

# Eco-Ice Chest: Banana Pseudo-Stem Fiber (*Musa balbisiana*) and Commercial Cassava Starch as an Alternative to Expanded Polystyrene

Roland Nicole P. Sechico<sup>1</sup>, Engr. Ilde B. Deloria<sup>2</sup>

<sup>1</sup>Department of Sanitary Engineering, Western Mindanao State University, Zamboanga City, Philippines-7000

<sup>2</sup>College of Engineering and Technology, Western Mindanao State University, Zamboanga City, Philippines-7000

Email address: sechicorolandnicole@gmail.com, ilde.deloria@wmsu.edu.ph

**Abstract**— Expanded polystyrene (EPS) is commonly used for insulation and packaging but poses serious environmental concerns due to its non-biodegradability. This study presents an eco-friendly alternative using banana pseudo-stem fiber and cassava starch to develop a biodegradable ice chest. Three treatments were evaluated and compared to commercial EPS based on water absorption, thermal insulation, flammability, mechanical strength, melting point, and biodegradability. Results showed significant differences among all treatments. Treatment 3 consistently demonstrated the best overall performance, particularly in flame resistance, mechanical strength, thermal stability, and biodegradation. While EPS remained superior in some aspects, the findings highlight the potential of Treatment 3 as a sustainable alternative. Further work is recommended to refine the material and evaluate long-term performance.

**Keywords**— Banana pseudo-stem fiber; Biodegradable insulation; Cassava Starch; Eco-ice chest; Expanded polystyrene alternative; Sustainable material.

## I. INTRODUCTION

Expanded Polystyrene Foam (EPS) is widely used in various applications such as packaging, household appliances, and construction materials due to its lightweight and easy-to-handle nature. Global production of EPS reaches approximately 10 million metric tons annually. However, EPS is non-biodegradable and resistant to natural decomposition, leading to significant environmental issues including land and water pollution, as well as risks to human health and marine ecosystems (Mendiola, 2022). Once discarded, EPS fragments into smaller pieces, often dispersing over long distances. Its buoyant nature allows it to enter waterways and oceans through urban runoff, where it accumulates, absorbs toxins, and is frequently mistaken for food by marine life—resulting in widespread ecological damage. Furthermore, EPS recycling remains limited, as it cannot be re-molded once expanded and requires a consistent market for reused material. The primary disposal methods, incineration and landfilling, both present environmental challenges.

In Southeast Asia, EPS ice boxes are commonly used in the fish trade and for transporting dairy products and vegetables. According to the UNDP Ocean Innovation Challenge (2021), these containers are widely criticized by traders and fishermen for being short-lived, hard to clean, and unpleasant to handle—often deteriorating within weeks. The lack of practical alternatives has contributed to the increasing

presence of EPS in marine environments. Estimates of plastic entering the oceans annually range from 5 to 12 million metric tons.

In response to the growing demand for sustainable materials, the engineering industry is increasingly focused on developing eco-friendly alternatives to synthetic polymers. Natural fibers such as banana, jute, coir, bamboo, and hemp offer several advantages, including high tensile strength, low weight, cost-effective processing, and biodegradability. Among these, banana fiber is particularly promising due to its strength and abundance (Jagadeesh et al., 2015). Research has shown its suitability for high-quality paper production and its sensitivity to chemical treatments that affect physical properties like density and flexibility (Ruznan et al., 2020).

Despite increasing interest in biodegradable materials like banana pseudo-stem fiber and cassava starch, their potential use as thermal insulation in eco-friendly ice chests remains underexplored. Most current studies focus on their application in packaging, overlooking their insulation capabilities. This study aims to address this gap by investigating the feasibility of using banana pseudo-stem fiber and cassava starch as sustainable alternatives to EPS in the design and development of biodegradable ice chests.

## II. METHODOLOGY

### 2.1 Experimental and Study Location

The experimental study was conducted at the researcher's residence in San Roque, Zamboanga City. This location provided adequate space for the fabrication process and allowed for continuous supervision and control of the experimental procedures.

