Journal of Research in Forestry, Wildlife & Environment Vol. 16(3) September, 2024
E-mail: *jrfwe2019@gmail.com*; *jfewr@yahoo.com*
http://www.ajol.info/index.php/jrfwe
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ISBN: 2141 – 1778
Oriire et al., 2024

ASSESSMENT OF DIMENSIONAL STABILITY AND MECHANICAL PROPERTIES OF PARTICLE BOARD FROM WOOD PARTICLES & CORN COB

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ABSTRACT

This study presents an experimental work which investigates the potentiality of sawdust - corn cob and top bond as adhesive for the production of particle board which was manufactured under pressure by using manual hydraulic press. The mean values obtained for water absorption and thickness swelling at both 24 hours and 48 hours ranged from 14.20 % to 35.65 % and 0.95 % to 35.05 %, respectively, water absorption and thickness values increases as the period of test increased to 48 hours. After 24 hours, the values obtained for water absorption and thickness swelling ranged from 14.20 % to 28.54 % and 0.95 % to 34.33 % but when the immersion period increased to 48 hours, the values also increase by 15.76 % to 35.65 % and 2.89 % to 35.05%. While values obtained for mechanical properties varies among the particle size and mixing ratio. The boards made from particle size had modulus of elasticity as 52.45 Nmm^{-2}, 42.37 Nmm^{-2} and 59.03 Nmm^{-2} and modulus of rupture as 0.57 Nmm^{-2}, 0.57 Nmm^{-2} and 1.37 Nmm^{-2} for fine, coarse and smooth particle respectively. The outcome of mean comparison shows that board made from smooth particle had better strength and more rigid than others, this study show that board made from 40/60 had the better strength and stronger than board made from 50/50 of adhesive to wood residue ratio. The observations from the physical and mechanical properties results showed that the percentage water absorptions of the immersed particle board increases with increasing time of immersion. Particle sizes of the solid material and adhesive ratio, pressing pressure in particle board manufacturing were important factors to determine its strength. Based on the results obtained from this study, it is evident that particle boards can be produced from the mixture of wood particles and corn cob.

Keywords: Dimensional stability, corn cob, and wood residues

Correct Citation of this Publication
Oriire L.T., Oyewumi R.O., Amoo-Onidundu O.N., Adebisi A.A and Adiji O.A. (2024). Assessment of dimensional stability and mechanical properties of particle board from wood particles & corn cob. *Journal of Research in Forestry, Wildlife & Environment* Vol. 16(3): 32 - 41

INTRODUCTION

Global demand for wood and wood-based materials is constantly increasing. Using wood more efficiently to meet projected demands for the production of wood-based panels is a key circular economy principle (Antov *et al*. 2021, Janiszewska *et al.* 2016). The growing environmental concerns and recent legislative regulations, related to promoting the cascading use of natural resources, have posed new challenges to both the wood-based panel industry, related to the optimization of the available wood and other lignocellulosic raw materials, recycling, reusing wood and wood-based composites, and the search for alternative resources (Edzik *et al*. 2021; Jivkov, *et al.* 2021).

A problem for many companies and producers of wood and wood-based products is the insufficient amount of wood on the local market, which results in significant competition between wood-based industries. This competition will become more and more intense due to the expanding production capacities resulting in greater supply as a response to the growing demand (Pedzik *et al*. 2021; Kwidzi *et al.* 2021). The factors affecting the timber market and the increase in the price of timber are random and can occur at any time. The increase in wood prices may be caused by the global economic crisis, market and economic conditions. In turn, the fall in wood prices is often caused by natural disasters and factors, such as storms, in Italy or Austria Gejdoš *et al.* (2021).

The export of significant amounts of unprocessed wood is another reason for the limited availability of wood raw material. The import of wood from other countries is associated with additional transport costs and emissions of harmful compounds. In Europe, the emphasis is on pro-ecological activities and reducing CO_2 emissions. However, since 2015, the amount of exported industrial round wood from European countries has increased from approx. 66 million m^3 to almost 78.5 million m^3 in 2020 FAO (2022).

The wood-based panel industry has certain flexibility about the use of raw materials, caused by the continuously changing wood raw material situation or regional variations of wood supplies. Moreover, the increased demand from other wood-based industries and the energy sector for wood previously used mainly for wood-based panel manufacturing has significantly increased worldwide Hildebrand *et al*. (2017). These challenges have forced the wood-based sector to shift towards alternative raw materials, including recovered wood and by-products from other forest-based industries, as well as to optimize the technological production processes in order to maintain a consistent quality level.

