

Recycling of Rice Husk into a Locally-Made Water-Resistant Particle Board

Alao Kehinde Temitope¹, Alao Taiwo Onaopemipo¹, Adeleke Adegbola Olawale¹ and Olalere Olusegun Abayomi^{2*}

¹Department of Mechanical Engineering, Ladoko Akintola University of Technology, Ogbomoso, Nigeria

²Department of Industrial and Production Engineering, University of Ibadan, Oyo State, Nigeria

Abstract

A large quantity of rice husk in Nigerian rice milling industries poses a serious environmental health hazards. Rice husk particleboard is therefore one of such material which may be considered a potential substitutes for woods-based board products.

This study presents an experimental work which investigates the potentiality of rice husk in the production of particleboards using starch wood glue (Top bond) as an alternative source of adhesives. The weighing scale was used to weigh the rice husk, starch, wood glue (Top bond) the mixture ratio adopted being 0.75 kg: 0.15 kg: 0.10 kg of the rice husk, starch, wood glue respectively, thoroughly mixed manually by using the mixer. The mixture was then poured into a mould with a dimension 300 mm × 300 mm × 15 mm. The particleboard was compacted using a hydraulic press in two (2) compacts. The particleboard was tested for water absorption in both cold hot media. The cold absorption test was performed by immersing the composite sample was immersed into the cold water a period of 30mins, 1 h, 2 h, 4 h, 6 h 8 h at room temperature (25°C) the thickness of the board. In hot absorption test, the composite sample was immersed into the hot water with temperature ranging 45°C, 65°C, 85°C and 100°C at constant time of period of 1hour the thickness of the board taken.

The percentages of absorption were then calculated for both the cold the hot medium. The thickness of the particle board produced increases with an increasing time temperature for both the cold hot media water, until a point is reached when a saturation point is attained the board could no longer accommodate any more water. At this point the density remains constant. This value indicates that the board should be reserved for indoor application since percentage water absorption absorbed increases with increasing time of immersion.

It is concluded that rice husk waste can be utilized in the manufacture of a water-resistant particleboard tropical area like Nigeria with long raining season. The use of starch, a biodegradable adhesive reduced the use of the more expensive synthetic adhesive based on petroleum resources. The test results showed that the rice husk, starch wood glue combination provides results which have high potential to be used in the production of particleboard.

Keywords: Particle board; Rise husk; Water-resistant; Biodegradable

Introduction

Rice husk is the by-product in rice milling operation with an approximately 20 percent of the total weight of the paddy grain being processed. The components of this rice husk are therefore determined by the milling method employed [1]. Despite the abundant nature of this waste products its unique physical chemical properties, it is however not being harnessed in Nigeria. Only a little portion of the rice husk produced is utilized in a meaningful way, the remaining part is burnt into ashes or dumped as a solid waste with little being used in animal feed formulation. Its proper used will therefore eliminate waste disposal problem experiences by rice milling industries provide an alternative use that will consequently improve the economic based of Nigeria among the committee of developing nations of the world. This research work will be limited to production of particleboard in small sizes using locally available rice husk adhesives within Oyo State, Nigeria. Rice husk utilization in this way is a waste to wealth project, since rice husk is not being in serious commercial/industrial usage.

Liu [2], investigated the potential uses of rice husk in the production of animal feeds, bedding materials, soil conditioner, fertilizer, bio-fuel, organic inorganic chemicals, carbon, abrasives components, refractory insulating materials, paper board manufacturing, etc.

