

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

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

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

The percentages of absorption were then calculated for both the cold and the hot medium. The thickness of the particle board produced increases with an increasing time and temperature for both the cold and hot media water, until a point is reached when a saturation point is attained and 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 and wood glue combination provides results which have high potential to be used in the production of particleboard.

**Keywords:** Recycling, Rice Husk, Particleboard, Absorption, Water Resistant, Starch.

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## I. 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. (Patel, 2005). Despite the abundant nature of this waste products and its unique physical and 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 use will therefore eliminate waste disposal problem experienced by rice milling industries and provide an alternative use that will consequently improve the economic base 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 and 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 et al (2014), investigated the potential uses of rice husk in the production of animal feeds, bedding materials, soil conditioner, fertilizer, bio-fuel, organic and inorganic chemicals, carbon, abrasives components, refractory and insulating materials, paper and board manufacturing, etc.

Ahiduzzaman, M. (2007), discussed the increasing applications and use of rice husk as a renewable source of energy and 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 and are concentrated, rice husk have been used to generate energy for the rice mills themselves (Patel, 2005). A survey of seven American States reported 10-100% rice husk being used in rice mill boilers (Ahiduzzaman, M. , 2007). The need for building materials in the country is great and 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 and wood-based board products. The medium-density range of the material is widely used for construction, furniture, and interior decoration (wall and 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, grape stalks, and palm stalks are inexpensive and valuable raw materials for particleboard production. The production of panel products from agricultural residues is important considering the increasing worldwide wood fiber shortage (Anbu Clemensis and Nordin Bin., 2009).

This research work therefore made use of the locally available rice husk from the local milling industry within Oyo state in Nigeria, and the properties of the raw material input was determined in relation to the particle board requirements. Because of the reliance of particleboard production on adhesives used as binders, adhesives therefore account for up to 32% of manufacturing costs in the glued-wood composites industry (Sellers, 2000). 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 and this is not unconnected to its cheap and abundant nature. In this way what was regarded as wastes are being converted to wealth.

## II. LITERATURE REVIEW

Rice husk can be used in the production of roofing tiles used in homes and 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 and 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 (1997) investigated the utility of rice husk and its derivatives in the building industry. In the said study, rice husk was subjected to various tests to determine its chemical composition and 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. Feasibility 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.

### 2.1 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 (90-150kg/m<sup>3</sup>), toughness, abrasive in nature, resistance to weathering and unique composition (Anbu Clemensis and Nordin Bin., 2009).

The main components in rice husk are silica, cellulose and lignin. According to Omoniyi (2009), rice husk contains high concentration of silica in amorphous and 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 and silica in the material.

Rice husk used for different applications depending upon their physical and 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 and silicon compounds. Ndazi et.al.,(2007), opined that rice husk have various application in different industries and domestic fields such as an industrial fuel, preparation of activated carbon, rice husk as a fertilizer and substrate, as pet food fiber, and substrate for silica and silicon compound.

**2.2 Production of Particleboards Using Traditional Method:**

Producing particleboard panels requires combining wood particles, such as wood chips, saw dust and rice husks with suitable binders while applying pressure in the presence or absence of heat (Poblete 2001). Rice husk is quite fibrous by nature and requires little energy input to prepare the husk for board manufacture. Rice husk density is less than 500kg/m<sup>3</sup>. Low density boards possess better thermal and insulation properties compared to medium-density boards.

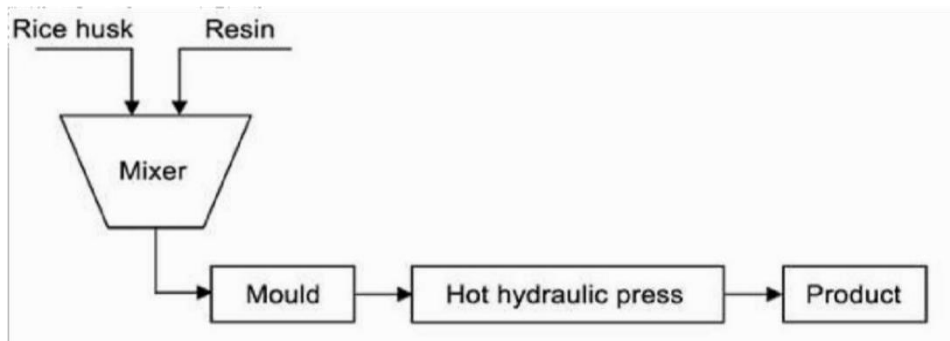


Figure 1: Schematic of the process involved in the production of rice husk particleboard.

