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Groundnut Shell Particleboard as an Alternative to Sawdust Particleboard

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Abstract

This project focuses on the innovative use of agricultural waste, especially peanut shells, in producing particle board, as well as being a sustainable and environmentally friendly alternative to conventional wood-based products. Particle board from groundnut shell (GS), coconut husk (CH) and rice husk (RH) were produced using casein-based adhesive of ratio 1:1, respectively. A hot and press machine was used at temperature of 150°C and compressed load of 1 tonned. The samples underwent a strength test, density and granular structure analysis. From the strength test, GS particle board was identified to be the strongest board compare to CH and RH as it can bear the maximum load of 400 g. This is due to higher density of GS particle board that is 244.44 kgm^{-3}. The granular structure of GS particleboard shows the most compacted and compressed which is considered as the most perfect structure of particle board. The data collected from these tests reveal varying outcomes in terms of strength across the different particleboard compositions.

1. Introduction

Particleboard is an engineered wood product created by bonding wood chips with synthetic resin or other binders under heat and pressure. Traditional production methods, which rely heavily on wood and formaldehyde-based adhesives, pose significant environmental and health risks. The excessive use of wood contributes to deforestation, leading to habitat destruction, soil erosion, and loss of biodiversity. Besides, the use of formaldehyde, commonly used in adhesives during particleboard making is a known carcinogen and poses serious health risks, including respiratory issues and skin irritation. These concerns necessitate the exploration of sustainable and safer alternatives for particleboard production [1].

Recent studies have highlighted the potential of agricultural waste materials, such as groundnut shells (GS), rice husks (RH), and coconut husks (CH), in particleboard production. These materials are not only abundant and low-cost but also offer promising mechanical properties when processed correctly. GS have shown great potential due to their availability and favorable characteristics [2]. Additionally, the use of eco-friendly adhesives like casein glue, derived from milk, presents a safer alternative to formaldehyde-based adhesives. Casein glue is biodegradable, non-toxic, and offers sufficient bonding strength for particleboard applications [1].

The main objectives of this study are to determine the ideal agricultural waste as an alternative to sawdust particleboard. This approach offers a dual benefit: addressing agricultural waste management and reducing the dependence on wood for furniture production, thus aiding in forest conservation. By utilizing agricultural waste and eco-friendly adhesives, this method not only contributes to sustainable practices but also mitigates the environmental and health hazards associated with conventional particleboard production [3].

Nomenclature is included if necessary	
ρ	density of the particle board
m	mass of the sample
V	volume of the sample
σ	strength of particle board
P	load acting
A	surface area

2. Materials and Method

The main materials used in this project are GS, RH, CH, soymilk, full cream milk, vinegar and sodium bicarbonate ($NaHCO_3$). The preparation of the raw materials, consisting of GS, RH, and CH, is a crucial step to ensure the uniformity and quality of the particleboard, including the adhesive.

2.1 Agricultural Particles

Initially, the agricultural particles were thoroughly cleaned to remove any impurities. These materials were then dried in an oven at 80°C for 30 minutes to reduce the moisture content, which is essential for effective bonding and preventing fungal growth [3]. The dried GS, RH, and CH were manually crushed using a mortar and pestle, and then further processed in a dry blender to reduce the particle size and improve the adhesive properties, resulting in finer and more cohesive particles [4]. After the crushing and blending processes, 100 g of each processed sample was carefully measured using a weighing scale and taken for subsequent sampling.

2.2 Animal-based and Plant-based adhesive

The soymilk and full cream milk were used to produce a plant-based and animal-based adhesive, respectively. Approximately 300 ml of soymilk and full cream milk were used as the base of the adhesive. Both samples were refrigerated for 24 hours to separate the fat. After the fat layer was removed, 70 ml of vinegar was added into the soymilk and full cream milk, separately [5]. The milk-vinegar mixture was gently heated and stirred using a hot plate stirrer until curds begin to form. After half an hour, the sample was filtered using filter paper to collect the curds. Next, 10 ml of tap water was added to the curds and stirred using a spatula to break up the large lump of curds. Finally, a $NaHCO_3$ of mass of 5 g was added into the curds to neutralize any remaining acid from the vinegar. Bubbles of gas appeared which indicates neutralization is occurring [6]. The sample was then placed inside a closed container to prevent any oxidation.

