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RIPENING INHIBITION OF SEA URCHIN (*Diadema setosum*)-DERIVED CHITOSAN COATING IN CLIMACTERIC BANANA VARIETIES

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ABSTRACT

Bananas (*Musa acuminata*) are a nutritious and economic crop globally; but, in tropical countries such as the Philippines, they are sensitive to premature postharvest ripening, resulting in significant losses. Synthetic chemicals are frequently used in preservation processes, which have negative environmental, health, and economic consequences. Chitosan, a biodegradable polysaccharide with antibacterial and antioxidant properties, has been found as a suitable natural replacement. This study investigated the efficacy of sea urchin (*Diadema setosum*) shell-derived chitosan as a postharvest covering for saba, lakatan, and latundan bananas. Chitosan was made by decolorization, deproteinization, demineralization, and deacetylation before being added to the experimental samples, leaving the control samples untreated. All samples were stored in a bamboo chamber, and peel color, pH, weight loss, and lowering sugar content were monitored and recorded for seven days. Results showed that treated bananas ripened more slowly, exhibited lower pH values and reduced weight loss compared to controls, indicating delayed senescence. The sugar content was higher in most control samples. Statistical analysis supported these findings, highlighting the potential of sea urchin-derived chitosan as an eco-friendly, cost-effective solution for extending banana shelf life.

Keywords: Banana, Chitosan, *Diadema setosum*, Ripening inhibition

1 INTRODUCTION

Bananas are among the world's most important fruit crops, serving as both a dietary staple and a major source of livelihood. Botanically classified as berries, bananas are primarily grown in tropical regions but valued worldwide for their flavor, nutritional benefits, and year-round availability. Bananas are among the most significant fruit crops on earth, being the fourth most significant staple food behind rice, wheat, and maize (Food and Agriculture Organization [**FAO], 2022**). More than 400 million individuals rely on bananas as a source of 15–27% of their total daily calorie supply (**The Guardian. 2025**).

There are more than 1,000 banana varieties grown worldwide, with the Cavendish variety controlling global trade with a share of almost 50%. Bananas are a key player in the economy of the world. On average, 20 million tonnes of bananas are exported every year, which is a major source of foreign exchange for most developing nations. On an income basis, smallholder producers in poor countries can generate up to 75% of household income from banana production (**FAO, 2022**).

In countries like the Philippines, bananas are not only consumed domestically but also represent a key export commodity, making them a cornerstone of the agricultural economy (**Magalang et al., 2021**).The Philippines is one of the world's top three banana exporters, having shipped 2.35 million tonnes in 2023, equivalent to 12.2% of world banana exports (**Context PH. 2024**). Most of the production takes place in Mindanao, where there is high-quality soil and a suitable climate (**StatLedger. 2024**). Bananas not only constitute an export crop but also a staple food in the diet of many Filipino families and a major source of income for smallholder farmers, who may earn most of their living from banana cultivation (**FAO, 2022**). Bananas are further processed into chips, purée, and other foods for local consumption and export (**StatLedger. 2024**). The Philippines is challenged by climate-related conditions, such as unpredictable rainfalls and intense heat, affecting the size, yield, and revenue of bananas. Female farmers in Palawan notice the effects of such changes (**Rappler. 2023**).

Despite their economic and nutritional value, bananas are highly perishable due to their climacteric nature, which causes rapid ripening after harvest. This ripening process leads to quick changes in texture, color, and flavor, resulting in a shortened shelf life, significant quality losses, and economic setbacks for farmers, retailers, and consumers (**Wang *et al.,* 2024**). Post-harvest losses in the Philippines have been estimated at 35% of total production, caused by improper handling, premature ripening, mechanical damage, and rotting (**Aruwajoye *et al.,* 2025**). This underscores the urgent need to explore effective methods of prolonging banana shelf life to reduce waste and sustain profitability.

Banana quality, shelf life, and nutrient retention are all impacted by postharvest handling, which minimizes losses and includes harvest stage, temperature control, ethylene presence, packaging, and treatment. Bananas are harvested in the green stage for transportation, and the rate of ripening, as well as the occurrence of chilling injury or accelerated senescence, are controlled by temperature and ethylene management. The best method will depend on factors like cultivar, supply chain length, and market destination, but recent reviews have offered new integrated approaches (temperature control, modified atmospheres, natural coatings, chemical treatments, and new composites) with the aim of reducing postharvest losses while maintaining physical, chemical, and nutritional quality (**Al-Dairi *et al.,* 2023; Munir *et al.,* 2024**).Shelf life and final quality are determined by postharvest factors, which include harvest maturity, temperature, relative humidity, ethylene exposure, mechanical damage, and packaging. Temperature control, controlled or modified atmospheres, ethylene management, natural edible coatings, and innovative nano/composite coatings are some strategies to maintain quality throughout the supply chain; the effectiveness of these strategies varies depending on the cultivar and length of the supply chain. Reviews place more emphasis on customized methods (specific to a particular cultivar and market) than on one-size-fits-all procedures (**Al-Dairi, 2023; Shinga *et al.,* 2025**).

Many techniques have been used to postpone ripening in order to reduce post-harvest losses. These consist of chemical treatments, packaging in a modified atmosphere, and refrigeration. Ethylene inhibitors, including salicylic acid (SA), aminoethoxyvinylglycine (AVG), and 1-methylcyclopropene (1-MCP), are commonl y employed chemical methods to inhibit ethylene perception or biosynthesis, thereby delaying the ripening process (**Al-Dairi *et al.,* 2022**). The capacity of ethylene scavengers like ozone (O_3), titanium dioxide (TiO_2), and potassium permanganate ($KMnO_4$) to lower ethylene concentrations in storage settings has also been investigated. These technologies have high costs, limited accessibility for smallholder farmers, potential health risks from chemical residues, and environmental concerns related to chemical use, despite the fact that they can increase shelf life (**Al-Dairi *et al.,* 2022**).These disadvantages have caused research to move more and more in the direction of natural, environmentally friendly substitutes. Antioxidant, antimicrobial, and ethylene-suppressive qualities have been shown by natural inhibitors and coatings made from plants, fungi, and marine resources. By strengthening antioxidant defenses and inhibiting ethylene biosynthesis, antioxidants like resveratrol, for instance, have been demonstrated to postpone fruit senescence. This demonstrates how bioactive substances may be used as all-natural means of preserving fruit quality while it is being stored (**Yang *et al*., 2022**).

Climacteric fruits, such as bananas, are extremely perishable due to their rapid ripening phase, resulting in large postharvest losses. Traditional methods of extending shelf life often rely on synthetic chemicals that may pose health and environmental concerns. Despite its potential, limited studies have explored the precise mechanisms through which chitosan coatings derived from sea urchins influence the ripening inhibition of climacteric fruits, particularly saba bananas, which are economically and nutritionally significant in the Philippines. By exploring this novel application of chitosan coating from sea urchin wastes, the research seeks to contribute to the development of natural, sustainable post-harvest preservation strategies. This study focuses on how using sea urchin shells, especially the chitosan, might limit food waste, lower post-harvest banana losses, and give farmers an affordable, environmentally beneficial substitute for artificial preservatives.

