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Physico-Mechanical Properties of Cement-Bonded Boards Produced from Mixture of Corn Cob Particles and *Gmelina arborea* Sawdust

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Abstract

Cement bonded boards of 10 mm in thickness were produced from the mixture of Gmelina arborea sawdust and corn cob particles. The strength and dimensional stability of cement bonded composites produced from these two mixtures were examined. A total of thirty experimental boards were produced at density level of 1,000 kg/m^3 with cement to fibre ratio of 2.5:1 and 3:1 and five (5) blending proportions of *G. arborea* sawdust to corn cob particles of 100:0; 75:25; 50:50; 25:75 and 100:0. The effect of the cement to fibre ratio and blending proportion on the Water Absorption (WA), Thickness Swelling (TS), Modulus of Rupture (MOR), and Modulus of Elasticity (MOE) were determined. The result indicates that as the mixing ratio of cement to fibre and blending proportion of maize cob (75%) to *G. arborea* (25%) increased, the thickness swelling, water absorption decreased, whereas the MOR and MOE increased. It also shows that most dimensionally stable and flexural strength boards were produced at the highest level of mixing ratios (3:1) and blending proportion of *G. arborea* to corn cob 25:75. However, the analysis of variance shows that TS and WA were significantly different, whereas, MOE and MOR were not significantly affected by mixing ratios and blending proportions. Finding of this study has shown that maize cob particles are suitable for cement bonded board production.

Key Words: cement-bonded boards, physical properties, *G. arborea*, mechanical properties, maize cob

Introduction

Cement bonded particles board (CBPB) are traditionally made of wood fibers cement water usually with small additives of speed up to bonding process in traditional production caused by hydration of cement (Marteinsson and Gudmundsson 2018). The production of these composites has increased dramatically over the past three decades due to a number of factors; the changing wood supply, the development of new composite technologies, and the widespread acceptance by architects and builders of wood composites for use in construction have each contributed to increased production (Gardner et al. 2003).

Furthermore, cement bonded composites (CBCs) are known to be lightweight, low-cost, durable and environmentally friendly products. Badejo (1987) and Mrema (2006) opined that CBPB have been and can be utilized in building construction for interior/exterior wall cladding, partitioning, decking, ceiling, roofing and shuttering. They have also been used for full construction of schools, thea-

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tres, hospitals and residential homes in many countries in North and Central America and Europe (Badejo 1989; Ramirez-Coretti et al. 1998).

Residues from softwood and hardwood are the major source of materials for CBCs production; it comprises about 90% of the board dry weight. The choice of a particular wood for the CBCs depends on the types of particles required for board manufacture, availability of such wood, continuity and sustainability of supply and the cost of such materials. These residues have been found to occur due to usage of old mill equipment, lack of expertise, low capital input, improper processing methods and low log recovery factor. The residues are estimated to be about 1.8 million tons (Ogunbode et al. 2013; Ogunwusi 2014; Oluoti et al. 2014). Often times, these residues litter the environments and are commonly disposed by land filling or open air incineration. Its improper disposal had results in emission of toxic and non-toxic particulates, pollution of inland and ground water due to leaching of chemicals, reduction in water percolation and may also contribute to health hazards (Oluoti et al. 2014; Malik 2015).

Agricultural residues such as the stalks of most cereal crops, rice husks, coconut coir, bagasse, maize cobs, groundnut shells, etc, are cheap and abundantly available in many developing countries such as Nigeria, Philippines, Indonesia, Sri Lanka, and India (Amenaghawon et al. 2013).

Corn cob is obtained after removing the maize seeds from the cob. The corn cob is made up of cellulose and lignin. The abrasive quality of corn cob particles makes them valued for their use as industrial abrasives. Corn cob (Zea may) are mostly used for subside of fuel wood (Fernández et al. 2004). Corn cobs, as well as other biomass resources, have the potential to be transformed into valuable bio-products for industrial and consumer use (Danladi and Patrick 2013).

Due to advancement in technology, there has been further renewed interest in the use of agricultural and industrial wastes. Their use will boost waste utilization, promote a cleaner environment and minimize production cost. It reduces the burning of agricultural wastes to the minimum, thus mitigating climate changes (Savastano et al. 2003; Ghaffer et al. 2020). Many value-added products have been produced from agricultural and industrial wastes (Chu et al. 2015). These have removed many of the negative consequences caused by indecent dumping and burning of wood residues as nuisance. Rana et al. (2019) stated that the utilization of these lignocellulosic materials for making cement-bonded construction materials, will offers an attractive alternative to their disposal and raw material for the industry of CBCs. This can also add a number of suitable features to the CBCs including low-density products, low requirements of processing equipment, negligible abrasion to the processing machinery and abundant raw material availability along with the forest conservation (Rana et al. 2019).