Ahiduzzaman [3], discussed the increasing applications use of rice husk as a renewable source of energy this is due to the increasing energy cost in developing countries. The rice husk energy content at

14.0% moisture content is 11.9-13.0 MJ/kg (5,116.5-5,589.4 Btu/lbs.) In developed countries, like the US, where rice mills are operating on a large scale are concentrated, rice husk have been used to generate energy for the rice mills themselves [1]. A survey of seven American States reported 10-100% rice husk being used in rice mill boilers [3], the need for building materials in the country is great panels such as rice husk particleboard would contribute to satisfying the need. Its panels can be produced from ligno-cellulosic materials that give them elevated strength. Rice husk particleboard is therefore one such material which may be considered as potential substitutes for wood wood-based board products. The medium-density range of the material is widely used for construction, furniture, interior decoration (wall ceiling paneling). The main raw material used in the particleboard production is wood, but other agro-based residues have been frequently utilized. Annual plant wastes, such as rice husk, bagasse, cotton stalks, peanut husks,

***Corresponding author:** Olalere Olusegun Abayomi, Department of Industrial and Production Engineering, University of Ibadan, Oyo State, Nigeria, Tel: +234(22)8103168; E-mail: olabayor@gmail.com

Received June 08, 2015; **Accepted** June 30, 2015; **Published** July 02, 2015

Citation: Temitope AK, Onaopemipo AT, Olawale AA, Abayomi OO (2015) Recycling of Rice Husk into a Locally-Made Water-Resistant Particle Board. Ind Eng Manage 4: 164. doi:10.4172/2169-0316.1000164

Copyright: © 2015 Temitope AK, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

grape stalks, palm stalks are inexpensive valuable raw materials for particleboard production. The production of panel products from agricultural residues is important considering the increasing worldwide wood fiber shortage [4].

This research work therefore made use of the locally available rice husk from the local milling industry within Oyo state in Nigeria, the properties of the raw material input was determined in relation to the particle board requirements. Because of the reliant of particleboard production on adhesives used as binders, adhesives therefore account for up to 32% of manufacturing costs in the glued-wood composites industry [5]. The use of a cheap binder is therefore imperative. For this research work, starch was used as adhesives or binder in the production of the particle board this is not unconnected to its cheap abundant nature. In this way what was regarded as wastes are being converted to wealth.

Literature Review

Rice husk can be used in the production of roofing tiles used in homes construction industries stated that the harvested rice kernel known as paddy is enclosed by the hull or husks otherwise called rice husk. To obtain the rice husk, the rice paddy is parboiled, dried milled to separate the rice from the husk. He also revealed that the rice husk contains cuticle, a biological membrane that does not allow for easy.

Onyemachi [6] investigated the utility of rice husk its derivatives in the building industry. In the said study, rice husk was subjected to various tests to determine its chemical composition properties. In the process, the liquid limit content of the rice husk ash was established. Compressive strength machine was used to determine the strength of the rice husk concrete. Defeasibility test was also carried out to determine the thermal conductivity of the rice husk. Rice husk has some organic substance which makes it difficult to bind effectively with cement.

Composition of Rice Husk in Relation to its Utilization

The reasons behind the use of rice husk in the construction industry are its high availability, low bulk density (90-150 kg/m³), toughness, abrasive in nature, resistance to weathering unique composition [4].

The main components in rice husk are silica, cellulose lignin. According to Omoniyi [7], rice husk contains high concentration of silica in amorphous crystalline (quartz) forms. The presence of amorphous silica determines the pozzolanic effect of Rice husk. Pozzolanic effect exhibits cementitious properties that increase the rate at which the material gains strength. The extent of the strength development depends upon the chemical composition of alumina silica in the material.

Rice husk used for different applications depending upon their physical chemical properties like ash content, silica content etc. In power plants, rice husk is directly used as a good fuel. It is also used as a raw material for making some compounds like silica silicon compounds. Ndazi et al. [8], opined that rice husk have various application in different industries domestic fields such as an industrial fuel, preparation of activated carbon, rice husk as a fertilizer substrate, as pet food fiber, substrate for silica silicon compound.