2.3 Production of Particleboard

Three types of particle boards (GS, RH, and CH) were produced by blending 100 grams of each particle type with 100 mL of SM adhesive. The mixture was placed in a 300x300x5 mm mold, with aluminum foil on top and bottom to prevent sticking. The mold was placed in a GOTECH hot press machine at 150°C and 1-2 tons compress load for 8 minutes. After pressing, the mold was removed with heat-insulating gloves and cooled for 20-30 minutes to ensure proper curing.

2.4 Analysis of Particleboards

The characteristics of the produced particleboard are thoroughly analyzed to ensure they meet the desired standards (refer to **Appendix 1**). The granular structure is examined using a microscope to confirm particle distribution and strong bonding, which is essential for strength and durability [7]. Density is calculated by dividing the specimen's mass (m) by its volume (V), with higher density values indicating better particleboard properties as shown in Equation (1).

$$\rho = \frac{m}{V} \quad \text{Equation (1)}$$

Strength testing is carried out using a Vilcase hanger balance, measuring from 10g until the board breaks. Samples are cut into rectangular dimensions of 300 mm in length, 300 mm in height, and 5 mm in width. The tensile strength is determined using Equation (2);

$$\sigma = \frac{P}{A} \quad \text{Equation (2)}$$

3. Results and Discussion

The performance of particleboards made from various agricultural waste and adhesive combinations is evaluated to understand their structural and mechanical properties, highlighting the practicality of this sustainable material for industrial applications [6].

3.1 Density of Particle Board

The density of the particleboard is a key indicator of its compactness and structural integrity [8]. In this study, density measurements revealed that the particleboards produced had varying densities depending on the composition of the agricultural waste materials used. Boards with higher proportions of GS and RH exhibited greater density, suggesting tighter particle compaction [7]. Tabulated in **Table 1**, the densities were 244.44 kg/m^3 for GS, 222.22 kg/m^3 for RH, and 155.56 kg/m^3 for CH, calculated using Equation (1). This higher density is beneficial for applications requiring strong and durable materials.

Table 1: Density of Each Type of Particleboard

Types of particleboards	Mass of particleboard (kg)	Density (kgm^{-3})
GS	0.11	244.44
RH	0.1	222.22
CH	0.07	155.56

Table 1 shows that the GS particleboard has the highest density, attributed to the hardness and finer grindability of GS, allowing more particles to be compacted into the mould. In contrast, RH is harder to grind into small particles, fitting only 100 g into the mould, and the long, dangling structure of CH requires it to be cut into shorter pieces, fitting only 70 grams. These findings indicate that controlling the ratio of different agricultural wastes can effectively tailor the density and mechanical properties of the particleboard [3].

3.2 Granular Structure

Analysing the granular structure of particleboard provides insights into the uniformity and distribution of particles within the board [7]. Microscopic examination of GS particleboards revealed a homogeneous mixture with casein adhesive, ensuring effective bonding and a relatively smooth surface under intense pressure. Visible textures from larger GS particles influenced the board's aesthetic appeal and porosity, demonstrating effective material preparation techniques for applications such as furniture and panelling. **Fig. 1** visually illustrates the surface textures and structural features of GS, RH and CH particleboards, highlighting their distinct qualities.

(a) (b) (c)

Fig. 1: The morphological structure of (a) GS particleboard, (b) RH particleboard, and (c) CH particleboard

Ground rice husks produced fine, homogeneous particles that maintained consistent density throughout the particleboard. The adhesive evenly coated these particles, fostering strong inter-particle connections crucial for mechanical strength. High pressure and uniform particle size minimized porosity, creating a densely stratified structure that enhanced durability and reduced surface texture [6]. Despite the fibrous nature of rice husks affecting directional strength, the boards exhibited reliable structural integrity, suitable for diverse industrial applications [8].

