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# Production and Characterization of Particle Boards from Common Agro Wastes in Nigeria

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**Abstract:- This work produced particle boards from eight composites of sawdust (SD), corncobs (CC) and rice husk (RH), using polyester resin as binder. Each component material was dried to a moisture content of 12 % before mixing them to form the composites. They were mixed in varying ratios of 34% composite, while the binder was kept constant at 66%. Eight composite samples of varying compositions (A) 17% SD and 17% RH, (B) 17% SD and 17% CC, (C) 17% RH and 17% CC, (D) 22% SD and 12% RH, (E) 22% SD and 12% CC, (F) 22% RH and 12% CC, (G) 22% CC and 12 %RH, and (H) 22% CC and 12% SD were cast into boards, using a mould of 500 x 500 x 10 mm in a particle board press. The particle boards were subjected to tests of density, water absorption, thickness swelling, flexural strength and compressive strength. They were also characterized, using optical microscope to evaluate the surface morphology. The results, showed that the particle boards had mean density ranging between 800 kg/m$^3$ and 860 kg/m$^3$, water absorption between 5.44% and 47.97%, thickness swelling between 1.26% and 13.24%, flexural strength between 4.86 MPa and 14.78 MPa, and compressive strength between 1.16 MPa and 4.41 MPa. Optimal properties were exhibited by composite D, while the least was F. The microstructural analysis revealed that the composites A, and F showed fewer voids and fiber pullout. They had small discontinuities and non-uniform distribution. The other six composite boards compared favourably with the prescribed IS3087 Standard and they can, therefore, be used for general purpose requirements like paneling and partitioning.**

***Keywords**:- Agricultural Waste, Composites, Environmental Problems, Mechanical Properties, Microstructure, Physical Properties.*

## I. INTRODUCTION

With advances in technology and increase in the global population, the demand for wood in the forest industry has grown over the years. In addition, the application of wood in new areas has also caused a significant pressure on the current standing forest resources [1]. This has generated the necessity for people in the forest industry and scientists studying in this field to find alternative biomasses as raw materials. Particle boards, within the concept of this research work, is a particle based panel product manufactured from various particles of wood lingo cellulosic materials and a binder, consolidated together under pressure and temperature. Particle boards are commonly used in structural applications such as flooring, wall bracing, ceiling boards, furniture, partitioning and cladding. The need to reduce the dependence on wood and forest resources has resulted in a great interest in the utilization of agricultural residues and wastes for particle board production [2] Some of these waste products can however be recycled into new products that are environmentally friendly that can equally add value to the economy and empower the unemployed youth.

According to the recently released quarterly report on crop prospects and food situation of the United Nation's Food and Agriculture Organisation conducted by The International Food Policy Research (IFPRI) forecast that as a result of increased production, global coarse grain stocks is expected to rise [3], and this would lead to an increase in agricultural wastes globally. Sawdust, corncobs and rice husk, which are the basic raw materials for this research work, are considered as waste materials and the commonest disposal method is incineration with its attending effect on the environment. Some still constitute menace as environmental pollution in so many areas. Recent developments have indicated the viability of using agricultural waste to produce particleboard. Some of the waste that have been tried include maize stalk, jute sticks, corncobs, palm fibres, rice husk, kenaf, groundnut husks, sawdust. A particle board was produced from mixed shredded flakes of banana stem, sawdust of mixed hardwood species and cement [4]. Particle boards had been manufactured from municipal solid waste, sawdust, and plant waste in different combination [5]. Production of particleboard from Bamboo Waste has been carried out [6]. Rice husk particle boards using starch wood glue also, have been produced [7]. Synthetic resins are used to bond the agro wastes together and other additives can be added to improve some of its properties.

Sawdust is the main component of particleboard. Sawdust is a by- product of wood working operations such as sawing, milling, planning, drilling and sanding Rice is one of the large groups of cereal grains that can be used to produce hull fibers. Rice husk is a major by- product of the rice milling industry. Among the particle boards produced from rice husk include rice husk - sawdust reinforced polyester composite for ceiling board [8]. Particle boards produced from rice husk, wood fibre as filler and modified starch as a binder [9].