The research questions addressed in this study are as follows: (1.) What are the physicochemical changes (pigment changes in peel color, pH and weight loss) observed in three banana varieties: a. *saba banana* (*Musa acuminata x M. balbisiana,* ABB Group), b. lakatan (*Musa acuminata Colla*), and c. latundan (*Musa acuminata x M. balbisiana,* AAB Group) samples treated with chitosan coating compared to untreated samples; (2.) Is there a significant difference in physicochemical changes (pigment changes in peel color, pH, and weight loss) observed in three banana varieties: a. *saba banana* (*Musa acuminata x M. balbisiana,* ABB Group), b. lakatan (*Musa acuminata Colla*) and c. latundan (*Musa acuminata x M. balbisiana,* AAB Group) samples treated with chitosan coating compared to untreated samples, and (3.) What is the chemical reaction of the chitosan-coated banana and the untreated banana to Benedict's Qualitative test? The study aims to determine whether a chitosan coating derived from sea urchin waste (*Diadema setosum)* can serve as an eco-friendly, effective postharvest treatment to extend shelf life and maintain the quality of three banana varieties. Ultimately, this study integrates the goals of food preservation, environmental sustainability, and innovative agricultural practices, offering practical value both in the Philippine context and beyond.

2 LITERATURE REVIEW

Studies have recently, explored natural biopolymers and marine-derived molecules as food coatings that would reduce the ripening rate. The application of biopolymer-based coatings on fruits and vegetables has garnered popularity among alternatives due to their efficacy in extending the postharvest shelf life (**Priya, *et.al.,* 2023**). Shrimp chitosan-derived coatings prolong the shelf life of vegetables, diminish food waste, and promote sustainability due to their biodegradable and non-toxic properties. They correspond with SDGs 2, 3, 12, and 13 by enhancing food security, safety, and nutrition, while diminishing dependence on synthetic preservatives and carbon emissions, so fostering environmental sustainability and human health (**Saberi Riseh *et al.,* 2023: Zakir *et al.,* 2022**). Likewise, freshwater crabs subject to processing often results in shell residues. The discharged shell of the freshwater crab also provide a valuable source of accumulated chitin and chitosan. In terms of physicochemical qualities, the quality of chitosan obtained from aquatic crustaceans, including shrimp and crab, is variable due to factors such as the seasonal and localized nature of the raw material and differences in extraction methods (**Knidri, 2018**). Similarly, crustacean shells, insects, Mollusca organs, and fungus all contain chitosan, which is one of the most environmentally-friendly compounds. Chitosan contains β-(1,4)-linked 2-amino-deoxy-d-glucopyranose, making it a copolymer of glucosamine and N-acetylglucosamine (**Listiarini*, et al.,* 2009: Li, *et al.,* 2012**)

Studies shows that chitosan has a wide range of application prospects in agricultural production due to its inherent antimicrobial activity, low cost, abundant availability, nontoxicity, good film-forming properties, and biocompatibility. Chitosan, a biopolymer made from poly-β-(1,4)-D-glucosamine, is produced by deacetylating chitin with a high alkali concentration. Following the normal chitin extraction technique, which involves demineralization and deproteinization, the material is alkali treated. Typically, NaOH or KOH are employed at concentrations of 40-60% and temperatures of 80-120 degrees Celsius, respectively (**Hajji , 2014: Dinculescu, 2024**).

Chitosan, b-(1-4) linked 2-amino-2-deoxy-b-D-glucopyranose, is an N-deacetylated derivative of chitin produced by converting the acetamide groups to main amino groups (Figure 1) (**Aranaz, *et al.,*2009**). As articlulated by Islam et al., 2017 chitosan has higher chemical activity than chitin due to the presence of primary and secondary hydroxyl groups on repeat units, as well as an amine group on deacetylated units (Figure 2), the study further discussed the structure properties and biomedical potential of chitin and chitosan.

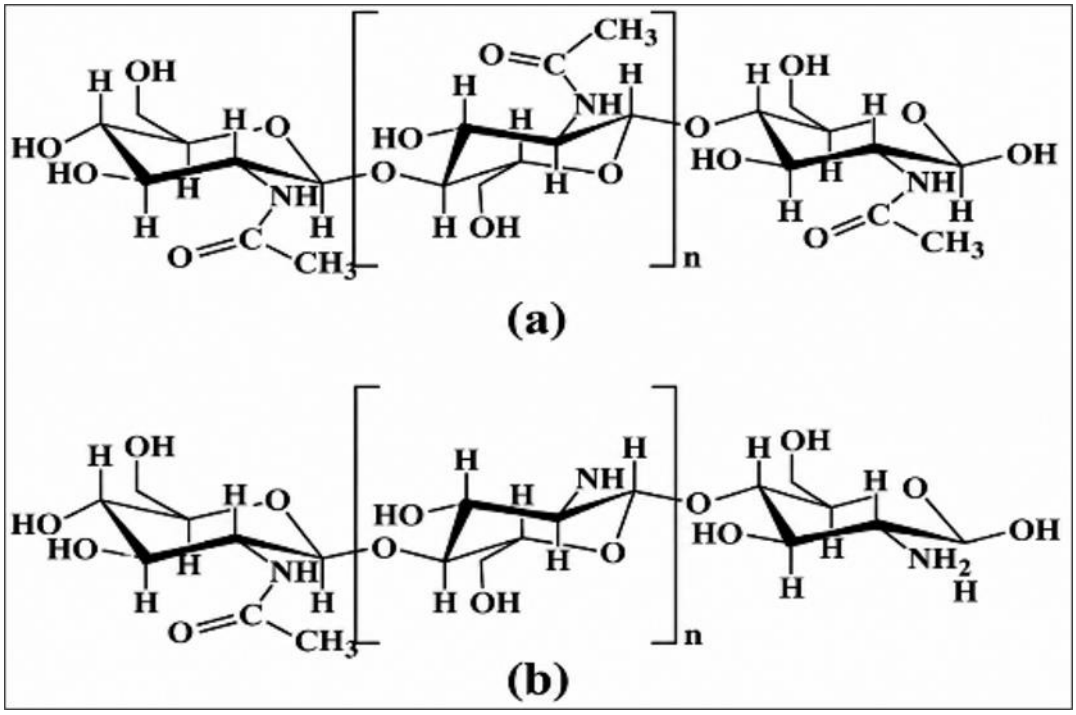


Figure 1: Comparison of Chemical Structure of Chitin and Chitosan

Chitosan's potent natural antibacterial and antifungal qualities help prevent fruit deterioration by extending shelf life and preventing microbial invasion. Exogenous chitosan treatment boosts antioxidant capacity, reduces transpiration and firmness loss, and enhances the overall quality of the harvested fruit (Wang et al., 2021). Chitosan, a biocompatible and biodegradable natural polysaccharide obtained from the deacetylation of chitin, is a highly potential substitute for artificial ripening inhibitors because it possesses film-forming characteristics (Ahmed et al., 2024).As noted by Safdar et al. (2024) treated mangoes with chitosan-based edible coatings and noticed prolonged ethylene production and respiration rate. The coating inhibited enzymatic activities (i.e., polygalacturonase) involved in cell wall deterioration, thereby maintaining the texture and nutritional value of the fruit. Another research by Abd El-Mageed et al. (2024) treated avocados with composite films consisting of Arabic gum, chitosan, and zinc nanoparticles. The composite coating both retarded ripening and increased the antioxidant enzyme activity of the fruit while providing double protection against ripening and microbial spoilage. The mechanisms underlying these effects are diversified.

