Development of an Antioxidant-Enriched Edible Coating Utilizing Paperflower (Bougainvillea Glabra) Bract Extract for the Post-Harvest Preservation of Lacatan Banana (Musa Acuminata)

A Quantitative Research Paper for Research Project and Practical Research

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ABSTRACT

The rapid post-harvest deterioration of climacteric fruits like Lacatan bananas (Musa acuminata) contributes to significant agricultural losses, which are traditionally mitigated by non-biodegradable plastic packaging. This study aimed to develop an eco-friendly, antioxidant-enriched edible coating, a "Bio-Composite Crown Seal", utilizing Bougainvillea glabra bract extract, pectin, and beeswax to extend the shelf life of bananas. Employing a quantitative experimental research design, the study evaluated four treatment groups: a negative control (untreated), a positive control (commercial cling wrap), and two bio-composite emulsions containing 10% and 20% Bougainvillea extract. The treatments were applied exclusively to the banana crowns using the dip-and-drip method.

Over a 7-day accelerated observation period at ambient conditions, physiological weight loss (PWL) and visual decay index (browning progression) were monitored. Results indicated that bananas treated with the 20% extract formulation exhibited the lowest physiological weight loss at 20.62%, outperforming the cling wrap (24.01%), the 10% extract (36.62%), and the untreated group (48.70%). Furthermore, the 20% Bougainvillea coating effectively slowed the spread of dark spots and delayed senescence, performing comparably to the commercial plastic wrap.

These findings suggest that the 20% Bougainvillea-pectin-beeswax composite holds substantial promise as a sustainable, low-cost, and natural alternative to synthetic packaging for minimizing moisture loss and delaying enzymatic browning in bananas. Further studies with larger sample sizes are recommended to statistically validate these descriptive findings

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Development of an Antioxidant-Enriched Edible Coating Utilizing Paperflower (*Bougainvillea Glabra*) Bract Extract for the Post-Harvest Preservation of Lacatan Banana (*Musa Acuminata*)

The global agricultural sector faces a massive challenge in the form of post-harvest loss, where a significant percentage of fruit production spoils before reaching the consumer. In tropical countries like the Philippines, the *Lakatan* banana (*Musa acuminata*) is a vital economic crop; however, its climacteric nature makes it highly perishable. Bananas undergo rapid physiological changes after harvest, including a sudden spike in respiration and ethylene production, making them highly susceptible to rapid moisture loss and fungal decay. To mitigate these losses, the agricultural industry currently relies heavily on synthetic preservation methods, predominantly the use of Low-Density Polyethylene (LDPE) plastic packaging. While plastic films effectively create a physical barrier that reduces transpiration, they are non-biodegradable and contribute significantly to global environmental pollution (Sunaiana et al., 2025). Furthermore, plastics can create a high-humidity microenvironment that promotes the growth of mesophilic bacteria and molds, a phenomenon known as "green damp", unless concurrently treated with synthetic fungicides (Ruiz Medina et al., 2025). Consequently, there is an urgent demand for sustainable, bio-based alternatives that can mimic the hydrophobic, protective functions of plastic without the ecological cost.

To create an effective, resource-efficient alternative to plastic wrapping, preservation efforts must address the most vulnerable region of the banana bunch: the crown. The severed tissue connecting the hand to the stalk serves as the primary entry point for vascular pathogens causing Crown Rot disease, and it acts as a major exit point for moisture loss. Research suggests that targeting this specific area with a protective coating can be as effective as coating the entire fruit. However, while hydrocolloid coatings like pectin are excellent for structural adhesion, they are naturally hydrophilic and poor at blocking moisture. Incorporating a lipid based coating, such as beeswax, is essential to establish a hydrophobic barrier capable of minimizing physiological weight loss (Kumah et al., 2020).

Beyond physical barriers, an active biological component is required to suppress decay. This study proposes the utilization of *Bougainvillea glabra* bracts, an often-discarded agricultural waste product. Belonging to the order Caryophyllales, *Bougainvillea* produces betalains, nitrogen, containing pigments that possess potent antioxidant and antimicrobial capabilities, making them highly effective at delaying enzymatic browning and pathogenic invasion (Kuhn et al., 2021).

Therefore, the purpose of this study is to develop a "Bio-Composite Crown Seal" by integrating the bioactive extract of *Bougainvillea glabra* into a Beeswax-Pectin emulsion. To rigorously evaluate the efficacy of this biodegradable coating, this research employs an accelerated decay model. By applying the formulated bio-coating to *Lakatan* bananas already at their peak climacteric phase (Ripening index D), the study aims to test the emulsion's ability to halt rapid weight loss, browning, and senescence over a critical 7-day observation period, ultimately offering a scientifically grounded, eco-friendly alternative to commercial plastic packaging.

Background of the Study

The shelf-life extension of climacteric fruits relies heavily on controlling respiration and transpiration. Al-Dairi et al. (2023) emphasize that without intervention, bananas rapidly degrade due to chlorophyll breakdown and cell wall softening. While refrigeration is effective, it is energy-intensive and risks chilling injury. Consequently, edible coatings have emerged as a viable alternative, creating a semi-permeable barrier that modifies the internal atmosphere of the fruit. However, polysaccharide based coatings like pectin are generally hydrophilic and fail to prevent moisture loss effectively on their own (Formiga et al., 2019). To address this, the incorporation of lipids is necessary. Zhang (2024) describes how beeswax forms "layered oleogels" with fibrous crystals that provide superior hydrophobicity, making it an ideal candidate for sealing the cut tissues of the banana.

To address the microbial and oxidative aspects of spoilage, *Bougainvillea glabra* serves as a highly potent active ingredient. Makerly and Hashim (2024) analyzed the metabolic profile of *Bougainvillea* and found that its extracts exhibit significant antibacterial activity against post-harvest pathogens. Furthermore, Ferreira et al. (2024) validated the safety of *Bougainvillea* extracts in food systems, demonstrating their ability to prevent lipid oxidation. This suggests that the extract can function not just as a passive physical barrier, but as an active preservative preventing the enzymatic browning driven by Polyphenol Oxidase (PPO) and Peroxidase (POD) (Kaewjumpol et al., 2021).

Despite these scientific advancements, a significant gap remains in both the application method and the testing timeline. Most studies focus on coating the entire fruit, which consumes large amounts of material and alters gas exchange across the whole peel, sometimes leading to anaerobic fermentation (Nasrin et al., 2020). Sripong et al. (2020) proved that treating *only* the crown effectively controlled Crown Rot; however, their study utilized paraffin, a petroleum byproduct. This study seeks to bridge this gap by replacing paraffin with a biodegradable Beeswax-Pectin-Tween 80 composite enriched with *Bougainvillea* extract. Furthermore, there is a lack of research examining the efficacy of these bio-coatings during the fruit's most vulnerable metabolic window. By utilizing an accelerated decay model on *Lakatan* bananas already at Ripening index D, this study tests the emulsion's ability to arrest rapid deterioration when respiration and moisture loss are at their absolute peak.

Statement of the Problem

This study aims to determine the efficacy of a Beeswax-enriched *Bougainvillea glabra* bract extract as a crown coating for the post-harvest preservation of *Lakatan* bananas (*Musa acuminata*). Utilizing an accelerated decay model on bananas at Ripening index D, the research seeks to answer the following specific questions:

1. Is there a significant difference in the Physiological Weight Loss (%) over a 7-day observation period between bananas treated with the *Bougainvillea*-Beeswax Crown Coating, those wrapped in LDPE Plastic (Positive Control), and the Uncoated (Negative Control) group?
2. Is there a significant difference in the progression of Crown Rot and Peel Browning (Visual Decay Index) among the treatment groups after 7 days?
3. Is there a significant difference in the Progression to Senescence (the rate at which the bananas transition into Ripening Index F) between the bio-coated groups, the Positive Control, and the Negative Control?

4. Is there a significant difference in short-term preservation efficacy among the 10% and 20% concentrations of *Bougainvillea* extract incorporated into the beeswax matrix?

Research Objectives

The general objective of this study is to develop a biodegradable crown-coating emulsion using *Bougainvillea glabra* extract and Beeswax to delay senescence, minimize weight loss, and prevent crown rot in *Lakatan* bananas during their peak climacteric phase (Ripening Index D).

Specifically, this study aims:

1. To extract bioactive betalains from *Bougainvillea glabra* bracts and formulate a stable composite emulsion at the laboratory facilities of Silliman University.
2. To evaluate and compare the Physiological Weight Loss (%) over a 7-day accelerated period between the bio-coated bananas, the LDPE Plastic (Positive Control), and the Uncoated (Negative Control) groups.
3. To assess the progression of Crown Rot and Peel Browning (Visual Decay Index) among the different treatment groups after 7 days.
4. To monitor the Progression to Senescence (the rate of transition into Ripening Stage F) of the coated bananas versus the control groups.
5. To determine the most effective concentration (10% or 20%) of *Bougainvillea* extract in the beeswax matrix for short-term preservation.

Hypothesis

The following null (H_0) and alternative (H_a) hypotheses will be tested at a 0.05 level of significance:

1. On Physiological Weight Loss (PWL)

H_0: There is no significant difference in the mean percentage of physiological weight loss over the 7-day observation period among the bananas treated with 10% and 20% *Bougainvillea* extract, the Positive Control (LDPE Plastic), and the Negative Control (Uncoated).

H_a: There is a significant difference in the mean percentage of physiological weight loss among the treatment groups, with the bio-composite emulsions expected to significantly reduce moisture loss compared to the Negative Control.

2. On Visual Decay Index and Senescence

H_0: There is no significant difference in the mean Visual Decay Index scores and the progression to senescence among the four treatment groups.

H_a: There is a significant difference in the mean Visual Decay Index scores and progression to senescence, with the *Bougainvillea*-treated groups showing delayed browning and crown rot due to the antioxidant and antimicrobial properties of the betalains.

3. On Concentration Efficacy

H_0: There is no significant difference in the preservation efficacy (weight loss and decay index) among the 10% and 20% *Bougainvillea* extract concentrations.

H_a: There is a significant difference in the preservation efficacy among the different extract concentrations, with higher concentrations expected to yield better protective results.

Scope and Delimitations

This study employs a Quantitative Experimental Research Design focused on developing a post-harvest "Crown Treatment" for *Lakatan* bananas (*Musa acuminata*). The coating utilizes a composite emulsion of Pectin, Beeswax, Tween 80, and varying concentrations (10% and 20%) of *Bougainvillea glabra* extract.

Due to logistical and equipment constraints, the study is delimited by separating the formulation and observation locales. The maceration of the plant extract (using 30 g of bracts in 650mL of 80% ethanol to prevent clumping) and the precise mixing of the composite emulsion using a magnetic stirrer are delimited to being outsourced and conducted at the laboratory facilities of Silliman University, following the researchers' prescribed methodology. The application of the treatments (dipping the crowns) will be conducted in the laboratory of Ramon Teves Pastor Memorial–Dumaguete Science High School, and the data gathering will be carried out by the researchers in a controlled, well-ventilated classroom within the same institution.

Crucially, the study is delimited to a 7-day accelerated observation period. To accommodate this timeframe, the *Lakatan* bananas selected for the experiment will already be at Ripening Index D. This specific stage represents the peak of the fruit's climacteric phase, where respiration, physiological water loss, and susceptibility to rapid browning and crown rot are at their absolute highest. Utilizing an accelerated decay model allows the researchers to immediately observe the coating's ability to halt rapid senescence compared to the uncoated controls. Furthermore, this research excludes complex chemical analyses such as total soluble solids (Brix) or specific enzyme activity assays (PPO/POD). Data collection is strictly delimited to observable physical indicators: Physiological Weight Loss (PWL) measured in percent, Visual Decay Index (A-F), and visual progression to Index F (over-ripening/decay).

Significance of the Study

This research aims to provide a sustainable solution to post-harvest losses in the banana industry. The findings of this study will redound to the benefit of the following:

Local Farmers and Vendors. They are the primary beneficiaries of this study. Operationally, the development of a low-cost, crown-specific coating allows them to extend the marketability of their produce during the highly vulnerable yellow-ripening stages. By reducing the rate of rapid spoilage and weight loss during final retail display, vendors can maintain profit margins without investing in expensive cold storage or synthetic fungicides.

