UTILIZATION OF SAWDUST AND RICE HUSK FOR PARTICLE BOARD APPLICATION

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ABSTRACT
The increasing amount of agricultural wastes generated is one of the major environmental problems in the country. Without proper segregation and utilization of these materials can cause pollution and may lead to environmental destruction. In this study, a particle board is developed utilizing various composition of sawdust, rice husk and starch. Different formulations of sawdust (30-60%) and rice husk (25-55%) and 15% starch with a fixed quantity of glue were tested for water absorption and density. Meanwhile, the performance of the pressing machine in developing the particle board was also evaluated. The testing of the machine was done to determine the various temperature of both molder and particleboard. Results showed that the maximum temperature of the side cover was 90°C while the surface and core layer temperatures of particleboard were 120°C and 87.62°C, respectively. The water absorption increases as the amount of rice husk decreases. Based on the density, the particle boards were classified as low-density grade type.

Keywords: particleboard, sawdust, rice husk, starch, water absorption, density.

INTRODUCTION
Rice plant or *palay* is sufficient in all parts of Philippines since the country's wet environment is best suitable for this food crop. In 2021, The Department of Agriculture (DA) of the Philippines has targeted to produce 20.4 million metric tons of *palay* (unhusked rice), which is so far, the highest target of rice in the country (DA Communications Group, 2021). As the seventh largest rice-producing country in the world, it generates an abundance of rice husk and rice straw waste, both of which are termite-resistant. However, the uses of rice husks are few and most of it are burned that leads to serious environmental hazards (Ota and Okamoto, 2015). Rice husk is usually high in ash, which is 92 to 95% silica, highly porous and lightweight, with a very high external surface area. Its absorbent and insulating properties are useful to many industrial applications, such as acting as a strengthening agent in building materials (Sulieman *et al.,* 2013).

On the other hand, wood sawdust is abundantly available solid waste in the area as by-product of saw mill enterprises. If these wastes are burnt directly, it results in very poor thermal efficiency and may create a lot of air pollution and contributing to global warming.

Due to the increasing amount of agricultural wastes nowadays, these problems need to be taken care of before it got to worst. One of the many applications of these agricultural wastes in the production on particle boards. Particle boards is a product used primarily in economy especially in construction and furniture sectors. It is one of the primary products used in the manufacture of value-added wood products such asfurniture, cabinets, millwork, stair treads, home construction, paneling, shelving, vanities, table tops, sliding doors, interior signs, lock blocks, kitchen worktops, pool tables, educational establishments, floor underlayment and other industrial product applications (Nemli *et al*., 2009). The usage of particleboard can be related to its economic advantages such as low-cost of raw materials, inexpensive adhesives and its simple processes (Guru *et al.*, 2006). Nassar (2010) studied combination of saw dust waste and rice husk fibers with different binders being used as alternative. Also, Temitope *et al.* (2015) studied the potential of rice husk as substitutes for production of particleboards with the utilization of starch wood glue as binder. The results indicated that the mixture of rice husk, starch wood glue mixture had a high potential to be used in the production.

One advantage of producing particleboards from these composites is the use of waste materials which helps in conservation of natural resources. Further, it will help reduce waste or garbage problem and minimize environmental hazards and devastation.

In this study, it is aimed to develop particleboard with the use of alternative raw materials such as sawdust and rice husk with starch as potential substitute for particleboard formed by a hot-press machine. The composition of sawdust and rice husk were varied and its effects were investigated. It also evaluated the performance of the manually-operated hot-press machine.

MATERIALS AND METHODS

Materials Gathering
The raw materials that used in this study were sawdust and rice husks produced from saw mills and rice mills respectively, and which were acquired in the surrounding areas in Cagayan de Oro City, Misamis Oriental, Philippines. While the binders used were cassava and corn starch were bought from the grocery store, on the other hand the glue was gotten from a hardware store in the vicinity of Cagayan de Oro City, Misamis Oriental, Philippines. The materials were stored in sacks and containers for easy access.

Preparation of Materials

The obtained rice husk was grounded for 2 minutes with the use of a milling machine in Cogon Market, Cagayan de Oro City. Sawdust and rice husks were pulverized separately. Both materials were sieved in screen - no. 5 mesh (4 mm). Different compositions of sawdust (30-60%), rice husk (25-55%) and starch (15%) with a fixed amount of glue was added and used in producing particleboard.

