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Bend curve characteristics of phenol formaldehyde resin treated oil palm wood (*Elaeisguineensis* Jacq.)

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Abstract: It is discovered that oil palm wood (OPW) could be used as wood alternative material upon properly treated. The properties and appearance of OPW can be improved through impregnation treatment with low molecular weight phenol formaldehyde resin, resulting excellent material suitable for furniture and other special applications. It is often that for such applications, the materials are applied in or needs to be shaped curve, but the treated OPW is very rigid material. Although resin treated OPW can be made curved in the development, yet no comprehensive study on this matter has been done. Therefore, the objective of this study is to know how far the treated OPW can be bending without any defect and how it should achieved. In this first stage of the study, there are two variables were used the initial thickness and the moisture content of the sample before final microwave heating and three parameters were observed namely external defect, internal defect and bend curve fixation angle. The results showed that the treated OPW can be bend curve and both variables gave significant effect to the minimum acceptable curvature radius of the sample. It was found that a smaller diameter curve needs thinner initial thickness can be made to the sample within15-30 mm initial thickness at 70-80% moisture content before microwave heating.

Key words: Impregnation; Bend curve; Thickness; Microwave heating; Treated oil palm

1. Introduction

The growth of world population in the last decade has been significant increase especially in developing countries. Population and economic development also will increase the demand of high quality wood as raw material for structural applications and furniture making. Furthermore, hardwood category which refers to heavy hardwood species today no longer sustains to the market demand and furthermore, harvesting of this wood category takes longer period of time (Gaddafi Bin Ismaili, 2015). Wood quality continue to decrease as a result of shorter rotation exploitation and changes in species from slow growing species into the fast growing species where this effort had been instituted in 1962 to plant fast growing species such as *Acacia mangium* (Malaysia Palm Oil Board, 2008) but, requirement on the quality of wood product continue to raise.

One such promising alternative is utilization of oil palm trunk. Currently, there are 4.17 million hectares planted oil palms in Malaysia (Malaysia Palm Oil Board, 2008). In addition, over 3.5 million hectares of replanting area will be available for the next 10 year in 2006, and each year 15 million^3 of oil palm trunk produce during replanting (Malaysia Palm Oil Board, 2008). From total amount of 110 – 120 stem per hectare with average diameter of 50 cm with the length 10 – 12 meter and ⅓ or 30% wood from the most outer part can be utilized as raw material for light structural, the total potential oil palm trunk sawn timber can reached 78 m^3/year (Bakar et al., 2005). At the end of its economic life for 25 – 30 years, the mature plants are felled and replaced with new crop. It has greater potential trunk production compared to natural forest.

The biomass trunk of oil palm wood has not been optimally utilized because of several weakness points in their properties namely, very low in strength properties (Class III – V), durability (Class V), dimensional stability and very bad machining properties (Bakar et al., 1999). There were many research conducted to utilize the oil palm trunk and to enhance the quality of oil palm wood. The latest studies by Bakar et al. (2000 and 2005) revealed that treatment with low molecular weight Phenol Formaldehyde (PF) resin through a modified impregnation method as known as “compreg” can significantly improve the properties of oil palm wood and solve practically all four its weak points concurrently. Wood treated with low molecular weight PF resin can improve the strength of oil palm wood due to the thermosetting characteristics of PF resin itself.

2. Oil palm

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The oil palm is a tropical palm tree. There are two species of oil palm, *Elaeisguineensis* Jacq, better known one is the one originating from Guinea, Africa and was first illustrated by Nicholaas Jacquin in 1763. Palm was introduced to Malaysia and then the British colony of Malaya in 1910 by Scotsman William Sime and English Banker Henry Darby. In 2007, Golden Hope Berhad, Kumpulan Guthrie Berhad and Sime Darby merged to form Malaysia's biggest publicly traded oil palm company with land bank exceeding 633,000 hectares. Its plantations are spread across Malaysia and Indonesian islands of Sumatera, Kalimantan and Sulawesi.

