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Production of Medium Density Fibreboard (MDF) from Oil Palm Trunk (OPT)

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Abstract: The possibility of using Oil Palm Trunk (OPT) as new material for MDF production was investigated. Important factors that contribute to the quality of the MDF made from OPT are the parenchyma content, density and resin content. The parameters studied for the MDF prepared from OPT are the density (650 and 750 kg m^{-3}), parenchyma content (10, 20 and 30%) and Urea Formaldehyde (UF) content (8, 9 and 10%). Thickness Swelling (TS), Internal Bonding (IB), Modulus Of Rupture (MOR) and Modulus Of Elasticity (MOE) of the test panels were determined according to European Standard EN 622-5:2006. Density and parenchyma content were found to have great effect on the properties of MDF panels meanwhile, the resin content have significant effect all panel properties except on the MOE. The results indicated that MDF panel produced at 750 kg m^{-3} is better than that of produced at 650 kg m^{-3}. Panels with low parenchyma content (10%) showed better dimensional stability with good bonding and bending strength compared to the panels with higher parenchyma content. For resin content, an increase in UF content resulted in decrease of TS and increase of IB, MOR and MOE. In general, MDF prepared at 750 kg m^{-3} with 10% of parenchyma content and 8% of UF content exhibits the best properties, which exceed the level requirement in the existing standard for fibreboard.

Key words: Oil palm trunk, medium density fibreboard, parenchyma content, board density, resin level

INTRODUCTION

The oil palm industry generates several types of oil palm biomass and the major contributors are from the Oil Palm Trunk (OPT), Oil Palm Frond (OPF) and Empty Fruit Bunch (EFB).

Oil Palm Trunk (OPT) consists of vascular bundles and parenchyma tissues. The high content of the vascular bundles or the fibres of the OPT contributes to the strength of the trunk and meanwhile the parenchyma tissues are scattered surrounding the vascular bundles (Killmann and Lim, 1985). Yamada *et al*. (2010) stated that parenchyma hold more moisture than the vascular bundle and is less hygroscopic compare to parenchyma.

There are a number of the applications of the OPT, besides as mulching during replanting, such as for MDF (Tomimura *et al*., 1996) and particle board (Lamaming *et al*., 2013). But there is still lack of study on the production of MDF using 100% of OPT, due to the believe that high parenchyma content contributes to the poor properties. There was a study by Tomimura *et al.* (1996) reported that, at 6 kg cm^{-2} of steam pressure, by using less parenchyma content in the MDF production, the superior internal bonding strength and bending strength were achieved.

In compromising the quality of the raw material, the density of MDF is one of the main factors influencing the panel properties. The results from the study by Akgul *et al*. (2010b) on using corn stalk and oakwood, showed that the density of MDF board had the effect on swelling of the boards. There was also a study by Guler and Ozen (2004), which concluded that denser MDF panels prepared from cotton stalks has lower void spaces in the microstructure and absorb less water.

Another important parameter in the production of MDF is the resin content. The most widely used resin in MDF industry is urea-formaldehyde (UF) because it is cheaper with versatile application (Sulaiman *et al*., 2008, 2009). Several researchers stated that, the application of UF during MDF production contributes to 60% of the overall cost of final products (Hashim *et al*., 2005; Laemsak and Okuma, 2000). But there are concern pertaining to the health and environmental issues aroused from the formaldehyde emission (Hashim *et al*., 2009).

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Therefore, it is encouraged to use less UF to minimize the formaldehyde emission and at the same time reducing the production cost.

The objective of this study is to optimize the parameters for the production of MDF from OPT, in which at the later stage will be used in the commercial plant. The performance of the panels was evaluated by measuring the Thickness Swelling (TS), Internal Bonding (IB), Modulus Of Rupture (MOR) and Modulus Of Elasticity (MOE) properties.

MATERIAL AND METHODS

Raw material and sample preparations: Oil Palm Trunk (OPT) was obtained from an oil palm plantation in FELDA Keratong, Pahang. The OPT was cut about 6 feet in length from the bottom part and then reduced to disc with 50 mm of thickness. The OPT then were reduced to chips using a laboratory Maier chipper and later were oven dried at 100°C for three days until the Moisture Content (MC) reached around 10%. The OPT chips were than hammer milled followed by screening using vibrator screener to separate the parenchyma from the vascular bundles based on the fragility. The vascular bundles were then refined in a refiner at MDF pilot plant located in MPOB/UKM Station Branch, Selangor. The OPT fibre were refined using Sprout Bauer (Andritz 12') refiner at a refining pressure of 6 bar for 300 sec. Refined fibres were then dried in the oven to achieve the MC of 4-5%.

