
**DESIGN AND EVALUATION OF PHYSIO-MECHANICAL,
THERMAL, AND BIODEGRADABILITY PROPERTIES OF BIOBOXES
FOR SUSTAINABLE DOMESTIC FOOD STORAGE**

BY

MWESIGWA SIMEON

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**A RESEARCH REPORT SUBMITTED TO THE DEPARTMENT OF
PHYSICS IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR
OF
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MAY 2026

DECLARATION

I MWESIGWA SIMEON declare that this project is my original work and it has never been presented for any award to any university or any other institution of higher learning and where other people's work has been used it has been referenced or cited

Signature

Simeon

DATE

1st June, 2026.

MWEIGWA SIMEON

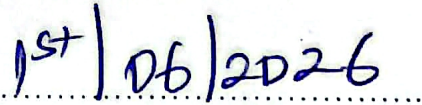
APPROVAL

This research on **design and evaluation of physio-mechanical, thermal, and biodegradability properties of bio boxes for sustainable domestic food storage** under the supervision of **DR.AKOBA RASHIDAH** has been submitted by **MWESIGWA SIMEON** for examination for the award of the degree of Bachelor of Science Education.

Signature

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date

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SUPERVISOR

Dr. AKOBA RASHIDAH (PhD)

PHYSICS DEPARTMENT

BUSITEMA UNIVERSITY

DEDICATION

I dedicate this work to my beloved parents :Nakato Christine and Kisule Stephen and to my beloved sisters: Naigaga rodah, Nairuba Monica, Naigaga viola and to my beloved brothers: Muyaka franco and Waiswa Isaac. I am very grateful for your support in all aspects. May the almighty God reward you abundantly.

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LIST OF ACRONYMS AND ABBREVIATIONS

NaCRRI	National Agricultural cultural resources Research Institute
PLA	Polylactic acid
PHAs	Polyhydroxyalkanoates
LCAs	Life cycle Assessment

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ABSTRACT

This study aimed to design and evaluate biodegradable bio-boxes using locally available materials for sustainable domestic food storage in Uganda. The research investigated physio mechanical properties, thermal performance, and biodegradability of the fabricated bio-boxes. Materials such as cassava starch, banana fibers, and paper pulp were used to produce bio-boxes. Mechanical tests showed moderate tensile strength suitable for domestic use, while thermal analysis revealed low thermal conductivity, indicating good insulation properties. Biodegradability tests demonstrated decomposition within 4–8 weeks under soil burial conditions. The study aligns with Uganda’s environmental policies, including the National Environment Act (2019), promoting sustainable alternatives to plastic packaging. The findings confirm that bio-boxes are a viable ecofriendly solution for reducing plastic waste in domestic food storage.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

In this chapter we are going to look on how the bio boxes came up and the background of this study am carrying out, the problem statement of the study, objectives of the study, research questions, significance of the study, and the scope of the study.

1.1 Background of the Study

In Uganda, the rapid increase in plastic packaging use has created serious environmental challenges. Studies indicate that plastic imports and consumption have grown significantly, with plastics becoming widely used in domestic food storage due to their affordability and durability. In recent years, the quest for sustainable practices in food storage has gained significant attention due to escalating concerns over food waste and its environmental implications(Berglund & Oksman, 2019). As the global population surges, the demand for effective and economical storage solutions has become increasingly critical. Traditional storage methods, predominantly utilizing non-biodegradable plastics, are major contributors to environmental pollution, with plastic waste occupying landfills and contaminating oceans .In response to these pressing challenges, the development of biodegradable alternatives, such as bio-boxes, has emerged as a promising solution that meets both environmental needs and consumer demands for practicality and usability(Doi, 2002). The role of bio-boxes in sustainable food storage can revolutionize how households preserve food, thereby mitigating food waste and reducing reliance on harmful plastic packaging(Smith & Kumar, 2021). As a result, households continue to depend on conventional plastic solutions that contribute adversely to environmental degradation. Despite these efforts, adoption of biodegradable packaging remains low, highlighting the need for locally designed sustainable alternatives such as bio-boxes.

