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EFFECT OF PRESSING PRESSURE ON PHYSICAL AND MECHANICAL PROPERTIES OF *ELAEIS GUINEENSIS* FRONDS COMPOSITE BOARD

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ABSTRACT

Performance of composite boards usually depends on the raw materials selection and fabrication parameters. This paper presents the effect of different level of applied pressure towards the performance of the end product of *Elaeis guineensis* composite board. The OPF was collected from a private plantation in Sarawak and refined into smaller particles by using a crusher machine. Sieved OPF particles that retained on the 0.60mm sieve mesh were used to fabricate composite boards with a targeted density of 0.7g/cm^3. The 20 cm × 20 cm × 0.50 cm composite boards were fabricated under same hot press temperature of 160℃ for three different applied pressures of 5MPa, 6MPa, and 7MPa respectively. The physical and mechanical properties test were conducted according to the Japanese Industrial Standard (JIS A5908:2003). It is indicated from the results that the performance of *Elaeis guineensis* composite board improved with increasing applied pressure. The composite boards satisfied the provision set for the internal bond (IB) strength and modulus of rupture (MOR) in JIS A5908:2003. Unfortunately, the thickness swelling percentage exceeded the maximum set value. Overall performance investigated that *Elaeis guineensis* composite board is suitable to be used in indoor applications such as based materials, decorative boards, and teaching aids.

Keywords: *Elaeis guineensis* Fronds, Physical Properties; Mechanical Properties; Pressure; Composite Board.

INTRODUCTION

Oil palm species *Elaeis guineensis* is one of the most important agricultural crops in this millennium era especially in Indonesia, Malaysia, and Thailand which are the top three countries of palm oil producers. Among different parts of oil palm biomass, oil palm fronds (OPF) have the highest availability throughout the year. This situation has initiated the need to recycle OPF by transforming the OPF into various valuable products such as pulp, feedstocks and composite boards.

Oil palm called as a lignocellulosic material due to the presence of sugar, starch, cellulose, hemicellulose, and lignin which can be found in the bark, leaves, fronds and trunks. The lignocellulosic materials present in oil palm (Akmar & Kennedy, 2001) makes it ideal to produce value-added composite panels in the same approach to that with other non-wood resources such as kenaf and coffee husk (Bekalo & Reinhardt, 2010; Okuda & Sato, 2008).

The innovation of composite boards from oil palm biomass as a new material in furniture manufacturing has increased steadily in recent years. The availability of large amount of oil palm residues such as oil palm trunk (OPT), oil palm fronds (OPF) and oil palm empty fruit bunches (EFB) in Malaysia has caught the attention of many researchers and industries to utilize this biomass effectively. Besides that, oil palm biomass is a quintessential raw material for the production of value-added, reasonably cheap, environmentally friendly and green composite boards due to its renewable and high carbohydrate characteristics (Tajuddin, Ahmad, & Ismail, 2016).

In 2014, a total of 24.87 ton per hectare OPF by pruning and replanting was available based on the standard biomass to fresh fruit bunches (FFB) extraction rate (Loh, 2016). In addition, having hemicellulose content of 1.5 to 3 times more than typical hardwood species, OPF show the same tendency to use as raw material in composite board making (F. & Najmuldeen, 2015; Laemsak & Okuma, 2000)**.** Numerous research and development have been conducted to study the feasibility of utilizing OPF as a raw material in composite board fabrication (F. & Najmuldeen, 2015; Laemsak & Okuma, 1996; Rasat et al., 2011).

Composite board is a material formed through the combination of two or more micro- or macroconstituents having a different structure and chemical composition. The significant of composite board is the possessing properties of the end product which are superior to the properties of individual constituents (Smith & Hashemi, 2011). One of the most important parameters in the fabrication of the composite board is the applied pressure during fabrication of the board to make sure a compact board being produced.

Hot pressing is an important step to fabricate composite boards by consolidating resinated particles under heat and pressure (Brauns & Rocens, 2007). Hot pressing plays the part of the decisive role in indicating the quality and productivity of end products by which the process is subjected to evaporation of moisture, solidification of adhesive and redistribution of water or fireproof agents. Pressed constituents of composite boards are subjected to a series of physical and chemical changes to induced bonding force between the particles subsequently fabricating required quality composite boards (Gul, Khan, & Shakoor, 2017).