### 2.2 Secondary Data Gathering

A thorough literature review from reliable internet resources was used to gather secondary data. The researcher focused on studies related to biodegradable foams derived from natural fibers and starch, using academic databases such as ScienceDirect, ResearchGate, and Google Scholar. These sources informed the research framework and supported the selection of materials and methods.

### 2.3 Raw Material Preparation and Biodegradable Foam Formulation

The production of the biodegradable foam involved the use of banana pseudo-stem fiber combined with a starch-based binder. The pseudo-stem was sourced locally and underwent several preparation steps, including soaking, washing, fiber extraction, sun-drying, and crushing, to ensure compatibility with the starch solution.

The starch solution was prepared by dissolving cassava starch in water and heating it while continuously stirring. Additives such as a plasticizer, polyvinyl alcohol, and magnesium stearate were incorporated to enhance flexibility and stability. The processed banana fiber was gradually mixed into the heated starch solution until a uniform, gel-like consistency was achieved.

To produce the biodegradable foam, the mixture was then oven-dried at a regulated temperature after being poured into molds. The molded samples were prepared based on three different fiber-to-starch ratios, selected according to previous research on biodegradable foam using natural fibers. After drying, the samples were removed from the molds and conditioned for analysis. These samples were subjected to physical and mechanical testing, as well as biodegradability assessment, to evaluate their potential as a sustainable alternative to expanded polystyrene.

## 2.4 Physical Properties

### 2.4.1 Water Absorption

Water absorption testing was conducted based on a modified version of ASTM D570, which outlines standard procedures for determining moisture uptake in polymer-based materials. The method was adapted to suit manual testing conditions while maintaining the standard’s principles.

Biodegradable foam samples were randomly selected and shaped uniformly to ensure consistency in size and thickness. Each sample was oven-dried until a constant weight was reached, and the initial dry weight was recorded.

The samples were then fully submerged in clean water at room temperature for a set duration. After immersion, surface moisture was gently removed, and the wet weight was measured. Water absorption was calculated as the percentage increase in weight. All procedures were performed under controlled conditions to ensure accuracy and consistency.

$$\text{Water Absorption (\%)} = \frac{[(\text{Wet Weight} - \text{Dry Weight}) / (\text{Dry Weight})] \times 100}{(1)}$$

### 2.4.2 Thermal Insulation

Thermal insulation testing of the Eco-Ice Chest was conducted using a modified version of ASTM C177, adapted to suit manual testing conditions. Samples were prepared based on the approximate dimensions of a standard commercial EPS ice chest. Each sample was filled with ice or cooling packs to simulate actual usage, and internal and external temperatures were monitored using calibrated thermometers. The samples were exposed to ambient temperatures above typical room temperature, and internal temperature readings were taken at regular intervals over an extended period until thermal equilibrium was reached.

Thermal performance was assessed by tracking the rate of temperature increase inside the Eco-Ice Chests and comparing it with external temperature fluctuations. The thermal

conductivity (k-value) was calculated and used to evaluate insulation efficiency across different sample groups.

$$Q = \frac{k \times A \times (T_{hot} - T_{cold})}{d} \tag{2}$$

### 2.4.3 Flammability

Flammability testing of the biodegradable foam was conducted following a modified version of ISO 11925-2, adapted for manual procedures. Randomly selected specimens were conditioned in a controlled environment to ensure consistent moisture and material properties. To replicate ignition circumstances, each sample was vertically mounted in a test chamber and subjected to a regulated flame for a brief period of time at a specified angle and distance.

During testing, observations included ignition time, flame spread, and the presence of self-extinguishing behavior or flaming debris. The distance of flame propagation was recorded, and heat release was calculated using a standard formula. The materials were evaluated based on whether flame spread remained within acceptable limits, ensuring alignment with ISO 11925-2.

$$\text{Flame Spread Heat} = \frac{\text{Distance traveled by Flame}}{\text{Time Taken}} \tag{3}$$

### 2.4.4 Melting Point

A modified version of ISO 11357, adjusted for manual processes, was used to determine the melting point of the biodegradable foams. Random samples from each treatment were heated in an oven, and the temperature was monitored using a calibrated thermometer. Samples were observed for visible signs of melting, such as softening or the transition to a liquid phase, which were taken as the melting point.

