PROPERTIES OF PARTICLEBOARD MADE FROM WASTE PINEAPPLE LEAVES AND RECYCLED STYROFOAM

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ABSTRACT:. *Transforming agro-industrial waste into a valuable product is one of the most efficient solutions to the overgrowing problem of waste disposal. The main objective of the study is to investigate the use of waste pineapple leaves and recycled Styrofoam in the production of particle board. Boards of 10mm thickness with dimensions of 250 mm x 250 mm are produced from pineapple leaves and melted Styrofoam with gasoline by using a hot-pressing machine at a temperature of 120°C and a pressure of 750 psi. The variables considered in the study are the application of NaOH treatment to the pineapple leaves, the particle size of pineapple leaves of 20mm and 2mm, and pineapple leaves - Styrofoam formulation ratio of 50:50, 60:40 and 70:30. Density (D) test, water absorption (WA) test, thickness swelling (TS) test, and flexural strength (FS)test are evaluated in accordance to appropriate standards. Pineapple leaves subjected to NAOH treatment have a lower density, however, an increased amount of water absorption and swelling are observed compared to the untreated boards. In formulation, increasing the amount of pineapple leaves has caused an increase in density, water absorption, and thickness swelling. Subsequently, the recorded flexural strength of the board ranges from 8.59 to 9.015 kN. This study proves that recycled Styrofoam is a good substitute for formaldehyde-based resin commonly used in particle board industries.*

Keywords: agro-industrial waste, particleboard, pineapple leaves, recycled Styrofoam, physical tests, flexural strength

1. INTRODUCTION

The increasing amount of agricultural waste 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. Poor management and improper disposal of agricultural wastes may lead to many negative environmental consequences and may constitute a nuisance to global health and a threat to food security [1]. More specifically, burning these wastes leads to increased levels of carbon dioxide in the atmosphere, which contributes to global warming. These wastes can also cause blockage of drains and canals which consequently results in flooding. Moreover, accumulated wastes release offensive odors, thereby contributing to air pollution, and also serve as a breeding ground for mosquitoes and flies which spread several diseases. Waste products also add to space problems in landfills, as they remain in landfills until they are biodegraded. The use of these materials offers potential benefits both environmentally and socio-economically. They are cheap, abundantly available, and resource-oriented when handled appropriately and the environmental problems associated with inappropriate disposal are eliminated. Moreover, recycling these agricultural solid wastes will result in the reduction of greenhouse gas emissions and use as fossil fuel as well as contribute significantly to the development of new green markets, creation of jobs, production of bio-energy, and bio-conversion of agricultural solid wastes to animal feed [1]. Also, agro-industrial wastes pave the way for some other important research fields, such as the production of new and alternative fuels and energy generation[2], bricks production [3], and many more.

One of the most successful approaches to the management of agricultural waste is the production of particleboards from it. Particleboard is a wood-based panel product manufactured under pressure and temperature from the particles of wood with adhesives. Recently, the use of alternative resources as a substitute for wood raw materials has increased in the particleboard industry because of the depletion of forest resources [4]. Studies of particleboard using wood residues and agricultural by-products have examined crop wastes [5], maize cob [6], rice husks [7], a combination of rice husk and wood sawdust [8-11], wheat straw [12], tree leaves [13], sunflower stalks [13], maize husks [14], coconut [15], banana bunch [16], and palm kernel shell [17].

Pineapple leaves are considered one of the agricultural wastes that can be utilized as a new raw material for producing particleboard [18]. Various studies on the utilization of pineapple leaves as particle board have already been conducted, such as those of [18-22], but none of which has entirely tackled and explored the effect of both the NaOH treatment and various formulations (fillers) and sizes of fillers on the properties of the board.

In producing a particle board, adhesives bind the wood particles together. It can be classified as synthetic or non-synthetic. However, concerns have been rising about the risks of using these synthetic substances that affect human health [23]. Due to the underlying risk of synthetic binders, non-synthetic binders pave the way as an alternative. Moreover, various studies have also utilized plastic waste as a binder for particleboard, such as Douglas fir beams and Expanded Polystyrene (**EPS**) [24], corn cobs and water sachets[25], styrofoam and sawdust [23], wood and styrofoam [26], PALF and polypropylene [27], date palm leaflets and EPS [28]. Considering the enormous amount of plastic material that can't degrade naturally, using styrofoam as an adhesive to bond wood particles is one of the measures to recycle styrofoam for disposal and could be one of the solutions regarding the management of waste [24].

In this study, pineapple leaves and styrofoam have been utilized to produce particleboard, and the effects of varying the application of NaOH treatment, formulation, and size of the raw material on the properties of the board were evaluated. In evaluating the properties, water absorption, density, thickness swelling, and flexural strength have been considered.

