Some properties of composite corn cob and sawdust particle boards

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HIGHLIGHTS

- Particle boards from corncob and sawdust with urea formaldehyde as binder showed good prospect.
- Selected physical and mechanical properties were determined.
- Indoor application is recommended.

ARTICLE INFO

ABSTRACT

This research examined the possibility of developing a composite corncob (CC) and sawdust (SD) particle board using urea formaldehyde as binder. The panels were produced using 0%, 25%, 50%, 75% and 100% variations for both agricultural wastes with a constant volume of adhesive to evaluate their effect on the physical and mechanical properties. The results showed that 25% and 50% replacement of SD with CC had favourable physical properties recommendable for indoor uses in buildings. In contrast, the particleboards cannot be recommended for load bearing purposes based on poor mechanical properties which improved as the composition of CC increased from 25% to 75% and also because it failed to satisfy European Standard requirements. 75% CC replacement had the highest value for both MOR and MOE but possessed poor physical properties. Within the experimental investigation and possible limitations the panels with 50% CC replacement were the most preferred since they had preferable performances for both physical and mechanical properties.

1. Introduction

A lot of housing challenges are faced by most developing countries which have created a lot of housing shortages as a result of high interest rates, increased taxes, high labour costs and government policy bottlenecks. Most banks are not interested in financing housing construction through provision of loans and where it is available the interest and collateral requested are ridiculous, as a result of these challenges, a larger percentage of the populace live in sub-standard and ramshackle buildings. As a way of finding a lasting solution to these problems, lots of researches are being conducted on the use of non-conventional building materials which has the same properties as those popularly used for development of structures [1]. Most of the developing countries are very rich in agricultural and natural fibre since majority are peasant farmers who produce rice, palm trees, sugarcane and a lot of other crops accompanied with a large portion of agricultural wastes which are used as fuel or burnt off in disposal sites thereby constituting health hazards. It has been observed through various researches that these natural fibres have very good physical and mechanical properties and have the potential of being used in the development of different materials for various building applications [2–4]. Particleboard (PB) is a panel product made of wood products or other materials having lignocellulose properties bonded together by urea formaldehyde or other synthetic resin under high temperature and pressure to produce sheets [5–8]. Particleboards are light weight boards that can be used as thermal insulators, ceiling boards, wall partitions, doors and some other household furnitures [9]. Agrowastes are being incorporated into green buildings because they are usually more economical at the long run. This led to the development of new environmentally friendly technologies for turning agricultural residues like maize cob, rice husk, groundnut shell [10,11] coconut coirs, durian peel [12,13] bamboo [14], bagasse, wheat straw, chir pine needles, chilli pepper stalks [15] woven cotton fabrics, rubber wood [16] cotton stalks, red cedar [17] and

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banana stem among others into quality value-added composite particle board products using conventional formaldehyde-based resins [2]. Some works have been done on development of composite particle and ceiling boards from both industrial and agricultural products in Nigeria. Sawdust, waste paper and starch were varied by weight to produce a ceiling board with good physical, mechanical and thermal conductivity properties [18]. Olorunmaiye and Ohijeagbon [19] also developed a composite particle board from wood waste and *jatropha curcas* seed cake with an observed improvement in the mechanical properties. In another study, general purpose particle boards which satisfied ANSI/A208.1-1999 specification were produced from cassava stalks and corn cobs [20]. Cengiz et al. [21] developed a composite particleboard panel by varying the sunflower stalks and calabrian pine percentage compositions using 100, 75, 50, 25 and 0% roportions. In a similar research, particles of empty fruit bunch of *Elaeis guineensis*, pineapple leaves, and Tetra Pak packages were mixed with 3 kinds of wood from *Gmelina arborea*, *Tectona grandis* and *Cupressus lusitanica in* 50:50, 70:30, and 90:10 variations [22]. The objectives of this research were to determine some physical and mechanical properties of composite corn cob and sawdust particles in a pre-determined proportions.

2. Materials

The materials used for the production of composite particleboard from corn cob and saw dust were sourced locally from the Landmark University community. These include 30 kg of corn cob (CC), 30 kg of saw dust (SD) which was from saw milled Mahogany specie of timber, Urea Formaldehyde resin (Top Bond) and plywood for the construction of moulds.

3. Methodology

3.1. Preparation of Corn Cob

The CC was collected at an average moisture content of 6.44%, room dried for 7 days to an average of 6.18% moisture content and manually crushed using a wooden mortar and pestle (Plate 1). The CC was hammer milled and sieved (Plate 2) so as to obtain particles passing through a B.S. sieve of aperture 3 mm and retained in a sieve of aperture 1.18 mm. The particles retained were re-milled and re-sieved while the particles that pass through the 1.18 mm sieve were discarded.