1.2 Problem Statement

The increasing reliance on non-biodegradable plastics for food storage presents a significant and multifaceted environmental threat. Current biodegradable packaging options frequently fail to exhibit the necessary mechanical strength, thermal insulation, and biodegradability required for

effective domestic food storage. Many existing products struggle to balance these essential properties, leading to consumer skepticism regarding their performance and effectiveness. This gap in the market highlights the need for innovative solutions that can provide both necessary functionality and environmental benefits. Households often select traditional plastic options due to their proven reliability, perpetuating a cycle of plastic dependency that ultimately harms the environment. This research aims to address these shortcomings by designing and evaluating bio-boxes made from innovative biodegradable materials. By exploring these alternatives, we aim to promote sustainable practices that can effectively diminish the environmental impact of food storage while providing consumers with reliable options that meet their everyday needs.

However, despite advances in biodegradable materials, practical applications in domestic food storage remain insufficiently explored. Existing bio-packaging solutions often lack adequate mechanical strength, thermal insulation, and timely biodegradability. Although policies exist to regulate plastic use, enforcement challenges and lack of affordable alternatives hinder effectiveness. However, plastic waste has become a major environmental concern, contributing to soil degradation, water pollution, and blockage of drainage systems in urban areas such as Kampala. To address this, Uganda has implemented environmental policies such as the National Environment Act, 2019, which promotes sustainable waste management and encourages the use of environmentally friendly alternatives. Therefore, there is a need to develop locally appropriate, biodegradable food storage solutions that align with national environmental policies.

1.3 Objectives of the Study

1.3.1 General Objective

To design and evaluate biodegradable bio-boxes using locally available materials for sustainable domestic food storage in Uganda

1.3.2 Specific Objectives

1. To design and fabricate bio-boxes using locally available biodegradable materials such as cassava starch and plant fibers

2. To determine physio-mechanical properties (tensile strength, compressive strength, density) of the bio-boxes
3. To evaluate thermal properties (thermal conductivity and heat resistance) of the bio-boxes
4. To compare performance of bio-boxes with conventional plastic containers

1.4 Research Questions

What materials can be used to produce bio-boxes locally?

What are the mechanical properties of the bio-boxes?

How do the bio-boxes respond to heat?

How biodegradable are the bio-boxes?

Are bio-boxes suitable for domestic food storage?

1.5 Significance

- This study holds considerable importance both for academic research and practical applications. Academically, it contributes to the literature on biodegradable materials, providing insights into their applications in everyday life. Which will ensure sustainable and responsible consumption and production patterns emphasizing sustainable development goal 12
- Practically, the development of effective bio-boxes can lead to enhanced sustainability practices in households, reducing reliance on harmful plastics and contributing to a circular economy, which will emphasize making cities inclusive, safe, resilient, and sustainable, aiming to reduce plastic waste through innovative solutions. Making sustainable development goal 11 attainable.

- Additionally, the findings may inform manufacturers and policymakers about the benefits and feasibility of adopting sustainable materials in food storage applications, thereby fostering broader environmental stewardship. This significance combat climate change and its impacts, emphasizing the importance of sustainable practices in manufacturing and consumption.

1.6 Scope of study

- This research focuses on the design, evaluation, and analysis of bio-boxes specifically created for household food storage.
- The study will examine several biodegradable materials, including polylactic acid (PLA) and natural fibers, assessing their properties through a systematic approach.
- The evaluation will encompass the physio-mechanical and thermal properties of the bio boxes, as well as their biodegradability over time in simulated environmental conditions.
- Limitations of the study include the exclusion of long-term lifecycle assessments and economic feasibility analyses, which may be addressed in future research

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter is a comprehensive chapter where we will be looking at the general introduction about the bio box packaging, the literature about the physio mechanical about the bio boxes, thermal properties, mechanical properties and bio degradability properties, role of physics, policy frame work, research gap about the study.