(Tajuddin et al., 2016) also mentioned that internal bond strength and mechanical properties of boards along with the physical properties can be boosted by elevating pressing pressure. In addition, (Quintana et al., 2009) studied that high pressing pressure helps in better bonding of manufactured board as lignin fluidity and physical-mechanical characteristic can be improved.

The objective of this research was to investigate the properties of *Elaeis guineensis* frond composite boards with 10% urea formaldehyde as binders focusing on the effect of applied pressure during fabrication. Three levels of applied pressure; 5MPa, 6MPa, and 7MPa respectively were studied. Both the mechanical and physical properties of the fabricated composite board were evaluated. In addition, the microscopic study was conducted to determine the bonding quality of the experimental composite boards as a function of applied pressure.

RESEARCH METHODOLOGY

Preparation of Materials

Elaeis guineensis fronds were obtained from the local plantation, Zumida Oil Palm Plantation Sibu. Fronds were processed to chips using a horizontal band saw and oven dried to 6-8 % moisture contents with a heating temperature of 100℃ before being reduced to smaller particles by using crusher machine. Crushed frond particles were then screened to get the desired particle size which retained on the 0.60mm sieve mesh for composite boards fabrication. Low formaldehyde emission urea formaldehyde resins which supplied by Hexzachem Sarawak Sdn. Bhd. was mixed with 1% of hardener (ammonium chloride) to be used as adhesive in the composite board making.

Fabrication of *Elaeis guineensis* Composite Board

The composite boards were made on a laboratory scale by standard techniques and controlled conditions. *Elaeis guineensis* frond particles were weighed and placed into a mould with dimension $(20 \times 20 \times 0.50) \pm 0.02$ cm with targeted densities of 0.7 g/cm^3 The mats were pressed by hand to consolidate the thickness and compressed using hot press machine with platen temperature of 160 ℃ and pressure of 5MPa, 6MPa and 7MPa for 20 minutes. The pressed composite boards then conditioned in a climate room having a temperature of 20 ± 2 ℃ and relative humidity of 65 ± 5% for two days followed by cutting of test specimens based on Japanese Industrial Standards (JIS A5908:2003).

Mechanical Tests of *Elaeis guineensis* Composite Board

Modulus of Rapture Test

Three MOR samples were prepared from each fabricated composite board. MOR tests were conducted on a Hegewald and Peschke Testing Machine equipped with a load of 10kN. Following the JIS A5908:2003, load speed of 10 mm/min was applied for modulus of rupture (MOR).

Internal Bond (IB) Strength Test

Three IB samples were prepared from each fabricated composite board and tested on a Hegewald and Peschke Testing Machine equipped with a load of 10kN. Load speed of 2 mm/min was applied according to the JIS A5908:2003 while conducting the IB strength test.

Physical Tests of *Elaeis guineensis* Composite Board

Physical tests were carried out according to JIS A5908:2003. Three samples with dimensions of 5 cm × 5 cm from each fabricated composite board were used to examine the thickness swelling (TS) and water absorption (WA).

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Thickness Swelling Test

The thickness of each sample was measured at four points midway along each side at 1 cm from the edge. Then, the samples were soaked in distilled water for 24 hours before thickness measurements were taken at the same points to calculate thickness swelling values. The thickness swelling (TS) was calculated according to equation (1), where T_1 is the thickness of the sample before immersion (mm) and T_2 thickness of sample after immersion (mm). The difference in the reading each sample's thickness was calculated and recorded.

$$\text{Thickness Swelling (\%)} = \frac{T_2 - T_1}{T_1} \times 100 \quad (1)$$

Water Absorption Test

The weight of each dry sample was weighed on an analytical balance with an accuracy of 0.01g and soaked in distilled water for 24 hours. After 24 hours, the wet samples were then weighed to determine the water absorption values. The water absorption (WA) was calculated according to equation (2), where W_1 is the weight of the sample before immersion (g) and W_2 weight of the sample after immersion (g). The difference in the reading of each sample's weight was calculated and recorded.

$$\text{Water Absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \quad (2)$$

Morphology Characterization of *Elaeis guineensis* Composite Board

A scanning electron microscopy (SEM) model JCM-6000 was used to study the texture and surface morphology of bonding quality between constituents in pressed composite boards as a function of applied fabrication pressure. Micrograph was taken from the surface and cross section of 0the .5 cm × 0.5 cm samples cut from each pressed composite. The samples were coated with gold by an ion sputter coater (JEC-3000PC Auto Fine Coater).

