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ASSESSMENT OF OIL PALM WOOD QUALITY IMPROVEMENT THROUGH INTEGRATED TREATMENT PROCESS AS FUNCTION OF SAWING PATTERN AND SLAB THICKNESS

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ABSTRACT

Oil palm wood (OPW) was treated using six-step integrated treatment process in this study. The method consists of six processing steps, namely, debarking-sawing, steaming and compression, drying, resin inclusion, resin semi-curing heating and hot pressing. The objective of this study was to evaluate the properties of the OPW produced from two different sawing patterns, namely reverse cant sawing and polygon sawing. The OPW was sawn into waned and squared slabs using reverse cant sawing and polygon sawing, respectively. The sawn slabs were then planed to thicknesses of 40, 60 and 80 mm, respectively. Dimensional stability and mechanical properties of the treated OPW were evaluated after the slabs had undergone the six processing steps. Density and weight percent gain of the treated OPW were also determined. From the results obtained, OPW produced from waned samples showed better mechanical properties and dimensional stability in comparison to that of OPW produced from squared samples. In conclusion, reverse cant sawing pattern is a more appropriate sawing technique to obtain better quality OPW.

Keywords: oil palm wood, sawing pattern, integrated treatment process, reverse cant sawing, polygon sawing.

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INTRODUCTION

Malaysia is the second largest producer of palm oil in the world and has over 5.74 million hectares of oil palm plantation in the year of 2016 (MPOB, 2017). Generally, oil palm will be replanted at the end of their economic lifespan, which is every 25 to 30 years (Salim *et al*., 2016). Bakar *et al*. (2008a) pointed out that an estimated 7 million tonnes of oil palm trunks (OPT) are felled annually during replanting. According to Bakar *et al*. (2005), 30% of the stem radius (outer part) of OPT could be used for lumber extraction, while the inner 70% is a waste that has the potential to serve as raw materials in wood composite fabrication (Lee *et al*., 2015). Therefore, effective utilisation of these felled OPT would be beneficial in terms of environmental and socio-economic aspects rather than leaving them to rot on sites.

However, oil palm wood (OPW) extracted from the outer part of the oil palm stem was acknowledged to have four main drawbacks. According to Bakar *et al*. (2013), OPW has very poor strength and durability, high dimensional instability and bad machining characteristic. Therefore, an effective method to modify the OPW is needed before it could be used efficiently. For that purpose, Bakar *et al*. (2008b) proposed a five-step impregnation-compression treatment with low molecular weight phenol formaldehyde (LmwPF) resin to overcome the drawbacks of OPW. The proposed five-step approach consists of sawing, drying, impregnation, heating and hot

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pressing. As a result of such treatment, the strength, durability, dimensional stability and the machining characteristic of the treated oil palm wood witness significant improvement.

However, there are various technical problems in the current processing method to convert OPT to lumber. The initial problem concerns the sawing technique for oil palm logs. Unlike conventional woods, the best parts of OPT are located in the outer parts nearer to the bark and these parts were not fully utilised by the conventional log sawing techniques. The matter calls for a more efficient sawing technique. Bakar *et al*. (2006) compared three sawing patterns of oil palm stems, namely polygon sawing, cobweb sawing and conventional life sawing pattern (*Figure 1*). The results revealed that the most suitable cutting pattern is polygon sawing, which yields high quality wide-outer lumbers with a recovery of about 30%-35% to the volume of log. Unfortunately, polygon sawing technique is difficult to employ in a mill as it requires skilled operators and good carriage system to run efficiently. For that reason, Bakar *et al*. (2014) introducerd a new sawing pattern called reverse cant sawing as shown in *Figure 2*. The technique could ensure a higher sawing recovery and maximise the procurement of the best outer portion of OPT with shorter sawing time.

