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An Investigation of the Effects of Manufacturing Parameters On Properties of Binderless Boards Produced from Abura (*Mitragyna Ciliata*) Sawdust

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Abstract: The production of particleboards without the use of synthetic binders is desirable to prevent environmental problems. This study has produced experimental binderless boards from untreated sawdust from Abura wood using a laboratory press. Response Surface Methodology using Box-Behnken experimental design was utilized to investigate the influence of pressing variables (pressure, pressing temperature and pressing time). Density of the bioboards produced was between 523.69 and 738 kg/m^3 which was comparable to medium density fibreboards. The maximum values for Internal Bonding Strength (IB), Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were 0.049 MPa, 1.1 MPa and 100.4 MPa, respectively. It was shown that, for the range of factors studied, pressure and the pressing temperature were the more significant factors in determining the density, MOE and IB. This study showed that the sawdust can potentially be used for the manufacture of binderless boards.

Keywords: Bioboard, biomass, binderless fibreboard, Abura sawdust, manufacturing parameters

1. Introduction

Fibreboards are produced from wood chips or other lignocellulosic fibres which are often readily available. Fibreboards can be utilized for various purposes which include furniture or heat and sound insulation [1,2]. Synthetic adhesives are conventionally used in the production of fibreboards. The commonly used adhesives are formaldehyde-based and are obtained from non-renewable sources. However, the synthetic adhesives need to be eliminated if the circular economy and sustainability principles have to be upheld [1-3]. Ongoing researches consider the production of fibreboard panels without the use of adhesives. Several researchers have investigated the properties of particleboards by replacing synthetic adhesives with lignin or other biobased adhesives [2,4]. The production of binderless bioboards utilizes residual lignocellulosic materials which are renewable and sustainable. From the review of natural binderless boards by Tajuddin et al. [5], the highlighted benefits of utilizing natural fibres include low specific weight, and high specific strength and stiffness. In addition, production requires little energy and low carbon dioxide levels are emitted since the resources utilized in the production are renewable. The production of boards using natural fibres require low-

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cost investment and the processing methods are friendly causing no skin irritation and limited tool wear. Boards produced using natural fibres are biodegradable and have desirable insulating properties for electrical, sound and thermal applications. The drawbacks highlighted from the work of Sreekumar and Thomas [6] include low impact strength of the boards and variable quality which is influenced by poor resistance to moisture causing the swelling of fibre. Natural fibres also have restricted maximum processing temperature. The boards also have lower durability and poor resistance to fire.

Shu et al. [7] considered the effects of varying mass proportions of high-strength bamboo, low-density poplar and walnut shells on board properties and bonding mechanisms. The study identified bioboard compositions with good performance. Wang et al. [8] studied the performance of melamine bamboo cellulose gum whilst investigating the influence of the temperature and time of pressing, quantity of cellulose gum and melamine dosage. From an orthogonal test, melamine was found to be significantly affect the quality of bamboo composite material. It had significant impact on the Internal Bonding strength (IB), Modulus of Rupture (MOR), Modulus of Elasticity (MOE) and other properties of the bioboards. Van Dam et al. [9] developed means of producing high-density boards with good strength without the utilizing synthetic binders. The manufactured boards from whole coconut husks exhibited characteristics which were similar to, or better than, commercial wood panels. Böger et al. [10] investigated the production of binderless panels from milled coconut husk by developing an energy-efficient manufacturing process at laboratory scale. The study found that required moisture content for the successful production of fiberboards using the hot-pressing process was between 10 and 25%.