2. METHODS

2.1. *Materials*

The study used waste pineapple leaves and Styrofoam as alternative materials for particleboard production. The pineapple leaves have been collected from pineapple farms in Brgy. Laturan, Manolo Fortich Bukidnon, and the styrofoam were collected at the University of Science and Technology of Southern Philippines and the Fil-Chi Community in Cagayan de Oro City.

2.2 *Preparation of pineapple leaves*

As shown in Figure 1, the collected pineapple leaves have been cleaned and divided into two sets for the application of NaOH treatment. The first set has undergone treatment, and the other one was treatment-free. One of the sets was soaked in a 10% concentration of NaOH for 30 minutes to soften the fibers and washed numerous times before being sun-dried for 3 weeks [19]. The dried sets of NaOH-treated and untreated pineapple leaves have been divided into two for the variation of size, which are 20 mm and 2 mm. To obtain 20 mm pineapple leaves, the dried leaves have been cut by hand, and to obtain 2 mm pineapple leaves, a food grinder in Cogon Market has been used.

(a) Collecting (b) Cleaning of (c) NaOH treatment (d) Sundrying

Figure 1 Preparation of Pineapple leaves

2.3 *Production of Particleboard*

In producing particleboard, Styrofoam melted by gasoline has been utilized as the main adhesive. Forty grams (40g) of Styrofoam have been dissolved in 120 ml of gasoline and stirred to enhance the dissolution. There are two different sizes (materials) of pineapple leaves: 2mm and 20mm. The formulation (% pineapple leaves, PL: Styrofoam, SF) was also varied in the study, such as 50:50 (PL: SF), 60:40 (PL: SF), and 70:30 (PL: SF). During hot pressing of the board, it was pressed for 10 minutes at 750 psi at a temperature of 120 °C.

The mold was composed of male and female set-ups with a dimension of 250 x 250 x 10 when making the specimen. Before testing, the board had been cut to 25 mm x 250 mm x 10 mm as per IS 2380. The waste pineapple leaves and Styrofoam adhesive are weighed before mixing. The varied sizes of pineapple leaves are manually mixed at room temperature with the Styrofoam adhesive through different formulations. Grease was applied first to the mold before it was covered by parchment paper. Then the mixture was fit into the mold and pressed using a hot press machine (HPM) for 10 minutes at 120 C.

2.4 *Evaluation of Physical and Mechanical Properties of Particleboards*

2.4.1 Evaluation of Physical Properties

Determination of Density

In getting the density of each particleboard, the mass of each product was divided by its volume wherein the volume of the particleboard was calculated by multiplying the thickness of the product by the area. Density (g/cm3) = m/v, where m is the mass of the produced board and v is the volume of the board.

Determination of Water Absorption

The water absorption test that was employed in each particle board is done as per IS 3087. The dried board was weighed first before being submerged horizontally under fresh clean water at room temperature which served as an initial weight. In getting the water absorption, the final weight is subtracted from the initial and divided by the initial weight.

$$\%\boldsymbol{WA} = \frac{W_f - W_i}{W_i}$$

Determination of Thickness Swelling

The thickness swelling test was employed in each particle board as per ASTM D 3502-76. In implementing the thickness swelling test, a board was submerged in water and drained for 10 minutes and the thickness of each original sample was measured and recorded first. The percentage of thickness swelling was calculated by the difference of final to initial thickness divided by initial thickness.

$$\%\boldsymbol{TS} = \frac{T_f - T_i}{T_i}$$

2.4.2 Evaluation of Mechanical Property (Flexural Strength) of Particleboards

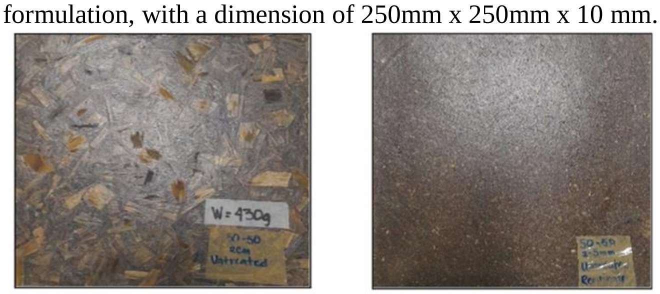
To test the Flexural Strength (Static bending) of the sample a three-point bending test is used to obtain the modulus of rupture (MOR) for the particle boards. The maximum load achieved during the test was recorded to calculate the MOR of the samples. The modulus of rupture is calculated using the formula:

$$MOR = \frac{3PmaxL}{2bd^2}$$

3. RESULTS AND DISCUSSION

3.1. Produced Particleboard Samples

Figure 2 shows the produced board samples using the three parameters, namely, NaOH treatment, particle size, and formulation, with a dimension of 250mm x 250mm x 10 mm.