Sea urchin test waste, has emerged as a valued source of chitosan, a barrier and antimicrobial polysaccharide which could be used to coat fruits and extend their senescence. Sea urchin tests, typically discarded as waste, are processed to obtain chitin and then chitosan via decolorization, deproteinization, demineralization, and deacetylation steps (Mendoza et. al., 2021).These are corroborated with larger literature on chitosan coatings from other authors that also report decreases in respiration, ethylene transmission, and microbial spoilage, ultimately leading to an extension in shelf life (Hosseini et al., 2018; Wantat et al., 2021).

Respecting sea urchin shells is consistent with the sustainable resource management and waste utilization principles. The functional components of shells can be recycled into natural preservatives for food systems rather than being thrown away as aquaculture by products. This strategy promotes ecologically friendly post-harvest technologies while also lowering marine waste. According to earlier research on marine-derived compounds, these natural sources might offer safer substitutes for artificial ripening inhibitors, lowering dependency on chemicals and promoting sustainability and food security (Moreno-García et al. 2022).

Antioxidants come into play during ripening delay since reactive oxygen species (ROS) speed up pigment deterioration, lipid peroxidation, and cell wall softening during senescence. Though direct links between sea urchin pigments and fruit ripening research have yet to be established, their existence indicates other avenues for sea urchin-derived products in postharvest use.

3 MATERIAL AND METHODS

3.1 Collection and Preparation of the Sea Urchin and Banana

Prior to the collection of the sea urchin samples (*Diadema setosum)* permit were secured from Local Government Unit (LGU) of Taytay and Palawan Council for Suatainable Development (PCSD). A total of thirty-five (75) sea urchins were collected from Pancol, Taytay, Palawan. The sea urchin species were sent to Palawan State University College of Sciences for identification and validation, by the Marine Biology Department. Sea urchins were washed with running tap water to remove impurities. The gonads of the samples were removed using tweezers, and the spikes were removed manually, as they affect the hastening of the degradation of the sea urchin samples. As for the banana, banana varieties were identified by the Herbarium in charge at Palawan State University. Ninety (90) samples of the following varieties: *saba banana* (*Musa acuminata x M. balbisiana,* ABB Group), lakatan (*Musa acuminata Colla*), and latundan (*Musa acuminata x M. balbisiana,* AAB Group) were collected from Poblacion, Taytay, Palawan by the local farmer. Forty (45) samples were untreated and served as the control group, while the remaining forty (45) were coated with chitosan and treated as the experimental group. There are 15 samples in each species of banana assigned to both the control and experimental groups. Each unripe banana sample was weighed using a digital weighing scale. The average weight of Saba bananas was 65.302 grams for Batch 1 and 64.988 grams for Batch 2. For Lakatan, Batch 1 had an average weight of 60.798 grams, while Batch 2 weighed slightly lower at 59.818 grams. Meanwhile, Latundan showed higher averages, with 88.595 grams for Batch 1 and 88.719 grams for Batch 2.

3.2 Decolorization and Powderization of sea urchin wastes

To decolorize and to disinfect the collected sea urchin samples it was treated with 6% sodium hypochlorite (NaOCl) for 24 hours and sundried for 24 hours. The dried sample was reduced to smaller pieces and then pulverized using a mortar and pestle. The powdered samples were placed in a glass bottle for further storage procedure was adapted from the study of Majekodumni et al., 2017. The powdered sea urchins were allocated for the preparation of the chitosan delay agent. NaOCl is a common bleaching or decolorization chemical used in chitin extraction methods. It oxidizes or degrades colored molecules (e.g., spinochromes in echinoderms or astaxanthin-related pigments in crustaceans) that would otherwise darken the final chitosan (**Pellis *et al.,* 2022**). Since it is the concentration of ordinary household or commercial bleach and works well without the need for specialist reagents, the 6% figure is commonly used in practical procedures and in this study (**Mendoza *et al.,* 2020**).



Figure 2: Preparation of the sea urchin-*Diadema setosum* waste (removing of spike, cleaning, decolorizing and powdering).

3.3 Deproteinization of sea urchin wastes

The collected powdered sea urchin samples weigh 114.09 grams undergone several physical and chemical procedures. To remove unnecessary proteins in the collected samples a 4% sodium hydroxide solution was formulated using 500mL of distilled water and 20 grams of Sodium Hydroxide (NaOH). Solution was then placed in a beaker and stirred using a magnetic stirrer. Temperature was set at 70°C-75°C adapting the deproteinization procedures of the study of Tjahjaningsih et al. (2023) Stirring of the solution after 5 hours was stopped right after the bubbles and foam disappeared. Eventually the solution were placed in a glass container for 24 hours. It was then washed with distilled water repeatedly for seven (7) times to remove other mineral contents. The pH level of the dilute were monitored until set to neutral pH. A 4% NaOH is used for deproteinization of sea urchin shell because it is strong enough to dissolve proteins and organic binders, yet mild enough to avoid significant degradation of chitin. It gives a good balance between efficiency and preservation of polymer quality (**Hosney *et al.,* 2022**).

3.4 Demineralization of sea urchin wastes

The deproteinized samples were eventually demineralized using 4%HCl and the mixture were stirred using a magnetic stirrer until bubbles disappeared. Demineralized sea urchin shells with 4% HCl because this concentration effectively eliminates the high calcium carbonate content while keeping chitin structural integrity, resulting in a purer, safer, and higher-quality material for subsequent processing into chitosan (Hosney et al., 2022.)The acid remains was drained and collected residue were washed eleven (11) times with distilled water until it reaches neutral pH. The powdered samples was eventually put in 2% sodium hydroxide and washed with distilled water for four (4) times until pH level achieved the neutral pH. A 1% hydrochloric acid was added to the collected residue to produce chitin . A total of 65 g crude chitin powder was obtained.Chitin is a tough, structural carbohydrate found in shells, insects, and fungi, and it is widely used once converted into chitosan for food, medical, and environmental applications (**Rinaulo *et al*., 2006**.)

3.5 Deacetylation of crude chitin to chitosan

To convert chitin to chitosan a 65% sodium hydroxide (NaOH) was added to the collected residue and was treated for three days. The deacetylated chitin was washed repeatedly with distilled water to remove some suspended particles. It was then filtered and air-dried. Chitin is a polysaccharide comprised of repeating units of N-acetyl-D-glucosamine. To create chitosan, part of the acetyl groups (-$COCH_3$) in chitin are removed using alkali treatment (typically concentrated sodium hydroxide or NaOH) (**Kumar, 2000**).

3.6 Testing whether chitin was totally converted to chitosan

To determine whether the sample was totally converted to chitosan, the dried sample of chitosan and crude chitin was stirred for 30 minutes in separate beakers of 20 mL of 1% acetic acid. It was then filtered to collect the liquids (filtrate) and compare the results. The clear filtrate from the solution indicates that the sample contained chitosan and not chitin, since chitosan is highly soluble in diluted acetic acid and chitin does not. Filtrate collected from the solution yield a transparent appearance indicating that the sample were totally converted to chitosan. The derived chitosan was then stored in a petri dish for banana coating application.