Today, there has been increased demand for wood residues by the wood- based and paper industry and the rapidly growing composites industry; in addition to rising timber prices and diminishing resource quality. As a result, focus moving towards exploring alternatives to solid wood. Utilizing this agricultural residue will go a long way to salvage the environment from the problem of environmental pollution constituted by this agricultural waste disposal and the gases emitted when burnt (Adelusi et al. 2019). This suggests the reason to explore the viable economic use to which these agricultural wastes can be put to aside from being dumped away and burnt off.

It is thus imperative that properties relating to the use of these raw materials for structural applications should be continuously studied for necessary improvement possibilities. Particular attention should be paid to composite boards being made from non-wood and or plantation grown wood species not converted in the Nigerian sawmills. Therefore, this study was carried out to produce CBPB from corn cob particles and *G. arborea* sawdust, determine its physical and mechanical properties with a view of finding supplementary materials for wood in particle board production.

Materials and Methods

Materials collection

The *G. arborea* sawdust was procured from Bodija Plank Market, while the corn cobs was collected from Apata market, Ibadan, Nigeria and milled at MTN Waste Recycling Centre, Aleshinloye market, Ibadan. The Ordinary Portland Cement (OPC) cement was procured from Lafarge Cement Company, Eleyele, Ibadan, Oyo State, Nigeria which conformed to the British Standards Institution (1996) requirements. The water used was cleaned and freed from any visible impurities which conformed to British Standards Institution (1980) requirements.

All the above materials were assembled and processed at the Department of Wood and Paper Technology Laboratory, Federal College of Forestry Ibadan, Oyo State.

Pretreatment of corn cob and sawdust

The process of manufactured begins with the grinding of corn cob (Fig. 1). This was done through grinding machine. In order to have knowledge of the sizes of the particles produced, a sieve analysis was carried out as described in British Standard 812, Part I. This was done by passing the ground particles through 2.0 mm sieve size. The sieve was shaken manually. The particles of sieved maize cob were submerged in a container and half full of water for about 20 minutes to remove dust, sand particles and other foreign products.

After submerging the particles, those which sank to the bottom of the container were rejected. The floating particles were collected for use. The submerging ones were discarded with the believed that it can increase the moisture content of the particles if used. The floated particles were cooked for one hour so as to soften the particles. Also by cooking process, complete mechanical disintegration of the materials was believed to be achieved. This followed the procedure of Zubairu (1989). On completing the cooking process, the whole content of the cooking basin was emptied into sieve and allowed to drain.

The collected sawdust (Fig. 2) was pre-treated in hot water at about 100°C for a soaking period of 1 hour. This was done in an aluminum bath. This pre-treatment was carried out in order to facilitate removal of water soluble sugars and other extractives present in the raw materials which may possibly retard or completely inhibit the setting and curing of the cement. At the end of the soaking period, the hot water was drained off while the saw dust was wash in cold water to remove residual extractives and air dried to a moisture content of 12% of the weight of the sawdust prior to use. It was sieved using a 2 mm standard sieve to have a homogenous material. The sawdust was store in a polythene bag in readiness for board formation.

Preparation of CBPBs

The quantities of the sawdust, corn cob and cement used for the production of the boards were calculated and measure out accordingly to the level of combination in the experiment. The ratio of sawdust and corn cob to the cement was calculated based on the sawdust/cement ratio. Water was made constant at 50 percent of the weight of cement and it was measured out inside measuring cylinder to mix the cement and fiber before board formation.

The required quantity of sawdust, corn cob and the cement were measured and pour inside a plastic bowl. The water was mixed with the contents of plastic bowl and then blended together using hand until a lump-free furnish was obtained.

The cement bonded particleboards (CBPBs) produced were of one layer with the sizes of 350 mm (length) by 350

Fig. 1. Ground maize cob particle.

Fig. 2. Sieved *G. arboreal* sawdust.

mm (width) by 10 mm (thickness). The mixed particles were evenly spread inside the mold of 350 mm×350 mm made with wooden frame. Mould was placed on ply wood plate and cover with polythene sheets to prevent the sticking of the formed boards on the plates. Mixed furnish was spread out on the plate to avoid the concentration of one of the materials in one sectional area of the board than the other. Thereafter, a wooden plate press was used to pre-press the furnish within the mould to reduced the thickness of mat formed in order to enter the cold press freely which was later covered with another polythene sheet, after which plywood plate was placed on it and transferred to the press and cold press under a pressure of 1.23 N/mm^2 for a period of 24 hours. All other boards were produce according to the method stated above.