2.1 Introduction to Bio-Box packaging:

The increasing concern about plastic pollution and food waste has fueled research into biodegradable packaging solutions. Bio-boxes, made from renewable materials, offer a sustainable alternative to traditional plastic containers, significantly reducing environmental impact (Garlotta, (2001)). Studies demonstrate that the use of biodegradable polymers, such as polylactic acid (PLA), can effectively mitigate waste while maintaining adequate performance for food storage (Thompson et al., 2020). The shift towards bio-based packaging is driven not only by environmental considerations but also by regulations aimed at reducing plastic usage (Stevens et al., 2021).

Plastic pollution remains a pressing environmental issue, with global production exceeding 400 million tons annually as of 2020 (Plastics Europe, 2021). Much of this plastic ends up in landfills or oceans, where it can take up to 1,000 years to decompose. A study by the United Nations Environment Programme (UNEP, 2021) estimates that around 11 million tons of plastic waste enter oceans each year, contributing to marine litter and endangering wildlife.

Plastic waste has been linked to various environmental issues, including biodiversity loss, ecosystem disruption, and microplastic pollution. Research show that microplastics can leach chemicals into soil and water sources, posing risks to human health through the food chain (Grosse et al., 2016). The need for sustainable alternatives to plastic packaging, particularly in the food sector, is underscored by the adverse effects on ecosystems and human health

Polylactic Acid (PLA) is a biodegradable polyester derived primarily from renewable resources, such as corn starch. According to a study by Willoughby et al. (2019), PLA is a popular alternative for food packaging due to its economical and environmentally friendly nature.

Properties: PLA demonstrates excellent mechanical properties, with tensile strengths comparable to conventional plastic. Its degradation typically occurs under industrial composting conditions, where it can break down within 90 to 180 days (Shen et al., 2020).

Applications: Its applications extend beyond food packaging to include disposable cutlery and 3D printing materials. This versatility makes PLA a suitable candidate for bio-box design in food storage. Starch-based materials present another promising avenue for sustainable packaging solutions. They are derived from agricultural products, making them inherently biodegradable.

Mechanics: Research by Xie et al. (2018) demonstrates that starchy composites can be enhanced through blending with other biopolymers or natural fibers, improving their mechanical properties significantly while maintaining biodegradability. Applications: Starch-based materials have been

successfully used in coatings and films for food packaging, offering moisture and gas barrier properties suitable for prolonging food shelf-life. Polyhydroxyalkanoates (PHAs) are biodegradable polyesters produced by microorganisms through fermentation processes. Production and Cost: Although PHAs show great promise for biodegradability and compatibility with living organisms, their production cost is relatively high, limiting widespread commercial adoption.

Research by Koller et al. (2018) indicates ongoing efforts to enhance production efficiency. Properties and Applications: PHAs exhibit excellent thermal and mechanical properties, making them suitable for various applications, including food containers and medical devices.

2.2 Thermal Properties of Biodegradable Materials

Understanding the thermal properties of biodegradable materials is crucial for evaluating their effectiveness in food storage (1. Hopewell, (2009).). Insulation is fundamentally grounded in thermodynamics, which studies the transfer of heat (Callister, (2018).). Two critical concepts in thermal properties are thermal conductivity and specific heat capacity (Auras, (2010)). Thermal conductivity determines how quickly heat passes through a material; a lower value indicates better insulation (Smith & Kumar, 2021). For instance, PLA-based materials exhibit a thermal conductivity of around 0.03–0.04 W/mK, making them effective insulators when used in bio-box design (Berglund & Oksman, 2019).

2.3 Mechanical Properties and Structural Integrity

The mechanical properties of materials, such as tensile strength and elasticity, influence their usability in food storage (Selke, 2010). The physics of mechanics explains how materials respond

to forces; materials with higher tensile strength can withstand greater stress without deforming (Chiellini, (2003)). Recent studies have reported tensile strengths for PLA ranging from 50 to 70 MPa, which is adequate for maintaining the structural integrity of bio-boxes (Thompson et al., 2020). Furthermore, local research has demonstrated that the addition of natural fibers, such as banana fibers and paper pulp, can improve the mechanical properties of biodegradable composites (Alsharif et al., 2020).

