Research Inventy: International Journal of Engineering And Science
Vol.14, Issue 9 (September 2024), PP 53-60
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Some Properties of Jute Fiber-Based On Non-Adhesive Medium Density Fiberboard (MDF)

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***Abstract**: One of the most reasonably priced natural fibers is jute.. Due to its similarity to wood in terms of cellulose and lignin content, it has the potential to be used as a material for fiberboard. Using lignin as a natural glue, binderless medium density fiberboard (MDF) made of jute fiber was created with the goal of lowering the amount of wood used and the emissions of synthetic adhesives such urea formaldehyde. This study set out to ascertain the mechanical and physical characteristics of MDF made from jute fiber using ASTM D790-86 stand and ASTM D570-8. Additionally, it looked into the impact of additional paraffin, pressing time, and oxidation treatment on the fiberboard's mechanical and physical characteristics. The fiberboards generated in this study satisfied the MDF standard with a medium density of 0.44-0.56 g/cm^3, according to the results. The majority of the jute fiber fiberboards used in this study satisfied the requirements for physical characteristics like density, moisture content, swelling, thickness, and screw holding power. However, due to a lack of material strength, the fiberboards' mechanical properties such as their modulus of elasticity, modulus of rupture, and internal bond did not meet standards (ASTM D790-86 and ASTM D570-8).*

***Keywords:** MDF board, Jute fiber, binderless, Mechanical properties, physical properties.*

Date of Submission: 06-09-2024 Date of acceptance: 20-09-2024

I. INTRODUCTION

The rate of deforestation is impacted by the timber industry's high raw material consumption of wood. The annual supply of wood from natural forests is only 22 million m^3, according to CIFOR. If there is no substitute for wood's natural fiber as a raw material, the forest's supply of wood will run out (Redwan et al., 2017). Natural fiber made of non-wood can be used in place of natural fiber made of wood. Its many benefits include ease of cultivation and harvesting in a shorter amount of time than a tree. There are plenty of lignocellulosic natural fibers in nature that come from non-wood natural sources. A prime example is jute fiber Jute fiber is a natural fiber derived from the stem of the jute plant (genus *Corchorus*), primarily *Corchorus capsularis* and *Corchorus olitorius* (Ashraf et al., 2019). It is one of the most affordable natural fibers and is second only to cotton in terms of production volume. With each having a distinct use, the conversion of jute fiber into coco fiber can provide long fiber, short fiber, and fiber dust. Jute fiber's strong tensile strength which enables it to withstand tension without breaking is one of its main advantages.

The primary characteristic of jute fiber is its intrinsic eco-friendliness. Jute is also a great insulator against noise and heat, which makes it useful for applications including noise reduction and temperature control (Zakariya et al., 2017). It is easy to wear and contributes to humidity regulation because of its breathability and moisture-absorbing qualities. Because of its biodegradability, it is a natural fiber that decomposes without endangering the environment. It's a more environmentally friendly option than synthetic fibers, which linger in the environment for a long period. Jute's adaptability and plasticity make it simple to weave into garments, spin into yarns, or combine with other fibers to improve its qualities (Aisyah et al., 2021).

In addition, jute is less expensive than many synthetic fibers. In addition, jute is a quick-to-harvest, renewable crop that requires little in the way of fertilizer or chemical inputs. Jute fibers are generally excellent materials for textiles, packaging, rope, and geotextiles since they are robust, insulating, permeable, biodegradable, adaptable, affordable, and sustainable.

Wood and jute fiber share a similar chemical composition. It can be utilized as a raw material for fiberboard since it includes 22-24% hemicelluloses, 59-61% cellulose, 12-14% lignin, 0.2-0.5% pectin, and 12-13% water (Islam et al., 2022). Fiberboard is a kind of composite material made from wood or other materials containing lignocelluloses, which are combined with binder or glue and heated to a high temperature before being pressed. The process of turning jute husks and fibers into fiberboards increases the value of these resources and could lessen the environmental impact associated with their disposal. Compared to other goods like doormats, brooms, and rope created from jute fiber, fiberboard offers a better added value and a more prospective market. According to the FAO, the worldwide market for fiberboards grew by 35% between 2009 and 2013.

