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Physical and Mechanical Properties of Particle Board Produced by Sawdust and Straw Rice

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Abstract

Particle board is a widely used engineered wood product that offers numerous advantages, including cost-effectiveness, versatility, and sustainability. In recent years, there has been a growing interest in exploring alternative raw materials for particle board production to reduce dependence on traditional timber resources. This study investigates the physical and mechanical properties of particle boards manufactured using sawdust and straw rice as the primary raw materials, with resin and hardener serving as the binder. Water absorption test, tensile test and bending test were determined based on the mixing ratios according to the standard. This study showed how sawdust and rice straw could be used to make particleboard, which can be used in industry as a raw material to make finished products like cabinets or furniture that are ready to assemble.

1. Introduction

Particleboard is made of wood pieces that are heated and pressed with an adhesive. The demand for particleboard has been steadily rising at a rate of 2% to 5% annually around the world [1]. The rising demand is driven by the construction, furniture, and packaging industries. With the increasing demand for wood-based raw materials and the decreasing supply of raw materials, it is unavoidable that appropriate substitutions are needed.

Rice straw and wheat are two examples of agricultural lignocellulosic fibers that are easily crushed into chips or particles that resemble wood fiber. These could serve as substitutes for raw materials derived from wood. Additionally, these systems aid in the recycling of agricultural waste. Since the supply of solid wood and wood-based materials has been declining, numerous studies have succeeded in creating substitutes for wood particles using lignocellulosic fibers to recycle natural resources and meet demand. In Malaysia, rice straw is widely accessible. Most rice straws were discarded after harvest. Traditionally, the waste will be burned outdoors, which will lead to air pollution and other risks due to the burning activity's intense smoke. Dried rice straw was studied by [2] as a potential fibrous acoustic material for construction. Additionally, acoustic composites made from rice straws mixed with commercial wood particles and urea-formaldehyde as a binder were discovered to be effective as sound-absorbing insulation materials [3].

Furthermore, mixtures of other waste products have successfully created particleboards. In a study [4], particle boards were made from sawdust and cassava waste. Whereas [5] uses paper and sawdust. The results of the study demonstrated that sawdust-made boards had the best qualities. As a bonus, [6] conducted research on ceiling boards made from sawdust and rice husks and tested the results on real-world samples. The results demonstrated that the boards produced had comparable standards to those of commercially available products.

The cutting, grinding, and sanding of planks or boards during milling produces sawdust. Most sawdust is disposed of in landfills or burned outdoors.

Due to their accessibility, sawdust and rice straw were used in this study, whereas resin and hardener, which are frequently used in the production of particleboard, were used as binders. Sawdust and rice straw, abundant byproducts of the wood and agricultural industries, respectively, possess promising characteristics for particle board manufacturing. These materials are often considered waste or underutilized resources, and their incorporation into the production process could mitigate environmental concerns and offer economic benefits.

The findings of this study will contribute to the growing body of knowledge on sustainable alternatives for particle board manufacturing and inform decision-making processes in industries seeking eco-friendly solutions. Therefore, the physical properties (water absorption content), and mechanical properties (tensile and bending tests) of the board were determined, to investigate the properties of the particleboard. As a result, the properties of the particleboards were assessed in accordance with Japan Industrial Standard for particle boards (JIS A 5908) (2003) standards and American Society for Testing and Material for particle boards (ASTM D1037).

2. Structure

2.1 Material

2.1.1 Rice Straw

The dried rice straw was obtained from a local seller in Kedah. This study uses two forms of particles, namely fine particles, and coarse particles. For fine particles, dried rice straw is ground using a grinder in Biology Structure and Function Laboratory 3 at the University Tun Hussein Onn Malaysia. For coarse particles, the dried rice straws were cut into 10mm to 30 mm pieces. Fig 1 shows the fine and coarse rice straws.

(a) **(b)**

Fig. 1 *Rice straw (a) Fine rice straw; (b) Coarse rice straw*

2.1.2 Sawdust

The sawdust was obtained from a wood technology laboratory at the University Tun Hussein Onn Malaysia. The sawdust we get from the laboratory is the waste material from manufacturing furniture in the factory. The sawdust that was taken is fine for making the particle board.