The volume of CC particles required for the production of 20 panels for the experimental design shown in Table 1 was 70,000 cm³. The processed CC particles were weighed and the weight recorded as initial weight. Thereafter, these particles were

Plate 2. Milled and sieved.

Table 1
Experimental mix.

Composition code	Composition of SD (%)	Composition of CC (%)	Replicates
C1	100	0	4
C2	75	25	4
C3	50	50	4
C4	25	75	4
C5	0	100	4

conditioned in the oven at 60 °C for 24 h to achieve a new equilibrium moisture content of 3% of the initial.

3.2. Preparation of saw dust

The SD was sourced from the dumpsite within the University at a moisture content of 12.54% when analyzed with the aid of AND MX-50 moisture analyzer, room dried for 7 days, oven dried at 60 °C for 24 h till the moisture content reduced to 9.41% and sieved (Plate 3) using B.S. sieves of 3 mm and 1.18 mm apertures to remove oversized and undersized particles, enhance uniformity and improve homogeneous mixing. The volume of CC particles required for the production 20 panels for the experimental mix in Table 1 was 70,000 cm³.

3.3. Production of composite particle board

To produce the composite, the calculated volumes of particles required as shown in Table 2 were measured using a graduated bucket. The different compositions were then batched into black

Plate 1. Mortar crushed CC.

Plate 3. Sieved saw dust CC particles.

Table 2
Batching of composite.

Composition code	Composition for batching SD:CC (%)	V.E.(cm^3)	V.A. (cm^3)
C1	100:0	7000:0	2100
C2	75:25	5250:1750	2100
C3	50:50	3500:3500	2100
C4	25:75	1750:5250	2100
C5	0:100	0:7000	2100

Note: V.E means volume equivalent and V.A. means volume of adhesive used which is 30% of batch volume.

cellophane bags and tightly sealed. These bags were labelled according to their SD:CC compositions.

The measured adhesive volume was poured into the head pan and half of the particles batched in the cellophane were first poured into the head pan and thorough mixing was done with hand after which the remaining particles were emptied into it and mixed until the adhesive was uniformly distributed and a homogeneous mixture obtained (Plate 4). This process was repeated for the batched compositions, C1, C2, C3, C4 and C5 to produce the replicates.

3.4. Casting and pressing operations

The homogeneous mixture obtained was transferred into the moulds filling it to a thickness of 35 mm which is 1.5 times the intended 20 mm panel thickness. A rectangular wooden rod was then used to tamp (Plate 5) the composite in order to remove air voids and also to give a compacted surface. The mould cover was put in place and the mould transported to the hydraulic jack for compression. A metal slab was placed on it before compressing to close the mould to 20 mm which is the desired thickness of the composite slab at room temperature. The mould cover was tied with a metal strip to ensure that the cover remained tightly fixed before removing from the hydraulic jack. The pressure was maintained for 10 min, after which they were transferred into the oven and allowed to dry for 1 h at 80 °C. The moulds were then removed from the oven and allowed to cool for 10 min before the compacting pressure (the cover) was removed and left for 24 h. After 24 h the panels were removed from the mould, returned into the oven to dry for 3 h at 130 °C and allowed to cool slowly in the oven for 30 min before they were removed and placed on a flat surface to cool for 1 h before stacking. In all, 20 panels were cast which were cut into smaller pieces for the various tests (Plate 6).

Plate 4. Hand mixing.

Plate 5. Tamping with rod.

Plate 6. Composite SD and CC particle boards.

3.5. Physical property determination

3.5.1. Density test

Density is a ratio of the mass of each test piece to its volume, both measured at the same moisture content. The tests were carried out based on the BS EN 323 [23].

3.5.2. Water absorption test

The water absorption (WA) test was carried out to determine the amount of water the particleboard can absorb after 2 and 24 h immersion.

3.5.3. Thickness swelling test

This is a dimensional analysis test which was used to determine the change in the thickness of the sample after it has been immersed in water for a given period of time. It was used to determine the effect of water on the thickness of the board by using a digital vernier caliper to measure the changes before and after immersion in water.

3.6. Mechanical property determination

3.6.1. Static bending test

The universal testing machine was used to carry out the tests following the central concentration loading method (Plate 7). From this test, the modulus of rupture (MOR) and modulus of elasticity (MOE) of the specimen were determined. MOR and MOE are measured in N/mm^2. These tests were carried out in accordance with BS EN 310 [24]. Before the test was conducted the test pieces were

Plate 7. Static bending test using UTM.

conditioned as specified in BS EN 310 until the results of two consecutive weighing operations carried out at an interval of 24 h did not vary by more than 0.1% of the test piece mass.