Source: (Anbu Clemensis Johnson and Nordin Bin Yunus, 2009).

These boards are resistant to attack by termites, wood-boring insects and wood decaying organisms (Bhatnagar, 1994).

**2.3 Production of Particleboards Using Classical Method:**

Many types of ceiling and roofing materials exist in the market, such as hard boards, paper boards and asbestos cement flat sheets boards (Kollmann et al. 1975). The use of Rice husk enables the production of much cheaper ceiling boards. According to Ajiwe et.al (1998), the classical method of producing particle board involves combining the rice husk and sawdust, with the resulting slurry produced by the heating of rice husk with caustic soda. The slurry is then washed with water and beaten into pulp, to which sawdust (filler) and glue is added and formed into sheets in the press and then sun dried. The schematic process flow diagram for the production of particleboard is given below. The boards with the admixture of rice husk and sawdust have a higher tensile strength (32N/m<sup>2</sup>) compared to only rice husk boards (22N/m<sup>2</sup>) and are comparable to commercial ceiling boards (23.5N/m<sup>2</sup>).

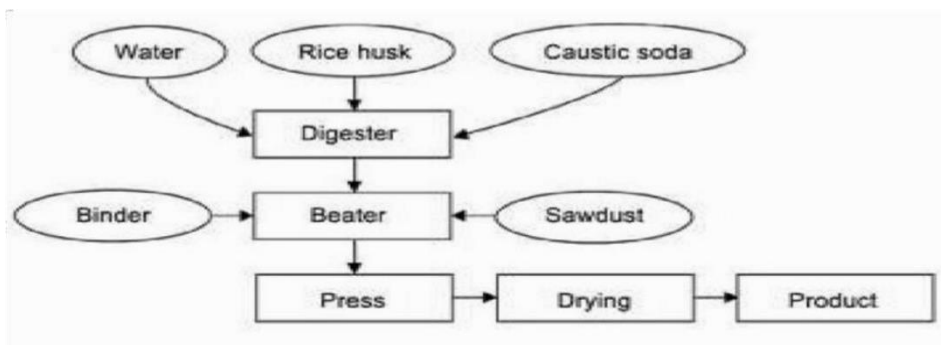


Figure 2: Process flow diagram for producing RH ceiling board.

Source: (Clemensis Johnson and Nordin Bin Yunus, 2009)

#### 2.4 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 and are becoming increasingly important in the modern construction industry. Adhesives are essential and extensively used in wood-based composite products. Adhesive type and cure schedule vary according to the composite application. Adhesives used in the manufacture of particleboard should be flexible and soft to respond to the dynamic effects of swelling and shrinkage, yet impart the required strength (Anbu Clemensis and Nordin Bin., 2009).

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

Starch adhesives is an easily available and inexpensive biodegradable whitish material which is typically tasteless and odourless. Available starches include corn starch, potato starch, sago and tapioca. Starches are modified to increase their stability against excessive physical conditions, to change their texture and to modify their characteristics for particular applications (Peng et.al, 1997).

Modified starch can also be formulated to produce rice husk particleboards. The rice husk particleboards are then made using a mixture of modified starch and 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 and drying it under the sun (Pan et. al, 2005).

### III. RESERCH METHOD AND MATERIAL

#### 3.1 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), and water.

##### 3.1.1 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 and some eventually find their way into drainage systems, blocking these.



Figure 3: Collection of rice husk from local milling industries

##### 3.1.2 Processing of the rice husk and 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  $300 \times 300 \times 15$ mm.