Lignin resin is typically pressed at high temperatures to create fiberboards (Savov et al., 2022). Fiberboards are typically made with synthetic binder or glue, such as formaldehyde (urea), formaldehyde (melamine), or formaldehyde (phenol). This study uses the lignin found in jute fiber as a natural adhesive instead of those adhesives, which were known to emit formaldehyde and contaminate the environment. It is employed to lower adhesive costs, lessen environmental contamination, and lessen reliance on synthetic adhesives derived from petroleum.

Due to structural similarities between lignin and phenol formaldehyde resins, lignin can be used in place of phenol formaldehyde since their chemical components are nearly identical to the phenolic group. Some researchers have developed techniques to directly activate lignin in wood, allowing wood fibers to connect without the need for extra adhesive, motivated by the potential of lignin as an adhesive (Karthauser et al., 2021).

Three techniques have been developed: enzymatic treatment, hot steam injection, and oxidation. In order to create binderless particleboard, the oxidation technique was developed utilizing hydrogen peroxide and ferro sulfate (Suhasman et al., 2013). Activating the lignin component of the wood particle with hydrogen peroxide and ferric sulfate allowed them to effectively create binderless particleboard. To stop the particleboard or fiberboard from absorbing water, more material like paraffin is required. Paraffin has the capacity to prevent water from penetrating the final product (Gulfam et al., 2019). We made the decision to look into the properties of binderless fiberboard made from jute fiber with additional paraffin, pressing time, and oxidation treatment after seeing those earlier studies.

II. EXPERIMENTAL PROCEDURES

The primary substance employed in this study is jute fiber. Water, paraffin, ferric sulfate, hydrogen peroxide, and other chemicals are employed in the examination. Oven, desiccators, baking pan, fiber container, hot press, mat (25 x 25 cm), spacer, aluminum foil, Instron mechanical testing tool (Universal Testing Machine), blender drum, compressor, sprayer gun, saw, mask, and gloves are among the tools and equipment used in this study.

Four steps were taken in the course of this study. The process started with the raw materials being prepared, then moved on to the production of medium density fiberboard (MDF), conditioning, and testing the MDF's mechanical and physical qualities. Jute fiber was removed from contaminants including dirt and the skin of the jute meat, which fiber still attached to, during the raw material processing process. Using a ring flaker, the process is repeated until the jute fiber's size is reduced to ± 1-2 cm. After that, the fibers were sun-dried and oven-dried at ± 55 ºC, or a temperature that is comparable to sun-drying. Weighing the fiber required to get 0.55 g/cm^3 density in accordance with material counts is the first step in the board-making process. Subsequently, fiber was placed within the blender drum and 20% of the dry particle material weight of hydrogen peroxide was sprayed on it at the same time. Spraying ferric sulfate (8% of hydrogen peroxide volume) was the next step in the procedure. Paraffin 0.6% was sprayed onto the fiber to finish it.

Subsequently, the treated fiber was laid out on a 25 by 25 cm mat that had been wrapped in aluminum foil beforehand. Following formation, the board is hot-pressed for 15 and 25 minutes at 180 ºC and 25 kgf/cm^2 of pressure. Suhasman's approach was modified for this manner (Suhasman et al., 2019). The combination of treatments used in this study is displayed in Table 1.

Table 1

Treatment mumber	Treatment code	Oxidation	Paraffin	Pressing time
A	OX1P1T1	√	0.6%	15
B	OX1P1T2	√	-	25
C	OX1P2T1	√	0.6%	15
D	OX1P2T2	√	-	25
E	OX2P1T1	X	0.6%	15
F	OX2P1T2	X	-	25
G	OX2P2T1	X	0.6%	15

H	OX2P2T2	X	-	25

This binderless fiberboard made of jute fiber should have a medium rate density of 0.6 g/cm^3. This particular type of MDF is used specifically for interior spaces that must withstand changes in density, moisture content, thickness, and absorption of water. Furniture is the primary usage for fiberboard. In order to minimize the strains caused by the hot press operation on the board's surface and to homogenize the moisture content of fiberboard, the board was conditioned for about a week at room temperature (Uitterhaegen et al., 2017). Following the conditioning phase, the samples were sectioned. Sample cutting patterns for evaluating mechanical and physical qualities are based on ASTM D790-86 stand and ASTM D570-8.standards.