Particleboards are one of the most important value-added panel products in the wood based industry with a wide variety of applications Bekhta *et al*. (2021). Compared to the pulp and paper industry or construction, the production of particleboards can utilize low-quality raw materials. Proper waste management, including wood and wood-based by-products, is of great importance for the environment Faraca *et al*. 2021). Many authors have investigated the potential applications of a particular material or the selection of appropriate manufacturing conditions, such as the type and amount of adhesive used or the temperature and pressure applied (Papadopoulos *et al*.2006; Sandak, *et al*. 2018; Gumowska *et al*. 2018; Borysiuk, *et al*.2018; Cai *et al*. 2010; Nazerian *et al*. 2016; Warmbier *et al*. 2013). In the case of the expected deterioration of the technological properties of the boards with the addition of various alternative lignocellulosic raw materials, one possible way to counteract these undesirable effects is to increase the amount of binder Dukarska, *et al*. (2015).

The selection of the resin type and content is made on the basis of assumptions regarding the selected properties and projected applications. Traditionally, composite panel manufacture is based on materials obtained from wood. Along with the growing production of Particle board, the raw material mix has extended and shifted over the years. While at the beginning, industrial wood acquired from the forest was the predominant resource, the ratio of industrial waste wood increased over the past five decades, the amounting in 2005 was 54%. Additionally, during the 1990`s, wood scrap and recycled Particle boards were introduced. Today, the material mix consists of 60 to 70% industrial waste wood, 10 to 20% industrial wood from the forest and 10 to 20% wood scrap and recycled Particle board Kuntz (2009). This study aims to evaluate the suitability of corn cob reinforced with wood particle in production of particle board with reference to its dimensional stability and mechanical properties

MATERIALS AND METHODS

Study Area:

The study was done in Forestry Research Institute of Nigeria (FRIN) located in Jericho hill Ibadan, Ibadan North West local Government Area of Oyo State, Nigeria. Coordinates (7.3911, 3.8582). The climate is typically dominated by rainfall pattern ranging between 1400 m – 1500 m and the temperature of 32^0C (FRIN Annual Metrological Report).

Preparation of Sample

The material collected (Gmelina sawdust and corn cob) was stored in reconstituted wood products section of Forest Product Development and Utilization FRIN Ibadan, at constant room temperature for two months to allow breakdown of wood components such as glucoses, lignin, and cellulose before use. Boards were manufactured based on the experimental design which includes board density at 1000 kg/m^3, particle geometries (i.e. mesh size of 2.0µm and 2.5µm) 2.0 µm (smooth particles), 2.5µm (fine particles) shaft was used for coarse particles.

Experimental Design

The experiment was designed using 2x3 factorial experiment in Randomized Complete Block Design. The main factors are the, mixing ratio and particle size. Analysis of variance was used to determine the level of significance among the factors and the effect of variables on the board's properties.

Laying of the mat

A wooden mould of 350 mm x 350 mm x 10 mm was placed on a metal caul plate covered with polythene sheet on which the mat was formed; plywood plate was used to pre-press the formed mat and covered with another polythene sheet before the top metal caul plate was placed on it. The formed mat was transferred to the cold press and press under a pressing pressure for 24 hours several mats were produced at once, clamped together in the press state. Thereafter, clamps were released, caul plates were removed, and the fabricated boards were stored at ambient temperature to dry. Boards were trimmed to avoid edge effect on test specimens, stored in the laboratory environment at a temperature of 20 ± 2 °C for 21 days. A total of 18 samples were used for dimensional stability test. After drying the samples, they were immersed in water at 30 °C for intervals of 24 and 48 hours at which they were weighed. However, test samples of 195 mm x 50 mm in size were used to determine the MOR; tests were carried out based on standardized procedures stated in American Standard (ASTM D1037, 1978).

RESULTS AND DISCUSSION

Physical properties

The mean values obtained for physical properties values are presented in Table 1, the mean values obtained for water absorption and thickness swelling at both 24 hours and 48 hours ranged from 14.20 % to 35.65 % and 0.95 % to 35.05 %, water absorption and thickness values increases as the period of test increased to 48 hours. After 24 hours, the values obtained for water absorption and thickness swelling ranged from 14.20 % to 28.54 % and 0.95 % to 34.33 % but when the immersion period increased to 48 hours, the values also increase by 15.76 % to 35.65 % and 2.89 % to 35.05%.