3.7 Solubility Testing

To evaluate solubility, 2 g of the extracted chitosan was dispersed in 20 mL of 1% (v/v) acetic acid and stirred using a magnetic stirrer at 350 rpm for 2 hours at 25 °C. The resulting mixture was filtered to separate the undissolved fraction. Solubility was calculated using the formula (Agarwal, et al. 2018): Based on the calculation, 100 – (0.45 g) x 100 ÷ (2.0 g) = 77.5%. The sample of chitosan showed 77.5% solubility. Showing that most of the material had been successfully dissolved in 1% acetic acid. This solubility indicates that the chitosan had a high enough degree of deacetylation to facilitate protonation of amino groups, enabling it to disperse well in an acidic medium. No, et al. (2003) stated that chitosan with solubility over 70% is suitable for film-forming and coating applications.

$$\text{Solubility (\%)} = 100 - (\text{Weight of insoluble fraction}) \times 100 \div (\text{Weight of initial sample})$$

3.8 Coating of the Banana Samples

To create a coating for banana samples, 5 grams of chitosan was added to 0.5% acetic acid with 25% glycerol plasticizer (19.8 ml of glycerin was added), which led to the formulation of a chitosan solution (Park et al., 2004). The mixture was stirred thoroughly and filtered to eliminate any insoluble components. 30 ml of 4% NaOH was added gradually while the liquid was constantly stirred until it was homogeneous (Mendoza et al., 2021). The banana samples were dipped in the chitosan solution for three minutes and dried for 30 minutes at room temperature (Mendoza et al, 2021). The untreated banana samples were labeled A1 to A15 for saba (*Musa acuminata x M. balbisiana,* ABB Group); C1 to C15 for lakatan (*Musa acuminata Colla*); and E1 to E15 for latundan, respectively (*Musa acuminata x M. balbisiana,* AAB Group). While the treated banana serves as the experimental group, banana samples coated with chitosan solution were labeled with B1-B15 for saba (*Musa acuminata x M. balbisiana,* ABB Group); D1 to D15 for lakatan (*Musa acuminata Colla*); and F1 to F15 latundan (*Musa acuminata x M. balbisiana,* AAB Group). Both the control and experimental bananas were placed into the bamboo chambers with the following measures: 20 inches long, 15 inches wide (Aksarani, 2014). Banana samples were placed at room temperature and were observed every 7 days.



Figure 3: Preparation and treating of banana samples with chitosan

3.9 Benedict's Test

Small quantities of two groups of bananas (control and experimental) were sliced and poured into different beakers. Subsequently, 10 mL of distilled water was added to the beakers, and the suspensions were mashed to a thick paste or slurry consistency. The slurries were strained through filter paper, and about 1 mL of each banana extract was poured into two test tubes. With the use of a dropper, a small amount of Benedict's reagent (about 2 mL or 10 drops) was added to every test tube of banana extract. The samples were then heated on a burner for 3-5 minutes, and the test tubes were held securely in a test tube holder and shaken continuously during heating (Microbe Notes, n.d.; Microbiology Info, n.d.).

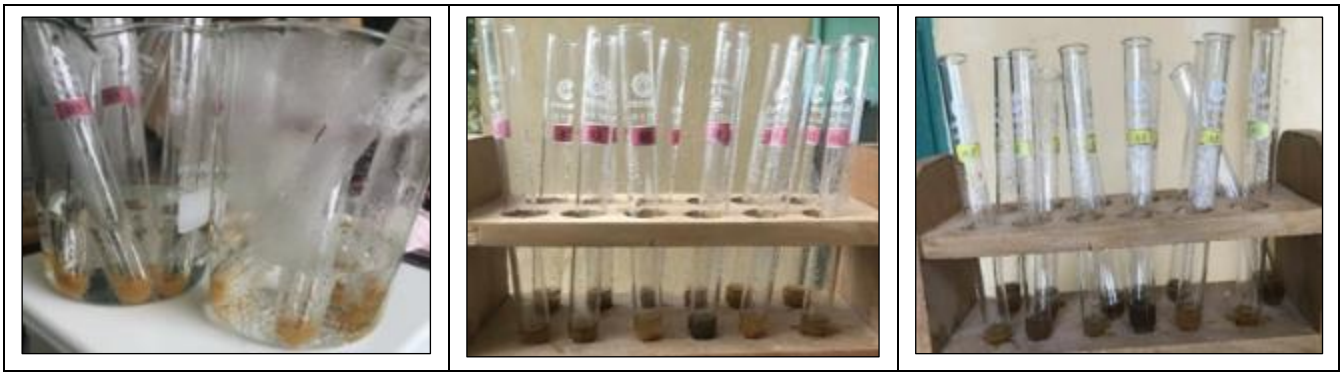


Figure 4: Benedicts test on banana samples after experimental period

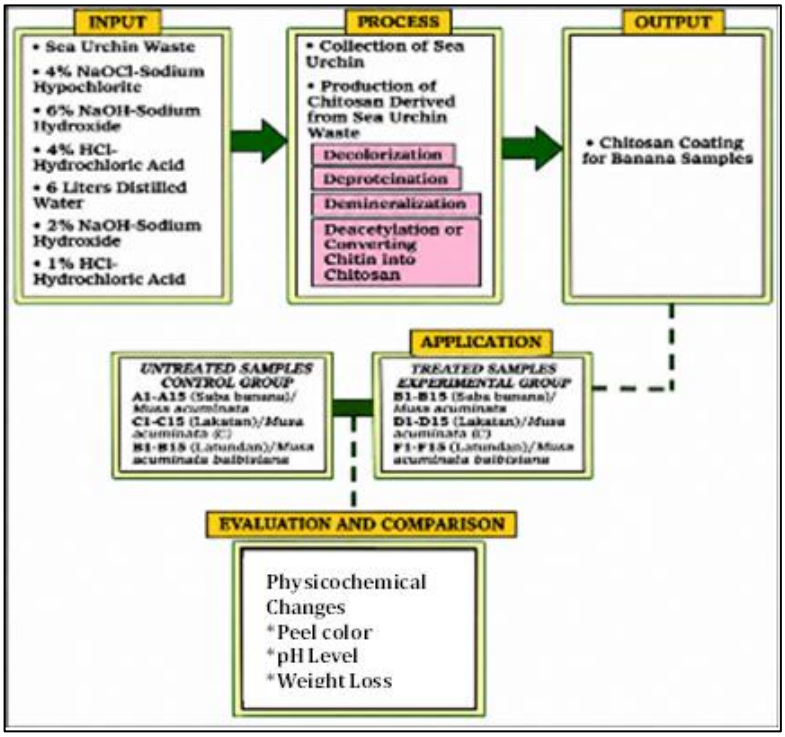


Figure 5: Research Process

4 RESULTS AND DISCUSSION

The different Physicochemical Changes were observed in the banana samples after post-harvest for a duration of seven (7) days. Physiochemical changes including peel color analysis using a peel color scale was used adapting Machovina and Feeley scale (2013). Observable changes are presented in tables located below.

