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Strength evaluation of agro waste particle board with melted pure water sachet as the binding agent

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Abstract. Particle board is a construction material that can be used either for construction form works or house furniture, roofing or insulating materials. Due to its usefulness, this research work is aimed at evaluating the mechanical strength and rheological properties of particle board using agro waste namely corncob (CC) and sawdust(SD) with melted pure water sachet as the binding agent. The use of the pure water sachet or low density polyethylene (LDPE) as the binder was also evaluated, by the use of dual purpose kerosene (DPK) to form the homogenous binder that was used to produce the board. The proportion of LDPE to DPK was 50g to 300ml. Three ratio of the LDPE to sawdust and corncob were used; 2:1, 1½: 1, and 1: 1 in which the ratio of CC to SD was interchanged in proportion of 25%:75%, 50%: 50% and 75%: 25% to make 100% aggregate or combination. The production of the particle board was then made with a dimension of 350mm x 350mm x 10mm. The rheological properties of the binder show that it has adequate viscosity, binding power and strength compatible with the sawdust and the corncob. The results from the physical and mechanical property such as density, water absorption (WA), thickness swelling (TS), modulus of rupture (MR) and the modulus of elasticity (ME) concluded that the particle board type 1:1 had favorable physical properties that are recommended for indoor uses in building.

Keywords: Particle board, low density polyethylene (LDPE), dual purpose kerosene (DPK), corncob (CC) and sawdust (SD)

1. Introduction

Wood is one of the major construction materials in the world that can be used in so many ways during and after construction. Particle board is the non-specific term for a board produced from lignocellulosic materials (normally wood), fundamentally as discrete pieces or particles, as recognized from strands, consolidated with an engineered resin or other appropriate adhesive[1]. Wasted wood materials may be converted into useful products by producing particle boards, thereby conserving our natural resources[2,3]. Present commercial products of comminuted wood have some very desirable characteristics: availability in large sheets, smooth surfaces, uniformity in properties from sheet to sheet, and freedom from localized defects. The first particle boards were made up from wood related materials which were of wood scraps, shavings, sawdust, and off cuts, all glued together using a specialist resin[4–7]. Before the pieces were glued together, they would be smashed and pounded in order to create small enough pieces that would pass through a specific size wire mesh of 1 mm. In recent times, the thought for a little bit of refinement to improve the properties of the particle board and this was done by making a uniform sized chip, made from processing woods such as birch, larch, pine, and spruce. With the refinement, the particle board produced had better overall strength and required less resin to bind the



whole lot together and better appearance of the board was achieved. Today's particle boards are formed by using compression and temperature to make a much harder consistency.

Agricultural waste product like sawdust and corncob has been alternatively used in the production of building material like particle board due to the damaging and continuous exploration of natural resources. The corncob been a lignocelluloses material can be used in the production of particle board which helps in the recycling of agricultural waste and which in return is capable of providing the particle board with high mechanical strength and a pre-established specific weight [3,8]. The application of sawdust as a material in the production of particle board gives rise to its density (compaction ratio), strength and stiffness [2,9,10]. The enormous discharge of this sachet in the street and public places is leaving the street to land pollution and this trigger the use as binder in this study. This study tries to produce a particle board from corncob and sawdust using melted pure water sachet as binder.

2. Materials and methods

The materials used are sawdust, corncob, pure water sachet, grease and Kerosene or Dual Purpose Kerosene (DPK)

2.1 Materials preparation

The required Corn cob (CC) was room dried for about 3-5 days. The CC was manually crushed into smaller sizes and was treated with water of about 85°C to remove undesirable water soluble chemical substances like phenolic compounds which may interfere with the mixture of the melted pure water sachet used as binder for the board formation. The CC was then milled with the aid of a grinding machine and sieved to obtain particles passing through a British standard sieve of aperture size 3mm and retained in 1.18mm. After the collection of the Sawdust (SD), it was room dried for 3-5 days in order to reduce initial moisture content of 12%. Pure water sachet also known as low density polyethylene (LDPE) was collected within the university community. The LDPE bags were washed thoroughly to remove dirt and debris that may stand as impurities. It was then sundried for 3-5 days in order to remove retained moisture on the sachet. After drying, the sachets were cut into smaller pieces then measured accordingly.

