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Article

Sustainable Housing Solutions in Nigeria: Agricultural Waste–Derived Particleboards from Mahogany Sawdust, Rice Husk, and Coconut Husk Blends

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Abstract: Nigeria faces a persistent housing shortage of over 20 million units, a challenge exacerbated by accelerated urban growth, deforestation, and a heavy reliance on imported construction materials. This study presents a critical synthesis of existing literature on the use of particleboards manufactured from agricultural residues as sustainable alternatives for affordable housing. Emphasis is placed on lignocellulosic wastes such as rice husks, coconut husks, and mahogany sawdust, which are increasingly recognized for their potential to substitute conventional materials. The review examines the evolution of particleboard technology, manufacturing processes, and the mechanical and physical performance indicators that govern material suitability, including modulus of rupture, modulus of elasticity, density, and dimensional stability. In addition, the environmental and health implications associated with formaldehyde-based binders are discussed, alongside emerging advancements in bio-based adhesive systems, particularly starch-derived and gum arabic alternatives. Within Nigeria's socio-economic framework, agricultural waste-based particleboards are evaluated for their capacity to reduce construction costs, stimulate local industries, enhance waste management, and support national sustainable development objectives. The findings indicate that the valorization of agricultural residues for particleboard production offers a viable and environmentally responsible pathway toward resilient and affordable housing in developing economies.

Keywords: Agricultural residues; Particleboard; Sustainable housing; Composite materials; Renewable resources

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1. Introduction

The availability of adequate housing remains a critical socio-economic concern in Nigeria and many other developing nations. Estimates from national and international agencies indicate that Nigeria's housing deficit, previously reported at approximately 17 million units in 2015, has increased to more than 20 million units in recent years. This shortfall reflects not only rapid population growth and urbanization but also structural challenges related to infrastructure provision, affordability, and material availability. With a population exceeding 200 million and an annual growth rate of about 2.6%, demand for cost-effective and durable housing continues to escalate.

Dependence on imported construction materials, including steel, aluminium, and polymer-based products, has exacerbated the housing crisis. These materials are vulnerable to foreign exchange fluctuations and global supply chain instability, making them inaccessible to a large proportion of low-income households[5], [17]. Consequently, informal settlements and substandard housing conditions persist, particularly in urban centers. Alongside affordability challenges,

conventional construction practices contribute substantially to environmental degradation through deforestation, resource depletion, and improper waste management[14], [15].

Although the construction industry represents a vital sector of Nigeria's economy, its growth has not translated into inclusive access to housing. Economic factors such as high transportation costs, currency depreciation, and limited regulation of building material markets further constrain housing delivery. Addressing these challenges requires innovative material solutions that prioritize local resource utilization, environmental sustainability, and cost efficiency.

Agricultural waste-derived composite materials, particularly particleboards, present a promising alternative. Nigeria's extensive agricultural activity generates large volumes of residues, including rice husks, coconut shells, corn cobs, palm fronds, and sawdust, which are often underutilized or improperly discarded. Transforming these materials into particleboards offers a dual benefit: reducing environmental hazards associated with waste accumulation and minimizing reliance on timber-based products[4][12]. Moreover, advancements in bio-based adhesive technologies provide opportunities to reduce the health and environmental risks associated with conventional formaldehyde-based resins[1], [16].

This paper situates agricultural waste-derived particleboards within the broader discourse on sustainable housing in Nigeria. By critically examining their production processes, performance characteristics, and socio-economic relevance, the study highlights their potential role in reducing construction costs, supporting local industries, and advancing sustainable development objectives.

Literature Review

Sustainable construction practices emphasize the use of materials that reduce environmental impacts, conserve natural resources, and limit waste generation throughout their life cycles. In this context, agricultural residues have attracted increasing attention as alternative raw materials for composite production[14][15]. Their utilization addresses challenges associated with waste disposal while alleviating pressure on forest resources traditionally used in particleboard manufacturing.

Particleboard is a widely used engineered wood product valued for its versatility, cost-effectiveness, and adaptability to diverse applications[19]. Conventional production processes rely heavily on virgin timber, contributing to deforestation and biodiversity loss[18]. In Nigeria, however, residues such as maize stalks, rice husks, oil palm waste, and sawdust present abundant alternatives that can be sustainably sourced[4]. The improper disposal of these materials is linked to environmental problems, including flooding, air pollution, and greenhouse gas emissions[8], [11].