The Environment. This study is significant for ecological preservation. By validating a biodegradable alternative to Low-Density Polyethylene (LDPE) plastic wraps, this research contributes to the reduction of single use agricultural plastics. This aligns with global sustainability goals by offering a product that decomposes naturally.

Future Researchers. This study serves as a reference for the scientific community, particularly in agricultural engineering and food technology. It fills a knowledge gap by combining the resource efficient "Crown Treatment" method with an accelerated decay model, providing baseline data on the short term efficacy of *Bougainvillea* betalains in lipid hydrocolloid preservation systems.

Definition of Terms

For clarity and better understanding of this study, the following terms are defined conceptually and operationally:

Accelerated Decay Model. Conceptually, a testing framework that observes subjects at their most vulnerable metabolic state to yield rapid data. Operationally, it refers to utilizing *Lakatan* bananas already at Ripening index D to force the rapid observation of weight loss and senescence within a strict 7-day timeframe.

Active Packaging. Conceptually, packaging systems are designed to deliberately interact with the food or its environment to improve safety or extend shelf life. Operationally, it refers to the *Bougainvillea*-Beeswax composite emulsion acting as a physical and biochemical barrier on the banana crown.

Betalains. Conceptually, the nitrogen-containing, water-soluble pigments found in *Bougainvillea glabra* bracts. Operationally, they are the active antioxidant phytochemicals extracted to delay enzymatic browning in the banana tissues.

Climacteric Fruit. Conceptually, fruits that experience a sudden, massive spike in respiration and ethylene production post-harvest. Operationally, it refers to the *Lakatan* bananas used in the study, which naturally undergo rapid physiological decline.

Composite Emulsion. Conceptually, a stable coating formulation created by mixing two immiscible substances, a hydrocolloid (Pectin) and a lipid (Beeswax). Operationally, this refers to the milky-white solution prepared at the Silliman University laboratory, into which the banana crowns are dipped.

Crown Rot. Conceptually, a postharvest fungal disease causes the blackening and softening of the cut stalk tissue. Operationally, it is the deterioration measured daily by the researchers using a Visual Decay Index scale ranging from A (No infection) to F (Severe rot extending to the fruit neck).

Crown Treatment. Conceptually, a targeted, resource-efficient preservation strategy. Operationally, it refers to the physical application of the composite emulsion strictly to the severed tissue connecting the banana hand to the stalk, rather than coating the entire fruit peel.

Enzymatic Browning. Conceptually, the discoloration of fruit tissues is caused by the oxidation of phenolic compounds, primarily catalyzed by Polyphenol Oxidase (PPO). Operationally, the visual darkening of the banana crown and peel was observed over the 7-day experimental period.

Maceration. Conceptually, the extraction process of soaking plant material in a solvent to release bioactive compounds. Operationally, the specific process conducted at Silliman University where 30 g of semi-crushed *Bougainvillea* bracts are steeped in 650ml of 80% Ethanol to prevent clumping.

Physiological Weight Loss (PWL). Conceptually, the reduction in fruit mass over time due to water vapor transpiration and respiration. Operationally, it is calculated as the percentage of the initial weight lost daily, measured using a digital scale over the 7-day observation period.

Progression to Senescence. Conceptually, the final stage of fruit development leads to cellular breakdown and death. Operationally, it replaces traditional shelf-life metrics and measures the rate at which the Index D bananas transition into ripening (yellow with heavy brown spots and structural decay) over 168 hours.

Tween 80. Conceptually, Polysorbate 80, a non-ionic surfactant. Operationally, it is defined as the emulsifying agent utilized by the laboratory, alongside a magnetic stirrer, to successfully disperse the hydrophobic beeswax into the hydrophilic pectin solution.

Review of Related Literature

Post-harvest deterioration in fruits is primarily driven by biochemical and physiological processes that continue even after harvest. Fruits such as bananas remain metabolically active and continue to respire, consuming oxygen and releasing carbon dioxide in a process that accelerates ripening and senescence. According to Kaewjumpol et al. (2021), the ripening and deterioration of bananas are closely associated with enzymatic oxidation processes involving enzymes such as polyphenol oxidase (PPO) and peroxidase (POD), which catalyze the oxidation of phenolic compounds in the presence of oxygen, leading to enzymatic browning. This oxidation process produces free radicals that damage cellular structures and contribute to the visual and physiological spoilage of the fruit. Consequently, controlling oxidative reactions has become a key strategy in extending the shelf life of climacteric fruits such as bananas.

One approach to mitigating oxidative deterioration is through the application of antioxidant compounds that neutralize reactive oxygen species and free radicals responsible for oxidation reactions. Plant-derived antioxidants have received significant attention due to their ability to inhibit oxidative degradation in food systems. Bougainvillea glabra bracts contain high concentrations of betalains and phenolic compounds, which have been identified as potent natural antioxidants. Kuhn et al. (2021) demonstrated that extracts from Bougainvillea bracts exhibit strong antioxidant activity due to their high phenolic content. Similarly, Ferreira et al. (2024) reported that Bougainvillea extracts effectively prevented lipid oxidation in food products, confirming their potential as natural alternatives to synthetic preservatives. The presence of these antioxidant compounds suggests that Bougainvillea bract extract may inhibit oxidation processes responsible for enzymatic browning and spoilage in bananas.

In addition to oxidative reactions, fruit spoilage is also influenced by the physiological respiration of the fruit. Fruits remain living tissues after harvest and continue to undergo metabolic processes, including respiration and ethylene production, which regulate ripening. Bananas are classified as climacteric fruits, meaning they experience a rapid increase in respiration and ethylene production during ripening (Ma et al., 2022). High respiration rates accelerate biochemical changes such as starch conversion, softening, and pigment degradation. Therefore, reducing gas exchange between the fruit and the surrounding environment can effectively slow respiration, delay ripening, and prolong shelf life. Edible coatings function as semi-permeable barriers that regulate the exchange of oxygen, carbon dioxide, and moisture, thereby creating a modified internal atmosphere that slows metabolic activity (Roman-Benn et al., 2023).

Another important factor in banana spoilage is the susceptibility of the crown region to microbial infection. The crown of a banana cluster contains exposed vascular tissues that serve as primary entry points for pathogens responsible for crown rot. Studies have shown that treating the crown area rather than the entire fruit can effectively reduce fungal infection while minimizing excessive coating use. Sripong et al. (2020) demonstrated that targeted crown treatments significantly reduced crown rot by sealing the vascular tissues and preventing pathogen penetration. By applying the coating specifically to the crown region, it is possible to create a protective barrier that prevents microbial invasion while maintaining natural gas exchange across the peel.

The effectiveness of edible coatings largely depends on their structural composition. Polysaccharide-based coatings such as pectin provide structural integrity and adhesion to the fruit surface. Pectin is widely used in edible coatings due to its film-forming capability and ability to create a uniform protective layer (Liang et al., 2022). However, polysaccharide coatings alone are highly hydrophilic and offer limited resistance to moisture loss. To address this limitation, lipid components such as beeswax are often incorporated into composite coatings. Beeswax forms a hydrophobic barrier that significantly reduces water vapor transmission and minimizes moisture loss from the fruit surface. Formiga et al. (2019) reported that the addition of beeswax to hydrocolloid-based coatings improved their moisture barrier properties and effectively reduced physiological weight loss in fruits.

By integrating these principles, the present study proposes a composite edible coating composed of pectin, beeswax, and Bougainvillea glabra bract extract. The pectin serves as the structural matrix that allows the coating to adhere to the banana surface, while beeswax provides a hydrophobic barrier that limits water loss and gas exchange. The incorporation of Bougainvillea extract introduces antioxidant compounds capable of inhibiting oxidative reactions associated with browning and spoilage. Together, these components form an antioxidant-enriched bio-composite coating that addresses the primary mechanisms of post-harvest deterioration—oxidation, respiration, moisture loss, and microbial infection. Through this mechanism, the coating is hypothesized to reduce physiological weight loss, delay browning, and extend the shelf life of Lacatan bananas.

Theoretical Framework

Post-harvest deterioration in fruits is primarily driven by biochemical and physiological processes that continue even after harvest. Fruits such as bananas remain metabolically active and continue to respire, consuming oxygen and releasing carbon dioxide in a process that accelerates ripening and senescence. According to Kaewjumpol et al. (2021), the ripening and deterioration of bananas are closely associated with enzymatic oxidation processes involving enzymes such as polyphenol oxidase (PPO) and peroxidase (POD), which catalyze the oxidation of phenolic compounds in the presence of oxygen, leading to enzymatic browning. This oxidation process produces free radicals that damage cellular structures and contribute to the visual and physiological spoilage of the fruit. Consequently, controlling oxidative reactions has become a key strategy in extending the shelf life of climacteric fruits such as bananas.

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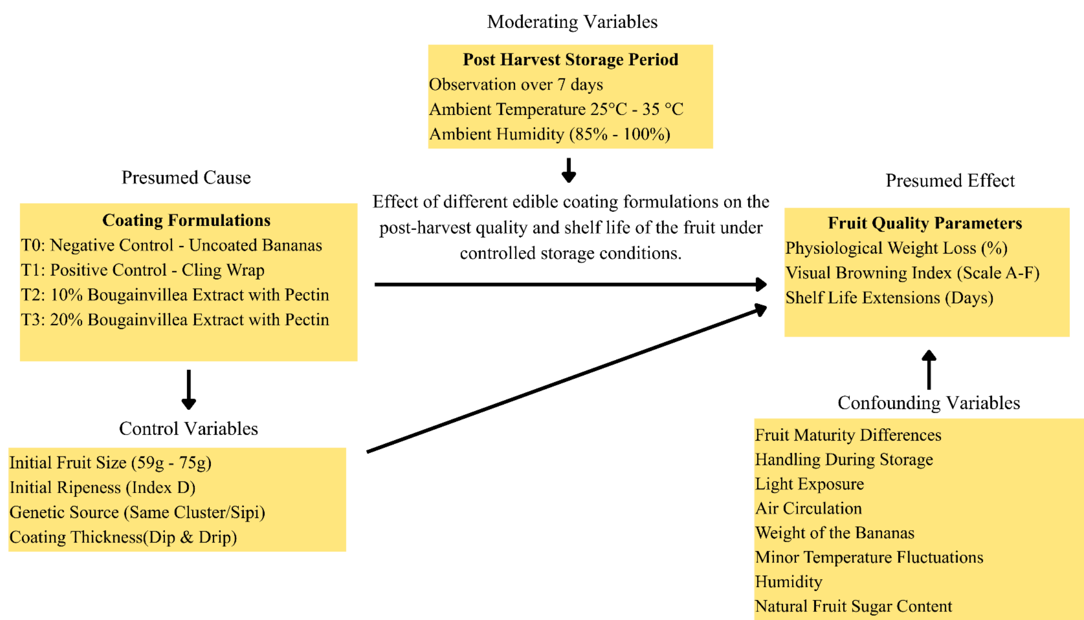
Conceptual Framework

Figure 1

Conceptual Framework



Methodology

Research Design

This study employed a quantitative experimental research design to evaluate the efficacy of a Bougainvillea glabra bio-composite emulsion on the postharvest preservation of Lacatan bananas. The experiment utilized a Completely Randomized Design (CRD) with four specific treatment groups: a negative control (untreated), a positive control (plastic wrapper), Treatment 1 (10% extract concentration), and Treatment 2 (20% extract concentration).

Research Environment

The extraction and formulation of the bio-composite coating solutions were carried out at the Silliman University Science Complex, specifically in the laboratories of the Biology Department, where laboratory equipment such as a rotary evaporator was used to remove ethanol from the bougainvillea bract extract, and a magnetic stirrer was also utilized during the preparation of the wax-based coating to ensure proper mixing and uniform formulation. Following the preparation and application of the coatings, the treated bananas were stored and observed at Ramon Teves Pastor Memorial–Dumaguete Science High School. The samples were placed in a designated indoor observation area where ambient temperature and relative humidity were monitored throughout the duration of the study.