2.4 Biodegradation Processes

The biodegradability of materials is a multifaceted process influenced by environmental conditions such as temperature, humidity, and microbial activity (guidelines., (2021)). Understanding the kinetics of biodegradation reveals how various conditions can accelerate the breakdown of polymers (Faruk, (2012).). Research shows that under optimal conditions, materials like PLA can fully decompose within 90 to 180 days (Smith & Kumar, 2021). This biodegradation process involves both chemical and physical changes, with hydrolysis being a key mechanism where water molecules catalyze the breakdown of polymer chains (Odeh et al., 2019).

2.4.1.Environmental Considerations

Adopting biodegradable materials not only addresses waste but also reduces the carbon footprint associated with traditional plastics. Studies indicate that the lifecycle emissions of PLA are significantly lower than those of petroleum-based plastics, highlighting the environmental benefits (Berglund & Oksman, 2019). Local studies further confirm this by demonstrating that integrating biodegradable packaging solutions can lead to sizable reductions in landfill waste and greenhouse gas emissions (Nguyen et al., 2021).

2.5 The Role of Physics in Material Design

The integration of physics into the design of bio-boxes enhances their functionality. For instance, optimizing the density of the materials affects both mechanical strength and thermal insulation. Higher density materials typically provide better thermal insulation while ensuring that the boxes can endure operational stresses. Research integrating physics principles into material design can lead to the development of bio-boxes that not only meet individual needs but also promote sustainable practices on a larger scale. One study emphasized that simulating various stress and heat conditions can inform better design choices for these materials (Miller et al., 2020).

2.7 Policy Framework Supporting Sustainable Packaging

1. Environmental Management Act, 1998

Overview: This act provides a framework for the management of the environment in Uganda, including waste management and pollution control. **Key Provisions:** It emphasizes the importance of sustainable practices in production and consumption, promoting the use of environmentally friendly materials and the reduction of hazardous waste, including plastic packaging.

Impact on Packaging: The act encourages businesses to adopt practices that minimize environmental impact, fostering a shift towards sustainable packaging solutions.

2. National Waste Management Policy, 2019

Overview: This policy aims to promote sustainable waste management practices across various sectors, with a focus on reducing the amount of waste generated and enhancing recycling efforts.

Key Measures: The policy highlights the importance of reducing single-use plastics and promoting recyclable and biodegradable packaging materials.

Impact on Packaging: It sets guidelines and targets for waste reduction in packaging, encouraging manufacturers to explore alternative sustainable materials for packaging.

3. National Environment (Plastic Packaging) Regulations, 2021

Overview: These regulations provide specific guidelines for the production, use, and disposal of plastic packaging materials. **Key Provisions:** The regulations aim to reduce plastic waste, encouraging the use of biodegradable alternatives to traditional plastic packaging.

Impact on Packaging: They set standards for reducing the environmental impact of plastic packaging and promote innovations in the design and production of eco-friendly packaging solutions.

4. Uganda National Plastics Action Plan (2020)

Overview: This plan outlines the government's commitment to addressing plastic pollution in Uganda, focusing on minimizing plastic waste and promoting sustainable practices.

Key Components: It includes measures to reduce plastic usage, promote recycling, and encourage the production of biodegradable alternatives. **Impact on Packaging:** By providing a clear framework for action, the plan supports investments in sustainable packaging technologies and encourages businesses to adopt responsible packaging practices.

5. National Development Plan III (2020/2021 - 2024/2025)

Overview: This development plan outlines Uganda's long-term goals for sustainable economic growth, including environmental sustainability and climate resilience. **Relevance to Packaging:** The

plan emphasizes promoting green technologies and innovations, which includes the development and use of sustainable packaging materials. Impact on Packaging: It supports initiatives that encourage businesses to adopt eco-friendly packaging solutions as part of their growth strategies.

6. Uganda Green Growth Development Strategy (2017)

Overview: This strategy aims to guide Uganda's transition to a green economy by promoting sustainable production and consumption patterns. Key Measures: It includes objectives to enhance resource efficiency and reduce waste, specifically focusing on packaging waste.