2.2 Production of binder

In order to make a good and effective binder, priority was given to the required viscosity-grade for the anticipated product. This determines the amount of solvent (DPK) that will be used, for complete melting of the solute(LPDE) which was a variable of N-LDPE to Dissolving agent (DPK) proportion- 50g to 300ml was used. The main essence of the DPK is for the achievement of a good binding effect, it is crucial that LDPE solid liquefies having more kinetic energy to translate, rotate and having a desirable molten state and this can only be achieved with the aid of an organic non polar solvent under heat. 300ml of DPK was measured in a volumetric cylinder and 50.0g of the cut tiny bit of the LDPE was added and heated at 101 to 116 °C which was measured with the use of a thermometer for 20 to 40 min until the complete molten state of the mixture was attained. For the board size adopted for this study in terms of length x breadth x thickness of 350mm x 350mm x 10mm, the set value of solute and solvent was determined by the amount of LDPE required for a particular amount of CC and SD for a particular size of particle board to be produced. Thereafter, the mixture of the LPDE and DPK was heated together until a homogenous molten compound was formed.

3. Experimental procedure

3.1 Production of composite

In order to produce the composite (particle board), the calculated volume (according to experimental design in Table 1) of the CC and SD particles required was measured using a graduated bucket before the LPDE was heated. The SD and CC was oven dried for maximum 24 hours due to moisture content rate. The different compositions were then being measured by grams and then kept in black cellophane bags to avoid moisture absorption. After arriving at the appropriate amounts of the materials required, the binder was formed by measuring separately, the amount of LDPE and DPK. In each case the mixture of LDPE

and DPK was heated together until homogenous molten state of the binder was formed. The appropriate amount of the two composite was then added immediately into the binder when it was still under heating and then thoroughly mixed until they are blended together as shown in Plate 1.

Table 1. Experimental design of particle boards

Board Type	% Composition of saw dust(SD)	% Composition of Corncob(CC)	Pure water sachet (LDPE)	Kerosene(DPK) (ml)
ASD ₂₅ CC ₇₅	25	75	700	4200
ASD ₅₀ CC ₅₀	50	50	700	4200
ASD ₇₅ CC ₂₅	75	25	700	4200
BSD ₂₅ CC ₇₅	25	75	525	3150
BSD ₅₀ CC ₅₀	50	50	525	3150
BSD ₇₅ CC ₂₅	75	25	525	3150
ESD ₂₅ CC ₇₅	25	75	350	2100
ESD ₅₀ CC ₅₀	50	50	350	2100
ESD ₇₅ CC ₂₅	75	25	350	2100

SD-Sawdust, CC-Corncob, LDPE to Sawdust Mixing Ratio A- 2:1, Ratio B - 1¹/₂:1, Ratio E – 1:1

After cleaning the mold with aid of a soft haired brush in order to remove dirt and grease with oil to ensure easy removal of the particle board, the composite mixture was quickly transferred into the metal molds filling it to the top or brim of the panel and evenly spread on it while the top cover was placed as shown in Plate 2.

Constant factors

1. Board thickness-10mm
2. Pressing pressure-**1.230N/mm²**
3. LDPE to dissolving agent (DPK) proportion-50g to 300ml
4. LDPE to sawdust mixing ratio– Ratio A(**1: 1**), Ratio B(1¹/₂: 1), and Ratio E(2: 1)
5. Sawdust and corncob volume for each level-350g

3.2 Pressing operations

After the top cover plate which has 4mm thickness was placed on the constituent in the molds, still in a semisolid form, the mold was transferred quickly to the hydraulic jack for compression. The pressure was maintained until the mixture becomes fairly cold before stacking took place (the process took place under 10-15min to ensure everything could be done when it was still in its semi solid form). Thereafter it was demolded and left in air as shown in plate 3.



