NAU Journal of Civil Engineering (NAUJCVE) November/December 2023
Nnamdi Azikiwe University Journal of Civil Engineering (NAUJCVE)

Volume-1, Issue-4, pp-24-40
www.naujcve.com
Research Paper Open Access

Investigation on the Physical properties of Particleboard produced from Biodegradeable Waste and Plastics

[1]Okoli C.C., [2]Ezeagu C.A and [3]Okonkwo V.O.

[1,2,3]Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

[1]okoliojii@gmail.com, [2]ac.ezeagu@unizik.edu.ng, [3]vo.okonkwo@unizik.edu.ng

Corresponding Author:- okoliojii @gmail.com

Abstract: *This paper investigated the physical properties of particleboard produced using Biodegradeable wastes (Rice husk, Sawdust, Breadfruit seed coating, Oil palm fruit fiber) and plastics. Five samples were examined. The moisture content, ash content, thickness swelling percent, water absorption percent, density, surface appearance, of these produced samples, were all examined and compared with the control sample (medium dense fireboard, (MDF)). The mean density of the board ranges from 240kg/m^3 to 648kg/m^3. The moisture content ranges from 21.81% to 69.39%. water absorption percent and thickness swelling percent ranges from 19.24% to 119.94% and 5.88% to 38.46% respectively at two hours soaking, 70.99% to 219.6% and 5.88% to 66.67% respectively at 24 hours soaking. The control sample (purchased medium dense fireboard, (MDF)) recorded the highest density (643kg/m3),highest ash content (9.55%),lowest moisture content (16.08%), lowest thickness swelling and water absorption percent (19.24%,5.88%) at 2 hours soaking in water, lowest thickness swelling and water absorption percent (70.99%,5.88%) at 24 hours soaking in water.Sample A (particleboard produced with Rice husk) gave the best performance among other produced samples for physical properties. Generally, the results of the physical properties of the samples were comparable to the control sample (MDF) which is available in the local Market. The result also shows that it is possible to produce particleboards with less sophisticated equipment and their production process were comparable to that of the control sample (MDF) which is available in the local Market. However,inadequate drying,compaction/ pressing and particles not properly milled into finer powdered form during the production process, were noticed to be the major diffrences between the production processes of the produced samples and the control sample.*

KEYWORDS: *Particle board, Sawdust, Rice husk, Oil-palm fiber, Breadfruit seed coating, Plastics, Physical properties, Density, Moisture content, Ash content, Thickness swelling and Water absorption Percent.*

Date of Submission: 09-11-2023 Date of acceptance: 12-11-2023

I INTRODUCTION

Waste generation has caused huge burden on our environment (Emmanuel and Edidiong, 2020). Previously, greater attention were directed toward the wood industries, which have produced a lot of toxic waste (Sawdust)(Ezeagu and Uzodinma, 2022) that are released into our environment (Harshavardhan and Muruganandam (2017). But nowadays, Attention are also directed to other Agricultural waste like rice husk breadfruit seed coating and palm fruit chaff, since their disposal are problematic, and the most significant challenge today is to find novel ways to utilize these residues or waste. (Ezeagu, Ugboaja and Okonkwor, 2022)(Ezeagu and Agboanike, 2020)(Kingsley and Ezeagu 2020)

Furthermore, Plastic wastes which are the commonest waste we see every day in our neighborhood, not only affect our Environment negatively, but also our Economy, since jobs which would have been created during the recycling process are being abandoned. Drinking water and soft drinks sold in plastic bottles may be a practical option for the consumers in Nigeria but the enormous problem caused by the discarded plastics has for a long time outweighed its convenience. These plastic waste not only creates an eyesore in the streets but chokes drains and harbors disease causing organisms.(Olatunji et al., 2012)

Several studies have shown that the Wood, Agricultural and Plastic industries' present state is unsustainable in the long run, because of improper waste management through recycling. An environmentally friendly alternative for these generated wastes is by using them to produce Particleboard. Since the production of particle board using wood is very expensive, there is therefore need for production of particle board using waste materials that will result to quality improvement and be always available and affordable to everybody including low income earners. Hence, plastics, rice husk, breadfruit seed coatings, palm fruit chaff and sawdust can be judiciously used in production of particle board.

Particle board (P.B) is a composite material and engineered wood products made mainly from chips of wood, or sawmill shavings and a synthetic resin, glue, or other suitable binder, (Bruce, 2014). It is pressed into a broad flat boards or sheets of uniform cross section and thickness under pressure and heat in a suitable mould after mixing.

A lot of works has been done on particleboards, (Sekaluvu et al., 2014) worked on Maize cobs Particleboard, (Astari et al., 2018), (Cengiz , 2015)worked on wood particleboard, (Asha, 2017) (Oladele et al., 2009; Suleiman et al., 2013; Madu et al., 2018), worked on Rice Husk Particleboard, (Abdulkareem et al., 2016),(Olatunji et al., 2012)worked on Plastics Particleboard, (Ogundipe, O. and Jimoh, Y. 2012) worked on Corncob particleboard, Banana fibres Particleboard (Stephen et al., 2014), jatropha curcas seedcake material Particleboard (Olorunmaiye and Ohijeagbon, 2015), water melon peels Particleboard (Idris et al., 2011), bamboo (Chibudike et al., 2011), corn cobs and cassava stalks Particleboard (Amenaghawon et al., 2016) as well as other synthetic wastes like sawdust Particleboard (Idehai, 2012; Akinyemi et al., 2016; Atuanya and Obele, 2016; Isheni et al., 2017; Olufemi et al., 2012), Breadfruit seed coating (Ezenwa et., 2019) and waste paper Particleboard (Ekpunobi et al., 2015).

In all literature reviewed, there is no research on the production of particleboard using rice husk, sawdust, breedfruit seed coating, Oil palm fiber, plastic and investigation of their respective physical properties comparing it to Medium dense Fiberboard available in the local market.

This study focuses on the investigation of the physical properties of particleboard produced from biodegradeable waste namely; Rice husk, Sawdust, Oil palm fruit fiber, Breadfruit seed coating and Plastics.

II. MATERIALS AND METHODS

A. Collection of sample

The sawdust was collected from Ogbo Osisi, a Timber market zone in Nkwo Nnewi located in Nnewi, a suburb of Anambra State in the south east Region of Nigeria. The sawdust was then transported to IDC construction company, Awka Anambra State where the research was to be conducted. The sawdust was air-dried for seven days and oven dried at 60 degrees Celsius for 24 hours till moisture content reduces from 15.56% to 9.42%. It was then sieved using B.S sieves of 2.56mm and 1.18mm apertures to remove oversized and undersized particles so as to enhance homogeneity, in order to aid the adhesive/ urea formaldehyde (top bond) to bind uniformly, the sawdust particles together and hence a uniform composite. The weight of sawdust required to produce one panel of particleboard for the experimental mix is 0.214kg.

