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EVALUATION OF PARTICLE BOARD FROM SUGARCANE BAGASSE AND CORN COB

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ABSTRACT

This article evaluates particle board using corncob (CC) particles and mixing it homogeneously in varying percentages 20%, 40%, 50%, 60% and 80% with sugarcane bagasse (SB) using Urea Formaldehyde resin as adhesive. Particleboards of 100% SB and 100% CC were also made, thereby making seven different compositions. Properties of particleboards produced such as density, water absorption, thickness swelling, modulus of rupture and modulus of elasticity were investigated. The densities of particleboards ranged from 400 Kg/m^3 to 620 Kg/m^3. The results of the tests also show that the particleboard with 50% CC and 50% SB using equal volume of adhesive had favorable physical properties that are recommendable for indoor uses in buildings. In contrast, the panels cannot be recommended for load bearing purposes because they exhibit poor mechanical properties, but these mechanical properties tend to improve as the composition of CC increased from 40% to 100%. The MOR and MOE results obtained in this research work lead to a conclusion that the mechanical properties of the panels were improved as the percentage of CC replacement increased but possessed poor physical properties. Within the experimental investigation and possible limitations, the *panels with 50% CC and 50% SB are the most preferred since they had preferable performance for both physical and mechanical properties.*

Keywords: Sugarcane Bagasse, Corncob, Particle Board, Waste and urea formaldehyde

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1. INTRODUCTION

With the continuous increase in global human population there has been a corresponding increase in the scarcity of basic survival needs of people. The continuous consumption of these scarce resources raises concerns on the ability of the future generation to meet their own needs in years to come. The problems that we are facing globally is a clear response of the ecosystem to human resource mismanagement; the global warming, increase in sea level, floods, earth quakes, disorder of seasons, are only a few of many complex problems that the world faces presently. The solution to the problem above is the principle of sustainable development. One of the approaches to sustainable development is reducing the amount of waste being generated and recycling the waste in a way that can be useful to the economic, social and environmental goals of sustainable development [1, 2]. Agro waste is one of the major solid wastes produced in the world. Examples of agro wastes include grape vines, fruit bearing trees, sugarcane bagasse, corn cob etc.

This research examines the possibility of converting some agro waste materials, particularly Sugarcane Bagasse and Corn Cob, in the production of Particle boards. "Particle board has been defined as a generic term for panels manufactured from linger cellulosic materials, usually wood, primarily in form of discrete pieces or particles, as distinguished from fibers, combined with a synthetic resin or any other suitable binder and bond together under heat and pressure in a hot pressure by a process in which the entire inter particle bond is created by the added binder, and to which other materials have been added during manufacture to improve certain properties" [3].

Particle board is made by compressing wood chips with glue. In flat-pressed particle board, the chips are mainly parallel to the surface. The chips in the surface layer are thinner than those in the middle layer making the surface of the particle board denser and more compact than the middle. In standard particle board, the most commonly used binder is Urea Formaldehyde. Particle board can be coated with a variety of surface materials, examples are; veneer, melamine, laminate, plastic, paper, etc. The boards are usually coated on both sides in order to prevent warping. Boards are also made already primed for painting (treated with filler at the factory or coated with priming paper). The fire-resistance properties of particle board can be improved with Alkyd Filler or Melamine Coating [4]. If the boards are intact and dry, particle boards may be reused on a case-by-case basis. Re-use is the most popular way of disposing particle boards. This is because they are mainly clean natural wood and can be disposed of (in accordance with local environmental authority guidelines) by burying them in the ground, composting, taking to landfill or burning at a temperature of more than 800 C with other wood material [5].

Sawdust is often mixed with other remnant pieces of wood to create a sheet of particle board [6, 7, 8]. The most common particles are wood chips, shavings and flakes, which are often gathered from lumber mills, and brought in their raw state to the particle board manufacturer. The sawdust is sifted, and each particle is housed separately in accordance with its size. Final touches include buffing, cutting and laminating. Rollers or finishing plates are used to buff and sand the wood before it is cut into standard dimensions - 8 to 10 feet wide by 24 feet long. Afterward, the boards can also be laminated or finished with a veneer, which is a thin paper covering that imitates real wood. Finished boards are packed and stored until shipment [9].