Kurokochi and Sato [11] examined the impact of pretreatments on the quality of rice straw bioboard. The effects of steam explosion and grinding on the IB, Water Absorption (WA) and Thickness Swelling (TS) of the boards were investigated. It was observed that defibration occurred during steam explosion to cause an increase in bonding area. Pretreatment methods which combined steam explosion and grinding was found to be the most effective method for increasing self-bonding. Zhang et al. [12] examined the effect of temperature on strength of rice straw bioboard. The study found that the rupture strength increased with increase in temperature. A study by Zuraida et al. [13] determined chemical composition to determine lignin distribution of rattan waste using optical microscopy and scanning electron microscope. Rattan waste was found to possess high amount of hemicellulose, cellulose and lignin contents which were beneficial to the manufacture of binderless boards. The study established that the characteristics of bioboards were mainly influenced by the pressing temperature of the hot-pressing process. The optimum pressing temperature was 180°C. Orisaleye et al. [14] carried out investigation on the influence of manufacturing parameters on corncob boards. The bioboards had density in a range of medium density fibreboards but had poor MOE, MOR and IB. The particle size was found to be the most influential variable on all quality parameters considered. Kurniati et al. [15] produced boards using cake from pressed castor seed whilst studying the importance of pressing temperature on quality of binderless boards. Density of the boards was targeted to be 900 kg/m^3 and the pressing temperature was varied from 150 to 190°C. With increase in temperature, MOR, MOE and IB increased whilst WA and TS decreased. Hashim et al. [16] produced experimental bioboards from oil palm biomass with density of 800 kg/m^3. Panels were produced from bark and leaves did not have satisfactory strength and dimensional stability but panels produced from the core of trunks had the highest MOR and IB with lowest TS and WA.

Ferrandez-Garcia et al. [17] produced binderless boards which can be used for thermal insulation from leaves of olive tree whilst varying the particle size, temperature and time but retaining constant pressure. The study noted that the IB, MOR and MOE of the boards were enhanced with smaller particle size, longer pressing times and higher pressing temperatures. Uitterhaegen et al. [18] produced self-bonded boards from de-oiled press cake of coriander fruits. The optimized process conditions resulted in a density of 1323 kg/m^3, MOE of 4.4 MPa, and flexural strength of 23 MPa. Heat treatment of the boards after thermo-pressing resulted in the reduction of thickness swelling. Xie et al. [19] studied the influence of hot-pressing factors on the quality of defibrated poplar fiber. The factors investigated were pressure, temperature, mat moisture content and pressing time. Statistical design methodology, or design of experiments (DOE), has been widely used for experimentation and also for process optimization. The response surface methodology (RSM) is suitable for model and analysis where the response is impacted by several factors. [20]. Statistical analysis involves the Analysis of Variance (ANOVA) with regression or correlation analysis. The objective is to optimize the response of interest by determining variables with high influence [20, 21]. Using statistical analysis, Boon et al. [22] observed that adding lignin was statistically significant to binderless boards from oil palm. Hidayat et al. [23] found that the pressing time was not significant to the properties of binderless boards from *Jatropha curcas* L. seeds cake. Saari et al. [21] found that the pressing time had more significance to the bending strength compared to pressing temperature.

Vitrone et al. [1] noted the selection of appropriate raw material selection has a huge effect on the quality of binderless boards. Residues generated from agricultural activities and industrial by-products are feasible alternatives for binderless board production. Fundamental knowledge on hot-pressing process for the manufacture of bioboards is still required. Optimal processing parameters also need to be identified [24]. This study investigates the quality of experimental bioboards manufactured from untreated Abura sawdust using an experimental hot press by varying the operating conditions relating to the bioboard production. The varied operating conditions within this study include the pressure, pressing temperature and the pressing time.

2. Materials and Methods

2.1 Experimental Press

In this work, a laboratory press for producing binderless boards was developed (Figure 1). The laboratory press is made up of a hydraulic jack that generates the necessary pressure, which is monitored by a hydraulic gauge attached to the jack. A rectangular chamber (200 × 100 mm) exists above the 50 tonnes hydraulic jack. Four 500 W cartridge heaters were installed in each pressing block (top and bottom blocks) to heat the pressing chamber to the desired temperature. The temperature of the pressing blocks was controlled in the control panel using temperature controllers with thermocouples.

Fig. 1 - Laboratory scale hot-press developed for manufacture of bioboards

2.2 Material Acquisition and Characterization

The material utilized for the manufacture of the binderless boards was sawdust generated from Abura (*Mitragyna sp.*). The sawdust was obtained from a sawmill at Oko-baba, Lagos State in Nigeria. The sawdust was air-dried at laboratory environment condition for a duration of three months. The dried sawdust was then sieved to remove stones, wood and lumps of material. After drying, the moisture content was evaluated using the procedure described in ASTM D 4442–92 standard test methods. Sample of sawdust was placed in an electric oven set to operate at $103 \pm 2°C$. The mass of the sample was determined after every 1 hour until the variability of masses was consistently less than 0.2 mg over a period of 3 hours. The fraction of the change in mass of sample to the original mass of sample was used for the determination of the moisture content of sawdust. The bulk density was determined in line with ASTM E 1109 – 86. A box was obtained and the internal dimensions was measured with a Vernier calliper and the volume was calculated as a product of the length, width and depth. The box was filled to overflowing and tamped three times by lifting it above the ground to a height of 6 cm and dropping squarely. The top of the box was then levelled using a straightedge. The bulk density was determined as the fraction of the mass of material contained in the box to the estimated volume of the box.