After the pressed boards have been removed from the press, they were sealed and conditioned inside polythene sheet in the laboratory for 21 days (post-curing process). The boards were trimmed to 10 mm in width from the four sides of the board to remove the edge defects (Fig. 3). Test specimens were cut from the board and kept under laboratory environment after which the test samples were subjected to various tests.

The experiment was subjected to factorial experiment in a Completely Randomized Design. The factors considered were:

Factor A=two (2) mixing ratios of cement to mixed Particles (2.5/1 and 3/1).

Factor B=five (5) blending proportions 100:0, 75:25, 50:50, 25:75, 0:100 (sawdust/maize cob)

Each of the boards were replicated three times making 30 boards altogether.

Board Density is constant at 1,000 g/cm^3

Testing

Physical properties

Water Absorption and Thickness swelling

The board samples were cut into testing specimen 50 mm×50 mm×10 mm dimensions size according to the British Standard 373 (1989) for particle board test and this was done for each board produced. This was carried out by weighing the boards test samples one by one on a sensitive weighing balance and taking the reading of the initial weight (W_1), while thickness swelling was done using veneer caliper and recorded thickness swelling (T_1). They were thereafter soaks in cold water for period of 24h and 48 h at which the final weight (W_2) Thickness swelling (T_2) was taken.

The water Absorption was calculated for each boards by using:

$$WA\ (\%)=\frac{W_2-W_1}{W_1}\times 100 \qquad (1)$$

Where WA = water absorption (%)

W_1=initial weight (g)

W_2=final weight (g)

The Thickness Swelling was calculated for each board by using:

$$TS\ (\%)=\frac{T_2-T_1}{T_1}\times 100 \qquad (2)$$

Where:

TS=Thickness swelling (%)

Fig. 3. CBBs produced.

Fig. 4. Board samples for MOE and MOR test.

T_2=Final thickness after treatment (mm)
T_1=Initial thickness before treatment (mm)

Mechanical properties

Modulus of Rupture (MOR)

Test samples were cut into dimension 195×50×6 mm (Fig. 4). This was carried out using Universal Testing machine (UTM) at the Department of Forest Products Development and Utilization (FPD&U), Forestry Research Institute of Nigeria, Ibadan, Oyo State. The test specimens were mounted one by one on the machine and load was applied at the center of the testing sample with the aid of an electro-mechanical motor till the point where failure occurs. The recording of the ultimate failure load (P) was estimated.

The Modulus of Rupture was calculated using:

$$MOR=\frac{3\rho L}{2bh^2} \quad (3)$$

Where;

MOR= Modulus of Rupture
ρ= Failing load
L= Span between centers of support (mm).
b= Width of test specimen (mm).
d= mean thickness of the specimen (mm).

While the panel's stiffness (MOE) was determined from the bending test performed on each specimen and calculated using the formula;

$$MOE\ (N/mm^2)=\frac{\rho L^3}{4bd^3H} \quad (4)$$

Where;

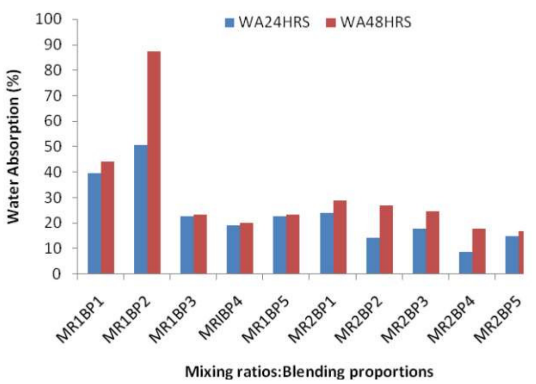

Fig. 5. Mean values of WA of the board with respect to mixing ratios and blending proportions.

MOE= Modulus of elasticity of panel stiffness
L=Span between centers of support (mm)
b=Mean thickness of the specimen (mm)
H=Increment in deflection (mm)

Data analysis

The data obtained from the experiment was analyzed and subjected to Analysis of Variance to estimate the relative importance of various sources of variation on MOE, MOR, WA, and TS. The follow- up test (Duncan Multiple Range Test) was conducted at 0.05 level of test.

Results and Discussion

Physical properties

Water absorption (WA)

From the results obtained in Fig. 5 for Water absorption (WA) properties, water resistance was lowest in boards made from 100% *G. arborea* sawdust without maize cob particles (Fig. 5) in the mixing ratio of cement to fibre (3/1) while water resistance was highest when maize cob particle was 75% of the weight (19.06% and 8.89%) of the volume of the boards in sawdust/ cob ratio 25 to 75 at cement to lingo-cellulosic material 2.5/1 and 3/1 respectively. According to the result obtained from this study, water resistance was highest in boards made from mixture of *G. arborea* and corn cob of blending proportion 25:75 and mixing ratios of cement to lignocellulosic material 2.5/1 and 3/1 after 24 hours and 48 hours respectively while it was lowest in sawdust: corn cob blending proportion 50:50 at cement to ligno-cellulosic material ratios 2.5:1 and 3:1 respectively after 24 and 48 hours cold water immersion (Fig. 5). It was also noticed that there is a general decrease in WA as corn cob inclusion levels increases.