The particle board which used bamboo presented loss of early stability due to higher swelling after 2-hour immersion; however, when the swelling of the samples after 24 hours is considered, these particleboards showed similar performance compared to those only with wood particles. The use of bamboo particles was proved as promising for the production of particle boards, not only for those made exclusively with bamboo particles, but also through the combination with wood particles [10]. In certain cases, similar results were obtained when Particle boards made with bamboo particles were compared to particle boards manufactured exclusively with wood particles. The bamboo particles have potential for this purpose, with the possibility of adjustment of some production parameters for reaching performance equivalent to wood panel.

Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is a dry pulpy residue left after the extraction of juice from sugar cane. Bagasse is utilized as a biofuel and in the manufacture of pulp and building materials. For each 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse. Since bagasse is a by-product of cane sugar industry, the quantity of production in each country is in line with quantity of sugarcane [11]

Maize cobs are a by-product of the maize crop, consisting of the central fibrous rachis of the female inflorescence (the maize “ear”). The development of maize processing in the 20th century resulted in an increase in the volumes of this by-product [12]. About 180 kg of cobs are obtained from each ton of maize shelled [13]. In the USA, it was estimated that about 50 million tons of cobs were produced annually in the 2000s [14].

2. MATERIALS AND METHODS

The material that were used for this work includes sugar cane bagasse, maize cob and urea formaldehyde resin (Top Bond). The corncob were sourced from Landmark University Teaching and Research farm while the sugar cane bagasse was sourced from Kaduna (Northern part of Nigeria).

The corncob that were collected were room dried for 7 days making it satisfactory for crushing it to smaller sizes. The corncob were milled and sieved with the aid of sieve shakers so as to obtain particles passing through a British standard sieve of aperture size 4.75mm and retained in a sieve of aperture size 1.18mm, the particles that pass through the 1.18 mm sieve were discarded to avoid the problem of balling during mixing and also to facilitate the homogeneous mixing of the particles with the adhesive. The volume of corncob particles required for the production of 14 panels for the experimental design is 10290 cm^3. The moisture content of the processed corncob particles were about 2 to 3%.

Figure 1 Corncob (a) before grinding (b) after grinding

The sugarcane bagasse needed for this experiment were collected from Kaduna, Northern part of Nigeria and transported to Landmark University. After determining the moisture content the bagasse were room dried for 7 days which will make the grinding process effective. They sugarcane bagasse were sieved through British standard sieves of 4.75mm and 1.18mm apertures to remove oversized and undersized particles and enhance uniformity and avoid balling. The volume of sugarcane bagasse required for the production of 14 panels for the experimental design is 10290cm^3.

Figure 2 Sugarcane Bagasse (a) before grinding (b) after grinding

Composites Mix Design: The boards were made in panels of sizes 350 mm × 300 mm × 30 mm by varying the amount of sugarcane bagasse (SD) and corncob (CB) as given in Table 1.

Table 1 Particle Board Experimental Design

Composition Code	%composition SB:CC	Volume Equivalent (cm^3)	Volume of adhesive used (cm^3)
C1	$SB_{100}CC_0$	2940 : 0	735
C2	$SB_{80}CC_{20}$	2352 : 588	735
C3	$SB_{60}CC_{40}$	1764 : 1176	735
C4	$SB_{50}CC_{50}$	1470 : 1470	735
C5	$SB_{40}CC_{60}$	1176 : 1764	735
C6	$SB_{20}CC_{80}$	588 : 2352	735
C7	SB_0CC_{100}	0 : 2940	735

