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Physical and Mechanical Properties Assessment for Particle Board made from Sugarcane Fiber

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Abstract

This research aimed to assess the water absorption, thickness swelling, density, shrinkage, Modulus of Elasticity (MOE), Modulus of Rupture (MOR), and sound insulation properties of particle board made from sugarcane fiber. Sugarcane fibers were cut into lengths of 0.3–0.5 cm and dried in a solar kiln to achieve a moisture content between 5% and 10%. A mixture of 1500 g of sugarcane fiber, 166 g of citric acid, and 283 g of water was prepared and pressed into a metal frame measuring 27 × 400 × 400 mm at a temperature of 200°C for 30 minutes. The resulting particle board sheets were then cut into sizes specified by the standard test methods. The results showed that the particle board had a water absorption rate of 143.8%, thickness swelling of 19.0%, density of 353.82 kg/m^3, thickness shrinkage of 1.69%, and longitudinal shrinkage of 0.8%. The MOE was 68.6 N/mm^2 for the board without surface paper, and 83.0 N/mm^2 for the board with top and bottom surface paper. The MOR was 0.65 N/mm^2 without surface paper and 1.0 N/mm^2 with surface paper. Additionally, the particle board demonstrated a 45% reduction in sound transmission, indicating its potential for sound insulation applications.

Keywords: Density, Mechanical properties, Sugarcane fiber, Sound insulation

1. Introduction

The production of agricultural waste is still limited and the source of scientific information in agricultural residual is being required for adding value for sustainable production. In the past in the period of 2007-2021, there has been a program to add value to products from plantations that have been funded by the Australian government. The importance has been accelerated, so there have been many trials and studies on products from agricultural waste (GÜrÜ et al., 2015) From this importance, the study of bringing waste sugarcane waste from sugarcane juice production into Broad Particle products is an option to increase value. For livestock of sugar cane in 2011 Lao PDR has about 1,200,000 tons and of that sugar cane pulp is about 400,000 tons/year (Elasmak, 2002) Create options for manufacturers in the construction or furniture industry. However, the production information and characteristics of this type of product in the Lao PDR is still the most limited, especially the information on the introduction of this type of raw material to produce various products, to make this knowledge and information studied as an alternative information for those interested in the wood industry.

Sugarcane (*Saccharum officinarum*) is a plant in the POACEAE family, the same family as bamboo, grasses, plants such as wheat, rice, corn and barley, native to tropical Asia. Sugar cane stalks used to make sugar at approximate of 17-35% (Madison, 2011). Sugarcane is an herbaceous plant with a height of 2-5m. The trunk is knotted and protected with red or white pith covering the roots and is strong and can be bent down to protect the soil. The single leaves alternate in two rows, 2.5-5 cm wide, 0.5-1 m long, vertical or curved leaves, lance-shaped leaves, the leaf sheath covers the stem, the leaves have hairs and white pips. The flowers are in bunches at the top of the stem, the flowers are white, they will bloom when they are fully mature, the stalks are hairless, with very sharp seeds. Around the base of the seeds, there will be a white panicle as a cover and this panicle can spread far away during storms (Kenneth, 2014). Sugarcane waste Bagasse is part of the sugarcane stem that has removed sugarcane juice or sugar. Currently, sugarcane waste can be used for many purposes in the agricultural sector, such as using as a compost ingredient, used as a soil cover to maintain soil moisture, protect plants, fuel to generate electricity, it is also used as raw material in the production of pulp, ingredient in food. Sugarcane residue contains Cellulose 45-55 %, Hemicellulose 20-25 %, Linen 18-24 %, Ash 1-4 %, Wax <1%. (Rowell, 2012). Hot pressing temperature is determined according to the performance of boards, type of glue, and production efficiency of hot press. During hot pressing, the thermal energy has enhanced the plasticity of the fiber and created conditions for the integration of different bonds. The thermal energy will cause the moisture in raw board to vaporize. Temporary heating will expedite the solidification of hot set resin for decreased friction and increased fluidity. The hot-pressing temperature usually refers to the temperature of hot-pressing plate, but what plays function in actual use is the temperature inside the raw board. This research investigates the performance of MDF with respect to hot pressing temperature. The strength and water resistance of the product are improved with the increase of hot-pressing temperature from 140°C to 160°C, the Modulus of Rupture (MOR) is increased by 9.8%, the Internal Bonding (IB) is increased by 33.6%, the water absorption (Wt) is decreased by 38.2%, and the thickness expansion rate (T_s) is decreased by 15.2%. (Gul, 2017)

Particle board product is a product that is considered to be playing an important role in the field of use. In the past, wood was used as a raw material for construction, furniture, and so on. Due to the difficulty in finding wood materials and the price, particle board production is another option that is affordable and easy to find because it is a material made from wood shavings, sawdust, sawdust and waste from agricultural plants and is also the effective use and value creation of wood waste and agricultural waste (Api Heri iswanto, 2013).