RESULT AND DISCUSSION

Final fabricated *Elaeis guineensis* composite board properties were concisely summarized in Table 1. The internal bond (IB) strength and modulus of rupture (MOR) are mechanical properties of the *Elaeis guineensis* composite board while thickness swelling (TS) and water absorption (WA) are the physical properties of the *Elaeis guineensis* composite board.

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Table 1: The properties of Pressed *Elaeis guineensis* Composite Board.

Pressure (MPa)	IB (N/mm^2)	MOR (N/mm^2)	TS (%)	WA (%)
5	4.74	11.85	29.55	136.99
6	4.95	12.03	23.49	132.64
7	5.23	12.40	21.60	126.84

Mechanical Properties of *Elaeis guineensis* Composite Board

Internal Bond Strength

Internal bond strength test was conducted to determine the interfacial bonding strength between particles and adhesive in a pressed composite board. Figure 1 shows that the applied pressure significantly affected the internal bond strength of the boards. The internal bond strength increased proportionally to the increasing hot pressing value. The internal bond strength at the hot pressing of 5MPa, 6MPa, and 7MPa respectively were 4.74, 4.95 and 5.23 N/mm2. In addition, with every increase of 1MPa of hot pressing, the internal bond strength improved by approximately 4-5%. This indicates that there is an alteration in term of physical and chemical processes on *Elaeis guineensis* frond particles besides geometrical changes which believed helped to enhance the internal bond strength of the boards. (Gul et al., 2017) Higher hot pressing value causes the distribution of *Elaeis guineensis* frond particles in a composite board to be more compact which strengthen the interfacial bond between particles. In term of chemical changes, higher pressure can assist in the better fluidity of lignin (Quintana, Velasquez, Betancourt, & Ganan, 2009) to improve the bonding properties of pressed *Elaeis guineensis* composite board.

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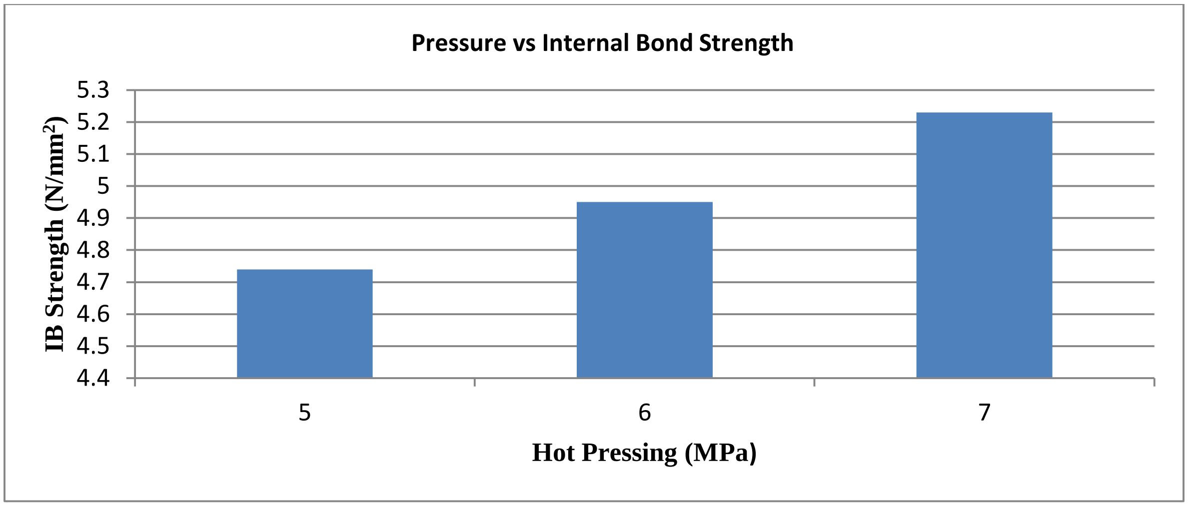
Figure 1: Relationship Between Hot Pressing and Internal Bond (IB) Strength