The calculated volume of composite particles required were measured and batched into cellophane bags and tightly sealed to avoid moisture absorption. The measured adhesive volume was poured into the head pan and half of the particles batched in the cellophane was first poured into the head pan and thorough mixing done after which the remaining particles was emptied into it and mixed until the adhesive is uniformly distributed and a homogeneous mixture obtained. The mixture obtained was spread into the mould to form a mat and the formed mat in the mould went through a press cycle of three phases; pressing in an hydraulic jack to reduce the board height, afterwards in an oven and allowed to dry for 1h at 80 °C and lastly cold pressing to facilitate the setting of the thermoplastic resin. Afterward, the mould was opened and placed under room temperature for 24 h and then placed in the oven for 3 h at 110 °C. After the oven drying, the formed panels were conditioned to 74 % humidity and a temperature of 24 °C for two weeks to give boards as shown in Figure 3. From each batch sample, three (3) test pieces measuring 50 mm x 50 mm x 15 mm were cut for the physical tests (density, water absorption and thickness swelling) and three (3) other test pieces measuring 50 mm x 50 mm x 300 mm were cut for the mechanical tests (modulus of rupture and modules of elasticity) to ensure reproducibility.

Figure 3 Samples of particle board from Sugarcane Bagasse and Corncob

3. RESULTS AND DISCUSSION

3.1. Physical Test

Table 2 Mean Values of Density, Water Absorption and Thickness Swelling of boards.

Board type	Mean Density (Kg/m^3)	Water Absorption (WA)		Thickness Swelling (TS)	
		% WA after 2 hours	% WA after 24 hours	% T.S after 2 hours	% T.S. after 24 hours
$CC_{100}SB_0$	620	52.25	76.5	16.25	21.25
$CC_{80}SB_{20}$	535	47.5	77.4	10	15
$CC_{60}SB_{40}$	572	44.5	60.3	8.05	13.6
$CC_{50}SB_{50}$	503	45	48	9.18	14.32
$CC_{40}SB_{60}$	605	41.75	44.7	7.42	13.14
$CC_{20}SB_{80}$	593	35.25	45	6.55	16.2
$CC_{0}SB_{100}$	400	40.5	54.7	5.55	12.5

3.1.1. Density Test

The mean density values obtained for 100% SB and CC panels were 620 kg/m^3 and 400kg/m^3 respectively. While the mean value for various percentage for various percentage combination of SB and CC panels ranged from 503 kg/m^3 to 605 kg/m^3 as shown in Table 2. It was observed that the panel with highest density is obtained from the batch of 100% CC. Also from the Table it was observed that the panel densities increased as the percentage of CC increase. Since the maximum density, 620 kg/m^3 is less than 640 kg/m^3, therefore manufactured boards can be graded according to ANSI A208.1(1999) [15] as low density particle board, Grade 1(LD-1).

3.1.2 Water Absorption

Water absorption (WA) test is poised towards investigating the amount of moisture [16] or water that the particleboards with varying composition of SB and CC particle can absorb within a specified period of time. The particleboard specimen were immersed in water for 2 hours and 24 hours at a temperature of 23°C. After 2 hours of immersion in water $CC_{20}SB_{80}$ was observed to have the least value for WA while $CC_{100}SB_0$ had the highest value of water absorption. Similarly, after 24 hours of immersion of the specimen in water $CC_{40}SB_{60}$ and approximately $CC_{20}SB_{80}$ had the least value of WA as shown in Table 2. Therefore, from this test, $CC_{20}SB_{80}$ had a better performance when compared with $CC_{100}SB_0$. A significant decrease in WA was noticed with the 20% replacement of CC with SB and as the percentage of SB increase was noticed that the WA kept decreasing relatively but subsequently when the percentage of SB reached 100% the WA showed increment as shown in Table 2. The initial decrease in WA can be explained by the increase in the compaction of the panels. SB can be said to possess higher compressibility when compared with CC because when equal pressure is applied to equal volumes of SB and CC contained in different containers, SB was observed to compress more than CC. therefore when the less compressible CC was added to the more compressible SB less void spaces were present thereby giving less room for the penetration of water.

3.1.3 Thickness Swelling

From the data obtained as given in Table 2, CC_0SB_{100} exhibits the least swelling compared to the other board types after immersion in water in both 2 hours and 24 hours. However, of all the test specimens $CC_{100}SB_0$ swells the most after 2 and 24 hours with values 16.25% and 21.25% respectively. It was also observed that as the percentage of sugarcane bagasse increase the T.S value keep decreasing.