4. Results and discussion

4.1. Physical properties

4.1.1. Density test

The mean density values obtained for 100% SD and CC panels were 436 kg/m^3 and 413 kg/m^3 respectively. While the mean values for various percentage combination of CC and SD panels ranged from 413 kg/m^3 to 486 kg/m^3 as shown in Fig. 1 which are similar to the values obtained by Rose et al., [25] and Idris et al., [26]. It was observed that the panel densities increased as the SD composition reduces until the peak was achieved at C4 with 25% SD after which the value dropped drastically, but there was an observed slight increment in the density as the percentage of CC increases but a sharp drop was observed after the peak was reached at C4 with 75% CC. Therefore, from the data obtained in Fig. 1, CC panels were of lower density compared to the SD panels. The densities obtained are comparable to the particleboard densities of 590 and 800 kg/m^3 of wood product industries. The variation of each mix was also evident from the standard error bars in Fig. 1.

Since the maximum density, 486 kg/m^3 is less than 640 kg/m^3, therefore the manufactured boards can be graded according to ANSI as a low density particleboard, Grade 1 (LD-1) [27].

4.1.2. Water absorption test

After 2 h of immersion in water C2 was observed to have the least value for WA while C5 which is 100% CC had the highest value of wate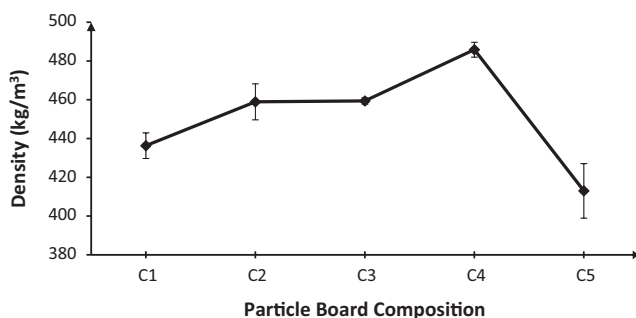r absorption. Similarly, after 24 h of immersion of the specimen in water C2 still had the least value of WA followed by C3, C4, and C1 respectively and C5 had the highest value of WA as shown in Table 3. Therefore, from this test, C2 which is a combination of 75% SD and 25% CC had a better performance when compared with C1 which is 100% SD. C1, C3 and C4 were seen to have similar performances after 24 h of immersion in water. A significant decrease in WA was noticed with the initial 25% replacement of SD with CC, but subsequent increase in CC percentage led to increase in WA as seen in Table 3. The initial decrease in WA can be explained by the increase in the compaction of the panels. SD can be said to possess higher compressibility when compared with CC because when equal pressure is applied to equal volumes of SD and CC contained in different containers, SD was observed to compress more than CC. Therefore when the less compressible CC was added to the more compressible SD less void spaces were present thereby giving less room for the penetration of water.

However, the subsequent increase in WA as a result of increase in CC can be attributed to the fact that the ability of the adhesive to bind the particles reduces as the agricultural residue increases. C5 was observed to flake off easily with the application of little pressure after curing thereby buttressing the fact that the binding ability of the adhesive is least in C5, this also explains the increase in WA with increase in CC. Scatolino et al. [28] also observed similar increase in WA with increase in CC against pinewood after 24 h..

4.1.3. Thickness swelling test

Variation in the thickness of the boards were observed after casting and curing, this variation can be explained by the fact that the moulds used in casting the panels were wooden and did not possess a uniformly flat surface. Furthermore, the variation in thickness as shown in the 0 h column on the thickness swelling table can be attributed to the non-uniform distribution of the compressive load during the compaction process.

From the data obtained from the tests that were carried out as shown in Fig. 2, C2 swells least after 2 h, but after 24 h of immersion in water C3 exhibits the least swelling compared to the other board types.

The thickness swelling difference between 2 and 24 h of water immersion was observed to reduce as the percentage of CC increases. This can be easily spotted in Fig. 2 as the 2 and 24 h line graphs converge as CC increases thereby suggesting that, the higher the CC composition the faster it is for the boards to get saturated with water. For physical properties C3 had the best performance followed by C2, while C5 had the poorest physical property performance.

4.2. Mechanical properties

4.2.1. Static bending

Modulus of rupture (MOR) was seen to increase with the addition of CC up to 75% but decreased afterwards. C4 had the highest value for MOR while C5 had the least value as shown in Fig. 3. Modulus of elasticity (MOE) also showed a similar increase and decrease pattern in values as shown in Fig. 4 where C1 had the least value which was 54.418 N/mm^2 and C4 had the highest value, 82.555 N/mm^2.

Fig. 1. Density of composite particle board.

Table 3
Mean values for water absorption tests.