Completely randomized design with factorial 2x2x2 and twice repetition was used in the experiment. Microsoft Office Excel and SPSS 16.0 software were used to conduct statistical analysis. ANOVA was used to assess the data distribution and significance value, with a 95% confidence interval and a 5% significant interval. The Duncan Multiple Range Test (DMRT) was performed to determine which treatments had a meaningful effect when the significance difference was less than 0.05.

III. RESULS AND DISCUSSIONS

1.1 Jute fiber characteristic

The numerous applications for its parts demonstrate the enormous value of the jute. Its fruit, stem, leaves, and roots can all be used and processed to make a range of goods. The many parts of a jute fruit are the jute meat, jute fiber, jute shell, and jute water. The primary product, dried jute meat, is highly valuable economically in the business and is referred to as copra. Concurrently, jute water, jute shell, and jute husk, also known as fiber, can be turned into a variety of commercial goods. The outermost layer of jute fruit that covers the jute shell is called jute fiber. Table 2 shows the results of the Standardization Research Facility's analysis of the composition of jute fiber (Islam et al., 2022).

Table 2. Chemical composition of jute fiber compared with wood.

No	Components	Fiber	Wood
1	Water (%)	12-13	
2	Cellulose (%)	59-61	40-50
3	Hemicellulose (%)	22-24	20-30
4	Pectin (%)	0.2-0.4	
5	Lignin (%)	12-14	25-30

Because the chemical composition of jute fiber and wood fiber are comparable, jute fiber can be utilized as a raw material to make fiberboard. Fiberboards are typically formed by hot pressing lignocellulosic materials into a certain shape after they have been combined with binder or adhesive (Hobbe et al., 2018). Testing the mechanical (internal bond, modulus of elasticity, modulus of rupture, and screw holding power) and physical (density, moisture content, thickness swelling, and water absorption) characteristics of fiberboard can be done in accordance with ASTM D790-86 stand and ASTM D570-8.

1.2 DENSITY

Porosity, or the percentage of volume in hollow spaces, is related to density. It follows that the greater the density, the greater the strength (Saw et al., 2014). The significance value is 0.009 according to the outcome of the density variance test conducted using ANOVA. Since it is less than 0.05, there are noteworthy differences between the therapies. As a follow-up, Duncan tests were performed to compare the means and look into any significant differences across treatment combinations. Three groups representing value equivalency within the same group are denoted by the letters a, ab, and b. The density of the fiberboard is displayed in Figure 1. For medium density fiberboard (MDF), the density ranged from 0.5-0.9 g/cm^3. 0.55 g/cm^3 was the maximum density seen on the OX2P2T2 treatment combination. The first hypothesis is based on a recent study that found that treatment combination OX1P1T2 will achieve the highest density because longer compression times allow the fiber bond to interface more compactly and well while oxidation may increase the inner fiber bond.