Manufacturing of Particleboard

Figure-1 shows the manufacturing of particle board. In producing particleboard, a weighing scale was used to weigh the sawdust, rice husk, starch and glue. These materials were mixed manually. The mixture was molded to a size of 250 mm x 250 mm x 10mm with the molder plate of the machine. The mixed raw materials were pressed using the fabricated hot-pressing machine. The molding temperature, pressure and pressing time were 120°C, 2 MPa and 10 minutes respectively. After pressing the mixture, the produced boards were sun dried for 4 hours, weighed and cut into desired sizes for various tests.

Figure-1. Manufacturing of the particle board.

Performance of the Machine

Through examining the produced particleboards, the performance of the machine was evaluated. The heat conduction and thermal conductivity of the particleboards were considered in the evaluation.

Maximum Centermost Part of Molder's Side Cover Temperature

Using an infrared thermometer, the temperature of the outer surface of the centermost part of molder's side cover was recorded to determine the temperature that remains constant throughout the surface. A thermal simulation of the molder was then conducted to confirm and validate the recorded temperature. The Solid works software was utilized in the simulation.

Surface and Core Layer Temperature of Particleboard

The maximum temperature of the surface of the centermost part of the molder's side cover was used to determine the surface temperature of the particleboard. Then the surface temperature calculated was used to determine the core layer temperature of the particleboard using the Fourier's law of heat of conduction (in one dimension), as follows:

$$q_x = -kA\frac{dT}{dx} \quad (1)$$

where:

q_x = heat flow in the x-direction

k = thermal conductivity of the material (particle board)

A = area normal to the heat flow direction

$\frac{dT}{dx}$ = temperature gradient

The thermal conductivity, *k*, of particle of the entire mat was estimated as the sum of the conductive heat transfer of the fiber and air layer (Nakaya *et al.*, 2016). Hence, the thermal conductivity of the particle board was computed as follows:

$$k_{particle\ board} = \sum k_i \quad (2)$$

where:

k_i = thermal conductivities of raw materials and air layer

That is,

$$k_{particle\ board} = k_{sawdust} + k_{rice\ husk} + k_{starch} + k_{all\text{-}purpose\ glue} + k_{air\ layer} \quad (3)$$

where:

$k_{sawdust}$ = 0.059 W/m.K (Benallou, 2018)

$k_{rice\ husk}$ = 0.48 W/m.K (Eric & Hensley, 2018)

$k_{cassavastarch}$ = 0.32 W/m.K (Cansee *et al.*, 2008)

$k_{all\text{-}purpose\ glue}$ = 2.63 W/m.K (Thermally Conductive Adhesives, n.d.)

$k_{air\ layer}$ = 0.03164 W/m.K (Li *et al.*, 1997)

Hence, $k_{particle\ board}$= 3.52064 W/m.K.

In computing the core temperature of the particle board, a 95% heat conversion efficiency of nichrome wire was assumed. That is, q_x = 1500 W (0.95) = 1425 W. Moreover, Δx = 0.005mand A = 250 mm x 250 mm = 0.0625m^2.

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Evaluation of Particle Board Properties

After the production of particle board samples, evaluation was conducted in terms of density and water absorption. The panel produced was trimmed based on the specified sizes for the testing procedures.

Density

The density of the products was evaluated to identify what particular grade these particle boards can be classified.

The mass of each product was weighed and recorded. These data were used in getting the densities of the manufactured boards. The volume of the particleboard was calculated by multiplying the thickness of the product by the area. The density is determined by getting the mass of the board before cutting into designated sizes for each test. The density was then calculated according to the following equation:

$$\text{Density (g/cm}^3) = \frac{\text{Weight of the composite sample (g)}}{\text{Volume of the composite sample (cm}^3)} \qquad (4)$$

Water Absorption

Water Absorption test was conducted manually under the testing procedures based on ASTM D1037. It was conducted by weighing the dry sample, after which, was submerged for 24 hours. After 24 hours, the submerged board was reweighed, and the quantity of water absorbed was obtained. The water absorption percentage (%WA) is calculated using the following formula:

$$\%WA = \left(\frac{W_f - W_i}{W_i}\right) \times 100 \qquad (5)$$

where:

W_f = weight of the sample after soaking in 24 hours, (g)

W_i = initial weight of the sample (dry), (g)

RESULTS AND DISCUSSIONS

Outer Surface Temperature of the Centermost Part of Molder's Side Cover of Machine

The average temperature of the outer surface of the centermost part of the side cover using an infrared thermometer was 90°C. In Figure-2, a thermal simulation on the side cover temperature of the molder is shown. The green color shown means that the temperature ranges from 84C - 94°C, which confirms the data gathered from the test.