The results of analysis of variance for physical properties as presented in Table 2, it was found that variations exist in all the main factors in such that the values obtained for level of significance were found to be lesser than the standard value of 0.05, this implies that there are significant different in all the main factors for water absorption and thickness swelling. It further showed in Table 2 that all the interactions except the three factor interaction were significantly different at 5% level of probability for water absorption. Meanwhile in thickness swelling, three factor interaction and particle size with time exposed and mixing ratio with time were found to be greater than 0.05 level of probability.

Table 1: Mean values obtained for physical and mechanical properties of particleboard using sawdust - corn cob and top bond adhesive

Particle size	Mixing ratio	Time factor (Hours)	Water absorption (%)	Thickness swelling (%)	Modulus of elasticity (Nmm-^{2})	Modulus of rupture (Nmm^{-2})
Fine	40/60	24	20.49±0.66	0.94±0.18	52.23±3.16	0.57 ± 0.14
		48	17.19±6.51	2.89 ±0.53		
	50/50	24	20.33±2.78	12.32±1.13	52.45±12.61	0.45± 0.13
		48	29.38±5.46	14.18±1.26		
Coarse	40/60	24	16.64±3.16	34.33±1.77	36.55±7.57	0.57±0.15
		48	15.76±1.76	35.05±2.09		
	50/50	24	28.54±3.74	33.44±1.41	42.37±13.55	0.51±0.18
		48	35.65±2.26	34.14±0.99		
Smooth	40/60	24	15.05±2.71	17.11±5.57	59.37±25.44	1.37±0.84
		48	17.08±5,33	17.89±4.62		
	50/50	24	14.20±5.28	25.92±3.19	50.67±12.18	0.24±0.16
		48	33.08±1.94	34.91±4.14		

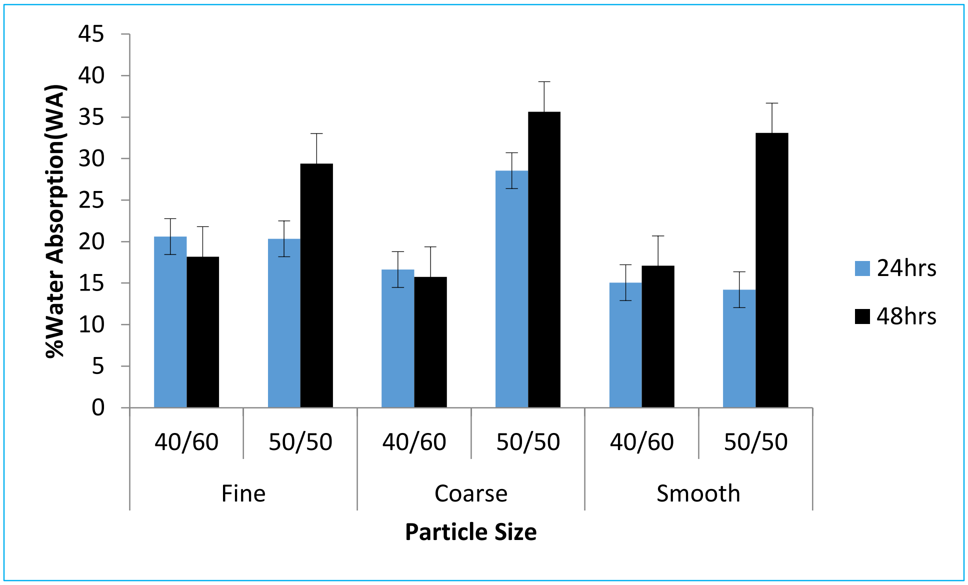

Figure 1: Showing the graph of water absorption at 24 and 48hours of cold water immersion