2.3 Production of Binderless Boards

Hot pressing was used to create bioboards from the collected sawdust. To start manufacture of the boards, the desired temperature was set, as stated in the experimental design which ranged between 100 and 170 °C, and the heaters were activated. The bottom of the cavity of the pressing chamber was then sealed by the lower block. Once the set temperature was reached, 100 g of sawdust was put into the die. Thereafter, the sawdust was enclosed in the chamber cavity by the top block. The press was operated to reach the specified pressure, which varied between 10 and 16 MPa. The setup was then left to stand at the stated pressure for the requisite pressing time, which ranged between 5 and 15 minutes. The top block was removed after the pressing time was up. The hydraulic press was then operated until the manufactured bioboard could be collected from the top of the press and cooled.

2.4 Properties of Binderless Boards

Quality parameters of the bioboards produced were determined using ASTM D1037 standard tests. The physical property which was determined was the density whilst mechanical properties included MOE, MOR and IB.

2.4.1 Density

Density is a measure of the degree of compactness of particles which make up the bioboard. The dimensions of the manufacture boards were measured and the volume of each bioboard was evaluated. Each manufactured board was weighed shortly after production using an electronic weighing scale. The density of the manufactured bioboards was calculated as the mass per unit volume.

2.4.2 Modulus of Elasticity

MOE of the bioboards measures the ability of the boards to withstand bending. The MOE is estimated from the gradient of the load-deflection curve obtained during static bending tests where a linear relationship exists. The MOE was determined using the methods prescribed in ASTM D1037 standard. The MOE was calculated from:

$$MOE = \frac{L^3}{4bd^3}\frac{\Delta P}{\Delta y} \tag{1}$$

where $\Delta P/\Delta y$ (N/mm) is the gradient of the load-deflection at the linear portion, L (mm) is the span of the bioboard, b (mm) is the breadth of the bioboard, and d (mm) is the depth of the bioboard.

2.4.3 Modulus of Rupture

The MOR is a measure of the ultimate stress of the bioboards in bending when subjected to flexural loads. Comparison of the performance of different materials for the production of bioboards can be carried out using MOR. Bending tests was used to evaluate the MOR for binderless board specimens manufactured from Abura sawdust. From ASTM D1037 standard procedure, MOR was estimated using:

$$MOR = \frac{3P_{\max}L}{2bd^2} \tag{2}$$

where P_{max} (N).is the maximum flexural load.

2.4.4 Internal Bond Strength

Degree of bonding of bioboards in the direction perpendicular to the plane of the boards is determined by tensile tests. The tensile strength or IB measures the resistance of the bioboards to failure when loaded perpendicular to the plane of the boards. The IB of the bioboards was determined from ASTM D1037 standard. The IB was calculated from:

$$IB = \frac{P_{\max}}{bL} \tag{3}$$

2.5 Experimental Design and Statistical Analysis

Box-Behnken RSM design of experiment was used in this study whilst varying the pressure, pressing temperature and pressing time. Minitab 19 was used for the statistical analysis. Analysis of Variance (ANOVA) was used to identify the manufacturing parameters which influenced the quality of the binderless boards. The significance of the interactions of the variables was also determined using ANOVA. Backward elimination was adopted to enhance the analysis by eliminating variables which had the least significance. Main effects plots were used to evaluate the influence of the manufacturing variables on the characteristics of the bioboards.

2.6 Scanning Electron Micrograph

A scanning electron microscope (Phenom ProX Desktop SEM, Thermo-Fischer) was used to generate micrographs which were used to analyse the surface morphology of a sample of bioboard. The sample used was formed from the combination of the highest settings for pressure, pressing temperature and pressing times. The Scanning Electron Microscope (SEM) images have the capability to determine the suitability of the pressing conditions for the production of the bioboards.