After testing, the materials were inspected for changes in appearance, including color and consistency. To improve reliability, multiple trials were conducted, and the average melting point for each treatment was calculated. The results were then compared to ISO 11357 guidelines to determine the thermal stability of the Eco-Ice Chest material.

## 2.5 Mechanical Properties

### 2.5.1 Tensile Strength

The tensile strength of the biodegradable foam was evaluated following a modified ASTM D638 standard, adapted for manual procedures. Random samples from each treatment were conditioned in a controlled environment to stabilize their properties before testing. A simple apparatus was constructed using clamps or a makeshift frame to secure the specimens, with a spring scale or weight system applied to gradually introduce tensile load until failure occurred.

The maximum force (F) at the point of breakage was recorded, and tensile strength was calculated using the appropriate equation. Multiple trials were conducted for each treatment to ensure accuracy, and the results were averaged. The data were then analyzed to determine the effect of different fiber-to-starch ratios on the tensile strength of the Eco-Ice Chest material.

$$\sigma = \frac{F}{A} \tag{4}$$

### 2.5.2 Flexural Strength

The flexural strength of the biodegradable foam was evaluated in accordance with a modified ASTM D790 standard. Random samples from each fiber-to-starch ratio were conditioned in a controlled environment to stabilize their properties prior to testing. A three-point bending setup was assembled using a simple apparatus to support the specimens horizontally, with force applied at the midpoint until failure or a limiting deflection was observed.

The maximum applied force and the corresponding deflection were recorded, and flexural strength was calculated using the appropriate equation. Multiple trials were conducted to ensure reliability, and the average values for each treatment group were determined. The results were then analyzed to assess the influence of different fiber-to-starch ratios on the flexural performance of the Eco-Ice Chest material.

$$\sigma_f = \frac{3FL}{2bd^2} \tag{5}$$

### 2.6 Biodegradability Test

#### 2.6.1 Biodegradation Rate

According to the ISO 17556 standard, the biodegradable foam's biodegradation rate was assessed. Random samples from each fiber-to-starch ratio were weighed to record their initial mass and stabilized in a controlled environment prior to testing. The samples were then buried in soil with uniform characteristics to ensure consistent exposure to microbial activity.

At regular intervals, the samples were retrieved, cleaned of any adhering soil, and reweighed to determine mass loss. The biodegradation rate was calculated using the appropriate equation. This process continued until the mass stabilized, marking the completion of significant biodegradation. Average values for each treatment group were computed for comparison and analysis.

$$\text{Biodegradation Rate (\%)} = \left( \frac{\text{Initial Mass} - \text{Final Mass}}{\text{Initial Mass}} \right) \times 100 \tag{6}$$

### III. RESULT AND DISCUSSION

The results were thoroughly analyzed in relation to the research objectives to ensure coherence and relevance. Emphasis was placed on the comparative performance of the treatment groups against the control, with key trends, variations, and patterns clearly identified. Furthermore, the implications of these findings were considered in terms of both practical applications and their contribution to the current body of knowledge. This analysis served as the foundation for the conclusion presented in the subsequent chapter.

The summary of results for the physical and mechanical properties of the Eco-Ice Chest, in comparison with conventional expanded polystyrene (EPS), was evaluated against the prescribed standards set by ASTM and ISO. Specifically, Water Absorption was assessed following ASTM D570, Flammability in accordance with ISO 11925-2, Thermal Insulation under ASTM C177, Tensile Strength as outlined in ASTM D638, and Flexural Strength according to ASTM D790. The Eco-Ice Chest treatments exhibited varying levels of performance across these parameters, with certain

formulations demonstrating closer alignment to the prescribed thresholds, while others reflected lower values. The traditional EPS, serving as the control benchmark, consistently conformed with or surpassed the established standards. These results provide a clear basis for evaluating the feasibility of the Eco-Ice Chest as a sustainable insulation material in comparison to conventional synthetic foam.

