amine (-NH) groups, which may indicate the presence of alcohols, and phenolics. These groups are typically abundant in polyphenolic compounds and contribute to free-radical scavenging, which can delay oxidation in preserved food samples²². Absorption peak near 2927 cm^{-1} was attributed to C–H stretching of aliphatic chains, suggesting the presence of organic constituents such as terpenoids or fatty acid derivatives that may enhance the extract's protective barrier properties²³. The C=O stretching band at 1704 cm^{-1} further confirmed the presence of carbonyl compounds, typically present in flavonoids and tannins. Amide-related band at 1618 cm^{-1} and the C–N vibration at 1045 cm^{-1} are indicative of functional groups related to the structure of alkaloids.

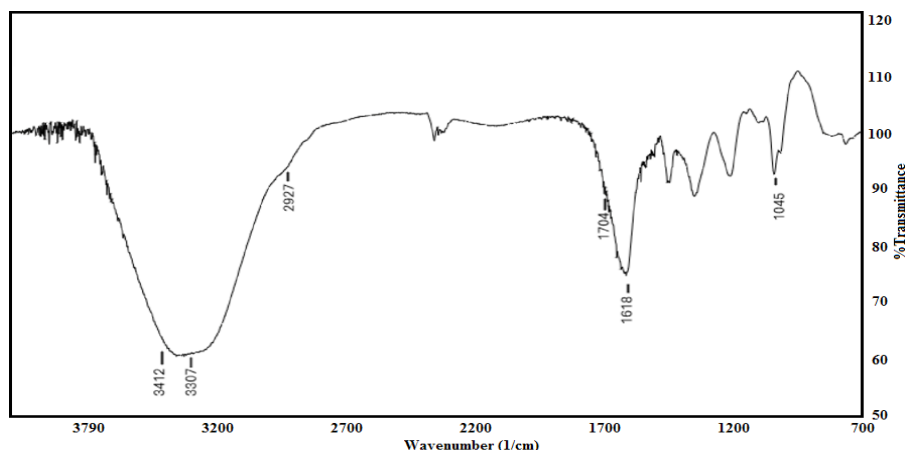


Fig. 1. FTIR spectrum of aratiles leaf extract showing prominent characteristic peaks confirmed by Phenols or Alcohols, Alkanes, Amines, Carbonyl functional group vibrations

Qualitative analysis of bioactive compounds in the ethanolic extract of ALE showed phytochemicals including polyphenols, terpenoids, alkaloids, flavonoids, saponins, tannins, and steroids²⁴. In recent studies, secondary metabolites have been recognized for their potential applications as natural preservatives in the food industry and have received significant attention in studies aimed at enhancing the shelf life of perishable products²⁵. These findings highlight the extract's potential as a natural, plant-based preservative, aligning with current efforts to develop sustainable postharvest preservation strategies while minimizing reliance on synthetic chemicals.

Evaluation of the Preservation Effect of Chitosan-ALE Coating

Postharvest quality attributes such as weight loss, firmness, total soluble solids (TSS), pH, and titratable acidity (TA) were monitored to evaluate the effectiveness of the ALE extract in preserving the physicochemical quality of eggplant during storage.

Weight Loss

Weight loss is a crucial factor in determining the efficiency of fruit preservation methods. Fruits gradually lose water content as they ripen and transpire, resulting in wilting and consequent weight loss²⁶. This phenomenon is mostly caused by water

loss during metabolic activities, including respiration and transpiration, as fruits mature²⁷. As a result, limiting weight loss in fresh produce during storage and marketing is essential²⁸. Table 1 presents the percentage of weight loss observed in various treatments. A noticeable reduction in weight loss was recorded in the treatments when compared to the uncoated control after a 6-day storage period at room temperature.

Table 1: Effect of different concentrations of chitosan-ALE coating on weight loss of eggplants

Treatment	Weight Loss, %
Control	37.105 ± 6.90 ^a
T1 (chitosan + 0% ALE)	28.315 ± 6.02 ^{abcd}
T2 (chitosan + 1% ALE)	24.275 ± 1.27 ^{cd}
T3 (chitosan + 2% ALE)	25.315 ± 3.94 ^{bcd}
T4 (chitosan + 3% ALE)	35.415 ± 2.45 ^{ab}

The values represent the mean ± STD of different treatments with 3 replications. Mean values from highest to lowest that share same superscript letter are not significantly different from one another, whereas means with different superscript letters are significantly different (p-value<0.05). Note: T=treatment, ALE=arattles leaf extract

Overall, the weight loss rate was higher in uncoated fruit than in those with protective coatings. Moreover, the data reflect a substantial disparity in weight loss between treatment 1 and treatment 4 groups, with the latter showing a greater weight reduction than treatments 1, 2, and 3. This observation is similar to the findings by Nur *et al.*,²⁹ that higher concentrations of plant extract can lead to phytotoxicity which can harm the fruit's cell tissue and render it susceptible to phytopathogenic organisms. Additionally, research by Bu *et al.*,³⁰ indicated that both excessively low and high concentrations of plant extract could accelerate weight loss and diminish fruit preservation efficacy under a storage temperature of 20°C. In this study, the application of chitosan with ALE at lower concentrations marginally reduced weight loss despite the absence of statistically significant differences among the treatments.