Subject of the Study and Sampling Technique

The primary biological subjects of this experiment were yellow-green Lacatan bananas (Musa acuminata), selected using purposive sampling to ensure uniform size, absence of bruises, and a baseline of Ripening Stage C (Refer to Figure 4). A total of eight (8) bananas were randomly assigned to the four treatment groups (two bananas per group). Additionally, the active ingredient was sourced from fully bloomed and colored Bougainvillea glabra bracts, specifically utilizing the purple, magenta, and pink varieties to maximize betalain and antioxidant content.

Research Instruments

The study utilized several instruments for the preparation of the Bougainvillea bract extract, the formulation of the bio-composite edible coating, and the monitoring of experimental conditions during the storage of Lacatan bananas. These tools were essential for extracting the bioactive compounds from the Bougainvillea bracts, producing a stable coating formulation, applying the treatment to the bananas, and maintaining controlled environmental conditions during the observation period. The use of appropriate laboratory equipment ensured accuracy, consistency, and reliability in both the preparation of materials and the collection of experimental data.

a. Bougainvillea Bracts. Bougainvillea bracts served as the primary biological material used for extracting natural antioxidant compounds. These colorful modified leaves contain betalains and phenolic compounds known for their antioxidant properties, which may help inhibit oxidative browning and delay spoilage in fruits. Fresh bracts were collected, cleaned, and processed to obtain the crude extract used as the active ingredient in the edible coating formulation. The selection of Bougainvillea bracts was based on their documented antioxidant potential and their accessibility as an abundant ornamental plant.

b. Food Processor. A food processor was used to grind and pulverize the dried Bougainvillea bracts into smaller particles. This mechanical breakdown of plant tissue increases the surface area of the bract material, allowing the extraction solvent to penetrate more efficiently and dissolve the bioactive compounds present in the plant cells. The use of a food processor ensured that the plant material was uniformly processed, thereby improving the efficiency and consistency of the maceration extraction process.

c. Ethanol (80%). Ethanol at an 80% concentration was used as the solvent for extracting antioxidant compounds from the Bougainvillea bracts. Ethanol is widely used in plant extraction procedures because of its ability to dissolve both polar and moderately nonpolar phytochemicals, including phenolic compounds and betalains. The solvent facilitates the separation of these bioactive compounds from the plant tissues during the maceration process, resulting in a crude extract that can later be incorporated into the edible coating formulation.

d. Glass Jars. Glass jars were used as containers for the maceration extraction process. The pulverized Bougainvillea bracts were submerged in the ethanol solvent inside the jars and left to soak for a designated period to allow the solvent to extract the bioactive compounds from the plant material. Glass containers were chosen because they are chemically inert and do not react with ethanol or the plant extract, ensuring the purity and stability of the extracted compounds.

e. Cheesecloth and Funnel. A cheesecloth in combination with a laboratory funnel was used to filter the macerated mixture after the extraction process. The cheesecloth acted as a filtration medium that separated the solid plant residues from the liquid extract, allowing only the crude Bougainvillea extract to pass through. This step ensured that the final extract was free from large plant particles that could interfere with the stability and uniformity of the coating formulation.

f. Rotary Evaporator. A rotary evaporator was used to remove excess ethanol solvent from the crude Bougainvillea extract through controlled evaporation. This equipment operates by rotating the sample under reduced pressure while gently heating it, allowing the solvent to evaporate at a lower temperature. The use of a rotary evaporator helps concentrate the extract while preventing thermal degradation of heat-sensitive antioxidant compounds such as betalains.

g. Beakers. Laboratory beakers were used as mixing containers during the preparation of the edible coating formulation. These glass vessels allowed the researchers to combine the coating components, including pectin, beeswax, Tween 80, and the Bougainvillea extract, in a controlled and measurable environment. The transparency and heat resistance of the beakers made them suitable for both mixing and heating procedures.

h. Heatplate with Magnetic Stirrer. A laboratory heat plate equipped with a magnetic stirrer was used to heat and continuously mix the coating solution during preparation. Heating was necessary to dissolve the pectin in the aqueous phase and to properly melt the beeswax component. Meanwhile, the magnetic stirring mechanism ensured uniform mixing of the ingredients, preventing separation between the hydrophilic and hydrophobic components of the coating.

i. Glass Stirring Rod. A glass stirring rod was used to manually mix and adjust the coating formulation when necessary. Manual stirring helped ensure that all components were evenly distributed within the mixture and prevented localized clumping of the polymer components such as pectin.

j. Glass Pipette. A glass pipette was used to measure and transfer precise volumes of Bougainvillea extract and other liquid components into the coating formulation. The use of a pipette allowed for accurate preparation of different extract concentrations used in the experimental treatments.

k. Plastic Wrap. Plastic wrap was used as the positive control treatment in the experiment. Bananas assigned to this group were wrapped using commercial plastic film, which served as a benchmark comparison against the experimental bio-composite coating. This allowed the researchers to evaluate whether the Bougainvillea-based coating could perform similarly or better than conventional plastic-based preservation methods.

l. Plastic Container. Plastic containers were used to store and organize the bananas during the experimental observation period. Each container housed bananas from specific treatment groups and was labeled accordingly to prevent mixing of samples. The containers also protected the fruits from external contaminants while allowing them to remain in a controlled indoor environment.

m. Digital Thermometer and Hygrometer. A digital thermometer and hygrometer were used to monitor the ambient temperature and relative humidity of the storage environment. These environmental factors significantly influence the respiration rate and spoilage of bananas. Recording these conditions daily ensured that all treatment groups were exposed to consistent environmental conditions, allowing the observed differences in fruit quality to be attributed primarily to the coating treatments.

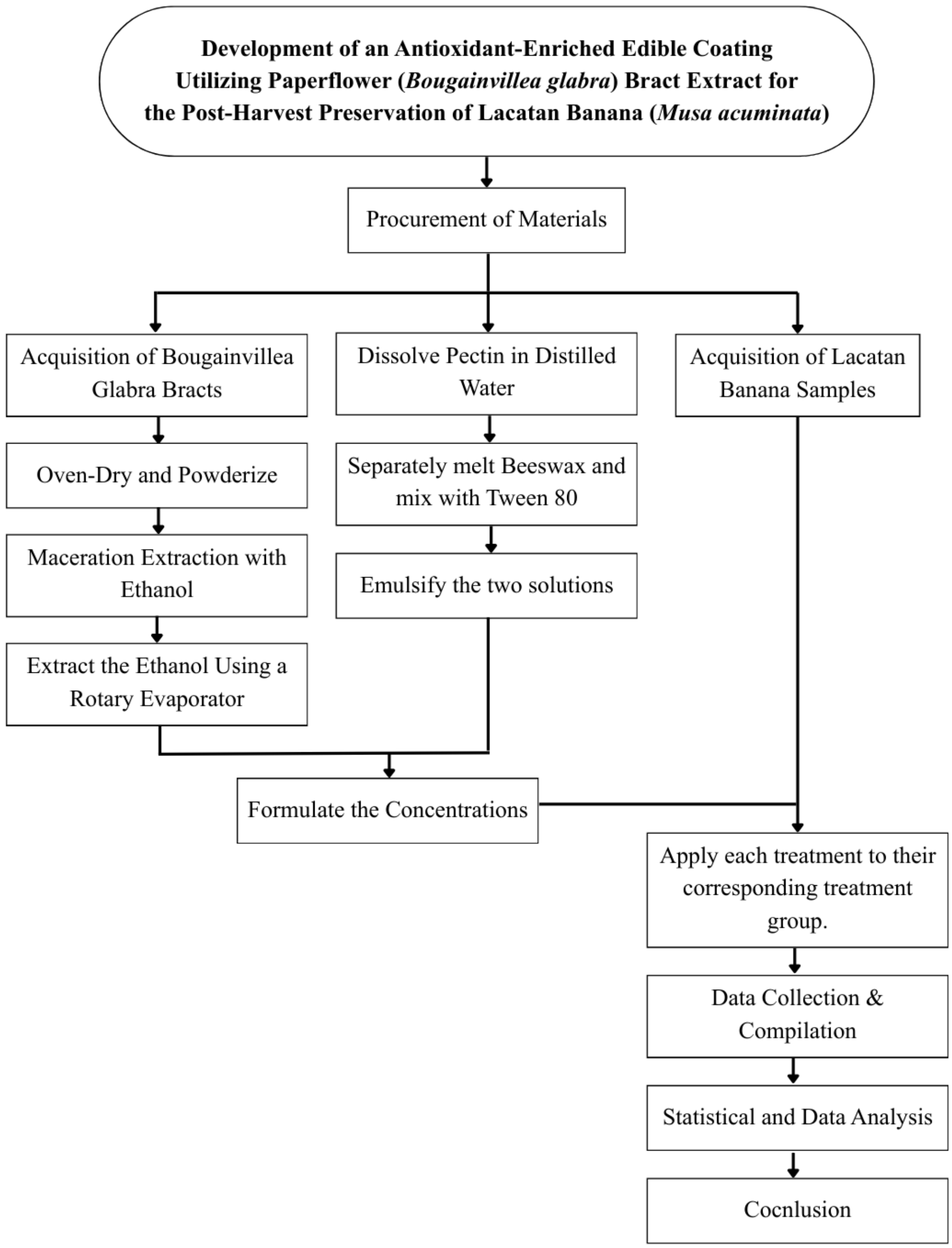
n. Digital Weighing Scale. A digital weighing scale was used to measure the mass of each banana before and during storage. The initial weight was recorded prior to coating application, and subsequent measurements were taken daily to determine weight loss caused by transpiration and respiration. These measurements were used to compute the percentage of weight loss and to compare the effectiveness of the Bougainvillea-based coating across treatments.

o. Banana Ripening Index. The banana ripening index was used to classify the ripeness stage of the samples based on peel color changes from green to yellow and speckled yellow. Bananas were visually compared with the standardized ripening scale to ensure consistent evaluation across treatments. The index was adapted from the study Edible Coatings Based on Natural Compounds for Extending Banana Shelf Life.

General Procedure

Figure 2

Procedural Framework



A. Bougainvillea Bract Collection and Extraction

Bougainvillea bracts were collected from multiple plants to obtain sufficient material for extraction. To reduce biological variability and ensure chemical uniformity, a composite sampling approach was employed, in which bracts from different plants were pooled into a single bulk sample and thoroughly mixed prior to subsampling for extraction (Lancaster & Keller-McNulty, 1994). Specific criteria were followed during bract selection to ensure consistency in pigment composition. Only magenta and purple bracts were collected, as studies have shown that purple Bougainvillea varieties contain the highest concentrations of betacyanin pigments compared with other color varieties (Kuhn et al., 2021). Although Bougainvillea bracts may occur in colors such as pink, magenta, and purple, only the magenta and purple bracts were included in the sample set for this study. Additionally, only fully bloomed and fully colored bracts were selected to maintain maturity consistency and maximize pigment concentration. Bract collection was conducted between 12:00 PM and 6:00 PM to maintain consistency in environmental conditions that may influence plant metabolite levels.

After collection, the bracts were washed thoroughly with distilled water to remove dirt and surface contaminants. The cleaned bracts were then dried at 40–50 °C to minimize degradation of heat-sensitive betalain pigments. Bougainvillea bracts are known to contain betalain pigments such as betacyanins and betaxanthins, which exhibit strong antioxidant activity and potential applications as natural food additives (Wu et al., 2022). The dried bracts were subsequently processed for extraction.

The dried bracts were pulverized into fine powder using a food processor and stored in airtight containers until extraction. For extraction, 30 g of powdered Bougainvillea bracts were macerated in 650 mL of 80 % ethanol in a sealed glass container. Ethanol was selected as the extraction solvent because studies have shown that ethanol-based solvents effectively extract phenolic compounds, flavonoids, and betalain pigments from Bougainvillea tissues (Alonso-Castro et al., 2016; Wu et al., 2022). The maceration process was allowed to proceed for five days (February 27 to March 3) at room temperature with periodic agitation to improve solvent penetration and maximize extraction yield.

