PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLEBOARD MADE FROM RICE HUSK

[1]Mohammed, I. S., [1]Balami, A. A., [1]Aliyu, M., [2]Ndanaimi, Y. and [3]Ibrahim, A. A.
[1]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M. B. 65, Minna, Niger State Nigeria.
[2]National Biotechnology Development Agency, Abuja Nigeria.
[3]Department of Chemical Engineering, FUT, Minna, Niger State Nigeria.
Corresponding Author's Email: mohd.shaba@futminna.edu.ng; +2347034930688

Abstract

In recent years, depleted resources and environmental concerns have stimulated research in recyclable and renewable materials for particle board production. This paper presents the research work on the production of particle boards using rice (*Oryza glaberrima*) husks and urea formaldehyde (UF) resin as an additives. The variable factors for the rice husk particle board densities were 800 kg/m³, 850 kg/m³ and 900 kg/m³ and pressing temperatures at 70 °C, 77.5 °C and 85 °C. The particle board panels were tested for their physical and mechanical properties. Predictive model was developed for the modulus of rupture. The average peak values obtained for the modulus of rupture (MOR), modulus of elasticity (MOE), linear expansion (LE), internal bending strength (IBS), thickness swelling (TS) and screw holding strength (SHS) were 22.19 N/mm², 1934 N/mm², 0.435 %, 0.35 N/mm², 6.91 % and 932 N respectively. The results show that the MOR, MOE and IBS values obtained were not within the set criteria, except the MOR values of density 900 kg/m³ at 70 °C and 850 kg/m³ at 77.5 °C, IBS values of density 900 kg/m³ at 85°C and 850 kg/m³ at 77.5 °C. The SHS values obtained conform to the set standard, except with density of 800 kg/m³ at 77.5 °C and 850 kg/m³ at 85 °C. The R – square value of the predictive model was calculated to be 82.09 % which show a good correlation between experimental data presented in this study. Rice husk can be considered as a valuable renewable biomass, which could be used for the production of particle board for low cost housing.

Key word: Rice Husk, Urea Formaldehyde Resin, Particle Board, Predictive Model

1. Introduction

Particleboard is a panel produced under pressure from particles of wood or other ligno-cellulosic materials and an adhesive. It has found typical applications as furniture, cabinets, flooring, table, counter and desktops, office dividers, wall and ceiling, stair treads, sliding doors, bulletin boards, and other industrial products (Wang *et al.,* 2008). The demand for wood composites from waste wood has been increasing as timber resources in natural forests decline. The use of renewable biomass as a raw material in composites production was one approach and the use of renewable biomass may result in several benefits such as environmental and socioeconomic (Rowell, 1995). Agricultural residues have become alternative raw materials for particleboard manufacturing. There are already more than 30 plants that utilize renewable biomass in production of particleboards around the world (Mohammad and Morteza, 2011). Therefore, it seems that the number of plants using renewable biomass in production will be more in the future. According to Nemli *et al* (2009) alternative raw materials such as agricultural residues will play an important role in the particleboard industry. Rice husk constitutes about 20 % of the weight of rice. It contains about 50 % cellulose, 25–30 % lignin, and 15–20 % silica (Murat, 2013). At present, most of these residues are burnt *in situ* after harvest. The field burning of rice husk and other agriculture residues in wide areas results in serious environment issues and wastes of precious resources, there has been recently revival of interest in using rice husk and other agriculture residues to produce building materials including composite panels (Zheng *et al.,* 2007; Ye *et al.,* 2007; Copur *et al.,* 2008). The properties of rice husk and other agro-residue fibers were reviewed by Rials and Wolcott (1997). Boquillon *et al* (2004) showed that the properties of wheat straw particleboards using urea-formaldehyde (UF) resins were poor, especially for internal bonding (IB) strength and thickness swelling (TS). Mobarak *et al* (1982) reported that the bending strength up to 130 N/mm^2 and water absorption as low as 10 % could be obtained for bagasse panels produced at 25.5 MPa pressing pressure and 175 °C. In most places where they are available, the husk is put to little economic use and is rather seen as a waste product constituting environmental nuisance. The objective of this work is to evaluate the performance of particle board made from rice husk by determining their physical and mechanical properties. Its use in the production of particle board will reduce the so called environmental nuisance and improved the welfare of the farm.