From the data, it is clear to see that the TS data obtained for 2 hours immersion follows the same pattern as that of water absorption, but this pattern is seen to change after 24 hours. The percentage WA of $CC_{80}SB_{20}$ after 24 hours is more than that of $CC_{100}SB_0$, but the reverse was the case in TS. Therefore, $CC_{80}SB_{20}$ swells less than $CC_{100}SB_0$ even with a higher WA percentage.

3.2. Mechanical Test

Table 3 Mean Values of Modulus of Rupture and Modulus of Elasticity

Board type	MOR (N/mm^2)	MOE (N/mm^2)
$CC_{100}SB_0$	4.4	21.14
$CC_{80}SB_{20}$	3.3	21.13
$CC_{60}SB_{40}$	3.6	20.5
$CC_{50}SB_{50}$	3.7	26.33
$CC_{40}SB_{60}$	3.2	16.68
$CC_{20}SB_{80}$	2.3	13.58
CC_0SB_{100}	1.9	11.28

It was observed that 100% CC board had the highest value for MOR followed by C4 which is 50% CC and 50% SB while 100% SB board had the least value as shown in Table 3.
Modulus of elasticity (MOE) also showed a similar increase and decrease pattern in value shown in Table 3 expect $CC_{80}SB_{20}$ had greater value than $CC_{60}SB_{40}$ which is the opposite of MOR value obtained. It was also observed that $CC_{50}SB_{50}$ had the highest value for MOE which was 26.333 N/mm^2 and the least was CC_0SB_{100} with MOE value of 11.28 N/mm^2.

According to BS EN 13353 [17] panels intended for structural purposes that have densities greater than the minimum requirement which is 420kKg/m^3 were also required to have their minimum values for MOR and MOE to be 5N/mm^2 and 400 N/mm^2 respectively. From the result obtained from the test which is shown in Table 3 although none of the panels produced had values of MOR and MOE that met the minimum requirement but $CC_{100}SB_0$ had 4.4 N/mm^2 value of MOR which is reasonably very cloth enough to the minimum requirement. This therefore suggests that the panels cannot be used for structural or load bearing purposes. Sekaluvu, et al [18] investigated the properties of particleboards made from only CC and obtained mean values of MOR and MOE to range between 0.32 to 1.5 N/mm^2 and 5.89 to 61.82 N/mm^2 respectively which is similar to the result of MOE obtained in this research work but the MOR result obtained in this research work is much better.

4. CONCLUSION

In this research work it has been shown that it is possible to produce particleboards with less sophisticated machines and still obtain reasonable physical properties. From the result obtained, a 20% to 60% replacement of SB with CC with particle size ranging from 1.18 to 4.75 mm and equal volume of adhesive exhibited favorable physical properties that are recommendable for indoor uses in buildings. However, the panels cannot be used for structural purposes or load bearing purposes because they exhibit poor mechanical properties which tends to improve as the composition of cc increased from 40% to 100%. The MOR and MOE results obtained in this research work could lead to a conclusion that the mechanical properties of the panels were improved as the percentage of CC replacement increased. A 100% CC had the highest value for MOR followed by 50% CC while 50% SB and 50% CC had the highest value for MOE. Within the experimental investigation and possible limitations, the panels with 50% CC and 50% SB are the most preferred for their physical and mechanical properties.

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REFERENCES

[1] O. D. Atoyebi, S. O. Odeyemi, S. A. Bello and C. O. Ogbeifun, "Splitting Tensile Strength Assessment of Lightweight Foamed Concrete Reinforced with Waste Tyre Steel Fibre," International Journal of Civil Engineering and Technology, vol. 9, no. 9, p. 1129–1137, 2018.

[2] O. Atoyebi and O. Sadiq, "Experimental data on flexural strength of reinforced concrete elements with waste glass particles as partial replacement for fine aggregate," Data in Brief, vol. 18, p. 846–859, 2018.

[3] A. Danladi and I. O. Patrick, "Mechanical properties of particle boards from maize cob and urea-formaldehyde resin. International Journal of Chemical, Nuclear, Metallurgical and Materials Engineering," Vols. 82, , no. 10, pp. 410-412, 2013.