MDF manufacture: The dimensions of the MDF boards used were 300×300 mm width and 12 mm thickness. The admixtures of parenchyma and vascular bundle fibres to make four MDF board at density of 650 and 750 kg m^{-3}, respectively were weighed and placed into a rotary blender for resin blending. Three level of Urea-Formaldehyde (UF) content; 8, 9 and 10% and wax content of 0.5%, respectively were sprayed onto the fibres admixture during the blending. The fibres were then accurately weighted (based on required density) and put into a former (300×300 mm), before it was manually pressed into a formed mat. The mat was then hot-pressed using a computer controlled hot press at a temperature of 200°C and a pressure of 160 kg cm^{-2} for 5 min.

MDF evaluation: Upon cooling, the MDF boards were conditioned at temperature of 23±2°C and relative humidity of 65±2% for a week prior to the testing. The boards were then cut into specific test specimens sizes according to the standard of European Standard EN 622-5:2006 (Anonymous, 2006). The boards evaluations are including the Thickness Swelling (TS), Internal Bonding (IB), Modulus Of Rupture (MOR) and Modulus Of Elasticity (MOE). The TS test was obtained by 24 h water immersion test. The IB, MOR and MOE tests were performed using Zwick 10 kN Universal Testing Machine.

Scanning electron microscopy (SEM): The microstructures of the MDF boards were examined by using the Hitachi 3400C scanning electron microscopy (SEM) to observe the interrelation between fibre and parenchyma. The cross-section of the MDF boards was used for the analysis.

Data analysis: The testing data were statistically analyzed using Statistical Analysis System (SAS) software by using Analysis of Variance (ANOVA) and Least Significant Difference (LSD) method for mean separation.

RESULTS AND DISCUSSION

Effect of parenchyma content on MDF properties: The mean values of all the MDF properties (from different density and resin content) for the study on the effect of the parenchyma content are presented in Table 1. The results showed that, parenchyma content had significant effect on the physical and mechanical properties of the MDF boards.

The TS value increased as the parenchyma content increased from 10-30%. This may be due to the hygroscopic properties of the parenchyma tissues that hold and attract more water. Being the parenchyma tissues in the monocotyledon plant, analysis found that the parenchyma tissues contains high amount of attractive -OH groups (Yamada *et al.*, 2010). The presence of -OH groups enhance the absorption of water by forming hydrogen bonding with water molecules (Mishra and Naik, 1998).

Meanwhile, the increase of parenchyma content has significantly reduced the IB, MOR and MOE values (Table 1). This also may be due to the fact that the parenchyma tissues which is physically in the form of small particles and spongy materials, contributes to the poor bonding and bending strength.

Table 1: Effect of parenchyma content on MDF properties prepared from different density and resin content

Parenchyma content (%)	TS (%)	IB (N mm^{-2})	MOR (N mm^{-2})	MOE (N mm^{-2})
10	14.76^b	1.19^a	39.6^a	3235^a
20	14.97^b	1.11^b	35.0^b	3010^b
30	15.72^a	0.97^c	31.7^c	2687^c

Means followed by the same letters in each column are not significantly different at p≤0.05 according to least significant difference (LSD) method