Table 4.1: Physicochemical Changes in Peel Color in Untreated and Treated Saba Banana (Musa acuminata x M. balbisiana, ABB Group), Lakatan (Musa acuminata Colla), Latundan (Musa acuminata x M. balbisiana, AAB Group) Samples

	SABA BANANA (*Musa acuminata x M. balbisiana,* ABB Group*)*		**LAKATAN BANANA (*Musa acuminata Colla)***		**LATUNDAN BANANA (*Musa acuminata x M. balbisiana,* AAB Group*)***	
Storage Time (days)	Control Group (Untreated)	Experimental Group (Treated)	Control Group (Untreated)	Experimental Group (Treated)	Control Group (Untreated)	Experimental Group (Treated)
Day 0 (freshly harvest)	1	1	1	1	1	1
Day 2	1.27	1.27	1.4	1.47	4.67	3.8
Day 4	3.53	3.87	2	1.47	7	6.8
Day 6	6.73	5.47	6.93	2.27	7	6.93
Day 7	7	6	5	4.53	7	7
Mean	*3.906*	*3.522*	*3.266*	*2.15*	*5.33*	*5.11*

***Legend:Ripening scale: Stage 1 = Green; Stage 2 = Green with some yellow; Stage 3 = Green more dominant than yellow; Stage 4 = Yellow more dominant than green; Stage 5 = Yellow with green tip; Stage 6 = Completely yellow; Stage 7 = Yellow, flecked with brown. Scale was adapted from Machovina and Feeley (2013)

Table 4.1 shows the pigment color changes that take place on three different banana varieties from day 0 to day 7. The data above shows that the average peel color for the control group is 3.906 (saba banana), 3.266 (lakatan) 5.33 (latundan), respectively. While experimental is 3.522 (saba banana) 2, 15 (lakatan), and 5.11(latundan), which can be interpreted that both control and experimental groups exhibit ripening; however experimental group slows down peel color ripening.



Figure 6: Peel color of 3 banana varieties on day 0



Figure 7: Peel color of 3 banana varieties on day 4



Figure 8: Peel color of 3 banana varieties on day 7

Table 4.2: Physicochemical Changes in pH Level of Untreated and Treated Saba Banana (Musa acuminata x M. balbisiana, ABB Group), Lakatan (Musa acuminata Colla), Latundan (Musa acuminata x M. balbisiana, AAB Group) Samples

	SABA BANANA (*Musa acuminata x M. balbisiana*, ABB Group)		**LAKATAN BANANA (*Musa acuminata Colla*)**		**LATUNDAN BANANA (*Musa acuminata x M. balbisiana*, AAB Group)**	
	Control Group (Untreated)	Experimental Group (Treated)	Control Group (Untreated)	Experimental Group (Treated)	Control Group (Untreated)	Experimental Group (Treated)
Mean	*3.55*	*3.20*	*4.07*	*3.53*	*4.07*	*3.73*

The pH analysis of three banana varieties is displayed in Table 2. The experimental group coated with sea urchin chitosan had a slightly lower mean value than the untreated control group. Data revealed that the experimental group continuously remained in a more acidic state, which indicates delay in ripening.

4.1.1 SABA

Table 4.3: Comparison of Physicochemical Changes in Untreated Saba Banana (Musa acuminata x M. balbisiana, ABB Group) Samples-Control Group (A1-A15) and Treated Samples-Experimental Group (B1-B15) in terms of weight loss.

Independent Samples Test[a]

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
WeightLoss	Equal variances assumed	2.422	.131	2.207	28	.036	4.59000	2.07967	.33000	8.85000
	Equal variances not assumed			2.207	23.646	.037	4.59000	2.07967	.29438	8.88562

a. Variety = Saba

The results showed a significant difference in weight loss between treated and control Saba bananas, t (28) = 2.20, p = 0.036. The treated group lost, on average, 4.59 g less weight than the controls, with a 95% confidence interval of [0.33, 8.85], which does not include zero and confirms significance. This suggests that chitosan-treated Saba bananas experienced slower ripening compared to the untreated control group.

Table 4.4: Sample Effect size in Saba banana

Independent Samples Effect Sizes[a]

		Standardizer[b]	Point Estimate	95% Confidence Interval	
				Lower	Upper
WeightLoss	Cohen's d	5.69540	.806	.053	1.545
	Hedges' correction	5.85385	.784	.052	1.503
	Glass's delta	4.30334	1.067	.236	1.868

Cohen's d = 0.81 → a large effect size. CI for d = [0.05, 1.55], suggesting the effect is meaningful and not trivial.

In comparison to the control group, the treated Saba bananas lost an average of 4.59 g less weight; this difference was statistically significant (p = 0.036). The therapy significantly slowed the ripening of Saba bananas, as evidenced by the substantial effect size (Cohen's d = 0.81).

4.1.2 LAKATAN

Table 4.5: **Comparison of Physicochemical Changes in Untreated Lakatan Banana (*Musa acuminata Colla*) Samples-Control Group (C1-C15) and Treated Samples-Experimental Group (D1-D15) in terms of weight loss.**

Independent Samples Test[a]

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
WeightLoss	Equal variances assumed	2.763	.108	1.191	28	.244	2.73267	2.29537	-1.96919	7.43452
	Equal variances not assumed			1.191	16.356	.251	2.73267	2.29537	-2.12471	7.59004

a. Variety= Lakatan

The weight reduction of treated and control Lakatan bananas did not differ significantly, according to the data (t (28) = 1.19, p = 0.244). With a 95% confidence range of [−1.97, 7.43], which includes zero, the mean difference was 2.73 g. This suggests that the weight reduction in Lakatan bananas was not statistically affected by the chitosan treatment.

Table 4.6: Sample Effect size in the Lakatan banana

Independent Samples Effect Sizes[a]

		Standardizer[b]	Point Estimate	95% Confidence Interval Lower	Upper
WeightLoss	Cohen's d	6.28613	.435	-.294	1.156
	Hedges' correction	6.46102	.423	-.286	1.124
	Glass's delta	2.48491	1.100	.263	1.906

Cohen's d = 0.44 → means that a small-to-medium effect size, but since p > 0.05, we cannot conclude the effect is statistically reliable.

Despite losing an average of 2.73 g less weight than controls, treated Lakatan bananas did not vary statistically significantly (p = 0.244). There is not enough data to draw the conclusion that treatment slowed ripening in Lakatan bananas, although the effect size was small to moderate (Cohen's d = 0.44), indicating a potential trend.

Table 4.7: Comparison of Physicochemical Changes in Untreated Latundan Banana (*Musa acuminata x M. balbisiana,* AAB Group) Samples-Control Group (E1-E15) and Treated Samples-Experimental Group (F1-F15) in terms of weight loss

Independent Samples Test[a]

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
WeightLoss	Equal variances assumed	1.824	.188	.793	28	.435	1.62867	2.05484	-2.58048	5.83781
	Equal variances not assumed			.793	25.258	.435	1.62867	2.05484	-2.60116	5.85850

a. Variety = Latundan

4.1.3 LATUNDAN

The results of the analysis showed that there was no significant difference in weight loss between treated and control Latundan bananas, t(28) = 0.793, p = 0.435. The mean difference was 1.63 g, with a 95% confidence interval of [−2.58, 5.84], which includes zero. This indicates that the chitosan treatment did not produce a statistically meaningful effect on reducing weight loss in Latundan bananas.