2.1.3 Binder

Polyester resin was used as the composite binder, along with a catalyst or hardener. Polyether in industry is used for several needs, such as reinforcing tires, ropes, seat belts, making bottles, and films. The resin is used according to standard. The catalyst here is employed to facilitate the drying of the resin. Two percent of the weight of resin is used [6].

2.2 Sample Preparation

To prevent particleboard from sticking to the mould, the mould was cleaned, and the inner surface was covered with aluminum foil. Table 1 shows the amount of matrix material utilized in the particleboard as well as the mix ratio.Rice straw and sawdust were weighed with an electronic balance before manual mixing. The particles and resin were manually combined, and the mixture was agitated until it was homogeneous. After that, the mixture was placed into the mould, spread, and transferred to a hydraulic press with a pressing load of 10 tons. Before removal, the particleboards were left to dry at room temperature for at least 4 hours to cool down the particleboard. The procedure of making particle board is as in Appendix.

Table 1 *Property of the particle board*

Item	Sawdust (g)	Rice straw (g)	Resin (g)	Hardener (g)
1	270.00	0.00	162.00	3.42
2	0.00	270.00	162.00	3.42
3	135.00	135.00	162.00	3.42

2.3 Testing Method

2.3.1 Physical Properties

Particle boards require physical property testing to assess their performance and appropriateness for different applications. These tests aid in identifying the board's mechanical durability, dimensional stability, resistance to moisture, and other crucial properties. These tests enable producers, academics, and customers to make well-informed choices on the usage and quality of particle boards.

The ability of a particle board to absorb and hold moisture is determined by conducting a water absorption test on it. This test aids in identifying the board's capacity to swell, its dimensional stability, and its vulnerability to moisture-related problems like warping or delamination. The water absorption test for particleboard is a fundamental evaluation conducted to assess the board's ability to resist water penetration and retain its structural integrity. The commonly engineered wood product known as particle board, commonly referred to as chipboard, is made of wood chips or particles that have been bonded with resin or adhesive. This test assists in determining whether the board is suitable for various applications, particularly those involving exposure to moisture or humidity. The procedure for this test is as in Appendix.

2.3.2 Mechanical Properties

Particleboards are subjected to tensile and bending tests in order to assess their mechanical characteristics and identify the applications for which they are most suitable. Testing materials for strength, stiffness, and durability, including particleboards, is frequently done using tensile and bending methods. Overall, tensile and bending tests assist in material selection, quality assurance, and design considerations for various applications by evaluating the mechanical performance of particleboards. These tests offer important information about the load-bearing capacity, structural integrity, and general toughness of particleboards in a variety of applications, including furniture construction, flooring, and other wood-based ones. This test was conducted at the University Tun Hussein Onn Malaysia's Automotive Laboratory.

2.3.2.1 Bending Test

The bending tests were conducted in accordance with the ASTM D1037 standard. This 3-point bending strength was determined using a Universal Testing Machine (UTM) as shown in Fig 2. Specimens were prepared with standardized dimensions and subjected to three-point bending using a universal testing machine. The sample was prepared in a rectangular-shaped piece of particleboard with a measurement of 180mm x 25mm x 5mm. In a three-point bending test, the sample rests on two supports with a defined distance between them, while the load is applied at the center of the sample. Place the particle board sample onto the supports of the bending apparatus, ensuring it is aligned properly and firmly secured in place.