Firmness

Firmness is an essential characteristic for measuring fruit maturity and has a considerable impact on customer acceptance of fresh produce³¹. One of the major causes of fruit perishability is textural softening, a physiological alteration

caused by variables such as ethylene production, respiration rate, and the activity of cell wall-degrading enzymes. This softening process is directly related to a decrease in cell wall hardness, which promotes pathogen penetration and subsequent spoilage. Elevated softening rates can result in significant quality deterioration, leading to consumer rejection and incurring big economic losses. As a result, preserving fruit firmness is crucial for commercial viability, as it affects both fruit salability and shelf life³².

Table 2: Effect of different concentrations of chitosan-ALE coating on firmness of eggplants

Treatment	Firmness, kg/cm ²
Control	7.515 ± 0.3 ^{4b}
T1 (chitosan + 0% ALE)	8.483 ± 1.66 ^{ab}
T2 (chitosan + 1% ALE)	10.665 ± 1.52 ^a
T3 (chitosan + 2% ALE)	8.868 ± 0.56 ^{ab}
T4 (chitosan + 3% ALE)	9.583 ± 1.46 ^{ab}

The values represent the mean ± STD of different treatments with 3 replications. Mean values from highest to lowest that share the same superscript letter are not significantly different from one another, whereas means with different superscript letters are significantly different (p-value<0.05). Note: T=treatment, ALE=arattles leaf extract

Table 2 highlights the firmness of eggplants after 6 days of storage at room temperature, indicating no significant differences among the treatments. The control group exhibited the lowest firmness value, indicating a subsequent softening characteristic of deteriorating fruit quality. Notably, eggplants subjected to treatment 4 demonstrated an elevated transpiration rate, which appeared to effectively aid in preserving fruit firmness. These findings align with the research conducted by Nur *et al.*,³³ which highlighted a similar contradiction between weight loss and firmness retention in tomatoes. Their study found that higher firmness values in treated tomatoes may be attributed to decreased hydrolytic enzyme activity within the cell wall, which sustains intercellular adhesion and ultimately enhances firmness.

Total Soluble Solids

Total soluble solids in eggplant fruit consist mainly of organic acids, chiefly malic and citric acids, as well as sugars and amino acids, all of which play a key role in determining flavor quality. TSS is widely recognized as a crucial quality attribute, as it

significantly influences consumer acceptability and reflects the fruit's maturity and ripening status. It is commonly used as an indicator of ripeness, providing an estimate of the concentration of soluble sugars in fresh produce³⁵. During storage, moisture loss and the enzymatic breakdown of structural carbohydrates, such as hemicellulose, pectin, proteins, and starch, lead to the formation of simpler soluble sugars. As a result, TSS generally increases over time as part of the ripening and senescence processes³⁶.

Table 3: Effect of different concentrations of chitosan-ALE coating on the TSS of eggplants

Treatment	TSS (°Brix)
Control	5.67 ± 1.53
T1 (chitosan + 0% ALE)	5.67 ± 0.58
T2 (chitosan + 1% ALE)	6.63 ± 0.58
T3 (chitosan + 2% ALE)	6 ± 0.0
T4 (chitosan + 3% ALE)	6 ± 0.50

The values represent the mean ± STD of different treatments with 3 replications. All of the treatment are not significantly different from each other (p-value<0.05). Note: T=treatment, ALE=arattles leaf extract

Table 3 shows that although no statistically significant differences were detected among treatments, notable trends in TSS were observed. The control and Treatment 1 exhibited similar TSS values, whereas Treatments 2, 3, and 4 recorded higher levels. The slight elevation in TSS among these treatments may be linked to the application of arattles leaf extract, which appears to contribute to enhanced soluble solid accumulation in the fruit. A comparable response was reported by Nxumalo and Fawole 22, who found that chitosan enriched with *B. pilosa* extract increased TSS in passion fruit, whereas the uncoated control exhibited a decline during storage. Their findings suggest that incorporating bioactive plant extracts into edible coatings may modulate metabolic activity, slowing starch degradation and thus altering the rate at which sugars accumulate.