2.1. Oil Palm Wood Characteristics

Anatomical Properties: As a monocotyledonous species, oil palm does not have cambium, secondary growth, growth rings, ray cells, sapwood and heartwood or branches and knots. The growth and increase in diameter of the stem resulted from the overall cell division and cell enlargement in the parenchymatous ground tissue, together with the enlargement of the fibers of the vascular bundles. Looking at a cross sectional view of the oil palm trunk, Killmann and Lim (1985) distinguished three main parts namely, cortex, peripheral region and central zone.

Mechanical Properties: Killmann and Lim (1985) investigated the mechanical properties of oil palm trunk (30 years old) and compared to the other species, such as coconut wood and rubberwood. Mechanical properties of oil palm trunk reflected that the density variation observed in the trunk both in radial as well as in the vertical direction. Bending strength values are obtained from the peripheral lower portion of the trunk and the central core of the top portion of the trunk gave the lowest strength. Bakar et al. (2005) found that all properties tested including Modulus of Elasticity (MOE), Modulus of Rupture (MOR), compressive strength, cleavage strength, shear strength, hardness and toughness were decreased from the outer to the center and from the bottom to top of the trunk, where the influence of trunk depth factor was higher than the trunk height.

2.2. Utilization

Due to its low quality, OPW and other parts of oil palm biomass are still underutilized. According to Bakar (2000) only OPW from one third of the trunk radius (outer region of the trunk) possesses the potential to be used as solid wood. To produce the outer lumber and maximize the outer lumber recovery, Bakar (2000) developed a new sawing pattern for OPT called "Polygon Sawing" which able to achieve a recovery rate of as high as 30% (Bakar et al., 2006). If this sawing pattern is used, about 54-58 m^3 actual OPW (the outer lumber) can be produced from each replanting hectare.

2.3. ComPress method

The "ComPress" method also known as "modified compreg" method was developed by Bakar (2000) on adopting the conventional compreg method. It consists of four main processes viz., (i) drying, (ii) impregnation, (iii) re-drying and (iv) bend hot pressing. According to Bakar *et al.* (2000), "ComPress" method using phenol formaldehyde (PF) is considered as one effective method to treat OPW comprehensively. This method improved the mentioned four weakness of OPW by filling the cell lumen of OPW through stages of impregnation of PF resin that act as an adhesive binding the vascular bundles and parenchyma tissues together (Bakar & Hadi, 2001; Bakar et al., 2003). PF resin penetrated more into the wood cells if low molecular weight PF is used, as it has smaller molecules.

2.4. Low molecular weight PF resin

Phenol formaldehyde polymers are the oldest class of synthetic polymers, having been developed at the beginning of the 20^{th} century. These resins are widely used in both laminations and composites because of their outstanding durability, which derives from their good adhesion to wood, the high strength of the polymer, and the excellent stability of the adhesive. In most durability testing, PF adhesives exhibited high wood failure and resist delimitation (Frihart, 2005). Impregnation method with resin into the wood structure could increase the durability, strength and dimensional stability. Resin penetration could also be improved by using compreg technique (pressure or vacuum-press) or using low molecular weight PF resin (Bakar & Hadi, 2001).

3. Sample preparation

Oil palm trunk used in this study is more than 25 years old. Samples were taken from the outer part of the trunk using polygon sawing pattern. Afterwards, sample dipped in borax solution to protect from fungi, termites and other insects attacked. Put the sample into drying-kiln with soft schedule until 15% moisture content has been achieved. Then, samples were cut with variable initial thickness which were (15 x 120 x 1000mm), (22.5 x 120 x 1000mm) and (30 x 120 x1000 mm), respectively. 33 pieces of sample needed to accomplish this study and label the specimens and coding each treatment.

Weigh and record the initial weight for all the labeled specimens. Lastly, final weight of the specimens will be calculated by the formula, as in

$$MC\ (\%) = \frac{Wi - Wf}{Wf} \times 100\%$$

$$Wf = \frac{Wi}{MC + 1} \quad (1)$$

Where MC is Moisture Content (%), Wi is Initial weight of specimen and Wf is final weight of specimen.