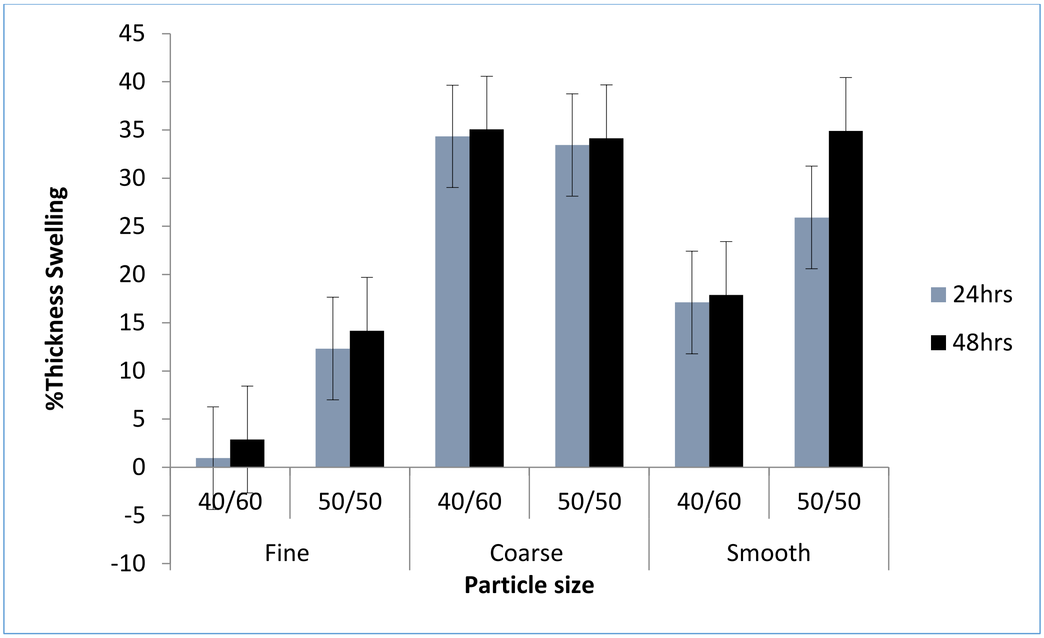

Figure 2: Showing the graph of 24 and 48 hours' thickness swelling of cold water immersion

Table 2: Results of analysis of variance for dimensional stability properties of particleboard using sawdust - corn cob and top bond adhesive

Physical properties	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Water Absorption (WA)	PS	110.882	2	55.441	3.749	0.038*
	MR	837.271	1	837.271	56.622	0.000*
	TIME	285.334	1	285.334	19.296	0.000*
	PS * MR	181.854	2	90.927	6.149	0.007*
	PS * TIME	104.722	2	52.361	3.541	0.045*
	MR * TIME	329.708	1	329.708	22.297	0.000*
	PS * MR * TIME	29.888	2	14.944	1.011	0.379ns
	Error	354.889	24	14.787		
	Corrected Total	2234.549	35			
Thickness Swelling(TS)	PS	4336.128	2	2168.064	270.004	0.000*
	MR	544.561	1	544.561	67.818	0.000*
	TIME	56.443	1	56.443	7.029	0.014*
	PS * MR	343.126	2	171.563	21.366	0.000*
	PS * TIME	27.813	2	13.906	1.732	0.198ns
	MR * TIME	16.438	1	16.438	2.047	0.165ns
	PS * MR * TIME	34.075	2	17.038	2.122	0.142ns
	Error	192.714	24	8.030		
	Corrected Total	5551.298	35			

Table 3: Result of Duncan Multiple Range Test for physical properties of particleboard using sawdust - corn cob and top bond adhesive.

Variables	Levels	Water absorption (WA)	Thickness swelling (TS)
Particle size	Fine	22.12ab	7.59a
	Coarse	24.15a	34.24c
	Smooth	19.85b	23.96b
Mixing ratio	40/60	17.22a	18.04a
	50/50	26.86b	25.82b
Time taken	24 hours	19.23a	20.68a
	48 hours	24.86b	23.18b

Mechanical properties

The mean values obtained for mechanical properties are presented in Table 1, the mean values obtained for modulus of elasticity and modulus of rupture ranged from 36.55 Nmm^{-2} to 67.38 Nmm^{-2} and 0.45 Nmm^{-2} to 1.81 Nmm^{-2} respectively. The value obtained for mechanical properties varies among the particle size and mixing ratio. The boards made from particle size had modulus of elasticity as 52.45 Nmm^{-2}, 42.37 Nmm^{-2} and 59.03 Nmm^{-2} and modulus of rupture as 0.57 Nmm^{-2}, 0.57 Nmm^{-2} and 1.37 Nmm^{-2} for fine particle, coarse particle and smooth particle respectively (Table 5), mean values obtained within the boards made from different mixing ratio were 55.39 Nmm^{-2}, 47.18 Nmm^{-2} and 1.01 Nmm^{-2}, 0.65 Nmm^{-2} for modulus of elasticity and modulus of rupture respectively. The outcome of the results of analysis of variance were presented in Table 4, all the main factor, and two factors interaction except particle size in modulus of rupture were significantly different at 5 % level of probability.