TABLE 1. Physical and Mechanical Properties in Comparison to EPS Foam Standards

Properties	T0	T1	T2	T3
Water Absorption (%)	0	24.91	16.79	9.82
Flammability	6	5.8	5.33	4.72
Thermal Insulation	0.0283	0.0274	0.0291	0.0301
Tensile Strength	0.0013	0.002	0.003	0.004
Flexural Strength	0.07	0.013	0.17	0.22

Prescribed Values / Standard	Remarks
ASTM D570	EPS (T0) complied with ASTM; all treatments exceeded the allowable range and failed.
ISO 11925-2	EPS (T0), Treatment 1, and Treatment 2 failed; only Treatment 3 complied with ISO 11925-2.
ASTM C177	All treatments and EPS (T0) complied with ASTM.
ASTM D638	All treatments and EPS (T0) were below the prescribed standard and failed.
ASTM D790	All treatments complied with ASTM; EPS (T0) was at the minimum allowable limit.

The Physical, Mechanical, and Biodegradability properties of Treatments 1, 2, 3, and 0 (Control Group) were assessed using a performance-based scoring system. Instead of ranking the treatments, scores were assigned based on conformity to standards using a 4-point scale: 4 – highly satisfactory (exceeds standard), 3 – satisfactory (meets standard), 2 – moderately satisfactory (below standard but functional), and 1 – unsatisfactory (far below standard).

TABLE 2. Scoring of Physical, Mechanical, and Biodegradability Properties

Properties	T0	T1	T2	T3
Water Absorption (%)	4	1	2	3
Thermal Insulation	4	3	2	1
Flammability	1	2	3	4
Melting Point	1	3	2	4
Tensile Strength	2	2	3	4
Flexural Strength	1	2	3	4
Degradation Rate (%)	1	2	3	4
<b>Total Score:</b>	<b>14</b>	<b>15</b>	<b>18</b>	<b>24</b>

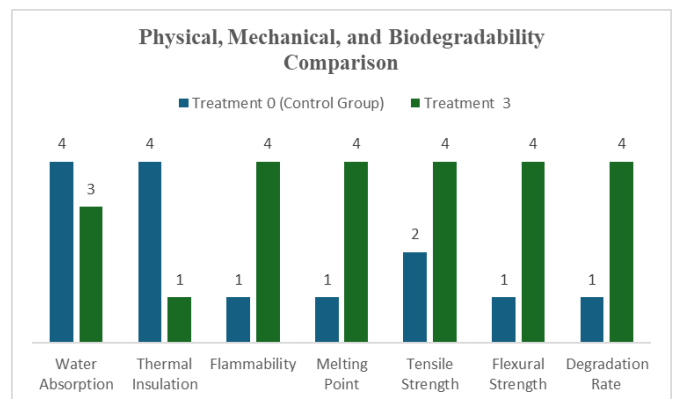


Figure 1. Physical, Mechanical, and Biodegradability Comparison of T0 and T3

The comparison between Treatment 0 (EPS – Control Group) and Treatment 3 reveals distinct differences in performance. EPS excelled in thermal insulation and water resistance, both rated highly satisfactory (4), while Treatment 3 was only satisfactory (3) in water absorption and unsatisfactory (1) in insulation. Conversely, Treatment 3 outperformed EPS in flammability resistance, thermal stability, and mechanical strength, achieving highly satisfactory (4) ratings compared to EPS’s poor to moderate scores. Biodegradability further distinguished the two, with EPS rated unsatisfactory (1) and Treatment 3 highly satisfactory (4), confirming its environmental advantage. Overall, while EPS remains the better insulator, Treatment 3 offers superior strength, safety, and sustainability, though improvements in insulation are still needed.

#### IV. CONCLUSION

The study evaluated the potential of banana pseudo-stem fiber and cassava starch composites as sustainable alternatives to expanded polystyrene (EPS) by assessing their physical, mechanical, and biodegradability properties.