The TSS values obtained in this study also fall within the ranges previously documented for various eggplant cultivars, which span from 2.8 to 6.5°Brix³⁶. These comparisons indicate that the fruits remained within the normal maturity window

and had not progressed to over-ripeness, regardless of coating treatment.

pH and Titratable Acidity (TA)

pH and titratable acidity (TA) are essential indicators for characterizing the physiological responses of eggplant during postharvest storage. As ripening advances, organic acids are increasingly consumed through respiratory metabolism, leading to a decline in TA and a gradual rise in pH-changes that collectively reflect shifts in fruit maturity and quality. In eggplant, pH is particularly relevant due to its influence on polyphenol oxidase activity, the enzyme responsible for oxidizing phenolic compounds and initiating pulp browning³⁷. The steady decrease in TA during storage is widely attributed to the utilization of organic acids as respiratory substrates. This further underscores metabolic adjustments and their role in driving the ripening process. Monitoring pH and TA, therefore, provides valuable insights into the biochemical status of fruit and the effectiveness of postharvest preservation strategies.

Table 4. Effect of different concentrations of chitosan-ALE coating on the pH of eggplants

Treatment	pH
Control	4.51 ± 0.07
T1 (chitosan + 0% ALE)	4.54 ± 0.02
T2 (chitosan + 1% ALE)	4.42 ± 0.14
T3 (chitosan + 2% ALE)	4.44 ± 0.03
T4 (chitosan + 3% ALE)	4.38 ± 0.06

The values represent the mean ± STD of different treatments with 3 replications. All of the treatment are not significantly different from each other (p-value<0.05). Note: T=treatment, ALE=arattles leaf extract

The pH values of the samples after six days of storage showed no statistically significant differences. The consistently lower pH observed in ALE-coated fruits compared with the control and Treatment 1 suggests a slower decline in organic acids. This trend is consistent with the findings of Gonzales and Benitez²¹, who associated pH increases during storage with acid consumption through respiration. The relatively suppressed rise in pH in ALE-treated eggplant indicates that the coating may moderate metabolic activity during senescence. This behavior is particularly relevant given that polyphenol oxidase activity has been reported to

increase above pH 5.0 and to decline sharply below pH 4.0 due to enzyme denaturation³⁸. Moreover, eggplant polyphenol oxidase exhibits optimal activity near neutral pH (6.4–7.0), with reduced efficiency under acidic conditions³⁹. Thus, the moderately acidic pH range recorded in this study implies a natural biochemical environment less conducive to browning, with ALE application offering an additional stabilizing effect on pH during storage.

Table 5: Effect of different concentrations of chitosan-ALE coating on the TA of eggplants

Treatment	TA (% citric acid)
Control	0.16 ± 0.01
T1 (chitosan + 0% ALE)	0.15 ± 0.03
T2 (chitosan + 1% ALE)	0.14 ± 0.02
T3 (chitosan + 2% ALE)	0.16 ± 0.11
T4 (chitosan + 3% ALE)	0.20 ± 0.06

The values represent the mean ± STD of different treatments with 3 replications. All of the treatment are not significantly different from each other (p-value < 0.05). Note: T=treatment, ALE=arattles leaf extract

Titrateable acidity values after six days of storage remained statistically comparable across treatments, with measurements ranging from 0.14 to 0.20. The slightly higher TA observed in Treatment 4 suggests that the chitosan with 3% ALE coating helped retain organic acids more efficiently than the control. This trend aligns with reports by Petriccione *et al.*,³⁹ who noted greater acid loss in uncoated fruit due to the metabolic consumption of organic acids during respiration. Additionally, Gonzales and Benitez²¹ discovered that uncoated eggplants had the highest titrateable acidity when compared to coated eggplants. These findings imply that coatings serve as a protective barrier, reducing acid loss in eggplants throughout the storage period. The TA values in the present study also fall within the ranges previously reported for various eggplant cultivars, indicating that acidity remained within a normal physiological window throughout the storage period. Given that eggplant naturally contains appreciable levels of citric acid and that TA generally declines as ripening advances, the maintained acidity suggests that the coatings, particularly the 3% ALE formulation, may have contributed to moderating ripening-related acid degradation.

CONCLUSION

This study demonstrated that incorporating arattles leaf extract into chitosan-based coating offers an effective and environmentally sustainable approach for maintaining the postharvest quality of eggplants. FTIR analysis confirmed the functional compatibility of the two components, supporting their use in stable coating formulations. Coatings containing 1–2% ALE significantly reduced weight loss and helped preserve firmness during six days of ambient storage. Although no significant effects were observed on TSS, pH, or TA, the treatment did not adversely affect these quality attributes. These findings highlight the potential of chitosan–ALE coatings as a practical, low-cost preservation technology that can be easily adopted by small-scale farmers to reduce postharvest losses and enhance the marketability of eggplant under typical storage conditions.

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Conflict of Interest

The authors declare that there is no conflict of interest in this work with regard to publication.

Author Contributions

Dalangin, CA: Conceptualization, Methodology, Data Collection, Analysis and Writing
Duldulao, DJ: Conceptualization, Writing, Review & Editing, Supervision

Data Availability Statement

This statement does not apply to this article.

Ethical Approval Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

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