Rice husk absorbent and insulating properties are useful to many industrial applications, such as it acting as a strengthening agent in building materials. Corn cob is obtained after removing the maize seeds from the cob. The corncob is made up of cellulose and lignin. One of the most important characteristic of corncob products is their absorbency, their capacity to hold up to four times their weight in fluid. This absorptive quality enables corncob products to be used to absorb finishing fluids, oil and water in industrial applications and to clean up industrial or environmental spills.

Polyester resin is a thermosetting unsaturated polymer resin, which is formed from the reaction between organic acids and polyhydric alcohols. These resins are styrene-based, flammable and catalyzed when combined with Methyl Ethyl Ketone Peroxide. The principal advantage of these resins is a balance of properties including mechanical, chemical, and electrical, dimensional stability, cost, and ease of handling or processing. In the previous work, physical or mechanical properties of the produced boards were not assessed. In this present work, the physical and mechanical properties of particle boards manufactured with different raw materials (sawdust, corncobs and rice husk) in different combinations are assessed using polyester resin as binder. The composites were prepared via casting method at varying compositions of the material.

## II. MATERIALS AND METHOD

### *A. Materials and Equipment*

About 30 kg each of rice husk, corncobs, and sawdust was sourced for in this research. The materials were obtained from different sources. The sawdust was obtained from the saw mill in Akure, Ondo state, rice husk was obtained from Ifon, Ogun State and the corn cobs from maize plantation in Akure, Ondo State, Nigeria. The binder used in this project was Polyester resin, accelerator (Methyl Ethyl Ketone Peroxide) and a catalyst. Some of the equipment used for the study includes; particle board press, digital weighing scale, measuring cylinder, sieve, wood stirrer, bowl, ball milling machine, Instron 3369 testing machine, Nikon Eclipse ME600 optical microscope.

### *B. Materials Preparation*

➢ *Segregation, Drying and Grinding*

Rice husk, corncobs, and sawdust were sorted and segregated at the source of generation. The initial weight of the composite was recorded and each of the materials was then sun dried to a moisture content of 12% prior to further processing. The dry corncobs and rice husk were crushed and milled into particles using ball milling machine for size reduction. Fine particles of corncobs and rice husk are obtained by ball milling. Then, the obtained fine particles of corncobs, rice husk and sawdust were sieved using a standard sieve to obtain 2 mm particles. The process of sieving is to reject the particles that are larger than required and to obtain particles of uniform size.

➢ *Pre-Treatment Process*

The obtained particles were subjected to hot water pre-treatment at a temperature of 85°C for a soaking period of one hour [10]. Soaking was necessary in order to reduce extractives and other chemical substances present in the waste materials as extractives interferes in wood-bonding processes. After the soaking period, the hot water was drained and the materials air dried. The drying is necessary because excessive moisture adversely affects the adhesion performance of particles with adhesives. Moisture content was found to be 12% using “(1)”

$$\text{MC \% (OD basis)} = \frac{\textit{weight of water}}{\textit{Dry weight of wood}} \times 100\% \quad (1)$$

➢ *Polyester Resin Mixing*

Polyester resin is measured using measuring jar and it is poured into a clean bowl. Then about 5 ml of accelerator is added to the measured polyester resin and the mixture is stirred well. This is necessary for polymerization to occur, polymerization is too slow for practical purposes and therefore accelerators and catalyst are used to achieve polymerization of the resin within a practical time period.

### *C. Composite Processing*

The prepared composites, sawdust (SD), corncobs (CC), and rice husk (RH) were weighed using a digital weighing machine. They were mixed in varying ratios of 34% composite, while the binder was kept constant at 66% as shown in Table 1.

| SAMPLE CODE | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Composite | SD 17 | SD 17 | RH 17 | SD 22 | SD 22 | RH 22 | CC 22 | CC 22 |
| | RH 17 | CC 17 | CC 17 | RH 12 | CC 12 | CC 12 | RH 12 | SD 12 |
| Polyester Resin | 66 | 66 | 66 | 66 | 66 | 66 | 66 | 66 |

Table 1:- Sample Formulations for the Varying Compositions of the Prepared Samples by Weight (%).