The other problem in the current processing method is that the drying of the sawn OPW is extremely difficult and highly time-consuming. The 20 mm thick OPW lumbers require three to four weeks drying time. And this normally results in many drying defects. To solve the problem, further improvements have been made by Bakar *et al*. (2014) and this led to an invention of a brand new six-step treatment method called the 'Integrated Treatment Process'. The methods which consist of six processing steps of debarking-sawing, steaming and compression, drying, resin inclusion, resin semi-curing heating and hot pressing are as shown in *Figure 3*. The advantages of this six-step treatment method in comparison with five-step treatment method are: (1) the reverse cant sawing pattern is much easier and faster without having to be supported by a perfect carriage system, (2) the compression of wood will forcibly remove the water within the oil palm wood and lower the moisture content of the wood without the use of high inputs of energy (drying), and (3) the compression of wood causes cracks in the wood which facilitates drying and resin impregnation and hence reduces the drying and curing time.

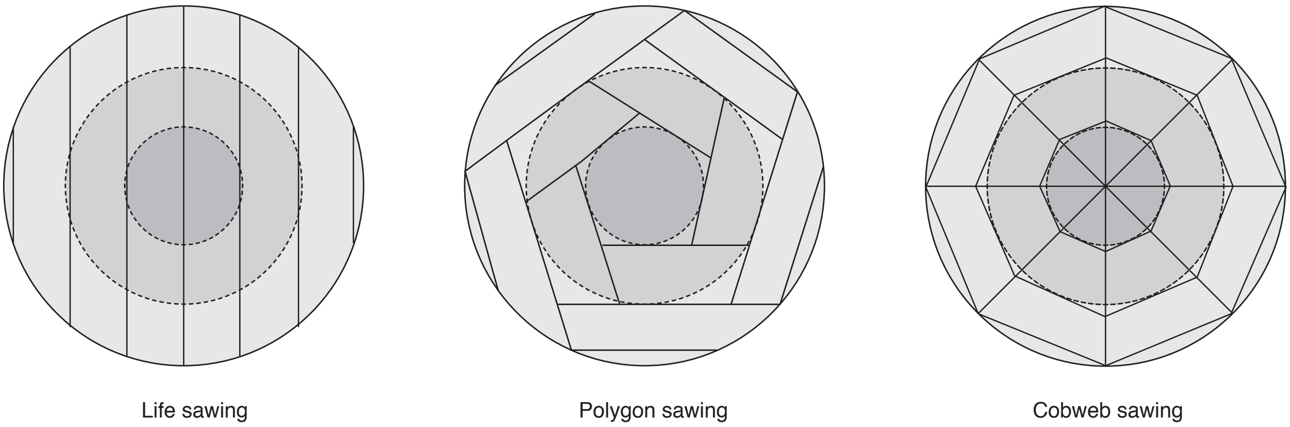

Figure 1. Three different sawing patterns of oil palm logs.

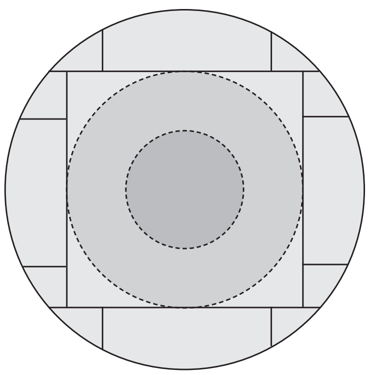

Figure 2. Reverse cant sawing patterns of oil palm logs.

The drying-impregnation process of the OPW in the five-step process was modified into compression-drying-resin soaking process in the newly invented six-step process in order to achieve better properties and shorter processing time. However, as the very first processing step in the treatment, the effect of sawing pattern is worth investigating for potential improvement in the properties of the treated OPW. Therefore, the six-step integrated treatment and process was employed in this study with sawing pattern and slab thicknesses as variables. The objective of this study was to compare the effects of slab thicknesses and two sawing patterns, polygon sawing and reverse cant sawing, on the properties of the treated OPW using the six-step integrated treatment.