After maceration, the extract was filtered using a cheesecloth and a laboratory funnel to remove plant residues. The filtrate was then concentrated using a rotary evaporator, which removes solvents under reduced pressure to lower the boiling point of ethanol and prevent thermal degradation of bioactive compounds. Rotary evaporation is commonly used for concentrating plant extracts while preserving sensitive phytochemicals. The evaporation process was conducted at approximately 40 °C for 48 minutes (March 4) until the ethanol solvent had been completely removed, leaving 24mL of the concentrated Bougainvillea extract.

B. Edible Coating Formulation

The edible coating base was prepared using a pectin–beeswax emulsion system adapted from formulations reported in recent edible coating research. In these systems, pectin functions as the primary film-forming polymer, providing viscosity and structural integrity to the coating matrix, while beeswax serves as a hydrophobic lipid barrier that reduces water vapor permeability and moisture loss from coated fruits (Vergel-Alfonso et al., 2025). The combination of polysaccharide and lipid components enables the formation of a thin protective film capable of slowing respiration and delaying fruit deterioration.

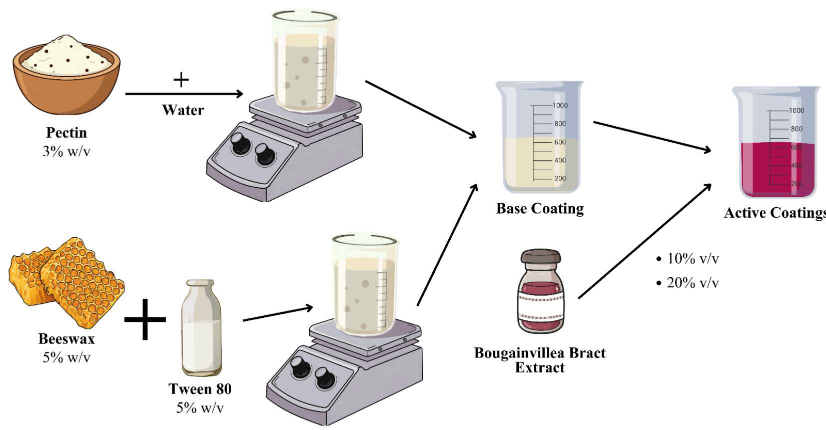
Because pectin is hydrophilic and beeswax is hydrophobic, emulsification is required to produce a stable coating mixture. Tween 80 (polysorbate 80) was incorporated as a food-grade non-ionic surfactant to facilitate the dispersion of the wax phase within the aqueous pectin matrix. Surfactants such as Tween 80 reduce interfacial tension between the lipid and aqueous phases, enabling the formation of stable emulsified coatings (Vergel-Alfonso et al., 2025).

To prepare the coating base, approximately 900 mL of distilled water was heated to 60–70 °C, after which 30 g of pectin (3 % w/v) were gradually added with continuous stirring using a magnetic stirrer until a homogeneous viscous solution was obtained. In a separate beaker, the lipid phase was prepared by melting 50 g of beeswax (5 % w/v) together with 50 g of Tween 80 (5 % w/v) at 70–75 °C until a clear liquid was formed.

The melted beeswax–Tween mixture was then slowly poured into the hot pectin solution while stirring continuously. The resulting mixture was maintained at approximately 70 °C and agitated at 1500 rpm for 15 minutes to promote proper emulsification and produce a stable coating solution. Continuous agitation ensured uniform dispersion of wax droplets within the pectin matrix, forming a milky emulsion suitable for edible coating applications (Vergel-Alfonso et al., 2025).

Figure 3

Coating Production Process



C. Formulation of Coating Concentrations

To evaluate the effect of Bougainvillea extract concentration on banana preservation, two active coating treatments were prepared by incorporating the extract into the base coating formulation.

Each banana required approximately 30 mL of coating solution. Therefore, 60 mL of coating mixture was prepared for each treatment group

The 10 % extract formulation was prepared by mixing 6 mL of Bougainvillea extract with 54 mL of base coating, while the 25 % extract formulation was prepared by mixing 12 mL of extract with 48 mL of base coating. The mixtures were gently stirred using a glass pipette to ensure uniform dispersion of the extract throughout the coating solution.

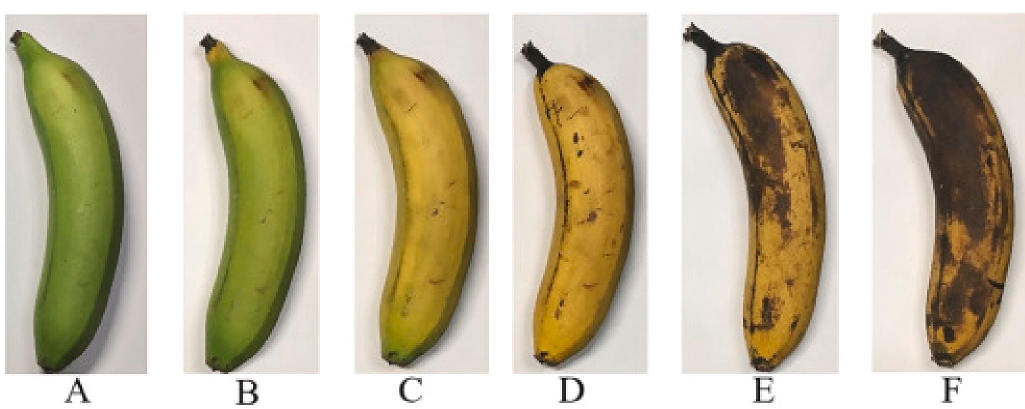
D. Application of Coating and Storage Conditions

Bananas selected for the study were standardized for size and weight to minimize variability. All fruits were obtained from the same bunch to ensure similar physiological age and were classified as Ripening Index C (Refer to Figure 4) prior to treatment. To avoid selection bias and ensure equal representation across treatments, randomized sampling was used to assign the bananas to their respective treatment groups. Bananas used in the experiment were washed thoroughly with distilled water and dried using paper towels to remove surface contaminants. Fruits were then standardized based on size, weight, and ripeness stage to reduce variability in the experiment.

Figure 4

Banana Ripening index based on color peel stages.

*Adapted from **Ma et al. (2022)***



The coating was applied using the dip-and-drip method, a widely used technique in edible coating research that allows uniform coating coverage on fruit surfaces (Ulya et al., 2010). Each banana was submerged in the coating solution for approximately 30 seconds and then suspended vertically to allow excess coating to drip off. The coated bananas were air-dried until the surface became non-tacky.

The bananas were placed inside a large plastic container for storage. The container was kept partially open to allow ventilation and minimize the accumulation of ethylene gas, which accelerates fruit ripening. The samples were stored under ambient laboratory conditions for 7 days.

Environmental conditions were monitored using a thermometer–hygrometer to record temperature and relative humidity. Observations were conducted daily at 3:00 PM to ensure consistent data collection intervals.

Data Gathering Procedure

The data gathering procedure was divided into three main phases: the formulation of the bio-composite concentrations, the application of the treatments, and the daily evaluation of the subjects.

Formulation of Concentrations

The composite coating was formulated into two experimental concentrations: 10% and 20% Bougainvillea extract. The target volume for each treatment batch was 60 mL, estimating 30 mL of coating per banana. The base emulsion was created using beeswax, pectin, and Tween 80. If the wax base solidified, it was placed on a heat plate and gently reheated until it reached a workable, liquid consistency. The concentrations were then formulated using a glass pipette following these exact ratios:

- 10% Concentration: 6 mL of the Bougainvillea extract was thoroughly mixed with 54 mL of the liquid wax base to yield 60 mL of the final coating.

- 20% Concentration: 12 mL of the Bougainvillea extract was thoroughly mixed with 48 mL of the liquid wax base to yield 60 mL of the final coating.

Treatment Application

The selected Lacatan bananas were washed thoroughly with distilled water and gently patted dry. For the experimental groups, the 10% and 20% formulations were applied evenly using a brush or spray method. For the positive control group, the bananas were tightly wrapped in commercial plastic wrappers. The negative control group was left completely untreated. The coated bananas were allowed to air-dry for 15 minutes. Once dry, they were placed inside labeled plastic containers with the lids left open to simulate market conditions.

Daily Observation and Measurement

Data collection was conducted daily at exactly 3:00 PM to ensure consistency and reliability. During each daily evaluation, the ambient temperature and humidity were recorded. Each banana was individually weighed to track physiological weight loss: Calculated using the formula:

$$\text{PWL (in percent)} = \frac{Initial\ Weight\ Loss - Final\ \ Weight\ Loss}{Initial\ Weight\ Loss} * 100$$

The physical appearance of the bananas was cross-referenced with the standard banana color index to document the progression of ripening and decay, tracking the transition up to Ripening Stage F (yellow with brown spots) over a targeted 7-day observation period. (Refer to Figure 4)figure

Data Analysis

The collected quantitative data, including daily weight measurements and the progression of the ripening or browning index, were organized using Google Sheets. Descriptive statistics were used to summarize the observed changes across the four treatment groups. To analyze the differences in physiological weight loss among treatments, a One-Way Analysis of Variance (ANOVA) Test was applied to determine whether significant differences existed between the untreated, cling wrap, 10% Bougainvillea extract, and 20% Bougainvillea extract groups. Meanwhile, the visual decay, which was measured using an ordinal scale, was analyzed using the Kruskal–Wallis test to assess whether significant differences in ripening progression were present among the treatment groups.

Ethical Considerations

While this study did not involve human participants, strict laboratory and environmental protocols were followed. The fully bloomed Bougainvillea glabra bracts were harvested sustainably. Furthermore, the formulation process at the Silliman University laboratory strictly adhered to safety guidelines regarding the heating of waxes and the handling of chemical emulsifiers like Tween 80. All biological wastes and residual solutions were disposed of properly to prevent environmental contamination.

Results and Discussions

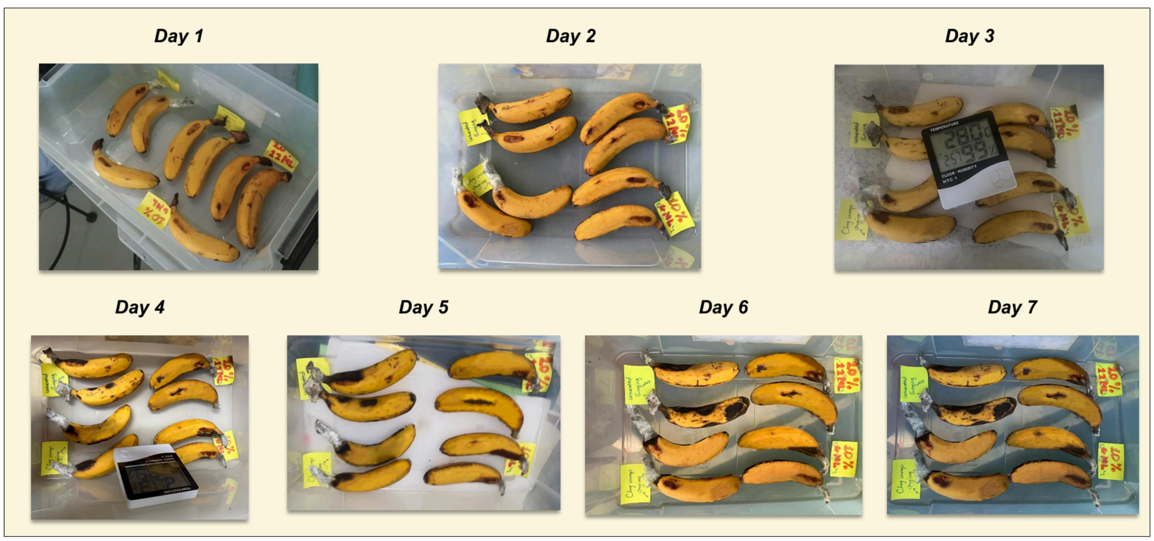
Presentation of Results

A. Visual Decay Index Data of Banana Samples

After the seven-day storage period, the researchers observed noticeable changes in each banana sample. These changes, shown in Figure 5, reflected the progression of browning and senescence throughout the observation period.

Figure 5

Seven-Day Banana Storage Documentation



Note. Following day two, untreated bananas are located at the top-left corner, bananas treated with cling wrap are located at the bottom-left corner, 10% bougainvillea at the bottom-right corner, and 20% bougainvillea at the top-right corner. Bananas on the top part of each treatment belong to group A, while the bottom part belongs to group B.