Adhesive systems play a critical role in determining particleboard performance. While synthetic resins such as urea formaldehyde and phenol formaldehyde remain dominant in the industry, their associated emissions pose health risks [16]. Consequently, research efforts have increasingly focused on bio-based binders, particularly starch-derived adhesives, which offer reduced toxicity and improved environmental compatibility [1], [6], [21] and polysaccharides/glycoproteins (Arabic Gum) is a naturally occurring glue derived from a byproduct of Acacia trees, due to their great affinity for water or saliva [22].

Particleboard Production Processes

The manufacture of particleboard typically involves sequential stages of raw material preparation, adhesive blending, mat formation, hot pressing, and finishing operations [7]. Performance enhancements are often achieved through the incorporation of additives such as waxes and melamine resins to improve moisture resistance and durability [20]. The quality of the final product is largely evaluated using mechanical indicators such as modulus of rupture, modulus of elasticity, and internal bond strength [3][9].

Mechanical and Physical Performance

Achieving optimal particleboard performance requires balancing mechanical strength with dimensional stability. Properties such as water absorption, thickness swelling, and linear expansion are particularly critical in humid environments [13]. Empirical evidence suggests that particleboards produced from agricultural residues can satisfy international standards for strength and stiffness when adhesive composition and processing conditions are appropriately optimized [3]. Density

variations further influence end-use applications, with lower densities favoring insulation purposes and higher densities offering enhanced structural performance [2].

Applications in Housing

Particleboards are commonly employed in furniture production, interior wall panels, flooring systems, and ceiling components [10]. Their adaptability and affordability make them particularly suitable for housing projects in both urban and rural contexts. Substituting imported materials with locally manufactured particleboards can significantly reduce construction costs while promoting job creation and industrial development [12].

Research Gap

Despite increasing research activity, several limitations constrain the large-scale adoption of agricultural waste-based particleboards in Nigeria:

Scale-Up Limitations: Most studies are confined to laboratory or pilot-scale investigations, with limited evidence on industrial-scale performance and cost viability.

Adhesive Innovation: Comparative evaluations of bio-based adhesives relative to conventional resins under tropical conditions remain insufficient.

Durability Concerns: Long-term resistance to moisture, biological degradation, and dimensional instability in humid climates is inadequately documented.

Policy and Market Integration: There is limited research on certification frameworks, consumer acceptance, and policy mechanisms required for mainstream adoption.

Regional Comparisons: Comparative analyses with other developing countries that have successfully implemented residue-based composites are scarce.

2. Materials and Methods

Research Design

This study adopts a critical review approach, synthesizing findings from peer-reviewed journals, technical reports, and case studies related to agricultural waste-based particleboard production and application.

Data Sources

Primary sources include Nigerian studies focused on particleboards produced from mahogany sawdust, rice husk, and coconut husk blends. Secondary sources consist of international literature on sustainable construction materials, composite performance, and adhesive technologies. Policy documents from national and international organizations complement the analysis.

Analytical Framework

The review is structured around material potential, performance assessment relative to established standards, and socio-economic relevance, with particular attention to affordability, employment generation, and alignment with sustainable development goals.

Limitations

The reliance on secondary data and the scarcity of large-scale industrial evidence limit the generalizability of findings, underscoring the need for further empirical research.

3. Results and Discussion

Agricultural waste-derived particleboards show substantial potential to contribute to affordable housing by reducing material costs and promoting local production. Environmentally, their utilization mitigates waste disposal challenges, reduces deforestation, and lowers associated emissions. Technically, while performance benchmarks can be achieved, durability in humid tropical environments remains an area requiring further investigation. Policy support, standardization, and regional collaboration are essential for large-scale implementation.

4. Conclusion

The conversion of agricultural residues into particleboards represents a viable strategy for addressing Nigeria's housing deficit while advancing sustainability objectives. These materials offer environmental, economic, and technical advantages but require further research on scalability, durability, adhesive innovation, and policy integration. Addressing these challenges will be essential for transitioning toward resilient and affordable housing solutions.

Policy Recommendations

Provide fiscal incentives to encourage local particleboard manufacturing
Establish national quality and certification standards
Support research into bio-based adhesives and durability enhancement
Integrate sustainable particleboards into public housing programs
Strengthen agricultural waste collection and management systems

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