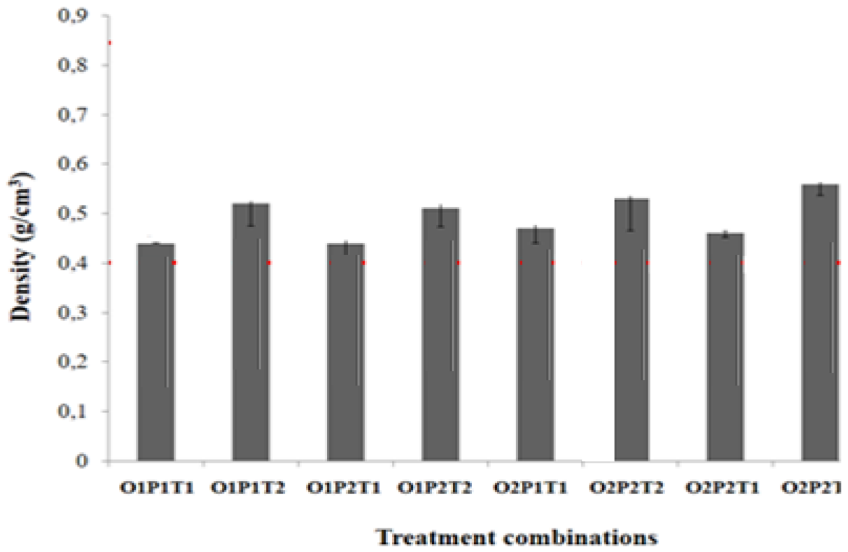

Figure 1. Density of the binderless MDFs

Nonetheless, the Duncan test revealed no statistically significant difference in the mean density of OX2P2T2 and OX1P1T2. The density is not greatly affected by paraffin addition or oxidation. Concurrently, the compression time exhibits a noteworthy impact on the binderless MDF density, increasing in tandem with the addition of pressing time. Density increased with a longer pressing duration (25 min) compared to a shorter one (15 min). Every treatment combination has reached the standard for density. Moisture adjustment during the conditioning process is another aspect that affects density and has the potential to improve fiberboard thickness (Wong et al., 2000).

1.3 MOISTURE CONTENT

The physical characteristics of fiberboard that reveal a material's moisture content are called moisture content. The results of the ANOVA test indicate that there is a significant difference between the treatment combinations, with a significance value of < 0.005. Then, to determine which treatment combinations are significantly different and which are not, the Duncan test was run. As seen in Figure 2, the moisture content means value were then divided into three groups: a, b, and c. In each group, the treatment combinations values did not differ significantly from one another.

Every sample's moisture content met the JIS (4–12%) and ASTM (max 12%) standards. Generally speaking, the moisture content decreases with increasing density. Maintaining the MDF's stability depends on its moisture content. The Duncan test indicates that there is no significant difference between the means of the moisture content values for OX1P1T2, OX1P2T2, OX2P1T2, and OX2P2T2. With regard to the remaining treatment combinations, they range considerably, nevertheless. It suggests that the moisture content is significantly impacted by the 25-minute compression duration. The water within the board won't completely evaporate to the surface due to the shortened compression time (Li et al., 2009). The physical and mechanical qualities of the board will deteriorate as moisture builds up beneath the surface.

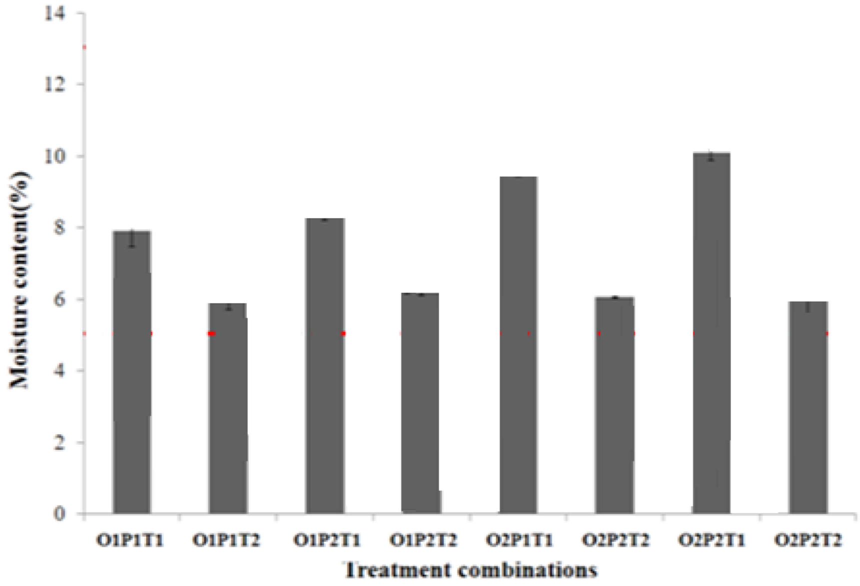

Figure 2. Moisture content of the binderlessMDFs from jute fiber \

1.4 WATER ABSORPTION

The capacity of fiberboard to absorb water following a 24-hour immersion in water is known as water absorption. Regarding water absorption, ASTM D570-8.do not establish any standards. Nonetheless, this assessment is required to look into the fiberboard's water resistance, particularly for outdoor applications where the board would be in direct contact with weather conditions like humidity and rain (Korai et al., 2012).