3. Results and Discussion

3.1 Properties of Biomass Material

The moisture content of the Abura sawdust was 14.75% whilst the bulk density was 115 kg/m^3. Böger et al. [10] found that required moisture content for the successful production of fiberboards using the hot-pressing process was between 10 and 25%. For binderless production of fibreboards, moisture content is required for the plasticization of lignin. However, excessive moisture content is detrimental to the properties of the boards [25]. The moisture content obtained for the sawdust was considered suitable for the production of bioboards.

3.2 Properties of Binderless Boards

The Box-Behnken RSM design of experiments utilized in this study is shown in Table 1. The results obtained for the responses considered in this study have also been presented in Table 1.

Table 1 - Box-Behnken RSM experimental design and responses for Abura sawdust bioboard production

Run Order	Pressure (MPa)	Temperature (°C)	Time (min)	Density (kg/m^3)	MOE (MPa)	MOR (MPa)	IB (MPa)
1	13	100	5	568.97 ± 28.43	20.33	1.10	0.011
2	10	170	10	539.39 ± 7.86	36.78	0.73	0.029
3	13	135	10	563.70 ± 13.71	0.01	0.39	0.000
4	10	100	10	591.79 ± 13.85	34.21	0.67	0.024
5	13	170	15	550.68 ± 18.61	39.68	0.70	0.028
6	13	170	5	541.21 ± 12.13	59.13	0.70	0.038
7	16	135	5	658.59 ± 56.81	12.20	0.60	0.009
8	13	100	15	637.67 ± 17.43	0.01	0.48	0.000
9	13	135	10	617.12 ± 6.45	3.26	0.63	0.004
10	13	135	10	609.53 ± 16.82	18.99	0.48	0.028
11	16	170	10	625.81 ± 5.01	100.40	0.27	0.049
12	10	135	15	561.12 ± 7.51	21.37	0.40	0.014
13	16	100	10	699.22 ± 29.50	73.44	0.40	0.043
14	16	135	15	655.43 ± 14.00	84.16	0.75	0.041
15	10	135	5	594.19 ± 7.03	37.21	0.77	0.028

3.2.1 Density of Binderless Boards

One of the most significant physical qualities of particle boards is density, which is affected by the density of the biomass utilised, the binder used, and the pressure exerted during pressing [26]. From results in Table 1, the density of the manufactured bioboards varied from 524.69 to 738.10 kg/m^3. According to Youngquist et al. [27], density of medium density hardboard was between 500 and 800 kg/m^3, medium density fiberboards have density from 64 to 800 kg/m^3, and insulating boards have a density of 160 to 500 kg/m^3. According to this categorization, the density of the manufactured bioboards falls within the medium density hardboard range. The density of the boards also falls at the high limit of density for medium density fiberboards. However, the density range of the bioboards is greater than that recommended for insulating boards.

Table 2 - ANOVA for density of binderless boards manufactured from Abura sawdust

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	82763	16552.7	18.76	0.000
Linear	3	68972	22990.5	26.06	0.000
Pressure	1	46611	46611.1	52.84	0.000
Temperature	1	21700	21700.3	24.60	0.000
Time	1	660	660.2	0.75	0.392
Square	1	11161	11160.6	12.65	0.001
Pressure*Pressure	1	11161	11160.6	12.65	0.001
2-Way Interaction	1	2631	2631.1	2.98	0.092
Temperature*Time	1	2631	2631.1	2.98	0.092
Error	39	34404	882.2		
Lack-of-Fit	7	9005	1286.5	1.62	0.165
Pure Error	32	25399	793.7		
Total	44	117167			

Table 2 presents the ANOVA for density of binderless boards using three replicates of the experimental design. It is shown from Table 2 that the pressure and temperature are significant terms (P<0.05) to the density of the bioboards. The square term of the pressure is statistically significant. The main effects plot of the manufacturing parameters on the board density is shown in Figure 2. It is observed that the pressure applied for compacting the particles to form the board has greater influence than the temperature. Increasing the level of pressure caused an increase in the density of the binderless bioboards. Increasing time has a slight positive effect on the mean density of the boards. However, increasing temperature did not have a positive effect on the mean density of the boards. The trend for temperature is unusual in comparison with studies from Song et al. [28] where density of bioboards from soybean straw increased from 0.8 kg/m^3 to 1.1 kg/m^3 with increase in temperature from 110 to 140°C although there were fluctuations in the values of the average density with temperatures between 140 and 230°C. From the study of Nonaka et al. [29], production of bioboards from bagasse and recycled chips using low temperatures below 200°C resulted in spring back due to poor bonding resulting in low density. Density of the boards, however, increased with increase in temperature up to 260°C beyond which there was devolatilization of the material. Previous studies on solid fuel production [30, 31] have noted that increasing temperature improves density of densified biomass.