The Breadfruit Seed Coating were collected from a vendor at Eke Awka Market Anambra State. It was then air-dried for seven days and oven dried at 60 degrees Celsius for 24 hours to reduce the moisture content, then grinded using local grinding machine. It was also sieved using B.S sieves of 2.56mm and 1.18mm apertures to remove oversized and undersized particles so as to enhance homogeneity.Rice husk were obtained from a rice mill at Oba Ofemmili Anambra State, oven dried at 60 degrees Celsius for 24 hours to reduce the moisture content. It was then sieved using B.S sieves of 2.56mm and 1.18mm apertures to remove oversized and undersized particles so as to enhance homogeneity.

Oil palm fruit fiber were obtained from an oil mill at Amansea Awka Anambra State air-dried for seven days and oven dried at 60 degrees Celsius for 24 hours to reduce the moisture content, then grinded using local grinding machine. It was then sieved using B.S sieves of 2.56mm and 1.18mm apertures to remove oversized and undersized particles so as to enhance homogeneity.

Plastics waste were gathered from Nnamdi Azikiwe University Premises Awka Anambra State. It was then washed to remove dirt and impurities. After which, it was air-dried for seven days and oven dried at 60 degrees Celsius for 24 hours to reduce the moisture content, then shredded using local grinding machine. Plywood was used to make the mould (formwork) with inner dimension of 200mm x 200mm and depth 50mm, the thickness of the mould cover is 15mm.

Plate 1: Showing sawdust particles waste

Plate 2: Showing Plastics waste

Plate 3: Showing Palm fruit Chaff waste

Plate 4: Showing Palm fruit Chaff waste

Plate 5: Showing Bread fruit Seed Coating

Plate 6: Showing Wooden Mould

Production of composite particleboard:

To produce the composite particleboard, the following procedures were done as recommended by Abdulkareem*et al.,* (2017):

1. The volume of particles required to produce one panel of the board was determined by first filling the mould with loosed particles and then weighing the loosed particles inside the mould.

2. The adhesive with respect to its designated percentage to the measured particles is then weighed.

3. The measured adhesive volume is then poured into a pan and half of the batched or measured loosed particles, was then poured into the pan containing the adhesive.

4. The particles were thoroughly mixed with half of the adhesive by hand, after which, the remaining were emptied into mix.

5. It was then mixed thoroughly until the adhesive was uniformly distributed and a homogenous mixture obtained.

6. This process was then repeated for the other replicates.

Casting and Pressing Operation:

1. The homogenous mixture obtained was transferred into mould filling it to a thickness of 50mm.

2. Before the filling of the mould, it was greased with oil for easy removal of sample from mould.

3. A metal spatula (tamping rod) was used to tamp the composite in order to remove air voids, to level the surface and also to give a compacted surface.

4. The mould cover was put in place and the mould was transported to manual compression machine for compression.

5. A metal slab was placed on it before compressing to close the mould. The mould cover was tied with metal strip to ensure that the cover remained tightly fixed before removing from the compression machine.

6. The pressure was maintained for 24 hours, after which they were transferred into the oven and allowed to dry for 1hour at 80^0c

7. The mould was then removed from the oven and allowed to cool for 10 minutes before the compacting pressure (the cover) was removed and left for 24 hours under the sun for drying.

8. After 24 hours the panels were removed from the mould and sun dried for 1 week before they placed on flat surface for stalking.

9. In all, 5 panels were casted

B. Determination of physical properties

Density Test:

The tests were carried out based on BS EN 323

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad 1$$

Water Absorption Test:

The test was carried out based on ASTM standard method (D1037-99, ASTM, 1999).

Water Absorption percent (%) = $\frac{mt - m0}{m0} \times 100\%$ 2

where mo and mt denotes the oven dry weight and wet weight after time t in water respectively.

Thickness Swelling Test:

The test was carried out based on ASTM standard method (D1037-99, ASTM, 1999).

Thickness swelling percent (%) = $\frac{t_t - t_0}{t_0} \times 100\%$ 3

Where t_0 and t_t denotes the thickness of the oven dry sample and thickness of wet sample immersed in water after some time respectively.

Moisture content test:

The moisture content of the particle boards was tested as per the relation as recommended by ASTM 2016-25 (Debdoubi *et al.*, 2004)

Moisture content (%) = $\frac{Wa - Wo}{Wo} \times 100\%$ 4

Where W_O = Oven dried weight of the particleboard, W_A = wet weight of the particleboard

Ash Content Test:

The test was carried out based on ASTM - 5142 as recommended by Debdoubi *et al.*, (2004).

Ash content (%) = $\frac{W_f}{W_t} \times 100\%$ 5

Where, W_f = initial weight of the particleboard (before burning) W_t = final weight of the particleboard (after burning)

III. RESULTS AND DISCUSSION

A. Production of Particleboard

Table 1: Production of particleboard result

Composite Code	**Particles Used**	**Mass of Particles used (g)**	**Percentage of Adhesive used (%)**	**Mass of Adhesive used (g)**	**Total mass used(g)**
A	Rice Husk	214	230	492.2	706.2
B	Sawdust	214	230	492.2	706.2
C	Oil Palm fruit Fiber	214	230	492.2	706.2
D	Grinded Breadfruit seed Coating	214	230	492.2	706.2
E	Shredded Plastics	114	300	342	456
F (Control)	Medium Dense Fiberboard	-	-	-	-

Composite Code F=Control Sample= Medium dense Fibreboard (MDF)

Sample A: Rice husk particleboard

Sample B (Sawdust Particleboard)

Sample C (Palm fruit chaff Particleboard)

Sample D (Breadfruit Seed coating particleboard)

Sample E (Shredded Plastics Particleboard)

Control Sample F (Medium dense fiberboard)

Table 2: The Results of particleboards production using different types of particles

Composite Code	Particles Used	Colour	Surface Appearance
A	Rice Husk	Greyish Brown	Fairly Smooth
B	Sawdust	Milky Brown	Fairly Rough
C	Oil Palm fruit Fiber	Dirty Brown	Rough
D	Grinded Breadfruit seed Coating	Blackish Brown	Fairly Rough
E	Shredded Plastics	White and Green	Very Rough
F (Control Sample)	Medium Dense Fiberboard	Blue	Very Smooth

Composite Code F=Control Sample= Medium dense Fibreboard (MDF)

The results in Table 2 shows that it is possible to produce particleboards with less sophisticated equipment and their production process were comparable to that of the control sample (MDF) which is available in the local Market (ANSI 2009). However,inadequate drying,compaction/ pressing and particles not properly milled into finer powdered form during the production process, were noticed to be the major diffrences between the production processes of the produced samples and the control sample.

The colour of sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) were greyish brown and milky brown respectively. While the color of sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded breadfruit seed coating) were dirty brown and blackish brown, the color of sample E (particleboard produced with shredded plastic) and control sample F (medium dense fiberboard) were white and green and blue as shown in table above.

The colour of the produced samples from A to D were observed to be quite similar to that of naturally wood which is brown in color. Hence can perfectly replace wood in furniture making where brownish colored product is quite considered for some particular reasons. Brownish colour tends to conduct and retain heat than other lighter colours. Also, it easily hides stains and dirt more than other lighter colour. Psychologically, People may easily accept it as replacement for wood based on their similar colour. Sample E being of entirely different colour, may be used other ornamental purposes and interior decorations.