The decrease in the WA could be attributed to the facts that as the corn cob particles contents increased (Table 1), many void spaces are filled and this assist in the possibility of getting a thorough and homogenous mix of the cement bonded board. This phenomenon can also be attributed to compatibility between the two fiber used in this study which brought about good bond formation, less void spaces and reduction in the rate of water absorption.

Frybort et al. (2008) and Falemara and Ajayi (2018) also attributed this low water absorption condition to improved

Table 1. Materials composition ratio used for CBBs formation

Density (g/m^3)	Mixing ratios (cement/fiber)	Blending proportion *G. arborea*/sawdust	Mass of cement (g)	Mass of fiber (g)	
				G. arborea	Corn cob
1,000	2.5/1	100/1	803.57	321.43	0
		75/25	803.57	241.07	80.36
		50/50	803.57	160.72	160.72
		25/75	803.57	80.36	241.07
		0/100	803.57	321.43	321.43
1,000	3/1	100/1	843.75	281.25	0
		75/25	843.75	210.94	70.31
		50/50	843.75	140.63	140.63
		25/75	843.75	70.31	210.94
		0/100	843.75	0	281.25

Table 2. Analysis of variance for the WA property of cement bonded board produced from *G. arborea* sawdust and corn cob particles

SV	SS	DF	MS	F
MR	878.45	1	878.45	23.76*
BP	489.78	4	122.45	3.31^{ns}
MR*BP	788.04	4	197.01	5.33*
Error	1478.61	20	73.93	
Total	5784.58	29		

*, significant (p<0.05%); ns, not significant (p>0.05%).

Table 3. Result of the DMRT on the effect of blending proportion on WA and TS of cement bonded board produced from *G. arborea* and corn cob

Blending proportion	Water absorption	Thickness swelling
25:75	16.48^a	2.15^a
50:50	20.34^{ab}	2.51^a
:25	20.92^{ab}	3.35^{ab}
0:100	24.45^b	4.94^b
100:0	25.38^b	7.24^c

Mean follow by the same letter in the same column are not significantly different at 5% probability level.

inter and intra particle bonding with cement and due to smoother board surfaces which perhaps have hindered absorption of water and increase the boards level of resistance to water penetration. The boards with mixing ratio 2.5/1 (cement to fiber) were detected to be more porous and absorbed more water, as this could be attributed to void spaces created by small quantity of cement available to bind the fiber (Falemara and Ajayi 2018; Adelusi et al. 2019).

There is a decrease in WA as corn cob particle inclusion levels increased. This was similar to some of the observations recorded by Papadopoulos et al. (2002). They suggested that a combination of coconut chips with industrial wood chips may be explored in order to improve the WA properties of the particleboards. WA was lowest in boards formed from cement and sawdust alone in a ratio of 2.5/1 and 3/1 respectively (weight: weight). This pattern of WA variations is in conformity with the observations of Del Meneéis et al. (2007), Erakhrumen et al. (2008), and Adelusi et al. (2019).

The result of ANOVA conducted on WA of the cement bonded boards produced is presented in Table 2. The effects of mixing ratios level and the two way interactions between the mixing ratios and blending proportion were significantly different on water absorption after 24 and 48 hours cold water immersion at 5% probability level, which implies that as the mixing ratio increases, moisture resistance of the boards were enhanced whereas the blending proportion is not significant.

The Duncan Multiple Range Test (DMRT) result in Table 3 shows that there is significant difference between the blending proportions 25:75, 0:100 and 100:0, whereas, between mixing ratio levels 50:50, 75:25, 0:100 and 100:0, there is no significance difference.

Thickness swelling (TS)

Fig. 6 shows the thickness swelling (TS) after 24 and 48 hours cold water immersion. The mean values obtained for TS after 24 hours water immersion ranged from1.97% to 11.55%, while that of 48 hours immersion ranged from 4.11% to 14.69 at mixing ratio 2:1. Whereas, for mixing ratio 3:1, the values ranged from 0.30% to 1.15% and 1.20% to 1.93% at both 24 and 48 hours cold water immersion respectively. The results shows that increase in mixing ratio level of cement to fiber (2.5/1 to 3/1) and blending proportion (*G. arborea*: corn cob) caused a reduction in thickness swelling.