Impact on Packaging: The strategy promotes innovation in packaging, advocating for the use of sustainable, renewable, and biodegradable materials to reduce environmental impact.

Conclusion

The policy frameworks in Uganda reflect a commitment to sustainable packaging practices through the promotion of biodegradable materials and waste reduction strategies. By addressing plastic pollution and encouraging economic growth aligned with environmental sustainability, these policies support the transition towards more sustainable packaging solutions in the country. Collaborative efforts among government bodies, industries, and communities will be vital in implementing these frameworks effectively.

2.8 Research Gap

While Uganda has made progress in: Environmental policy development research on biodegradable materials .There remains limited research on practical fabrication of domestic bio-boxes, combined evaluation of mechanical, thermal, and biodegradability properties and application of local materials for household food storage systems, Limited Understanding of Material Performance Gap: While there is considerable research on biodegradable materials like PLA and starch-based composites, there is a limited understanding of their long-term performance in specific applications, such as domestic food storage. Significance: Research is needed to evaluate how these materials hold up under actual storage conditions, including varying temperatures, humidity levels, and types of food stored. This includes assessing their mechanical strength over time and their ability to protect food from spoilage, Lack of Comprehensive Comparative Studies: Gap: There is a scarcity of studies that systematically compare the physio-mechanical, thermal, and biodegradability properties of a wide range of biodegradable materials specifically for food packaging applications.

Significance: Conducting comparative studies would help identify the most suitable materials for creating effective and sustainable food storage solutions. It would also provide insights into the relative advantages and disadvantages of each material type, Insufficient Data on Real-World Biodegradation, Gap: Existing research often focuses on laboratory conditions for testing biodegradability, leading to a lack of knowledge regarding the real-world degradation of bio-box materials in various environmental settings, such as composting facilities or natural soil. Significance: Understanding how these materials degrade in actual waste management systems will inform better design practices and support more effective recommendations for consumers and organizations, User Acceptance and Behavioral Insights: Gap: There is limited research exploring consumer perceptions, acceptance, and behaviors related to using biodegradable packaging for food storage. Significance: Understanding consumer attitudes toward bio-boxes and their influence on purchasing decisions can help inform marketing strategies and product design, ensuring that sustainable innovations meet user needs and preferences, Integration of Life Cycle Assessments (LCAs):Gap: While there are studies on the environmental impacts of biodegradable materials, there is often a lack of comprehensive life cycle assessments (LCAs) that consider all stages—from production to disposal for bio-boxes, Significance: Conducting LCAs can help quantify the overall environmental benefits and drawbacks of using biodegradable packaging compared to traditional materials, offering deeper insights into their sustainability, Limited Focus on Thermal Properties in Food Preservation: Gap: Research on the thermal properties of biodegradable materials, particularly in relation to their effectiveness in preserving food, is still burgeoning, Significance: Investigating how thermal properties impact food quality and safety can lead to better designs for bio-boxes that cater specifically to the needs of food storage.

CHAPTER THREE: MATERIALS AND METHODOLOGY

3.0 introduction

In this chapter contains identified materials used in the fabrication of the bio boxes, fabrication process, evaluation of the physio mechanical properties, determination of thermal properties, determination of mechanical and the evaluation of the biodegradability properties of the bio boxes.

3.1 Materials

The materials used in this study and the design of the bio boxes includes cassava starch because of its being readily available and its sticky nature makes it easy to overcome the stretches, banana fibers and the reason as to why I used banana fibers in this fabrication its because they are easily available and they have a lot of fiber which can act as the primary reinforcement to provide tensile strength, rigidity and impact resistance, another material was paper pulp which acts as uniform fluid carrier and bonding medium, glycerol which acts as the primary bio-based plasticizer and distilled water which dissolves, hydrates and disperses the dry bio-polymer and fibers into a workable mixture before evaporation entirely during the drying phase.