The surface of sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) were found to be fairly smooth and fairly rough respectively. While the colour of sample c (particleboard produced with Oil palm fruit fiber) and sample D (particleboard produced with grinded breadfruit seed coating) were rough and fairly rough, respectively the surface of sample E (particleboard produced with shredded plastic) and control sample F (medium dense fiberboard) were very rough and very smooth respectively as shown in table above

The rough surface of sample E (particleboard produced with shredded plastic) is an indication that the sample was not well pressed as a result its particles being coarse in nature while control sample F (medium dense fiberboard) were laminated with smooth plywood for a smoother surface.

Density Test:

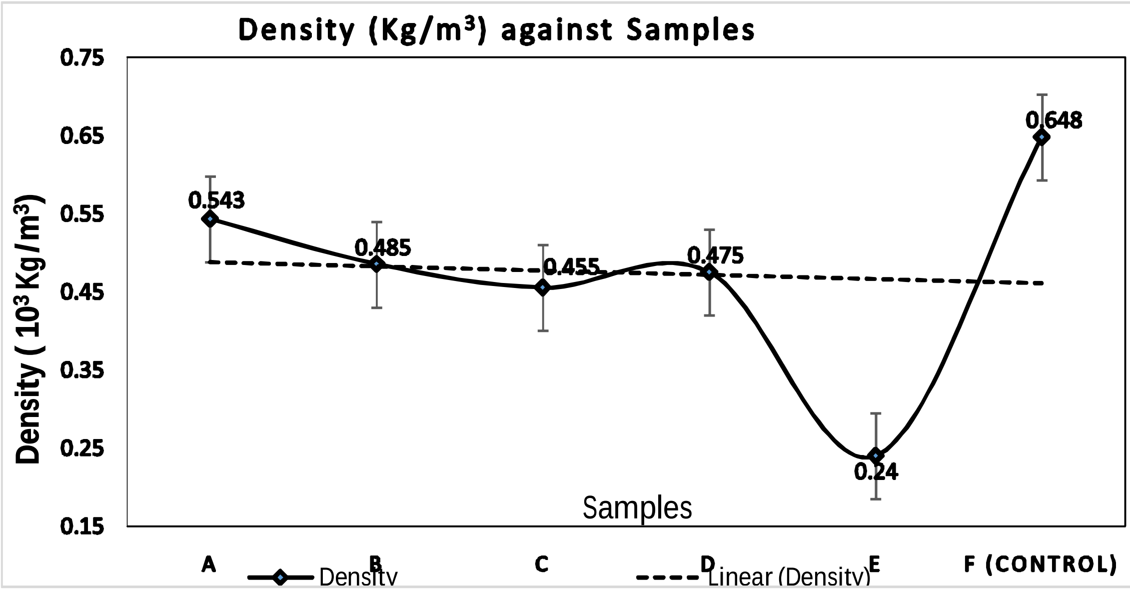

Fig.4.1: Density (kg/m^3) against Samples

(Particleboard produced with Grinded Palm Fruit Chaff) and Sample D (Particleboard produced with Grinded Breadfruit seed coating) were 455 kg/m^3 and 475 kg/m^3, the mean Density of Sample E (Particleboard produced with Shredded Plastic) and Sample F (Control /Medium Dense Fiberboard) were 240 kg/m^3 and 648 kg/m^3 as shown in Fig. 4.1. These values are similar to the values obtained by A.B. Akinyemi *et al*., (2016) and also values obtained by Rose *et al*., (2009).

It was observed that the difference in densities of produced panel, when compared to the control sample were minimal except for Sample E (Particleboard produced with Shredded Plastic). The reason may be due to size of the particles used, since the particles were shredded. It should be noted that the density could be improved be further grinding the plastics particles into fine form to reduce the void spaces, also improve adhesion and cohesion of the particles through larger contact area and smaller surface area The control sample F obviously recorded the highest density with 643kg/m^3. Probably because it has a more homogenous finer particles with little voids.The observed slight difference in Density of other produced samples when compared to the control sample may be due to the fact that the particles of those produced samples were almost the same size with that of our control sample. This indicates that the sizes of Particles is a function of its Particleboard density. From Fig. 4.1, Sample A (Particleboard produced with Rice Husk) recorded maximum Density among other produced samples. The reason may be as a result of the Rice husk Particles have Pozzolonic or binding ability, hence causing its particles to cohesively bind to each other thereby reducing its void spaces and volume which will in turn reduce its density. The densities obtained are comparable to the particles board densities of 590kg/m^3 and 800kg/m^3 of wood product industries.

The sample C (Particleboard produced with Grinded Palm Fruit Chaff) and Sample D (Particleboard produced with Grinded Breadfruit seed coating) recorded the lower densities. This may be as a result of local Impurities in the particles; hence its density can be improved by first washing the particles to remove the local impurities and then drying before production. Since all the densities of produced samples are less than 640kg/m^3, therefore the manufactured boards can be graded according to ANSI as a low density particle boards, Grade 1. While the purchased particle board having a density of 643kg/m^3 which is greater than 640kg/m^3, will be regarded as a medium density particle board, Grade 1[LD-1] [ANSI] A208.1. 1999. More so, the density of Sample B (Particleboard produced with Sawdust) could have been increased to that of the control sample, if the core density of sawdust was slightly reduced (Wong *et al.,* 1998) and better adhesive were used (Han *et al*., 1998). Moreover increasing the pressure of the press to consolidate the particle mat and eliminate more void in mat to compact wood structures could have increased density of board (Kelly, 1974).

Ash content Test:

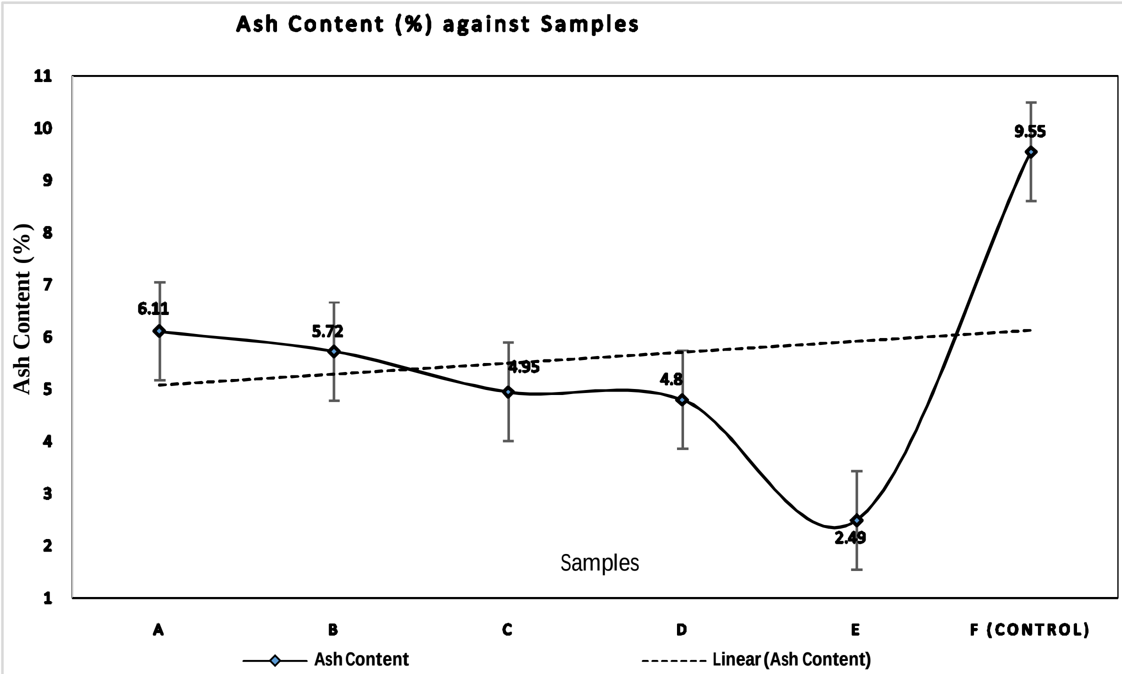

Fig. 4.2 Ash Content (%) against Samples

According to Elehinafe *et al*., (2019), the properties of particle board sample corresponds or is related to its ash content after burning. Ash content is the residue after a particle board sample has been burnt (Elehinafe *et al*., (2019)).The Ash content of sample A (particleboard produced with rice husk) and Sample B (particleboard produced with sawdust) were 6.11% and 5.72% respectively. While Ash content of sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded breadfruit seed coating) were 4.95% and 4.8%, the Ash content of sample E (particleboard produced with shredded plastic) and control sample F (medium dense fiberboard) were 2.49% and 9.55% as shown in Fig. 4.2. From the test result; sample E (Particleboard produced with Shredded Plastic) has the lowest Ash content with a value of 2.49% and also the lowest density. While the Control sample F has the highest Ash content with a value of 9.55% and the highest Density. This is a clear indication that Ash Content of the Particleboard after burning is a function of the density of the Particleboard. It should also be noted that increase in density bring about increase in ash content. Since there is very little void in a very dense particle board giving it a higher composition of particles for a particular volume. And these particles is what generate ashes during burning. Sample E (particleboard produced with shredded plastic) has the lowest Ash content. It is also an indication that plastics generate lower Ash than the Biodegradable Particles of other samples. Ash content percent is also a function of materials ability to resist fire and thermal conductivity. Hence Sample A (particleboard produced with rice husk) will resist fire more than any other produced sample while the control sample F obviously retain more heat and absorb less heat than any other samples. Hence can serve as a strong shield or shelter against heating from the Sun and can also store heating easily during harmattan or winter. The amount of Ash after burning is also a function of the amount of voids in the particle board. Increase in Ash content result from increase in density and obviously decrease of void volume of the particle board composite.

Moisture Content Test:

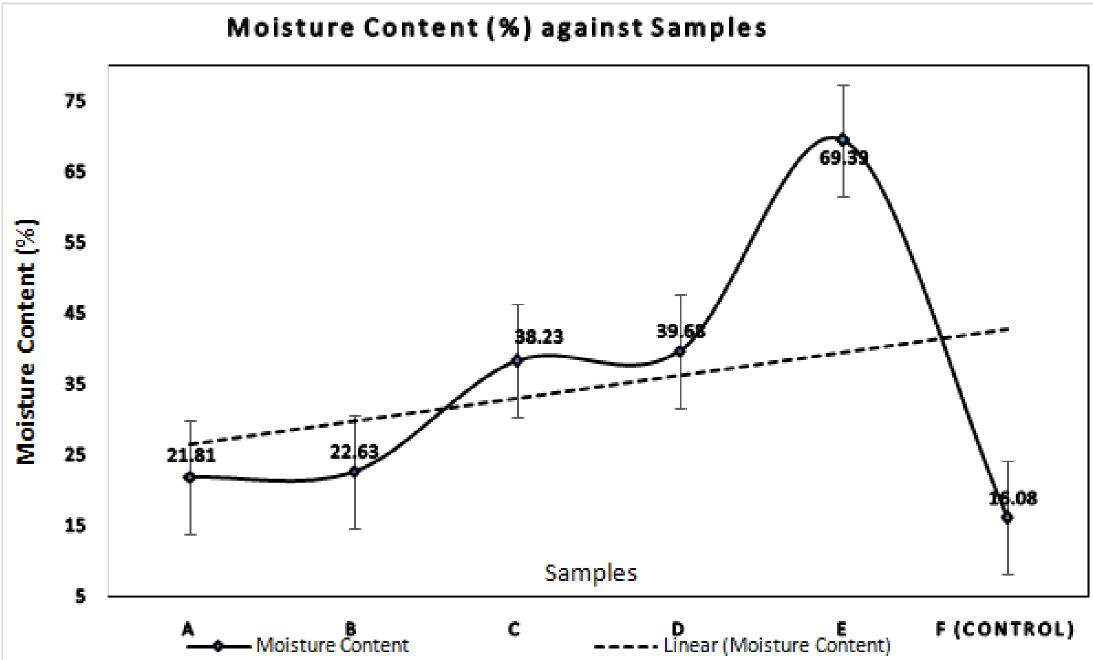

Fig.4.3: Moisture Content (%) against Samples

The study of Elehinafe *et al*., (2019) proved that moisture content is a very significant property which can adversely affect the mechanical and physical properties of particle boards.From the Fig. 4.3, it shows that the moisture content of sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) were 21.81% and 22.63% respectively. While the moisture content of sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded breadfruit seed coating) were 38.23% and 39.68%, the moisture content of sample E (particleboard produced with shredded plastic) and sample F (control /medium dense fiberboard) were 69.39% and 16.08% as shown in Fig. 4.3.

It can also be deduced that moisture content increases with increase in the composition of the adhesive. The reason may be because of the type of adhesive used which is a water based adhesive (Top bond). Hence introducing more moisture in composites on its application. The purchased medium dense fiberboard (sample F) had a very low moisture content when compared to that sample E (particleboard produced with shredded plastic) with a difference of 53.31% but slight lower moisture content when compared to sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) with a difference of 5.73% and 6.55% respectively. Also lower moisture content when compared to sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded bread fruit seed coating) with a difference of 22.15% and 23.06%.

These results also show that the produced samples were not adequately dried and compacted during production when compared to the control sample which were adequately cured, compacted, seasoned and dried during production. Also the results were similar to that of Elehinafe *et al*., (2019) which ranged from 15.96% to 17%. It should also be noted that the reason why sample E (particleboard produced with shredded plastic) recorded a very high moisture content of 69.39% was because of the high percentage composition of the water based adhesives used during Production. More so, sample B (particleboard produced with sawdust) recorded a higher moisture content is as a result of the Sawdust in the matrix, which increases the moisture content due to the hydrophilic nature of wood.

Additionally, the gaps and flaws at the interfaces and the micro-cracks in the matrix formed during the manufacturing process can boost up the moisture content as reported by Adhikary *et al*., (2008). It should be noted that from the results of both Moisture and Ash Content Test, that Moisture Content is a Function which is indirectly proportional to Ash Content. Hence Increase in Moisture Content of Particleboard will bring about decrease in Ash content and vice versa. ANSI (1999) standard, state that the mean moisture content of the board shall not exceed 10% (based on the oven dry weights of the board). The moisture content of produced particle is lower than the standard moisture content and hence satisfied.