Production of Particleboards Using Traditional Method

Producing particleboard panels requires combining wood particles, such as wood chips, saw dust rice husks with suitable binders while applying pressure in the presence or absence of heat [9]. Rice husk is

quite fibrous by nature requires little energy input to prepare the husk for board manufacture. Rice husk density is less than 500 kg/m³. Low density boards possess better thermal insulation properties compared to medium-density boards (Figure 1).

These boards are resistant to attack by termites, wood-boring insects wood decaying organisms [10].

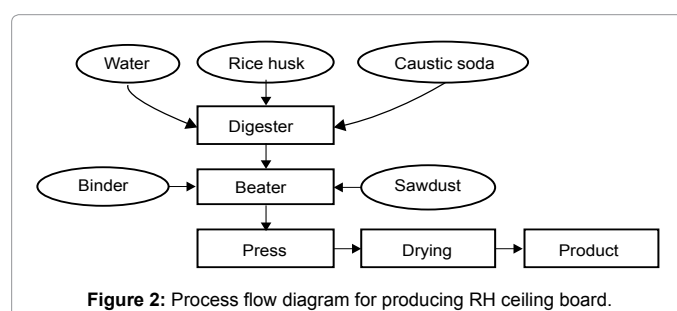
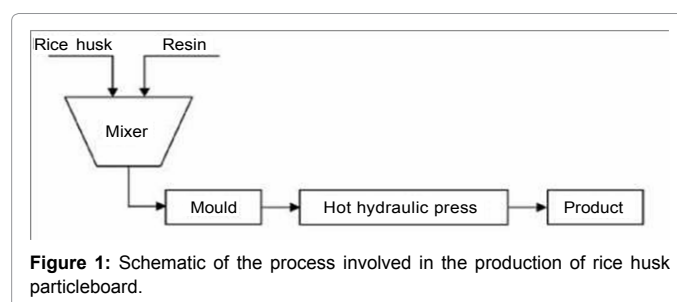
Production of particleboards using classical method

Many types of ceiling roofing materials exist in the market, such as hard boards, paper boards asbestos cement flat sheets boards [11]. The use of Rice husk enables the production of much cheaper ceiling boards. According to Ajiwe et al. [12], the classical method of producing particle board involves combining the rice husk sawdust, with the resulting slurry produced by the heating of rice husk with caustic soda. The slurry is then washed with water beaten into pulp, to which sawdust (filler) glue is added formed into sheets in the press then sun dried. The schematic process flow diagram for the production of particleboard is given below. The boards with the admixture of rice husk sawdust have a higher tensile strength (32 N/m²) compared to only rice husk boards (22 N/m²) are comparable to commercial ceiling boards (23.5 N/m²) (Figure 2).

The Role of adhesives in particle board production

Adhesive is a compound that adheres or bonds particles together. Adhesives are produced from either natural or synthetic sources. Some adhesives produce extremely strong bonds are becoming increasingly important in the modern construction industry. Adhesives are essential extensively used in wood-based composite products. Adhesive type cure schedule vary according to the composite application. Adhesives used in the manufacture of particleboard should be flexible soft to respond to the dynamic effects of swelling shrinkage, yet impart the required strength [4].

They are classified as natural, starch modified starch adhesives. The natural adhesives are also called biodegradable binder they are predominantly water soluble. However, their major limitation is their inability to be used for outdoor purposes.



Starch adhesives is an easily available inexpensive biodegradable whitish material which is typically tasteless odourless. Available starches include corn starch, potato starch, sago tapioca. Starches are modified to increase their stability against excessive physical conditions, to change their texture to modify their characteristics for particular applications [13].

Modified starch can also be formulated to produce rice husk particleboards. The rice husk particleboards are then made using a mixture of modified starch wood fibre together with raw rice husk made available from a rice milling factory. However, these rice husk particleboards are produced by placing the mixture on a flat surface mould drying it under the sun [14].

Material Methods

Materials used for the production of particleboard

The materials required for this work were sourced locally. These are rice husks, starch, wood glue (Top Bond), water.

