Atisflex: Utilizing Atis (Annona Squamosa L.) Fiber for Innovative and Eco-Friendly Bioplastic Production

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ABSTRACT

Overconsumption of plastic has led to various environmental concerns, contributing to pollution and greenhouse gas emissions impacting both human health and wildlife. Addressing this issue requires immediate and sustainable solutions. The main intent of this study is to determine the effectiveness of atis *(Annona squamosa* L.) fiber for bioplastic applications. This quantitative study utilized true experimental research to accurately obtain the crucial findings after the intervention takes effect. The samples were manually collected from a healthy atis tree while ensuring it is suitable for bioplastic application. Afterwards, the researchers formulated and tested bioplastic samples using different concentrations of *A. squamosa* fiber to evaluate their performance such as tensile strength and water absorption. Through complete random sampling, each sample including the control group is guaranteed for equitable treatment and unbiased selection. The results revealed that the bioplastic exhibits excellent tensile strength; S3 had the highest tensile strength (M = 96.47 MPa), followed by S2 (M = 91.67 MPa) and S1 with only M = 72.37 MPa had the lowest among the three setups. For the water absorption, S1 maintained the highest water absorption capacity (M = 100%), S2 had the lowest with M = 66.67%, and S3 remained moderate after 24-hour observation. Bioplastics have a good potential to serve as an eco-friendly alternative to traditional plastics, reducing plastic waste and promoting environmental sustainability. Furthermore, this study helps to investigate other applications of atis fiber for sustainable materials to reduce plastic waste and protect the environment.

Keywords: bioplastics, *Annona squamosa* L. fiber, commercial plastics, plastic pollution, eco-friendly innovation

INTRODUCTION

Plastic waste is one of the main contributors to environmental issues. Overconsumption of these plastics constitutes a more significant threat in our daily lives. The rising predicament of plastic waste caused detrimental effects that affected several sectors such as marine life, soil quality, and serious health problems. Hence, there is a need for comprehensive action and efforts to mitigate further damage caused by plastic pollution. This includes recycling and reducing single-use plastics, supporting organizations addressing plastic pollution, and creating renewable alternatives for conventional plastics, promoting a systematic approach to sustainable development. Furthermore, bioplastic offers promising outcomes over traditional plastics' harmful effects on the planet. Thus, finding local alternative sources such as atis (*Annona squamosa* L.), which is abundant in Mindanao, can serve as a sustainable raw material for bioplastic production. This study primarily focuses on determining the potential benefits of atis for bioplastic applications and promoting eco-friendly solutions.

Plastic pollution stands as one of the most urgent environmental threats today, causing widespread harm to natural ecosystems, human health, and global economies. Global plastic production now exceeds 359 million tons annually (Pilapitiya & Ratnayake, 2024), but the world struggles to effectively manage and recycle the waste. The accumulation of plastic significantly pollutes soil, water, and air (Sikorska et al., 2021). A major driver of this issue is the prevalence of short-lived plastic products, particularly packaging and single-use plastics (Organization for Economic Co-operation and Development [OECD], 2022). Notably, around 40% of all plastic produced is used for packaging, making it the largest contributor to plastic waste and a primary target for reduction efforts (Geyer et al., 2017). In 2018, the United States generated 35.7 million tons of plastic waste, but only 8.7% was recycled, leaving nearly 27 million tons in29 landfills (United States Environmental Protection Agency [EPA], 2024). Caribbean countries, which depend heavily on marine resources, are among the top ten global marine polluters per capita, highlighting the urgent need for sustainable solutions to address plastic waste (Clayton et al., 2020). Marine plastic pollution also causes an estimated $13 billion in annual losses due to environmental damage, reduced tourism, and harm to the fishing industry (Husaini et al., 2024). This escalating crisis not only disrupts natural ecosystems but also places immense strain on the communities and industries that rely on them, highlighting the urgent need for innovative and sustainable alternatives to conventional plastics.

Plastic consumption and waste generation have surged in Asia due to rapid industrialization and urbanization. However, inadequate waste management infrastructure has increased environmental pollution, making the region a major contributor to global plastic waste (Bosquet, 2024). For example, in Thailand, plastic production has increased by 2.9% annually, leading to a surge in waste generation (SEA Circular Project, 2023). Similarly, in China, plastic waste generated 63 million tons in 2019, of which the buried, incinerated, and recycled accounted for about one-third, with the remaining 7% thrown into the environment (Straková et al., 2022). In contrast, Indonesia has seen rising public concerns over plastic pollution, with citizens demanding more government intervention (Lotulung, 2023). Meanwhile, Vietnam struggles with poor waste management infrastructure. As a result, the country recycles less than 30% of its plastic waste, significantly impacting marine ecosystems (Okumah, 2024). This highlights the growing plastic waste crisis across Asia with the pressing importance of adopting eco-friendly alternatives and strengthening waste management efforts to protect both communities and ecosystems.

Bioplastics have emerged as a promising alternative to commercial plastics, offering environmental benefits but facing challenges in production and sustainability. While plastics are widely used, they significantly contribute to global pollution. To address this, Tamang (2023) highlights the development of safer, more sustainable alternatives, such as bioplastics. These bioresource-based polymers are considered both environmentally and economically sustainable (Nanda et al., 2021). In 2020, global bioplastic production capacity exceeded 2.1 million tons and is expected to reach 2.9 million tons by 2025 (European Bioplastics, 2021). Asia leads production with 46%, followed by Europe (26%), North America (17%), and South America (10%). Bioplastics are widely used in packaging (Nasir & Othman, 2020) due to their biodegradability, helping reduce environmental harm (Sidek et al., 2019). However, high production costs limit large-scale commercialization.

To make bioplastics more affordable, many researchers are exploring using plant fibers as a cost-effective option. Kamarudin et al. (2022) highlight that natural fibers offer various advantages, including being eco-friendly, cost-effective, biodegradable, producing lower carbon emissions, and promoting energy efficiency during disposal at the end of their lifecycle. Similarly, a study by Sethupathi et al. (2024) identified lignin and lignocellulosic fibers as valuable natural bioresources that serve as primary fillers in bioplastics, categorized based on their biodegradability in soil. Moreover, incorporating up to 10% or more of lignocellulosic fibers and lignin has been shown to enhance the overall properties of bioplastics (Yang et al., 2019). However, a significant drawback of plant fibers is their hydrophilic nature due to hydroxyl groups, which creates compatibility issues with hydrophobic thermoplastics and makes them vulnerable to moisture damage (Elfaleh et al., 2023). These contrasting findings highlighted both the potential and the challenges of fiber-based bioplastics, emphasizing the need for further research and advancements to improve their performance and sustainability.

The rapid growth of population and industrialization in the Philippines has led to an increasing demand for plastic, contributing significantly to the country's waste problem. As a sustainable alternative, bioplastics derived from renewable raw materials offer a promising solution to mitigate plastic pollution. Bioplastics are plastics made from renewable raw materials or non-food sources, which are either biodegradable, derived

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from bio composite materials, or both (Rentoy et al., 2020). A solution is for the Philippines to implement affordable, cost-effective bioplastics made from agricultural residues, which could help reduce plastic pollution. With the country's abundant resources, these bioplastics could be an alternative to single-use plastics (Tabañag, 2022). However, large-scale commercial production of bioplastics is not yet established in the Philippines.

Multiple studies in the country explore plant-based materials and residual waste for sustainable bioplastics. Casiño et al. (2023) found that cornstarch bioplastic reinforced with *Bambusa vulgaris* had the highest tensile strength (2703.37-3341.2 Pa) and better water absorption than the unreinforced version. *B. blumeana* bioplastic had the highest water absorption at 157.36%. Saray et al. (2023) also examined bioplastics from taro and sea grapes, showing increased tensile strength ranging from (0.003-0.007 MPa) and water absorbency with higher concentrations (4-14%). Another study by Peralta et al. (2024) on the potential of using Indian mango peel and banana pseudostem fiber as materials for biodegradable plastic revealed that 70:30 ratio of mango peel to banana pseudostem fiber demonstrated the best performance, with a tensile strength of 15.8 MPa and water absorption of 8%. In contrast, the 30:70 ratio exhibited a tensile strength of 10.2 MPa and water absorption of 16%, likely due to the increased banana fiber content. Overall, plant-based bioplastics reinforced with natural fibers demonstrate improved tensile strength and water resistance, making them viable alternatives to traditional plastics.