Jalernsouk (2020, p. 1) studied the physical quality of particle board made from rice husk (husk) in the evaluation of the density of the fiber board using different compression periods. The density properties of the product with a compression time of 60 min have an average density of 1.00 (g/cm^3), a 90 min compression has an average value of 1.01 (g/cm^3) and a 120 min compression has an average value 1.03 (g/cm^3), the thickness of the bubble during compression 60 minutes has an average value of 4.17 mm, 90 min average value is 4.63 mm, and 120 min average value is 4.88 mm, and (Xainoy, 2023) Researched to find out the properties of particle board made from sawdust, the water absorption ratio of particle board made from sawdust for 2 hours has an average water absorption of 66.31 %, 24 hours has an average water absorption of 79.32 %, the water absorption ratio made from coarse sawdust has an average water absorption of 64.79 %, 24 hours has an average water absorption of 78.65 %, the percentage of growth from sawdust in 2 hours with an average growth of 2.26 %, 24 hours with an average growth of 5.64 %, the percentage of growth from sawdust in 2 hours with an average growth of 1.85 %, 24 Hour has an average swelling of 6.08 %, density assessment is 558.61%. and (Ramkuma, 2023) Using Lantana in the area of IPIRTI, Bangalore, Karnataka, India, in the study, 3-layer particle board was produced), there is swelling in thickness 10 %, lateral swelling 0.34 %, longitudinal swelling 0.39 %, MOR=16.4 MPa, MOE=2896 MPa. The properties of the pineapple leaf fiber showed the possibility the production of construction materials made from plant fibers. The mechanical properties (bending strength and IB) and physical properties (TS and water absorption) values were elevated the requirements of the JIS A 5905-1994.

The mechanical and physical properties seem to be promising for the development of a construction material. It might be useful as an alternative construction material for region with abundant of agricultural fibers. Additional research by using the natural adhesive is indispensable for the near future to enhance the properties of the bio-based composite (Indrayani et al., 2013), The results show the performance of straw particleboards is highly dependent upon the straw particle size. The static bending and internal bonding strength of pMDI resin-bonded boards initially increases then decreases with decreased particle size. The LE, TS and WA of particleboards decrease with increasing particle size. Compared with pMDI resin-bonded panels, UF resin-bonded particleboard exhibits much poorer performance due to the poor compatibility between rice straw and UF resin (Xianjun Li, 2010). the use of renewable materials such as rice husk for the development of particleboard could enhance the solution of raw materials shortage in particleboard industry. Results showed that particleboards made from rice husk had the requirement of MOR, IB, SHS and LE. The density at 800kg/m3 and temperature 77.5oC yield the highest IB which is greater than the IB obtained by (Vanchai, 2010). The R-square of the regression model developed was calculated to be 82.07% which show that the change in MOR of the particleboard is mostly explained by independent variables. The temperature at 70oC and density condition of 900 kg/m3 yields the highest results which is acceptable for production. The above results suggest that it is possible to use rice husk for the production of particleboard for lower cost housing (Mohammed, 2019)

Therefore, this study will go into depth about the production of Particle Broad sheets from sugarcane, to test the physical properties of Particle Broad sheets from sugarcane to know the amount of water absorption, swelling and tightness, to study the mechanical properties of Particle Broad sheets from sugarcane by testing the strength of the index of elasticity (MOE) and the index of fracture (MOR), to study the production process of Particle Broad from sugarcane, especially the use of natural glue (Citric Acid) or acid and test the noise level of particle board sugar cane.

2. Materials and methods

2.1 Materials

Using sugarcane waste from sugarcane juice shops at dongdok Village, selecting sugarcane waste 7000g according to the required amount, and then sending it from the factory to the Wood Science and Products Research Center of the Department of Forest Economics and Wood Processing Technology to produce Particle Broad boards and test the properties of the products.

2.2 Laboratory

Preparation of materials, equipment, tools, machines and templates that must be used in production such as: designing a frame, crushing sugarcane waste, cutting samples, marking numbers, baking sugarcane waste, pressing and testing Particle board products according to standards.

1). Materials: Sugar cane (*Saccharum officinarum)* is 5000g from sugarcane juice shop in Dong dok village, water, natural glue (Citric Acid) or acid as a compound, brush it (the details of the mixing rate are specified in the study method).

2). Equipment: digital scale (DA-K08, Made in China) A set of particle board molder size of 400 mm x 400 mm. Plastic bowl, glue container, fiber size dryer, oven dry (Wide Ven-221, Made in Chinna), moon saw, thermometer, greaseproof paper, high quality mouth mask, apron, camera, and A solar kiln (PT solar kiln drying service, Lao P.D.R) Temperature measuring instrument (TES-9902, Made in China).

