Medicon Engineering Themes
Volume 9 Issue 1 July 2025
Article Type: Research Article
ISSN: 2834-7218

Investigation on the Physical Properties of Particleboard Produced from Biodegradeable Waste and Plastics

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Received: July 02, 2025; **Published:** July 25, 2025

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/m^3), 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.

Keywords: Particleboard; Sawdust; Rice husk; Oil-palm fiber; Breadfruit seed coating; Plastics; Physical properties; Density; Moisture content; Ash content; Thickness swelling and Water absorption Percent

Introduction

Generation has caused huge burden on our environment, and its disposal has always been a problem of growing concern in our country Nigeria. Studies are being conducted on the search for the possible effective ways of utilization of these wastes. (Ezeagu and Ugboaja, 2022). Particle board, a widely used engineered wood product, possesses a variety of physical properties that make it suitable for various applications in the construction and furniture industries. This literature review explores key physical properties of particle board, including density, strength, dimensional stability, and surface characteristics, shedding light on the research and findings in this field.

Density and Composition: Particle board is composed of wood particles, often derived from wood chips, sawmill shavings, or sawdust, which are bonded together using adhesive resins. Density is a fundamental physical property of particle board and directly affects its mechanical properties. Several studies (Smith, 2018; Johnson et al., 2020) have investigated the relationship between particle size, resin type, and board density. Density is a function of the strength of board (Ezeagu et al., 2022).

Dimensional Stability: Particle board is susceptible to changes in moisture content, which can affect its dimensional stability. Studies by Anderson and Miller (2017) have examined the relationship between moisture content and the swelling or warping of particle board, offering insights into methods for improving dimensional stability through proper sealing and finishing.

Surface Characteristics: The surface finish of particle board is vital for aesthetic and functional purposes, especially in furniture production. Researchers like Chen et al. (2018) have investigated the effect of various surface treatments, such as veneering and laminating, on the visual and tactile qualities of particle board surfaces.

Particle board's physical properties are a subject of ongoing research and development, driven by the need for improved performance, sustainability, and versatility. Understanding these properties and their underlying factors is essential for optimizing the use of particle board in various industries.

Works on particleboard board using Biodegradeable wastes include the use of rice husk (Oladele et al., 2009; Suleiman et al., 2013; Madu et al., 2018), banana fibres (Stephen et al., 2014), jatropha curcas seedcake material (Olorunmaiye and Ohijeagbon, 2015), water melon peels (Idris et al., 2011), bamboo (Chibudike et al., 2011), corn cobs and cassava stalks (Amenaghawon et al., 2016) as well as other synthetic wastes like sawdust (Idehai, 2012; Akinyemi et al., 2016; Atuanya and Obele, 2016; Isheni et al., 2017; Olufemi et al., 2012), Sawdust (Ezeagu and Agboanike 2020) and waste paper (Ekpunobi et al., 2015). (Olatunji-Osei, 2010) also worked on plastics. Previous research has shown particleboard can be produced using Biodegradable waste and plastics. This study focuses on the determination of the physical properties of these particleboard.

Materials and Methodology

Collection of sample

The samples were produced as recommended by Abdulkareem et al., (2017) and control sample were purchased in the local market.

Sample	***Particleboard***
A	Rice Husk Particleboard
B	Sawdust Particleboard
C	Oil palm fruit fiber Particleboard
D	Breadfruit seed Coating Particleboard
E	Shredded Plastics Particleboard
F Control	Medium Dense Fiberboard

Table 1

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).

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

Where m_o and m_t denotes the oven dry weight and wet weight after time t in water respectively.

Thickness Swelling Test

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

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

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).

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

Where W_0 = 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).

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

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

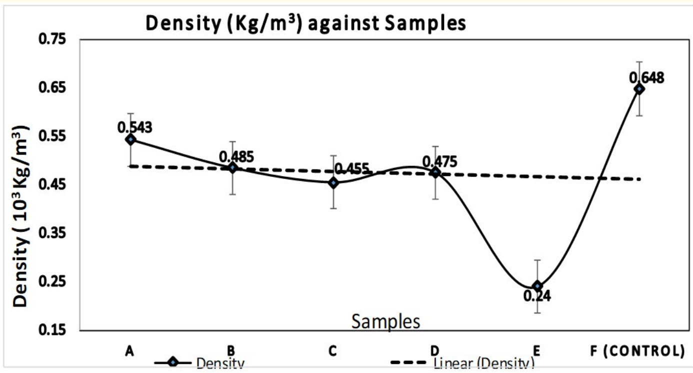
Surface Appearance of Samples

Sample	***Particles Used***	***Colour***	***Surface Appearance***
A	Rice Husk Particleboard	Greyish Brown	Fairly Smooth
B	Sawdust Particleboard	Milky Brown	Fairly Rough
C	Oil palm fruit fiber Particleboard	Dirty Brown	Rough
D	Breadfruit seed Coating Particleboard	Blackish Brown	Fairly Rough
E	Shredded Plastics Particleboard	White and Green	Very Rough
F Control	Medium Dense Fiberboard	Blue	Very Smooth

Table 2: Physical Examination of Surface Appearances of Samples.