### 3.1.3 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 and pouring operations as well as the wet and 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 and after sun-drying the rice husk.
- **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 in cross section. It is created directly from continuous casting or indirectly by rolling an ingot. Slabs are usually further processed via flat rolling and 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
- **Trowel:** - The hand trowel is used for the mixture and for the surface finishing of the particleboard. The reason for using hand trowel is to avoid injury to the hand.
- **Sieve:** - The use of sieve is to separate the rice husk into two degree of finest. The first is inform of the coarse fineness and the second is inform of fine as yam flour.
- **Hand glove:** - The use of hand glove is to protect the hand 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.

### 3.2 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, and wood glue (Top Bond). The mixture ratio adopted for this work was 0.75kg: 0.15kg: 0.10kg. These were then thoroughly mixed manually by using wooden stirrer. Thereafter, the mixture was then poured into a wooden mould measuring 300mm x 300mm x 15mm. 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 and air holes. The mould was then carefully broken and the particleboard was carefully removed. After the particleboard was removed from the mould, it was sun-dry for 6 days.

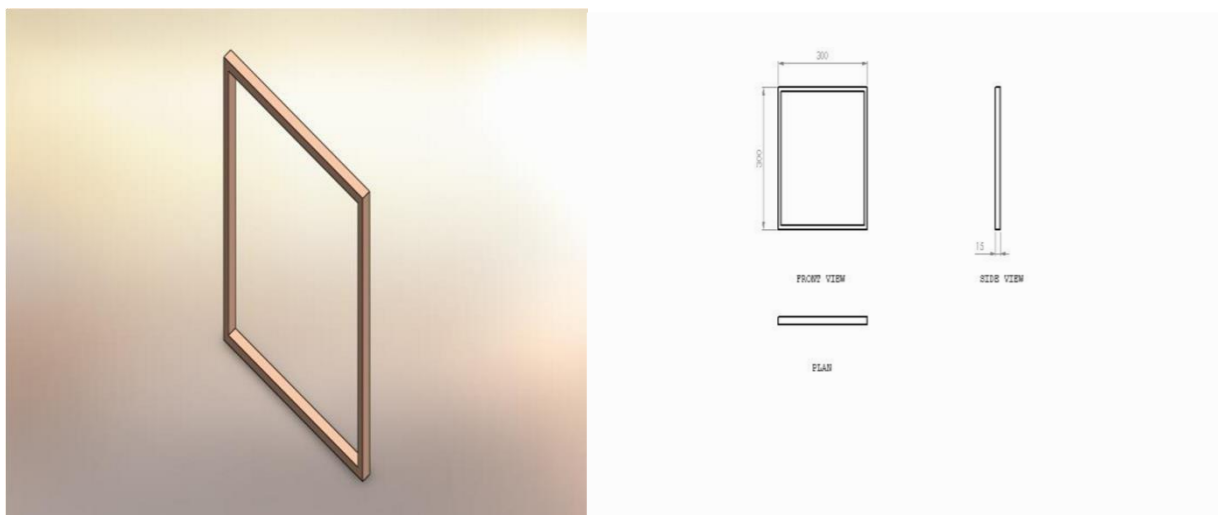


Figure 4 Solid and Isometric views of Mould

### 3.2.1 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.



Figure 5: Particleboard after curing/ drying



Figure 6: Weighing of the particleboard after drying

### 3.3 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

#### 3.3.1 Water absorption test (Cold Water):

The composite sample was immersed into the cold water a period of 30mins, 1hr, 2hrs, 4hrs, 6hrs and 8hrs at room temperature (25oC) and the thickness of the board taken.

#### 3.3.2 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 on the

particleboard so that it will rest at the base of the boiling water container. After 1hour, the particleboard was reweighed and 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 and 100°C at constant time of period of 1hour and the thickness of the board taken.

**IV. RESULTS AND DISCUSSIONS**

**4.1 Physical Properties of the Particle Board Produced:**

**4.1.1 Density of the Particle Board Produced:**

The density of the particle board produced was calculated from the dimension 300mm x300mm x15mm as shown from equation (1).