Table 4.8: Sample Effect size in Latundan banana

Independent Samples Effect Sizes[a]

		Standardizer[b]	Point Estimate	95% Confidence Interval Lower	Upper
WeightLoss	Cohen's d	5.62741	.289	-.433	1.007
	Hedges' correction	5.78397	.282	-.421	.979
	Glass's delta	4.60798	.353	-.380	1.075

The average weight loss of the treated Latundan bananas was 1.63 g less than that of the controls; however, this difference was not statistically significant (p = 0.435). The therapy had a modest and unreliable impact, as seen by the tiny effect size (Cohen's d = 0.29, 95% CI: -0.43 to 1.01). All things considered, the findings point to little to no proof that chitosan coating successfully slowed down Latundan banana ripening.

Table 4.9: General Physicochemical Changes in Untreated Varieties of Three Banana Samples-Control Group and Treated Samples-Experimental Group in terms of weight loss.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
WeightLoss	Equal variances assumed	7.055	.009	2.415	88	.018	2.98378	1.23555	.52838	5.43917
	Equal variances not assumed			2.415	67.169	.018	2.98378	1.23555	.51773	5.44983

4.1.4 OVERALL RESULT

The weight loss of treated and untreated bananas differed significantly, according to an independent samples t-test ($t(67.17) = 2.42$, $p = 0.018$). With a 95% confidence interval of 0.52 to 5.45 g, the treated bananas lost an average of 2.98 g less weight than the controls. This result suggests that the chitosan coating treatment may have a function in preserving fruit quality while it is being stored because it successfully decreased weight loss.

Table 4.10: Sample Effect size among all varieties of the banana samples

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
WeightLoss	Cohen's d	5.86072	.509	.088	.928
	Hedges' correction	5.91127	.505	.087	.920
	Glass's delta	3.90130	.765	.318	1.204

The effect size analysis showed that Cohen's d was approximately 0.51, indicating a medium effect size. This suggests that the treatment not only produced a statistically significant difference but also had a moderately practical impact in slowing down the ripening process of bananas.

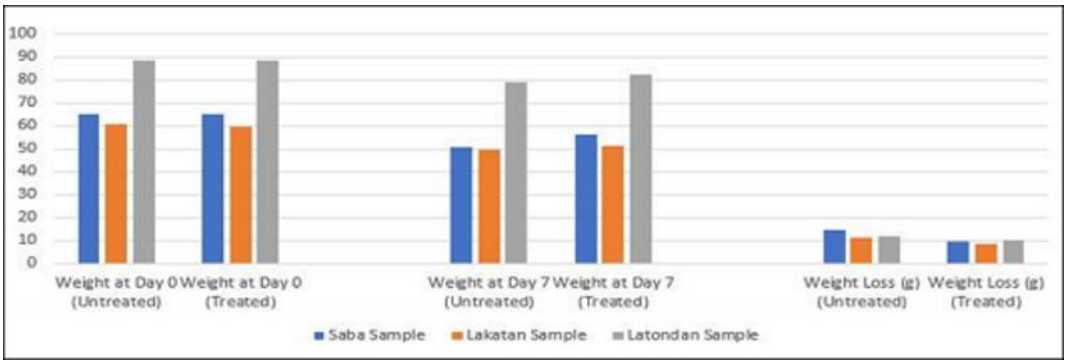


Figure 9: Untreated and Treated Banana Samples Weight Differences

Figure 9 shows the average weights of different banana samples on day 0, day 7, and their average weight losses, respectively

Table 4.11: Benedict's Test Results of Untreated (Control) Saba Banana Samples

Sample Code	Observation after Heating with Benedict's Reagent	Color Change	Interpretation (Reducing Sugar Present)
A1	Moderate Precipitate	Orange	1-1.5%
A2	Moderate Precipitate	Orange	1-1.5%
A3	Moderate Precipitate	Yellow	0.5-1%
A4	Moderate Precipitate	Yellow	0.5-1%

A5	Moderate Precipitate	Orange	1-1.5%
A6	Moderate Precipitate	Orange	1-1.5%
A7	Moderate Precipitate	Yellow	0.5-1%
A8	Moderate Precipitate	Orange	1-1.5%
A9	Moderate Precipitate	Yellow	0.5-1%
A10	Moderate Precipitate	Orange	1-1.5%
A11	Moderate Precipitate	Yellow	0.5-1%
A12	Moderate Precipitate	Yellow	0.5-1%
A13	Slight Precipitate	Green	0.1-0.5%
A14	Moderate Precipitate	Orange	1-1.5%
A15	Moderate Precipitate	Orange	1-1.5%

***Legend: Color and percentage of reducing sugar present: green 0.1-0.5%, yellow 0.5-1%, orange 1-1.5%, red 1.5-2.0 % Scales were adapted from Aryal (2022)

Table 4.11 shows the chemical test results of the Untreated Saba Banana (Control) on the Benedict's test showcasing the observation after heating with Benedicts Reagent, color change, and its interpretation (reducing sugar present) from A1 to A15. The majority of results exhibited a moderate precipitate with orange or yellow coloration, suggesting the presence of reducing sugar concentrations from 0.5% to 1.5%. There was only one sample that had a slight precipitate with green coloration, which is equivalent to a low sugar level of 0.1% to 0.5%. This implies that untreated Saba bananas naturally amassed reducing sugars during ripening.

Table 4.12: Benedict's Test Results of Treated (Experimental) Saba Banana Samples

Sample Code	Observation after Heating with Benedict's Reagent	Color Change	Interpretation (Reducing Sugar Present)
B1	Moderate Precipitate	Yellow	0.5-1%
B2	Moderate Precipitate	Orange	1-1.5%
B3	Moderate Precipitate	Yellow	0.5-1%
B4	Moderate Precipitate	Orange	1-1.5%
B5	Moderate Precipitate	Yellow	0.5-1%
B6	Moderate Precipitate	Orange	1-1.5%
B7	Moderate Precipitate	Yellow	0.5-1%
B8	Moderate Precipitate	Yellow	0.5-1%
B9	Moderate Precipitate	Orange	1-1.5%
B10	Slight Precipitate	Green	0.1-0.5%
B11	Moderate Precipitate	Yellow	0.5-1%
B12	Moderate Precipitate	Yellow	0.5-1%
B13	Moderate Precipitate	Orange	1-1.5%
B14	Moderate Precipitate	Yellow	0.5-1%
B15	Moderate Precipitate	Yellow	0.5-1%

***Legend: Color and percentage of reducing sugar present: green 0.1-0.5%, yellow 0.5-1%, orange 1-1.5%, red 1.5-2.0 % Scales were adapted from Aryal (2022)

Table 4.12 shows the chemical test results of the Saba Banana (Experimental) on the Benedict's test, showcasing the observation after heating with Benedict's Reagent, color change, and its interpretation (reducing sugar present) from B1 to B15. Most also showed moderate precipitate with yellow or orange color, reflecting sugar contents from 0.5% to 1.5%. There were, however, some samples, notably B10, that indicated slight precipitate with green color, reflecting a lower sugar content of 0.1% to 0.5%. This reflects that the treatment caused minimal impact in slowing down sugar accumulation as compared to the control.