(a) Particleboard with 20mm long pineapple leaves (b) Particleboard with 2-5mm size pineapple leaves

Figure 2. Produced Particleboard Samples

3.2. Density of particleboard

Effect of particle size on the density of a particleboard

As shown in Figure 3, particleboard with 2 mm-long pineapple leaves is more dense than the 20 mm-long pineapple leaves. This is due to the smaller interparticle space; the particleboards made from finer particles had a higher density [29]. Moreover, the density of the particle board decreases when the particle size increases [30]. This means that the value of the density profile for the particleboard is significantly dependent on the particle configuration.

Effects of formulations on the density of a particleboard

As shown in Figure 3, the density of the board increases with decreasing particle size. A 50:50 (PL: SF) formulation with particle sizes of 20 mm long and treated with NaOH has the lowest density. This board has an average density of 0.628 g/cm3, while the particle board that is denser than the other board samples has an average density of 0.84 g/cm3 and was produced using the formulation 70:30 with a particle size of 2 mm long and was not subjected to NaOH-treatment. The increment in densities can be due to the increasing amount of pineapple leaves in the formulation.

Effects of NaOH treatment on the density of a particleboard

As shown in Figure 3, particleboard with untreated pineapple leaves is denser than with NaOH-treated pineapple leaves. NaOH treatment can remove some substances in the pineapple leaves, such as waxes and fatty substances that are present in the pineapple leaves [30] Therefore, this removal decreases the mass of the pineapple leaves which may cause a decrease in density in the particleboard.

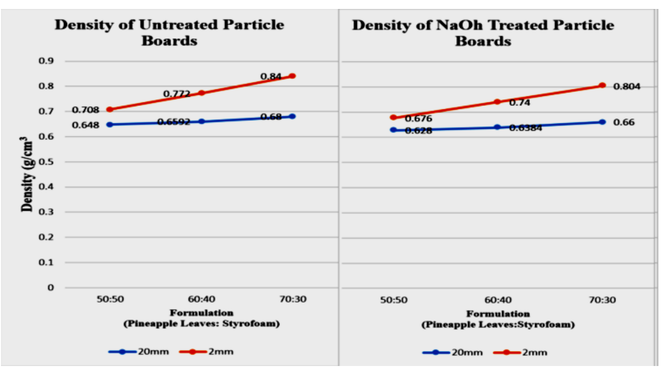


Figure 3. Effects of particle size, formulation & NaOH Treatment on the density of the particleboards

3.3 Water absorption of the particleboard

Effects of particle size on the water absorption of a particleboard

As shown in Figure 4, a particleboard with a particle size of 2 mm size absorbs more water than 20-mm-long pineapple leaves. A smaller particle size absorbs more water due to its high surface area ratio, which allows it to be more exposed to moisture. Hence, they absorb more water than larger particles[31]. Laminate-like films are also shown in the outer area of the particleboard with 20-mm long pineapple leaves that might also cause the blockage of some water from sipping through the particleboard. These laminated-like films are induced by the Styrofoam adhesive that is used as a binder. Thus, the fabricated particle boards are classified as MD (medium density) grade particle boards.

Effects of formulations on the water absorption of a particleboard

Figure 4 shows that increasing the amount of pineapple leaves significantly affects the amount of water absorption in the particleboard. The water absorption percentage increases when the amount of pineapple leaves also increases. This might be due to the mixing ratio of two raw materials that have different water absorption capacities. Styrofoam is a hydrophobic polystyrene material; it is resistant to water and moisture, hence, it does not absorb more water. Pineapple leaves, on the other hand, are lignocellulose materials that are hygroscopic due to the presence of hydroxyl, which is responsible for water absorption [32]. Therefore, the higher the content of pineapple leaves, the more they absorb water.

Effects of NaOH treatment on the water absorption of a particleboard

Based on Figure 4, particleboard with NaOH-treated pineapple leaves absorbs more water than untreated particleboard. This is due to the removal of hemicellulose and the binder lignin. The waxes and fatty substances that are present in the pineapple leaves were removed by the treatment with NaOH, which contributes to the water absorption of the board.

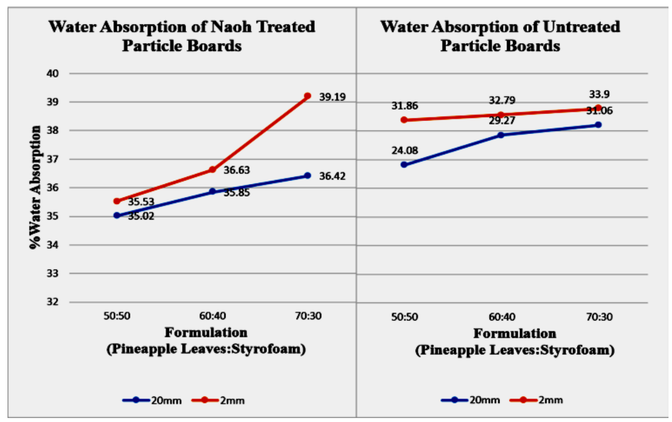


Figure 4. Effects of particle size, formulation & NaOH Treatment on the water absorption of the particleboard (24 hrs.)