MATERIALS AND METHODS

Materials Preparation

OPW, *Elaeis guineenisis* Jacq. was extracted from matured OPT (27-year old) obtained from Taman Pertanian, Universiti Putra Malaysia (UPM), Selangor, Malaysia. The lengths of the oil palm log ranged from 400 to 600 cm and only the bottom parts (around 200 cm) were used for the OPW extraction in this study. LmwPF resin with solid content of 44.3%, viscosity of 0.21P at 30°C, pH of 8.68 and specific gravity of 1.185 g cm^{-1} was used as treating solution. Five percent of borax solution was prepared in order to prevent fungi attack by dipping the OPW in the solution.

The Six-step Processing Method

The method consisted of six processing steps including debarking-sawing, steaming and compression, drying, resin inclusion, resin semi-curing heating and hot pressing (*Figure 3*). Oil palm stems were debarked and sawn into waned and squared slabs using reverse cant sawing pattern and polygon sawing pattern, respectively, as shown in *Figure 4*. The sawn slabs were planed to thicknesses of 40, 60 and 80 mm, respectively. The samples were first compressed to a range of 50% to 75% followed by drying to a moisture content (MC) of 15%. Prior to compression, the slabs were steamed at 150°C for 15-30 min depending on the thickness of the slabs. After compression, the samples were soaked in 15% LmwPF for 30-45 min and then were partially cured

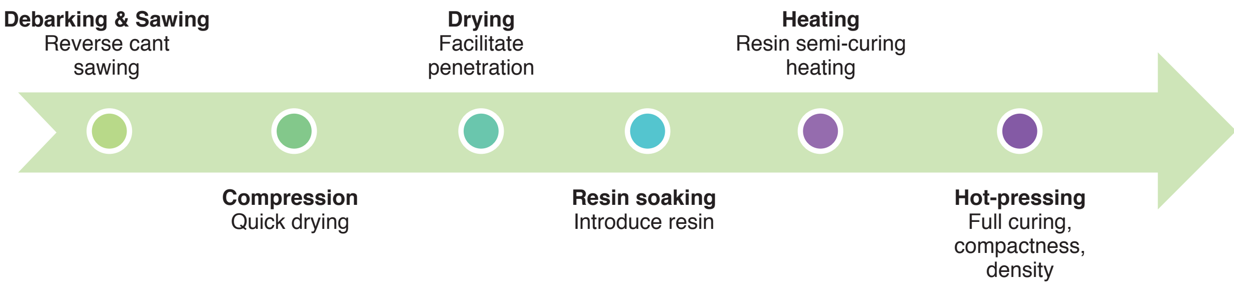

Figure 3. The six-step processing method.

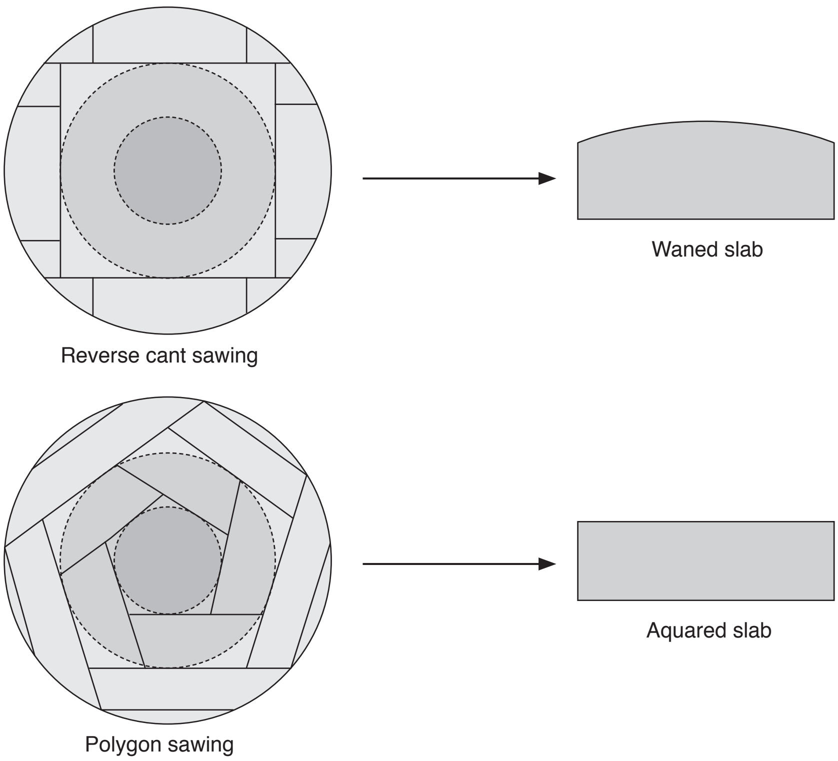

Figure 4. Production of waned and squared slabs using reverse cant sawing and polygon sawing.