Plate 1: Composite of sawdust and corncob been mixed



Plate 2: Composite mixture filled in the mold



Plate 3: Particle Board after demolding

4. Testing of particle board properties

The tests for the particle board are divided into two segments which is the physical properties test (Density Test, Water Absorption Test and Thickness Swelling Test) and the mechanical properties test (Static Bending Test (modulus of rupture (MOR) and modulus of elasticity (MOE)).

4.1 Physical Properties Tests

4.1.1 Density Test.

Density test was carried out on the particle board to determine the mean density for each produced board. The mean density values obtained for the 9 boards produced in the three (3) different ratios are shown in Table 2 and Figure 1. The board density obtained ranges from 491kg/m^3 to 729kg/m^3 . For all the three ratios A (2:1), B ($1\frac{1}{2}$:1) and C (1:1), boards with higher sawdust content has the highest density. The densities that were obtained are comparable to the particle board densities of 590kg/m^3 and 800kg/m^3 of wood product industries. According to the American National standard particle board [11] which

categorized board with densities lesser than 640kg/m^3 as low density particle board, three of the boards can be said to be a high density particleboard while the ones below the ANSI standard can be regarded as a low density particleboard.

Table 2. Density result of the particle board produced

Board Type	Density (Kg/m^3)
ASD ₂₅ CC ₇₅	501
ASD ₅₀ CC ₅₀	537
ASD ₇₅ CC ₂₅	577
BSD ₂₅ CC ₇₅	659
BSD ₅₀ CC ₅₀	491
BSD ₇₅ CC ₂₅	688
ESD ₂₅ CC ₇₅	502
ESD ₅₀ CC ₅₀	605
ESD ₇₅ CC ₂₅	729