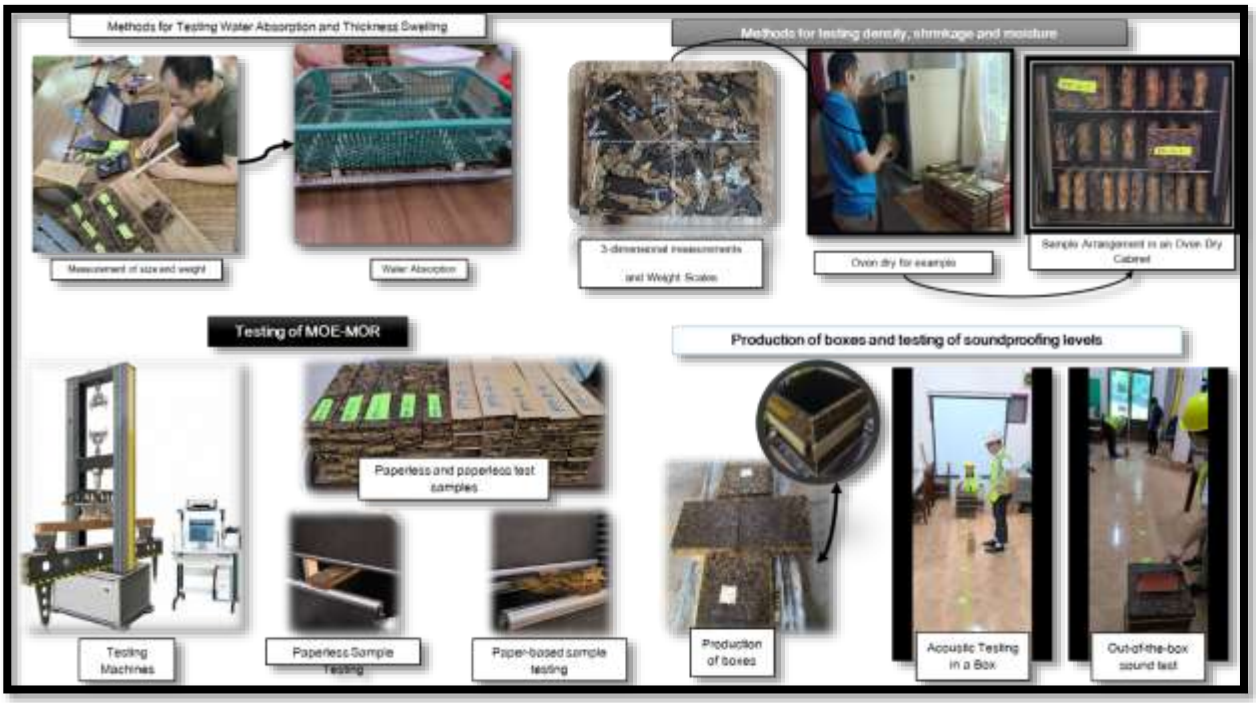
2.3 Methods

Bring the sugarcane scraps obtained (*Saccharum officinarum*) from general sugarcane juice shops, cut the sugarcane scraps to a size of 1Cm, then bring them to dry with the size by 0.3-0.5Cm, take the cut or softened sugarcane scraps to the size and bake them with a solar kiln so that the sugarcane scraps dry and obtain the desired moisture content between 5 and 10%. Then mix the citric acid amount of 166 g with 283 g of water then spray on 1500 g of sugarcane residual. After that, pour the sugarcane residual onto the prepared molder of 27x400x400 mm then press it using the DAKE machine. The desired temperature was set at 524 degrees Fahrenheit (F) or 200 degrees Celsius (^{o} C) until the temperature is stabilized (Approximately, it took 20-30 min), then load the molder of sugarcane into the heat press (DAKE machine) at 5MPa pressure for 40 min.

Picture1: Waste Particle Board Manufacturing Process

Location: This study site is a laboratory of department of forest economic and wood technology, faculty of forestry science.

2.4 Testing Properties of Particle board sugarcane fiber



Water Absorption and Thickness Swelling Test

50 samples were taken and cut into 27x50x50 mm pieces to test for water absorption and thickness swelling. The method was to take all the samples and mark them as PW-1-1 (in order), weigh them and measure the thickness (T). Then, all the samples were placed in a container, covered with a wooden board that was larger than the sample so that the sample could float freely (so that the sample would not be pushed by the flat surface of the container), and then water was poured into the container to fill the container as shown in the picture.

The test time is 2 hours and 24 hours. After 2 hours, the sample is weighed and the thickness is measured. Then, it is soaked in water again. After waiting 24 hours, the sample is weighed and each side is measured, and the data is recorded for analysis.