Modulus of Rupture

Modulus of rupture determines the ultimate strength before failure during bending of a pressed composite board. From Figure 2, it can be seen that the applied pressure influence correspondingly to the modulus of rupture of *Elaeis guineensis* composite board. The modulus of the rupture of *Elaeis guineensis* composite board increased from 11.85 to 12.40 as the hot pressing value increased from 5MPa to 7MPa. Composite board with the hot pressing value of 7MPa has the highest MOR because the particles and adhesive of the composite board have better bonding. Compactness of *Elaeis guineensis* composite board had reduced the number of voids and subsequently enhanced the resistance to rupture of composite boards due to better inter particles contact area (Chiang, Hamdan, & Osman, 2016). Whereas, *Elaeis guineensis* composite board pressed under pressure of 5MPa has lowest MOR resulting from weak inter particles contact area and presence of large voids.

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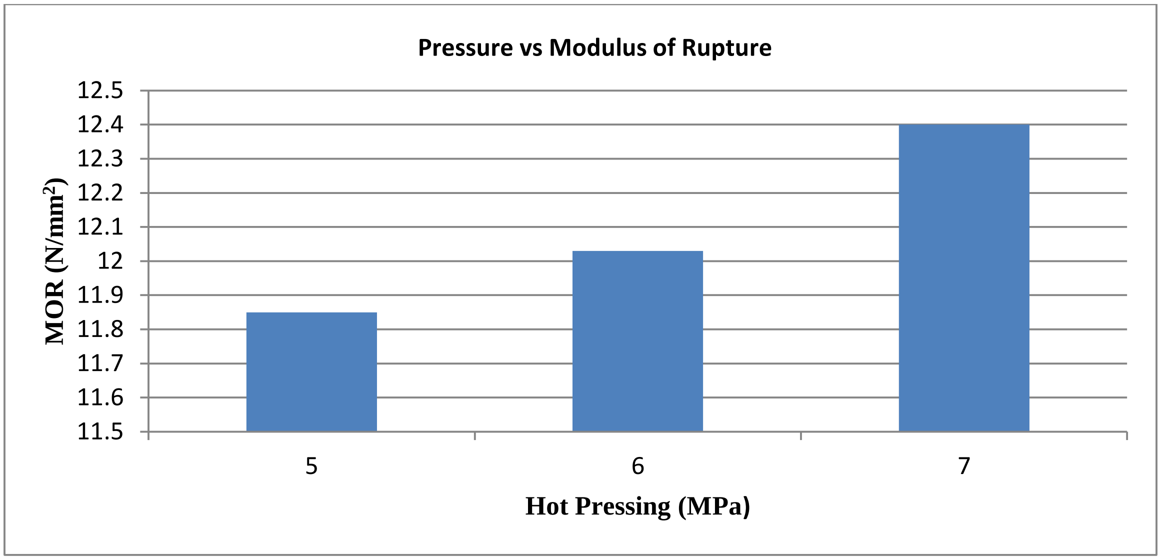
Figure 2: Relationship between hot pressing and modulus of rupture (MOR).



Physical Properties of *Elaeis guineensis* Composite Board

Thickness Swelling

Thickness swelling measures the maximum physical changes in term of the thickness of the composite board after being immersed in water for 24 hours. The decreased in thickness swelling percentage with increased of hot pressing value has been plotted in Figure 3. It can be seen that the thickness swelling percentage of *Elaeis guineensis* composite board gradually decreased as the hot pressing value increase from 5MPa to 7MPa. The total decreased in percentage of thickness swelling in *Elaeis guineensis* composite board is 26.9%. This indicates that the reduction of void spaces due to high pressure applied during fabrication of particles helped to improve the durability of the *Elaeis guineensis* composite board.