The weighed composites and the prepared polyester binder were mixed with each percentage composition. The mixture is stirred well until it is uniformly mixed. The mixture was manually mixed for 10 min to ensure that the particles are evenly mixed with the resin. The catalyst (which has no reaction chemically with the mixture, but speeds up the reaction) of about 10 ml is added to the mixture and is stirred well. The mixture itself will settle without the addition of catalyst but takes very long time to get harden. So, catalyst is added to speed up the reaction, which reduces the cure time of the board. Once the catalyst is added and stirred well, it is poured into the mould of dimension 500 mm x 500 mm x 10 mm and hot pressed with particle board press which uses hydraulic mechanism. The press applies heat and pressure to activate the resin and bond the fiber into a solid panel. The board was pressed for 10 minutes at a temperature of 80 °C and at a pressure of 2.8 kN/mm$^2$, it was then ejected and allowed to cool. The procedure was repeated for all 8-blend formulation. Each produced board was weighed using the digital weighing scale to determine the initial weight. Produced particle boards were then subjected to tests of density, water absorption, thickness swelling, flexural strength and compressive strength. They were also characterized using optical microscope to evaluate the surface morphology.

## III. RESULTS AND DISCUSSION

### *A. Density*

Produced Particle Boards were tested for the density using "(2)"

$$\text{Density (kg/m}^3\text{)} = Wa \,/\, Va \quad (2)$$

where

$W_a$ is the air- dried weight

$V_a$ is the air- dried volume.

Each sample was weighed using a calibrated weighing machine and recorded. The prescribed standard IS3087 for density ranged from 500 kg/m$^3$ – 900 kg/m$^3$, from the values obtained from the study, the mean density values for various percentage combination panels ranged from 800 kg/m$^3$ – 860 kg/m$^3$. Composite D, E, G, and H are of higher densities. It was observed that the panel densities increased as sawdust and corncobs compositions increased. The densities values obtained for all the boards met IS3087 standard of density range between 500 kg/m$^3$ – 900 kg/m$^3$, therefore the produced boards can be graded as a medium density particle board. The range of values for the samples were in agreement with the work [7] and [6] who reported values of 711.1 kg/m$^3$, 821 kg/m$^3$ and 700 kg/m$^3$, 800 kg/m$^3$ respectively.

### *B. Water Absorption and Thickness Swelling*

The water absorption test of samples was carried out in the laboratory at room temperature. The dry samples were first measured on the weighing balance and then soaked in a bowl for 24-hours at room temperature and then measuring the weight of each and then soaking them again and the procedure was repeated until there was no significant increase in the weight of the specimen. The water absorption of the particle board was calculated using "3"

$$\text{Water absorption (\%)} = \frac{M_2 - M_1}{M_1} \times 100\ \% \quad (3)$$

where

$M_2$ is the Final weight of material

$M_1$ is the Initial of weight of material

Each board had taken approximately 12 hours to attain a constant weight. The final weight of each is measured and the water absorption value was recorded. The thickness of each original sample was first measured and recorded. Then the samples were soaked in water for a period of 24 hours.

The thickness of the soaked samples is then measured and the percentage thickness swelling is calculated using "4". This test was done to determine the dimensional stability of the materials.

$$\text{Thickness swelling (\%)} = \frac{T_f - Ti}{Ti} \times 100\ \% \quad (4)$$

where

$T_f$ is the Final thickness of material

$T_i$ is the Initial thickness of material

Fig. 1. shows the water absorption rate with time of the produced boards. The records were taken at 6 hrs, 12 hrs, 18 hrs and 24 hrs.