Water Absorption (W) in accordance to JIS-A 5098

$$(W_{\%}) = \frac{(\text{W1}-\text{W2}))}{\text{W2}} * 100$$

(W%) = Water absorption (%)

W1 = Pre-hydration weight (g)

W2 = Mass after soaking (g)

Swelling Thickness in according to JIS-A 5098

$$(ST_{\%}) = \frac{(\text{t2}-\text{t1}))}{\text{t1}} * 100$$

(ST%) = Swelling in thickness (%)

t1 = Dimensions of pre-absorbent thickness (g)

t2 = Dimensions of post-absorption thickness (g)

Density and shrinkage test

50 samples cut into 27x100x100 mm size were tested to obtain the density and shrinkage values. The method is to take all the samples and mark them with the code PD-1-1 (in order), weigh them and measure each side: thickness (T), width (b) and length (L), then arrange the samples so that the edge of the sample is in the direction of the fan in the OVENDRY oven as shown in the picture.

The test time is 2 hours and 24 hours, after 2 hours, the samples are weighed and measured on each side, then put them back in the oven, wait for 24 hours, then the samples are weighed and measured on each side and the data is recorded for analysis. JIS-A 5098 standard

Density according to JIS-A 5098

$$(D_{(Kg/m3)}) = \frac{M}{\text{V}}$$

D = Density (Kg/m^3)

M = Mass (kg)

V = Volume (m^3)

Thickness Shrinkage in accordance to JIS-A 5098

$$\%(Shr_t) = \frac{(\text{t1}-\text{t2}))}{\text{t1}} * 100$$

$\%(Shr_t)$ = Shrinkage in thickness (%)

t1 = thickness before heating (g)

t2 = thickness after heating (g)

Mechanical testing Modulus of Elastic (MOE) and Modulus of Rupture (MOR)

The machine (Universal Testing Machine) is used to test the sample plate, the test time is 3-5 min per sample, by setting the speed of the machine to hit the wood at 2 mm/min, and then observe the bending and breaking distance of the wood of each sample. After completing one sample, a new sample must be replaced until 50 samples are completed, which has 2 types of tests: Type (1) without paper, 25 samples, and Type (2) with paper, 25 samples. After the test, there will be a data reader in the testing machine, which records the required data such as the load value (P1, P2), (P max), and test time. Then, the data is analyzed using Microsoft Excel and SPSS programs to help with the analysis.

Module of Elastic in accordance to JIS-A 5098

$$\text{MOE (N}/mm^2) = \frac{(\text{3PL}))}{2\text{b}t^2}$$

P= Maximum load (N)

L = length of the span (mm)

b = Wieth of the sample (mm)

t = thickness of the sample (mm) Module of Rupture in accordance to JIS-A 5098

$$\text{MOR (N}/mm^2) = \frac{(L^3)}{4\text{b}t^3} x \frac{\Delta P}{\Delta y}$$

$\frac{\Delta P}{\Delta y}$= is the value of the relationship between P and y, expressed in Graph (N)

P= Maximum load (N)

L = length of the span (mm)

b = Wieth of the sample (mm)

t = thickness of the sample (mm)

2.5 Analysis

After completing the experimental research and recording the data in Microsoft Excel, the data was analyzed using the Multilinear Regression tool and Using SPSS software to analyze mean, maximum, minimum standard deviation, frequency counts, Percentage.

3. Results

Completed the production of Particle Broad sheets from sugarcane waste measuring 27x27x400 cm for testing.

The 2-hour water absorption percentage had a minimum value of 93.38%, a maximum value of 151.16%, and an average value of 112.78%, while the 24-hour water absorption percentage had a minimum value of 105.30%, a maximum value of 194.19%, and an average value of 143.80%.

The 2-hour inflation percentage has a minimum value of 5.50%, a maximum value of 23.91%, and an average value of 14.61%. The 24-hour inflation percentage has a minimum value of 7.69%, a maximum value of 28.41%, and an average value of 19.01%.

The density of particle board before baking has a minimum value of 294.40 kg per cubic meter, a maximum value of 389.14 kg per cubic meter, and an average value of 342.52 kg per cubic meter. The density of particle board after baking has a minimum value of 302.65 kg per cubic meter, a maximum value of 400.46 kg per cubic meter, and an average value of 353.82 kg per cubic meter.

The percentage shrinkage of the 2-hour test time had a minimum value of 0.08 %, a maximum value of 2.35%, and an average value of 0.72%, and the percentage shrinkage of the 24-hour test time had a minimum value of 0.55%, a maximum value of 3.10%, and an average value of 1.69%.

The percentage shrinkage of the 2-hour test time has a minimum value of 0.02%, a maximum value of 1.68%, and an average value of 0.37%, and the percentage shrinkage of the 24-hour test time has a minimum value of 0.05 %, a maximum value of 1.79%, and an average value of 0.80%.