Thickness Swelling Test:

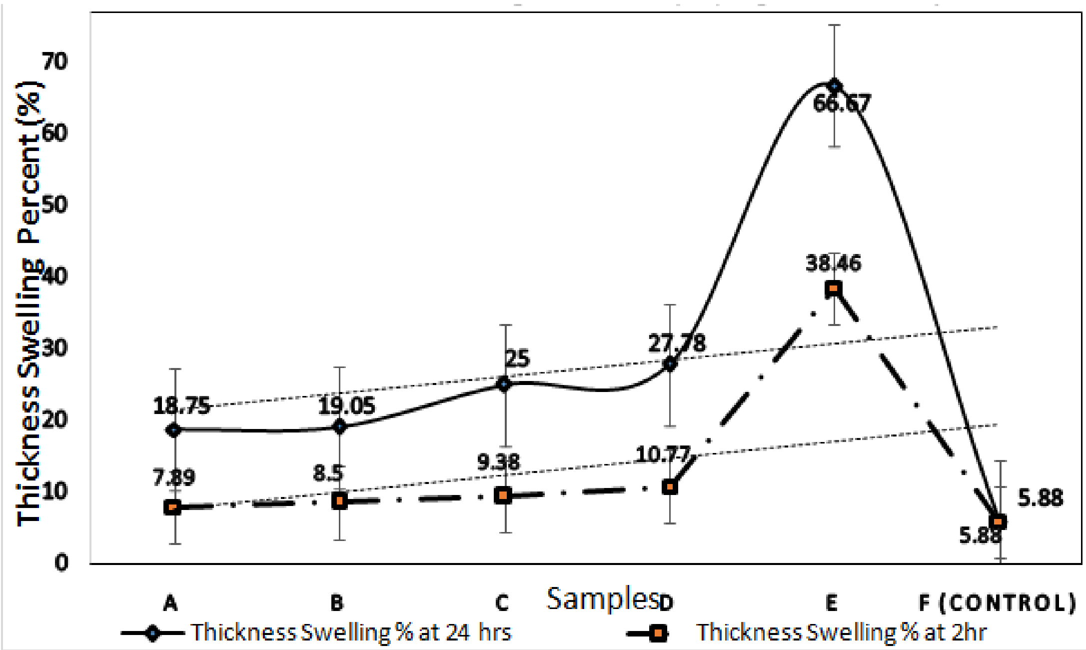

Fig. 4.4: Thickness Swelling Percent (%) against Samples

Variation in the thickness of the boards was observed after casting and curing. This variation can be explained by the non-uniform wooden mould. Also the cover did not possess a uniformly flat surface. Also the variation in thickness can be attributed also to the non-uniform distribution of the compressive load during the compaction process. From the data obtained from the thickness swelling test that was carried out as shown in the Fig. 4.4, after 2 hours of immersion of all the samples (A, B, C, D, E, F) in water.

It was observed that the thickness swelling percent at 2 hours of sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) were 7.89% and 8.50% respectively. While the thickness swelling percent at 2 hours of sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded breadfruit seed coating) were 9.38% and 10.77%, thickness swelling percent at 2 hours of sample E (particleboard produced with shredded plastic) and sample F (control /medium dense fiberboard) were 38.46% and 5.88% as shown in Fig. 4.4.

It was also observed that the thickness swelling percent at 24 hours of sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) were 18.75% and 19.05% respectively. while the thickness swelling percent at 24 hours of sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded breadfruit seed coating) were 25% and 27.78%, thickness swelling percent at 24 hours of sample E (particleboard produced with shredded plastic) and sample F (control /medium dense fiberboard) were 66.67% and 5.88% as shown in Fig. 4.4 It was observed that all samples tends to swell more in thickness when immersed in water for 24 hours than when immersed in water for only 2 hours. This is an indication that the duration in water is a function of thickness swelling percent. Hence increase in duration of water increases the percentage of thickness swelling.

Sample F (control /medium dense fiberboard) swells least in thickness after 2 hours and after 24 hours of immersion in water while sample E (particleboard produced with shredded plastic) exhibited the worst performance in swelling compared to the other board samples. This can be easily spotted in Fig. 4.4 of 2 hours and 24 hours soaking. It suggests that the higher the composition of adhesive the faster it is for the particleboards to get saturated with water. It should also be noted that increase in water absorption percent, moisture content of particleboard brings about increase in thickness swelling percent of particleboard.

For thickness swelling properties, sample F had the best performance followed by sample A, then sample B, then sample D while sample E has the poorest thickness swelling performance. Akinyemi, (2016) stated that the increase in particle board density can result in higher contact between particles and improvement of glue bonds which may reduce thickness swelling. This is true with our test results since as density increases the thickness swelling percentage was also decreasing. The EN 312-3[EN 2003] standard for thickness swelling after 24 hours requires values below 14% for non-load bearing board for use in humid conditions. Since all Samples swells above the maximum stipulated by the standard. Hence they are all unfit for non-load bearing board under humid conditions. Sample A (particleboard produced with rice husk) having a thickness swelling percent of 7.89% and 18.75% after 2 hours and 24 hours immersion in water is the best dimensional stable sample among produced samples.

Also sample B having a thickness swelling percent of 8.5% and 19.05% after 2 hours and 24 hours immersion in water making it the second best dimensional stable sample among the produced samples.The Fig.ical illustrations of the results of the thickness swelling of the particle board showed that the degree of thickness swelling; a measure of dimensional stability of particle boards in humid environment is a function of the density. As the density of the panel increases, the thickness swelling percent decreases and thus had similar trend to the water absorption regardless of the impact of nature of particles used. The result of thickness swelling when compared with previous work indicate overall poor performance which may be because of poor and inefficient materials used during its production process.

Water Absorption Test:

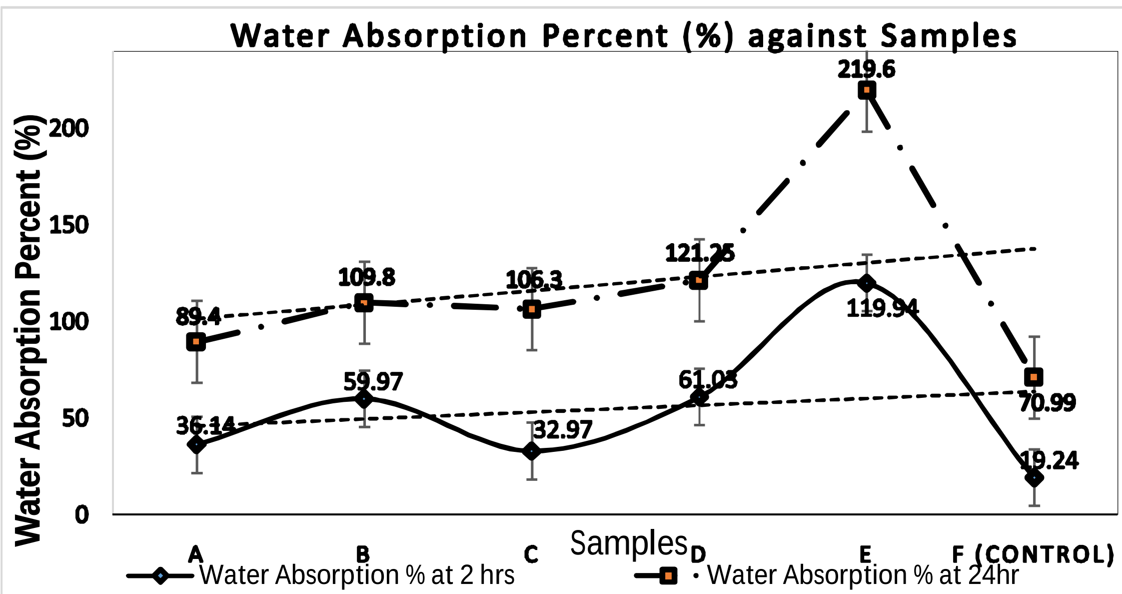

Fig. 4.5 : Water Absorption Percent (%) against Samples

After 2 hours of immersion of all the samples (A, B, C, D, E, F) in water. It was observed that the water absorption percent at 2 hours of sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) were 36.14% and 59.97% respectively. while the water absorption percent at 2 hours of sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded breadfruit seed coating) were 32.97% and 61.05%, the water absorption percent at 2 hours of sample E (particleboard produced with shredded plastic) and sample F (control /medium dense fiberboard) were 119.94% and 19.24% as shown in Fig. 4.5.

It was also observed that the water absorption percent at 24 hours of sample A (particleboard produced with rice husk) and sample B (particleboard produced with sawdust) were 89.40% and 109.80% respectively.

While the water absorption percent at 24 hours of sample C (particleboard produced with grinded palm fruit chaff) and sample D (particleboard produced with grinded breadfruit seed coating) were 106.30% and 121.25%, the water absorption percent at 24 hours of sample E (particleboard produced with shredded plastic) and sample F (control /medium dense fiberboard) were 219.6% and 70.99% as shown in Fig. 4.5.

From the results, the control sample E (medium dense fiberboard) has the best performance when compared with the other produced board. Sample A has the best performance among the produced particleboard. It was also noticed that decrease in density and ash content increases the water absorption percent at both 2 hours and 24 hours immersion in water. It was observed that sample E (particleboard produced with shredded plastic) has the worst performance in terms of water absorption percent possibly because of the shredded particles being coarse, poor compaction during production process and existences of void or water site in its volume. The reason sample E (purchased particle board) has low water absorption percent is because of its fine sawdust particles which are highly homogenous. Also their well compacting process using ho pressing lamination method, coupled with the lamination of low water absorbing plywood at its surface also contributed to its low water absorption percent. A significant decrease in water absorption percent was noticed sample A (particleboard produced with rice husk) at both 2 hours and 24 hours water immersion. These may be as a result of decreasing void spaces, pozzolonic ability of rice husk and the ability of adhesive to bind particles more effectively due to larger contact area.

It was also observed that sample E (particleboard produced with shredded Plastic) flake off easily with little application of pressure after the immersion in water. Owing to the fact that the binding efficiency of the adhesives are least in sample E (particleboard produced with shredded plastic). Scatolino *et al*., (2015) and A.B Akinyemi *et al*., (2016) both explained that increase in amount of compaction decreases water absorption percent hence improving the performance of the particle board. Abdulkareem *et al*., (2017) explained that water absorption percentage decreases with increasing adhesive content in the composite due to less water site but this is not true with our results. Since sample E (particleboard produced with shredded plastic) having the highest percentage composition of adhesive has the worst performance or the highest water absorption percent. The reason may be due to poor compaction and pressing process during its production process. It is noted that higher density particle board has higher compression ratio and hence decreased void spaces. This in turn will reduce the water absorption percent (Buffalino *et al*., (2012)) our results tend to concur to these assertions.

IV. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

It has been shown that it is possible to produce particleboards with less sophisticated Equipmentand their production process were comparable to that of the control sample (MDF) which is available in the local Market. However, inadequate drying,compaction/ pressing and particles not properly milled into finer powdered form during the production process, were noticed to be the major diffrences between the production processes of the produced samples and the control sample.

More so, the type of waste particles used during the production of these particleboard generally affects the color and texture and the physical properties of particleboard.

It has been shown by the results obtained from the physical properties test of rice husk, breadfruit seed coatings, palm fruit chaff, plastics and sawdust particleboards that the produced samples exhibited a slight favorable physical properties that are recommendable for indoor uses in buildings.

It can also be concluded that the physical properties were very similar with slight differences when compared to that of the control sample (medium dense fiberboard)

In addition, it can also be concluded that increase in density of produced particleboard brought about increase in ash content, and decrease in moisture content, thickness swelling percent when immersed in water, water absorption percent when immersed in water (physical performance of the particleboard).

Furthermore, within the scope and limitations of this research, particleboard produced with rice husk (sample A) has the best performance for the physical properties among the produced samples. Sample A had the highest density of 543 kg/m^3, highest ash content of 6.11%, lowest moisture content of 21.81%, lowest thickness swelling percent of 7.89% at 2 hours and 18.75% at 24 hours, lowest water absorption percent of 36.14% at 2 hours and 89.4% at 24 hours, among the samples.

Sample E (particleboard produced with shredded plastic) had has the worst performance for the physical properties. Sample E (particleboard produced with shredded plastic) had the lowest density of 240 kg/m^3, lowest ash content of 2.49%, highest moisture content of 69.39%, highest thickness swelling percent of 38.46% at 2 hours and 66.67% at 24 hours, highest water absorption percent of 119.94% at 2 hours and 219.6% at 24 hours among the samples.Sample A (particleboard produced with rice husk) is the most preferred for physical properties.

B. Recommendations

The following recommendations are made from this study;

1. Particleboard made from Rice Husk, Sawdust, Breadfruit Seed coatings, Palm fruit chaff can suitably be used for making furniture, door and other wood products so as to reduce pressure on solid board (wood) and the natural forest.
2. Particleboard made from Plastics could be used interior decorations, Artifacts, Ornamental Figure and other product that will require no load bearing operations, very low exposure to humidity and other climatic conditions.
3. Water based Urea formaldehyde adhesive resin (Top bond) can be appropriately used as adhesive in particleboard manufacturing in Nigeria, since it is readily available and cheaper in Nigeria market.
4. Since sawdust, rice husk, plastics, breadfruit seed coatings, palm fruit chaff are nuisance to the environment, they can be appropriately used in the formation of particleboard so as to help accelerate the realization of the United Nations Millennium Development Goals (MDGs) of achieving zero wastes and also improve the economy of Nigeria.

References

A.B Akinyemi, Abdulkareem, S.A. & Adeniyi, A.G. (2016). "Production of Particleboards Using Polystyrene and Bamboo Wastes". *Construction and Building Material*, Vol. 127, No. 3, July 2016, **pp. 436– 441**

Abdulkareem, S.A., Raji, S.A. & Adeniyi, A.G. (2017). "Development of Particleboard from Waste Styrofoam and Sawdust". *Nigerian Journal of Technological Development*, **14(1):** 18 – 22

Amenaghawon, A.N. & Bienose, K.C. (2016). "Particle Boards Produced From Cassava Stalks: Evaluation of Physical and Mechanical Properties". *South African Journal of Science.* **111(5/6),** 1 – 4.