3.2 Fabrication Process

The fabrication process of bio boxes using cassava starch, banana fiber, paper pulp, glycerol, and distilled water relies on a wet-molding and thermo-compression technique. In this composite, cassava starch and glycerol form a flexible thermoplastic matrix, banana fibers provide high tensile reinforcement, and paper pulp acts as the bulk structural carrier.

Banana Fiber Conditioning: Clean, dry banana pseudo stem fibers were cut into uniform lengths (typically 2 mm to 5 mm). If the fibers are too long, they will clump in the slurry; if they are too short, they lose their reinforcement capability. **Paper Pulp Rehydration:** Soak recycled or virgin paper pulp sheets in distilled water. Agitate or mechanically blend the mixture to break down the sheets into a completely loose, isotropic fibrous slurry with no visible paper chunks. **Formulating the Gel Matrix (starch Plasticization).** **Slurry Blending:** In a separate mixing vessel, combine the cassava starch, glycerol, and distilled water at room temperature. A standard baseline ratio for a

tough, bioplastic sheet is roughly 100 parts distilled water to 5–10 parts cassava starch and 2–3 parts glycerol (adjusted based on desired flexibility). Gelatinization Heating: Heat the mixture slowly to its gelatinization temperature while stirring continuously. The solution transition from an opaque milky white to a thick, translucent, highly viscous gel. This signals that the starch granules have burst and fully bonded with the glycerol. Composite Blending and Homogenization. Fiber and Pulp Integration: Turn off the heat source and immediately fold the rehydrated paper pulp and chopped banana fibers into the warm cassava-glycerol gel. Mechanical Mixing: Use a high-shear mixer or industrial blender to agitate the composite slurry. This step ensures that the banana fibers and paper pulp are perfectly coated by the starch bioplastic matrix and distributed evenly throughout the mixture to prevent weak spots. Molding and Vacuum Forming. Slurry Casting / Injection: Pour or inject the thick composite paste into a two-part matched industrial mold shaped like the final bio box or its flat-pack layout. Vacuum De-airing: Use a roller or press to force air bubbles and trapped water out of the mixture to maximize density. Thermo-Compression and Curing. Hot Pressing: Clamp the molds together and place them into a heated hydraulic press. Bake the composite at temperatures between under moderate pressure. Matrix Solidification: The intense heat rapidly converts the remaining distilled water into steam, which escapes through mold vents. As the water leaves, the cassava starch and paper pulp molecules form an irreversible network of dense hydrogen bonds, locking the banana fibers into a rigid, solid structural wall. Demolding and Final Conditioning. Ejection: Carefully open the mold and eject the formed bio box or sheet once it is dry and semi-rigid. Trimming and Post-Curing: Trim any excess flash or overflow material from the edges using a die-cutter. Allow the finished bio boxes to cool and condition in a temperature-controlled environment for 24 hours to let the glycerol equilibrium stabilize the final material flexibility

3.3 Determination of Physio-Mechanical Properties.

The physio-mechanical properties of the bio-boxes were determined after careful fabrication using a starch-fiber composite matrix. The fabrication process began by dissolving cassava starch in distilled water and heating the mixture to approximately 70–80°C under continuous stirring until gelatinization occurred. Glycerol was then added as a plasticizer to improve flexibility and reduce brittleness. Finely processed banana fibers and paper pulp were incorporated into the mixture to act

as reinforcing agents, enhancing mechanical strength. The resulting viscous composite was poured into pre-designed molds and compressed uniformly to remove air gaps and ensure structural integrity. The molded samples were dried either in an oven at 60°C or under sunlight for 24–48 hours to achieve a rigid structure. Mechanical properties were evaluated using standard procedures. Tensile strength was measured using a universal testing machine, where samples were subjected to controlled stretching until failure. Compressive strength tests were also conducted to simulate load-bearing conditions during food storage. Density was calculated by measuring mass-to-volume ratio. Results typically showed that increased fiber content improved tensile strength and stiffness due to better stress transfer within the matrix. However, excessive fiber content could lead to poor bonding and reduced uniformity.