The result also shows that increasing blending proportion of corn cob fiber to that of *G. arborea* and the cement/fiber mixing ratio caused decrease in TS properties (Table 1). The lowest values were obtained from the boards produced at 25:75 (*G. arborea*: corn cob) and 3:1 cement/fiber ratio (Fig. 6). Because of this, more dimensionally stable boards were produced at these levels as they showed relatively better performance of TS of the manufactured boards. Generally, board with high resistance to water intake and thickness increase was produced at the highest proportion of corn cob (75%) to *G. arborea* (25%) and cement/fiber ratio of 3:1 as the board exhibited less spring back tendency and lowest thickness swelling during cold water immersion.

This result conform with the findings of Sotannde et al. (2012), and Owoyemi et al. (2018), in which they clearly stated that increase in cement content caused reduction in TS value recorded due to sufficient encapsulation of fibers, thus, less irregular void spaces in the board and the fiber particles. This is also in agreement with Babatunde (2008) that the lower the TS means more cement coating on the fibers may have restricted the boards from swelling.

Wood composite material has shown to absorb variable amount of moisture that can cause dimensional changes (Deppe and Ernst 1996; Klyosov 2007). Further study by Marinho et al. (2013) recorded higher TS with respect to higher WA. Therefore, water absorption is expected to result in dimensional changes such as its TS (Olaoye et al. 2019). The thickness swelling recorded in this study thus decrease with respect to the WA of the board when blended with more of corn cob particles.

The result of ANOVA conducted on TS of the cement bonded boards produced is presented in Table 4. The effects of mixing ratio levels, blending proportions and the two way interactions between the mixing ratios and blending proportion were significantly different on water absorption at 5% probability level, which implies that as the mixing ratio of cement to fiber contents and blending proportion of maize cob particle increases, moisture resistance of the boards were enhanced, thus aids the board stability.

Mechanical properties

Modulus of elasticity

The mean values obtained for Modulus of Elasticity (MOE) is presented on Fig. 7. The MOE mean values ranged from 6804.88 N/mm^2-14,617.35 N/mm^2 and 10,797.18 N/mm^2-21,285.50 N/mm^2 for mixing ratios 2.5:1 and 3:1 respectively. The result shows that increase in mixing ratio of cement/ fibre (2.5:1 to 3:1) caused an increase in elasticity of the board produced.

As shown in Table 1, cement bonded board substituted

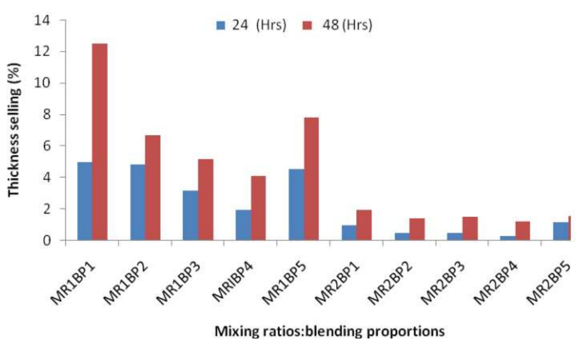

Fig. 6. Mean values of TS of the board with respect to mixing ratios and blending proportions.

Table 4. Analysis of variance for the thickness swelling (TS) property of CBBs produced from *G. arborea* sawdust and corn cob particles

SV	SS	DF	MS	F
MR	514.86	1	514.86	70.05*
BP	208.75	4	52.19	7.1*
MR*BP	183.92	4	45.98	6.26*
Error	293.98	20	14.7	
Total	1,327.19	29		

*, significant ($p<0.05\%$).

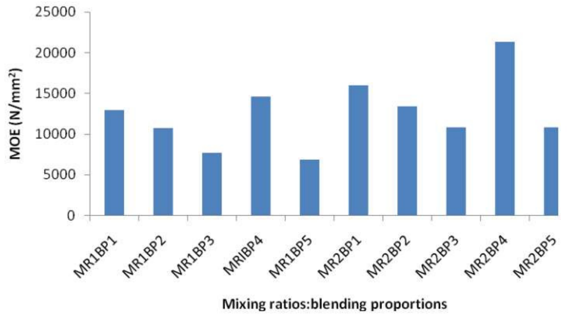

Fig. 7. Mean values of MOE of the board with respect to mixing ratios and blending proportions.

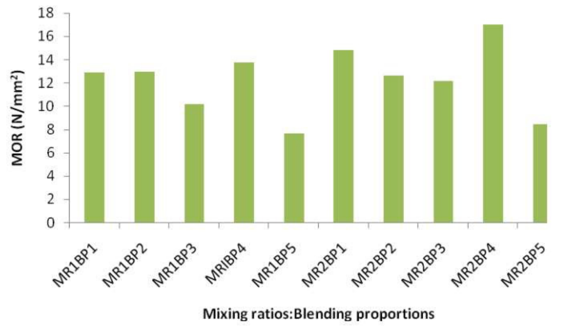

Fig. 8. Mean values of MOR of the board with respect to mixing ratios and blending proportions.