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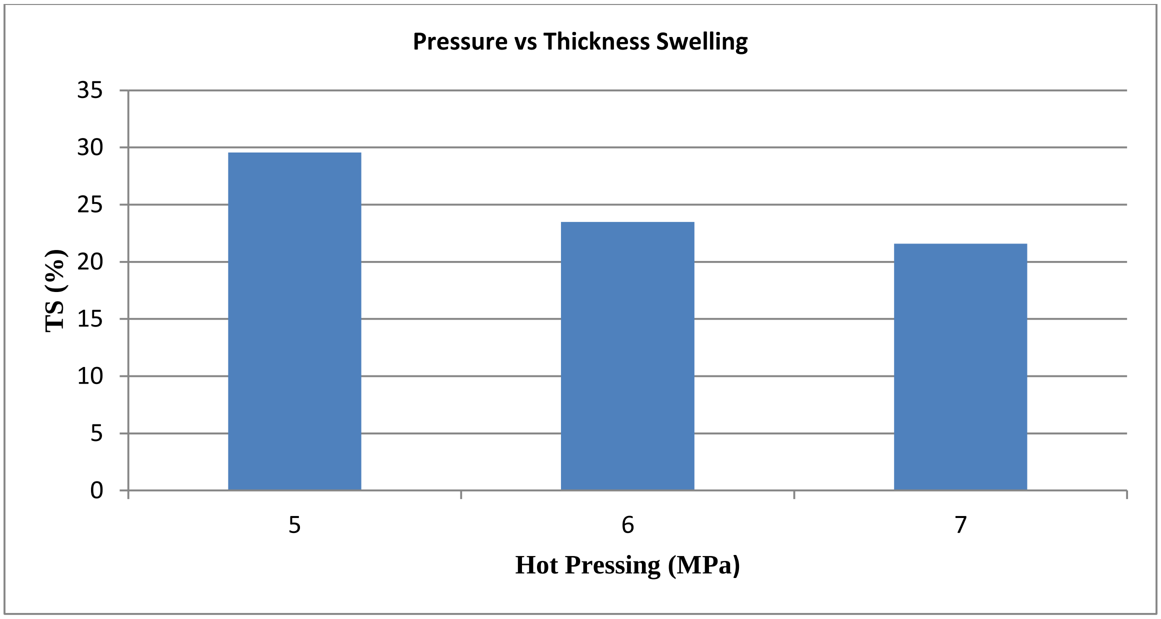
Figure 3: Relationship Between Hot Pressing and Thickness Swelling (TS)



Water Absorption

Water absorption test was conducted to study the dimension stability of the composite board by weighing the water that had been successfully uptake by the composite board after being immersed for 24 hours. Water absorption results fabricated under an applied pressure of 5MPa, 6MPa and 7MPa respectively were plotted in Figure 4. The decreasing in height of graphs plotted shows water absorption percentage of 136.99%, 132.64% and 126.84% for hot pressing of 5MPa, 6MPa, and 7MPa respectively. Water absorption percentage in any composite board contributes to the concern of composite board applications. Hot pressing plays an important role in the compactness and void reduction of *Elaeis guineensis* composite board because the lesser the void in a pressed composite board, the lower will be the water uptake during immersion of composite board. Apart from that, the presence of free hydroxyl groups in cellulose and hemicelluloses which are accessible to water may also affect the water absorption behavioral of *Elaeis guineensis* and other natural fibers.