Table 4.13: Benedict's Test Results of Untreated (Control) Lakatan Banana Samples

Sample Code	Observation after Heating with Benedict's Reagent	Color Change	Interpretation (Reducing Sugar Present)
C1	Slight Precipitate	Green	0.1-0.5%
C2	Slight Precipitate	Green	0.1-0.5%
C3	Slight Precipitate	Green	0.1-0.5%
C4	Moderate Precipitate	Yellow	0.5-1%
C5	Moderate Precipitate	Orange	1-1.5%
C6	Slight Precipitate	Green	0.1-0.5%
C7	Slight Precipitate	Green	0.1-0.5%
C8	Moderate Precipitate	Orange	1-1.5%
C9	Moderate Precipitate	Yellow	0.5-1%
C10	Moderate Precipitate	Yellow	0.5-1%
C11	Moderate Precipitate	Yellow	0.5-1%
C12	Moderate Precipitate	Orange	1-1.5%
C13	Slight Precipitate	Green	0.1-0.5%
C14	Moderate Precipitate	Yellow	0.5-1%
C15	Moderate Precipitate	Yellow	0.5-1%

***Legend: Color and percentage of reducing sugar present: green 0.1-0.5%, yellow 0.5-1%, orange 1-1.5%, red 1.5-2.0 % Scales were adapted from Aryal (2022)

Table 4.13 indicates the chemical test results of the Untreated Lakatan Banana (Control) on the Benedict's test, showcasing the observation after heating with Benedict's Reagent, color change, and its interpretation (reducing sugar present) from C1 to C15. The scale used for this study was adapted from Sagar Aryal (2022). Variations occurred between samples, from trace precipitate with green coloration (0.1% to 0.5%) to moderate precipitate with yellow or orange coloration (0.5% to 1.5%). This is because it shows the natural variations between stages of ripeness of the untreated fruits.

Table 4.14: Benedict's Test Results of Treated (Experimental) Lakatan Banana Samples

Sample Code	Observation after Heating with Benedict's Reagent	Color Change	Interpretation (Reducing Sugar Present)
D1	Slight Precipitate	Green	0.1-0.5%
D2	Slight Precipitate	Green	0.1-0.5%
D3	Moderate Precipitate	Yellow	0.5-1%
D4	Slight Precipitate	Green	0.1-0.5%
D5	Slight Precipitate	Green	0.1-0.5%
D6	Slight Precipitate	Green	0.1-0.5%
D7	Slight Precipitate	Green	0.1-0.5%
D8	Slight Precipitate	Green	0.1-0.5%
D9	Slight Precipitate	Green	0.1-0.5%
D10	Slight Precipitate	Green	0.1-0.5%
D11	Slight Precipitate	Green	0.1-0.5%
D12	Moderate Precipitate	Orange	1-1.5%
D13	Slight Precipitate	Green	0.1-0.5%
D14	Slight Precipitate	Green	0.1-0.5%
D15	Slight Precipitate	Green	0.1-0.5%

***Legend: Color and percentage of reducing sugar present: green 0.1-0.5%, yellow 0.5-1%, orange 1-1.5%, red 1.5-2.0 % Scales were adapted from Aryal (2022)

Table 4.14 shows the chemical test results of the Lakatan Banana (Experimental) on the Benedict's test, showcasing the observation after heating with Benedict's Reagent, color change, and its interpretation (reducing sugar present) from D1 to D15. The treated Lakatan banana samples (Table 26) generally exhibited tiny precipitate with green coloration, equivalent to a reducing sugar level of merely 0.1% to 0.5%. Few samples had elevated sugar content, with one sample exhibiting yellow (0.5% to 1%) and another exhibiting orange (1% to 1.5%). This proves that treatment was very successful in retarding sugar buildup and ripening in Lakatan bananas.

Table 4.15: Benedict's Test Results of Untreated (Control) Latundan Banana Samples

Sample Code	Observation after Heating with Benedict's Reagent	Color Change	Interpretation (Reducing Sugar Present)
E1	Moderate Precipitate	Yellow	0.5-1%
E2	Moderate Precipitate	Yellow	0.5-1%
E3	Moderate Precipitate	Orange	1-1.5%
E4	Moderate Precipitate	Orange	1-1.5%
E5	Moderate Precipitate	Yellow	0.5-1%
E6	Moderate Precipitate	Yellow	0.5-1%
E7	Moderate Precipitate	Orange	1-1.5%
E8	Moderate Precipitate	Yellow	0.5-1%
E9	Moderate Precipitate	Yellow	0.5-1%
E10	Moderate Precipitate	Orange	1-1.5%

E11	Moderate Precipitate	Yellow	0.5-1%
E12	Moderate Precipitate	Orange	1-1.5%
E13	Moderate Precipitate	Yellow	0.5-1%
E14	Moderate Precipitate	Yellow	0.5-1%
E15	Moderate Precipitate	Yellow	0.5-1%

***Legend: Color and percentage of reducing sugar present: green 0.1-0.5%, yellow 0.5-1%, orange 1-1.5%, red 1.5-2.0 % Scales were adapted from Aryal (2022)

Table 4.15 shows the chemical test results of the Untreated Latundan Banana (Control) on the Benedict's test, showcasing the observation after heating with Benedict's Reagent, color change, and its interpretation (reducing sugar present) from E1 to E15. The majority of the results presented moderate precipitate with orange or yellow coloration, implying a sugar content of 0.5% to 1.5%. There were no samples seen at the low sugar range, demonstrating that Latundan bananas ripened consistently without treatment.

Table 4.16: Benedict's Test Results of Treated (Experimental) Latundan Banana Samples

Sample Code	Observation after Heating with Benedict's Reagent	Color Change	Interpretation (Reducing Sugar Present)
F1	Moderate Precipitate	Yellow	0.5-1%
F2	Moderate Precipitate	Orange	1-1.5%
F3	Moderate Precipitate	Orange	1-1.5%
F4	Moderate Precipitate	Orange	1-1.5%
F5	Moderate Precipitate	Yellow	0.5-1%
F6	Slight Precipitate	Green	0.1-0.5%
F7	Moderate Precipitate	Orange	1-1.5%
F8	Moderate Precipitate	Orange	1-1.5%
F9	Slight Precipitate	Green	0.1-0.5%
F10	Moderate Precipitate	Orange	1-1.5%
F11	Slight Precipitate	Green	0.1-0.5%
F12	Slight Precipitate	Green	0.1-0.5%
F13	Moderate Precipitate	Orange	1-1.5%
F14	Slight Precipitate	Green	0.1-0.5%
F15	Moderate Precipitate	Yellow	0.5-1%

***Legend: Color and percentage of reducing sugar present: green 0.1-0.5%, yellow 0.5-1%, orange 1-1.5%, red 1.5-2.0 % Scales were adapted from Aryal (2022)

Table 4.16 shows the chemical test results of the Latundan Banana (Experimental) on the Benedict's test, showcasing the observation after heating with Benedict's Reagent, color change, and its interpretation (reducing sugar present) from F1 to F15. The scale used for this study was adapted from Sagar Aryal (2022). The treated Latundan banana samples (Table 28) had variable results. Some samples had low sugar content with green color (0.1% to 0.5%), whereas some had higher sugar content marked by yellow (0.5% to 1%) and orange color (1% to 1.5%). This indicates that treatment was only partially effective as ripening was delayed in some fruits but not in others, where sugar accumulation was not stopped.