Table 5. Analysis of variance for the modulus of elasticity (MOE) property of cement bonded board produced from *G. arborea* sawdust and corn cob particles

SV	SS	DF	MS	F
MR	113060643.4	1	113060643.4	5.05^{ns}
BP	101960568	4	25490142.01	1.14^{ns}
MR*BP	261510011.9	4	65377502.98	2.92*
Error	447395976.1	20	22369798.8	
Total	923927199.5	29		

*, significant at 5% probability level ($p \leq 0.05$); ns, not significant.

with 75% corn cob particles recorded the highest significant MOE (21,285.50 N/mm^2) while the 100% maize cob substitution had the least MOE (6,804.88 N/mm^2 and 10,797.18 N/mm^2) at both mixing ratios respectively (Fig. 7). What this suggests is that incorporation of corn cob particles in the composite mix enables better interfacial bonding and enhanced the flexural properties more than those of pure wood particles.

The values obtained for MOE for cement to ligno-cellulosic material mixing ratio 3/1 was slightly higher than that for mixing ratio 2.5:1 and increased substantially to the highest values with the inclusion of corn cob component in both mixing ratio by weight of sawdust to corn cob particles respectively. Subsequent increase of the corn cob component and reduction of *G. arborea* sawdust (Table 1) with increase in quantity of cement in the mixing ratios gave an inconsistent but increase in MOE values (Fig. 7).

Modulus of Elasticity has been described as the ability of a material to regain its original shape and size after being stressed (Panshin 1980). The increase in the values of MOE obtained in this study could be attributed to higher quantity of cement component to fiber (3:1) in the mixing ratios which is in contrast with similar studies on cement-reinforced ligno-cellulosic composites made from *Pinus carribaea* and *Cocos nucifera* by Erakhrumen et al. (2008). From this experiment, it clearly shows that the higher the mixing ratios of cement and percentage of corn cob particles in the boards, the more the resistance of the boards to stress, stiffness and actual breaking strength points of the composite boards.

The results of analysis of variance (ANOVA) presented in Table 5 shows that the mixing ratio and blending proportions were not significantly different, whereas, the two factors interaction was significantly different at 5% probability level. This implies that individual processing factors (blending proportions and mixing ratio levels) does not have significant effect on the strength properties of the boards produced, but their combinations influence greatly on the property examined.

Modulus of rupture

The mean values obtained for Modulus of Rupture (MOR) is tabulated in Fig. 8. The MOR mean values ranged from 7.64 N/mm^2-13.73 N/mm^2 and 8.42 N/mm^2-17.00 N/mm^2 for mixing ratios 2.5:1 and 3:1 respectively. The result shows that increase in mixing ratio of cement to fiber (2.5:1 to 3:1) caused an increase in rupture point of the board produced (Fig. 8). The results also shows that blending proportion (BP) and cement/fiber mixing ratio are related to the MOR values as it was directly influenced by each level of combination. As the con-

Table 6. Analysis of variance for the modulus of rupture (MOR) property of CBBs produced from *G. arborea* sawdust and corn cob particles

SV	SS	DF	MS	F
MR	17.77	1	17.77	1.88^{ns}
BP	67.19	4	16.8	1.78^{ns}
MR*BP	133.3	4	33.33	3.53*
Error	188.62	20	9.43	
Total	406.88	29		

*, significant at 5% probability level ($p \leq 0.05$); ns, not significant.

tents of corn cob increases in blending proportion to *G. arborea* sawdust with more of cement to fiber contents (mixing ratio), there was an increase in MOR values as shown in Fig. 8. Result further revealed that strong experimental boards were produced at the highest levels of BP of corn cob (75%) to *G. arborea* (25%) and cement/wood mixing ratio 3:1.

The influence of BP becomes increasingly significant as the proportion of corn cob and that of cement increased. Greater compaction of boards was achieved as a result of increased number of bonds, inter particles contact areas and adequate encasing of the particles with cement. This study confirms the work of Ajayi (2006), stating that greater bonding quality and cohesive strength inherent in the boards manufactured from high cement/fiber ratio and high blending proportion of materials accounts for the flexural strength observed in such boards.

However, the data of MOR and MOE obtained in this study satisfies the specified property most especially with a BP of 25:75 and at the two mixing ratios respectively for cement bonded sawdust particleboard production. The results obtained for the MOR of the panels in this study were significantly higher than the European standard (>9 N/mm^2) even at the density range from 1,200 to 1,300 kg/ as stated by CEN (1996).