The percentage shrinkage of the 2-hour test time has a minimum value of 0.02%, a maximum value of 1.59%, and an average value of 0.29%, and the percentage shrinkage of the 24-hour test time has a minimum value of 0.08%, a maximum value of 2.20%, and an average value of 0.70%.

The test without paper had a minimum value of 23.91 newtons per square millimeter, a maximum value of 145.64 newtons per square millimeter, and an average value of 68.62 newtons per square millimeter, and the test with paper had a minimum value of 47.97 newtons per square millimeter, a maximum value of 156.04 newtons per square millimeter, and an average value of 83.08 newtons per square millimeter.

The test without paper had a minimum value of 0.25 Newtons per square millimeter, a maximum value of 0.99 Newtons per square millimeter, and an average value of 0.65 Newtons per square millimeter, and the test with paper had a minimum value of 0.74 Newtons per square millimeter, a maximum value of 1.32 Newtons per square millimeter, and an average value of 1 Newton per square millimeter.

The sound insulation test in the box showed that the sound level decreased with the test distance: the measurement distance in the box was 100 dB, the test distance of 0 cm was 65 dB, the test distance of 50 cm was 60 dB, the test distance of 100 cm was 59 dB, the test distance of 150 cm was 58 dB, the test distance of 200 to 250 cm was 56 dB, and the test distance of 300 to 500 cm was 55 dB.

The sound insulation test outside the box showed that the sound level decreased with the test distance: 0 cm test distance measured 96 dB, 50 cm test distance measured 87 dB, 100 cm test distance measured 83 dB, 150 cm test distance measured 81 dB, 200 cm test distance measured 80 dB, 250 cm test distance measured 79 dB, 300 cm test distance measured 78 dB, 500 cm test distance measured 77 dB.

4. Discussion

The percentage of thickness shrinkage of this research is equal to 1.69%, but the research of (Jalernsouk, 2020), (Xainoy, 2023) and (Ramkuma, 2023) (respectively) found that the percentage of thickness shrinkage is 4.8%, 1.74%, and 10.6%, compared to the results of the previous research, this research found that the rate of thickness shrinkage is less.

The percentage of deer shrinkage of this research is equal to 0.8%, but from the research of (Xainoy, 2023) and (Ramkuma, 2023) (respectively) found that the percentage of deer shrinkage is 0.34% and 1.09%, when compared to the results of the previous research, it is seen that this research has a smaller rate of deer shrinkage than the research of (Ramkuma, 2023), but there is more shrinkage than the research of (Xainoy, 2023).

For the percentage of longitudinal shrinkage of this research is equal to 0.70%, but from the research of (Xainoy, 2023) and (Ramkuma, 2023) (respectively) found that the percentage of longitudinal shrinkage is equal to 1.02 and 0.39%, compared to the previous research, it is found that this research has a higher rate of longitudinal shrinkage than the research of (Ramkuma, 2023), but lower than the research of (Xainoy, 2023), The reason for the different shrinkage is due to the use of higher compression temperature, compression time and less compression force, use of raw materials, and use of different adhesive (Ramkuma, 2023).

The density of this research is 353.83 Kg/m^3, but from the research of (Jalernsouk, 2020), (Xainoy, 2023) and (Ramkuma, 2023) (respectively) see that the density is equal to 558.61, 889 and 1030 Kg/m^3 when compared to the results of previous research that this research is the lowest density. The compaction density is due to less compaction time and compression force and the use of different adhesives. (Ramkuma, 2023)

The water absorption percentage of this research is 143.80%, but from the research of (Xainoy, 2023) and (Ramkuma, 2023) (respectively) it is seen that the water absorption rate is 79.32% and 45.23%, when compared to the previous research, it is found that this research has a high water absorption rate because of the density of the particle board, less time for compression and the use of glue different (Ramkuma, 2023) and also makes the percentage of inflation of this research higher than the peers equal to 19.01 %, Compared with the results of the research, it is equal to 5.64 and 7.33 % as the research of (Xainoy, 2023) and (Ramkuma, 2023) (respectively).

The modulus of rupture (MOR) of this research is equal to 0.99 N/mm^2, compared to the research results of V.R Ramkumar (2023) it is less than 16.40 N/mm^2.

The modulus of elasticity (MOE) of this research is equal to 2896 N/mm^2 as the research of (Ramkuma, 2023), the reason for the compaction value is due to the compression time and low compression force than and the use of different adhesives (Ramkuma, 2023).

5. Conclusion

Through a research study on evaluating the physical and mechanical properties of Broad Particle products made from sugarcane residual. The results were summarized as following:

The moisture content of the particle board is 7.9% at the range of MC=5-10%.