A major change observed during the storage period, aside from the presence of mold, was the progression of browning in the form of dark spots on the banana peel. These dark spots gradually spread and became noticeably darker starting around the fourth day of observation. This change was most evident in the bananas that received no treatment, where the dark spots expanded more extensively over time.

In contrast, most of the bananas treated with Bougainvillea extract showed a slower spread of dark spots. Yet, one banana from the 10% Bougainvillea treatment exhibited a more pronounced spread of dark spots compared to the other treated samples. Bananas treated with cling wrap and the 20% Bougainvillea coating showed fewer and less intense dark spots compared to the other groups. Among all treatments, cling wrap remained the most effective method in minimizing the spread and intensity of browning throughout the storage period.

Table 1 presents the progression of the visual decay index of bananas under different preservation treatments over seven days. The browning index data indicate that bananas without any preservation treatment experienced the fastest rate of ripening and browning, reaching index F as early as Days 5–6. In contrast, bananas treated with Bougainvillea extract coatings maintained lower browning index values for a longer duration throughout the storage period. Among the treatments, the 20% Bougainvillea coating demonstrated the slowest progression of browning, with most samples remaining at index D for the majority of the observation period. These findings suggest that the Bougainvillea coating may help slow enzymatic browning and delay the ripening process, thereby contributing to the preservation of the bananas during storage.

Table 1

Progression of Visual Decay Index of Bananas Under Different Preservation Treatments

GROUP A BANANAS							
Preservation Method	DAYS						
	1	2	3	4	5	6	7
Cling Wrap	D	D	D	D	D	D	E
No Treatment	D	D	D	E	F	F	F
Bougainvillea (10%) & Beeswax	D	D	D	D	E	E	E
Bougainvillea (20%) & Beeswax	D	D	D	D	D	D	E

GROUP B BANANAS							
Preservation Method	DAYS						
	1	2	3	4	5	6	7
Cling Wrap	D	D	D	D	D	E	E
No Treatment	D	D	E	E	F	F	F
Bougainvillea (10%) & Beeswax	D	D	D	D	E	E	E
Bougainvillea (20%) & Beeswax	D	D	D	D	D	E	E

Note. The values indicated are based on the banana browning index present in Figure 4 within the methodology section

B. Physiological Weight Loss Data of Banana Samples

After the seven-day storage period, the researchers observed that most of the banana samples appeared slightly lighter in mass compared to their initial condition. This change is likely due to moisture loss and respiration occurring during the storage period. Following the prescribed procedures for measuring weight, the researchers recorded the final mass of each banana sample. Table 2 presents the amount of weight lost by each banana throughout the seven-day observation period.

Table 2

Changes in Banana Weight Under Different Preservation Treatments

Group A BANANAS							
Preservation Method	Day						
	1	2	3	4	5	6	7
Cling Wrap	62	58	57	57	56	54	54
No Treatment	59	57	55	52	50	47	46
Bougainvillea (10%) & Beeswax	62	59	57	53	52	50	48
Bougainvillea (20%) & Beeswax	62	60	59	57	56	55	55

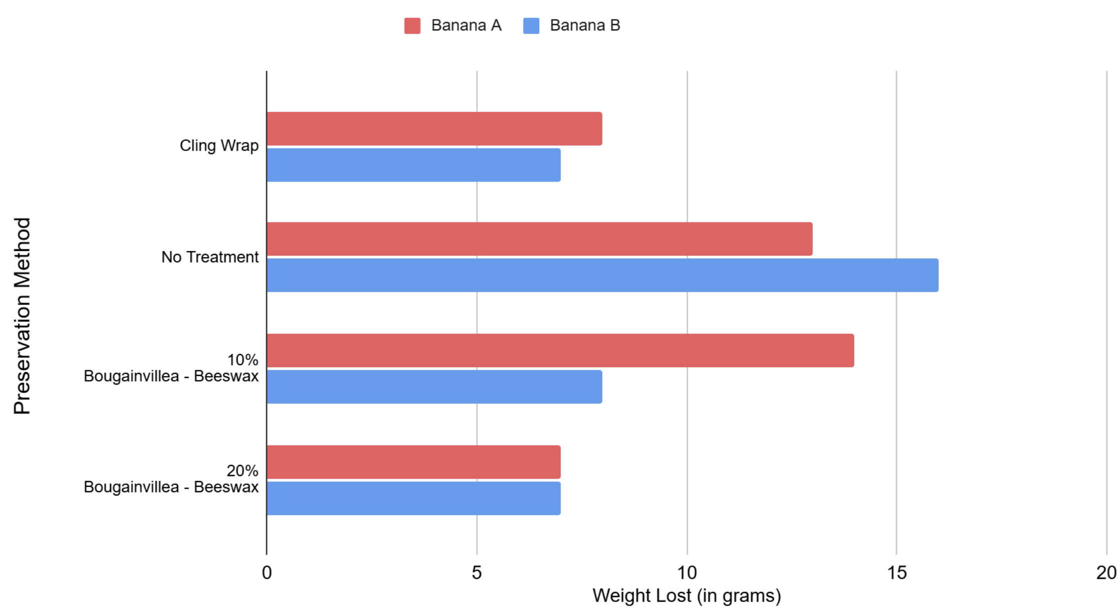
GROUP B BANANAS							
Preservation Method	Day						
	1	2	3	4	5	6	7
Cling Wrap	63	60	59	58	58	57	56
No Treatment	60	56	53	51	49	46	44
Bougainvillea (10%) & Beeswax	57	55	53	52	51	51	49
Bougainvillea (20%) & Beeswax	75	73	72	71	70	70	68

Note: The values recorded are the weight of each banana measured in grams.

The bananas preserved using cling wrap and the 20% Bougainvillea coating exhibited smaller intervals of weight loss compared to the other treatments throughout the seven-day storage period. These samples showed a more gradual decrease in weight, indicating that both preservation methods were more effective in slowing moisture loss during storage. In contrast, the bananas that received no treatment experienced the largest intervals of weight loss, with their mass decreasing more rapidly over time.

Figure 6

Total Weight Loss of Bananas Under Different Preservation Treatments



This graph suggests that the absence of a protective coating allowed greater moisture loss through transpiration and respiration. While the 10% Bougainvillea coating provided some level of preservation, its weight loss pattern was still more pronounced than that of the cling wrap and the 20% Bougainvillea treatment. Overall, the results indicate that cling wrap and the higher concentration Bougainvillea coating were more effective in reducing weight loss and maintaining the physical condition of the bananas during the storage period.

Table 3

Physiological Weight Loss of Bananas Under Different Preservation Treatments

Preservation Method	Group A Bananas	Group B Bananas	Total
Cling Wrap	12.90%	11.11%	24.01%
No Treatment	22.03%	26.67%	48.70%
Bougainvillea (10%) & Beeswax	22.58%	14.04%	36.62%
Bougainvillea (20%) & Beeswax	11.29%	9.33%	20.62%

Bananas without treatment exhibited the highest total weight loss at 48.70%, indicating greater moisture loss during storage. The Bougainvillea (10%) and beeswax treatment showed moderate weight loss at 36.62%. In comparison, cling wrap resulted in lower weight loss at 24.01%, while the Bougainvillea (20%) and beeswax coating recorded the lowest total weight loss at 20.62%, suggesting it was the most effective treatment in minimizing weight loss.

Discussion

As the evidence presented indicates that applying bougainvillea coating to bananas has the potential to be as effective as cling wrap for preservation, a hypothesis test will be conducted to support this further. However, with the sample size being small (n = 2), the researchers cannot conduct a reliable inferential statistical test because the limited number of samples does not provide sufficient data to estimate variability within each treatment group. Conducting statistical tests under these conditions may produce unreliable or misleading results. (Makin & De Xivry, 2019)

Although descriptive analysis suggests that the Bougainvillea coating may be as effective as cling wrap in delaying browning and senescence, relying solely on descriptive observations is insufficient to establish a definitive conclusion. Descriptive analysis summarizes observed trends in the data but does not determine whether observed differences between treatments are statistically significant or merely reflect natural variation among bananas (Alabi & Bukola, 2023). While the results indicate a promising potential for Bougainvillea coating as a preservation method, further experimentation with a larger sample size and appropriate statistical analysis is necessary to validate and generalize these findings.

Implications

The results of the study suggest that Bougainvillea extract combined with beeswax may help delay browning and reduce weight loss in bananas, indicating its potential as a natural fruit coating. This finding highlights the possible use of plant-derived compounds with antioxidant properties as alternatives to synthetic preservatives in post-harvest storage. Additionally, the coating may offer a low-cost preservation method for small-scale fruit vendors and households. However, further studies with larger sample sizes are necessary to validate these findings and explore the broader applications of Bougainvillea-based coatings in fruit preservation.

Summary, Conclusion, and Recommendation

Summary of Findings

This study investigated the effectiveness of a Bougainvillea extract and beeswax coating as a natural preservation method for bananas during a seven-day storage period. The study examined its effects on browning progression and physiological weight loss, comparing the coating with cling wrap and bananas that received no treatment.

The results of the visual decay index showed that bananas without treatment experienced the fastest browning and ripening, reaching higher browning index values earlier than the other treatments. In contrast, bananas coated with Bougainvillea extract showed a slower spread of dark spots and delayed browning. Among the coated treatments, the 20% Bougainvillea extract combined with beeswax maintained lower browning index values for a longer period. Cling wrap also effectively reduced the spread and intensity of dark spots during storage.

The physiological weight loss data further supported these findings. Bananas without treatment showed the highest total weight loss at 48.70%, while the Bougainvillea (10%) coating recorded 36.62%. In comparison, cling wrap and the Bougainvillea (20%) coating showed the lowest weight loss at 24.01% and 20.62%, respectively, indicating better moisture retention. However, due to the small sample size used in the experiment, only descriptive analysis was conducted. Further studies with larger sample sizes are recommended to confirm the effectiveness of the Bougainvillea coating as a preservation method.

Conclusion

Based on the results of the study, the Bougainvillea extract combined with beeswax demonstrated potential as a natural preservation coating for bananas. The treatment helped slow the progression of browning and reduced physiological weight loss compared to bananas that received no treatment. Among the treatments tested, the 20% Bougainvillea coating showed the most promising results, performing similarly to cling wrap in maintaining the quality of bananas during the storage period.

However, because the experiment used a limited number of samples, the findings cannot yet be generalized with certainty. Further experimentation with larger sample sizes and more rigorous statistical analysis is necessary to fully determine the effectiveness of Bougainvillea-based coatings as an alternative preservation method.