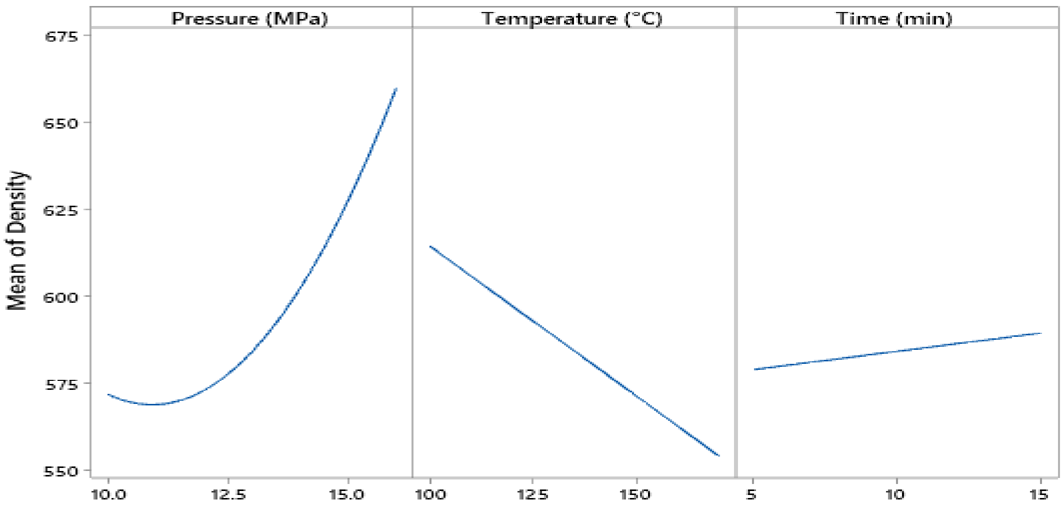

Fig. 2 - Main effects plot for density of binderless boards manufactured from Abura sawdust

3.2.2 Modulus of Elasticity of Binderless Boards

Observation of the responses in Table 1 reveal that MOE of sawdust bioboards reached 100.4 MPa at highest pressure and temperature setting and pressing time of 10 minutes. According to Mitchual et al. [26], ANSI A208.1 specifies minimum MOE for particle boards for general usage and furniture manufacture of 1550 MPa as the minimum value. The ANOVA for the MOE of the boards is shown in Table 3. The pressure is seen to be significant (P<0.05) to the MOE. The temperature is also significant (P<0.1) but with a lower confidence level. Square terms of pressure and temperature along with the interaction of pressure with pressing time are significant (P<0.05). This suggests that interactions of processing parameters in determining the properties of bioboards need to be considered. The main effects plot of the parameters on the MOE is shown in Figure 3. From Figure 3, the pressure and temperature are seen to have similar effect on the MOE of the manufactured bioboards. From the figure, it is seen that by utilizing pressures of less than 12.5 MPa and temperatures less than 125°C, MOE is low and has an unusual trend. The situation is most likely due to the poor and insufficient binding of particles in the pressed boards. Higher levels of pressure and temperature result in high values of MOE. However, the pressing time increases the mean MOE of the boards only negligibly. Nonaka et al. [29] found that MOE of bioboards from bagasse and recycled chips increased with increase in temperature.