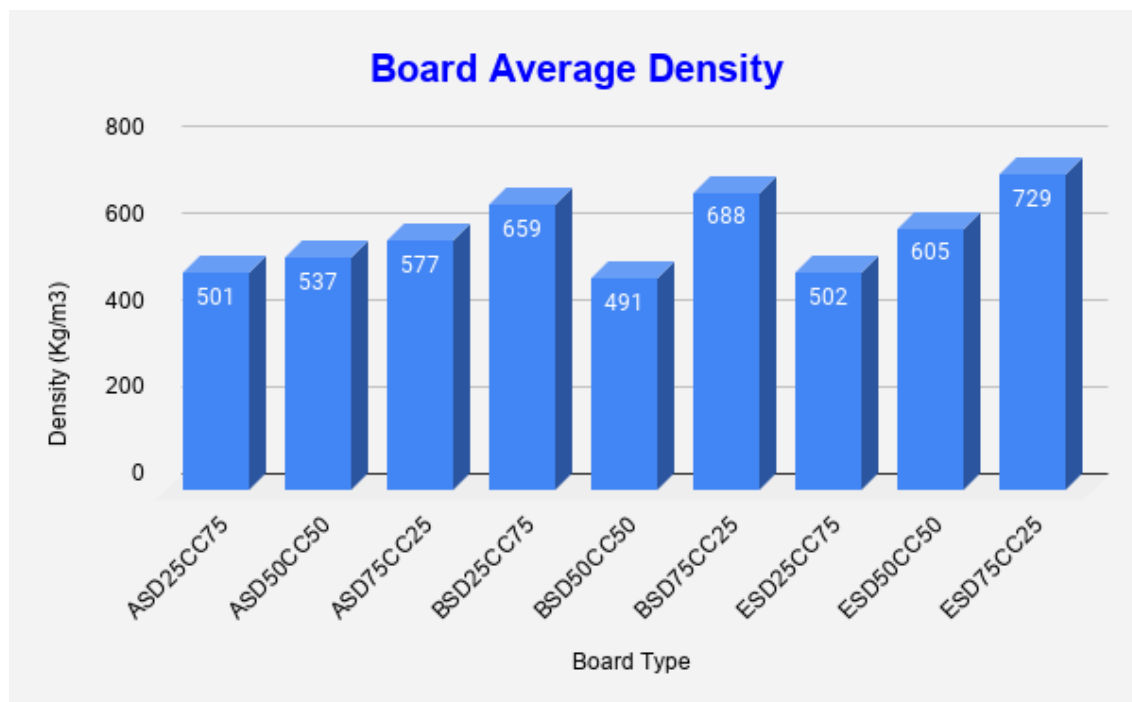


Figure 1: Board Average Density

4.1.2 Water absorption test.

The water absorption (WA) test was done to investigate the amount of moisture that could be retained in the particle board with varying composition of SD and CC and considering the binder that was used. The result of the nine (9) particle boards produced with different ratio after immersion in water for 2 hours and

24 hours at room temperature is presented in figure 2. After 2 hours of immersion, it was observed that ratio 2:1 board sample ASD₇₅CC₂₅ has a least value for the WA while ratio 1:1 board sample ESD₅₀CC₅₀ has the highest value. After 24 hours of immersion, it was also observed that the ratio 1:1 board sample ESD₅₀CC₅₀ still retained the highest value for WA while ratio 2:1 board sample ASD₂₅CC₇₅ has the lowest value for WA. It was also observed that there was a wide difference in WA for the boards ratioE (1:1) after the final immersion for 24 hours compared to the initial immersion in water for 2 hours, while the boards ratio A and B has a slight difference in the final and initial immersion.