The properties of bioplastics vary based on their composition, with factors such as glycerin and plasticizer content influencing their physical characteristics. For instance, Kadell and Callychurn (2023) found that algae-based bioplastics exhibited the highest water absorption at 54.4% due to their strong water retention capacity, compared to glycerol (1.96%), starch (26.23%), and acetic acid (17.77%) after 2-hour intervals, continuing up to 24 hours. Similarly, Rajamehala et al. (2024) reported that aloe vera-derived bioplastics absorbed significant water, with 80% dissolving, demonstrating their low water resistance. In contrast, Abotbina et al. (2021) observed that samples without plasticizers retained more water (194.3%), highlighting the role of plasticizers in enhancing water resistance. Additionally, Shanmathy et al. (2021) found that bentonite-infused films exhibited higher water absorption due to their water-reactive properties. Moreover, Lee and Yeo (2021) revealed that increasing glycerol content led to greater water absorption, with set D reaching 22.8%, compared to 4.27% in set A. Overall, the water resistance of bioplastics varies significantly based on their composition, with plasticizers enhancing durability and reducing water absorption.

Researchers have been eyeing *A. squamosa* for its promising potential as a natural sustainable alternative, due to their wide range of pharmacological properties and biological activities, such as antioxidant, antimicrobial, antiviral, anticancer, and hepatoprotective effects. Yet, despite its medical applications, its potential for commercial utilization in bioplastics remains unexplored. This tropical tree, native to the Philippines, yields about 50% to 61% edible material and is rich in carbohydrates, vitamins, and proteins (Datiles & Rodriguez, 2015). Atis is widely recognized for its phytochemical properties, contributing to its use in traditional medicine (Murakami & Yamamoto, 2023). Similar to other plants like rice straw, which contains about 37.71% cellulose (Laya et al., 2022), and teak wood sawdust, which holds approximately 50% cellulose (Rohmawati et al., 2018). Additionally, *Cladophora sp.* algae, known for its rich cellulose content, has been used in hydrogel-based bioplastics (Steven et al., 2022). These plant fibers highlight the viability of atis as a potential raw material for sustainable bioplastic production.

With the increase in plastic waste posing a threat to the environment and public health, there is an urgent need for sustainable alternatives to commercial plastics. While various plant-based alternatives have been explored, many still rely on costly or resource-intensive materials, limiting their widespread adoption. Despite many studies conducted on bioplastics, the potential of *A. squamosa* as a bioplastic component remains largely unexplored, as it has not been utilized for bioplastic production despite its abundant fibers. This study is grounded in the Cradle-to-Cradle Theory by McDonough and Braungart (2002), which emphasizes that biodegradable materials can be disassembled and renewed as high-quality products or returned as a biological nutrient, ensuring a non-waste production system. Hence, this study aimed to explore the potential benefits of atis fibers in bioplastics for innovative solutions, particularly by assessing their tensile strength and water absorption.

Statement of the Problem

This study aimed to convert atis fiber into bioplastic for eco-friendly applications while assessing its tensile strength and water absorption. Thus, this study provided explicit answers to the following questions:

1. What is the level of the tensile strength of different bioplastic setups at:
   1.1 2.5 units of pulverized atis bark fiber;
   1.2 5 units of pulverized atis bark fiber;
   1.3 7.5 units of pulverized atis bark fiber; and
   1.4 Strip of commercial plastic
2. What is the level of water absorption of bioplastic setup and commercial plastic at:
   2.1 2.5 units of pulverized atis bark fiber;
   2.2 5 units of pulverized atis bark fiber;
   2.3 7.5 units of pulverized atis bark fiber; and
   2.4 Strip of commercial plastic
3. Is there a significant difference between the bioplastic properties of atis bark fiber and commercial plastics?

Hypothesis

The hypothesis of the study was tested at a 0.05 alpha level of significance. To answer the problems listed in the preceding section objectively, the given null hypothesis was formulated:

H_o: There is no significant difference between the bioplastic properties of the potential *A. squamosa* bark fiber and commercial plastics.

Significance of the Study

The investigation of this study will benefit the organization and people, in particular:

Department of Environment and Natural Resources (DENR) Officials. This study could provide DENR officials with a sustainable alternative to address plastic pollution. It could support policy development, enhance environmental programs, and promote eco-friendly materials, aligning with the agency's conservation goals.

Local Communities. Communities with abundant *A. squamosa* plants could benefit from this study economically through the job creation for harvesting and processing the atis fiber. At the same time, it could contribute to the livelihood of local people while developing environmental conservation efforts.

Waste Management Experts. These individuals would benefit from this study by gaining insights into the potential of *A. squamosa* fiber as a biodegradable material for bioplastic production. They could apply the research findings to enhance waste management strategies by identifying biodegradable materials that support eco-friendly disposal and reduce environmental impact.

Manufactures. This study would benefit these professionals by providing data on *A. squamosa* fiber's mechanical properties, enabling them to explore sustainable alternatives for product development and support the shift toward environmentally friendly production.

Farmers. This study could help reduce farm waste by providing an eco-friendly solution to pollution. It could also promote sustainable farming practices and support a circular economy approach, benefiting farmers both environmentally and economically.

Future Researchers. The study would provide a foundation for future research on sustainable materials, offering data and insights into bioplastic production from *A. squamosa* fiber. It would inspire further exploration of eco-friendly alternatives to traditional plastics.

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Scope and Limitations

The study focused on converting *A. squamosa* fiber into bioplastic for eco-friendly applications by evaluating its tensile strength and water absorption. The creation of the bioplastics was conducted at home instead of the laboratory during the school year 2024-2025 due to the unavailability of specific apparatus such as the heating plate. Three formulations of *A. squamosa* fiber-based bioplastics were tested, with a commercial plastic as the control group. The study was limited to measuring tensile strength and water absorption, from data gathering to result dissemination.

This study had several limitations, including excluding biodegradability testing, as it only focused on the tensile strength and water absorption of the atis fiber-based bioplastic. The study did not examine other properties, biodegradability, or long-term environmental impact due to resource and time constraints. Since the research was conducted at home rather than in a laboratory, the accuracy of measurements was affected by the available resources and equipment. The study also had a small sample size, testing only three formulations of atis fiber-based bioplastics and making no comparisons to other biodegradable plastics. Future studies should look into these areas to offer a more thorough assessment of atis fiber-based bioplastics.

Definition of Terms

The following terms were conceptually and operationally defined to have a better understanding of this study.

Atisflex. This refers to the name of the potential film-type bioplastic research product made from *A. squamosa*

fiber. The name Atisflex was a fusion of the words "atis" and "flexibility," reflecting the product's natural origin and its intended flexible, eco-friendly properties.

Atis. This refers to a tropical fruit tree that produces a sweet, edible fruit with a knobby rind and soft, white pulp (Crane et al., 2020). In this study, the atis plant (especially the branches) was the source of the natural fiber used to produce Atisflex bioplastic for this study.

Bioplastics. This refers to a type of plastic derived from biological substances rather than petroleum (Fillplas, 2018). In this study, bioplastics are defined as plastics made from biological materials such as agar powder and *A. squamosa* fiber.

Tensile strength. This refers to the ability of a material to resist a force that tends to pull it apart (Ismail & Matsuura, 2019). In this study, it refers to how much the bioplastic, named Atisflex, could handle the maximum force under tension before breaking. The tensile strength of bioplastics was measured in megaPascals (MPa).

Water absorption. This refers to the ability to take up and retain water (Kreo, 2025). In this study, it refers to how much water was absorbed by the bioplastic in specific time intervals, measuring its initial and final weight. The water absorption of bioplastics was measured in percentage.

METHODS

This chapter contains the methodologies that are utilized in carrying out the research study. It covers aspects that include the research design, sample of the study, sampling methodologies, measures, methods of analysis

and interpretation, and as well as the procedures for data collection.

Research Design

This study used a quantitative true experimental research design utilizing a posttest-only control group design. A clear understanding of the experimental design's purpose was essential in guiding the research

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process, particularly in determining cause-and-effect relationship between variables (McKee, 2024). The independent variable was the concentration of *A. squamosa* fiber incorporated into the bioplastic formulations. In contrast, the dependent variables were the measured properties such as tensile strength and water absorption. The researcher assessed the results in the experimental group. The procedure allowed the researchers to contrast separate concentrations of the effectiveness of bioplastic with commercial plastic qualities. Afterward, once the following intervention took effect, the desired result was assessed (Choueiry, 2021). In addition, three types of bioplastic composition, as well as commercial plastic, which was the control group, were included in this design. In this instance, *A. squamosa* fiber bioplastic differed in the amount incorporated. Then, the following outcome of the four groups was evaluated if the *A. squamosa* fiber bioplastic was functional.

