International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

VALORIZATION OF AGRICULTURAL RESIDUES BY ELABORATION AND PHYSICO-MECHANICAL CHARACTERIZATION OF CORN COB PARTICLEBOARDS

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DOI: 10.5281/zenodo.8159310

ABSTRACT

Among all agricultural residues, corncobs have been underutilized until now. This study aims to valorize them as agro-materials for manufacturing particleboards using either tannic powder from Parkia biglobosa pod husks or bone glue in pearl form. The methodology is divided into two parts: panel production and characterization of the mechanical and physical properties of the resulting panels. For particleboard manufacturing, we used bone glue and tannic powder from Parkia biglobosa pod husks as binders, varying their proportions and the particle size of the corncobs. To determine the mechanical and physical properties, the panels were subjected to three-point bending, tensile, and water swelling tests. The bending test allowed the determination of the modulus of elasticity (MOE), ranging from 77.3 MPa to 186.74 MPa, and the modulus of rupture, ranging from 1.8 MPa to 3.42 MPa. In tension, the determined Young's modulus varied from 7.12 MPa to 13.65 MPa, and the modulus of rupture (MOT) ranged from 0.38 MPa to 9.01 MPa. Density measurements classified the corn cob panels as low- and medium-density categories. The swelling test revealed that the panels can only be used in dry environments. Notably, an increase in binder content improved the physical and mechanical properties of the panels for both types of glue used. The optimal binder content range was determined to be 10% to 15%. Particle size variation also influenced panel properties, with particle size ≤ 0.8 mm yielding the best results. A comparative study between the two types of binders showed that panels made with bone glue exhibited superior characteristics. This work demonstrates the potential of utilizing corn cob agricultural residues in the production of particleboards.

Keywords: Particleboards, corn cobs, tannic powder, Parkia biglobosa pod husks.

1. INTRODUCTION

In recent years, our work has focused on the valorization of industrial and, particularly, agricultural waste to contribute to environmental management and improve quality of life. By adopting the techniques of developing and manufacturing particle boards using wood sawdust [1, 3], we deemed it necessary to valorize corn cobs, which are often burned without any specific purpose after harvesting.

Our contribution aims to develop and determine the thermomechanical characteristics of particle boards made from pressed and bonded corn cob sawdust using tannic powder from Parkia biglobosa pod husks [2] as a binder. The specific objectives involve the elaboration and characterization through a series of mechanical tests. After describing the equipment used and the process for obtaining corn cob particle boards in our approach, we will discuss the test results before drawing a conclusion.

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2. MATERIALS AND METHODS

2.1 Material

Various materials were used in this research for the development of corn cob-based particleboards. We utilized the following:

- Plant material: The flour derived from corn cobs served as the primary raw material. These agricultural residues were collected from corn harvesting sites.
- Tannins from Parkia Biglobosa (Parkia biglobosa pod husk, Fig. 1), the mechanical testing properties of which constituted one of the objectives of our study.

Firstly, the Parkia biglobosa pod husks were harvested from northern Togo. Upon arrival in Lomé, they were sun-dried to remove any moisture. Subsequently, they were crushed and sieved using a 1.6 mm diameter sieve. To extract the tannin, the powder was resieved with successive sieves of 1 mm and 0.125 mm.

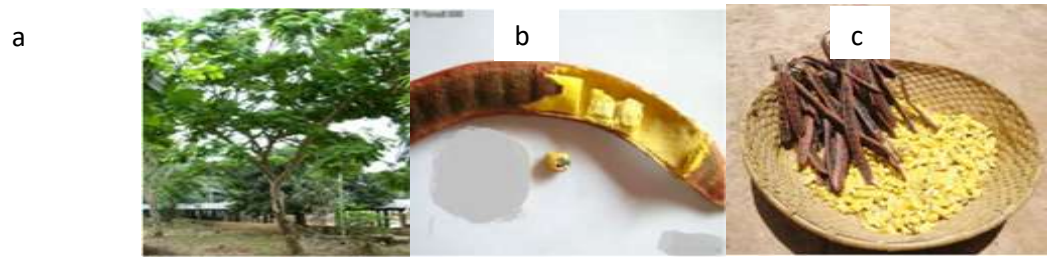

***Figure 1: Parkia biglobosa plant (a); fruits (b) and yellow floury pulp and seeds (c* Sub-subheading**

The panels are obtained using laboratory equipment, which includes:

- An electronic balance with a weighing range from 1 g up to 5,000 g;
- A knife mill of the RETSCH SK 1000 type equipped with sieves of various mesh diameters to reduce the cellulose material;
- A mixer for blending the mixture (particles + binder);
- A manual hydraulic press of the CARVER type: The press consists of two electrically heated plates with automatic temperature control. The plate dimensions are 300 mm x 300 mm. The maximum pressure of the 10-ton press is achieved using a hydraulic system. It is equipped with a mold measuring 30 cm x 30 cm for panel shaping;
- A bending test bench.