Given that the weight of the particle board = 0.96kg

The Volume of the particle board =Length x Breath x Thickness= (300 x 300 x 15) mm<sup>3</sup>  
 =1,350,000mm<sup>3</sup> =0.00135m<sup>3</sup>

$$\text{Density}\left(\frac{\text{kg}}{\text{m}^3}\right) = \frac{\text{Weighth of the Particle Board}}{\text{Calculated Volume of the Particl Board}} \dots\dots\dots(1)$$

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

**4.1.2 Water Absorption Test (Cold Water):**

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

$$\text{Percentage Cold Absorption}(\%) = \frac{\text{Weighth After Immersion}-\text{Weighth before Immersion}}{\text{Weighth before Immersion}} \times 100 \dots\dots\dots(2)$$

Weight of particleboard before water immersion =0.96Kg

The composite sample was immersed into the cold water a period of 30mins, 1hr, 2hrs, 4hrs, 6hrs and 8hrs at room temperature (25°C) and the thickness of the board taken. The results of the densities and the percentages of absorptions of the particle board were shown in table1 and 2 respectively.

**Table 1: Result of Cold Water Absorption of the Particle-Board Produced**

Time of immersion(Minutes)	Weight of the Board after immersion(kg)	Thickness of swelling( mm)	Volume of the Particle board in water(m <sup>3</sup> )	Density of the Board in water(kg/m <sup>3</sup> )
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

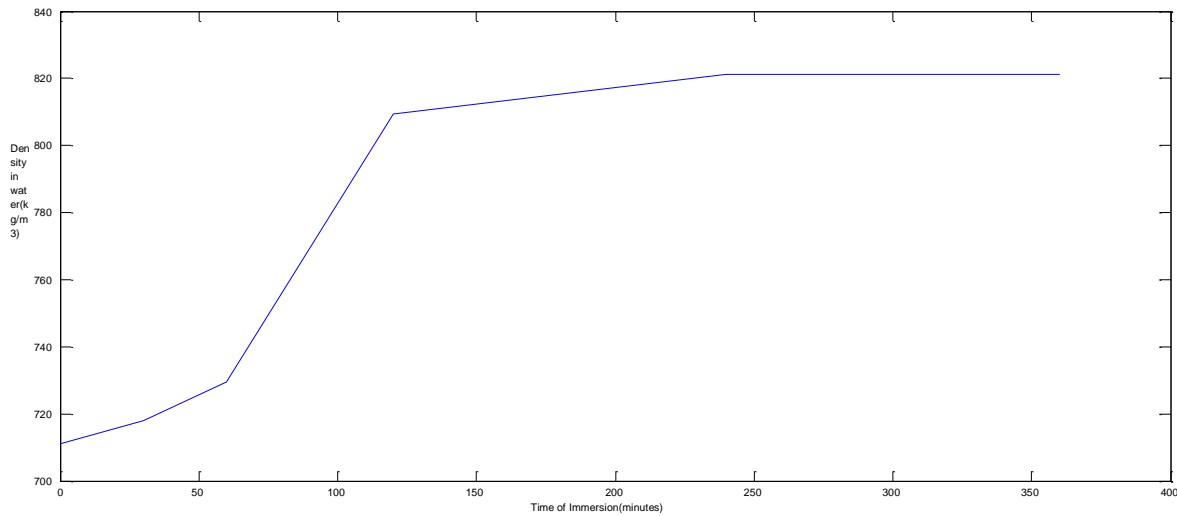


Figure 7: The Graph of Density of Particle Board against Time

Table 2: Estimated Percentage 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