The result of Analysis of Variance is presented in Table 6 shows that the mixing ratio, blending proportions were not significantly different, whereas, the interactions of the two factors are significantly different at 5% probability level. This implies that individual processing factors (blending proportions and mixing ratio levels) does not have significant effect on the strength properties of the boards produced, but their combinations greatly influence the property examined.

Conclusion

Cement-bonded board were successfully produced from *G. arborea* and maize cob particle with mixing ratio cement/fiber (2.5:1 and 3:1) and with board density at 1,000 kg/m^3. Maize cob residues inclusion positively affected both physical and mechanical properties of the cement bonded boards produced. The board produced with blending proportion 25:75 (*G. arborea*: maize cob) and mixing ratio of 3:1 has the lowest thickness swelling and water absorption after 24 and 48 hours cold water immersion. Lower mixing ratio of cement: wood have poor performance in water resistance. The dimensional stability of the boards improved as the mixing ratio of cement to fiber and blending proportion of maize cob to *G. arborea* increases. The use of cement and blending of *G. arborea* with maize cob manifested in the production of stronger, stiffer and more dimensionally stable CBBs.

Inclusion of more maize cob particles in this research work has greatly help in resisting water incursion into the board and improved mechanical properties of the boards. Also, this research work is an eye opener to further investigation of efficient utilization of maize cob and sawdust that has been hitherto lying as waste.

Thus, utilizing these wood and agricultural residues will go a long way to reduce environmental degradation and pollution caused during the indiscriminate disposal and burning of maize cob and sawdust, and eventually create a clean environment.

References

Adelusi EA, Adedokun SA, Adelusi FT. 2019. Dimensional Stability of Cement Bonded Boards Produced from *Thaumatococus danielli Stalk*. J Mater Sci Res Rev 4: 1-7.

Adelusi EA, Olaoye KO, Olaoye FG. 2019. Strength and Dimensional Stability of Cement-bonded Boards Manufactured from Mixture of *Ceiba pentandra* and *Gmelina arborea* Sawdust. J Eng Res Rep 8: 1-10.

Ajayi B. 2006. Properties of maize-stalk-based cement-bonded composites. For Prod J 56: 51-55.

Amenaghawon NA, Osayuki-Aguebor W. Okieimen CO. 2016.

Production of Particle Boards from Corn cobs and Cassava stalks: Optimisation of Mechanical Properties Using Response Surface Methodology. J Mater Environ Sci 7: 1236-1244.

Babatunde A, Olufemi B, Fuwape J, Badejo S. 2008. Effect of wood density on bending strength and dimensional movement of flakeboards from *Gmelina arborea Leucaena leucocephala*. In: 11th International Inorganic-Bonded Fiber Composites Conference; Madrid, Spain; Nov 5-7, 2008. pp 230-236.

Badejo SOO. 1987. An investigation on the influence of cement binder content on properties of cement-bonded particle board from four tropical hardwoods. Malays For 50: 107-120.

Badejo SOO. 1989. Influences of pre-treatment temperature and additive concentration on the properties of cement-bonded particleboard from plantation-grown tropical hardwoods. Trop Sci 29: 285-296.

British Standards Institution. 1980. Methods of Test for Water for Making Concrete (Including Notes on the Suitability of the Water). British Standards Institution, London.

British Standards Institution. 1996. Specification for Portland Cement. British Standards Institution, London.

CEN. 1996. Cement-Bonded Particleboards-Specifications- Part 2: Requirements for OPC Bonded Particleboards for Use in Dry, Humid and Exterior Conditions. Swedish Institute for Standards, Stockholm.

Chu TV, Phuong LX. 2015. Effect of Rice Straw Steaming Time and Mixing Ratio between Acacia mangium Willd Wood and Steamed Rice Straw on the Properties of the Mixed Particleboard. J For Environ Sci 31: 119-125.

Danladi A, Patrick IO. 2013. Mechanical Properties of Particle Boards from Maize Cob and Urea-Formaldehyde Resin. Int J Mater Metall Eng 7: 751-753.

Del Menezzi CHS, de Castro VG, de Souza MR. 2007. Production and Properties of a Medium Density Wood-Cement Boards Produced with Oriented Strands and Silica Fume. Maderas Cienc Tecnol 9: 105-115.

Deppe HJ, Ernst K. 1986. Reducing Particleboard Pressing Time. An Exploratory Study. US Dept. of Agriculture Forest Service, Madison, WI, pp 3-14.

Erakhrumen AA, Areghan SE, Ogunleye MB, Larinde SL, Odeyale OO. 2008. Selected physico-mechanical properties of cement-bonded particleboard made from pine (*Pinus caribaea* M.) sawdust-coir (*Cocos nucifera* L.) mixture. Sci Res Essays 3: 197-203.