3.1. Impregnation

A total of 33 of OPW treated samples and their initial weight were obtained and recorded. The OPWs were impregnated with low molecular weight Phenol Formaldehyde. The process began by inserting OPW samples into impregnation cylinder. Only six OPW samples were placed into the cylinder tank for each impregnation cycle. Vacuum was applied to the closed cylinder for 15 minutes and then 25 liters of PF resin was inserted into the cylinder using vacuum's suction by applying pressure of 120 psi into the cylinder for 30 minutes using a compressor. Afterward, the remaining PF was drain out, vacuum was applied for a period of 5 minutes to further drain out the excess PF from lumbers

3.2. Semi-cure resin heating (Re-drying)

The impregnated OPWs were then placed into an industrial oven for re-dying under temperature at 60°C for about 24 hours until target MC of 100%, 90% and 80% were reached. The target MC was determined in order to reduce the squeezed out of PF during the process of hot pressed. After that, the impregnated OPW placed into microwave oven that being set for high power output until target MC of 70% were reached. The targeted MC was determined by weight basis. Finally, the samples were undergone for hot press processing densification.

3.3. Bend-curve hot pressing

The re-dried OPWs were readied for bend-curve hot pressing process. The re-dried OPWs were wrapped up with aluminum foil and layer with lubricant by spraying into the samples as to prevent them from sticking OPWs on the aluminum foil. The hot press was set at a temperature of 150°C and with the pressure of 70 bars with duration of 1 hour. There were three different thicknesses of stoppers viz., 20 mm, 15 mm and 10 mm and placed at the end side with the compression ratio of 33.3%. The stoppers must be measured accurately at each end side to get the equal compression ratio. After 1 hour pressing, the sample was cooled down and placed in conditioning room. The pressed sample was weighed to get the final MC after pressing.

3.4. Properties test

After pressing completed, samples need to be visually observed and described by looking into its properties. The properties tested are external and internal defect observation and bend curved fixation angle. The experimental designs for properties test as shown in Tables 1, 2 and 3.

a) External defect observation: The value in bracket is the description type of defect or deformation of external view. The result on defects and pictures were taken at three different curvature angles by looking at visual cracking such as many defect, less defect, minimal defect and no defect.
b) Internal defect observation: The value in bracket is the description type of defect or deformation of internal view. The result on defects and pictures were taken at three different curvature angles by looking at visual cracking such as many defect, less defect, minimal defect and no defect.
c) Bend curve fixation angle: Fixation of bend-curved curvature angles were observed at 3 different angles (A, B and C). The value in bracket is the angle after exposing for 2 weeks in high humid condition 90%RH.

Table 1: External cracking observation result

Variable		Control (untreated)	MC before hot pressing (Combination Oven Microwave)		
			100% - 70%	90% - 70%	80% -70%
Initial Thickness	(30-20) mm	Alot ofdefect and deform	A lot ofdefect and deform	less defect and deform	Little defect and deform
	(22.5-15) mm	Less defect and deform	A lot ofdefect and deform	Less defect and deform	Minimal defect and deform
	(15-10) mm	Minimal defect and deform	A lot ofdefect and deform	Less defect and deform	No defect and deform

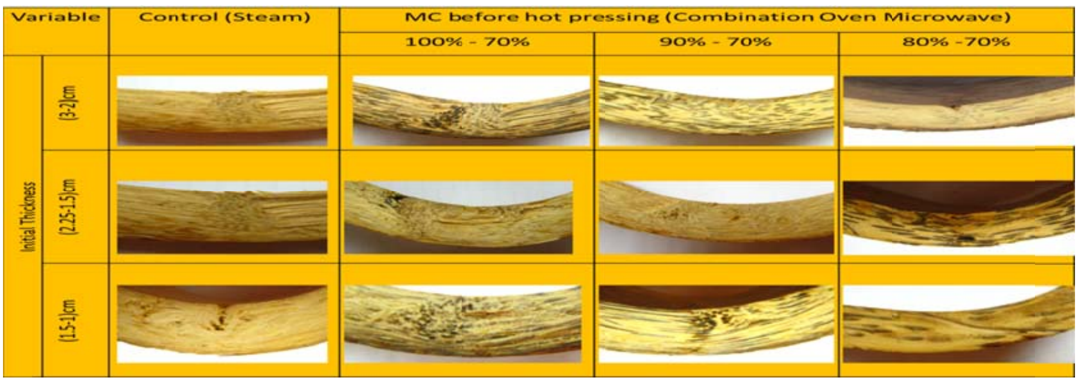

Fig. 1: Initial thickness and moisture content before microwave re-drying for external defect observation