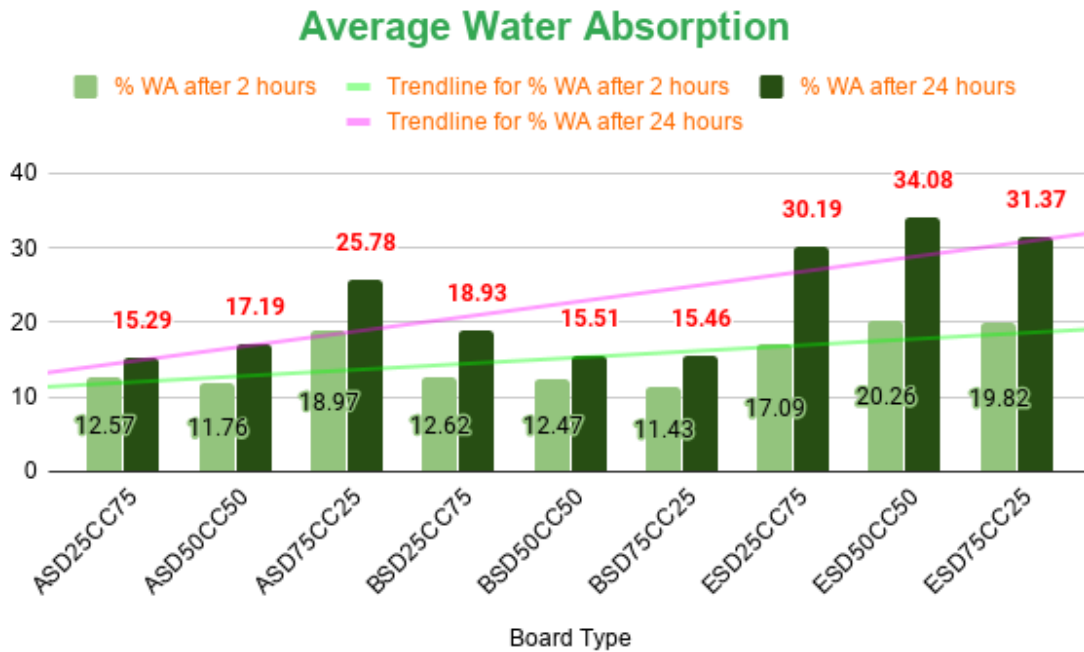


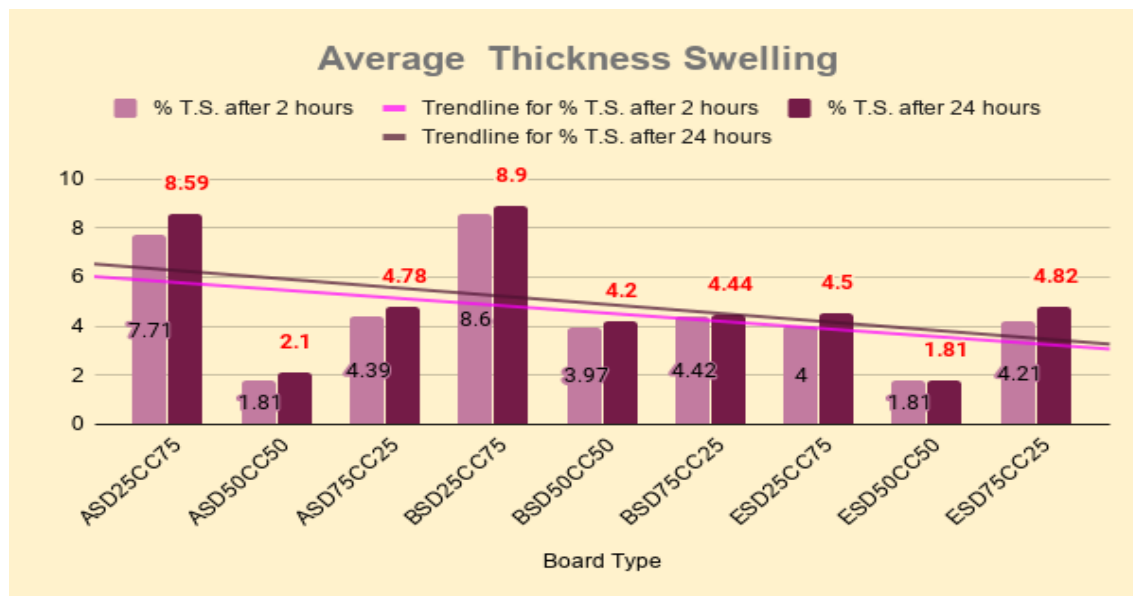
Figure 2. Board Average Water Absorption

4.1.3 Thickness swelling test.

Thickness swelling test (TS) is a dimensional analysis test that was used to determine the change in thickness of the board sample after it has been immersed in water for a given period of time. From the result in Table 3, it was observed that ASD₅₀CC₅₀ and ESD₅₀CC₅₀ has the lowest value for TS after the immersion in water also bringing to notice that the least board with the TS for each ratios are the ones having 50% CC and 50% SD in it. While BSD₂₅CC₇₅ has the highest value for TS. It could be deduced that the quantity of CC is directly proportional to the value of TS for the different ratios. The difference between the TS values for the Initial and final time was not a very high or significant difference while C2 board type did not even change value in thickness at all due to the application of DPK or Kerosene with the pure water sachet which was used as the binder.