In terms of physical properties, the control group (Treatment 0 using EPS) exhibited superior thermal insulation and complete resistance to water absorption. Among the fiber-based treatments, Treatment 3 demonstrated the lowest water absorption, indicating improved moisture resistance compared to Treatments 1 and 2. For flammability, Treatment 3 showed slower flame spread than EPS, highlighting the fire-retardant qualities of banana fiber. Thermal stability tests further revealed that fiber-based treatments had significantly higher melting points compared to EPS, confirming their resistance to degradation under elevated temperatures.

For the mechanical properties, EPS (Treatment 0) showed higher flexural strength, reflecting greater resistance to deformation under load. However, Treatment 3 outperformed EPS in both tensile and flexural strength, suggesting stronger performance under stretching and bending stresses. These findings demonstrate the reinforcing role of banana pseudo-stem fibers in improving the structural strength of the eco-materials.

In terms of biodegradability, EPS showed no notable degradation, underscoring its persistent nature in the environment. In contrast, fiber-based treatments, particularly Treatment 3, exhibited significant mass loss during testing, confirming their rapid decomposition and environmental advantage over EPS.

When comparing the overall performance, EPS excelled in thermal insulation, flexural strength, and water resistance, making it ideal for applications requiring durability and dimensional stability. However, the fiber-starch composite, especially Treatment 3, provided higher tensile and flexural strength, greater fire resistance, superior thermal stability, and significantly better biodegradability. These results suggest that while EPS remains dominant in certain physical aspects, banana pseudo-stem fiber composites offer a more sustainable and environmentally responsible alternative for insulation and packaging applications.

#### V. APPENDICES



Figure 2. Banana Pseudo-Stem Fiber (Crushed into Smaller Pieces)



Figure 3. Newly molded Treatment 1 ratio



Figure 4. Newly molded Treatment 2 ratio



Figure 5. Newly molded Treatment 3 ratio

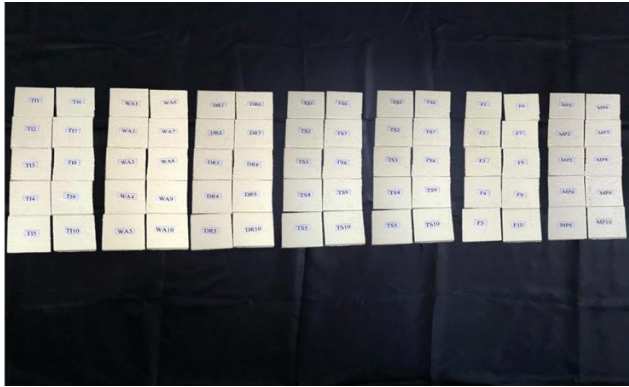


Figure 6. Traditional Expanded Polystyrene samples



Figure 7. Treatment 1 Samples

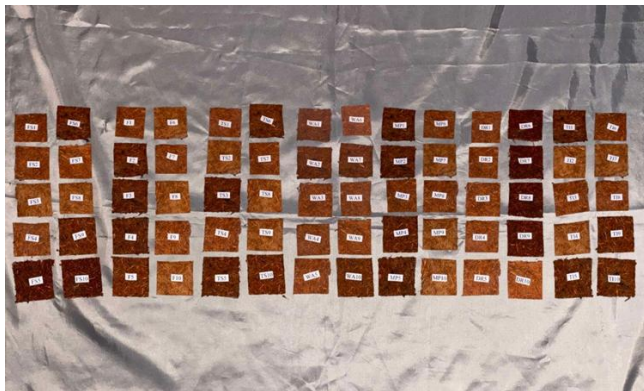


Figure 7. Treatment 2 Samples



Figure 8. Treatment 3 Samples

ACKNOWLEDGEMENT

The researcher extends her deepest gratitude to all individuals whose guidance, support, and contributions made the successful completion of this study possible. Their

assistance and encouragement were invaluable in addressing the challenges encountered throughout this research.

The researcher owes her utmost gratitude to the ever-supportive Engr. Ilde B. Deloria, M.Eng., Thesis Adviser – for providing the thesis topic, his technical guidance, constructive feedback, and unyielding encouragement, which significantly contributed to the refinement and success of this study. His expertise and dedication provided the researcher with the clarity and direction needed to navigate this academic pursuit.