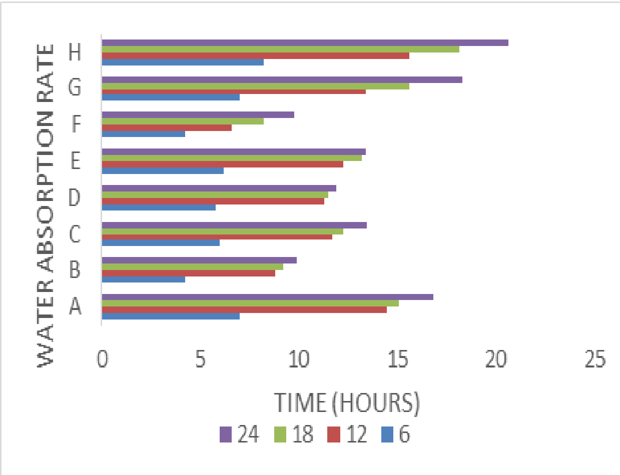


Fig 1:- Water Absorption rate with time of the produced particle boards

This shows that water absorptivity of the produced boards increased with time. All the produced boards were still hard after the 24 hours immersion in water. Water absorption of sample board can be improved by adding wax to reduce water intake.

Fig. 2 shows the thickness swelling rate of the produced boards

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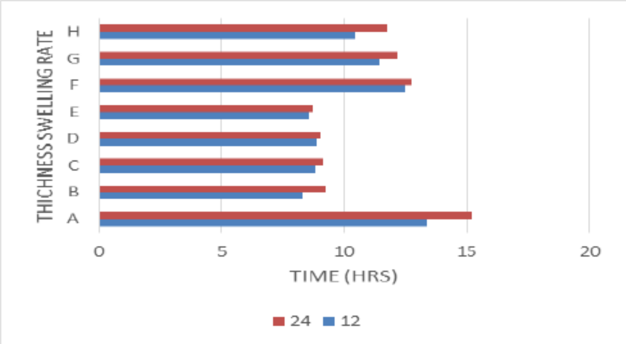

Fig 2:- Thickness swelling rate of the produced boards

Fig. 2 shows the thickness swelling rate of the produced boards. It was observed that the thickness of the material in water increases with time. The records were taken after 12 hrs and 24 hrs. Board sample B, sample C, sample E, sample F, sample G and sample H were still hard after 24 hrs in water. Sample A soften after 24 hrs soaking. This shows that board sample A is not dimensionally stable.

Table 2 shows the analysis of variance (ANOVA) on the physical properties of the produced boards. The follow up test on the produced boards is shown in Table 3.

| Test | Source | Type III Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Water Absorption | Sample | 4765.038 | 7 | 680.720 | 2650.090 | .000* |
| | Error | 4.110 | 16 | .257 | | |
| | Total | 15867.448 | 24 | | | |
| Thickness Swelling | Sample | 564.818 | 7 | 80.688 | 549.071 | .000* |
| | Error | 2.351 | 16 | .147 | | |
| | Total | 1578.571 | 24 | | | |

Table 2: Analysis of Variance (Anova) on the Produced Boards from Sawdust, Corncobs and Rice Husk
(* Represent Significant at P 0.05)

| Sample | Density (kg/m$^3$) | Water absorption (%) | Thickness swelling (%) |
|---|---|---|---|
| A | 800 | $16.46 \pm 0.02^e$ | $13.24 \pm 0.39^f$ |
| B | 800 | $11.29 \pm 0.35^c$ | $12.17 \pm 0.04^e$ |
| C | 800 | $14.02 \pm 0.31^d$ | $3.28 \pm 0.36^c$ |
| D | 860 | $5.44 \pm 0.06^a$ | $1.26 \pm 0.04^a$ |
| E | 860 | $9.67 \pm 0.09^b$ | $2.28 \pm 0.10^b$ |
| F | 840 | $47.97 \pm 0.21^h$ | $1.68 \pm 0.27^{ab}$ |
| G | 860 | $35.96 \pm 0.23^g$ | $5.91 \pm 0.16^d$ |
| H | 860 | $31.24 \pm 0.60^f$ | $12.11 \pm 0.17^e$ |

Table 3: Follow-Up Test on the Produced Boards from Sawdust, Corncobs and Rice Husk
(Means of Different Alphabet are Significantly Different at (P 0.05))