The water absorption for the 24-hour test ranged from 105.30 % to 194.19% (the average value of 143.80%±SD).

The swelling percentage of the 24-hour test ranged from 7.69 % to 28.41% (The average value of 19.01%±SD).

The density of particle board after baking for 24 hours ranged from 302.65 kg to 400.46 kg/m^3 (The average is 353.82±SD kg/m^3.

The thickness shrinkage of the 24-hour test time ranged from 0.55% to 3.10% (The average value is 1.69±SD%).

The shrinkage of the 24-hour test ranged from 0.05% to 1.79% (The average value is 0.80±SD%).

The lengthwise shrinkage of the 24-hour test ranged from 0.08% to 2.20% (The average is 0.70±SD%).

The modulus of elasticity (MOE) of non-paper tests ranged from minimum value of 23.91 N/mm^2, a maximum 145.64 N/mm^2 (The average is 68.62±SD N/mm^2), and the both the paper tests a minimum value of 47.97 N/mm^2, and a maximum of 156.04 N/mm^2, (The average is 68.62±SD N/mm^2).

The modulus of rupture (MOR) of non-paper tests ranged from minimum value of 0.25 N/mm^2, a maximum 0.99 N/mm^2 (The average is 0.65±SD N/mm^2), and the both the paper tests a minimum value of 0.74 N/mm^2, and a maximum of 1.32 N/mm^2, (The average is 1±SD N/mm^2).

The measured sound protection level of both types of tests is reduced as the test period increases, the sound protection level test in the measurement booth decreased from 100 dB to 55 dB or equal to 45%, the sound protection level test outside the measurement booth decreased from 96 dB to 77 dB or equal to 23%.

6. Interest of conflict

I certify that all information contained in this research article is not a conflict of interest with any financial organization.

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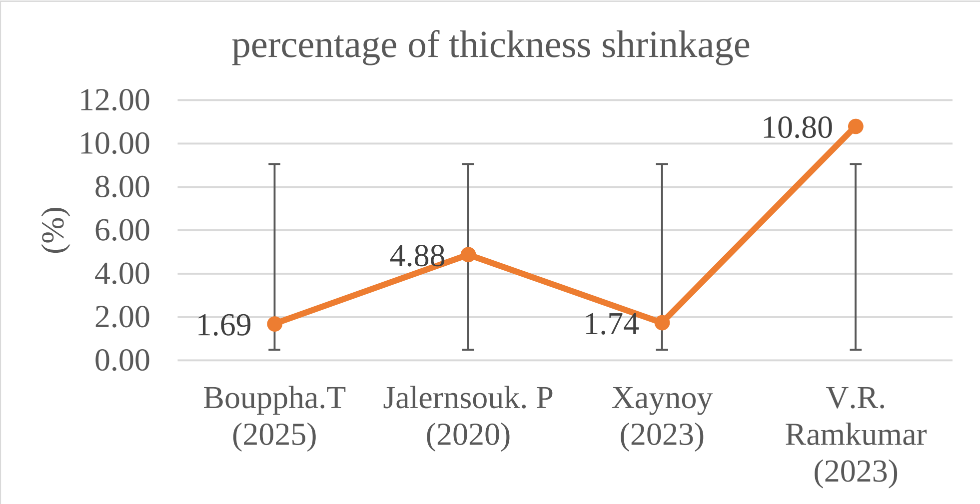