Sample of the Study

The study samples consisted of manually collected *A. squamosa* fiber from the branches of mature and healthy atis trees to ensure they were suitable for bioplastic production. The fibers were collected by carefully selecting trees with no visible signs of damage. After trimming suitable branches, small sections of the outer bark were gently peeled away to expose the inner fibrous layer, which was then manually extracted to preserve fiber integrity. Any clean, intact, and undamaged fiber was included, while short, brittle, or contaminated fibers were excluded. After collection, the fibers were thoroughly cleaned with distilled water to remove impurities and then sun-dried by spreading them evenly on a clean container under direct sunlight. Once fully dried, the fibers were stored in sealed containers to maintain their quality until further processing. The sample size depended on the amount of fibers needed for testing, ensuring enough material for repeated trials.

Sampling Technique

This study used complete random sampling. This study used complete random sampling. Complete random sampling is a sampling method that ensures each sample has an equal probability of being selected to represent the entire population (Taylor, 2024). In this case, complete random sampling minimizes the risk of confounding variables influencing the results, as it ensures a balanced distribution of such factors across all groups. Since our set-up 1 involves mixtures where each sample is composed of three strips, random sampling allows for unbiased selection and representation of each strip in the experimental group. This method eliminates biases in sample assignment, allowing observed effects to be attributed to experimental variables like the atis fiber bioplastics composition, rather than external factors. Furthermore, by using complete random sampling, we increase our findings' generalizability, improve the experiment's statistical precision, and strengthen the overall credibility of the conclusions drawn about the potential of atis bark fiber in eco-friendly bioplastic production.

Data Gathering Procedures

The following steps were taken to ensure an organized approach to the data collection and attain the intended result of obtaining sufficient and essential information:

Pre-experimental Protocol

1. The researchers secured a letter of approval from the Basic Education Department School Principal to conduct the study.
2. The researchers then assessed the atis tree to ensure that it was healthy and had enough branches to use for the study.
3. The researchers sought guidance from the teacher on the proper extraction of atis fiber to prevent harming the tree.
4. The necessary materials, including glycerol, agar powder, and measuring equipment, were gathered and purchased.

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B. Preparation of Atis Fiber for Bioplastic

The researchers were guided by the following procedures adapted from the research of Baring et al. (2024):

1. The researchers selected and collected mature branches from healthy *A. squamosa* trees, ensuring sufficient quantities. The outer layer was scraped and peeled off, exposing the fibrous material, and soaked in water to loosen the fibers.
2. The soaked fibers were manually stripped by hand to separate them from the remaining plant material.
3. To remove contaminants, the extracted fibers were thoroughly rinsed with distilled water and a mild detergent solution.
4. After cleansing, the fibers were dried under a shade until standardized dehydration was achieved.
5. Once dried, the researchers used a mechanical process with a blender to pulverize the fibers into a uniform size.

C. Formulation of the Bioplastic Base Solution

1. A solution was prepared using measuring tools by thoroughly mixing 180 mL of water and 22 mL of glycerol in a container.
2. After being mixed, 36 g of agar powder was added.
3. The prepared solution was then heated on a stove burner.

D. Mixing of the Atis Fiber to the Bioplastic Base Solution

1. The container that contains the solution is placed on a stove burner at low-medium heat.
2. Once the mixture started to heat up, the atis fibers were added. Different set-ups had different amounts of atis fibers (S1=2.5 units, S2=5 units, S3=7.5 units).
3. After adding the atis fiber, the solution is boiled for 1-2 minutes in low-medium heat without letting the solution reach 90 degree celsius.

E. Molding of the Atis Fiber Mixtures

1. The gel-like substance from the atis fiber mixture was carefully transferred to a rectangular container to maintain its consistency in the shape of each bioplastic.
2. The researchers poured each mixture into a mold, ensuring the amount was equal for each mold.
3. The molds with the mixtures are placed in a safe and controlled environment to ensure their development as bioplastics.

F. Performance Assessment of the Tensile Strength of the Samples

1. The bioplastic samples are cut into uniform sizes, and their width and height were measured for a tensile strength test (Baring et al., 2024):

   1.1 Each end of the sample, which measured 80x10 cm was attached securely using a clamp and universal C-clamp, positioned vertically.
   1.2 The weights were attached to the universal C-clamp using a thick cotton tie. For each test, weights were tied to the cotton tie and incrementally added to apply increasing force.
   1.3 The force was gradually applied to the sample by adding weights in every test until the bioplastic breaks.
   1.4 The maximum weight the sample can hold before breaking was recorded as its tensile strength.

The following formulas were used to calculate the megapascals (MPa):

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$$\text{Kg} = \frac{g}{1000}$$

Figure 1. Converting Grams to Kilograms

$$\text{N} = \text{kg} \times \text{g}$$

Figure 2. Converting Kilograms to Newtons

$$\text{A} = \text{Width} \times \text{Thickness}$$

Figure 3. Cross-sectional area

$$\text{Pa} = \frac{F}{A}$$

Figure 4. Computation for Pascal (Pa)

$$\text{MPa} = \frac{Pa}{10^6}$$

Figure 5. Converting Pascal (Pa) to MegaPascal (MPa)

G. Performance Assessment of the Water Absorption of the Samples

The bioplastic samples underwent a water absorption test inspired from a study by Gbadeyan et al. (2023):

1. The bioplastic samples were dried to remove moisture before testing then the initial weight will be taken.
2. The samples were immersed in 100 mL of water at room temperature for 4 hours, 12 hours, and 24 hours.
3. After the specified periods, the samples were removed from the water and wiped with a dry napkin to remove excess water, and immediately recorded their final weight.

The following formula was used to calculate the percentage of water absorption:

$$Water\ Absorption\ (\%) = \frac{(Final\ weight - Initial\ weight)}{Initial\ weight} \times\ 100$$

Figure 6. *Water Absorption formula*

Measures

This quantitative study applied the solvent-casting technique by Haider and Haider (2022) to assess the tensile strength of the bioplastics, which will be interpreted based on Table 1 shown below. The bioplastics were cut into uniform strips (80x10 cm) and were tested by continuously adding weights until they broke. Moreover, a study by Gabriel et al. (2020) further supports this categorization, stating that the tensile strength can be adjusted by incorporating natural fibers to enhance the bioplastic's mechanical properties. Mixing fibers and polymers can significantly influence the bioplastic's properties, making the tensile strength reach up to 50 MPa or more (Fatima et al., 2022).

Table 1. Measure of Interpretation for the Tensile Strength of Bioplastics and Commercial Plastic

Tensile Strength Range (MPa)	Descriptive Equivalent	Interpretation
> 25 MPa	High	Bioplastics are strong and durable.
10-25 MPa	Moderate	Bioplastics have fair strength and

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		durability.
< 10 MPa	Low	Bioplastics are flexible but lack durability.

This study also utilized a water absorption test to determine the amount of water absorbed under specified conditions, which measures the weight absorbed by the bioplastic sample (Choubey et al., 2023). The study of Nasir and Othman (2021) is used to interpret the amount of water absorbed by the bioplastic shown in Table 2. The bioplastics were soaked in the water over specific time intervals (4 hours, 12 hours, and 24 hours) and were measured based on their initial and final weights.

Table 2. Measure of Interpretation of the Water Absorption of Bioplastics and Commercial Plastic

Water Absorption (%)	Descriptive Equivalent	Interpretation
> 100%	High	Bioplastics can break down faster when they come into contact with water.
61%-100%	Moderate	Bioplastics can absorb a certain amount of moisture but will remain stable.
< 60%	Low	Bioplastics resist any moisture and keep their shape and durability.

Analysis and Interpretation

In analyzing the data, both descriptive and inferential statistics were used, with interpretations based on a 0.05 level of significance. The statistical tools applied are as follows:

Mean. Descriptive mean and standard deviations are both measures of dataset variability. Mean deviation is a statistical measure used to determine the average deviation from the mean value of a given dataset (Admin, 2021). They were used to assess tensile strength measurements of bioplastic made from agar powder, and atis fiber deviated from the mean. These measures highlight the variability, durability, and flexibility.