Collection of rice husk: Rice husks were collected from local rice milling industries in Laka Area, Ogbomoso, Oyo State. The reason for choosing this area is because the rice husks are readily found in large quantities as they are usually carelessly disposed of some eventually find their way into drainage systems, blocking these (Figure 3).

Processing of the rice husk mould preparation: For this work, rice husks were collected separately, for varieties type of rice milled. After the various types of rice husks were collected, the moisture was determined before they were placed separately directly under sun. This was to dehydrate the rice husk for two days. Being in powdery form the drying was quite fast. The rice husk was sieved to two degrees of fineness. The finest particles were used for the surface. This was to ensure very fine surface finish as rice husk of larger particles will give a rough surface finish.

Wood was used for the construction of the mould for the casting operation. The inner part of mould was covered with nylon sheet. This was for the particleboard to have a fine surface finish. The mould was made having a rectangular cross-section measuring 300 mm × 300 mm × 15 mm.

Equipment used for the production of particleboard: The equipment used in this work is listed below;

- **Weighing scale (digital):** This is a measuring instrument use for weighing; shows the amount of mass. The weighing scale was for accurate measurement of the mixes during mixing pouring operations as well as the wet dry weights of the samples. The weighing scale also used to determine the moisture content of the rice husk. i.e. before sun-drying the rice husk after sun-drying the rice husk.



Figure 3: Collection of rice husk from local milling industries.

- **Hydraulic hot press:** The use of hydraulic hot press is to press the mixture of rice husk with starch which have already prepare in the wooden rectangular slash into particleboard.

- **Metal slab:** A slab is a length of metal that is rectangular is cross section. It is created directly from continuous casting or indirectly by rolling an ingot. Slabs are usually further processed via flat rolling pipe rolling.

- **Measuring cylinder:** The measuring cylinder in this work is use to determine the volume (amount) of water is to be added to the mixture of rice husk with the starch during the process of prepare the particleboard.

- **Thermometer:** This is used to measure the temperature of the boiling water of immersion

- **H trowel:** The h trowel is used for the mixture for the surface finishing of the particleboard. The reason for using h trowel is to avoid injury to the h.

- **Sieve:** The use of sieve is to separate the rice husk into two degree of finest. The first is inform of the coarse fineness the second is inform of fine as yam flour.

- **H glove:** The use of h glove is to protect the h from being harm from the delicate chemicals.

- **Wood stirrer:** The useful of wood stirrer is to stir rice husk with the starch during the mixing process.

Production procedure of particleboard

The variable in this work was the percentage binders/hardeners used, while the mass of the milled rice husks was held constant throughout. To produce the particleboard, the weighing scale was used to weigh the rice husk, starch, wood glue (Top Bond). The mixture ratio adopted for this work was 0.75 kg: 0.15 kg: 0.10 kg. These were then thoroughly mixed manually by using wooden stirrer. Thereafter, the mixture was then poured into a wooden mould measuring 300 mm × 300 mm × 15 mm. This was pressed using a heavier medium in two (2) uniform compacts. These however enabled the particleboard to take the shape of the mould cavity giving it a smooth surface free of voids air holes. The mould was then carefully broken the particleboard was carefully removed. After the particleboard was removed from the mould, it was sun-dry for 6 days (Figure 4).

Cure: Curing is the process by which glue/starch adhesive penetrate into the particleboard. The time the glue/starch penetrates into the particleboard was determined. The next step is to allow the particleboard to dry naturally in free air (Figures 5 and 6).

Physical tests on particleboard

Tests were carried on the particleboard samples to find out if they will efficiently serve the purpose of ceiling board in tropical environment characterized with long period raining season. These were presented in

Water absorption test (cold water): The composite sample was immersed into the cold water a period of 30mins, 1 h, 2 h, 4 h, 6 h and 8 h at room temperature (25°C) the thickness of the board taken.