Recommendations

Based on the findings of the study, the following recommendations are proposed:

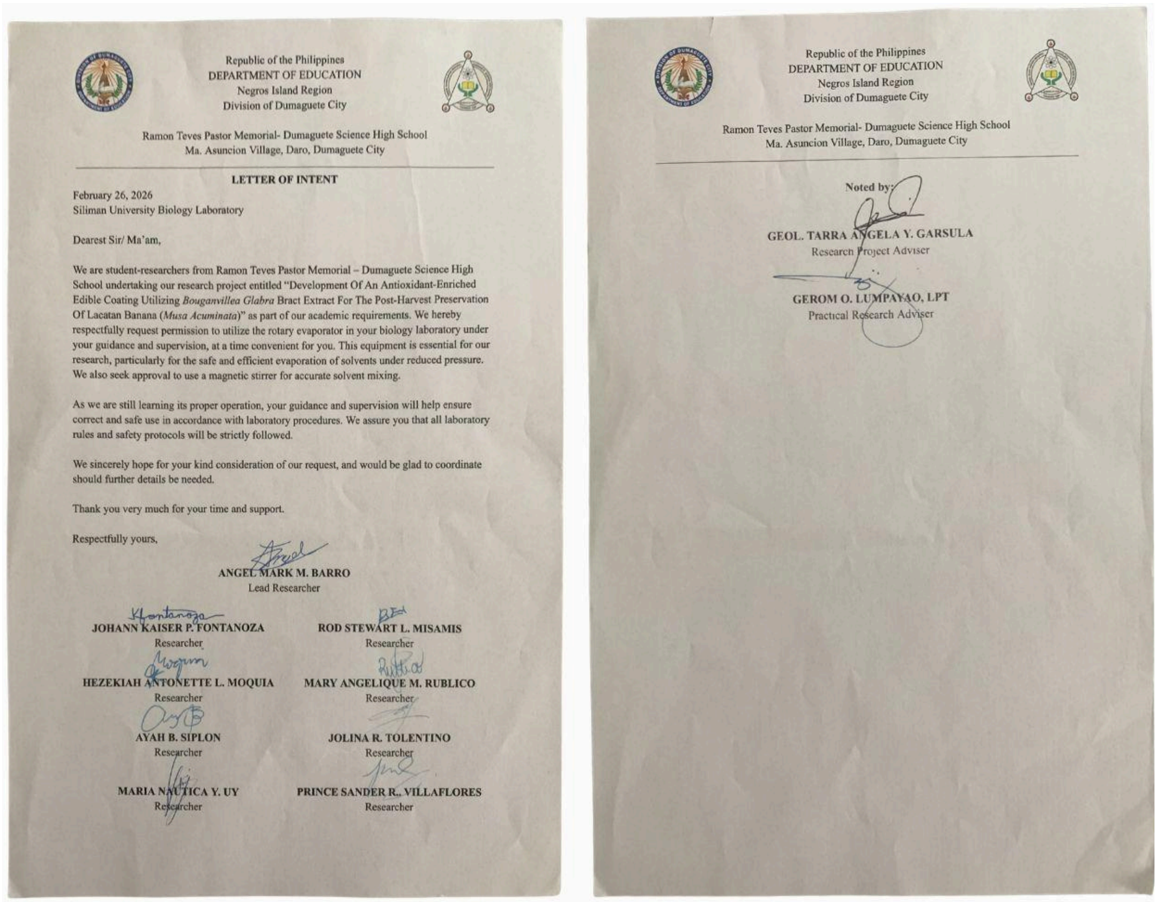
1. Future researchers should conduct similar studies using a larger sample size to allow for more reliable statistical analysis and stronger conclusions.
2. Further experiments may explore different concentrations of Bougainvillea extract to determine the most effective formulation for fruit preservation.
3. Future studies may test the Bougainvillea coating on bananas at an earlier stage of ripeness, particularly when the bananas are still green (corresponding to index A in the browning index chart), in order to determine whether applying the coating earlier can further extend the storage life of the fruit.

4. Additional research could also examine the effectiveness of Bougainvillea-based coatings on other fruits to evaluate their potential applications in post-harvest preservation.
5. Researchers may also investigate the specific chemical properties of Bougainvillea extract that contribute to its potential antioxidant and preservation effects.

APPENDICES

APPENDIX A. Letter of Intent

Photo of the approved letter of intent submitted to the school administration requesting permission to conduct the research study.



Republic of the Philippines
DEPARTMENT OF EDUCATION
Negros Island Region
Division of Dumaguete City

Ramon Teves Pastor Memorial- Dumaguete Science High School
Ma. Asuncion Village, Daro, Dumaguete City

LETTER OF INTENT

February 26, 2026
Siliman University Biology Laboratory

Dearest Sir/ Ma'am,

We are student-researchers from Ramon Teves Pastor Memorial – Dumaguete Science High School undertaking our research project entitled "Development Of An Antioxidant-Enriched Edible Coating Utilizing *Bouganvillea Glabra* Bract Extract For The Post-Harvest Preservation Of Lacatan Banana (*Musa Acuminata*)" as part of our academic requirements. We hereby respectfully request permission to utilize the rotary evaporator in your biology laboratory under your guidance and supervision, at a time convenient for you. This equipment is essential for our research, particularly for the safe and efficient evaporation of solvents under reduced pressure. We also seek approval to use a magnetic stirrer for accurate solvent mixing.

As we are still learning its proper operation, your guidance and supervision will help ensure correct and safe use in accordance with laboratory procedures. We assure you that all laboratory rules and safety protocols will be strictly followed.

We sincerely hope for your kind consideration of our request, and would be glad to coordinate should further details be needed.

Thank you very much for your time and support.

Respectfully yours,

ANGEL MARK M. BARRO
Lead Researcher

JOHANN KAISER P. FONTANOZA
Researcher

ROD STEWART L. MISAMIS
Researcher

HEZEKIAH ANTONETTE L. MOQUIA
Researcher

MARY ANGELIQUE M. RUBLICO
Researcher

AYAH B. SIPLON
Researcher

JOLINA R. TOLENTINO
Researcher

MARIA NAUTICA Y. UY
Researcher

PRINCE SANDER R.. VILLAFLORES
Researcher

Republic of the Philippines
DEPARTMENT OF EDUCATION
Negros Island Region
Division of Dumaguete City

Ramon Teves Pastor Memorial- Dumaguete Science High School
Ma. Asuncion Village, Daro, Dumaguete City

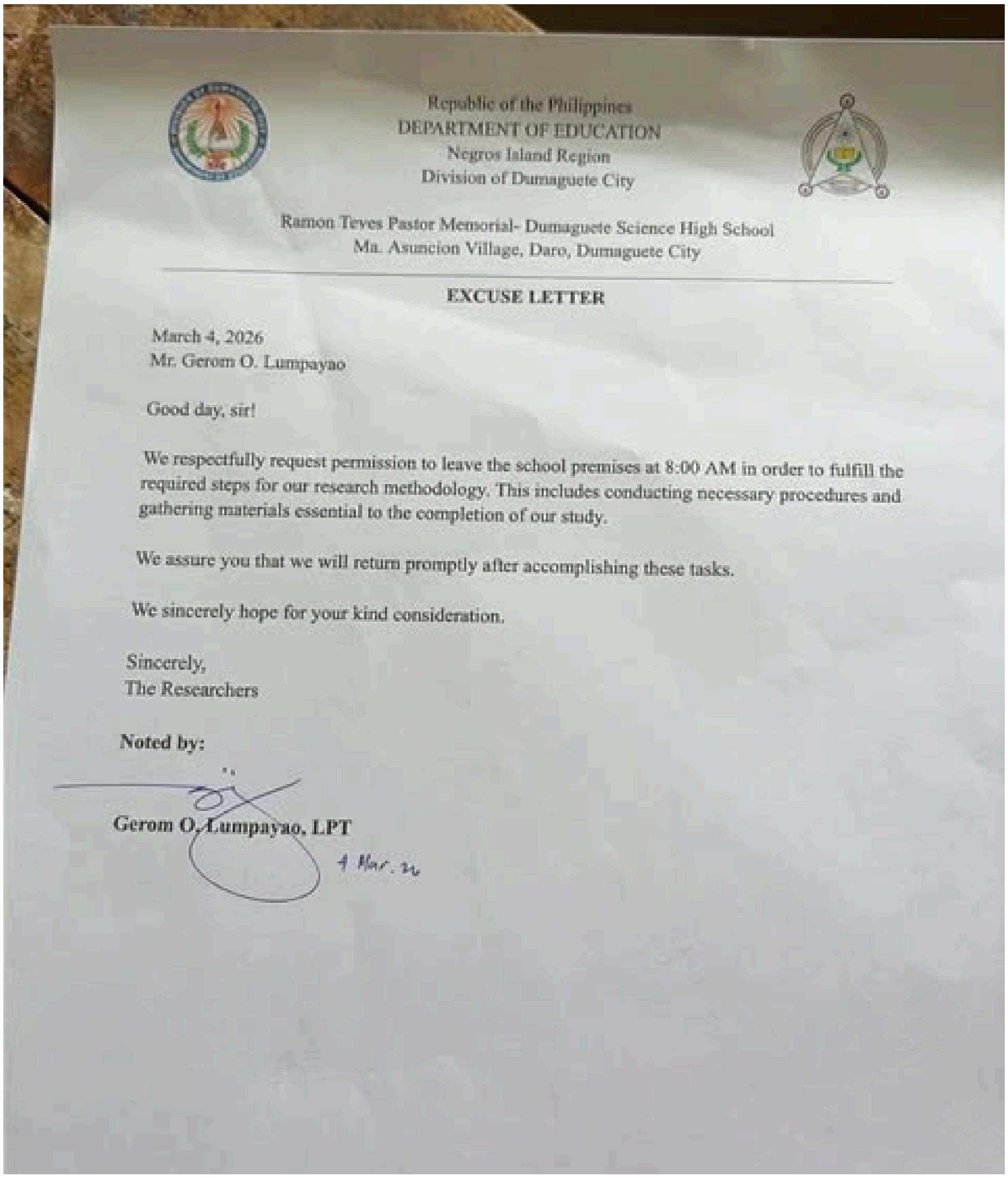
Noted by:

GEOL. TARRA ANGELA Y. GARSULA
Research Project Adviser

GEROM O. LUMPAYAO, LPT
Practical Research Adviser

APPENDIX B. Excuse Letter

Photo of the excuse letter informing the teacher about the researchers' absence for research activities.



Republic of the Philippines
DEPARTMENT OF EDUCATION
Negros Island Region
Division of Dumaguete City

Ramon Teves Pastor Memorial- Dumaguete Science High School
Ma. Asuncion Village, Daro, Dumaguete City

EXCUSE LETTER

March 4, 2026
Mr. Gerom O. Lumpayao

Good day, sir!

We respectfully request permission to leave the school premises at 8:00 AM in order to fulfill the required steps for our research methodology. This includes conducting necessary procedures and gathering materials essential to the completion of our study.

We assure you that we will return promptly after accomplishing these tasks.

We sincerely hope for your kind consideration.

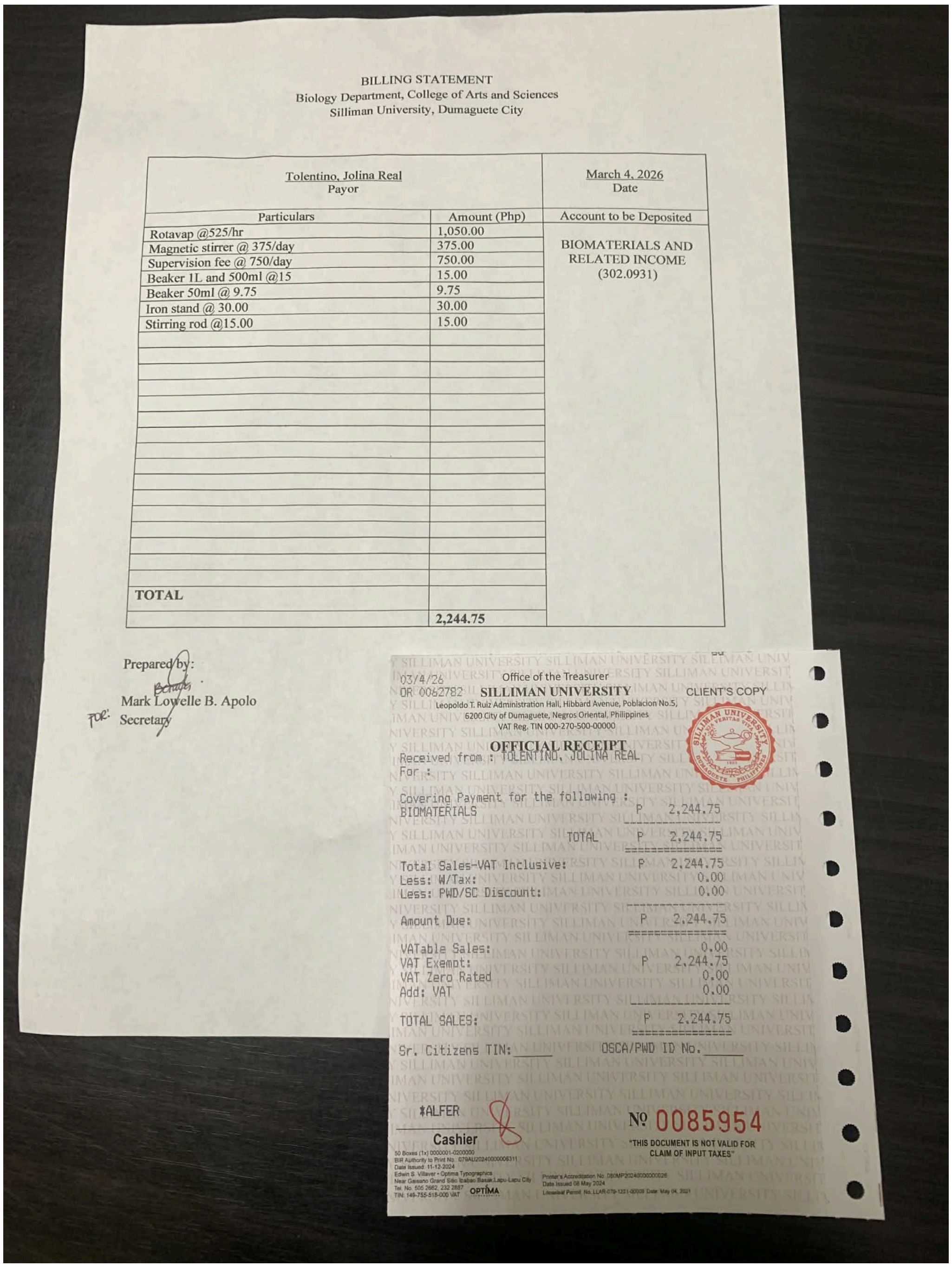
Sincerely,
The Researchers

Noted by:

Gerom O. Lumpayao, LPT
4 Mar. 26

APPENDIX C. Billing Statement

Photo of the billing statement showing the costs of the equipment used during the laboratory testing.