One-way ANOVA. This statistical method involves a single categorical independent variable—commonly referred to as the study group variable—and a single continuous dependent variable (Schober & Vetter, 2020). One-way ANOVA was conducted to determine whether significant differences existed among the three mixtures of atis fibers and commercial plastics. A p-value below 0.05 statistical significance warrants a post-hoc analysis to identify which mixture is the most effective.

Tukey's Honestly Significant Difference. Tukey's Honestly Significant Difference Test (HSD) tests differences among sample mean for significance. Tukey's HSD controls the likelihood of making one or more Type I mistakes while testing all pairwise differences. This Type I error rate is entirely controlled by Tukey's HSD test, one of several tests created for this purpose (Lane, 2024). To help determine which groups differed significantly, this method was utilized. This method compared various treatments and factors influencing the bioplastic production process using *A. squamosa*. The analysis will assist in determining the impact of bioplastic composition variations on performance.

Ethical Considerations

In the conduct of the study, the researchers were guided by the following ethical considerations:

Permission and Responsible Sourcing. The researchers sought and obtained verbal permission from the owner of the A. squamosa tree before collecting branches for the study. The collection was conducted with care to ensure that the tree was not harmed, and no essential part was taken beyond what was necessary for experimentation. The purpose of obtaining these materials was strictly for academic and scientific inquiry, with no intent for personal gain.

Safety and Risk Management. The experimentation process, particularly in the production of bioplastic, involved the use of heat and other procedures that could pose risks. All activities were conducted in a safe environment where safety measures were strictly observed to prevent burns or heat-related injuries. The researchers ensured that proper handling and protective equipment were used throughout the process.

Environmental Responsibility. Waste materials generated during the experimentation were managed properly and disposed of responsibly to minimize environmental impact. The researchers upheld eco-friendly practices in all phases of the study, from material collection to waste disposal, in alignment with the goal of promoting sustainable alternatives.

Integrity and Transparency. Data collection was conducted accurately and without misrepresentation. The researchers ensured that the results of the study were presented truthfully, fairly, and without bias. No data was fabricated or altered, and the conclusions drawn were based solely on the outcomes of the experimentation.

Conflict of Interest. The researchers declared that there was no financial or personal conflict of interest in the conduct of this study. The study was carried out solely for research purposes, and no external funding, sponsorship, or incentives influenced the results. The integrity of the research process was maintained throughout the study.

RESULTS AND DISCUSSION

This chapter deals with the presentation, analysis, and interpretation of data. The first part describes the results of the experiments between the tensile strength of different mixtures of the atis (*Annona squamosa* L.) fiber bioplastic and control group, highlighting variations in mechanical durability among the samples. The second part presents the results of the water absorption capacity of different atis fiber bioplastics, evaluating their stability and moisture resistance under different conditions.

Tensile Strength of Different Atis Fiber Bioplastic Setup and the Control Group

The study investigated the tensile strength of the following bioplastic experiment setup: S1 - 2.5 units pulverized atis fiber, S2 - 5 units pulverized atis fiber, and S3 - 7.5 units pulverized atis fiber, as well as the control group. The researchers assessed the tensile strength of the following setup by stretching the material with weights to the opposite ends of the bioplastic, this process was repeated three times for each mixture of the same size (80x10 cm). Hence, the researchers obtained the following results.

Table 3. Tensile Strength of Different Atis Fiber Bioplastic Setup and the Control Group

	Replicate (in MPa)			**Mean**	**SD**	**Interpretation**
	R1	**R2**	**R3**			
S1	72.40	86.80	57.90	72.37	14.45	High
S2	57.90	130.30	86.80	91.67	36.44	High
S3	86.80	86.80	115.80	96.47	16.74	High

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Commercial Plastic	43.40	28.90	28.90	33.73	8.37	High

Table 3 compares bioplastics with different setups to the control group in terms of tensile strength, which is the greatest stress the material can withstand before breaking when stretched. Among the bioplastic setups, S3 had the highest tensile strength (M = 96.47 MPa), whereas S1 had the lowest tensile strength (M = 72.37 MPa). This means that the mixture that produced the most durable bioplastic was the one with 7.5 units of powdered atis fiber, while the mixture that produced the lowest durability was the 2.5 units of powdered atis fiber. For the positive control, the table showed that commercial plastic had an average tensile strength of 33.73 MPa, which means that the bioplastic mixture containing 5 units (S2) and 7.5 units (S3) of powdered atis fiber yielded better results, with average tensile strengths of 91.67 MPa and 96.47 MPa, respectively. This indicates that increasing the amount of atis fiber enhances the tensile strength of the bioplastic, making it a stronger alternative to commercial plastic.

Moreover, the results align with the study of Yang et al. (2019). This study on fiber-matrix compatibility supports the finding that the addition of lignocellulosic fibers enhances bioplastic strength, emphasizing that the fiber-to-matrix interaction plays a crucial role in the mechanical properties of the final product. A previous study by Bousfield et al. (2018) and Blancia (2021) confirms that the inclusion of natural fibers improves tensile strength, often making bioplastics stronger and more sustainable alternatives to traditional plastics. Additionally, the study of (Rumi et al., 2021) states that plasticized films with 30% glycerol were more versatile due to their flexibility and stretchability. Furthermore, the study by Abera et al. (2023) observed that increasing the fiber content leads to higher tensile strength, with results ranging from 0.2 to 7.25 MPa, which is aligned with the results as the study demonstrated that combining banana pseudo-stem fiber with banana peel starch underscoring the synergy between fiber and starch matrices. The combination of natural fiber matrices is demonstrated in this study, where it shows that *A. squamosa* fiber not only boosted the tensile strength but also likely enhanced the bioplastic's durability and its ability to resist breaking under stress.

Water Absorption Capacity of Different Atis Fiber Bioplastic Setup and the Control Group

The study examined the water absorption capacity of the following *A. squamosa* fiber bioplastic experiment setups as well as the control group. The researchers assessed the water absorption of the following setup by immersing the bioplastic into 100 units of water and measuring its initial and final weights for 4 hours, 12 hours, and 24 hours. This process was repeated three times with the same initial weights and was constantly measured over the specified time. As a result, the researchers observed the following data.

Table 4. Water Absorption Capacity of Different Atis Fiber Bioplastic Setup and the Control Group

	Replicate (in percentage)			**Mean**	**SD**	**Interpretation**
	R1	**R2**	**R3**			
4 hours						
S1	87.50	75	112.50	91.67	19.09	Moderate
S2	75	37.50	62.50	58.33	19.09	Moderate
S3	50	62.50	100	70.83	26.02	Moderate
Commercial Plastic	0	0	0	0	0	Low
12 hours						
S1	100	75	112.5	95.83	19.09	Moderate
S2	87.5	62.5	62.5	70.83	14.43	Moderate

S3	50	62.5	100	70.83	26.02	Moderate
Commercial Plastic	0	0	0	0	0	Low
24 hours						
S1	100	88	113	100.00	12.50	Moderate
S2	88	63	50	66.67	19.09	Moderate
S3	75	75	100	83.33	14.43	Moderate
Commercial Plastic	0	0	0	0	0	Low

Table 4 compares the water absorption characteristics of bioplastics with different mixtures to the control group. The water absorption performance of the bioplastics and the control material was observed over specific time intervals to assess their respective behaviors. In the 4-hour observation, for the bioplastic setup, S1 exhibited the highest water absorption capacity (M = 91.67%), while S2 demonstrated the lowest (M = 58.33%). At the 12-hour mark, S1 continued to show the highest water absorption (M = 95.83%), reflecting an increase of approximately 4.16% in its water-holding capacity, whereas S2 and S3 both had the same water absorption rate (M = 70.83%). At the 24-hour observation, S1 maintained the highest water absorption capacity (M = 100%), while S2 had the lowest (M = 66.67%). Meanwhile, the commercial plastic group consistently showed zero absorption across all intervals, demonstrating its complete resistance to water uptake. These findings suggest that 2.5 units (S1) of powdered atis significantly increases the water absorption rate, indicating that lower fiber content can break down easily when coming into contact with water. On the other hand, 5 units (S2) of powdered atis showed a lower absorption rate during the 4-hour and 24-hour observation. In contrast, 7.5 units (S3) of powdered atis exhibited moderate across the time intervals, suggesting that higher fiber concentration can resist moisture and enhance the water resistance of the bioplastic. Additionally, the commercial plastic group exhibited high resistance to water absorption throughout the observation periods.