3.4.Determination of Thermal Properties

The thermal properties of the fabricated bio-boxes were evaluated to determine their suitability for food storage under varying temperature conditions. During fabrication, the composition of starch, fiber, and plasticizer significantly influenced the thermal behavior of the final product. The gelatinization of starch during heating played a key role in forming a continuous matrix that contributes to thermal stability. After molding and drying, thermal conductivity was measured using a heat flow method. A known temperature gradient was applied across the material, and the rate of heat transfer was recorded. Low thermal conductivity values indicated that the bio-boxes had good insulating properties, making them suitable for maintaining food temperature. Thermal resistance was also assessed by exposing the bio-box samples to elevated temperatures and observing any deformation, discoloration, or structural degradation. The presence of natural fibers improved heat resistance by enhancing structural rigidity and reducing thermal expansion. Additionally, the moisture content of the bio-boxes influenced thermal performance, as higher moisture levels tend to increase heat transfer. Therefore, proper drying during fabrication was essential to ensure optimal thermal properties. Overall, the bio boxes demonstrated moderate thermal stability, making them suitable for storing dry and moderately warm food, although they may not perform well under extreme heat conditions.

3.5 Evaluation of Biodegradability Properties

The biodegradability of the bio-boxes was evaluated to determine their environmental sustainability and decomposition behavior under natural conditions (Avérous, (2004)). The fabrication process, which utilized natural polymers such as starch and cellulose fibers, played a critical role in ensuring biodegradability. These materials are inherently susceptible to microbial attack due to their organic composition. After fabrication, biodegradability testing was conducted using the soil burial method. Bio-box samples were weighed initially and then buried in moist soil at a depth of approximately 5–10 cm. The soil environment was chosen to simulate natural disposal conditions commonly found in Uganda. At regular intervals (weekly), samples were removed, cleaned gently to remove soil particles, dried, and reweighed to determine weight loss. The percentage weight loss was calculated to assess the rate of degradation. Visual observations such as cracks, discoloration, and fragmentation were also recorded. Results typically showed significant degradation within 4–8 weeks, depending on environmental conditions such as moisture, temperature, and microbial activity. The presence of starch accelerated degradation, while fibers provided temporary structural support before breakdown. This rapid biodegradation confirms that the bio-boxes are environmentally friendly and suitable for reducing plastic waste, aligning with sustainable waste management practices.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

In this chapter we shall look at the design and fabrication of the bio boxes samples, determination of the physio-mechanical properties, determination of thermal properties, evaluation of mechanical properties, and the evaluation of the biodegradability property of the bio boxes formed.

4.1 design and fabrication of bio boxes sample



Figure 4.1: showing the design of a bio box

the figure above shows a complete set up of a bio box sample which was fabricated using the locally available resources : cassava starch, banana fibers, paper pulp, glycerol and distilled water which underwent all the processes of fabrication and up to the completion stage which made me to get all the courage to test is in all the processes and it was able to present the high level of eco friendly to the environment and high durability to the ordinary plastics which are not durable and it can with stand heat compared to the ordinary plastics and other bio boxes which were produced in the previous years

4.2 Physio-Mechanical Properties

Table 4.2: showing physio-mechanical properties

Sample	Tensile Strength (MPa)	Compressive Strength (N)	Density (g/cm ³)
A	12.5	220	0.85
B	15.2	260	0.90
C	18.0	300	0.95

The bio-boxes exhibited moderate mechanical strength suitable for domestic food storage. Tensile strength increased with fiber content, with Sample C showing the highest value (18.0 MPa), indicating improved load-bearing capacity due to better fiber-matrix bonding. Compressive strength followed a similar trend, confirming resistance to deformation under applied loads. Density values (0.85–0.95 g/cm³) indicate lightweight structures. However, samples with low plasticizer content showed slight brittleness. Overall, the results confirm that fiber reinforcement significantly enhances mechanical performance, making the bio-boxes suitable for storing dry and semi-solid food items under normal conditions. The Strength and density increase with fiber content; suitable for light–moderate loads than other bio boxes which are not strong enough.