BILLING STATEMENT
Biology Department, College of Arts and Sciences
Silliman University, Dumaguete City

Tolentino, Jolina Real Payor		March 4, 2026 Date
Particulars	Amount (Php)	Account to be Deposited
Rotavap @525/hr	1,050.00	BIOMATERIALS AND RELATED INCOME (302.0931)
Magnetic stirrer @ 375/day	375.00	
Supervision fee @ 750/day	750.00	
Beaker 1L and 500ml @15	15.00	
Beaker 50ml @ 9.75	9.75	
Iron stand @ 30.00	30.00	
Stirring rod @15.00	15.00	
TOTAL	2,244.75	

Prepared by:
FOR: Mark Lowelle B. Apolo
Secretary

03/4/26
OR 0062782
Office of the Treasurer
SILLIMAN UNIVERSITY
CLIENT'S COPY
Leopoldo T. Ruiz Administration Hall, Hibbard Avenue, Poblacion No.5,
6200 City of Dumaguete, Negros Oriental, Philippines
VAT Reg. TIN 000-270-500-00000
OFFICIAL RECEIPT
Received from : TOLENTINO, JOLINA REAL
For :
Covering Payment for the following :
BIOMATERIALS P 2,244.75
TOTAL P 2,244.75
Total Sales-VAT Inclusive: P 2,244.75
Less: W/Tax: 0.00
Less: PWD/SC Discount: 0.00
Amount Due: P 2,244.75
VATable Sales: 0.00
VAT Exempt: P 2,244.75
VAT Zero Rated 0.00
Add: VAT 0.00
TOTAL SALES: P 2,244.75
Sr. Citizens TIN: OSCA/PWD ID No.
*ALFER
Cashier
№ 0085954
"THIS DOCUMENT IS NOT VALID FOR CLAIM OF INPUT TAXES"

APPENDIX D. Formulation of Bougainvillea Extract and Liquid Wax

Figure D1

Gathering of Bougainvillea Bracts

Figure D2

Macerated Bougainvillea crude extract

Figure D3

Filtration process of the crude extract

Figure D4

Measuring of the volume of the filtered extract

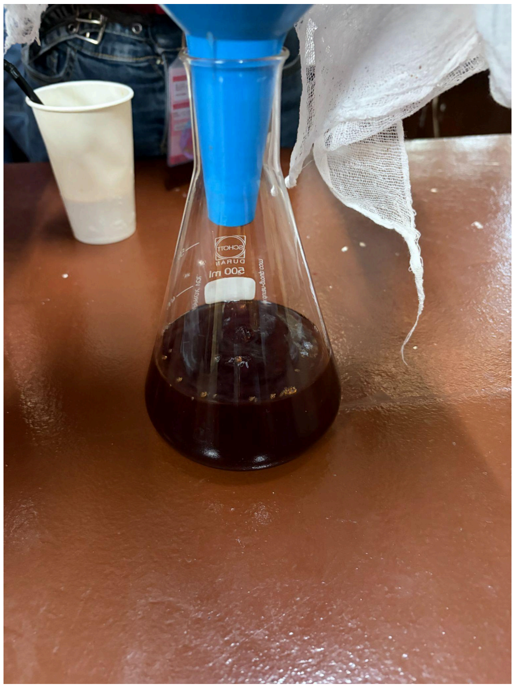


Figure D5

Use of a rotary evaporator to concentrate the extract

Figure D6

Use of a magnetic stirrer and hotplate in the preparation of the liquid wax formulation

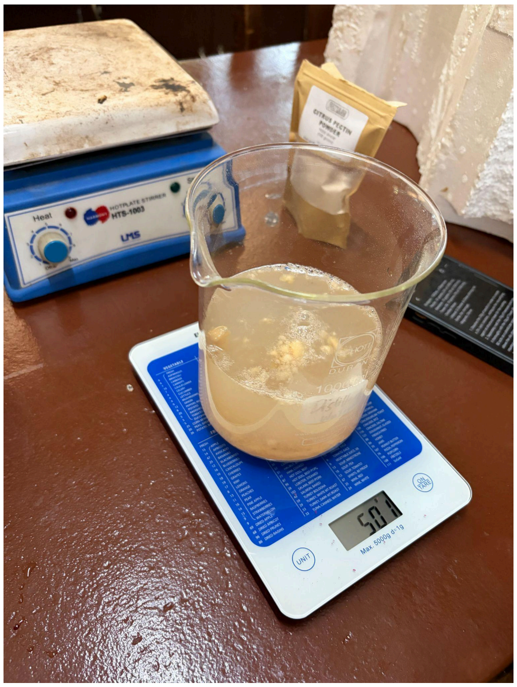
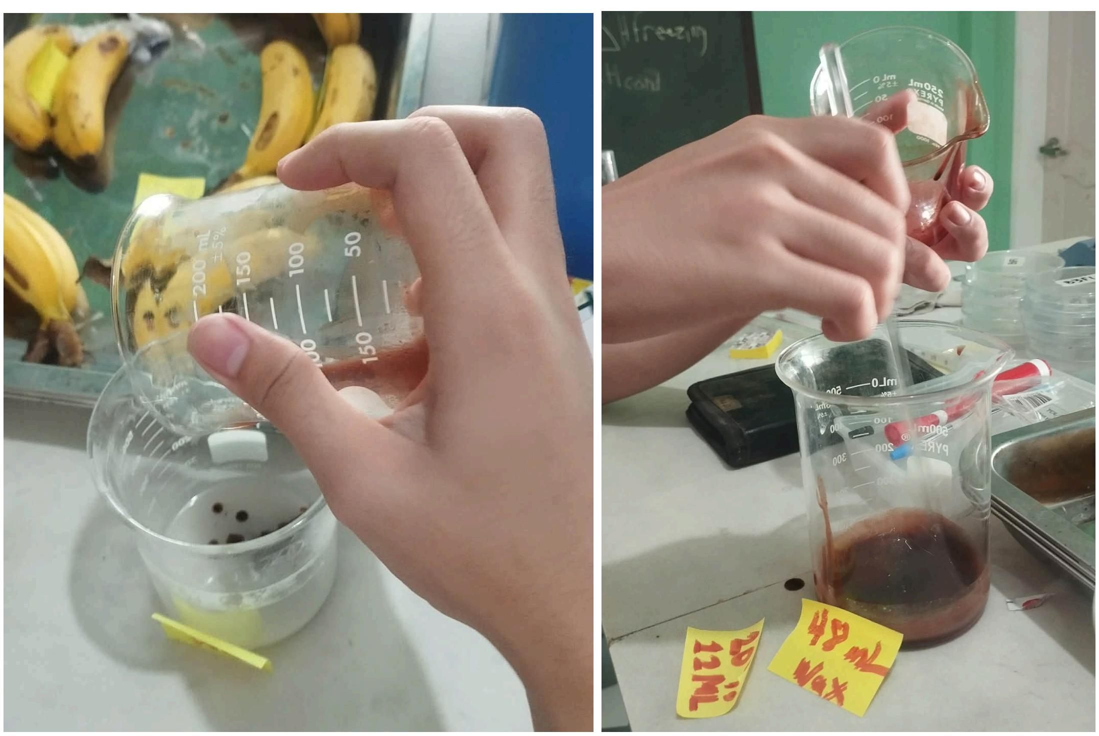


Figure D7

Making of the 10% and 20% concentration



APPENDIX E. Four Treatment Groups to Each Banana

APPENDIX F. Equipments Used

Figure F1

Rotary Evaporator

Figure F2

Magnetic Stirrer

Figure F3

Hot Plate

Figure F4

1L Beaker

Figure F5

50mL Beaker

Figure F6

500ml Beaker

Appendix G. Observation Report During the Seven-Day Storage Period of Bananas

Table G1

Daily Report on Banana Weight Loss and Visual Decay Index

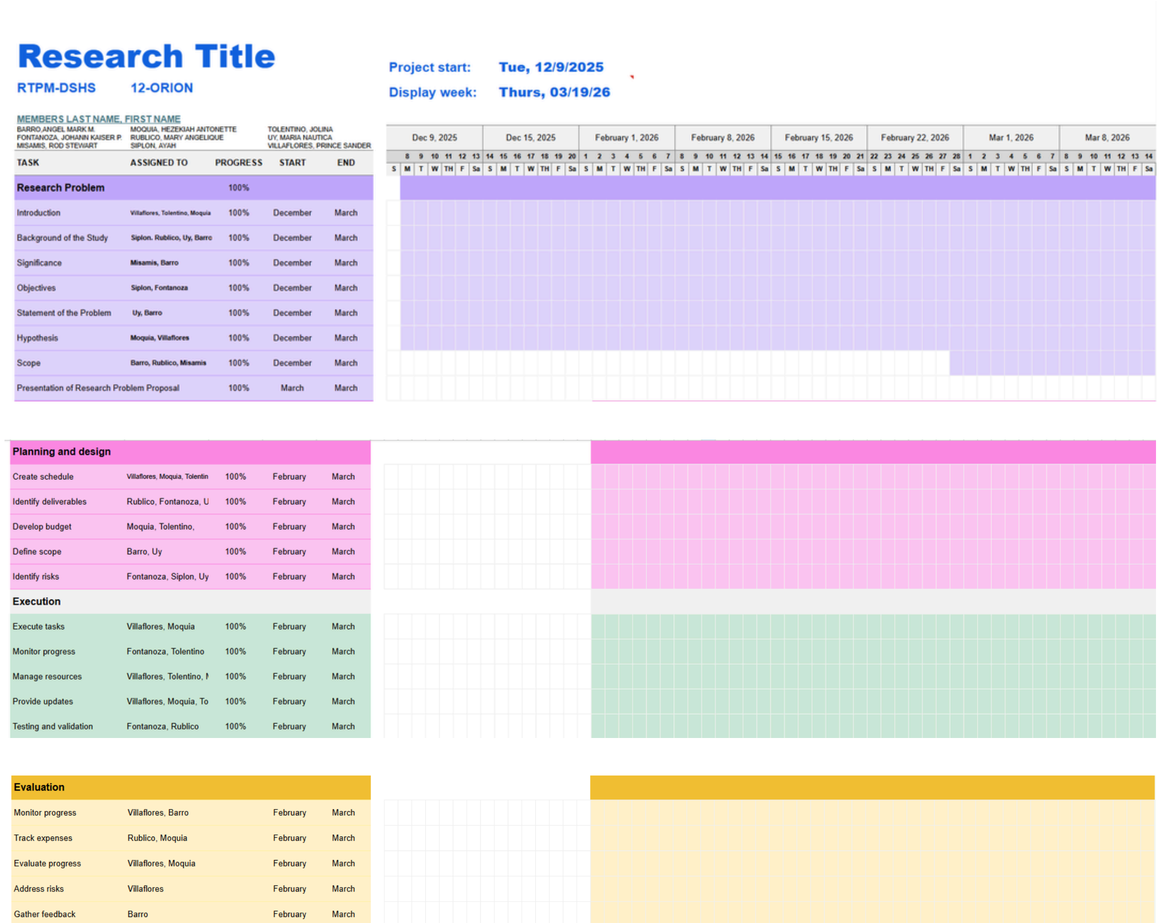
POSITIVE CONTROL / CLING WRAP METHOD				
Day	BANANA 1		BANANA 2	
	Browning Index	weight loss (in g)	Browning Index	weight loss (in g)
1	D	62	D	63
2	D	58	D	60
3	D	57	D	59
4	D	57	D	58
5	D	56	D	58
6	D	54	D	57
7	E	54	D	56