Table 3 - ANOVA for MOE of binderless boards manufactured from Abura sawdust

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	11067.0	1844.51	6.32	0.010
Linear	3	3963.5	1321.17	4.53	0.039
Pressure	1	2472.1	2472.10	8.48	0.020
Temperature	1	1458.0	1458.00	5.00	0.056
Time	1	33.4	33.42	0.11	0.744
Square	2	5176.3	2588.16	8.87	0.009
Pressure*Pressure	1	3655.5	3655.50	12.53	0.008
Temperature*Temperature	1	1867.7	1867.68	6.40	0.035
2-Way Interaction	1	1927.2	1927.21	6.61	0.033
Pressure*Time	1	1927.2	1927.21	6.61	0.033
Error	8	2333.0	291.63		
Lack-of-Fit	6	2126.9	354.49	3.44	0.242
Pure Error	2	206.1	103.04		
Total	14	13400.1			

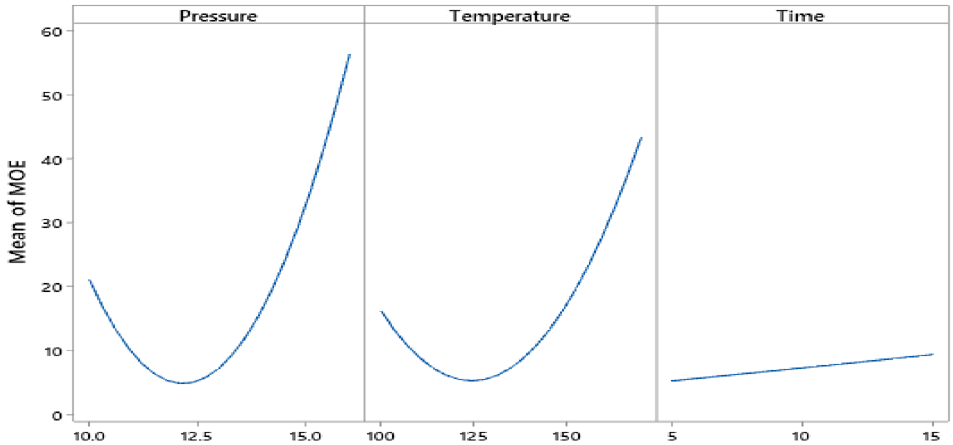

Fig. 3 - Main effects plot for MOE of binderless boards manufactured from Abura sawdust

3.2.3 Modulus of Rupture of Binderless Boards

Results presented in Table 1 show that MOR for bioboards ranges between 0.27 and 1.10 MPa. The MOR obtained are much lower than 10 MPa which is stated as the lowest MOR value for interior fitments by ANSI A208.1 [26]. Table 4 presents the ANOVA for the MOR. None of the terms is significant to the MOR of the bioboards at a confidence level of 95%. However, the square term of pressing time is significant ($P<0.01$) at a lower confidence level of 90%. The main effects plot of the manufacturing parameters on the MOR is shown in Figure 4. It was observed that times below 12.5 minutes were not suitable for production of bioboards with high MOR as unpredictable responses are obtained due to poor particle binding. From Vitrone at al. [1], increasing pressing time, along with pressing temperature, resulted in increase in the MOR. From the study of Nonaka [29], increasing temperature between 200 and 260°C resulted in higher MOR but between 260 and 280°C, no obvious change was observed.

Table 4 - ANOVA for MOR of binderless boards manufactured from Abura sawdust

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	2	0.20582	0.10291	3.09	0.083
Linear	1	0.08820	0.08820	2.65	0.130
Time	1	0.08820	0.08820	2.65	0.130
Square	1	0.11762	0.11762	3.53	0.085
Time*Time	1	0.11762	0.11762	3.53	0.085
Error	12	0.39975	0.03331		
Lack-of-Fit	10	0.37035	0.03703	2.52	0.317
Pure Error	2	0.02940	0.01470		
Total	14	0.60557			