Water absorption test (hot water): The weight of the particleboard to be tested was obtained with the aid of a weighing scale. The particleboard was the dipped into boiling water for 1hour. The particleboard was observed to float; therefore a stone was placed

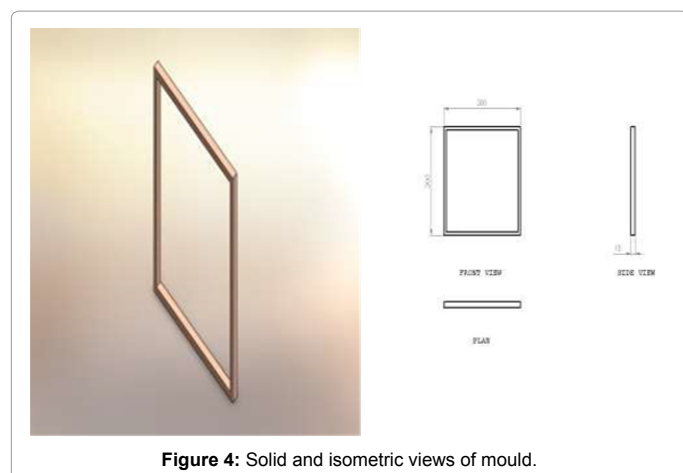


Figure 4: Solid and isometric views of mould.



Figure 5: Particleboard after curing/drying.



Figure 6: Weighing of the particleboard after drying.

on the particleboard so that it will rest at the base of the boiling water container. After 1hour, the particleboard was reweighed the quantity of water absorbed was obtained. The composite sample was immersed into the hot water with temperature ranging 45°C, 65°C, 85°C 100°C at constant time of period of 1hour the thickness of the board taken.

Results Discussions

Physical properties of the particle board produced

Density of the particle board produced: The density of the particle board produced was calculated from the dimension 300 mm × 300 mm × 15 mm as shown from equation (1).

Given that the weight of the particle board=0.96 kg

The Volume of the particle board=Length × Breath ×

$$\text{Thickness}=(300 \times 300 \times 15) \text{ mm}^3=1,350,000 \text{ mm}^3=0.00135 \text{ m}^3$$

Density (kgm³)=Weight of the particle board/Calculated Volume of Particle board (1)

$$=0.96 \text{ kg}/0.00135 \text{ m}^3=711.11 \text{ kg/m}^3$$

Water absorption test (cold water): The particleboard was immersed in cold water the percentage absorption was mathematically described in equation (2).

Percentage Cold Absorption (%)=(Weight after immersion-Weight before immersion)/Weight before immersion × 100

Weight of particleboard before water immersion=0.96 Kg

The composite sample was immersed into the cold water a period of 30 mins, 1 hr, 2 hrs, 4 hrs, 6 hrs 8 hrs at room temperature (25°C) the thickness of the board taken. The results of the densities the percentages of absorptions of the particle board were shown in Tables 1 and 2 respectively (Figures 7 and 8).

The thickness of the particle board produced increases with an increasing time inside the cold water, until a point is reached when a saturation point is attained when the board could no longer accommodate any more water. At this point the density remains constant. This value indicates that the board should be reserved for indoor application since percentage water absorption absorbed increases with increasing time of immersion.

Furthermore, there was no surface change no cracks on the surfaces of the particleboard which would result from the immersion of the particleboard in cold water.

Water absorption test (boiling test)

The composite sample was immersed into the hot water with temperature ranging 45°C, 65°C, 85°C and 100°C at constant time of period of 1hour the thickness of the board taken. The percentage of absorption was then calculated using the equation (3) the result is shown in Table 3 below.

Weight of the particleboard before water immersion=0.96 Kg (Figure 9).