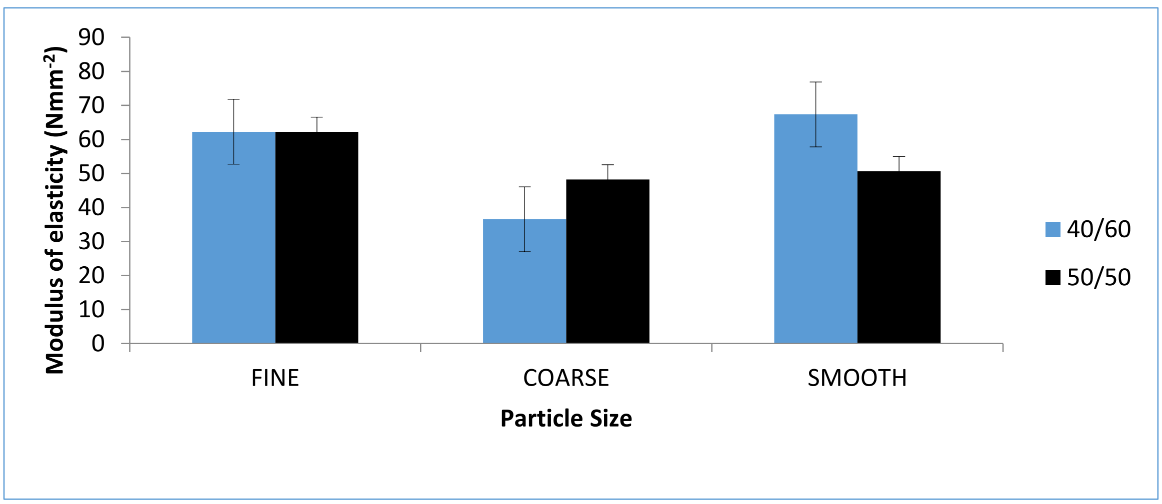

Figure 3: Showing the graph of MOE for all the variable factors

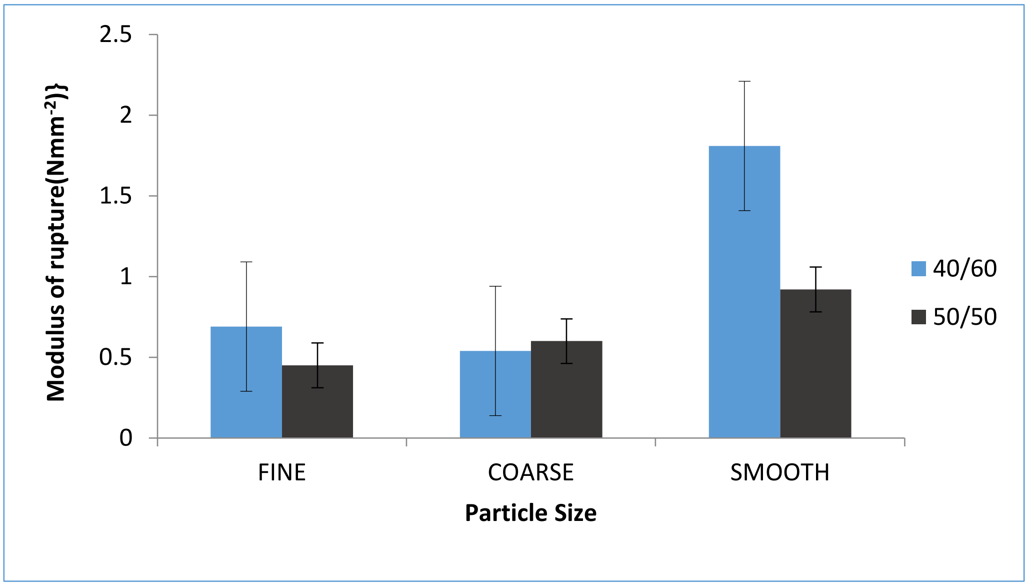

Figure 4: Showing the graph of MOR for all the variable factors

Table 4: Results of analysis of variance for mechanical properties of particleboard using sawdust - corn cob and top bond adhesive