4. External defect observation

This test was based only on the visual external assessment and deforms or defects that observed on the surface of each side and angle of samples. The treated and untreated bend–curved OPWs samples are then assessed and pictures were taken on three different angles and any type of defect or deform occurred were recorded accordingly.

The Table 1 summarized the result of bend-curved OPW with two variables namely initial thickness and moisture content before microwave re-drying at treated and untreated OPW. The untreated bend curved samples used as control which using steam process before going to hot press. The pictorial observation on each combination of initial thickness and moisture content before microwave re-drying is shown in Fig. 1. Based on the Tables 1 and Fig. 1, it is obvious that bend curved samples produced with MC before microwave re-drying of 80%-70% produce good results. Better result was obtained especially when the initial thickness was in between 15-10mm as compared to the higher initial thickness. When the two variables are compared, it was found that the moisture content before microwave re-drying gave more significant effect on the quality of bend curved OPW.

5. Internal defect observation

This test was based only on the visual internal assessment and deforms or defects that occurred to the internal of curvature to each side and angle of samples. The treated and untreated bend curved OPWs were ripped into 20 mm strips to find out the internal cracking. Pictures of all the strips were taken on three different angles and any type defect or deform of occurred were then recorded accordingly.

Table 2: Internal Cracking observation result

Variable		Control* (untreated)	MC before hot pressing (Combination Oven Microwave)		
			100% - 70%	90% - 70%	80% -70%
Initial Thickness	(30-20) mm	Alot of defect and deform	A lot ofdefect and deform	A lot ofdefect and deform	Little defect and deform
	(22.5-15) mm	Alot of defect and deform	A lot of defect and deform	Less defect and deform	Less defect and deform
	(15-10) mm	Less defect and deform	A lot ofdefect and deform	Less defect and deform	No defect and deform

*3 replications

The Table 2 summarized the results and the information of bend curved OPW made under two variables, initial thickness and moisture content before microwave re-drying at treated and untreated OPW. The untreated bend curved samples were used as control which using steam process before going to hot press. The pictorial observation on each combination of initial thickness and moisture content before microwave re-drying is shown in Fig. 2. Based on the Tables 2 and Appendix B, it was observed that bend curved samples with 80%-70% MC before microwave re-drying produced good results. Better results were obtained when the initial thickness was lesser (15-10) mm as compared to the higher initial thickness. The thinner the initial thickness is the fewer defects and deforms the wood is, and the lower MC difference before microwave is the better the result and less deform or defect occurred towards the curve angle.

6. Bend curve fixation angle

After observing visual cracking, the samples of treated and untreated bendcurved OPWs were ripped into 20 mm strips and put at the humid condition for two weeks to examine the curve fixation angle of the samples. The samples were then put in a large container sealed with the relative humidity (RH) of 90% and temperature ranged between 28°C-34°C. The fixation angles were assessed at three different curvature angles before and after exposing for alternate two days and the angle were recorded within two weeks accordingly.