Figure 1 Compare Percentage of thickness shrinkage

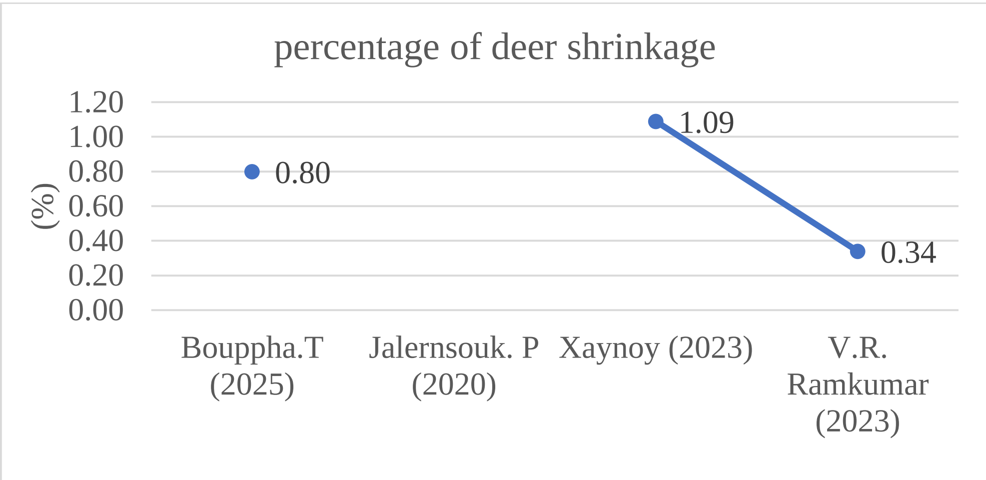

Figure 2 Compare Percentage of deer shrinkage

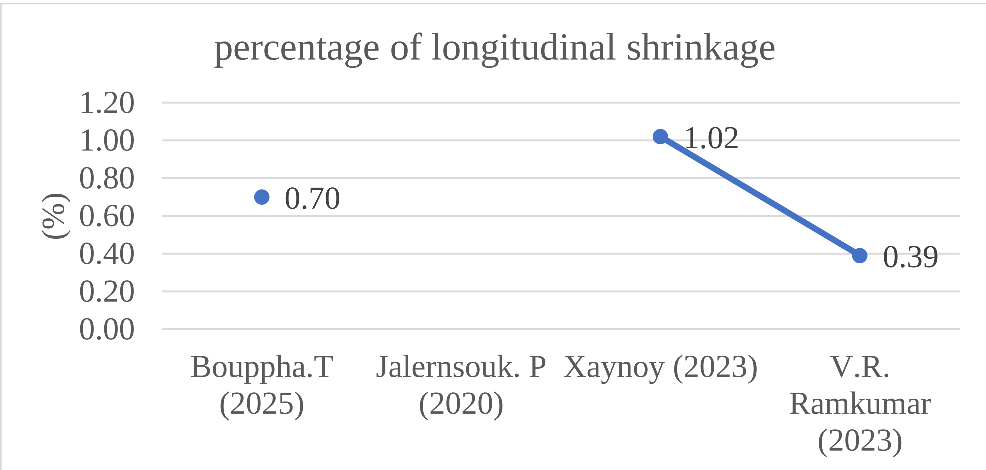

Figure 3 Compare the Percentage of longitudinal shrinkage

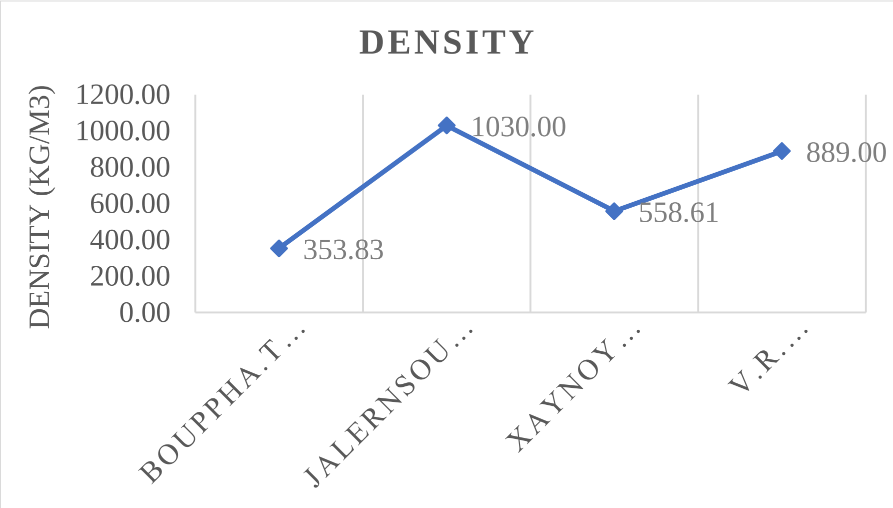

Figure 4 Compare the Density