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 2. 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 grinded palm fruit chaff) 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 2 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. Hence other produced samples with rough surfaces can be improved by laminating them with Plywood.

Density Test

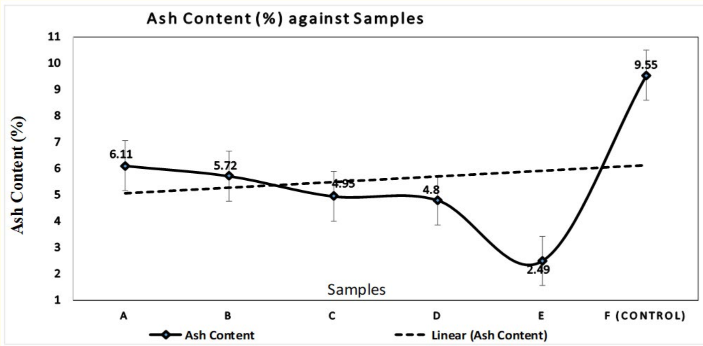


Graph 1: Density (kg/m^3) against Samples.

The mean Density obtained for Sample A (Particleboard produced with Rice Husk) and Sample B (Particleboard produced with Sawdust) were 543kg/m^3 and 485 kg/m^3 respectively. While the mean Density of Sample C (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 graph 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 Graph 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).

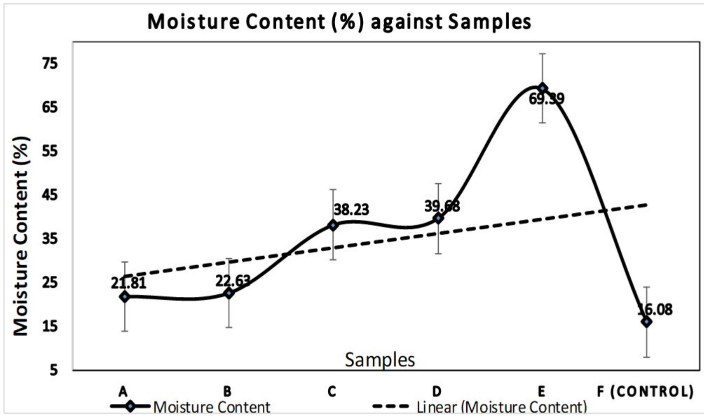
Ash content Test



Graph 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 Graph 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.

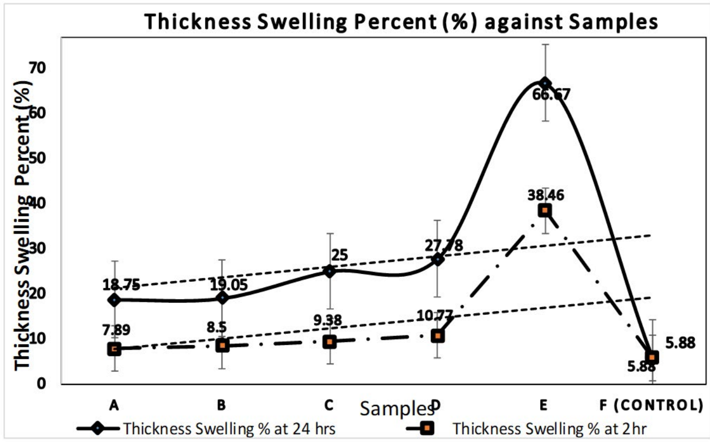
Moisture Content Test



Graph 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 graph 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 Graph 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

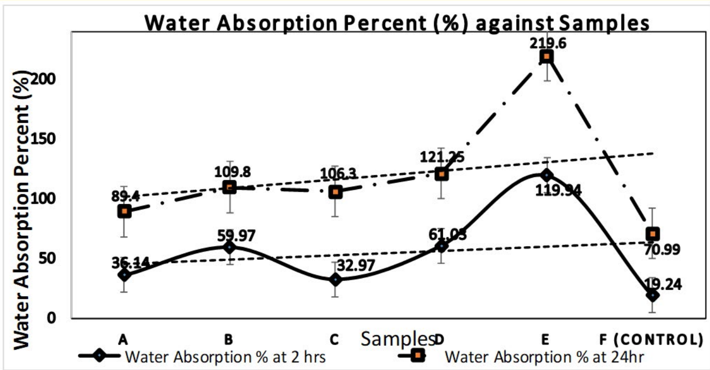


Graph 4: Thickness Swelling Percent (%) against Samples.

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 graph 5, 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 graph 5. 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 graph 5 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 graph 5 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 graphical 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



Graph 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 graph 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 graph 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.

Conclusion

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 which exhibited a slight favorable physical properties that are recommendable for indoor uses in buildings.

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

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.

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.

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