ANSI (American National Standards Institute) (2009) American National Standard for Particleboard. ANSI/A208.1. Composite Panel Association, Gaithersburg**.**

Atuanya, C.U., Obele, C.M., 2016. Optimization of process parameter for sawdust/recycled polyethylene composites. J. Miner. Mater. Charact. Eng. 4, 270–277.

Asha, A. (2017). "Fabrication of Particle Boards from Rice Husk". International Journal of Modern Engineering Research (IJMER), 7(5): 30 – 38.

Astari, L., Prasetiyo, K.W. & Suryanegara, L. (2018). "Properties of Particleboard Made from Wood Waste withVarious Size". *IOP Conference Series: Earth and Environmental Science*, 166 (2018) 012004

Bruce, R. (2014) Understanding Wood: A Craftsman's Guide to Wood Technology (Newtown, CT: Taunton Press), p. 235.

Cengiz Guler, Ibrahim Bektas, Hulyaka Laycloglu (2006). The Experimental Particleboard Manufacture From Sun Flower Stalks (*Helianthus annus I.*) and Calabrian Pine (*Pinusbrutia ten*). For Prod j. 56(4).

Chibudike,H.O., Anyakora,A.N., Suleiman, M.A., et al., 2011. Utilization of baamboo intheproductionofceilingboard.J.Eng.Res.16(1),1–10

Ekpunobi,U.E.,Ohaekenyem,E.C.,Ogbuagu,A.S.,etal.,2015.Themechanicalproperties of ceiling board produced from waste paper. Br. J. Appl. Sci. Technol. 5(2), 166–172

Ezeagu C.A, Agboanike O.J, (2020) Experimental Investigation using Design Experiment software for light weight concrete production with sawdust as a partial replacement for fine aggregate. Nigerian journal of Engineering vol 27, (2) pp9-16

Ezeagu C.A, Uzodinma F.C, Chukwuneke P.T, (2022) Effect of grain orientation on the Structural characteristics of Sawdust Laminates. Nigerian journal of Engineering vol 29, (2) pp9-16

Ezeagu C.A, Ugboaja C.E, Okonkwo V.O, (2022). Experimental study on the properties of sawdust concrete with partial replacement of cement with sawdust ash . Journal of Inventive engineering and technology (JIET) vol2 issue 2 pp 1-11

Emmanuel, MU; Edidiong, SS (2020). The Recycling of Sawdust Waste into Particleboard Using StarchBased Modified Adhesive. Comm. in Physical Sci. 6(1):760-766

Ezenwa O.N. Obika E.N, Umembamalu C., Nwoye F.C.. Development of ceiling board using breadfruit seed coat and recycled low density polyethylene Heliyon2405- 8440/© 2019 The Author(s). Published by Elsevier Ltd licensehttps://doi.org/10.1016/j.heliyon.2019.e02712(http://creativecommons.org/licenses/by/4.0/).

Harsavardhaa, A; Murugananandam, I (2017). Preparation and characteristic study of particleboard from solid waste. 14th Int’l conference on Sci. Eng. (ICSET). 263(1):1001

Idehai,O.O.,2012.Retrofitingcompositeceilingtileswithsawdustintroduction.Cuvillier291–295.

Idris, U. D., Aigbodion, V. S. Gadzama, R. M. and Ahmed, T. Y. (2012). Suitability of Maize Cob Particles and Recycled Low Density Polyethylene for Particleboard Manufacturing. *Materials Science*, *MSAIJ*,**8**(1) 34-37.

Isheni, Y., Yahaya, B.S., Mbishida, M.A., et al., 2017. Production of agro waste compositeceiling board (a case study of the mechanical properties). J. Sci. Eng. Res. 4 (6),208–212**.**

Okafor K.K , Ezeagu C.A, (2020) ‘ The analysis of bending stiffness and strength of glue laminated Nigerian timber’,European journal of engineering research and science vol5, n0 2

Madu,O.G.,Nwankwojike,B.N.,Ani,O.I.,2018.Optimaldesignforricehusk-sawdustreinforcedpolyesterceilingboard.Am.J.Eng.Res.(AJER)7(6),11–16.

Olatunji-Osei, O. (2010). Plastic Waste - What is the Solution For Ghana? Retrieved April 7, 2010, from http://ezinearticles.com/?Plastic-Waste---What-is-the-Solution-For-Ghana?&id=3495228

Olatunji-Osei, O. (2010). Plastic Waste - What is the Solution For Ghana? Retrieved April 7, 2010, from http://ezinearticles.com/?Plastic-Waste---What-is-the-Solution-For-Ghana?&id=3495228

Oladele, I.O., Akinwekomi, A.D., Aribo, S., et al., 2009. Development of fiber Reinforced cementitious composite for ceiling application. J. Miner. Mater. Charact. Eng. 8 (8),583–590.

Olorunmaiye, J.A., Ohijeagbon, I.O., 2015. Retrofiting composite ceiling boards withjatropha curcas Seedcake material. J. Production Eng. 18 (2), 96–102.

Olufemi, A.S., Abiodun, O.O., Omaojor, O., et al., 2012. Evaluation of cement-bondedparticle board produced from afzelia africana wood residues. J. Eng. Sci. Technol. 7(6), 732–743

Ogundipei, A.C. 2012. Assessment of Waste from Conversion of Indigenous Timber Species in Ogun State, Nigeria. Bells University Journal of Applied Sciences and Environment l (1), 80-86

Sekaluvu L, Tumutegyereize P and Kiggundu N 2014 Investigation of factors affecting the production and properties of maize cob-particleboards. Waste Biomass Valor. 5 27–32

Stephen,K.,Zachary,O.S.,Joan,J.K.,etal.,2014.Comparative studyofcompositemadefrom ensete false banana fibres and polyethylene with block board. J. EnergyTechnol. Policy 4 (12), 48–54.

Suleiman, I.Y., Aigbodion, V.S.,Shuaibu, I., et al., 2013. Developmentof eco-friendlyparticleboardcompositesusingricehuskparticlesandgumArabic.J.Mater.Sci.Eng.Adv. Technol. 7 (1), 75–91.

A.B Akinyemi, Abdulkareem, S.A. & Adeniyi, A.G. (2016). “ProductionofParticleboards Using Polystyrene and Bamboo Wastes”. *Construction and Building Material*, Vol. 127, No. 3, July 2016, **pp. 436– 441**

Abdulkareem, S.A., Raji, S.A. & Adeniyi, A.G. (2017). "Development of Particleboard from Waste Styrofoam and Sawdust". *Nigerian Journal of Technological Development*, **14(1):** 18 – 22

AdhikaryK.B,PangS.&StaigerM.P.(2008)DimensionalStabilityandMechanical BehaviourofWood-PlasticCompositesBasedonRecycledandVirginHigh- Density Polyethylene (HDPE). Compos Part B39:807–815

Amenaghawon, A.N. & Bienose, K.C. (2016). "Particle Boards Produced From Cassava Stalks: Evaluation of Physical and Mechanical Properties". *South African Journal of Science.* **111(5/6),** 1 – 4.