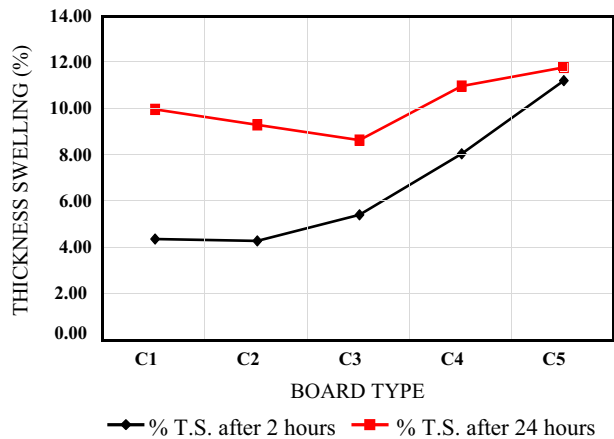| Board type	% WA after 2 h	% WA after 24 h
C1	58.77	121.06
C2	49.85	106.14
C3	57.09	119.34
C4	66.20	120.21
C5	110.20	145.15

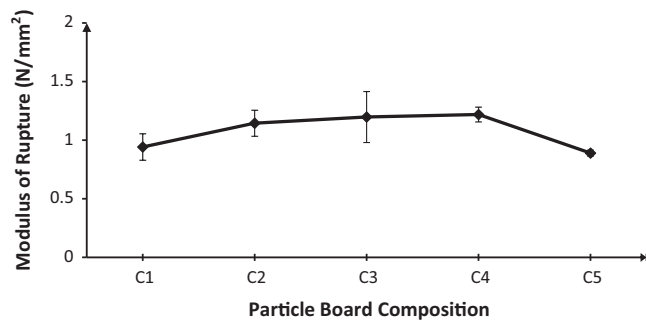Fig. 2. Thickness swelling for different boards.

Fig. 3. Modulus of rupture of composite particle board.
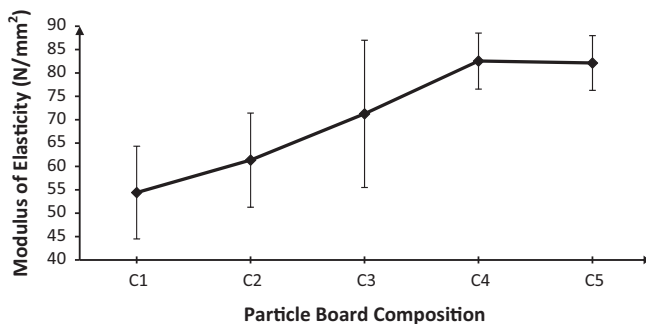

Fig. 4. Modulus of elasticity of composite particle board.

According to BS EN 13353 [29] panels of thickness greater than 20 mm but less than 30 mm were expected to have a minimum density of 420 kg/m^3. C1, C2, C3 and C4 possess densities greater than the minimum requirement, while C5 with a density of 413 kg/m^3 did not meet up to the minimum requirement. However, panels intended for structural purposes that have densities greater than the minimum requirement were also required to have their minimum values for MOR and MOE to be 5 N/mm^2 and 400 N/mm^2 respectively. A similar result was obtained by Lawrence et al. [11]. From the result obtained from the tests which was shown in Figs. 3 and 4, none of the panels produced had values of MOE and MOR that met the minimum requirement. This therefore suggests that the panels cannot be used for structural or load bearing purposes. The low performances in MOE and MOR could be due to the relationship among the bond quantity, particle arrangement and low density of the agricultural residue CC used [28]. The

particles used for the study may be smaller in size compared to those used by other researchers because they were produced from hammer mills [7]. Also, the compaction and curing method could also be responsible for the poor performances of the panels. Sekaluvu, et al. [11] investigated the properties of particleboards made from only CC and obtained mean values of MOE and MOR to range between 5.89 ± 6.00 N/mm^2 to 61.82 ± 10.09 N/mm^2 and 0.32 ± 0.14 N/mm^2 to 1.50 ± 0.16 N/mm^2 respectively which is similar to the results obtained in this research work. Therefore the particleboards produced for this research work can be used as ceiling boards and wall claddings.

5. Conclusion

It has been shown that it is possible to produce particleboards with less sophisticated machines and still obtain reasonable physical properties. From the results obtained, a 25–50% replacement of SD with CC with particle size ranging from 1.18 to 3 mm and equal volume of adhesive exhibited favourable 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 tend to improve as the composition of CC increased from 25% to 75%. 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 75% CC replacement had the highest value for both MOR and MOE but possess poor physical properties. Within the scope and limitations of this research, the panels with 50% CC replacement are the most preferred for their physical and mechanical properties.

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