2. Materials and Methods

The rice husks were collected from central northern region of Nigeria. They were chipped using a hacker chipper before the chips were reduced into smaller particles using a knife ring flaker. The adhesive used was urea formaldehyde (UF) resin at 86.94% solid content (SC). Chips were divided into coarse chips, which passed through 4 mesh and were retained by 8 mesh screen, and fine chips, which passed through an eight-mesh and were retained by a 20 mesh screen. The ratio of coarse/fine chips used for particleboard was 2:1. The chips were oven-dried to 4% moisture content (MC). Dried chips were then blended with UF resin in a rotating drum type mixer fitted with a pneumatic spray gun. Based on oven dry particle weight, 13% UF resin was applied. No wax or any other additives were applied for panel manufacturing. As a hardener, ammonium chloride (NH_4Cl) was applied with 1% weight. The materials were placed in a mould of 400 mm x 400 mm box. The adhesive coated was then inserted into the cold press and pressed to reach 20 mm thickness and was then compressed on aluminum cauls in a hot press until it reached 15 mm stoppers at a temperature of 70 °C, 77.5 °C and 85 °C using a pressure of 150 kg/cm^2 for 5 min and densities of 800, 850 and 900 kg/m^3. After manufacture the boards were conditioned at 20 °C and 60% relative humidity until they reached equilibrium moisture content. After conditioning, test samples were cut from the particleboard panels and the following physical and mechanical properties were determined in accordance with appropriate Japanese Industrial Standard (JIS A 5908, 1994).

2.1 Experimental Design

A two – variable, three – level full factorial design (N = 3^2) provide the framework for the experiments. With two factors and three levels, an orthogonalised design leads to a total of nine experimental runs. In the 3^2 full factorial experiment the low, medium and high levels of the factors were coded as (-), (0) and (+) respectively as reported by Olorunsogo and Agidzi (2010). Data were collected from 3^2 full factorial experiment conducted in a randomized order in three replication as given in the design matrix in Table 1.

Table 1: Design Matrix for a 3^2 Full Factorial Experiment

Run	x_0	x_1	x_2
1	+	-	-
2	+	0	-
3	+	+	-
4	+	-	0
5	+	0	0
6	+	+	0
7	+	-	+
8	+	0	+

9	+	+	+

x_0 = Dummy Variable, x_1 = Density (kg/m^3) and x_2 = Temperature (°C)

The data obtained from the design matrix above was fitted to the regression equation to give the require model equation.

$$y = x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_1^2 + \beta_5 x_2^2 \qquad 1$$

Where β_1, β_2, β_3, β_4 and β_5 are the coefficients of regression.

y = dependent variable and x_1, x_2 = independent variables.

3. Results and Discussion

Results for the particleboard evaluation parameters at three different densities levels of 800kg/m^3, 850kg/m^3 and 900kg/m^3 with three different pressing temperatures levels at 70°C, 77.5°C and 85°C respectively, are presented in Table 2.

Table 2: Rice Husks Particle board Evaluation Parameters at Difference Densities and Pressing Temperatures.

Densities (kg/m^3)	Temperature (°C)	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)	SHS (N)	LE (%)	TS (%)
800	70.0	13.24	1437	0.163	576	0.0134	6.91
850	70.0	16.96	1934	0.196	523	0.234	6.40
900	70.0	22.19	2145	0.210	557	0.198	6.01
800	77.5	10.34	789	0.320	673	0.345	6.10
850	77.5	21.11	1932	0.260	662	0.252	6.30
900	77.5	15.75	1633	0.310	932	0.156	6.03
800	85.0	8.90	1586	0.120	878	0.405	6.17
850	85.0	13.00	1234	0.290	912	0.215	6.09
900	85.0	14.00	873	0.160	218	0.435	6.00

Based on JIS A 5908 -1994 standard, 3000, 18 and 0.30 N/mm^2 are the minimum requirement for MOE, MOR and IB of the particleboard panels for general uses and furniture manufacturing. The average values of MOR and IB obtained were 22.19 and 0.32 N/mm^2 which conformed to standard, also the average value of MOE obtained was 2145 N/mm^2 which does not conformed to standard. The screw holding strength (SHS) of the particleboard produced was found to be 912N which is higher than JIS A 5908 – 1994 standard (500N). According to EN standards, particleboard should have a maximum thickness swelling value of 15% for load-bearing application after 24h immersion (EN312-4, 1996). None of the panels met the minimum thickness swelling requirement of the EN standard for load-bearing application after 24h immersion. The average linear expansion value found from the test carried out was 0.435 % which is higher than the recommended range (0.30 -0.35%) by ASTMD 1037-1994.