The result of analysis of variance conducted for the WA, TS, following 24-hour immersion are presented in Table 2. The result shows that there are significant differences in water absorption and thickness swelling of the samples at ($p \leq 0.05$). However, the result of the follow-up test using Duncan Multiple Range Test (DMRT) in Table 3 reveals the board density 860 kg/m$^3$ for sample D and E. The result shows that sample D had the lowest water absorption and thickness values of 5.44 % and 1.26 % respectively, followed by sample E with water absorption and thickness swelling of 9.67 % and 2.28 %respectively. However, table 3 also shows that the board density 860 Kg/m$^3$ for sample G and H gave high water absorption and low thickness swelling. The water absorption for sample G and H are 35.96 % and 31.24 % respectively while their Thickness swellings are 5.91% and 12.11 % respectively. Sample F with board density 840 Kg/m$^3$ had the highest water absorption and lowest thickness swelling of 47.97 % and 1.26 % respectively. This could be because of the high percentage of rice husk in the mixture which have high tendency of water absorption. The result also showed board density 800kg/m$^3$ for sample A, B and C. the result revealed that sample A had moderate water absorption as it value fall within the standard but failed the thickness swelling due to its high thickness swelling value. This implies that the board is not dimensionally stable. However, sample B and C are good at water absorption and thickness swelling level as shown in table 6. The observation is in agreement with the report of [4]. The decrease in water absorption values indicated that water could not easily penetrate the board when the proportion of sawdust in the board is high. The range of values for sample G and H are in agreement with the work of [5] who reported values of 34.1, 30.1 and 31.3 for his samples. Sample F did not meet the prescribed standard value of 40 %. It can be attributed to the fact that water absorption increases with increase in rice husk, this in agreement with the findings [11]. Sample C, D, E, F and G met the prescribed standard of 12 % with density of 860 kg/m$^3$ and 840 kg/m$^3$. Sample D, E, and F are in agreement with the work [5], who reported values of 2.4 %, 2.6 % and 1.25 % for his sample. The result for Sample C (3.28 %) agrees with the value of [4], with a value of 3.69 %, although its cement bonded particle board. Sample G result of 5.91 % agrees with the value of [6], with the value of 6.1 %.

*C. Flexural Strength*

Flexural test of the samples was carried out at Engineering Materials Development Institute (EMDI), Akure using INSTRON 3369 Testing Machine in accordance with ASTM D790. As the specimen is stretched the computer generates the required data. The flexural test was performed at the speed of 50 mm/min. The readings were recorded in the form of a plot of flexural stain vs flexural stress. Maximum load, maximum flexural stress, and modulus were obtained from the graph. Table 4 shows the flexural strength of the composite board. The flexural strength of the produced boards ranged from 4.86 MPa to 14.78 MPa. The static bending requirement for general purpose boards according to EN 312 – 2 (1996) is 11.5 $N/mm^2$ and Indian standard is between 9 $N/mm^2$ to 11 $N/mm^2$.The result for sample F (6.393 MPa) agrees with the work of [5], with a value of 6.47 MPa. This sample failed the test and was far from standard. However, samples A, C, and G were within standard values while, sample B, and D were greater than standard, and hence could be used for load bearing applications.

*D. Compressive Strength*

Compressive strength is a maximum stress that a material can sustain under crush loading. The Compressive strength test was carried out at Engineering Materials Development Institute (EMDI) Similar equipment used for the flexural test was utilized. The samples were tested using INSTRON 3369 as per testing procedure on IS 3087 (2005). The specimen is placed between compressive plates parallel to the surface. The specimen is then compressed at a uniform rate. The maximum load is recorded along with stress-strain data. The analysis report is given in Table 5.

The mean compressive strength of the produced boards ranged from 0.05 MPa to 4.41 MPa. The prescribed IS3087 compressive strength value should be greater than 2.5 MPa. Sample A, C, E, and F met the standard, even at high compressive loads of 549.12, 552.96, 750.91, and 643.36 N respectively. Sample B was a bit below standard while sample F, G and H were far from standard. The range of values for samples A, B, and C were in agreement with the work of [5] who reported values of 3.41, 2.13 and 2.33 for his samples.