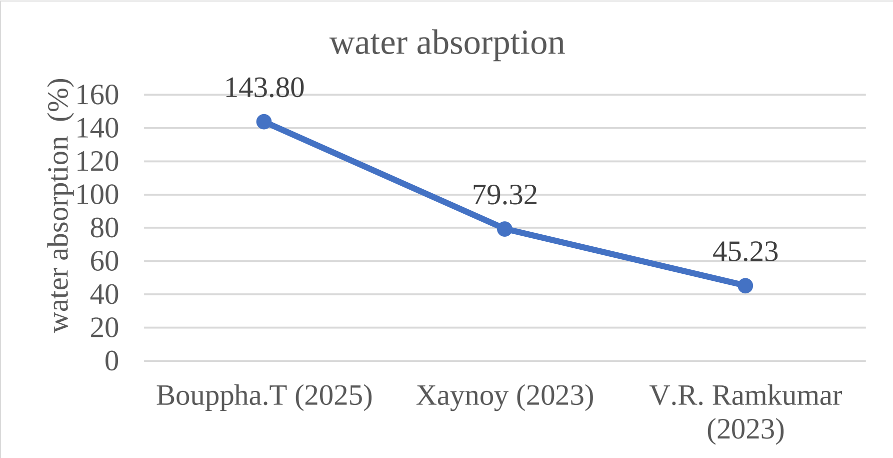

Figure 5 Compare the water absorption %age

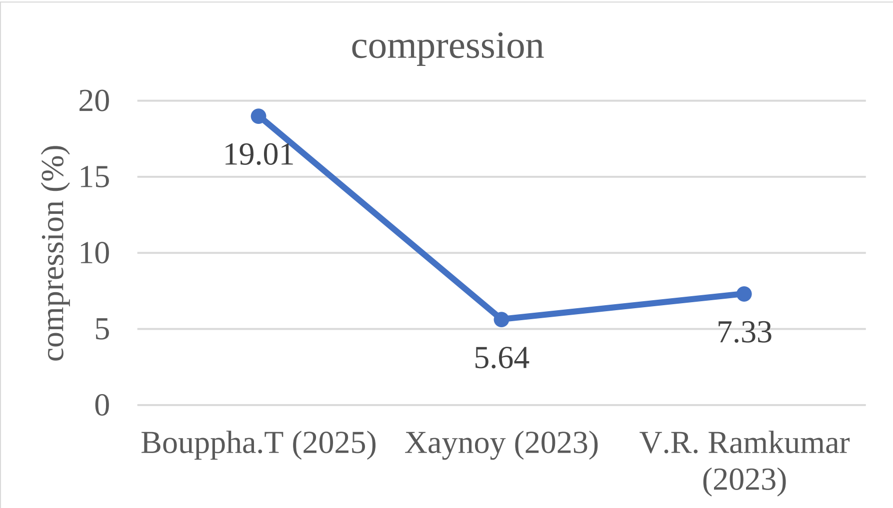

Figure 6 Compare the compression

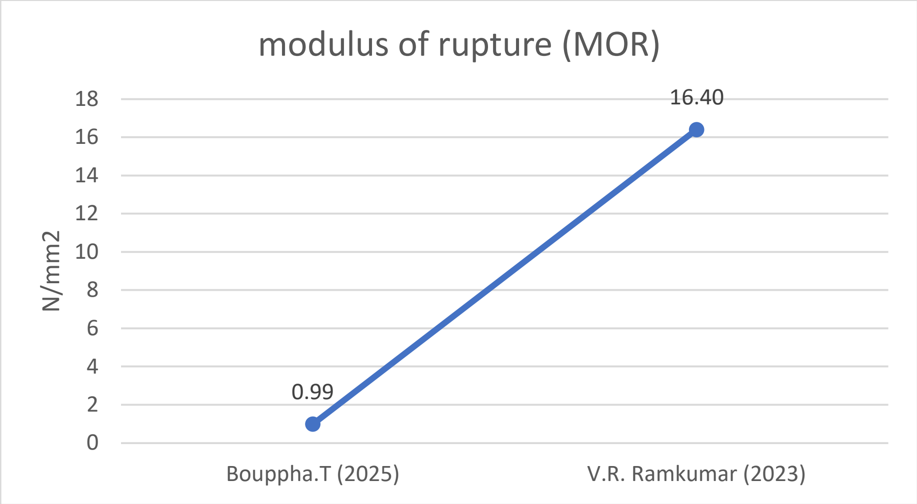

Figure 7 Compare the modulus of rupture (MOR)

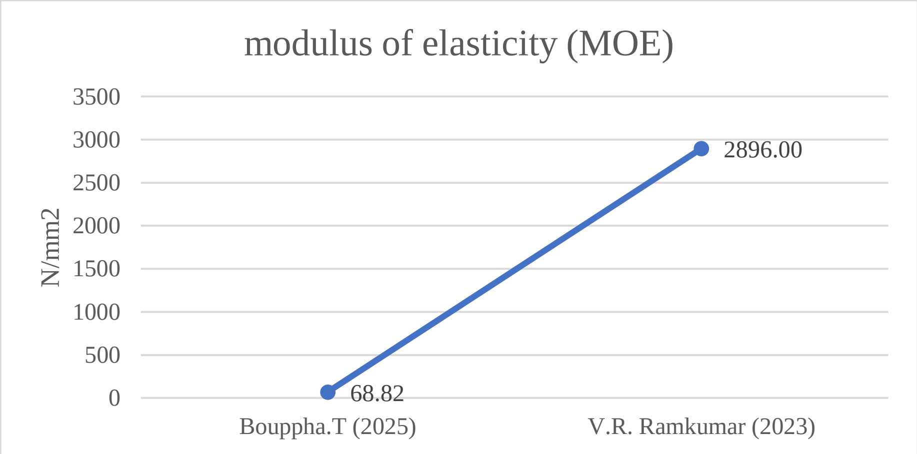

Figure 8 Compare the modulus of elasticity (MOE))