3.3 Strength Test

The tensile strength test using the Villcase hanger balance varied among particleboard compositions, reflecting the influence of agricultural waste materials. Identifying the strength for each materials can help emphasizing the potential for optimizing mechanical properties through tailored material selection to meet specific application requirements [8].

(a) (b) (c)

Fig. 2: (a) Strength Test on GS Particleboard (b) Strength Test on RH Particleboard (c) Strength Test on CH Particleboard

Among the tested particleboards, GS demonstrated the highest strength, capable of holding up to 400 g of weight. Groundnut shells, rich in cellulose, hemicellulose, and lignin, contributed significantly to its mechanical properties, resulting in a dense packing and strong final product shown in **Fig. 2** (a) [9]. In **Fig. 2** (b), RH particleboards exhibited moderate strength, holding up to 120 g of weight, attributed to the silica content in rice husks which enhances bonding despite their irregular structure. In contrast, CH particleboards showed the lowest strength, withstanding up to 90 g of weight due to the challenges in achieving a compact structure with coconut husk fibers as seen in **Fig. 2** (c). Despite lower strength, CH boards exhibited flexibility and bending resilience, characteristic of coconut fibers' high lignin content [7].

4. Conclusion

This study demonstrates the feasibility of producing particleboard from agricultural waste materials such as GS, RH and CH. The optimal ratio of these materials to adhesive was found to be 1:1, with 100 ml of adhesive adequately bonding 100 g of particles. Comparing different adhesives revealed that the animal-based SM adhesive outperforms the plant-based FC adhesive, with GS particleboards bonded with SM adhesive showing superior strength. Analysis of physical properties further indicated that GS particleboards are the most robust, capable of bearing a load of 400 g compared to 120 g and 90 g for RH and CH boards, respectively. These findings suggest that agricultural waste, particularly GS, can be effectively used to produce strong, sustainable particleboards, providing a viable alternative to traditional wood-based products and contributing to waste management and environmental conservation efforts.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Aqil Aqlan Azman, Mohamad Aiman Naser, Muhammad Asyraaf Mustafa Kamal;* ***data collection:*** *Muhammad Aqil Aqlan*

Azman, Mohamad Aiman Naser, Muhammad Asyraaf Mustafa Kamal; ***analysis and interpretation of results:*** *Muhammad Aqil Aqlan Azman, Siti Noraiza Ab Razak;* ***draft manuscript preparation:*** *Muhammad Aqil Aqlan Azman, Siti Noraiza Ab Razak. All authors reviewed the results and approved the final version of the manuscript.*

Appendix

SPECIFICATION FOR SUBTRATES - FOR INTERIOR FITMENTS (INCLUDING FURNITURE) FOR USE IN DRY CONDITIONS (TYPE P2)					
Properties	**Standard Board (UF)**				
Board Thickness (Units)	9mm < x 13mm	13mm < x 20mm	20mm < x 25mm	25mm < x 32mm	32mm < x 40mm
Bending Strength (N/mm2)	13	13	11.50	10	8.50
Modulus of Elasticity (N/mm2)	1,800	1,600	1,500	1,350	1,200
Internal Bond (N/mm2)	0.40	0.35	0.30	0.25	0.20
Edge Screw Holding N	360	360	250	N/A	N/A
Thickness Swelling - 1 hour immersion (%)	Max 8%	Max 8%	Max 8%	Max 8%	Max 8%
	EN 312 : 2003 Table 1 - General Requirements				
Formaldehyde Emmission **E1** **E2 - CARB EMISSION PHASE 1**	 x ≤ 8mg HCHO/100g oven - dry board (EN120 : 1997 Standard) 8 < x ≤ 30mg HCHO/100g oven - dry board (EN120 : 1997 Standard 0.18ppm)				
Board Dimension Thickness	1,830mm x 2,440mm (Tolerance +/- 5mm) 1,220mm x 2,440mm (Tolerance +/- 5mm)				
Grading Allowance	9mm, 12mm, 15mm, 16mm, 18mm, 25mm, 32mm & 36mm (Tolerance +/- 0.3mm) *Optional Thicknesses upon request* *3% admissible*				

Appendix 1

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