Table 3. Result of thickness swelling (TS) of the particle board produced

Board Type	Average Thickness Swelling	
	% T.S. after 2 hours	% T.S. after 24 hours
ASD ₂₅ CC ₇₅	7.71	8.59
ASD ₅₀ CC ₅₀	1.81	2.1
ASD ₇₅ CC ₂₅	4.39	4.78
BSD ₂₅ CC ₇₅	8.6	8.9
BSD ₅₀ CC ₅₀	3.97	4.2
BSD ₇₅ CC ₂₅	4.42	4.44
ESD ₂₅ CC ₇₅	4	4.5
ESD ₅₀ CC ₅₀	1.81	1.81
ESD ₇₅ CC ₂₅	4.21	4.82

**Figure 3:** Board Average Thickness Swelling value

4.2 Mechanical properties test

Static bending: This test was carried out in accordance to the British Standard BS EN 310[12]. The MOR and MOE are being measured with the use of a Universal Testing Machine in N/mm². From the result, MOR was observed to increase in the board with higher percentage of saw dust i.e.75% SD. ESD₇₅CC₂₅ has the highest value for MOR while the BSD₅₀CC₅₀ has the lowest value. It was also observed that in each ratio, the board with 50% CC and also 50% SD has the least value of MOR and MOE as shown in Table 4. MOE also show a similar value result to that of the MOR in term of board with higher percentage of SD having higher value in MOE, while ASD₅₀CC₅₀ possesses the lowest value.

Table 4. Result of MOR and MOE of the particle board produced

Board Type	Average MOR (N/mm ²)	Average MOE (N/mm ²)
ASD ₂₅ CC ₇₅	2.39	18.71
ASD ₅₀ CC ₅₀	1.52	5.14
ASD ₇₅ CC ₂₅	2.93	19.65
BSD ₂₅ CC ₇₅	2.64	20.84
BSD ₅₀ CC ₅₀	0.86	6.93
BSD ₇₅ CC ₂₅	6.35	52.82
ESD ₂₅ CC ₇₅	6.02	59.23
ESD ₅₀ CC ₅₀	3.81	35.4
ESD ₇₅ CC ₂₅	8.19	63.07