The results are congruent to the study of Kadell and Callychurn (2023) where they examined the water absorption of different bioplastic compositions at 2-hour intervals, followed by 6-hour intervals until the 24-hour mark. Their study revealed that the glycerol concentration has a minimal contribution with only 1.96%, followed by starch (26.23%) and acetic acid (17.77%). Hence, the algae-based bioplastics remained statistically significant, with 54.4%, indicating that they have increased water absorption due to their high-water retention capacity. Similarly, Rajamehala et al. (2024) stated that the aloe vera-derived bioplastic with 80% being dissolved in water and only 20% remaining after 24 hours, the bioplastic is attributed to its primary ingredient aloe vera which has hydrophilic content. Furthermore, Shanmathy et al. (2021) stated that low-concentration (0.5wt%) bentonite sample film exhibited increased water absorption because of the characteristics of bentonite when exposed to water. Additionally, the study of Abotbina et al. (2021), observed that the control sample exhibited the highest water absorption, reaching nearly 194.3%, primarily due to lack of plasticizer. These results demonstrated that bioplastics' ability to retain water is caused by the properties of the components incorporated with them. Hence, these characteristics can alter the composition of the bioplastic, making it vulnerable to water.

Significance of the Difference in the Tensile Strength of Different Atis Fiber Bioplastic Setup and the Control Group

Table 5 shows the results of a one-way analysis of variance to determine the significance of the difference in the tensile strength of different mixtures of bioplastics and the control group. It can be observed that the F value is 5.171 with 3 and 8 degrees of freedom. The p-value is 0.028, which is less than 0.05. This further means that there is a need to reject the null hypothesis. This indicates that the three experimental groups significantly differ from the positive control in terms of their tensile strength.

Table 5. Significance of the Difference in the Tensile Strength of Different Atis Fiber Bioplastic Setup and the Control Group

	Sum of Square	df	Mean Square	F	p	Decision
Between Groups	7320.463	3	2440.15	5.171	0.028	Reject H_0
Within Groups	3774.847	8	471.856			(Significant)
Total	11095.31	11				

To determine which of the four setups significantly differs from the other, post hoc analysis was conducted, particularly the pairwise comparisons of sample mean via the Tukey HSD test. The Tukey's honestly significant difference test (Tukey's HSD) tests differences among sample means for significance. The Tukey's HSD tests all pairwise differences while controlling the probability of making one or more Type I errors. The Tukey's HSD test is one of several tests designed for this purpose and fully controls this Type I error rate (Lane, 2024).

Table 6. Post Hoc Comparisons using the Tukey HSD Test

	Mean Difference	p	Decision	Interpretation
Between S1 and S2	-19.3000	0.706	Fail to Reject H_o	No Significant Difference
Between S1 and S3	-24.1000	0.555	Fail to Reject H_o	No Significant Difference
Between S1 and Control	38.6333	0.209	Fail to Reject H_o	No Significant Difference
Between S2 and S3	-4.8000	0.993	Fail to Reject H_o	No Significant Difference
Between S2 and Control	57.9333	0.046	Reject H_o	Significant Difference
Between S3 and Control	62.7333	0.031	Reject H_o	Significant Difference

Table 6 displays the results of post-hoc comparisons using the Tukey HSD test. It revealed that there were no significant differences between the 2.5 units, 5 units, and 7.5 units treatment groups, as well as between the 2.5 units group and the control group, with p-values of 0.706, 0.555, and 0.209, respectively, which is greater than the set alpha. However, significant differences were found between the control group and both the 5 units and 7.5 units groups, with p-values of 0.046 and 0.031, respectively. This implies that the treatment's impact is evident and only effective at higher concentrations (5 units and 7.5 units) compared to the control group. In contrast, 2.5 units showed no significant difference between the treatment and control group, suggesting that lower fiber content showed no noticeable effect.

The results agree with the statement by Saray et al. (2023) that the tensile strength of bioplastics increased with higher concentrations of taro starch and sea grapes, with Concentration 1 (20g of taro and sea grapes) exhibiting the lowest tensile strength (0.003 MPa), followed by Concentration 2 (40g) with a tensile strength of 0.005 MPa, and Concentration 3 (60g) with the highest tensile strength (0.007 MPa). This indicates that increasing the concentration enhances the tensile strength of bioplastics. Additionally, Babalola and

Olorunnisola (2019) reported tensile strength values ranging from 0.36 to 0.68 MPa, showing that as fiber content of coconut husk increased, tensile strength also increased, showing that the strength of the bioplastic is dependent on fiber concentration. Similarly, the results of this study showed that there was a significant difference at higher concentrations, as the 5 units and 7.5 units treatment showed significant differences when compared to the control group, whereas the 2.5 unit did not. This suggests that a higher concentration of *A. squamosa* fiber is more effective in enhancing the tensile strength of the bioplastic compared to a lower concentration.

Significance of the Difference in the Biodegradability of Different Mixtures of Bioplastics and the Control Group

Table 7 shows the results of a one-way analysis of variance (ANOVA) conducted to assess the significance of differences in the water absorption capacities of various bioplastic mixtures at 4, 12, and 24 hours. The analysis revealed statistically significant differences at each time point. At 4 hours, the mean square was 4947.917, the F-value was 14.074, and the p-value was 0.001, indicating that there were significant differences in water absorption among the bioplastics and the control group. Similarly, at 12 hours, the mean square was 5117.187, the F-value was 16.375, and the p-value was 0.001, further supporting the presence of significant differences. At 24 hours, the mean square was 5763.889, the F-value was 31.619, and the p-value was 0.000, reinforcing the finding of significant differences. These results suggest that, over the observed time intervals, there are clear differences in the water absorption behavior of the bioplastics compared to the control group, with each time point showing statistically significant variations in water retention.

Table 7. Significance of the Difference in the Water Absorption of Different Mixtures of Bioplastics and the Control Group

	Mean Square	**F**	**p**	**Decision**
4 hours	4947.917	14.074	0.001	Reject H_o (Significant)
12 hours	5117.187	16.375	0.001	Reject H_o (Significant))
24 hours	5763.889	31.619	0.000	Reject H_o (Significant)

Table 7 presents the results of post-hoc comparisons using the Tukey HSD test, which was conducted to determine significant differences in water absorption between the different bioplastic setups (S1, S2, S3) and the control group (commercial plastic) at three-time intervals: 4, 12, and 24 hours. At the 4-hour interval, significant differences were observed between the control group and all bioplastics, with the control group showing no absorption (p = 0.001 for S1, p = 0.022 for S2, p = 0.007 for S3). However, no significant differences were found between any of the bioplastics (S1 vs. S2, S1 vs. S3, and S2 vs. S3). At the 12-hour mark, similar results were observed, with significant differences between the control and all bioplastics (p = 0.001 for S1, p = 0.005 for S2, p = 0.005 for S3), but no significant differences were detected between the bioplastics themselves. At the 24-hour interval, the control group again exhibited significant differences in comparison to all bioplastics (p = 0.000 for S1, p = 0.001 for S2, p = 0.000 for S3), while no significant differences were observed between the bioplastics (S1 vs. S2, S1 vs. S3, S2 vs. S3). These results indicate that significant differences were consistent between the bioplastics and the commercial plastic, highlighting that the bioplastics are more absorbent than the commercial plastic, but not significantly different from one another in their water absorption behavior.