Anderson, K. R., & Williams, M. P. (2016). Environmental Implications of Breadfruit Seed Coating Particleboard: A Life Cycle Assessment. *Environmental Science and Technology*, 42(5), 1205-1218**.**

ANSI (American National Standards Institute) (2009) American National Standard for Particleboard. ANSI/A208.1. Composite Panel Association, Gaithersburg**.**

ANSI (2009). American National Standards Institute, A208.1-2009, Composite Panel Association, 19465 Deerfield Avenue, Suite 306, Leesburg, VA 20176, USA. ANSI A208.1-2016 – Particleboard.

American Society for Testing and Materials, Standard test methods for evaluating properties of wood-based fiber and particle panel materials. ASTM D1037-12. Annual Book of ASTM Standards. ASTM, West Conshohocken, PA, 2012, pp. 137-155

American National Standard Institute, American National Standard Particleboard. ANSI A208.1-2016. Composite Panel Association, Leesburg, VA, 2016

Atuanya, C.U., Obele, C.M., 2016. Optimization of process parameter for sawdust/recycled polyethylene composites. J. Miner. Mater. Charact. Eng. 4, 270–277.

British Department Env. 323 Wood Based Panels- Determination of Density, European committee for standardization (CEN) (1975).

BS EN 312 (2010) Particleboards. Specifications. European Committee for Standardization, Brussels

Bufalino, L., Albino, V.C.S., De Sa, V.A., Correa, A.A.R., Mendes, L.M. & Almeida, N.A. (2012). "Particleboards made from Australian Red Cedar: Processing Variables and Evaluation of Mixed-Species". *Journal of Tropical Forest Science*, **24(2): 162 -172.**

Chen, Y., et al. (2018). Effect of Urea-Formaldehyde Resin Modified with Silicon Dioxide on the Properties of Rice Husk Particleboard. BioResources, 13(4), 7682-7696.

Chibudike,H.O., Anyakora,A.N., Suleiman, M.A., et al., 2011. Utilization of baamboo intheproductionofceilingboard.J.Eng.Res.16(1),1–10.

Debdoubi A, J. Cano, R. Kiveka, E. Colacio, Production of Fuel Briquettes From esparto partially pyrolyzed. Energy Conversion and Management 46, 2004, 1877-1884.

Ekpunobi,U.E.,Ohaekenyem,E.C.,Ogbuagu,A.S.,etal.,2015.Themechanicalproperties of ceiling board produced from waste paper. Br. J. Appl. Sci. Technol. 5(2), 166–172

Elehinafe, F.B., Okedere, O.B., Odulami, O.A., Mamudu, A.O. & Bamidele, S.F. (2019). "Proximate Analysis of the Properties of some Southwestern Nigeria Sawdust of Different Wood Species". *International Journal of Civil Engineering and Technology (IJCIET)*, 10(3): 51 – 59.

Ezeagu C.A, Agboanike O.J, (2020) Experimental Investigation using Design Experiment software for light weight concrete production with sawdust as a partial replacement for fine aggregate. Nigerian journal of Engineering vol 27, (2) pp9-16

Ezeagu C.A, Uzodinma F.C, Chukwuneke P.T, (2022) Effect of grain orientation on the Structural characteristics of Sawdust Laminates. Nigerian journal of Engineering vol 29, (2) pp9-16

Ezeagu C.A, Ugboaja C.E, Okonkwo V.O, (2022). Experimental study on the properties of sawdust concrete with partial replacement of cement with sawdust ash . Journal of Inventive engineering and technology (JIET) vol2 issue 2 pp 1-11

Han, G.; Zhang, C.; Zhang, D., Umemura, K. and Kawai, S.; (1998), Upgrading Of Urea Formaldehyde-Bonded Reed and Wheat Straw Particleboard Using Silane Coupling Agents. Journal of Wood Science, Vol 44, pp 282-286, Springer

Idris, U. D., Aigbodion, V. S. Gadzama, R. M. and Ahmed, T. Y. (2012). Suitability of Maize Cob Particles and Recycled Low Density Polyethylene for Particleboard Manufacturing. *Materials Science, MSAIJ*,**8**(1) 34-37.

Idehai,O.O.,2012.Retrofittingcompositeceilingtileswithsawdustintroduction.Cuvillier291–295.

Isheni, Y., Yahaya, B.S., Mbishida, M.A., et al., 2017. Production of agro waste compositeceiling board (a case study of the mechanical properties). J. Sci. Eng. Res. 4 (6),208–212.

Kelly, M.W (1977). Critical Literature Review of Relationship between Processing Parameters and Physical Properties of Particleboard. USDA, Forest Service, Forest Products Laboratory, Madison, Wisconsin

Madu,O.G.,Nwankwojike,B.N.,Ani,O.I.,2018.Optimaldesignforricehusk-sawdustreinforcedpolyesterceilingboard.Am.J.Eng.Res.(AJER)7(6),11–16.

M.V Scatolino, D.W Silva, R.F Mendes, I.M. Mendes, Use of Maize cob for Production of Particleboard, 2015 retrieved from dol: 10.1590/51413-70542013000400006

Olatunji-Osei, O. (2010). Plastic Waste - What is the Solution For Ghana? Retrieved April 7, 2010, from http://ezinearticles.com/?Plastic-Waste---What-is-the-Solution-For-Ghana?&id=3495228

Oladele, I.O., Akinwekomi, A.D., Aribo, S., et al., 2009. Development of fiber Reinforced cementitious composite for ceiling application. J. Miner. Mater. Charact. Eng. 8 (8),583–590.

Olorunmaiye, J.A., Ohijeagbon, I.O., 2015. Retrofiting composite ceiling boards withjatropha curcas Seedcake material. J. Production Eng. 18 (2), 96–102.

Olufemi, A.S., Abiodun, O.O., Omaojor, O., et al., 2012. Evaluation of cement-bondedparticle board produced from afzelia africana wood residues. J. Eng. Sci. Technol. 7(6), 732–743

Olufemi, A.S., Abiodun, O. O., Omaojor O. and Paul, F. A. (2012). Evaluation of Cement Bonded Particle boards made from Banana stalk (Musa sapientum). Global Journal of Advance Engineering Technologies and Sciences. 2(675):2349-2368.

Rose Marie, Garay Francisco, Macdonald Maria, Luisa Acevedo, Beatrize Calderon, Jaime E. Araya, Particleboard Made From Crop Residues Mixed With Wood From Pinusradiata, Bioresources 4(4)(2009)1396-1408

Smith, A., et al. (2020). Nanoscale Additives for Improving Particle Board Properties. *Materials and Manufacturing Processes*, 37(6), 643-657

Stephen,K.,Zachary,O.S.,Joan,J.K.,etal.,2014.Comparative studyofcompositemadefrom ensete false banana fibres and polyethylene with block board. J. EnergyTechnol. Policy 4 (12), 48–54.

Suleiman, I.Y., Aigbodion, V.S.,Shuaibu, I., et al., 2013. Developmentof eco-friendlyparticleboardcompositesusingricehuskparticlesandgumArabic.J.Mater.Sci.Eng.Adv. Technol. 7 (1), 75–91.