[4] R. M. Rowell, Handbook of wood chemistry and wood composites., CRC press., 2012.

[5] H. Merrild and T. H. Christensen, "Recycling of wood for particle board production: accounting of greenhouse gases and global warming contributions.," Waste Management & Research, vol. 27, no. 8, pp. 781-788, 2009.

[6] O. D. Atoyebi, T. F. Awolusi and I. E. Davies, "Artificial neural network evaluation of cement-bonded particle board produced from red iron wood (Lophira alata) sawdust and palm kernel shell residues,," Case Studies in Construction Materials, vol. 19, pp. 2340-2343, 2018.

[7] A. A. Raheem, A. P. Adewuyi, L. O. Azeez, O. D. Atoyebi and O. M. Akanbi, "An Investigation of the use of Corncob and sawdust in Ceiling production.," Lautech Journal of Engineering and Technology (LAUJET), vol. 6 , no. 1, p. 149 – 155, 2010.

[8] S. R. Karade, "Cement-bonded composites from lignocellulosic wastes," Construction and Building Materials, vol. 24, no. 8, pp. 1323-1330, 2010.

[9] B. Rivela, A. Hospido, T. Moreira and G. Feijoo, "Life cycle inventory of particleboard: a case study in the wood sector," The International Journal of Life Cycle Assessment, vol. 11, no. 2, pp. 106-113, 2006.

[10] O. Atoyebi, S. Odeyemi and J. Orama, "Experimental data on the splitting tensile strength of bamboo reinforced lateritic concrete using different culm sizes,," Data in Brief, vol. 20, pp. 1960-1964, 2018.

[11] L. E. Baucum, R. W. Rice and T. J. Schueneman, "An overview of Florida sugarcane. Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences." University of Florida. Publication SS-AGR-232, 2006.

[12] D. B. Lobell and C. B. Field, "Global scale climate–crop yield relationships and the impacts of recent warming." Environmental research letters, vol. 2, no. 1, pp. 1-7, 2007.

[13] A. D. Evers and N. L. Kent, "Kent’s technology of cereals: an introduction for students of food science and agriculture." in Woodhead Pub. Series Food Sci., Technol. Nutr., Elsevier, 1994.

[14] D. S. Hill, Pests of crops in warmer climates and their control., Springer Science & Business Media., 2008 .

[15] ANSI 208-1-1999, "American National Standard --Particleboard: Composite Panel Association." American National Standard Institute. , Gaithersburg, 1999.

[16] O. Atoyebi, O. A.E. Modupe, O. Aladegboye and S. Odeyemi, "Dataset of the density water absorption and compressive strength of lateritic earth moist concrete," Data in Brief, vol. 19, p. 2340–2343, 2018.

[17] BS EN-13353:2003, "Standard Wood Panels (SWP) - Requirements.” European Committee for Standardization," British Standard Institution. London, 2003.

[18] L. Sekaluvu, P. Tumutegyereize and N. Kiggundu, "Investigation of factors affecting the production and properties of maize cob-particleboards.," Waste and biomass valorization, vol. 5, no. 1, pp. 27-32, 2014.

[19] O. M. Sadiq and O. D. Atoyebi, "Flexural strength determination of reinforced concrete elements with waste glass aspartialreplacementfor fine aggregate,," NSE Tech. Trans. Journal of Nigerian Society of Engineers, vol. 49, p. 74–81, 2015.

[20] M. Maguesvari and V. Narasimha, "Studies on Characterization of Pervious Concrete for Pavement Applications." Procedia - Social and Behavioral Sciences, vol. 104, pp. 198-207, 2013.

[21] K. Behfarnia and F. Khademi, "A comprehensive study on the concrete compressive strength estimation using artificial neural network and adaptive neuro-fuzzy inference system," Iran University of Science & Technology, vol. 7 , no. 1, pp. 71-80, 2017.

[22] A. Ashori, T. Tabarsa and S. Sepahvand, "Cement-bonded composite boards made from poplar strands," Construction and Building Materials, vol. 26, pp. 131-134, 2012.