Special appreciation is extended to Dr. Lizamyl R. Laping, The Chairman – for her unwavering support, professional insight, and constructive recommendations, which greatly enhanced the methodologies and findings of this research.

The researcher extends heartfelt thanks to Mrs. Nimfa P. Sechico for being an unwavering source of strength and for the mental, emotional, and financial support she provided throughout this journey. Her steadfast belief in the researcher’s potential served as a cornerstone in overcoming challenges. Also, to the researcher’s siblings, Rollaine and Rollie, for their invaluable assistance in providing the materials and resources necessary for this study.

Ms. Lyza Lee M. Pabilona, the researcher’s steadfast companion through thick and thin, for her technical assistance in providing the devices essential to this study, for ensuring the researcher’s well-being by providing meals during periods of intense focus, and for her unwavering support and timely words of encouragement that helped sustain the researcher’s determination throughout this endeavor.

Ms. Rhiane Dane D. Santos – the researcher’s comrade, for her assistance in various aspects of the study, from the initial formulation of the introduction to the testing of materials and data analysis. Her commitment and support were instrumental in ensuring the study’s success.

The researcher is grateful to her OG college circle, Jeshier John and Zoilene Jhoyz, and the “thesis gurlies” – Arwina, Fhian, Darkisa, and Angelica – for their camaraderie, encouragement, and support.

Lastly, the researcher extends her deepest gratitude to God Almighty, the ultimate witness to her doubts, moments of despair, sleepless nights, and silent struggles. His unwavering guidance, love, and wisdom provided the researcher with the strength and clarity necessary to persevere. Throughout this endeavor, His presence remained constant, offering support and direction. The successful completion of this study is attributed to His boundless grace and protection, which sustained the researcher throughout the journey.

REFERENCES

- [1] ASTM C177 Test Lab - VTEC Laboratories Inc. (2023). VTEC Laboratories. Retrieved September 25, 2024, from <https://www.vteclabs.com/testing/thermal-analysis/astm-c177/>
- [2] ASTM D638: Tensile Properties plastics. (n.d.). Retrieved September 17, 2024, from <https://www.zwickroell.com/industries/plastics/thermoplastics-and-thermosetting-molding-materials/tensile-properties-astm-d638/>
- [3] ASTM D790 - Flexural Properties Testing of Unreinforced and Reinforced Plastics - TRL. (2015). TRL. Retrieved from September 17, 2024, from [https://www.trl.com/astm\\_d790\\_flexural\\_properties\\_testing\\_of\\_unreinforced\\_and\\_reinforced\\_plastics/](https://www.trl.com/astm_d790_flexural_properties_testing_of_unreinforced_and_reinforced_plastics/)

- [4] Jagadeesh, D., Nallakumarasamy, G., & Venkatachalam, R. (2015). Characterization of banana fiber - A review. Retrieved August 09, 2024, from <https://nanoient.org/upload/pdf/ENT%20152154.pdf>
- [5] Mendiola, Rodrigo (2022). Expanded Polystyrene, friend or foe? - BioPlaster Research Inc. Retrieved September 2, 2024, from <https://www.bioplaster-research.com/blog-english/expanded-polystyrene-friend-or-foe>
- [6] Ruznan, W. S., Suhaimi, S. A., Mohd Yusof, N. J., Pairan, N., Mazlan, A. U., Azrain, A. N., Md Rosli, I. S., & Othman, N. I. (2020). Physical Properties Of Banana Pseudo-Stem Woven Fabric Treated With Softening Agent. In *Journal of Academia* (Vols. 8–8, Issue 2, pp. 76–83). Retrieved September 12, 2024, from <https://ir.uitm.edu.my/id/eprint/41443/>
- [7] UNDP Ocean Innovations and Actions (2021). A cool way to beat plastic pollution and empower farmers. Exposure. Retrieved September 4, 2024, from <https://oceaninnovationsandactions.exposure.co/a-cool-way-to-beat-plastic-pollution-and-empower-farmers>