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Modulus of elasticity	PS	844.762	2	422.381	2.103	0.165
	MR	303.401	1	303.401	1.510	0.243
	PS * MR	893.040	2	446.520	2.223	0.151
	Error	2410.413	12	200.868		
	Corrected Total	4451.615	17			
Modulus of rupture	PS	2.528	2	1.264	9.386	0.004
	MR	0.572	1	.572	4.251	0.062
	PS * MR	0.695	2	.347	2.579	0.117
	Error	1.616	12	.135		
	Corrected Total	5.411	17			

Table 5: Result of Duncan Multiple Range Test for Mechanical properties of particleboard using sawdust - corn cob and top bond adhesive

Variables	Levels	Modulus of elasticity	Modulus of rupture
Particle size	Fine	52.45^{b}	0.57^{b}
	Coarse	42.37^{c}	0.57^{b}
	Smooth	59.03^{a}	1.37^{a}
Mixing ratio	40/60	55.39^{a}	1.01^{a}
	50/50	47.18^{b}	0.66^{b}

DISCUSSION

Physical properties of the particle boards produced, variations exist among each factor used in this study. As presented in Table 2, the values obtained for each particle size used in this study revealed that smooth particles had the lowest water absorption value at 19.85% followed by fine particles and coarse particles, this implies that boards made from smooth particles resist moisture intake than the others but averagely swelled at 23.86 %. It was also revealed that boards made from fine particles resist swelling more than others. It was revealed that fine particles and coarse particles were not significantly different to each other while fine and smooth were also not significantly different from each other too but coarse particle and smooth particles were significantly different due to the letters attached “a, b” in water absorption. Also in Table 3, all the particle sizes were significantly varied to each other (a, b and c). Among the mixing ratio, 40/60 was found to be better than 50/50 in the mean values obtained for both water absorption and thickness swelling as presented in (Table 1) and figure. It seems that the embedding of wood inside board restricts expansion. Meanwhile, by using low adhesive – solid particle ratios the solid particles are not totally encapsulated by adhesive, which results in low bonding and therefore in low internal bonding and increased thickness swelling making the particleboards not dimensionally stable when exposed to moisture, this finding is in agreement with Oriire *et al.,* (2016) and Meneeis *et al.,* (2007) which state that increasing adhesive coating on the particles may have a positive impact on thickness swelling. Also in between the time period of exposure to moisture test, values found at 24 hours were lower than 48 hours for values obtained in water absorption and thickness swelling.

Mechanical properties, from this study, factors such as particle size and mixing ratio were found not to have significant influence on the modulus of elasticity meanwhile in modulus of rupture, the particle size and mixing ratio have influence on the boards, the outcome of mean comparison in (Table 1) shows that board made from smooth particle size had better strength and more rigid than others, also between the mixing ratios, board made from 40/60 and 50/50. This signifies that increased in adhesive content contributes positively to the strength of the boards, thereby enhancing the modulus of elasticity in the boards and influenced the particleboards strength properties. However, modulus of rupture (MOR) decreases with an increase in wood-adhesive ratio because higher quantity of wood in the board enhanced flexural properties of the board. It was observed in this study that board made from 40/60 had the better strength and more rigid than board made from 50/50 this work is in line with findings of Dunky and Niemz (2013) and Oriire *et al* (2019) which stated that particle size and mixing ratio influence the strength properties of particle boards.

CONCLUSION

Observations from the physical and mechanical properties results showed that the percentage water absorptions of the immersed particle board increases with increasing time of immersion. The particle sizes of the solid material and adhesive ratio, pressing pressure in particle board manufacturing were important factors to determine the internal bonding. It is concluded that sawdust - corncob with top bond as adhesive can be utilized in the manufacturing of Particle board and use in summer area with long dry seasons or by panting Formica and veneer and can be used for industrial purpose.

Recommendations

There is need to create and increase awareness to the society on the utilization of lignocellulosic materials for particle boards production, production process be improved upon to increase the strength and dimensional properties.

Contribution of Research to Knowledge

This research work has contributed to the knowledge through the production of cost effective particle board with mechanical and physical properties which can be used as kitchen cabinets, doors and speaker box. Industrial production of this particleboard will create employment opportunity for the citizen when exported to neighboring countries. The conversion of waste to wealth also achieved.

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