*2.2 Metho***d**

The husk of Parkia biglobosa or Parkia biglobosa is collected, dried, and finely ground using a RETSCH SM 100 knife mill equipped with a 5 mm mesh screen. The resulting powder is then sieved through screens with respective diameters of 1.6, 0.8, 0.250, and 0.125 mm until obtaining a fine powder, which is used as the binder. Our work was conducted by varying the binder content from 5% to 15% (Table 1) at a constant pressing temperature of 160°C.

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Table 1 : Example of material batching for panel production

Contents of binder (%)	Mass of Corn Husk (g)	Mass of Binder (g)	Amount of Water (H_2O) mass (g) is the same for all
5	570	30	120
7.5	562	38	120
10	540	60	120
12.5	525	75	120
15	510	90	120

Once the panels were obtained, we conducted a series of tests in three-point bending and tension for their mechanical characterization. The quality parameters selected for the particleboards produced in this study are their bending strength and tensile strength. The particleboards were cut into specimens measuring 300 mm in

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length and 50 mm in width, as well as 200 mm in length and 30 mm in width, on which the characterization tests were performed following the American standard ANSI A208.1-2009. For each panel, six (6) specimens were cut for the bending test and another six (6) for the tensile test. The three-point bending test involves subjecting the specimen, supported on two points, to a gradually increasing load P applied at its center. The deflection is measured as the load increases until the specimen ruptures.

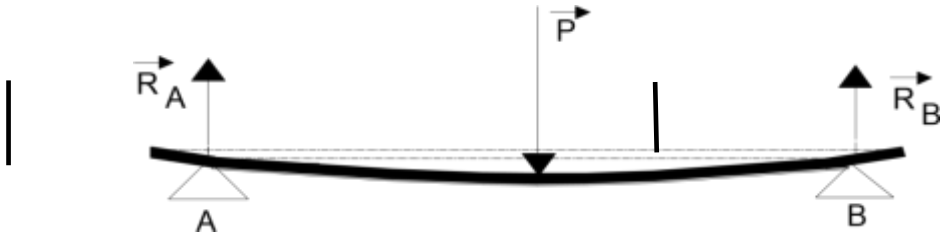


Figure 1: Principle of the three-point bending test

In the case of a homogeneous and isotropic material, the modulus of elasticity is given by equation (4.6):

$$E = \frac{Fl^3}{4be^3y} \qquad \text{(i)}$$

The NBN EN 310:2009 standard for particle boards recommends an elasticity modulus with the force F taken between 10% and 40% of the breaking strength. Consequently, we have the following relationship (ii):

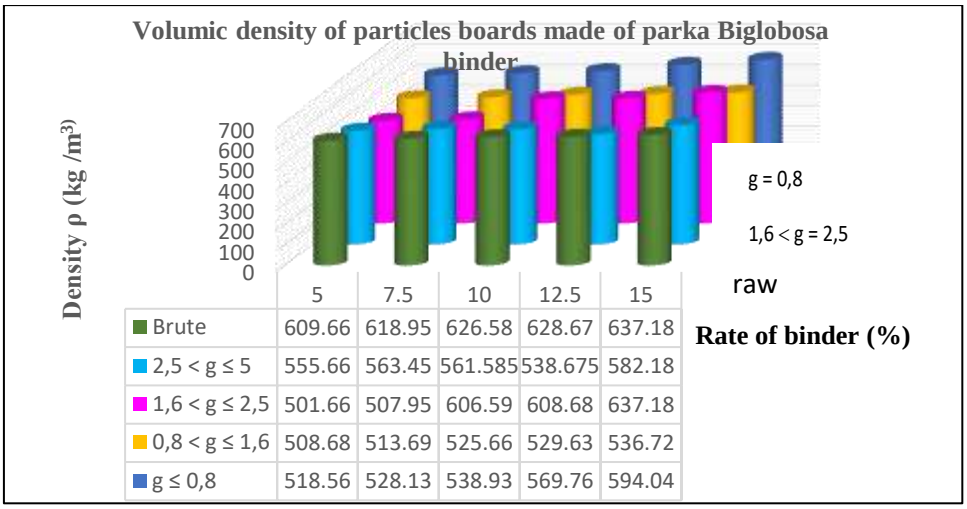
$$E = \frac{(F_2 - F_1)l^3}{4be^3(y_2 - y_1)} \qquad \text{(ii)}$$

With**:**

l: distance between supports;
b: width of the specimen;
e: the thickness of the specimen;
F: breaking force;
F1 = 10% of F;
y1: deflection corresponding to F1;
F2 = 40% of F;
y2: deflection corresponding to F2.

3. RESULTS AND DISCUSSION

The density of the corn cob panels obtained during this research varies depending on the particle size and binder content, leading to the following results.