The results obtained above was used to developed a model equation to predict the modulus of rupture of the particleboard, the model equation is given as;

$$MOR = -1.140 + 2.272x_1 + 4.621x_2 - 0.0026x_1x_2 - 0.0012x_1^2 - 0.0181x_2^2 \quad 2$$

From the above equation for MOR it can be seen that temperature with regression coefficient of 4.621, has positive impact on the MOR of the particleboard. It therefore means that the higher the temperature the better the MOR of the particleboard. It was also observed from the model equation that the interaction of the two variables (x_1 and x_2) have little effects on the MOR with lower regression coefficient of 0.0026. This interaction has a negative impact on the MOR, it therefore means that the lower the values of the interaction between the two variables the higher the MOR of the particleboard. However, the statistical analysis of the data revealed that all regression coefficient were significant ($P <= 0.05$).

The R- square and mean standard error (MSE) of the model were calculated to be 82.07% and 9.5899 respectively values that validates the model, the MOR of the particleboard show that the change in MOR is mostly explained by independent variables. The R- square values are similar in response variables (82.07% - 80.69%) confirming that the response variable values predicted by the model reflect the actual values obtained by experimental studies which is presented in figure 1.

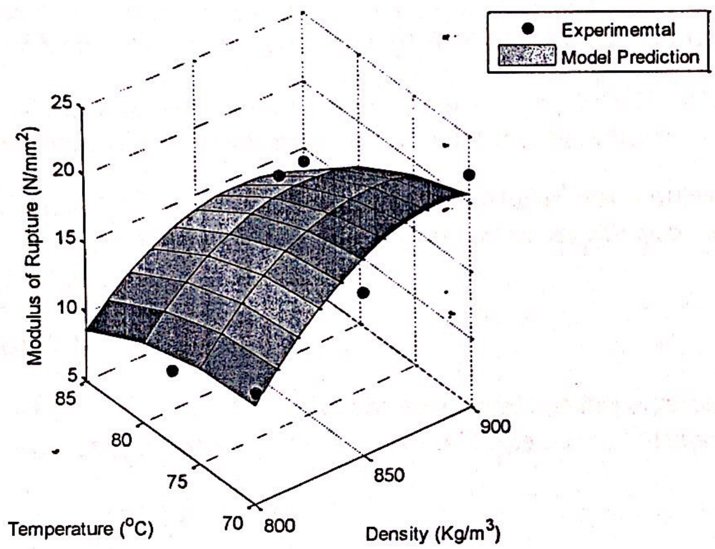

Figure 1: Response Surface of MOR

Figure 2 shows the contour plot of the MOR of the particleboard, from the plot it can be clearly seen that the optimum MOR of the particle board is 20N/mm^2 which is in line with Vanchai (2010).

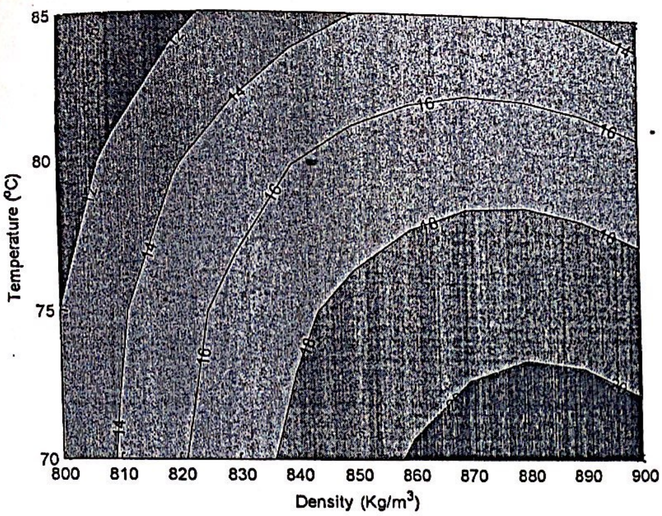

Figure 2: Contour Plot of MOR

Conclusion

In this study, the use of renewable materials such as rice husk for the development of particleboard could enhance the solution of raw materials shortage in particleboard industry. Results showed that particleboards made from rice husk had the requirement of MOR, IB, SHS and LE. The density at 800kg/m^3 and temperature 77.5°C yield the highest IB which is greater than the IB obtained by Vanchai (2010).