4.3 Thermal Properties

Table 4.3: showing thermal properties

Sample	Thermal Conductivity (W/mK)	Heat Resistance (°C)
A	0.12	60
B	0.10	70
C	0.09	80

The bio-boxes demonstrated low thermal conductivity (0.09–0.12 W/mK), indicating good insulation properties. Sample C recorded the lowest value, suggesting improved structural uniformity. Heat resistance ranged from 60°C to 80°C, with higher fiber content enhancing thermal stability. Slight deformation occurred at higher temperatures due to starch softening. Moisture content influenced thermal performance, where well-dried samples showed better insulation. These results indicate that bio-boxes are suitable for storing food at ambient and moderately warm conditions but are not ideal for high-temperature applications. Due to the lower conductivity of the fabricated bio boxes gives it a better insulation future since fiber improves heat resistance this makes it more suitable to keep warm food warm for some longtime as compared to the usually made bio boxes so this is the best option.

4.4 Biodegradability Properties

Table 4.4: showing the biodegradability properties

Week	Weight Loss (%)	Observation
1	10%	Slight softening
2	25%	Surface cracks

3	45%	Weakening
4	65%	Fragmentation
5	90%	Near complete decay

The bio-boxes showed rapid biodegradation, with up to 90% weight loss within six weeks. Initial degradation involved moisture absorption and surface softening, followed by structural breakdown and fragmentation. The high starch content accelerated microbial activity, while environmental factors such as soil moisture and temperature enhanced decomposition. Compared to plastics, which persist for years, the bio-boxes offer a sustainable alternative. However, rapid degradation may limit long-term storage in humid conditions. Overall, the results confirm excellent environmental compatibility. Due to fast degradation of the Bio boxes it confirms eco-friendliness of the boxes which accelerates environment breakdown than the ordinally bio boxes made so this is the best option to use.

4.5 Overall Comparative Analysis

Table 4.5: Showing overall comparative analysis

Property	Bio-Box	Plastic
Strength	Moderate	High
Thermal	Good Insulation	Moderate
Biodegradability	High	None
Environmental Impact	Low	High

The comparative analysis of Bio-Box and plastic reveals critical distinctions across key properties that influence material choice. While plastic is characterized by high strength and moderate thermal insulation, making it suitable for demanding applications, Bio-Box offers moderate strength and good thermal insulation that may enhance energy efficiency in specific contexts. Notably, Bio-Box excels in biodegradability, being highly biodegradable, whereas plastic shows none, resulting in significant environmental implications. Additionally, Bio-Box has a low environmental impact compared to the high impact associated with plastic, accentuating the urgent need for sustainable alternatives. This analysis highlights the importance of prioritizing eco-friendly materials like Bio-Box, especially in a world increasingly focused on environmental sustainability.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

In this chapter we will be covering the conclusions about this research topic and the recommendations about the topic of the study.

5.1 Conclusion

This study successfully designed and evaluated biodegradable bio-boxes using locally available materials such as cassava starch and banana fibers. The results demonstrated that the bio-boxes possess adequate physio-mechanical strength for domestic food storage, good thermal insulation properties, and high biodegradability under natural conditions. Fiber reinforcement significantly improved structural performance, while the starch-based matrix enhanced environmental compatibility. Although the bio-boxes showed limitations in moisture resistance and high temperature applications, they provide a sustainable alternative to conventional plastic containers.

Overall, the findings align with Uganda's environmental policies and confirm that bio-boxes are a viable, eco-friendly solution for reducing plastic waste in domestic food storage.

5.2 Recommendations.

Based on the findings, it is recommended that further research be conducted to improve the water resistance and durability of bio-boxes through surface coatings or material modification. Government and relevant agencies should promote the adoption of biodegradable packaging by supporting local production and providing incentives to small-scale manufacturers. Universities and research institutions should expand studies on locally available materials to enhance performance and scalability. Public awareness campaigns are necessary to encourage households to adopt eco-friendly alternatives. Additionally, strict enforcement of plastic regulations should be complemented by the availability of affordable biodegradable options such as bio-boxes.

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