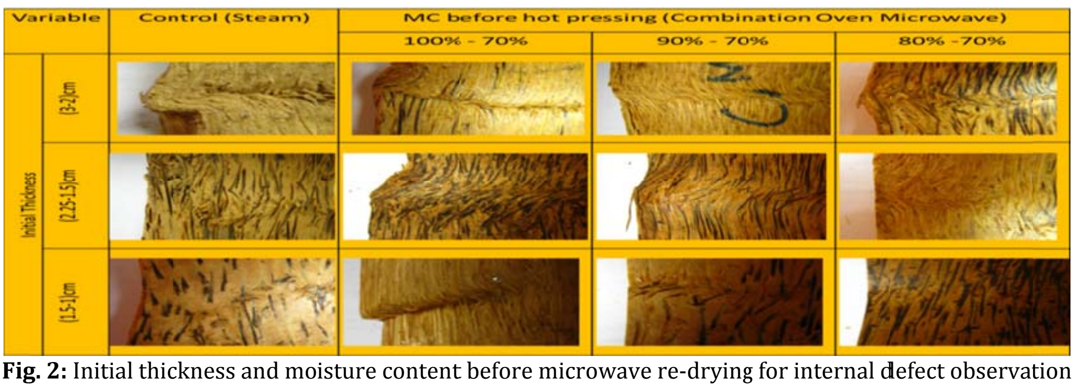

Fig. 2: Initial thickness and moisture content before microwave re-drying for internal defect observation

Table 3: Bend Curve fixation angle test result

Variable		Control (untreated)	MC before hot pressing (Combination Oven Microwave)		
			100% - 70%	90% - 70%	80% -70%
Initial Thickness	(3-2) cm	A→147°(155°) B→120°(144°) C→140°(160°)	A→147°(155) B→115°(123) C→145°(145)	A→155°(156°) B→122°(125°) C→152°(153°)	A→160°(162°) B→122°(125°) C→150°(153°)
	(2.25-1.5) cm	A→150°(150°) B→122°(149°) C→140°(160°)	A→145°(148) B→122°(126) C→145°(149)	A→140°(145°) B→122°(126°) C→150°(152°)	A→150°(152°) B→122°(124°) C→152°(155°)
	(1.5-1) cm	A→149°(155°) B→125°(145°) C→145°(160°)	A→152°(155) B→122°(125) C→152°(153)	A→152°(158°) B→122°(126°) C→151°(154°)	A→145°(147°) B→122°126°) C→160°162°)

Table 3 summarized the result of angle before and after 2 weeks exposed in humid condition (value in bracket). All the samples were not fixed in their angles after 2 weeks exposing under humid condition. The untreated bend curve OPWs shows significant angle difference which increases from 10° to 20° whereby the treated samples show an increase of 2° to 5°. From these results, it is found that treated bend curve OPW has more stability than untreated bend curve OPW.

7. Bend curve fixation Angle A, B and C

Figs. 3, 4 and 5 show the timeline how the curve move or the fixation of an angle after exposing in high humidity on RH 90% within two weeks. From the three Figures, it shows that curve angle A, B and C of treated OPW is more fix than the untreated samples. The curve angle of untreated OPW shows significant angle difference which increase from 10° to 20° whereby the treated samples show an increase of 2° to 5°. From these result it is found that treated bend curve OPW has more stability than untreated bend curve OPW. These phenomenon occurs when the untreated Curve angle A, B and C adsorb more moisture whereby the moisture fill in the porous area and swell the cell within and makes it less fix. Rather than curve angle A, B and C of treated OPW are more fix and less swell and less adsorb the moisture because of the PF has fill up the cell lumen. So, these prevent treated OPW from adsorbing water as no extra space for water to enter into the wood.