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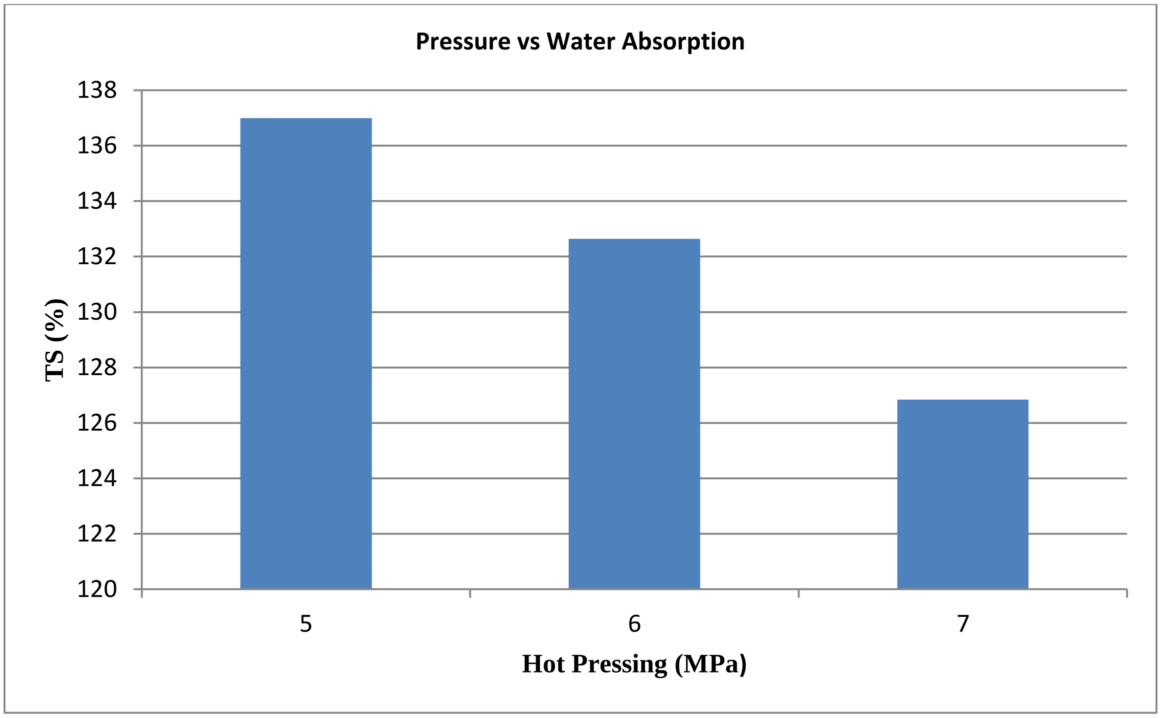
Figure 4: Relationship Between Hot Pressing and Water Absorption (WA).



Morphology Characterization of *Elaeis guineensis* Composite Board

The interphase and surface morphologies of the *Elaeis guineensis* composite board was investigated as a function of elevating hot pressing values. The micrographs labeled a to c indicated the surface of *Elaeis guineensis* composite board whereas the micrographs labeled d to f indicated the cross-section of *Elaeis guineensis* composite board. The micrographs of composite board fabricated with an applied pressure of 5MPa are shown in Figure 5 (a&d), whereas for composite boards fabricated with an applied pressure of 6MPa and 7MPa respectively the micrographs are shown in Figure 5 (b&e) and Figure 5 (c&f). For *Elaeis guineensis* composite board that underwent hot pressing of 5MPa, the large void had been detected in Figure 5(d) while in cross section micrograph shown in Figure 5(a), the texture of the particles are still intact or granular form can be clearly seen. In Figure 5 (d&f), it can be seen that the size of voids appeared was smaller as compared to micrograph in Figure 5 (d). Besides, micrographs are shown in Figure 5(b&c) showed a smoother texture of interphase as compared to Figure 5 (a). These changes in micrographs of hot pressing from 5MPa to 7MPa indicate that higher pressure will change the shape of particles and reduce the gaps between particles which subsequently give better bonding performance toward *Elaeis guineensis* composite board.