	5	7.5	10	12.5	15
Brute	609.66	618.95	626.58	628.67	637.18
2,5 < g ≤ 5	555.66	563.45	561.585	538.675	582.18
1,6 < g ≤ 2,5	501.66	507.95	606.59	608.68	637.18
0,8 < g ≤ 1,6	508.68	513.69	525.66	529.63	536.72
g ≤ 0,8	518.56	528.13	538.93	569.76	594.04

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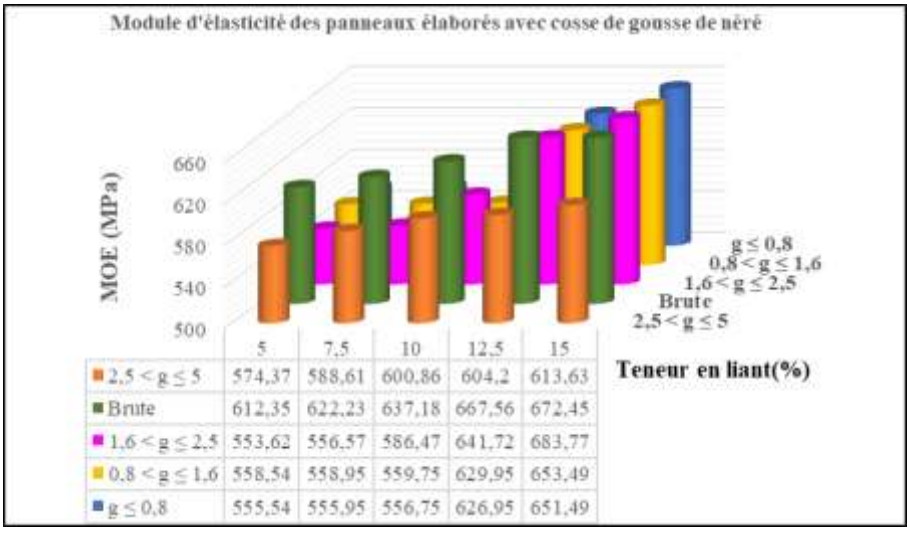
Figure 2: Histogram showing the variation in density of the panel as a function of the rate of Parkia Bigloboard (néré) binder obtained from its pod and type of particle size

The density of the corn cobs panels obtained during this research varies according to the type of particle size and the rate of the binder:
- 609.66 kg/m^3 to 637.18 kg/m^3 for panels of sawdust from unscreened corn cobs with tannic powder from the Parkia Biglobosa pod binder.
- 538.67 to 582.18 for panels of sieved corn cobs $2.5 < g \leq 5$ with tannic powder from the Parkia Biglobosa pod binder.
- 501.66 kg/m^3 to 637.18 kg/m^3 for sifted corn cobs panels $1.6 < g \leq 2.5$ with tannic powder from the Parkia Biglobosa pod binder.
- 508.68 kg/m^3 to 536.72 kg/m^3 for sifted corn cobs panels $0.8 < g \leq 1.6$ with tannic powder from the Parkia Biglobosa (néré) pod binder.
- 518.56 kg/m^3 to 594.04 kg/m^3 for panels of sieved corn cobs $g \leq 0.8$ with the tannic powder from the Parkia Biglobosa (néré) pod binder

The mechanical results, based on particle size and binder content, are represented by the histogram (Figure 3), which provides the values of the modulus of elasticity.



	5	7,5	10	12,5	15
2,5 < g ≤ 5	574,37	588,61	600,86	604,2	613,63
Brute	612,35	622,23	637,18	667,56	672,45
1,6 < g ≤ 2,5	553,62	556,57	586,47	641,72	683,77
0,8 < g ≤ 1,6	558,54	558,95	559,75	629,95	653,49
g ≤ 0,8	555,54	555,95	556,75	626,95	651,49

Figure 3: Histogram showing the variation of the MOE as a function of binder content using tannic powders from Parkia biglobosa pod husks and different particle sizes

4. CONCLUSION

We conducted a water swelling study on particleboards made from corn cob sawdust, using tannic powder from Parkia biglobosa pod husks and bone glue in pearl form as binders. The results indicate that panels made with these two binders cannot be used in a humid environment.

The obtained diagrams demonstrate that the modulus of elasticity (MOE) increases with the binder content. It is worth noting that panels manufactured with bone glue in pearl form exhibit a higher modulus of elasticity compared to those made with tannic powder from Parkia biglobosa pod husks. Additionally, we observe that particle size influences the results.

After a meticulous comparative study of the two binders with different particle sizes, we can rank the performance within the optimal binder content range of 5%, 7.5%, 10%, 12.5%, and 15%. Panels made with a particle size equal to or less than 0.8 mm occupy the first position, followed by those with a particle size between 0.8 and 1.6 mm. Next come the panels with a particle size between 1.6 and 2.5 mm, followed by those between 2.5 and 5 mm, while panels with the coarsest particle size rank last. In conclusion, the use of bone glue in pearl form (COP) is preferred over tannic powder from Parkia biglobosa pod husks [2].

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CITE AN ARTICLE

Ayarema, A., Soviwadan, D., Sinko, B., & Assogba, K. K. (n.d.). VALORIZATION OF AGRICULTURAL RESIDUES BY ELABORATION AND PHYSICO-MECHANICAL CHARACTERIZATION OF CORN COB PARTICLEBOARDS. INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 12(7), 32–36. https://doi.org/10.5281/zenodo.8159310