The samples' water absorbance capacity has a significance value of 0.001 according to the ANOVA test. The fact that it is less than 0.005 suggests that the treatment combinations differ significantly from one another. Then, to determine which treatment combinations are significantly different and which are not, the Duncan test was run. As seen in Figure 3, the means value was then divided into a, b, bc, and c groups where the treatment combinations values within the same group do not differ significantly.

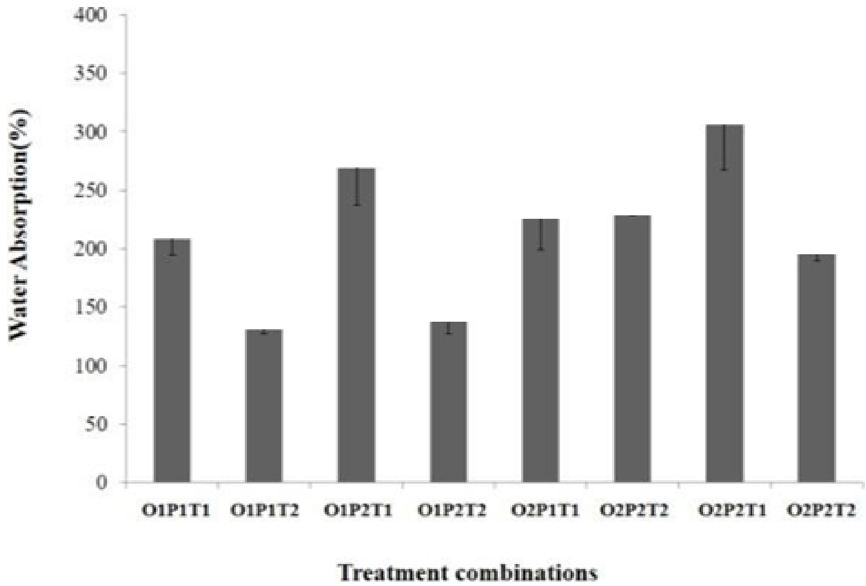

Figure 3. Water absorption of the binderless MDFs from jute fiber

1.5 THICKNESS SWELLING

The increase in water absorption will be accompanied by an increase in thickness swelling. The significance value, as determined by the ANOVA test, is 0.000. The fact that it is less than 0.005 suggests that the treatment combinations differ significantly from one another. Then, to determine which treatment combinations are significantly different and which are not, the Duncan test was run. As seen in Figure 4, the means value was then divided into the following groups: a, ab, bc, c, and d, where the treatment combinations values within the same group do not differ substantially. For MDF type 25, the maximum thickness swelling standard based on ASTM is 18%. After 25 minutes of pressing, samples with oxidation, 0.5% paraffin, and no paraffin attained the required thickness swelling values of 8% and 12%, respectively.

In order to predict that water will slowly seep into the board through particle pores and hollow spaces between particles, the smallest value is optimal (Ramaswamy et al., 2004). Samples with oxidation have average thickness swelling that is lower than samples without oxidation at the same pressing time. This process may be brought about by a cross-bond between hydroxyl molecules or by a cross-bond between radical molecules that forms during oxidation and becomes more compact inside. Hot pressing produces covalent bonds between radical molecules created during oxidation, making the link stronger and more stable. Samples with oxidation and a 20-minute pressing period likely to have lower values, according to the Duncan test. This indicates that the thickness swelling is influenced by oxidation and the 20-minute pressing duration.