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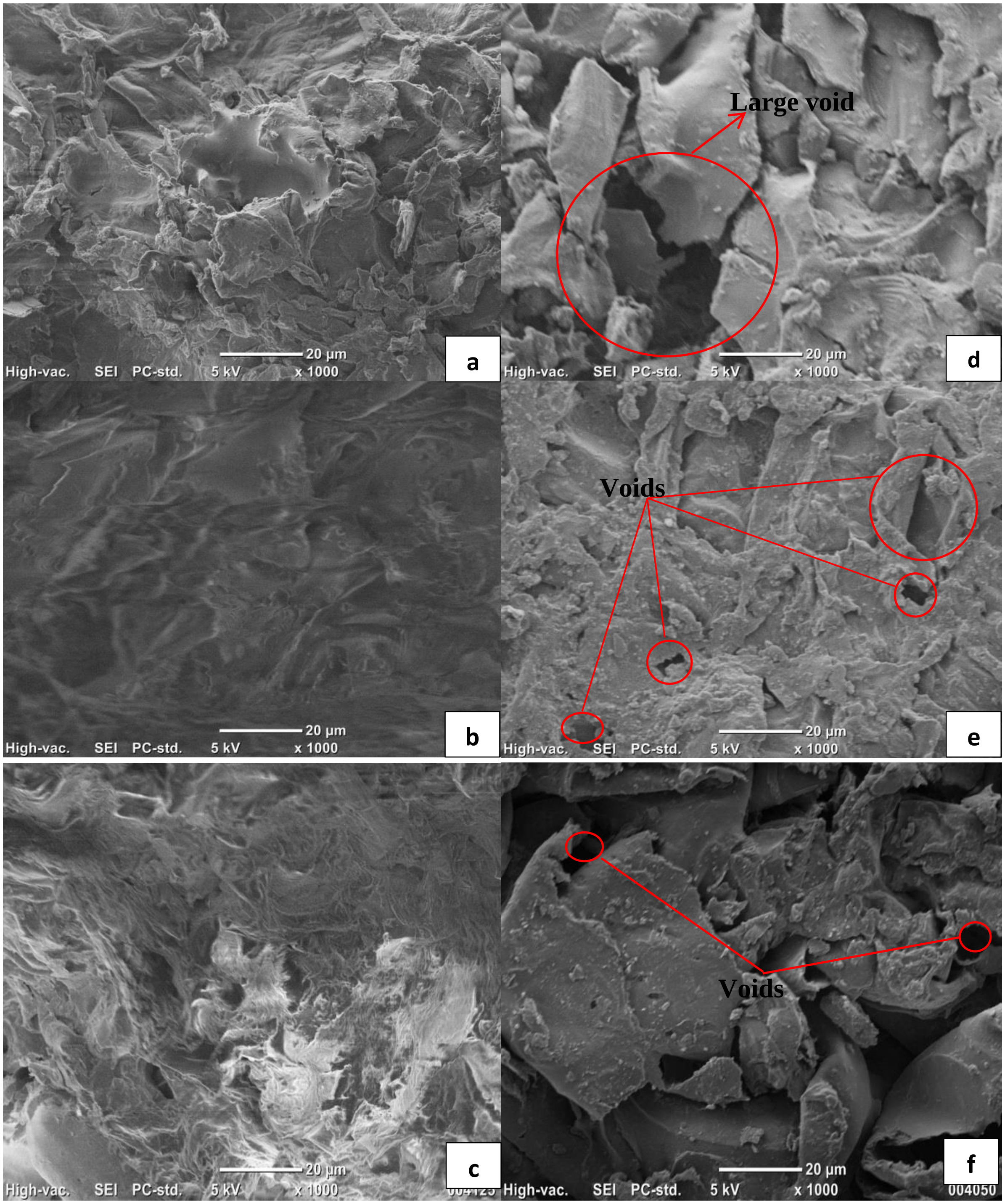
Figure 5: Scanning Electron Micrograph (SEM) of The Cross Section (A-C) and Surface (D-F) of Pressed *Elaeis Guineensis* Composite Board.



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CONCLUSION

In this research, it shows that hot pressing value does affect the mechanical and physical properties of *Elaeis guineensis* composite board. As the hot pressing pressure elevated from 5MPa to 7MPa, results showed increasing values in mechanical properties and decreasing values in physicals properties which indicated that the performance of *Elaeis guineensis* composite board has been improved gradually. The mechanical properties of *Elaeis guineensis* composite board exceed the minimum value required by JIS A5908:2003. The physical properties of *Elaeis guineensis* composite board in other hand had shown that the composite boards are less suitable to be used in a place with high humidity or prolong wet weather. Overall performance investigated that *Elaeis guineensis* composite board is suitable to be used in indoor applications such as based materials, decorative boards, and teaching aids. The physical properties of *Elaeis guineensis* composite board can be improved further by adding some waterproof agents such as epoxy or wax to improve the resistance to water property of composite board.

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