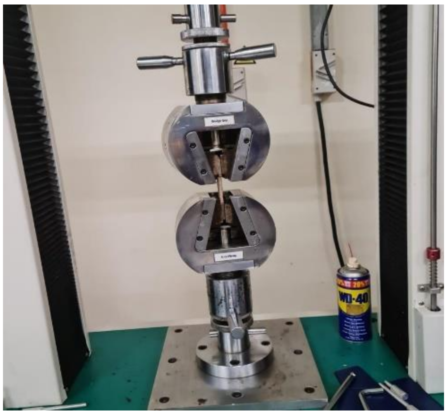
Gradually apply a load to the center of the particle board sample by using the Universal Testing Machine. The test was conducted at a pace of 30 mm/min across the waist of the specimen. As the load is applied, measure the amount of bending that occurs in the sample. Record the load and corresponding deflection values at regular intervals. The load should be applied at a constant rate until the sample reaches the desired deformation or until it fails. The load-displacement data were recorded during the tests, and the bending strength and modulus of elasticity were calculated. The bending strength of the particleboard was determined as the maximum stress experienced before failure under bending loads. The results showed variations in bending strength based on panel density, resin content, and thickness. A statistical analysis was performed to assess the significance of these factors on bending strength.


(a) **(b)**

Fig. 2 *3-point bending test (a) Sample in rectangular (b) 3-point bending test*

2.3.2.2 Tensile Test

According to ASTM D1037, the tensile test was conducted using a universal testing machine as in Fig 3. The specimens were prepared in dumbbell shapes with a measurement of 125mm x 25mm x 5mm and an average waist of 49mm. Each specimen was tested once for each particle board. The Universal testing machine grips a piece of the sample at both ends and gently pulls it lengthwise until it breaks. The displacement of the material is plotted against the pulling force, which is known as a load. The displacement is transformed into a strain value, and the load is transformed into a stress value. The test was conducted at a pace of 30mm/min across the waist of the specimen.

(a) **(b)**

Fig. 3 *Tensile test (a) Sample in dumbbell shape (b) Tensile test*

3. Result and Discussion

3.1 Water Absorption

A water absorption test was conducted based on ASTM D1037 standard. Table 2 and Fig 4 shows the water absorption result.

Fig 4 shows that sawdust particle board has the highest water absorption, which is 82.54%, and particle board mix sawdust and rice straw have the lowest water absorption, which is 52.38% for 7 hours of soaking. For 24 hours of soaking, the rice straw particle board has the highest water absorption, which is 142.86%, and the particle board mix of sawdust and rice straw still has the lowest water absorption, which is 81.82%.

From the graph shows that, the water absorption standard for particle boards typically falls within the range of 6% to 12%, as specified. If the water absorption of a particle board exceeds 100%, it indicates that the board has absorbed more water than its initial weight. This situation is highly unlikely and would suggest a significant failure in the particle board's structure or composition. Exceeding 100% water absorption can have severe consequences for particle boards, including swelling. Excessive water absorption can cause the particle board to swell significantly, leading to dimensional changes and distortion. Other than that, there is structural integrity. The excessive moisture content can weaken the internal bond between the wood particles, resulting in reduced structural integrity and strength.

Table 2: *Water absorption test on particle board for 7 & 24 hours soaking.*

Particle Board	Initial Weight (g)	Final Weight (g)	Water Absorption	
			7 Hours	24 Hours
Sawdust 100 (%)	5.35	10.65	82.54	122.73
Course Rice Straw (100%)	6.15	12.25	70.27	142.86
Sawdust (50%) + Course Rice Straw (25%) + Fine Rice Straw (25%)	7.5	12.4	52.38	81.82