3.2.4 Internal Bond Strength of Binderless Boards

From the responses of the design of experiment in Table 1, IB of the Abura sawdust bioboards reached up to 0.049. The highest IB was obtained at the same conditions that produced the highest MOE. Mitchual et al. [26] observed that the IB is positively correlated with the MOE and MOR. However, the IB obtained in this study are lower than 0.5 MPa which was stated to be the acceptable minimum limit by ANSI A208.1. It was also lower than 0.4 MPa specified as the minimum limit for IB by EN 312 [26]. The ANOVA for the IB using backward elimination is shown in Table 5. At a level of confidence of 95%, only the square term of pressure is significant. However, at a lower level of confidence of 90%, the pressing temperature is significant to the IB of the bioboards. The square term of temperature and the interactions between pressure and pressing time are also significant (P<0.1). From the main effects plot in Figure 5, the pressure and temperature are seen to have similar effect on the IB of the manufactured bioboards. Higher levels of pressure and temperature result in high values of IB. However, the effect of the pressing time is almost negligent as it doesn't seem to have much effect on the IB of the boards. This is contrary to observation from the review of Vitrone et al. [1] which states that increasing the pressing time, along with pressing temperature, causes an increase in IB. As previously noted, the pressing parameters used resulted in low IB of the boards which is indicative of insufficient particle binding. Therefore, the responses at lower settings of the pressing variables didn't follow the trend reported in Vitrone et al. [1].

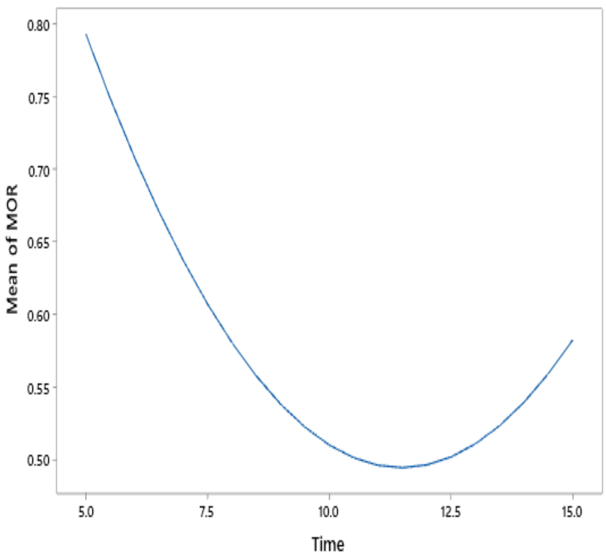

Fig. 4 - Main effects plot for MOR of binderless boards manufactured from Abura sawdust

Table 5 - ANOVA for IB of binderless boards manufactured from Abura sawdust

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	0.002496	0.000416	3.36	0.059
Linear	3	0.000805	0.000268	2.17	0.170
Pressure	1	0.000276	0.000276	2.23	0.174
Temperature	1	0.000528	0.000528	4.26	0.073
Time	1	0.000000	0.000000	0.00	0.951
Square	2	0.001162	0.000581	4.69	0.045
Pressure*Pressure	1	0.000787	0.000787	6.36	0.036
Temperature*Temperature	1	0.000454	0.000454	3.67	0.092
2-Way Interaction	1	0.000529	0.000529	4.27	0.073
Pressure*Time	1	0.000529	0.000529	4.27	0.073
Error	8	0.000991	0.000124		
Lack-of-Fit	6	0.000553	0.000092	0.42	0.826
Pure Error	2	0.000438	0.000219		
Total	14	0.003486			

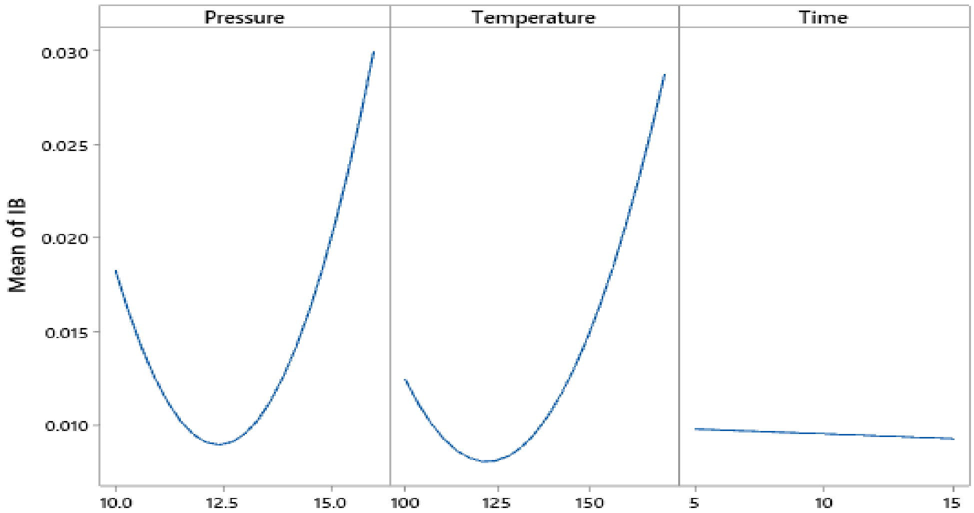

Fig. 5 - Main effects plot for IB of binderless boards manufactured from Abura sawdust