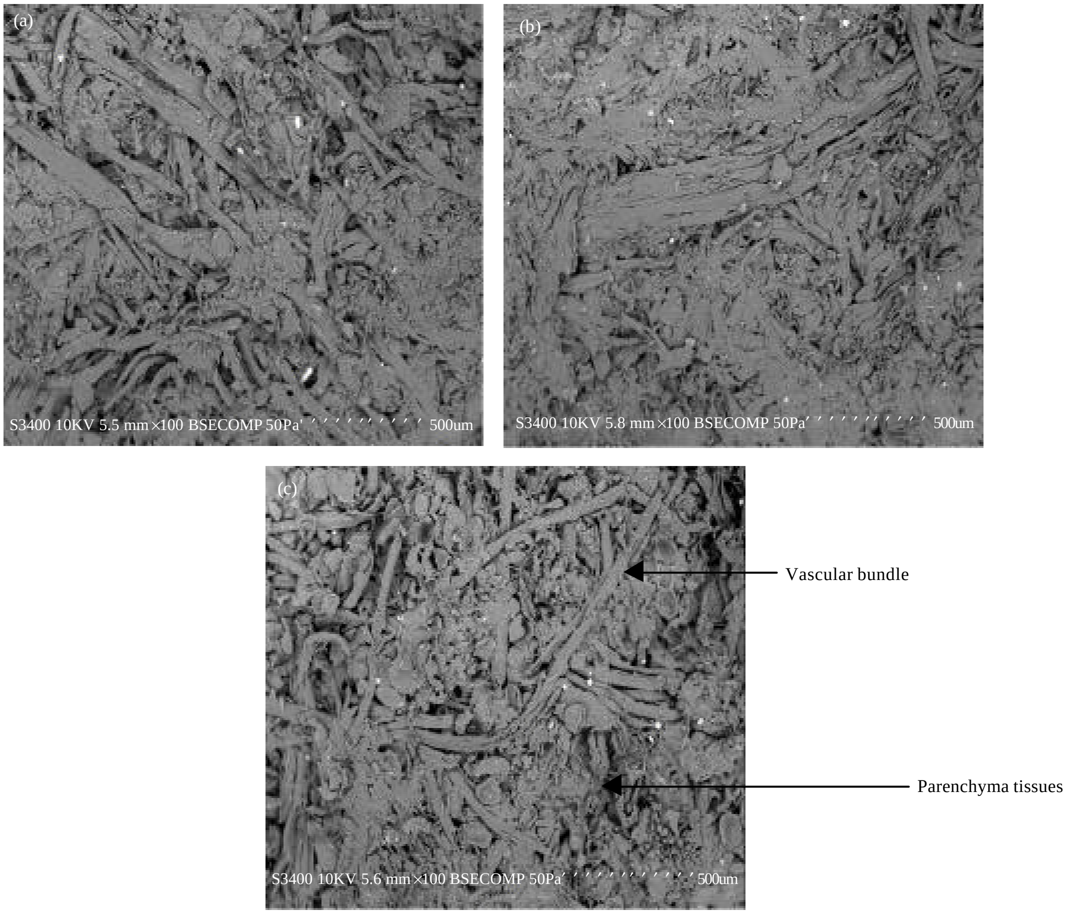

Fig. 1: SEM images of MDF with 10% (a), 20% (b) and 30% (c) of parenchyma content (magnification 100x)

Table 2: Effect of board density on MDF properties prepared from different parenchyma tissues and resin contents

Density (kg m^{-3})	TS (%)	IB (N mm^{-2})	MOR (N mm^{-2})	MOE (N mm^{-2})
650	15.52 ^{a}	0.91 ^{b}	28.4 ^{b}	2439 ^{b}
750	14.78 ^{b}	1.28 ^{a}	42.5 ^{a}	3515 ^{a}

Means followed by the same letters in each column are not significantly different at $p \le 0.05$ according to least significant difference (LSD) method

Table 3: Effect of resin level on MDF properties prepared from different parenchyma tissues content and board density

Resin level (%)	TS (%)	IB (N mm^{-2})	MOR (N mm^{-2})	MOE (N mm^{-2})
8	16.73 ^{a}	0.89 ^{c}	34.5 ^{b}	2992 ^{a}
9	15.19 ^{b}	1.07 ^{b}	35.4 ^{ab}	3006 ^{a}
10	13.54 ^{c}	1.31 ^{a}	36.7 ^{a}	2993 ^{a}

Means followed by the same letters in each column are not significantly different at $p \le 0.05$ according to least significant difference (LSD) method

The SEM micrograph of the MDF panels for board made from 10, 20 and 30% of parenchyma content are shown in Fig. 1(a-c). From the images, large amount of parenchyma with open and porous characteristic was observed in Fig. 1(c). Anatomically, the parenchyma tissues are like spherical spongy substances and very hygroscopic, hence making it easier to absorb water and moisture (Ramle *et al*., 2012).

Effect of board density on MDF properties: The mean values of all the MDF properties (from different parenchyma tissues and resin contents) as the function of the board density are shown in Table 2.

MDF boards made with the density of 750 kg m^{-3} have better properties with an average value of 14.8%, 1.28, 42.5 and 3515 N mm^{-2} for the TS, IB, MOR and MOE, respectively. These values were higher than that of the boards with density of 650 kg m^{-3}. The higher TS value in less dense boards could be attributed by the compatibility of the fibre and UF resin (Akgul *et al*., 2010a).

Furthermore, denser boards have less void spaces in their structure, thus absorb less water (Guler and Ozen, 2004). The IB and bending strength values are higher in the boards with the density of 750 kg m^{-3} due to the increasing of the fibre-to-fibre contact, thus creating more