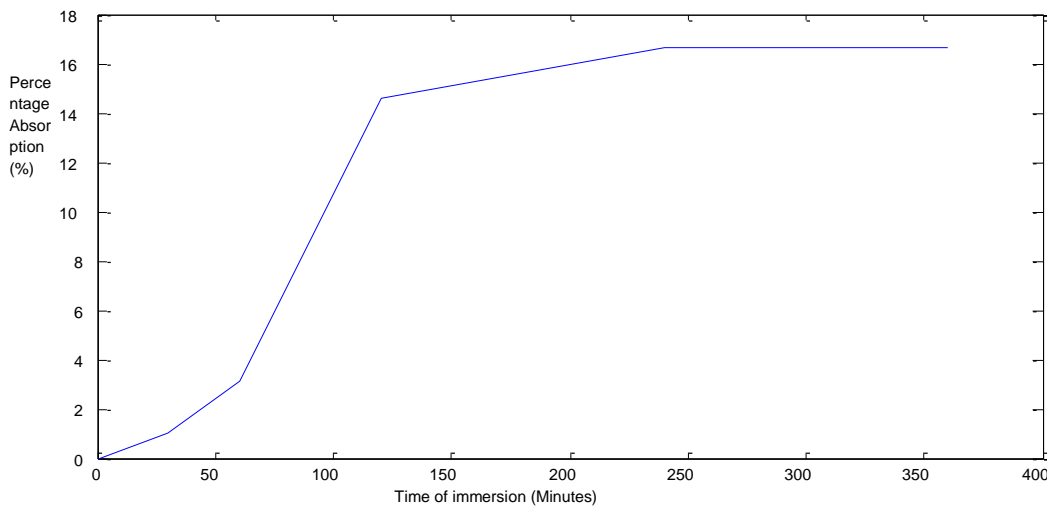


Figure 8: The Graph of Particle Board percentage absorption against time

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 and no cracks on the surfaces of the particleboard which would result from the immersion of the particleboard in cold water.



**4.2 Water Absorption Test (Boiling Test):**

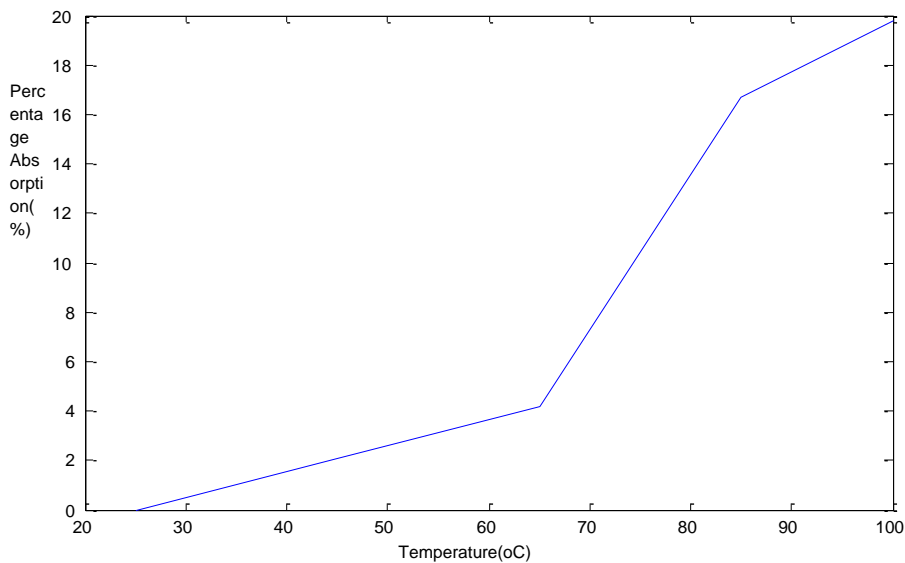
The composite sample was immersed into the hot water with temperature ranging 45°C, 65°C, 85°C and 100°C at constant time of period of 1hour and the thickness of the board taken. The percentage of absorption was then calculated using the equation (3) and the result is shown in table 3 below.

**Table 3: Result of Estimated Percentage Absorption of the Particle-Board Produced**

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

Weight of the particleboard before water immersion = **0.96Kg**

$$\text{Percentage Hot Absorption}(\%) = \frac{\text{Weighth After Immersion} - \text{Weighth before Immersion}}{\text{Weighth before Immersion}} \times 100 \dots\dots\dots (3)$$



**Figure 9: 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 and 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.

**V. CONCLUSION**

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 and 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 and 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 and form excellent replacement for wood and wood based composite materials.

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