in an oven at 70°C until a MC of 70% was reached. Finally, the samples were compressed using hot press at a temperature of 150°C for 30 to 60 min until final thickness of 20 mm was achieved. The samples were conditioned at 20 ± 2°C and relative humidity of 65 ± 5% until constant weight were reached before properties evaluation.

Properties Evaluation

Weight percent gain and density. The weights of the samples before and after treatment were recorded and the weight percent gain (WPG) were determined using:

WPG (%) = (W_{odt} - W_{od}) / W_{od} x 100
where, W_{odt} = oven dry weight of treated wood (g)
W_{od} = oven dry weight of untreated wood (g)

On the other hand, the density of the samples was determined usin g the equation mass over volume.

Dimensional Stability

The thickness swelling (TS) and water absorption (WA) of the samples after 24 hr immersion were recorded. Five samples with dimensions of 50 mm × 50 mm × 20 mm were prepared. The samples were immersed in a container filled with distilled water maintained at 23 ± 1ºC for 24 hr. Before immersing the samples, each sample was weighed and its thickness recorded. After immersing for 24 hr, the specimens were taken out from the water and reweighed and the changes in thickness and weight were expressed in percentage.

Mechanical Properties

The mechanical properties of the treated samples, including modulus of elasticity (MOE), modulus of rupture (MOR), compression parallel to the grain, and shear strength were performed according to the procedures specified in British Standard BS 373:1957 with a modification of the specimen size. Five samples with dimensions of 300 mm × 20 mm × 20 mm were used in static bending test. For compression parallel to the grain, samples with 60 mm × 20 mm × 20 mm were used while five samples with dimensions of 20 mm × 20 mm × 20 mm were assigned to shear strength test. All of the tests were conducted using INSTRON Universal Testing Machine.

Data Analysis

The data were analysed using Statistical Package for the Social Sciences (SPSS) procedure for the analysis of variance (ANOVA) at 95% confident level (P ≤ 0.05). The two main variables were the shape of the samples (two levels) and the thicknesses (three levels). The difference between the mean value of each treatment level was compared by Tukey's honest significance different (HSD) test.

RESULTS AND DISCUSSION

Table 1 summarises the ANOVA result of the effect of sample shape and thickness on the physical and mechanical properties of treated OPW. The ANOVA result revealed that both shape and thickness of samples did not significantly affect the WPG but did exert significant influence on the density of the treated samples. On the other hand, both the dimensional stability attributes (WA and TS) were significantly affected by both sample shape and thickness. The shapes of samples were found significantly influenced the bending and compression strength of the treated OPW while the thickness of samples did not show any significant effect on the mechanical properties of OPW.

Density and Weight Percent Gain

The density and WPG of the treated OPW with different shapes and thicknesses are shown in *Table 2*. As the resin penetrated into the OPW accompanied by the compression in the hot press, gained in weight were observed in the treated samples. According to *Table 2*, waned samples showed higher WPG (14.75%-30.03%) in comparison to the squared sample (15.34%-17.83%). The densification process

TABLE 1. SIGNIFICANT PROBABILITIES FOR STUDIED VARIABLES AND INTERACTION

Source of variant	Df	WPG	Density	WA	TS	MOE	MOR	Compress-ion	Shear
Shape (S)	1	0.075	0.01*	0.045*	0.046*	0.002*	0.007*	0.054	0.178
Thickness (T)	2	0.129	0.02*	0.005*	0.032*	0.591	0.684	0.810	0.334
S x T	2	0.325	0.68	0.183	0.541	0.482	0.435	0.100	0.821

Note: * Significant at p ≤ 0.05.
WPG - weight percent gain; WA - water absorption; TS - thickness swelling; MOE - modulus of elasticity; MOR - modulus of rupture.