NEGATIVE CONTROL / NO TREATMENT				
Day	BANANA 1		BANANA 2	
	Browning Index	weight loss (in g)	Browning Index	weight loss (in g)
1	D	59	D	60
2	D	57	D	56
3	D	55	E	53
4	E	52	E	51
5	E	50	F	49
6	F	47	F	46
7	F	46	F	44

10% BOUGAINVILLEA EXTRACT & BEESWAX COATING				
Day	BANANA 1		BANANA 2	
	Browning Index	weight loss (in g)	Browning Index	weight loss (in g)
1	D	62	D	57
2	D	59	D	55
3	D	57	D	53
4	D	53	D	52
5	D	52	E	51
6	E	50	E	51
7	E	48	E	49

20% BOUGAINVILLEA EXTRACT + BEESWAX COATING				
Day	BANANA 1		BANANA 2	
	Browning Index	weight loss (in g)	Browning Index	weight loss (in g)
1	D	62	D	75
2	D	60	D	73
3	D	59	D	72
4	D	57	D	71
5	D	56	D	70
6	D	55	E	70
7	E	55	E	68

Appendix H. Gantt Chart



Research Title

RTPM-DSHS 12-ORION

Project start: Tue, 12/9/2025

Display week: Thurs, 03/19/26

MEMBERS LAST NAME, FIRST NAME

BARRO,ANGEL MARK M. | MOQUIA, HEZEKIAH ANTONETTE | TOLENTINO, JOLINA
FONTANOZA, JOHANN KAISER P. | RUBLICO, MARY ANGELIQUE | UY, MARIA NAUTICA
MISAMIS, ROD STEWART | SIPLON, AYAH | VILLAFLORES, PRINCE SANDER

TASK	ASSIGNED TO	PROGRESS	START	END
Research Problem		100%		
Introduction	Villaflores, Tolentino, Moquia	100%	December	March
Background of the Study	Siplon. Rublico, Uy, Barro	100%	December	March
Significance	Misamis, Barro	100%	December	March
Objectives	Siplon, Fontanoza	100%	December	March
Statement of the Problem	Uy, Barro	100%	December	March
Hypothesis	Moquia, Villaflores	100%	December	March
Scope	Barro, Rublico, Misamis	100%	December	March
Presentation of Research Problem Proposal		100%	March	March
Planning and design				
Create schedule	Villaflores, Moquia, Tolentin	100%	February	March
Identify deliverables	Rublico, Fontanoza, U	100%	February	March
Develop budget	Moquia, Tolentino,	100%	February	March
Define scope	Barro, Uy	100%	February	March
Identify risks	Fontanoza, Siplon, Uy	100%	February	March
Execution				
Execute tasks	Villaflores, Moquia	100%	February	March
Monitor progress	Fontanoza, Tolentino	100%	February	March
Manage resources	Villaflores, Tolentino, I	100%	February	March
Provide updates	Villaflores, Moquia, To	100%	February	March
Testing and validation	Fontanoza, Rublico	100%	February	March
Evaluation				
Monitor progress	Villaflores, Barro		February	March
Track expenses	Rublico, Moquia		February	March
Evaluate progress	Villaflores, Moquia		February	March
Address risks	Villaflores		February	March
Gather feedback	Barro		February	March

Appendix I

Researcher's Profile

Name:	Angel Mark M. Barro	**Age:**	17
Date of Birth:	September 15, 2008	**Sex:**	Male
Address:	133 San Jose Extension, Dumaguete City, Negros Oriental, 6200	**Nationality:**	Filipino
Civil Status:	Filipino	**Religion:**	Iglesia Ni Cristo
Contact Number:	0994 942 3360	**E-mail:**	someomeat517@gmail.com

Educational Background:

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School 2020 — 2024
Elementary:	Silliman University Elementary School 2015-2020 Southdale Integrated School 2013 — 2015

Awards and Achievements

2013 —2015	With High Honors
2015 — 2024	With Honors
2026	2nd Place IE-lympics

Membership

2024 — 2026	RTPM Euclidean Mathematics Club (EMC), Member
2025 — 2026	LIKAPIYAN Club, Member

Researcher's Profile

Name:	Johann Kaiser P. Fontanoza	Age: 18	
Date of Birth:	November 3, 2007	Sex:	Male
Address:	Northville Subdivision, Sibulan, Negros Oriental, 6201	Nationality:	Filipino
Civil Status:	Filipino	Religion:	Catholic
Contact Number:	09926761191	E-mail:	johannkaiserf@gmail.com

Educational Background:

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School 2020 — 2024
Elementary:	Little Village Educational Foundation, Inc., Dumaguete City 2014 — 2015 West City Science Elementary School. Dumaguete City 2015 — 2020

Awards and Achievements

2010 — 2024	With Honors
2024 — 2025	With High Honors
2025	PhilMath Numerical Ability Competition Gold Medalist

Membership

2024 — 2026	RTPM Euclidean Mathematics Club (EMC) Vice President
2023 — 2026	RTPM EMC Tabulations Committee Member

Researcher's Profile

Name:	Rod Stewart L. Misamis	Age: 17	
Date of Birth:	July 18, 2008	Sex:	Male
Address:	Polo Tanjay City	Nationality:	Filipino
Civil Status:	Filipino	Religion:	Catholic
Contact Number:	09948349591	E-mail:	misamisrodstewart@gmail.com

Educational Background:

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Diaz College 2020 — 2024
Elementary:	Polo Elementary School 2014 — 2020

Awards and Achievements

2010 — 2024	With Honors
2024 — 2025	With Honors

Researcher's Profile

Name:	Prince Sander R. Villaflores	Age: 17	
Date of Birth:	October 16, 2008	Sex:	Male
Address:	Bagacay, Dumaguete City	Nationality:	Filipino
Civil Status:	Single	Religion:	Roman Catholic
Contact Number:	0975 636 5868	E-mail:	villaflorespreincesander@gmail.com

Educational Background:

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2020 — 2024
Elementary:	Divine Grace International Christian School Buntis, Bacong, Negros Oriental 2014 — 2020

Awards and Achievements

2024 — 2025	E-Likha Visual Graphic Design Competition - 2nd Place
2024 — 2025	Division Schools Press Conference - CDP - 1st Place
2024 — 2025	Regional Schools Press Conference - CDP - 5th Place
2024 — 2025	DSPC Layout and Page Design - 1st Place
2025 — 2026	Division Schools Press Conference - CDP - 1st Place

Membership

2024 — 2025	DuScian Coordinating Council-EAC-Graphic Design Head
2024 — 2026	YES-O Public Information Officer
2024 — 2026	Ang Umalohokan - Layout & Design Editor
2025 — 2026	Duscian Multimedia CreativesCreative Design Chairperson

Researcher's Profile

Name:	Hezekiah Antonette L. Mquia	Age: 18	
Date of Birth:	November 2, 2007	Sex:	Female
Address:	Mangnao-Canal, Dumaguete City	Nationality:	Filipino
Civil Status:	Single	Religion:	Roman Catholic
Contact Number:	09531677896	E-mail:	hezekiahantonettemoquia@gmail.com

Educational Background:	
Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2020 — 2024
Elementary:	South City Elementary School Mangnao-Canal, Dumaguete, Negros Oriental 2014 — 2020

Awards and Achievements	
2014 — 2020	Consistent Merit Awardee
2019 — 2020	Ukulele and Flute Ensemble Awardee & Champion District and Division Level
2020 — 2024	With Honors
2024 — 2025	With High Honors

Membership	
2019 — 2020	Campus Journalist
2025 — 2026	DuScian Artisan in Motion Club, Member
2025 — 2026	Campus Youth Ministry, Fellowship Co-Head
2023 — 2026	Museon: League of Maestros Club, Member

Researcher's Profile

Name:	Mary Angelique M. Rublico	Age: 17	
Date of Birth:	September 8, 2008	Sex:	Female
Address:	La Libertad, Negros Oriental	Nationality:	Filipino
Civil Status:	Single	Religion:	Roman Catholic
Contact Number:	09207962423	E-mail:	rublicoangel28@gmail.com

Educational Background:

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	La Libertad Technical Vocational School South Poblacion, La Libertad 2020 — 2024
Elementary:	La Libertad Central Elementary School South Poblacion, La Libertad 2014 — 2020

Awards and Achievements

2013 — 2016	With Honors
2017 — 2018	With High Honors
2019 — 2020	Math Challenge, 2nd Place
2019 — 2020	With High Honors
2023 — 2024	Siyensikula, 3rd Place
2024 — 2025	With High Honor

Membership

2024 — 2026	DuScian Medics, Member
2024 — 2025	DuScian Campus Youth Ministry, Member
2024 — 2026	DuScian Equilibrium, Member

Researcher's Profile

Name:	Ayah B. Siplon	Age: 17	
Date of Birth:	June 16, 2008	Sex:	Female
Address:	Pencil Looc, Sibulan	Nationality:	Filipino
Civil Status:	Single	Religion:	Catholic
Contact Number:	09956642283	E-mail:	ayahsiplon@gmail.com

Educational Background:

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School 2020 — 2024
Elementary:	Arjune Learning Center 2014 — 2016 Balance Achievement School of Excellence 2016 — 2020

Awards and Achievements

2014 — 2024	With Honors
2024 — 2026	With Honors

Membership

2024 — 2026	DuScian Artisan in Motion Club, Member
2025 — 2026	DuScian Youth for the Environment in Schools Organization Club, Member
2024 — 2026	LIKAPIYAN Club, Member
2024 — 2026	Duscian Marching Band Club, Member

Researcher's Profile

Name:	Jolina R. Tolentino	Age: 17	
Date of Birth:	April 17, 2008	Sex:	Female
Address:	Candau-ay, Dumaguete City	Nationality:	Filipino
Civil Status:	Single	Religion:	Latter day saints
Contact Number:	09627941563	E-mail:	jolinatolenti no2008@g mail.com

Educational Background:

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Negros Oriental High School Daro, Dumaguete City 2020 — 2024
Elementary:	West City Elementary School, Dumaguete City 2014 — 2020

Awards and Achievements

2014 — 2024	With Honors
2024 — 2026	With High Honors

Membership

2025 — 2026	DuScian Artisan in Motion Club, Member
2025 — 2026	DuScian Youth for the Environment in Schools Organization Club, Member
2023 — 2024	Science Club, Member

Researcher's Profile

Name:	Maria Nautica Uy	Age: 17	
Date of Birth:	July 12, 2008	Sex:	Female
Address:	Banilad Bacong, Negros Oriental	Nationality:	Filipino
Civil Status:	Single	Religion:	Roman Catholic
Contact Number:	09996031924	E-mail:	riaaajiao@gmail.com

Educational Background

Senior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2024 — 2026
Junior High School:	Ramon Teves Pastor Memorial — Dumaguete Science High School Ma. Asuncion Village, Daro, Dumaguete City 2020 — 2024
Elementary:	West City Elementary School, Dumaguete City 2014 — 2020

Awards and Achievements

2014 — 2024	With Honors
2024 — 2026	With High Honors

Membership

2023 — 2026	DuScian Marching Band, Member
2024 — 2026	DuScian Girl Scouts Club, Member
2025 — 2026	YES-O Club, Member
2025 — 2026	Duscian Campus Youth Ministry, Member
2025 — 2026	Elysian Club, Member

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