3.3 Scanning Electron Micrograph

The scanning electron micrograph presented in Figure 6 is for a binderless board produced with the highest settings of pressure (16 MPa), temperature (170°C) and pressing time (15 minutes) used in this study. The micrograph shows that the board has an uneven surface, and also shows that the sizes of particles used in the production of the board are uneven. The micrographs show the existence of voids due to insufficient compaction and poor or loose binding between particles which indicate that the pressing conditions were not sufficient enough to plasticize the lignin in the sawdust particles. This gives a reason for the poor quality obtained for the manufactured boards. In boards produced by Zuraida et al. [13] from rattan wastes, it was noted that at a temperature of 170°C, there were void spaces shown in the micrograph of binderless boards which improved at higher temperature of 180°C to produce good adhesion. Araújo Junior et al. [32] also observed smooth surfaces from micrographs produced at 230°C with some transversal fissures compared to lower temperatures for coconut husks. Observations by Song et al. [28] from micrographs show that higher temperatures up to 200°C was beneficial to the production of binderless board from soybean straw.

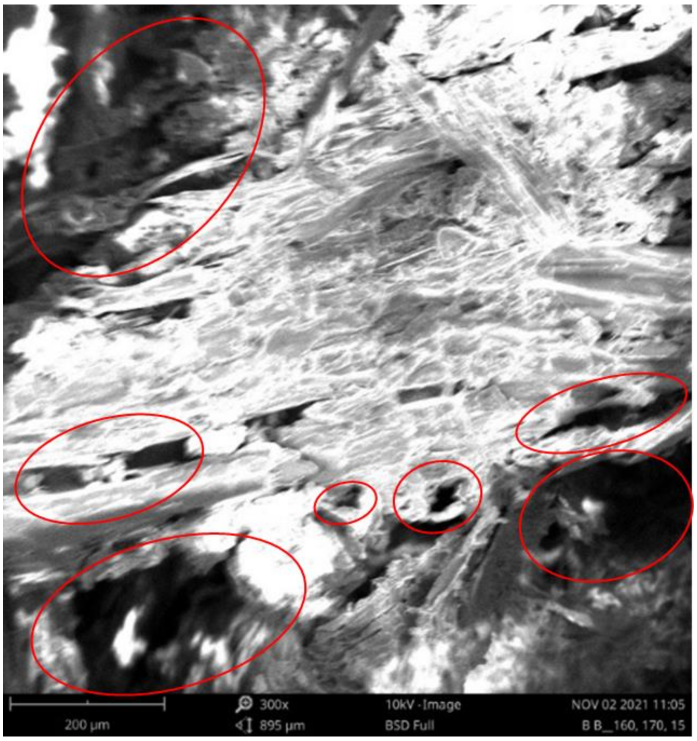

Fig. 6 - SEM of bioboards produced at 16 MPa, 170°C and 15 minutes for magnifications of ×300 (with voids highlighted)

4. Conclusion

This study has produced experimental binderless boards from untreated sawdust from Abura wood using a developed laboratory press. The influence of the pressing variables including pressure, pressing temperature and pressing time were determined using a Box-Behnken Response Surface Methodology for the experimental design. The range of values for density was within the range specified for MDF with the maximum density obtained as 738.10 kg/m^3. The maximum values for MOE, MOR and IB were 100.4 MPa, 1.1 MPa and 0.049 MPa, respectively. From ANOVA of the responses, it was shown that pressure and the pressing temperature were the more significant terms in determining the density and MOE. This study shows that the sawdust can potentially be used for the manufacture of bioboards. However, further work should investigate the means to improve the quality of the binderless boards. This should include the use of different pretreatment methods which will make lignin more available for proper binding of the particles for high quality bioboards. The utilization of broader and higher range of variables would be useful in determining how the variables affect the properties of bioboards. Finally, optimization of the parameters for the manufacture of the boards using hot-pressing need to be carried out for different potential biomass resources.

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