| Sample | Max. Load (N) | Max. flexure stress (MPa) | Max. extension (mm) | Modulus (MPa) |
|---|---|---|---|---|
| A | 169.218 | 10.452 | 6.988 | 182.979 |
| B | 220.139 | 13.597 | 5.879 | 258.443 |
| C | 189.537 | 11.706 | 7.9612 | 186.607 |
| D | 239.399 | 14.786 | 6.820 | 292.986 |
| E | 78.792 | 4.866 | 5.944 | 96.502 |
| F | 103.509 | 6.393 | 6.162 | 143.087 |
| G | 173.802 | 10.735 | 8.509 | 154.011 |
| H | 133.715 | 8.259 | 7.981 | 135.179 |

Table 5:- Compressive Strength

*E. Microstructural Examination*

The produced board samples were scanned using Nikon Eclipse ME600 optical microscopy. This was done to examine the microstructural structure of the cast specimens at various compositions. Fig.3 shows the optical micrographs of the developed composites. The particles were dispersed randomly within the polyester. The microstructure is to look at the grain size in the material and how it forms. The uniform distribution of the particles and the binders in the microstructure of the board composites is the major factor responsible for the improvement in the properties [12]. The result revealed that samples B, C, D, and E particles are well distributed with good bonding of the resin and the agro wastes and this lead to good interfacial bonding. Sample A, F, G and H showed fewer voids and fiber pullout. They had small discontinuities and non-uniform distribution

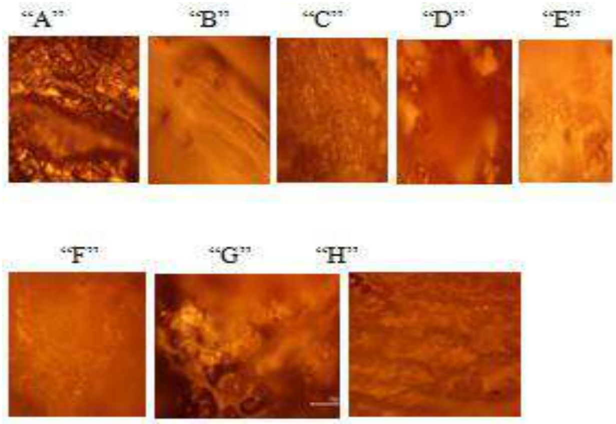


Fig 3:- Optical micrographs of the produced Particle board at varying particles composition at 400x magnification

| Properties | A | B | C | D | E | F | G | H | Prescribed value as IS3087 |
|---|---|---|---|---|---|---|---|---|---|
| Density ($Kg/m^3$) | 800 | 800 | 800 | 860 | 860 | 840 | 860 | 860 | 500-900 |
| Water Absorption (%) | 16.46 | 11.29 | 14.02 | 5.44 | 9.67 | 47.97 | 35.96 | 31.24 | Max.40 % |
| Thickness Swelling (%) | 13.24 | 12.17 | 3.28 | 1.26 | 2.28 | 1.68 | 5.91 | 12.11 | Max.12 % |
| Compressive Strength | 3.23 | 2.15 | 3.25 | 4.41 | 3.78 | 0.12 | 0.05 | 0.16 | > 2.5 |
| Flexural Strength (MPa) | 10.45 | 13.59 | 11.70 | 14.78 | 4.86 | 6.39 | 10.73 | 8.25 | 9-11 |

Table 6: Physical and Mechanical Properties of the Particle Board

## IV. CONCLUSION

The particle board for partitioning has been made from the composite of sawdust, corncobs and rice husk using polyester resins as binder. The uniform distribution of particle in the microstructure of board sample B, sample C, sample D, and sample E results in stronger bond. The results, showed that the particle boards had density ranging from 800 kg/m$^3$ and 860 kg/m$^3$, water absorption between 5.44 % and 47.97 %, thickness swelling between 1.26 % and 13.24 %, flexural strength between 4.86 MPa and 14 78 MPa and compressive strength between 1.16 MPa and 4.41 MPa. Optimal properties were exhibited by composite E, it had the best dimensional stability with good compatibility strength. while the least was H. The microstructural analysis revealed that the sample A, F, G and sample H, showed fewer voids and fiber pullout. They had small discontinuities and non-uniform distribution. The other six composite boards compared favourably with the prescribed IS3087 Standard and they can therefore be used in medium density particleboards for general purpose requirements like paneling and partitioning.

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