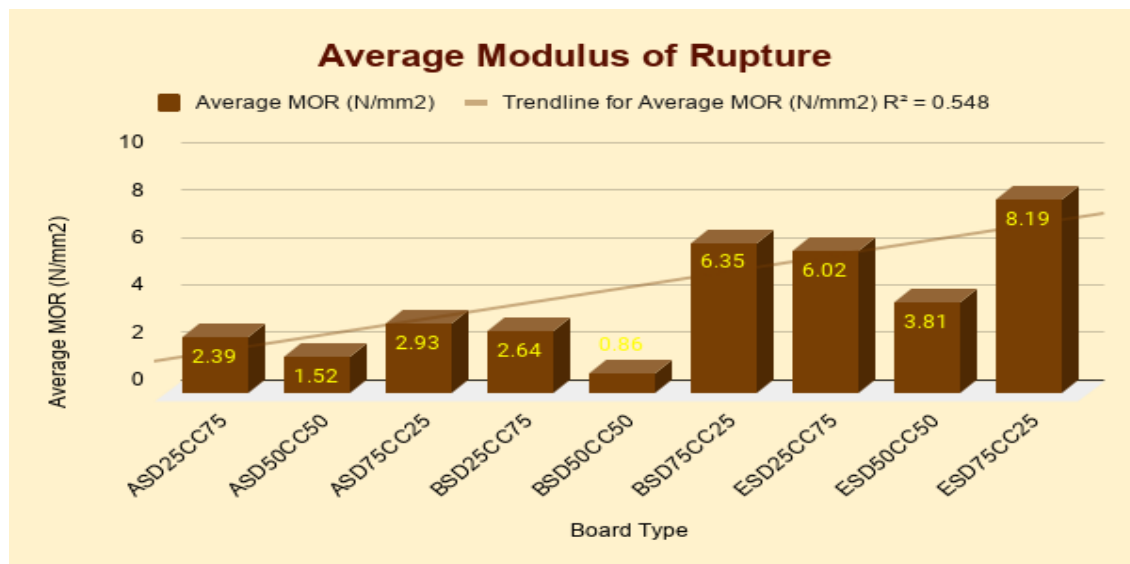


Figure 4: Graphical representation of MOR values

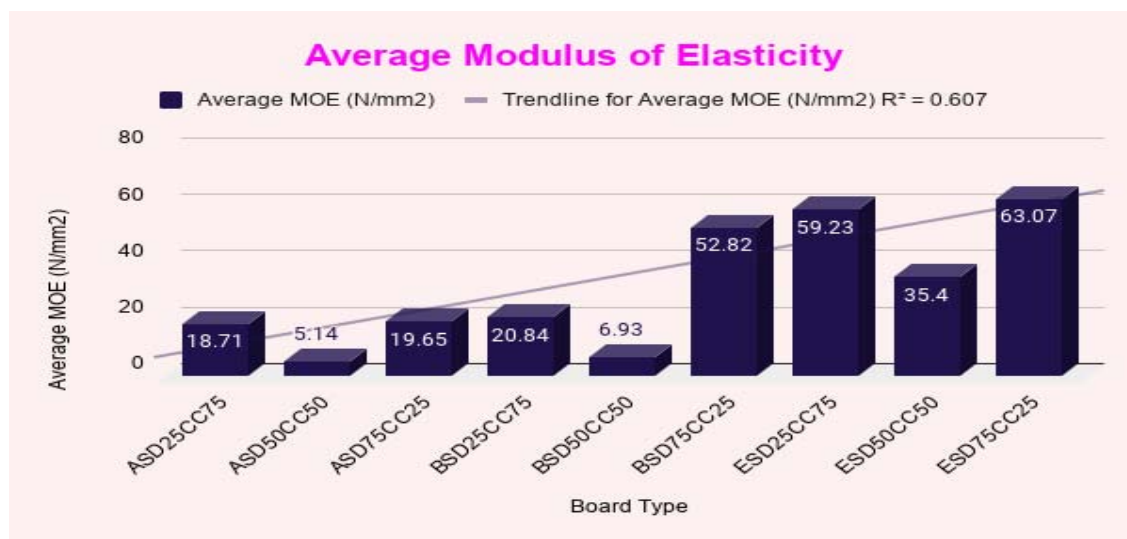


Figure 5. Graphical representation of MOE values

From the MOE and MOR graph in Figure 4 and 5, there was a very high increase in the values of MOR and MOE as the quantity of binder reduces. According to BS EN 13353 [13], it was recommended that panel or board of thickness greater than 20mm but less than 30mm are expected to have a minimum density of 420kg/m³. It also required that, boards which are intended for structural purposes which have densities greater than the minimum requirement are required to have their minimum values for MOR and MOE to be between a 5N/mm² and 400N/mm² respectively. From the result acquired, all the boards passed the minimum requirement for board density having its lowest density to be 491kg/m³. However, the requirement for MOR and MOE could not be attained by the board but for the MOR, only three (3) boards were above the 5N/mm² while for the MOE, none of the board attained the minimum requirement of 400N/mm² and this is in accordance with Sekaluvu, et al. [14] who worked on particle board made out of CC obtained mean values of MOE to range between 5.89 ± 6.00 N/mm² to 61.82 ± 10.09 N/mm² and also MOR which ranged between 0.32 ± 0.14N/mm² to 1.50 ± 0.16 N/mm². The low performance of the board in MOE and MOR could be caused by the compaction or pressing and also the curing process and also a slight consideration to the binder used in the production of board. Therefore, the board could be used for ceiling board and wall cladding and not for structural and load bearing because the board did not meet such requirement for work.

5. Conclusion

It is therefore established that particleboard could be produced from the combination of SD and CC with the addition of LDPE as binder which gave result of boards which fell into the two type board according to ANSI A208.1 [11] as three board type passed 640kg/m³. Also the Mechanical properties of the board such as MOR and MOE were influenced by the amount of agro residue and binder used but they were not influenced by the board density. In conclusion the particle board produced could be used for ceiling board and wall cladding.

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