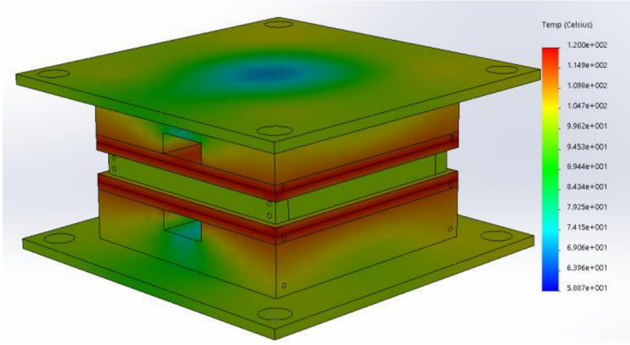

Figure-2. Thermal simulation of molder (top view).

Surface and Core Layer Temperature of Particleboard

The surface temperature value was determined from the thermal simulation result. Figure-3 shows the simulated data on the molder (cut view). This indicates that the temperature was on its peak value, which is equivalent to 120°C. Thus, the temperature of the surface of the particleboard was 120°C.The core layer temperature is calculated using equation 1. The surface temperature is set to 120°C, particleboard's thermal conductivity of 3.52064 W/m·K, surface area of 0.0625m^2 , thickness of 0.005m and q_x is 1425 W. Using equation 1, the calculated value of the core layer temperature was 87.62°C. Data show that the core layer temperature of the particleboard is linearly dependent on its surface temperature. It implies that the heat from the surface conducted through its core layer at a smaller temperature. It can also be observed that the temperature difference of the surface and core layer is at around 32C, which is in agreement to the temperature difference from the study of Kavourras (1997).

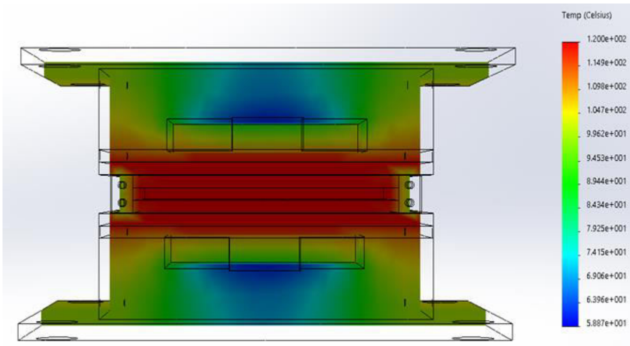

Figure-3. Thermal simulation of molder (cut view).

Fabrication of Particle Board

The fabricated hot press machine can produce one particleboard at a single pressing operation. Figure-4 shows a sample manufactured particle board with sawdust: rice husk: starch of 30/55/15.

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Figure-4. Sample particle board (sawdust: rice husk: starch - 30:55:15).

Water Absorption of the Particle Board

Water Absorption test was conducted based on ASTM D1037. Figure-5 shows the water absorption at various sawdust: rice husk composition. As shown in the figure, water absorption increases as the amount of rice husk decreases. This may be due to the presence of less content of the silica from rice husk which acts as a protecting layer for the water. The same result was also observed in the study of Nassar (2010). Hence, in this particular experiment, sample 1(30:55/ sawdust: rice husk) shows good water absorption capability.

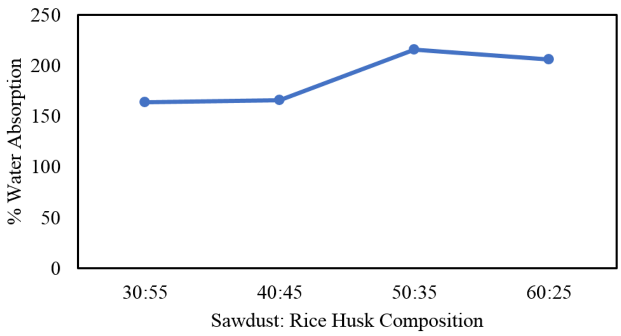

Figure-5. Water Absorption Test of Particle Board at Various Sawdust: Rice Husk Composition

Density of the Particle Board

The density of particleboard was determined to identify what particular grade these particle boards can be classified. Figure 6 shows the density of the particle board at various sawdust-rice husk compositions. As the saw dust percentage increases, a very slight increase in density is observed. Results of this test did not influence the overall performance of the machine and product, instead, the test was conducted to know what type of grade it can be classified. As the data shows, all compositions are classified as Low Density (LD) grade-type of particleboards.