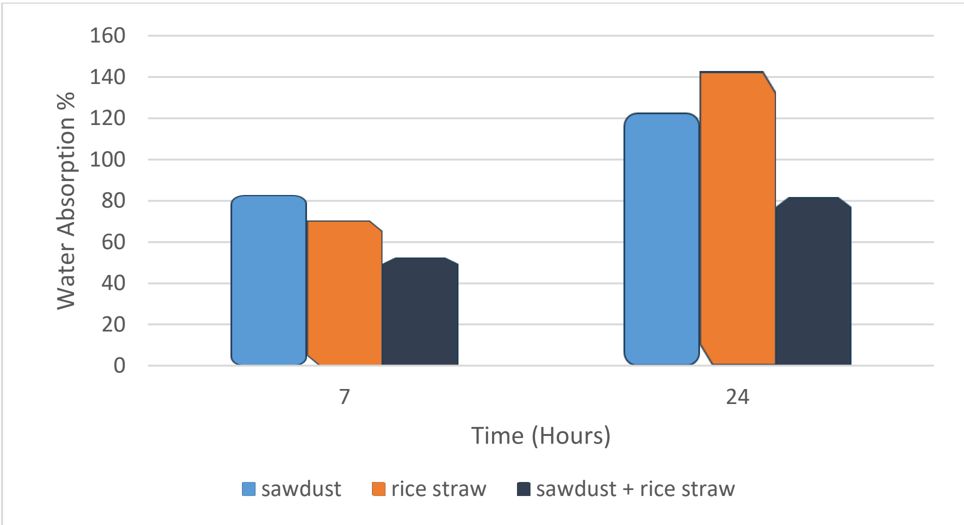
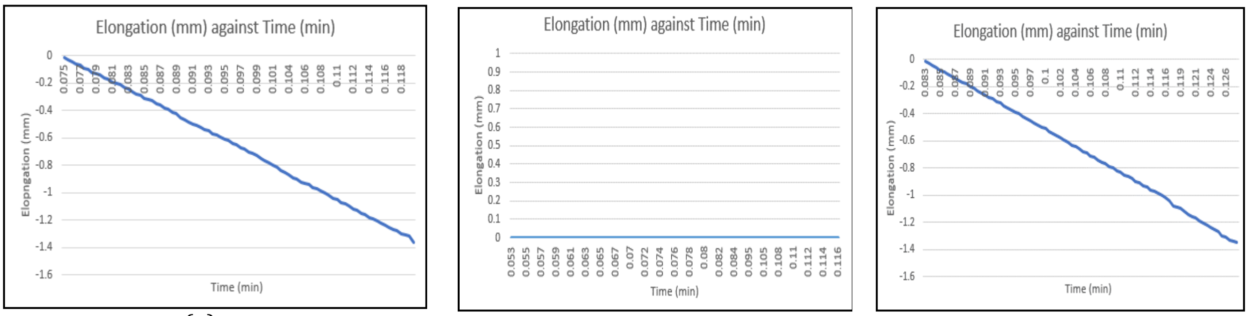


Fig. 4 *Tensile test (a) Sample in dumbbell shape (b) Tensile test*

3.2 Bending Test

The results of the bending test for three samples of particleboard Fig 5 indicated that rice straw-based particleboard could withstand approximately 110N of bending force and sawdust-based particleboard had the lowest bending force approximately 50 N. These results may be attributable to the rice straw's strong bonding with epoxy resin as compared to the sample of particleboard made from sawdust, which had a poorer bond with the resin and hardener.



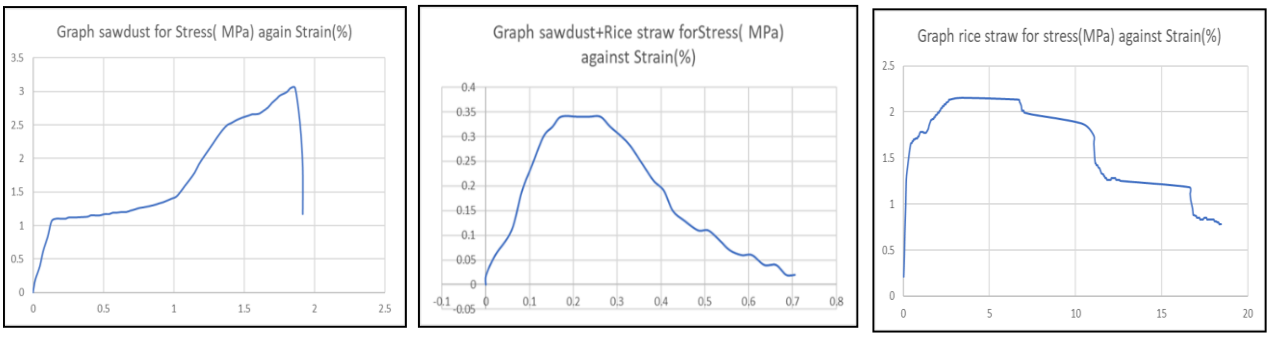
(a) (b) (c)