TABLE 2. WEIGHT PERCENT GAIN AND DENSITY OF THE TREATED OIL PALM WOOD

Thickness (mm)	Weight percent gain (%)	Density (kg m-3)
Waned		
40	14.75 ± 3.32^{b}	733.00 ± 71.89^{a}
60	25.78 ± 16.29^{ab}	708.25 ± 57.22^{ab}
80	30.03 ± 11.20^{a}	709.75 ± 39.11^{ab}
Squared		
40	15.34 ± 1.37^{b}	583.00 ± 62.27^{c}
60	17.83 ± 5.82^{ab}	620.00 ± 68.61^{bc}
80	17.58 ± 1.24^{ab}	617.25 ± 94.2^{bc}

Note: Numbers after ± are standard deviation values.
Means followed by the same superscript letter in the same numbered column are not significantly different at P ≤ 0.05.

of OPW led to an increased in its weight (Choowang and Hiziroglu, 2015). It is interesting to note that the WPG increased along with increasing thickness especially for waned sample. Waned sample with initial thickness of 80 mm gained twice the weight compared to that of waned sample with initial thickness of 40 mm. Samples with higher thickness represent higher volume and therefore a higher compression is needed to compress the samples into targeted final thickness and this eventually led to a higher WPG. As for the density, waned samples displayed significantly higher density than squared sample. The density of waned samples ranged from 708 to 733 kg m^{-3} while the squared samples ranged from 583 to 620 kg m^{-3}. Lee and Zaidon (2015) stated that the WPG and density displayed a positive correlation suggesting that the density increased along with increasing WPG. The void volume in the samples was compressed to a great extent and the compressed samples become hardened and are more rigid. This resulted in a higher final density in the compressed wood (Ang *et al*., 2014). However, dissimilar to WPG, the density of the treated OPW did not show a consistent pattern of increase with the increasing thickness.

Dimensional Stability

The average values of TS and WA of treated OPW are listed in *Table 3*. From the results displayed in *Table 3*, one can see that the WA of treated OPW increased along with the increasing initial thickness of sample. The WA for treated OPW made from waned sample ranged from 25% to 35%, while treated OPW made from squared sample ranged from 26% to 42%. The LmwPF resin could penetrate into the parenchyma tissues of OPW as the bulking agent and led to the improvement in dimensional stability (Bakar *et al*., 2005). The void spaces in the OPW were occupied by PF resin resulting in the lower capacity for water absorption (Nabil *et al*., 2015). Apart from that, compression also resulted in the decrement in the void spaces of OPW and contributed to the reduction in WA. The compression of OPW with a higher thickness required a higher compression pressure producing a less porous material. Since WA of wood increased with increasing porosity, lower WA were observed in the OPW samples with higher thickness (80 mm) that required higher compression pressure (Buyuksari, 2012). The TS values for the waned samples ranged from 0.12% to 0.89%. The samples with an initial thickness of 60 mm showed the highest swelling after water immersion. On the other hand, the squared samples had TS values ranging from 0.14% to 0.51%. The lowest swelling value was observed in the samples with an initial thickness of 60 mm. These findings suggest that waned and squared samples required different processing parameters. Initial sawing thickness and compression ratio are among the parameters that need to be taken into consideration in the processing of OPW.