Falemara BC, Ajayi B. 2018. Effects of additive levels on dimensional stability and strength of cement composite before and after accelerated aging procedure. In: 16th International Inorganic-Bonded Fiber Composite Conference (IIBCC 2018); Cape Town, South Africa; Oct 23-26, 2018. pp 213-224.

Fernández Bertos M, Simons SJ, Hills CD, Carey PJ. 2004. A review of accelerated carbonation technology in the treatment of cement-based materials and sequestration of CO2. J Hazard Mater 112: 193-205.

Frybort S, Mauritz R, Teischinger A, Müller U. 2008. Cement Bonded Composites- A Mechanical Review. Bioresources 3: 602-626.

Gardner DJ, Tascioglu C, Wålinder ME. 2003. Wood composite protection. In: Wood Deterioration and Preservation: Advances in Our Changing World (Goodell B, Nicholas DD, Schultz TP, eds). American Chemical Society, Washington, pp 399-419.

Ghaffar SH, Burman M, Braimah N. 2020. Pathways to circular construction: an integrated management of construction and demolition waste for resource recovery. J Clean Prod 244: 118710.

Klyosov AA. 2007. Wood-Plastic Composites. Wiley-Interscience, Hoboken, NJ, 729 pp.

Malik KR. 2015. Use of waste plastic in concrete mixture as aggregate replacement. Int J Eng Educ Technol 3: 1-8.

Marinho NP, Nascimento EM, Nisgoski S, de Domenico Valarelli I. 2013. Some Physical and Mechanical Properties of Medium-Density Fiberboard Made from Giant Bamboo. Mater Res 16: 1387-1392.

Marteinsson B, Gudmundsson E. 2018. Cement Bonded Particle Boards with Different Types of Natural Fibres- Using Carbon Dioxide Injection for Increased Initial Bonding. Open J Compos Mater 8: 28-42.

Mrema AL. 2006. Cement bonded wood wool boards from podocarpus spp. for low cost housing. J Civ Eng Res Pract 3: 51-64.

Ogunbode EB, Fabunmi FO, Ibrahim SM, Jimoh IO, Idowu OO. 2013. Management of Sawmill Wastes in Nigeria: Case Study of Minna, Niger State. Greener J Sci Eng Technol Res 3: 34-41.

Ogunwusi AA. 2014. Wood Waste Generation in the Forest Industry in Nigeria and Prospects for Its Industrial Utilization. Civ Environ Res 6: 62-69.

Olaoye KO, Abiola JK, Adelusi EA, Adebawo FG. 2019. Selected Physical and Mechanical Properties of Medium Density Fibreboard Composite Produced from Waste Paper and Sawdust. J Mater Sci Res Rev 4: 1-10.

Oluoti K, Megwai G, Pettersson A, Richards T. 2014. Nigerian Wood Waste: A Dependable and Renewable Fuel Option for Power Production. World J Eng Technol 2: 234-248.

Owoyemi JM, Ajayi B, Oyeleye IO. 2018. Effect of production variables on the properties of cement bonded flake board from *Polyalthia longifolia* (Sonn.)Thw. Wood. In: 16th International Inorganic-Bonded Fiber Composite Conference (IIBCC 2018); Cape Town, South Africa; Oct 23-26, 2018. pp 203-212.

Panshin AJ, De Zeeuw C. 1980. Textbook of Wood Technology. 4th ed. McGraw-Hill, New York, NY, 704 pp.

Papadopoulos A, Traboulay E, Hill C. 2002. One layer experimental particleboard from coconut chips- (*Cocos nucifera* L.). Eur J Wood Wood Prod 60: 394-396.

Ramirez-Coretti A, Eckelman CA, Wolfe RW. 1998. Inorganic-bonded composite wood panel systems for low-cost housing: a Central American perspective. For Prod J 48: 62-68.

Rana MN, Islam MN, Nath SK, Das AK, Ashaduzzaman M, Shams MI. 2019. Properties of low-density cement-bonded composite panels manufactured from polystyrene and jute stick particles. J Wood Sci 65: 1-10.

Savastano H Jr, Warden PG, Coutts RSP. 2003. Potential of alternative fibre cements as building materials for developing areas. Cem Concr Compos 25: 585-592.

Sotannde OA, Oluwadare AO, Ogedoh O, Adeogun PF. 2012. Evaluation of cement- bonded particle board produced from *Afzelia africana* wood residues. J Eng Sci Technol 7: 732-743.

Zubairu IK. 1989. The suitability of maize cobs for the production of particle board. PhD thesis. Ahmadu Bello University, Zaria, Nigeria. (in English)