Table 8. Post Hoc Comparisons using the Tukey HSD Test

	Mean Difference	**p**	**Decision**	**Interpretation**
4 hours				
Between S1 and S2	37.5000	0.144	Failed to Reject H_o	No Significant Difference

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Between S1 and S3	25.0000	0.414	Failed to Reject	No Significant Difference
Between S1 and Control	95.8333	0.001	Reject H_o	Significant Difference
Between S2 and S3	-12.5000	0.845	Failed to Reject	No Significant Difference
Between S2 and Control	58.3333	0.022	Reject H_o	Significant Difference
Between S3 and Control	70.8333	0.007	Reject H_o	Significant Difference
12 hours				
Between S1 and S2	25.0000	0.369	Failed to Reject	No Significant Difference
Between S1 and S3	25.0000	0.369	Failed to Reject	No Significant Difference
Between S1 and Control	95.8333	0.001	Reject H_o	Significant Difference
Between S2 and S3	0.0000	1.000	Failed to Reject	No Significant Difference
Between S2 and Control	70.8333	0.005	Reject H_o	Significant Difference
Between S3 and Control	70.8333	0.005	Reject H_o	Significant Difference
24 hours				
Between S1 and S2	33.3333	0.064	Failed to Reject	No Significant Difference
Between S1 and S3	16.6667	0.474	Failed to Reject	No Significant Difference
Between S1 and Control	100.0000	0.000	Reject H_o	Significant Difference
Between S2 and S3	-16.6667	0.474	Failed to Reject	No Significant Difference
Between S2 and Control	66.6667	0.001	Reject H_o	Significant Difference
Between S3 and Control	83.3333	0.000	Reject H_o	Significant Difference

This study contradicts the findings of Elfaleh et al. (2023) and Peralta et al. (2024), which found that bioplastic composition significantly influences water absorption. Elfaleh et al. (2023) found that higher fiber content increases water absorption due to the hydrophilic nature of plant fibers. Similarly, Peralta et al. (2024) observed that a 70:30 mango peel-to-banana pseudostem fiber ratio exhibited 8% water absorption, while the 30:70 ratio absorbed 16%. Thus, this study found significant differences in water absorption across different bioplastic mixtures, with p-values of 0.001, 0.001, 0.000 at 4, 12, and 24 hours. Additionally, while prior research suggests glycerol increases water uptake, these results indicate that neither glycerol concentration nor fiber type significantly influenced absorption. Moreover, water degradation significantly impacts the environmental rate of bioplastics in aquatic ecosystems. The rate at which biodegradable plastics break down depends largely on their ability to absorb and retain moisture (Sathiaseelan et al., 2024). If bioplastics absorb too much water, it may degrade too quickly, losing mechanical integrity and potentially forming persistent bioplastics. On the other hand, minimal water absorption can slow degradation, reducing their intended environmental benefits. Given the plastic pollution crisis, bioplastics offer a promising alternative, but their effectiveness depends on material composition, fiber treatment, and structural properties. These findings highlight the need for further research into how these factors influence both water absorption and degradation. A deeper understanding of water degradation mechanisms will help improve bioplastic formulations, ensuring they degrade efficiently without contributing to plastic pollution.

CONCLUSION

Plastic is widely used for its versatility and cost-effectiveness. However, the excessive consumption of plastic has caused pollution and various environmental issues that affect both human health and wildlife. Addressing this problem requires an urgent solution. The main goal of this study is to evaluate the effectiveness of *A. squamosa* fiber for bioplastic applications. With the data gathered, the following conclusions were obtained:

1. The data showed that the *A. squamosa* fiber bioplastic performs excellently in tensile strength, compared to commercial plastics, with S3 showing the highest tensile strength, closely followed by S2, then S1 and the control, respectively;
2. The data concluded that the water absorption of the *A. squamosa* fiber bioplastics were moderate while the commercial plastic is low. These data suggest that the structural integrity of the atis bioplastics is not as high compared to the commercial plastic. Nevertheless, this could indicate the higher degradability of the said bioplastics; and
3. In conclusion, there is a significant difference between the *A. squamosa* fiber bioplastic and the control group in terms of tensile strength and water absorption. The observed properties of the atis bioplastics points to their potential as an eco-friendly and sustainable alternative to commercial plastics.

RECOMMENDATIONS

Based on the findings, the researchers suggest the following:

1. This study recommends the Department of Environment and Natural Resources (DENR) officials to explore eco-friendly and sustainable bioplastics by utilizing *A. squamosa* fiber for production. Using atis fiber as a raw material offers an eco-friendly alternative that can help reduce plastic pollution and promote sustainable waste management practices;
2. This study recommends that local communities with atis trees develop bioplastic from *A. squamosa* fiber as an alternative to commercial plastics or collaborate with bioplastic manufacturers. This would promote sustainable development and provide a source of income by creating an eco-friendly product;
3. This study recommends manufacturers to adopt *A. squamosa* fiber bioplastic as a sustainable alternative to reduce reliance on petroleum-based plastics. By integrating atis fiber bioplastic into their production, manufacturers can contribute to minimizing environmental pollution and promoting the use of renewable resources;
4. This study recommends that farmers look further into the possibility of adopting *A. squamosa* fiber bioplastic to reduce farm waste and promote sustainable farming practices. Utilizing atis fiber for bioplastic production can also create new income opportunities by adding value to agricultural by-products.
5. This study recommends that future researchers further enhance and improve the mechanical properties of *A. squamosa* bioplastic and explore the addition of other reinforcing agents to optimize its strength and flexibility. It is also recommended to conduct a biodegradability test to assess the decomposition rate under different environmental conditions, ensuring its eco-friendliness and potential as a sustainable alternative to commercial plastics. Furthermore, researchers are encouraged to use standardized measurements for all mixtures and to carry out the study in a standardized, well-equipped laboratory to ensure accuracy and reliability of results.

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APPENDIX A

CERTIFICATE OF EDITING AND STATISTICAL REVIEW

COR JESU COLLEGE, INC.

Sacred Heart Avenue, Digos City, Province of Davao del Sur, Philippines
Tel. No.: (082) 553-2433 local 101 • Fax No.: (082) 553-2333 • www.cjc.edu.ph

CERTIFICATE OF EDITING AND STATISTICAL REVIEW

Name of Students: **AGCANG, ACE V., AGUILAR, GRAZELL C., CELERES, STEVEN C., DAGATAN, KYLLE L., GAPASIN, JOANALYN O., GOMITO, LEONIZ D., MANTE, ANGEL M., PALAMOS, ELIZABETH P., RUDA, XYRIL V.**

Grade and Specialization: **GRADE 12 – HEALTH STUDIES**

Research Title: **ATISFLEX: UTILIZING ATIS (*Annona squamosa L.*) FIBER FOR INNOVATIVE AND ECO-FRIENDLY BIOPLASTIC PRODUCTION**

PART I. *For Editor*

This is to certify that the above study, prepared as a requirement for the basic education, was submitted to the undersigned for grammar checking and proofreading. I endorse the manuscript submitted as it has generally met the standards and requirements, including the form and style as prescribed by Cor Jesu College.

Signed: **APPLE JOY P. FLORES, MEd-LT** Date: 04 | 14 | 25

PART II. *For Statistician*

I endorse the manuscript submitted by the student with the statistical requirements checked and found appropriate for thesis purpose(s).