The R-square of the regression model developed was calculated to be 82.07% which show that the change in MOR of the particleboard is mostly explained by independent variables.

The temperature at 70°C and density condition of 900 kg/m^3 yields the highest results which is acceptable for production. The above results suggest that it is possible to use rice husk for the production of particleboard for lower cost housing.

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References

American Society for Testing and Material (ASTM) ASTMD 1034-94, (1994). Standard Test Method for Evaluating the Properties of Wood Based Fiber and Particle Panel Materials. ASTM, Philadelphia.

Boquillon, N., Elbez, G., Schonfeld, U. (2004). Properties of wheat straw particleboards bonded with different types of resin. *Journal of Wood Science* 50, 230–235.

Copur, Y., Guler, C., Tascioglu, C., Tozluoglu, A. (2008). Incorporation of hazelnut shell and husk in MDF production. *Bioresource Technology* 99 (5), 7402–7406.

EN 312-2 (1996). 'Particleboards-specifications. Part 2. requirements for general purpose boards for use in dry conditions'. European Committee for Standardization, Brussels, Belgium.

Japanese Industrial Standard Particle Boards (JIS A 5908 1994: Particle Board), (1994).

Mobarak, F., Fahmy, Y., Augustin, H. (1982). Binderless lignocellulose composite from bagasse and mechanism of self-bonding. Holzforschung 36 (3), 131–135.

Mohammad, D. G. and Morteza, N. (2011). Producing Roselle (Hibiscus Sabdariffa) Particleboard Composites. Ozean *Journal of Applied Sciences* 4(1).

Murat, Olgun., (2013). The effects and optimization of additives for expansive clays under Freeze – thaw conditions. journal homepage: www.elsevier.com/locate/coldregions Cold Regions Science and Technology 93. 36–46, Accepted 14 June 2013.

Nemli, G., Demirel, S., Gumuokaya, E., Aslan, M. and Acar, C. (2009). 'Feasibility of incorporating waste grass clippings (Lolium perenne L.) in particleboard composites'. Waste Manage 29:1129–1131.

Olorunsogo, S. T. and Adgizi, D. (2010). Use of Factorial Design Methodology in Fruit Juice Quality Retention Studies. *Journal of Natural Science, Engineering and Technology* 9(2): 1-15

Rials, T.G., Wolcott, M.P. (1997). Chapter 4: physical and mechanical properties of agro-based fibers. In: Rowell, R.M. et al. (Eds.), Paper and Composites from Agro-Based Resources. CRC Press, Boca Raton, FL.

Rowell, R. M. (1995). A new generation of composite materials from agrobased fiber. in *Proceding 3rd International Conference on Frontiers of Polymers and Advanced Materials*. pp. 659–665.

Vanchai, L. (2010). Physical and Mechanical Properties of Particleboard from Bamboo Waste. *World Academy of Science, Engineering and Technology.*

Wang, S.Y., Yang, T.H., Lin, L.T., Lin, C.J. and Tsai M.J. (2008). 'Fire retardant treated low formaldehyde emission particleboard made from recycled wood waste'. *Bioresources Technology* 99:2072–7.

Ye, X.P., Julson, J., Kuo, M., Womac, A., Myers, D. (2007). Properties of medium density fiberboards made from renewable biomass. *Bioresource Technology* 98 (5), 1077–1084.

Zheng, Y., Pan, Z.L., Zhang, R.H., Jenkins, B.M., Blunk, S. (2007). Particleboard quality characteristics of saline jose tall wheatgrass and chemical treatment effect. *Bioresources Technology* 98 (6), 1304–1310