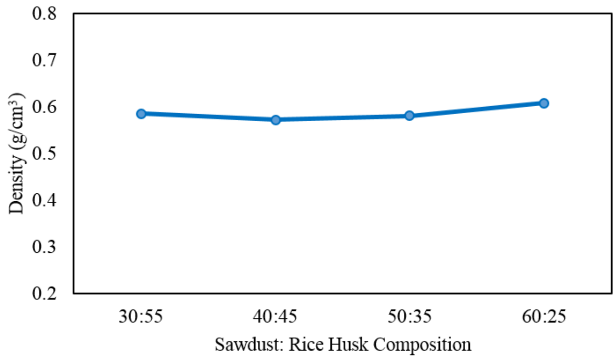

Figure-6. Density of particle board.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the present study, the following conclusions were derived:

a) The maximum outer surface temperature of the centermost part of the molder's side cover agreed with that of the thermal simulation result of the machine's molder. Surface and core layer temperatures of the particleboard were also determined. The core layer temperature was then linearly dependent on its surface temperature. The temperature difference of both particleboard's surface and core layer temperatures was determined and agreed with that of the result of study of Kavourras (1997).

b) Evaluation of the water absorption property of the particle board shows that it is considerably affected by the composition of the mixture. Water absorption increases as the amount of rice husk decreases. No considerable effect of the composition to the density of the board was observed. Results of the density test classified the particle board as low-density (LD) - grade type. It is recommended to conduct some mechanical tests to evaluate the strength of the particle board at various sawdust-rice husk compositions.

REFERENCES

ASTM D1037-12. 2020. Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials, ASTM International, West Conshohocken, PA, 2020, www.astm.org.

Benallou Abdelhanine. 2018. Conduction Applications in Thermal Insulation. In book: Energy Transfers by Conduction. John Wiley and Sons. 55-97.

Cansee S., Watyotha C., Thivavarnvongs T., Uriyapongson J. and Varith J. 2008. Effects of temperature and concentration on thermal properties of cassava starch solutions. Songklanakarin J. Sci. Technol. 30(3): 405-411.

DA Communications Group. 11 January 2021. DA eyes bigger rice production in 2021. https//www.da.gov.ph/da-eyes-bigger-rice-production-in-2021/

Eric G. K. and Hensley B.K. 2018. Analysis of the Thermal Insulation Properties of Rice Husk Ceiling Board Compared to Selected Fibre Based Ceiling Materials Used in Yola Metropolis, Adamawa State Nigeria. American Journal of Mechanical and Materials Engineering. 1(4): 83-88.

Gürü M., Karabulut A. F., Aydın M. Y. and Bilici İ. 2015. Processing of fireproof and high temperature durable particleboard from rice husk. High Temperature Materials and Processes. 34(6): 599-604.

Kavvouras P. K. 1997. Uptake of formaldehyde by MDF wood-fibres. Holzals Roh- und Werkstoff. 55, 323-325.

Li B., K. Kudo and A. Kuroda. 1997. Analysis on effective thermal conductivity of glass wool insulations. SHASE JPN. 65: 7-13.

Nakaya T., M. Yamasaki and Y. Sasaki. 2016. Thermal conductivity and volumetric specific heat of low-density wooden mats. Forest Prod. J. 66(5/6): 300-307.

Nassar Mona A. 2007. Composites from Sawdust-Rice Husk Fibers, Polymer-Plastics Technology and Engineering. 46: 5, 441-446.

Nemli G., Demirel S., Gumuskaya E., Aslan M and Acar C. 2009. Feasibility of incorporating waste grass clippings (Loliumperenne L.) in particleboard composites. Waste Management. 29, 1129-1131.

Ota T. and Okamoto T. 2015. Mechanical Properties of Particleboard Made from Rice Husk. Journal of Materials Science and Engineering B. 5(8): 263-269.

Suleiman Y., Aigbodion V. S., Shuaibu L., Shangalo M. and Umaru W. 2013. Development of eco-friendly particleboard composites using rice husk particles and gum Arabic. J. Mater. Sci. Eng. Adv. Technol. 7, 75-91.

Temitope A. K., Onaopemipo A. T., Olawale A. A. and Abayomi O. O. 2015. Recycling of Rice Husk into a Locally-Made Water-Resistant Particle Board. Ind Eng Manage. 4(164): 2169-0316.

Thermally Conductive Adhesives (n.d.), http://www.creativematerials.com/products/thermally-conductive-adhesives.