Signed: **CLEFORD JAY D. BACAN, MAEd-MT** Date: 4 | 14 | 25

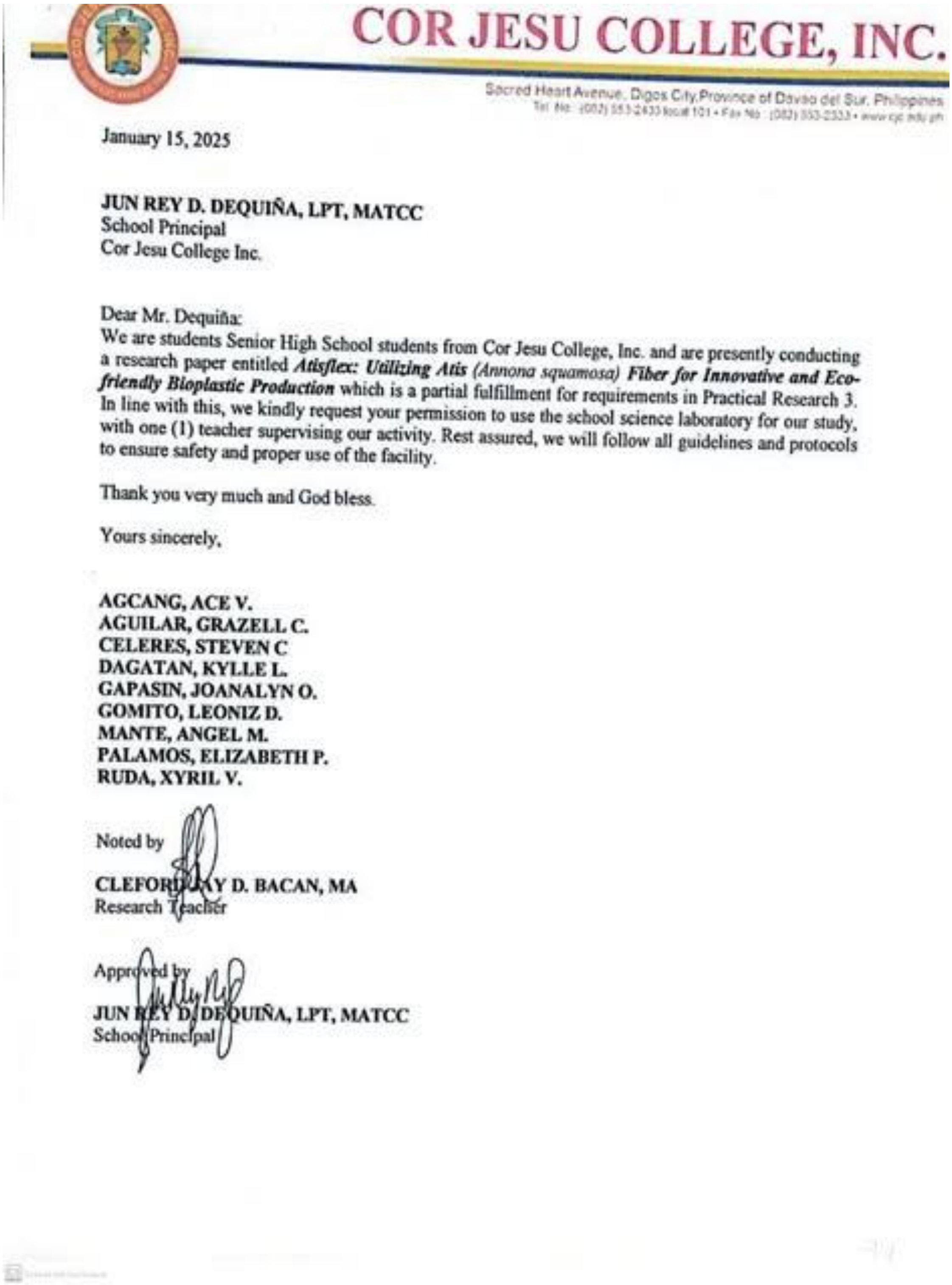
PART III. For *Research Adviser/Mentor*

I am satisfied with the student's manuscript and accept this in partial fulfillment of the requirements for the degree identified.

Signed: **CLEFORD JAY D. BACAN, MAEd-MT** Date: 4 | 14 | 25

APPENDIX B1

LETTER OF APPROVAL FROM THE SCHOOL PRINCIPAL



COR JESU COLLEGE, INC.

Sacred Heart Avenue, Digos City,Province of Davao del Sur, Philippines

January 15, 2025

JUN REY D. DEQUIÑA, LPT, MATCC
School Principal
Cor Jesu College Inc.

Dear Mr. Dequiña:
We are students Senior High School students from Cor Jesu College, Inc. and are presently conducting a research paper entitled ***Atisflex: Utilizing Atis** (Annona squamosa) **Fiber for Innovative and Eco-friendly Bioplastic Production*** which is a partial fulfillment for requirements in Practical Research 3. In line with this, we kindly request your permission to use the school science laboratory for our study, with one (1) teacher supervising our activity. Rest assured, we will follow all guidelines and protocols to ensure safety and proper use of the facility.

Thank you very much and God bless.

Yours sincerely,

AGCANG, ACE V.
AGUILAR, GRAZELL C.
CELERES, STEVEN C
DAGATAN, KYLLE L.
GAPASIN, JOANALYN O.
GOMITO, LEONIZ D.
MANTE, ANGEL M.
PALAMOS, ELIZABETH P.
RUDA, XYRIL V.

Noted by

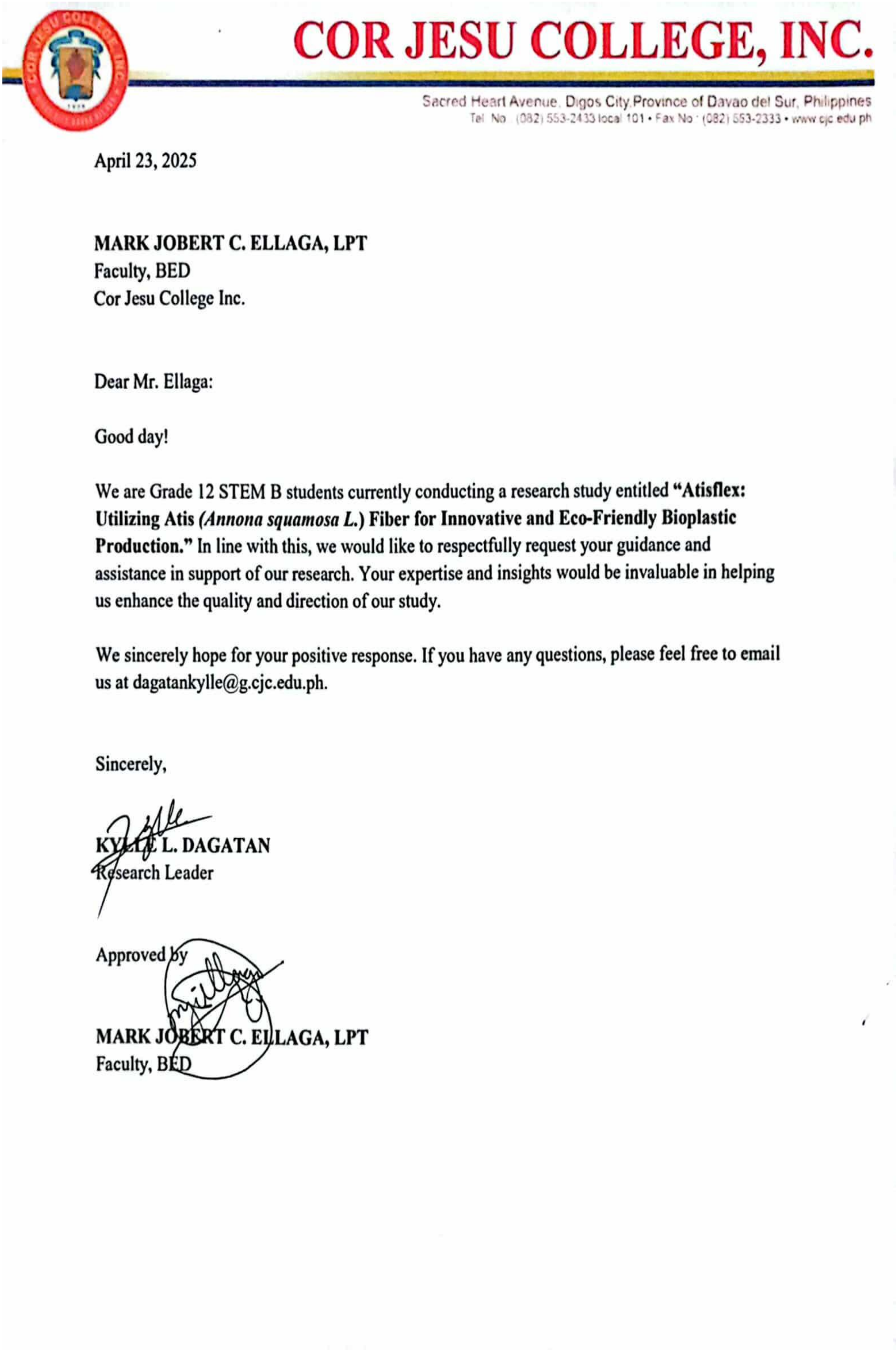
CLEFORD JAY D. BACAN, MA
Research Teacher

Approved by

JUN REY D. DEQUIÑA, LPT, MATCC
School Principal

APPENDIX B2

LETTER FOR QUALIFIED SCIENTIST



COR JESU COLLEGE, INC.

Sacred Heart Avenue, Digos City, Province of Davao del Sur, Philippines
Tel. No.: (082) 553-2433 local 101 • Fax No.: (082) 553-2333 • www.cjc.edu.ph

April 23, 2025

MARK JOBERT C. ELLAGA, LPT
Faculty, BED
Cor Jesu College Inc.

Dear Mr. Ellaga:

Good day!

We are Grade 12 STEM B students currently conducting a research study entitled **"Atisflex: Utilizing Atis *(Annona squamosa L.)* Fiber for Innovative and Eco-Friendly Bioplastic Production."** In line with this, we would like to respectfully request your guidance and assistance in support of our research. Your expertise and insights would be invaluable in helping us enhance the quality and direction of our study.

We sincerely hope for your positive response. If you have any questions, please feel free to email us at dagatankylle@g.cjc.edu.ph.

Sincerely,

KYLLE L. DAGATAN
Research Leader

Approved by

MARK JOBERT C. ELLAGA, LPT
Faculty, BED

APPENDIX C

FINANCIAL STATEMENT

COR JESU COLLEGE, INC.