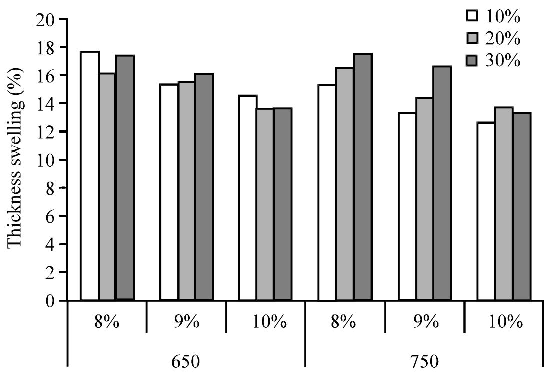

Fig. 2: Mean value of thickness swelling (TS) of all parameters

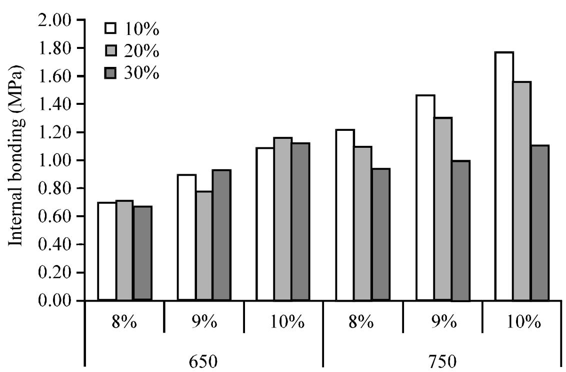

Fig. 3: Mean value of internal bonding (IB) of all parameters

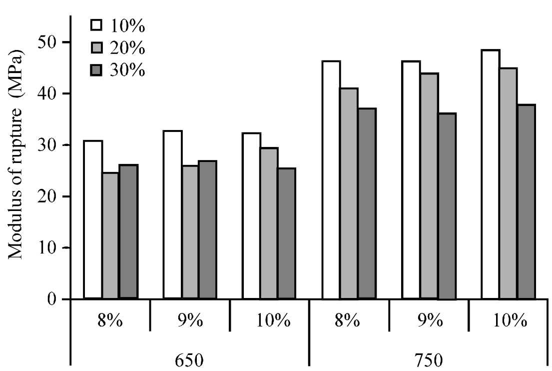

Fig. 4: Mean value of modulus of rupture (MOR) of all parameters

inter-bonding between the fibres. Similar correlation of density towards the properties of MDF was also observed from the MDF made from wheat straw (Halvarsson *et al*., 2008) and admixture of corn stalk and pinewood (Akgul *et al*., 2007).

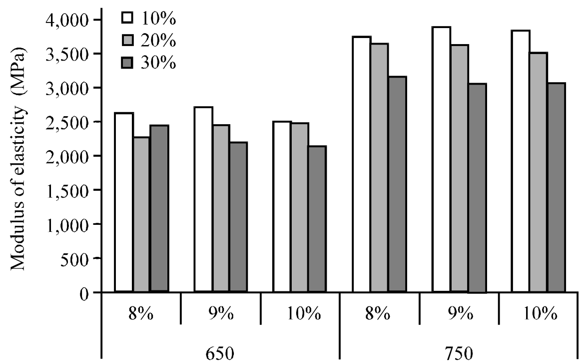

Fig. 5: Mean value of Modulus of Elasticity (MOE) of all parameters

Effect of resin level on MDF properties: The mean values of MDF boards as a function of resin content (from different parenchyma tissues content and board density) are showed in Table 3.

Results showed that there are significant effects of resin content towards the TS, IB and MOR of the MDF boards but not significant in the MOE results. The lowest TS value was achieved in MDF from different parenchyma tissues content and board density using 10% of UF, in which the TS value was reduced from 16.73-13.54%. This is due to the increase of the No. of links between fibres and the UF resom, so that moisture cannot disintegrate them (Halvarsson *et al*., 2008). Abdullah *et al*. (2012) stated that high resin content which covered the fibre has reduced the ability of the fibre to absorb water. The IB value increased as the additional amount of UF added. The No. of fibre-fibre contact, create more inter-bonds between resinated fibres, which improve the IB strength of the panels. However, the bending strength not have much significant effect, with no significant on MOE value. This might be due to the bending properties of MDF were strongly dependent on the density of the panels as indicated by several researchers Wong *et al*. (2000) and Shi *et al*. (2005).

The mean values of MDF panels are presented in Fig. 2 (for TS), Fig. 3 (for IB), Fig. 4 (MOR) and Fig. 5 (for MOE), to compare the effects of all parameters (parenchyma content, board density and resin level) on the MDF properties.

The results have shown that MDF made with 10% of parenchyma content resulted in better dimensional stability, good bonding and bending strength. In general, high parenchyma content resulted in poor panel properties due to the existence of parenchyma that hold and absorb water easily (Norralakmam, 2007). Higher density has shown better properties of the MDF boards.

However, the effect of resin content was suppressed with the effect of parenchyma content and board density.

CONCLUSION

This study revealed that it is possible to produce MDF from 100% OPT fibre but the occurrence of parenchyma tissues can deter the MDF properties. In this study, it is proven that the parenchyma content and the board density have a great effect on the MDF properties as compared to the effect of resin level. MDF properties made from OPT of 10% of parenchyma content, 750 kg m^{-3} board density and with 8% resin content possess acceptable properties as compared to those boards from higher parenchyma content and lower board density. There was no advantage in using higher resin content as it was found that by using low percentage of resin, acceptable MDF properties can be achieved.

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