Mechanical Properties

Table 4 summarises the average values of MOR, modulus of elasticity (MOE), compression strength parallel to the grain and shear strength of treated OPW. Based on *Table 4*, the MOR values for treated OPW made from waned and squared samples were respectively in the range of 40.19 to 50.16 N mm^{-2} and 20.40 to 32.08 N mm^{-2}. The MOE values of treated OPW made from waned and squared samples ranged from 5648.69 N mm^{-2} to 6659.85 N mm^{-2} and 2816.5 N mm^{-2} to 4334.70 N mm^{-2}, respectively. Sulaiman *et al*. (2012) suggested that the new mechanical properties of compressed OPW was observed as the cellular structure of OPW was altered permanently during compression process. The higher bending strength recorded in waned sample could be attributed to its higher initial density after sawing as density is the most important parameter that affect the properties of the material (Missanjo and Matsumura, 2016). Reverse cant sawing pattern produced slabs with

TABLE 3. DIMENSIONAL STABILITY OF THE TREATED OIL PALM WOOD

Thickness (mm)	Water absorption (%)	Thickness swelling (%)
Waned		
40	24.70 ± 3.33^{c}	0.32 ± 0.12^{ab}
60	29.07 ± 2.93^{bc}	0.89 ± 0.09^{a}
80	34.86 ± 5.80^{abc}	0.12 ± 0.12^{b}
Squared		
40	25.57 ± 0.74^{c}	0.51 ± 0.40^{a}
60	38.48 ± 9.24^{ab}	0.15 ± 0.08^{b}
80	42.34 ± 11.53^{a}	0.41 ± 0.21^{ab}

Note: Numbers after ± are standard deviation values.
Means followed by the same superscript letter in the same numbered column are not significantly different at P ≤ 0.05.

TABLE 4. MECHANICAL PROPERTIES OF THE TREATED OIL PALM WOOD

Thickness (mm)	Modulus of elasticity ($N\ mm^{-2}$)	Modulus of rupture ($N\ mm^{-2}$)	Compression ($N\ mm^{-2}$)	Shear ($N\ mm^{-2}$)
Waned				
40	$5\ 648.69 \pm 1213.47^{ab}$	40.19 ± 9.45^{ab}	62.01 ± 24.42^{b}	5.67 ± 3.70^{a}
60	$6\ 659.85 \pm 1577.40^{a}$	50.16 ± 16.75^{a}	109.91 ± 57.48^{ab}	4.16 ± 2.10^{a}
80	$5\ 882.82 \pm 920.66^{ab}$	40.28 ± 2.54^{ab}	102.86 ± 24.23^{ab}	3.31 ± 0.72^{a}
Squared				
40	$4\ 334.70 \pm 1947.89^{abc}$	32.08 ± 16.15^{ab}	173.01 ± 69.32a	3.74 ± 2.13^{a}
60	$3\ 631.20 \pm 1712.50^{bc}$	22.09 ± 14.40^{b}	127.71 ± 76.90^{ab}	2.79 ± 2.17^{a}
80	$2\ 816.57 \pm 2065.18^{c}$	20.40 ± 23.22^{b}	104.35 ± 30.50^{ab}	2.71 ± 1.73^{a}

Note: Numbers after ± are standard deviation values.
Means followed by the same superscript letter in the same numbered column are not significantly different at $P \leq 0.05$.

higher density in comparison with polygon sawing and therefore showed better properties.

The highest MOE was recorded in waned sample with an initial thickness of 60 mm while the highest MOE for squared samples was observed in the 40 mm samples. Zaidon *et al*. (2015) suggested that a higher compression may increase the brittleness of the wood and subsequently a lower MOE. As for the shear strength, although statistically insignificant, OPW made from waned samples revealed a higher shear strength compared to that of OPW made with squared samples. As for compression parallel to the grain, the highest value was obtained in the OPW samples made with squared sample with an initial thickness of 40 mm. Dissimilar to other properties where waned samples exhibited better results, OPW made from squared samples generally showed higher compression strength than that of waned samples.

CONCLUSION

It can be concluded that reverse cant sawing pattern is a more appropriate method in sawing the oil palm logs compared to polygon sawing. OPW produced from waned samples sawn by reverse cant sawing showed better mechanical and physical properties. Furthermore, reverse cant sawing are much faster and easier to employ compared to polygon sawing. On the other hand, the thickness of the sawn slabs showed lesser influence on the properties of the treated OPW, except dimensional stability.

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