Sacred Heart Avenue, Digos City,Province of Davao del Sur, Philippines
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PRACTICAL RESEARCH 2
FINANCIAL STATEMENT

Research Title:	***Atisflex: Utilizing Atis (*Annona squamosa*) Fiber for Innovative and Eco-friendly Bioplastic Production***
Grade and Section	12 STEM B
Submission Date:	April 8, 2025

Particulars	Price	Quantity	Amount
Distilled Water (10 L)	₱ 125	1	₱ 125
White vinegar	₱ 20	1	₱ 20
Glycerin	₱ 154.5 per bottle	2	₱ 309
Agar Powder	₱ 12.50 each	8	₱ 100
		TOTAL	₱ 554.00

Prepared by

KYLLE L. DAGATAN
Group Leader

Noted by

CLEFORD JAY B. BACAN, MAEd-MT
Research Teacher

Approved by

JUN REY D. DEQUIÑA, MATCC
School Principal

APPENDIX D

SPSS RESULTS

Descriptives

Tensile Strength

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
T1	3	72.3667	14.45003	8.34273	36.4708	108.2625	57.90	86.80
T2	3	91.6667	36.44452	21.04126	1.1335	182.1999	57.90	130.30
T3	3	96.4667	16.74316	9.66667	54.8744	138.0590	86.80	115.80
Control	3	33.7333	8.37158	4.83333	12.9372	54.5295	28.90	43.40
Total	12	73.5583	31.75948	9.16817	53.3793	93.7373	28.90	130.30

ANOVA

Tensile Strength

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7320.463	3	2440.154	5.171	.028
Within Groups	3774.847	8	471.856		
Total	11095.309	11			

Post Hoc Tests

p

Multiple Comparisons

Dependent Variable: Tensile Strength
Tukey HSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
T1	T2	-19.30000	17.73614	.706	-76.0974	37.4974
	T3	-24.10000	17.73614	.555	-80.8974	32.6974
	Control	38.63333	17.73614	.209	-18.1640	95.4307
T2	T1	19.30000	17.73614	.706	-37.4974	76.0974
	T3	-4.80000	17.73614	.993	-61.5974	51.9974
	Control	57.93333*	17.73614	.046	1.1360	114.7307
T3	T1	24.10000	17.73614	.555	-32.6974	80.8974
	T2	4.80000	17.73614	.993	-51.9974	61.5974
	Control	62.73333*	17.73614	.031	5.9360	119.5307
Control	T1	-38.63333	17.73614	.209	-95.4307	18.1640
	T2	-57.93333*	17.73614	.046	-114.7307	-1.1360
	T3	-62.73333*	17.73614	.031	-119.5307	-5.9360

*. The mean difference is significant at the 0.05 level.

Tests of Normality

	Kolmogorov-Smirnov[a] Statistic	Kolmogorov-Smirnov[a] df	Kolmogorov-Smirnov[a] Sig.	Shapiro-Wilk Statistic	Shapiro-Wilk df	Shapiro-Wilk Sig.
Water Absorption - 4 hours	.170	12	.200*	.907	12	.197
Water Absorption - 12 hours	.198	12	.200*	.881	12	.090

Water Absorption - 24 hours	.202	12	.189	.854	12	.042

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Water Absorption - 4 hours	Between Groups	14843.750	3	4947.917	14.074	.001
	Within Groups	2812.500	8	351.563		
	Total	17656.250	11			
Water Absorption - 12 hours	Between Groups	15351.562	3	5117.187	16.375	.001
	Within Groups	2500.000	8	312.500		
	Total	17851.563	11			
Water Absorption - 24 hours	Between Groups	17291.667	3	5763.889	31.619	.000
	Within Groups	1458.333	8	182.292		
	Total	18750.000	11			

Post Hoc Tests

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Water Absorption - 4 hours	T1	T2	37.50000	15.30931	.144	-11.5258	86.5258
		T3	25.00000	15.30931	.414	-24.0258	74.0258
		Control	95.83333*	15.30931	.001	46.8075	144.8591
	T2	T1	-37.50000	15.30931	.144	-86.5258	11.5258
		T3	-12.50000	15.30931	.845	-61.5258	36.5258
		Control	58.33333*	15.30931	.022	9.3075	107.3591
	T3	T1	-25.00000	15.30931	.414	-74.0258	24.0258
		T2	12.50000	15.30931	.845	-36.5258	61.5258
		Control	70.83333*	15.30931	.007	21.8075	119.8591
	Control	T1	-95.83333*	15.30931	.001	-144.8591	-46.8075
		T2	-58.33333*	15.30931	.022	-107.3591	-9.3075
		T3	-70.83333*	15.30931	.007	-119.8591	-21.8075
Water Absorption - 12 hours	T1	T2	25.00000	14.43376	.369	-21.2220	71.2220
		T3	25.00000	14.43376	.369	-21.2220	71.2220
		Control	95.83333*	14.43376	.001	49.6114	142.0553
	T2	T1	-25.00000	14.43376	.369	-71.2220	21.2220
		T3	.00000	14.43376	1.000	-46.2220	46.2220
		Control	70.83333*	14.43376	.005	24.6114	117.0553
	T3	T1	-25.00000	14.43376	.369	-71.2220	21.2220
		T2	.00000	14.43376	1.000	-46.2220	46.2220
		Control	70.83333*	14.43376	.005	24.6114	117.0553
	Control	T1	-95.83333*	14.43376	.001	-142.0553	-49.6114
		T2	-70.83333*	14.43376	.005	-117.0553	-24.6114
		T3	-70.83333*	14.43376	.005	-117.0553	-24.6114
Water Absorption - 24 hours	T1	T2	33.33333	11.02396	.064	-1.9693	68.6359
		T3	16.66667	11.02396	.474	-18.6359	51.9693
		Control	100.00000*	11.02396	.000	64.6974	135.3026
	T2	T1	-33.33333	11.02396	.064	-68.6359	1.9693
		T3	-16.66667	11.02396	.474	-51.9693	18.6359
		Control	66.66667*	11.02396	.001	31.3641	101.9693
	T3	T1	-16.66667	11.02396	.474	-51.9693	18.6359
		T2	16.66667	11.02396	.474	-18.6359	51.9693

		Control	83.33333*	11.02396	.000	48.0307	118.6359
	Control	T1	-100.00000*	11.02396	.000	-135.3026	-64.6974
		T2	-66.66667*	11.02396	.001	-101.9693	-31.3641
		T3	-83.33333*	11.02396	.000	-118.6359	-48.0307

*. The mean difference is significant at the 0.05 level.

APPENDIX E PLAGIARISM REPORT

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Author(s)

DAGATAN, KYLLE L., GAPASIN, JOANALYN O.

Coordinator

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APPENDIX F CAPTURED PROCESSES AND RESULTS

Figure 1. Production of bioplastic. (a) Preparation of atis fiber; (b) Formulation of bioplastic base solution; (c) Mixing the formulation of atis fiber mixture; (d) Molding of atis fiber mixture; (e) Performance assessment for tensile strength test; (f) Performance assessment for water absorption.

Figure 2. *Set-up 1 that contains 2.5 units of pulverized atis fiber*

Figure 3. *Set-up 2 that contains 5 units of pulverized atis fiber*

Figure 4. *Set-up 3 that contains 2.5 units of pulverized atis fiber*

	Tensile strength *Measured in MegaPascal (MPa)*			
	Set-up 1	Set-up 2	Set-up 3	
	2.5 mL atis fiber	*5 mL atis fiber*	*7.5 mL atis fiber*	*Commercial plastic*
Replicate 1	72.4	57.9	86.8	43.4
Replicate 2	86.8	130.3	86.8	28.9
Replicate 3	57.9	86.8	115.8	28.9

	Water absorption *Measured in percentage (%)*			
	Initial weight	4 hours	12 hours	24 hours
2.5 mL atis fiber Replicate 1	8	87.50%	100%	100%
Replicate 2	8	75.00%	75%	87.50%
Replicate 3	8	112.50%	112.50%	112.50%
5 mL atis fiber Replicate 1	8	75.00%	87.50%	87.50%
Replicate 2	8	37.50%	62.50%	62.50%
Replicate 3	8	62.50%	62.50%	50%
7.5 mL atis fiber Replicate 1	8	50.00%	50%	75%
Replicate 2	8	62.50%	62.50%	75%
Replicate 3	8	100%	100%	100%
Control Group	0	0%	0%	0%

Figure 5. Results of the tensile strength test and water absorption test