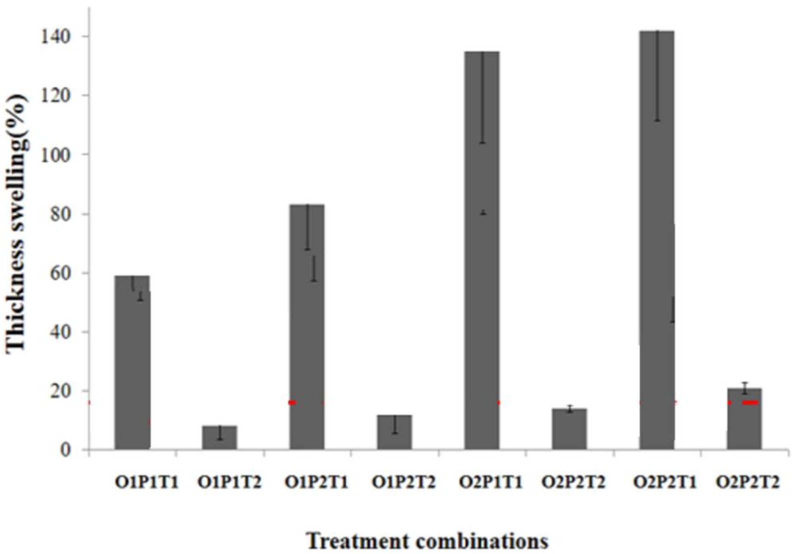

Figure 4. Thickeness swelling of the MDFs from jute fiber

1.6 MODULUS OF ELASTICITY (MOE)

The MOE is a number that expresses how resistant a material is to elastic deformation in response to applied force. It only momentarily strains and returns to its original shape once the force is withdrawn. It is defined as the ratio of tensile stress to tensile strain below the elasticity limit (Ispir et al 2022). Adhesion holding capacity, fiber length, and adhesive type and component all affect tensile elasticity.

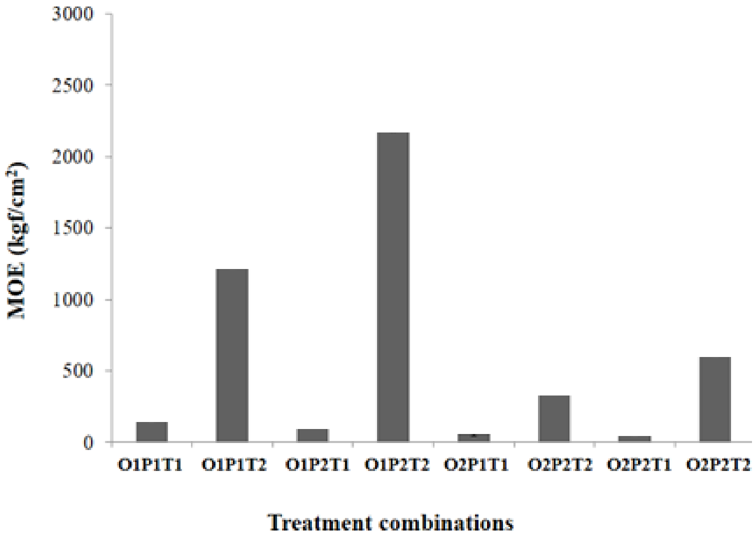

Figure 5. MOE of the binderless MDFs from jute fiber

According to this measurement, none of the samples have met the minimum MOE value of 8300 kgf/cm2 for MDF type 5 set out in ASTM standard. The ANOVA test indicates that there is a significant difference between the treatment combinations, with a significance value of 0.001 for MOE. Then, to determine which treatment combinations are significantly different and which are not, the Duncan test was run. As seen in Figure 5, the means value was then divided into two groups, a and b, where the treatment combinations value in one group is not substantially different from the other while it is in a different group.

1.7 MODULUS OF RUPTURE (MOR)

MOR describes a material's bending strength. It describes a material's resistance to deformation when subjected to stress. A board with a greater MOR is of higher quality (Craig & Taleff., 2020). As with MOE, adhesion holding ability, fiber length, and adhesive type and component all affect MOR.

