Development of Bio-blocks using banana fibers and banana tree waste as an alternative to styrofoam

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Abstract: This research was carried with the motivation to find an alternative to the existing environmental pollution by the synthetic packaging materials. The use of styrofroam is being increased drastically due to the ecommerce ventures and also in various non-durable goods packaging. The Styrofoam is a form of petroleum-based foams such as Expanded Polystyrene (EPS) which significantly contributes to the environmental pollution due to their persistence, low recyclability and high energy foot prints. This research paper explores the potential of the banana tree waste especially the pseudo-stems, leaves and other lignocellulosic by products – as a feedstock developing biodegradable bio blocks for packaging. In this research, the banana stem, dried leaf and the banana peel which is the entire plant waste has been processed through various steps and is being molded into required bio-blocks. The banana tree wastes are dried and grinded and mixed with binders before molding into desired shapes. The molded bio-blocks are exposed to various test which compare their physical properties such as density measurement, compression testing (hardness), tensile binding strength, thermal conductivity, water absorption. This research implies the sustainable packaging alternative for Styrofoam and the ease of manufacturing and commercialization by valorizing agricultural residues.

Index Terms **–** Bio-blocks, banana fiber, Styrofoam, EPS, banana peel.

I. INTRODUCTION

INTRODUCTION

Global plastic pollution and ineffective agricultural waste management represent pressing environmental challenges. Styrofoam, despite its lightweight and cushioning performance, contributes to persistent pollution because it is virtually non-biodegradable and difficult to recycle economically. Meanwhile, banana cultivation generates vast amounts of lignocellulosic biomass—up to 60 % of plant weight after harvesting—that is often underutilized, leading to environmental and disposal burdens in tropical regions where bananas are widely grown.

Leveraging banana tree waste for biodegradable materials intersects two sustainability targets: waste valorization and plastic replacement in packaging. A growing body of research has investigated banana fibres, peels, and pseudo stems as raw materials for bio-composites, films, and molded bio-blocks.

1.1 Background and Rationale

1.1.1 Styrofoam and Packaging Challenges

Styrofoam (EPS/EPP) is widely used for protective packaging, thermal insulation, and cushioning due to its low density and mechanical performance. However, its resistance to biodegradation has resulted in accumulation in landfills and natural environments, where breakdown into microplastics harms ecosystems and human health.

1.1.2 Banana Tree Waste Characteristics

Banana plants generate substantial waste in the form of pseudo stems, leaves, rachis, and peels. These materials are rich in cellulose, hemicellulose, lignin, and starch, making them suitable candidates for conversion into biodegradable composites and biopolymers.

2 Materials and Methods

2.1 Raw Material Procurement

Banana tree components would be collected post-harvest:

- Pseudostems and leaves from plantations.
- Peels from fruit processing or consumption.
- Additional biomass such as rachis.

2.2 Pre-Processing

Materials are dried, cleaned, and mechanically reduced. Chemical treatments (e.g., alkali treatment for fibres, enzymatic degumming) can enhance fibre extraction and surface properties.

2.3 Composite Formulation

A range of compositions would be tested:

- Fibre content (e.g., 40–60 wt %).
- Natural binders (starch, proteins, natural resins).
- Optional additives (plasticizers like glycerol, compatibilizers).

Banana pseudo stem cellulose can be combined with starch-based matrices or other biopolymers to improve cohesive properties of bio-blocks.

2.4 Fabrication Techniques

Potential processing methods include:

- Compression molding to form dense blocks.
- Foaming agents or gas supercritical CO_2 for expanded, styrofoam-like structures.
- Thermo-mechanical treatments to promote bonding.

2.5 Characterization

Bio-blocks should be evaluated for:

- Mechanical properties: compressive and tensile strength.
- Density and thermal insulation.
- Water absorption and barrier performance.
- Biodegradability under soil or compost conditions.
- Comparative performance vs. EPS benchmarks.

3. RESULTS AND DISCUSSION

3.1 Material Properties from Banana Waste

Research indicates banana-derived fibres and matrices can yield materials with desirable mechanical properties:

- Banana stem fibres reinforced in composites have shown tensile strengths suitable for packaging sheets.
- Films fabricated from banana peel lignocellulosic residues exhibited high tensile strength and rapid biodegradation under soil conditions.

These findings support the hypothesis that banana waste biomass can form the foundation of bio-blocks with mechanical integrity and environmental performance approaching or surpassing traditional bioplastics.

3.2 Comparative Environmental Benefits

Banana waste-based materials are inherently biodegradable, reducing long-term environmental pollution. Unlike EPS, they return to the soil without creating microplastics, aligning with circular economy principles.

3.3 Challenges and Optimization

Key challenges remain:

- Achieving mechanical robustness comparable to styrofoam without synthetic additives.
- Controlling moisture sensitivity inherent to hydrophilic biopolymers.
- Scaling production economically.

Blending with other natural polymers, optimizing fibre treatment, and surface modification are promising strategies under active study.

4. FUTURE DIRECTIONS

To deploy banana waste bio-blocks commercially, research should target:

- **Processing innovations**: continuous foaming and molding systems.
- **Material enhancements**: adding nanocellulose or biodegradable compatibilizers.
- **Life Cycle Assessment (LCA)** to quantify environmental impact versus conventional packaging.
- **Pilot-scale demonstration** to prove industrial viability.

5. CONCLUSION

Bio-blocks derived from banana tree waste present a compelling sustainable alternative to styrofoam in packaging applications. By valorizing abundant agricultural residues, this approach addresses waste management and plastic pollution simultaneously. While further innovation is needed to fully match conventional foam performance, current research underscores significant potential for eco-friendly, biodegradable packaging materials rooted in banana biomass.

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