Time of Immersion (Minutes)	Weight of the Board after immersion (kg)	Thickness of swelling (mm)	Volume of the Particle board in water (m ³)	Density of the Board in water (kg/m ³)
0	0.960	15.00	0.001350	711.111
30	0.97	15.02	0.001351	717.987
60	0.99	15.08	0.001357	729.550
120	1.10	15.10	0.001359	809.419
240	1.12	15.15	0.001364	821.114
360	1.12	15.15	0.001364	821.114

Table 1: Result of cold water absorption of the particle-board produced.

Time of Immersion (Minutes)	Weight of the Board after immersion (kg)	Weight of Water Absorbed (kg)	Percentage Absorption (%)
0	0.960	0.00	0.00
30	0.97	0.01	1.04
60	0.99	0.03	3.13
120	1.10	0.14	14.58
240	1.12	0.16	16.67
360	1.12	0.16	16.67

Table 2: Result of estimated percentage absorption of the particle-board produced.

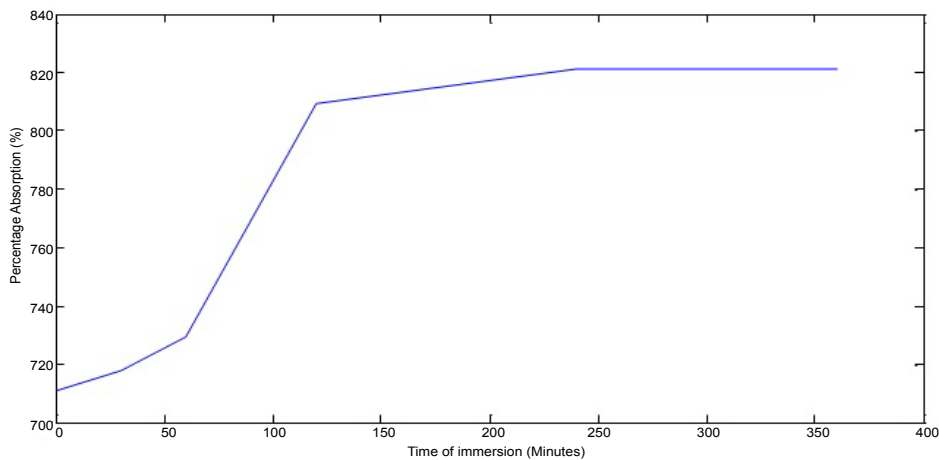


Figure 7: The graph of density of particle board against time.

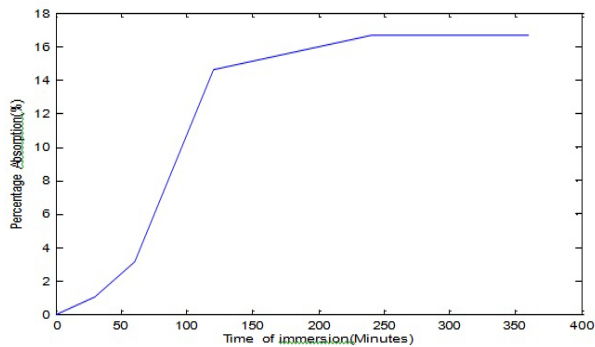


Figure 8: The graph of particle board percentage absorption against time.

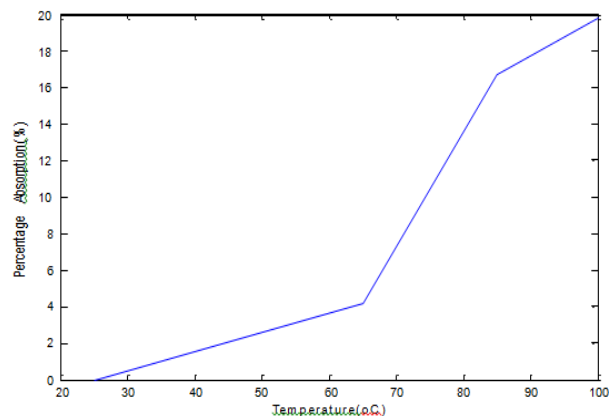


Figure 9: The graph of particle board percentage absorption against time.