The majority of the study's samples did not meet the minimum 51 kgf/cm2 requirements for ASTM D790-86 standard. In this investigation, the hydroxyl radicals produced during oxidation were not completely interacted with the lignin of the jute fiber during heat compression. The reaction created a covalent connection, but it was insufficiently strong to support the given weight (Jin et al., 2013). The individual fiber strength and fiber geometry, in addition to the bonding strength between fibers, all affect the value of MOR. A significant degree of hydrolysis or other chemical component alteration brought on by harsh steam treatment conditions may lower the fiber strength. The significance value, as determined by the ANOVA test, is 0.000. The fact that it is less than 0.005 suggests that the treatment combinations differ significantly from one another. Then, to determine which treatment combinations are significantly different and which are not, the Duncan test was run. As seen in Figure 6, the means values were then divided into a, b, bc, c, and d groups where the treatment combinations values within the same group do not substantially differ.

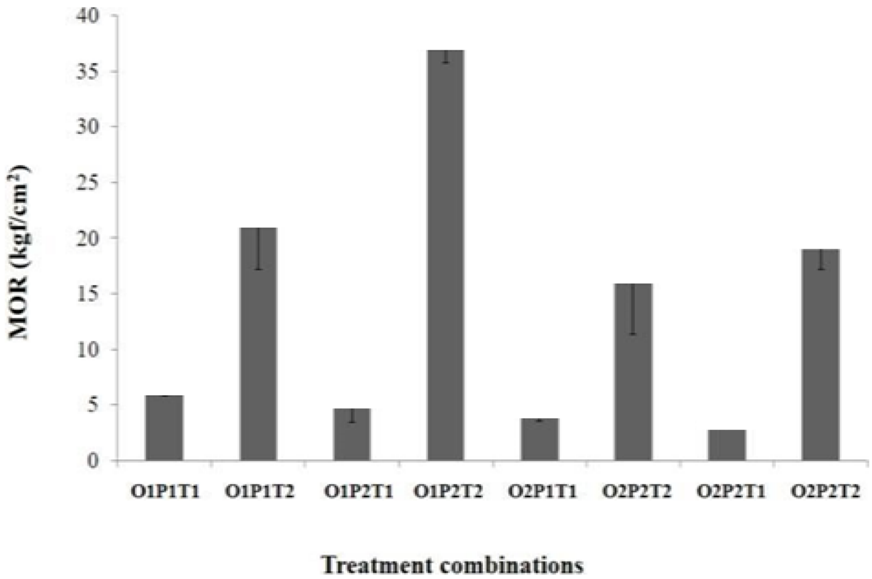

Figure 6. MOR of the binderless MDFs from jute fiber

IV. CONCLUSION

Using jute fiber, binderless medium density fiberboards (MDF) were effectively created. Using ASTM D790-86 stand and ASTM D570-8.standards, the mechanical and physical characteristics of MDF made from jute fiber were ascertained. The fiberboards generated in this study met the MDF standard with a medium density of 0.44–0.56 g/cm3, according to the results. The majority of the jute fiber fiberboards used in this study satisfied the requirements for physical characteristics like density, moisture content, swelling, thickness, and screw holding power. However, the mechanical properties of the fiberboards, including their modulus of elasticity, rupture modulus, and internal bond, did not fulfill the standards of ASTM D790-86 stand and ASTM D570-8. because of a lack of material strength. MDF that has been oxidized, mixed with 0.5% paraffin, and pressed for 20 minutes (OX1P1T2) is suitable for use indoors, while MDF that has been oxidized, mixed with no paraffin, and pressed for 20 minutes (OX1P2T2) is suitable for outdoor usage.

ACKNOWLEDGMENT

The researcher would like to thank the Department of Chemistry and Faculty of Sciences, Bani Waleed University for facilities and services given. The authors wish to thank Polymer Research Centre, Universiti Kebangsaan Malaysia for all facilities offered and the Malaysia Ministry of Science, Technology and Innovation for facilities given.

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