Fig. 5 *Bending Test Result, (a) Rice straw-based particleboard. (b) Sawdust-based particleboard. (c) Rice straw and sawdust-based particleboard*

The results of the bending tests indicate that the bending strength of particleboard is influenced by various factors, including panel density, resin content, and thickness. Higher panel density generally leads to increased bending strength, as the denser structure provides better resistance against applied loads. Similarly, higher resin content resulted in improved bonding between particles, enhancing the overall strength of the particleboard. Thicker panels also exhibited higher bending strength due to the increased material volume and structural stability.

3.3 Tensile Test

In Fig 6, the tensile strength of particle board at various mixing materials is shown. The tensile strength of the specimen sawdust-based particle board was 3.05 MPa before fail. The tensile strength of the specimen rice straw-based particle board decreased to 2.15 MPa before its failure. It shows that the sawdust particle board has more tensile strength, which is almost 0.9 times higher than rice straw. The combination of sawdust and rice straw particle board shows the lowest tensile strength among the other particle boards [7].



(a) (b) (c)

Fig 6 *Tensile Test Result, (a) Sawdust based particle board, (b) Rice straw – based particle board, (c) Rice straw and sawdust-based particleboard.*

The results received show that each particle board has a different tensile strength. The tensile strength of a particle can be affected by numerous factors, including panel density, the content of the particle board, thickness, and resin content. A good mixture of material and resin will impact the particle board when particles are pressed and develop better bonding between particles in each board. Too much resin may also make the panels lose their tensile strength. The thickness of the panels also gives them more tensile strength; when the panels are more compact, it is better.

4. Conclusion

In conclusion, this project study investigates the feasibility of producing particleboard from sawdust and rice straw and evaluates its bending strength, tensile strength, and water absorption properties. The results obtained from the experimental testing provide valuable insights into the potential applications of this sustainable composite material. The bending tests conducted on the particleboard panels revealed promising results. Particleboard made from sawdust and rice straw has enough strength to withstand bending loads, as evidenced by the maximum bending strengths of rice straw particleboard, mixed rice straw-sawdust particleboard, and sawdust particleboard, which were all close to 110 N, 100 N, and 50 N, respectively. This indicated that the particleboard made from sawdust and rice straw possesses sufficient strength to withstand bending loads. These findings suggest that this composite material has the potential for use in various structural applications where bending strength is a critical requirement. Based on the results of the water absorption test, conclusions can be drawn regarding the particle board's suitability for specific applications and environments. If the board exhibits low water absorption and minimal swelling, it indicates a higher level of moisture resistance and durability, making it suitable for areas with high humidity or potential water exposure.

Conversely, if the board absorbs water excessively and swells significantly, it may not be suitable for moisture-prone areas and could be prone to damage or structural failure. These findings suggest that this composite material has the potential for use in various structural applications where bending strength is a critical requirement. Based on the tensile test, the particleboard made from sawdust and rice straw achieved the minimum tensile strength of the panels. The results obtained in this project suggest that particleboard made from sawdust and rice straw can be a viable alternative to traditional wood-based particleboard. However, further research is recommended to optimize the use of rice straws and sawdust in the manufacturing of particle boards.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design, data collection, draft manuscript, draft manuscript preparation**: Muhammad Ezzat Zulkifli, Zulfadhli Zulkefli, Muhammad Afif Danish Azeli, Aslila Abd Kadir. All authors reviewed the results and approved the final version of the manuscript.

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Appendix

Procedure of making particle board

(a) Cut the rice straw

(b) Mixed with the desire ratio

(c) Compress the particle board for 8 minutes

(d) Cooling down process

(e) sample

Water absorption test procedure

(a) Sample Preparation

(b) Label the Specimens

(c) Weighing the Specimens

(d) Water immersion

(e) Weighing the specimens (after absorption