Table 4.17: Benedict's Test results among the Untreated and Treated Three Banana Varieties samples

	SABA BANANA (*Musa acuminata x M. balbisiana*, ABB Group*)*		**LAKATAN BANANA (*Musa acuminata Colla)***		**LATUNDAN (*Musa acuminata x M. balbisiana*, AAB Group*)***	
	Control Group (Untreated)	Experimental Group (Treated)	Control Group (Untreated)	Experimental Group (Treated)	Control Group (Untreated)	Experimental Group (Treated)
Mean	*0.99*	*0.89*	*0.67*	*0.39*	*0.92*	*0.83*

Table 4.17 presents the mean reducing sugar content of Saba, Lakatan, and Latundan bananas in both treated and untreated samples. Since Benedict's test produces semi-quantitative results, midpoint values were assigned to each percentage range to calculate the mean reducing sugar content. The results reveal that the application of chitosan coating derived from Diadema setosum effectively reduced the formation of reducing sugars across all banana varieties. Untreated Saba samples recorded a mean of *0.99%*, while treated ones showed a slightly lower mean of *0.89%*. For Lakatan, the untreated samples exhibited *0.67%*, whereas the treated samples had the lowest value at *0.39%*, indicating the most significant reduction. Latundan showed a smaller difference, with *0.92%* for the untreated and *0.83%* for the treated samples. These findings suggest that the chitosan coating inhibited the starch-to-sugar conversion process responsible for fruit ripening. The treatment was most effective in Lakatan, followed by Saba and Latundan. This outcome supports that chitosan acts as a semi-permeable barrier, reducing oxygen and ethylene diffusion, thereby slowing down respiration and sugar accumulation in climacteric fruits like bananas.

A. CONCLUSION

The changes in peel color were prominent in both untreated (control) and treated (experimental) groups of three different banana varieties from day 0 to day 7. Data revealed that the average peel color using the pigment color scale adapted from the study of *Machovina and Feeley (2013)* for the control group is 3.906 (saba banana), 3.266 (lakatan) 5.33 (latundan), respectively. While experimental is 3.522 (saba banana) 2, 15 (lakatan), and 5.11(latundan), which can be interpreted that both control and experimental groups exhibit ripening; however experimental group slows down peel color ripening.

The pH readings of Saba, Lakatan, and Latundan bananas, as recorded in experimental samples, showed that the trial samples constantly had higher acidity than the control samples over observation time. The majority of control pH readings for Saba samples were within 2 to 5, whereas experimental samples were more stable at pH 2 to 4, which resulted in a lower mean pH for the treated group. Lakatan also exhibited the same trend, with the control having an average of 4.07 and the experimental group an average of 3.53, which indicates that treatment preserved acidity for a longer time. Latundan also exhibited the same results, with the control group reaching an average of 4.07 while the experimental group had a higher average value of 3.73. This indicates that the treated samples are less ripe than their controls, as the pH for a banana would normally be between 4.5 and 6.7, depending on the ripeness and condition of the banana. Unripe bananas are more acidic, ranging from 4.4 to 5.2 in terms of pH, and ripe bananas are less acidic, up to approximately 6.5 to 6.7. The acidity of bananas shifts as they mature. When they are unripe, they are lower on the pH scale (more acidic) and will decrease in acidity as they further develop (Bottaro, A. 2025; Anyasi, et al. 2015)

In all three types of bananas: Saba, Lakatan, and Latundan—the results consistently show that both untreated (control) and treated (experimental) samples experienced weight loss during the 7-day storage period, regardless of the treatment. However, the treated groups showed significantly less weight loss than their corresponding controls, which supports the success of the experimental coating in maintaining water retention and retarding physiological breakdown. For Saba bananas, the mean final weight loss of treated samples (9.812 g) was less than that of the control (14.402 g), whereas for Lakatan, treated samples lost a weight of 8.324 g compared to 11.056 g of the control group. Similarly, Latundan exhibited the same pattern, with treated samples' average weight loss of 10.072 g, which was lower than the control's 11.701 g. Among the three, lakatan showed the least significant weight loss, indicating higher sensitivity to the coating, while saba and latundan also indicated significant preservation effects, generally the chitosan coating derived from sea-urchin (*Diadema setosum*) delays banana ripening for about two to three days. Overall, the findings agree that the coating successfully minimized transpiration and respiration-induced weight loss and is a potential post-harvest treatment to prolong the shelf life of various banana varieties.

Various studies have demonstrated that chitosan coatings are capable of controlling postharvest weight loss and ripening delay in bananas, which is in line with the findings of this study. Hosseini et al. (2018) showed that 1–2% chitosan markedly

inhibited weight loss, slowed down changes in peel color, and preserved firmness in bananas, whereas Wantat et al. (2021) indicated that increasing concentrations of chitosan (0.75–2.0%) improved shelf life by reducing weight loss and postponing physicochemical changes. In like manner, Nguyen et al. (2024) showed that chitosan-based edible coatings were efficient in delaying ripening during storage, and Roidoung et al. (2025) enhanced the above effects further by adding nanoclay to reinforce chitosan. Other research, such as Mubarok et al. (2022), likewise indicated that blending chitosan with ethylene inhibitors, such as 1-MCP, more efficiently inhibited weight loss than when using chitosan alone. This is supported by the notable decrease in weight loss experienced in Saba bananas that were treated with chitosan in this study, and they also offer a reasonable explanation for the non-significant results in Latundan and Lakatan bananas due to the fact that varietal differences and treatment concentrations could affect the effectiveness of the coating.

The findings of this study align with previous reports on the role of chitosan and similar treatments in slowing the ripening process of bananas by delaying starch degradation into sugars. Dwivany et al. (2025) demonstrated that chitosan coating downregulated genes involved in starch-to-sugar conversion, thereby maintaining lower sugar levels during storage. Similarly, Hosseini et al. (2018) reported that postharvest chitosan treatment effectively reduced respiration rates and delayed sugar accumulation in fruits, supporting the present results where treated samples exhibited slower ripening. However, the variation observed among different banana varieties in this study suggests that treatment efficiency is cultivar-dependent, which is consistent with previous findings that the physiological response to postharvest coatings varies depending on fruit variety and genetic background (Ali et al., 2011). Thus, the observed higher effectiveness in Lakatan, moderate impact in Saba, and inconsistent effect in Latundan underscore the importance of considering cultivar-specific responses when applying postharvest treatments.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflict.

Conceptualization

J.P.A.-M..; methodology, M.D.D.; investigation, N.B.M.; data curation, J.O.B.; writing; N.B.M. original draft preparation, J.P.A.-M.; writing—review and editing, J.P.A.-M.; project administration, J.O.B. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

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