3.4 Thickness Swelling of the particleboard

Effects of particle size on the thickness swelling of a particleboard

As shown in Figure 5, particleboards with 2mm particle size exhibit higher thickness swelling. After 24 hours, the 2mm particle size board with NaOH treatment recorded a percentage swelling of 42.5%, compared to 34.5% of the 20 mm size board. The large surface areas of larger-sized strands have efficient contact with each other in a panel [33], which can be considered a major parameter of having lower thickness swelling in such samples.

Effects of formulations on the thickness swelling of particleboard

From Figure 5, thickness swelling of the particleboards increases with increasing amount of pineapple leaves (70:30 formulation has the highest swelling). Since pineapple leaves are hydrophilic, they're attracted to water molecules, explaining the behaviour of boards with a greater ratio of pineapple leaves. A board which is composed of a greater amount of Styrofoam has a positive effect on decreasing the moisture content and thickness swelling of a board.

Effect of NaOH treatment of on the thickness swelling of particleboard

The pineapple leaves treated with NaOH are notable for thickness swelling more than the untreated ones, though the difference is considerably small. In the case of 50:50 board, after submerging the treated and untreated specimens for 24 hours, boards that were treated with NaOH incurred at least 20.5% swelling, while the untreated ones had a minimum swelling of 18.5%. The application of treatment has caused the removal of the pectineus gum and lignin that are present in the pineapple, which may result in faster liquid penetration such as fiber swelling and defibrillation.

3.5 Flexural Strength of the particleboard

Figure 6 shows the flexural strength of both NaOH-treated and untreated particle boards of various sizes and formulations. The strength ranges from 8.58–9.25 kN. For treated particle board, the flexural strength increases with increasing amount of pineapple leaves and decreases with particle size.

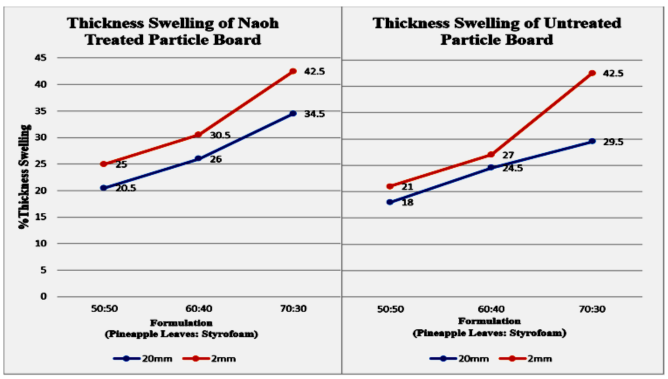


Figure 5. Effects of particle size, formulation & NaOH Treatment on the thickness swelling of the particleboard for 24 hrs.

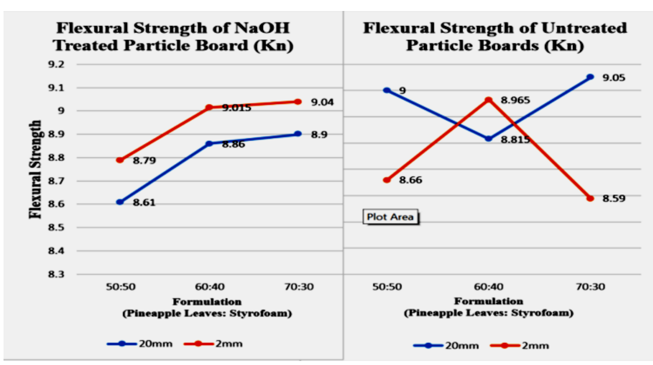


Figure 6. Effects of particle size, formulation & NaOH treatment on the flexural strength of the particleboards

4. CONCLUSIONS

The main objective of this study was to utilize wastes from pineapple leaves (PL) and Styrofoam (SF) in producing a particleboard. Results showed that size of particle, formulation (PL:SF) and NaOH treatment have influence on the density, water absorption, thickness swelling, and flexural strength of the particleboards. The density of particleboards increases with decreasing particle size, increasing amount of pineapple leaves and without NaOH treatment. The water absorption and thickness swelling of the board increase with decreasing size, increasing amount of pineapple leaves and with NaOH treatment. For treated particle board, the flexural strength increases with increasing amount of pineapple leaves and decreases with particle size. Lastly, the board passed the EN standards for flexural strength, with values of 11.5, 13.0, and 1600 N/mm2 being the minimal requirements.

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