Temperature (°C)	Weight of the Board after immersion (kg)	Weight of Water Absorbed (kg)	Percentage Absorption (%)
25	0.960	0.00	0.00
45	0.98	0.02	2.08
66	1.00	0.04	4.17
85	1.12	0.16	16.67
100	1.15	0.19	19.79

Table 3: Result of estimated percentage absorption of the particle-board produced.

The graph of particle board percentage absorption against time

From the Figure 9, the percentage absorption increases as the temperature increases. Furthermore, the surfaces of the particleboard became rough after immersion in hot water cracks on the surfaces of the particleboard which would result from the immersion of the particleboard in boiling water. This emphasizes further that particleboard strictly used for interior application.

Conclusions

It is concluded that rice husk waste can be utilized in the manufacture of particleboard. The use of starch, a biodegradable adhesive reduced

the use of the more expensive synthetic adhesive based on petroleum resources. The test results showed that the rice husk, starch wood glue combination provides results which have high potential to be used in the production of particleboard. The observations from the physical tests conducted showed that the densities the percentage absorptions of the immersed particle board increases with increasing time of immersion. Since the construction industry is a growing industry, the use of renewable resources such as rice husk can reduce the strain on forest resource form excellent replacement for wood wood based composite materials.

References

- Patel PM (2005) Supercritical fluid extraction of rice bran with adsorption on rice hull ash (Doctoral dissertation, Louisiana State University).
- Liu X, Chen X, Yang L, Chen H, Tian Y et al. (2014) A review on recent advances in the comprehensive application of rice husk ash. Research on Chemical Intermediates 1-21.
- Ahiduzzaman M (2007) Rice Husk Energy Technologies in Bangladesh. Agricultural Engineering International: the CIGRE Journal. Invited Overview N0.1.:IX.
- Johnson AC, Yunus YBDN (2009) Particleboards from Rice Husk: a brief introduction to Renewable materials of Construction 12-14.

5. Sellers T (2000) Growing markets for engineered products spurs research. *Wood Technol* 127: 40-43.
6. Onyemachi GA (1997) Effect of Flake Geometry on Selected Mechanical Properties of Gmelina Arborea Flake Board. Unpublished B.Sc Project Report. Department of Agricultural Engineering, University of Ibadan.
7. Omoniyi TE (2009) Development and Evaluation of Bagasse Reinforced Cement Composite Roofing Sheets. Unpublished Ph.D. Thesis, Department of Agricultural Engineering, University of Ibadan.
8. Ndazi BS, Karlsson S, Tesha JV, Nyahumwa CW (2007) Chemical and Physical Modifications of Rice Husks for Use as Composite Panels, Composites Part A: Applied Science and Manufacturing 38: 925-935.
9. Poblete, H (2001) Tableros de particulas, Facultad de Ciencias Forestales, Universidad Austral de Chile. Editorial El Kultrún, Valdivia, Chile, p. 177.
10. Bhatnagar SK (1994) Fire and Rice Husk Particleboard. *Fire and Materials* 18: 51- 55.
11. Kollmann F, Kuenzi E, Stamm A (1975) Principles of Wood Science and Technology II. Wood Based Materials. Springerling-Verlag, New York, p. 703.
12. Ajiwe VIE, Okeke CA, Ekwuozor SC, Uba IC (1998) A Pilot Plant for Production of Ceiling Boards from Rice Husks. *Bioresource Technology* 66: 41-43.
13. Peng W, Fanta GF, Eskins K (1997) Particleboard Made with Starch Based Adhesives.
14. Pan Z, Cathcart A, Wang D (2005) Thermal and Chemical Treatments to Improve Adhesive Property of Rice Bran. *Ind. Crops Prod* 22: 233-240.