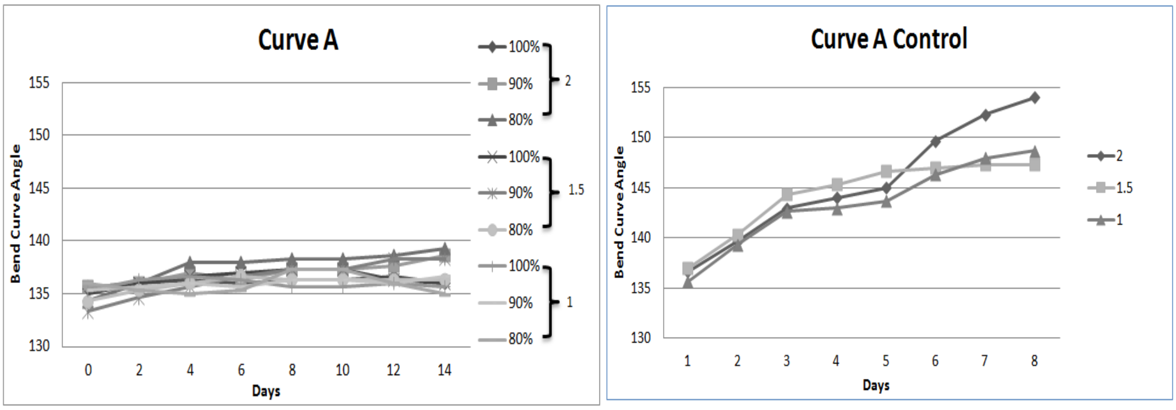

Fig. 3: Bend curve fixation angle A of Treated OPW and Untreated OPW

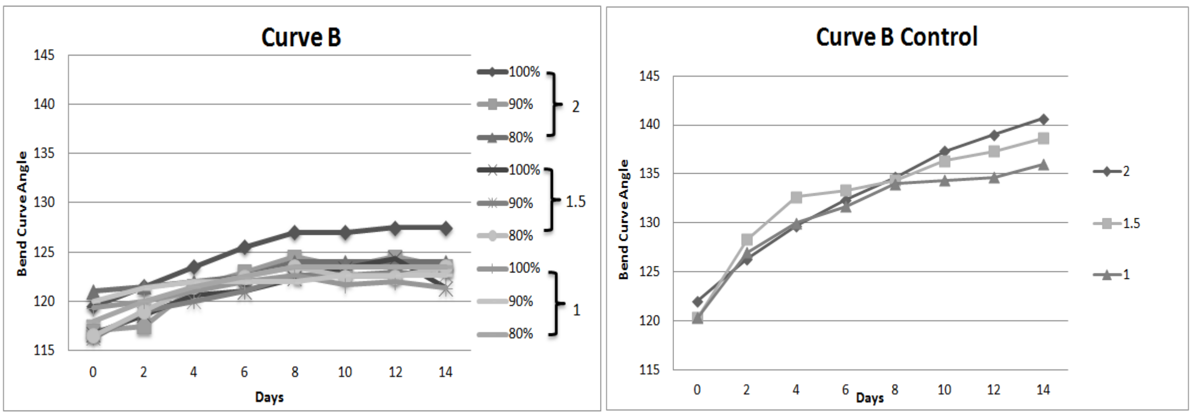

Fig. 4: Bend curve fixation angle B of Treated OPW and untreated OPW

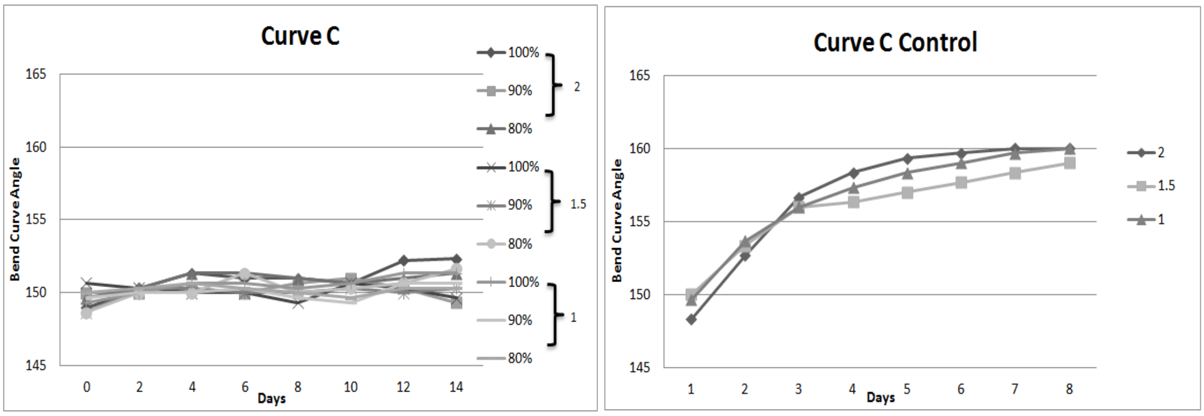

Fig. 5: Bend curve fixation angle B of Treated OPW and untreated OPW

8. Conclusion

The findings of the study are as follows, the treated oil palm wood can be made curved with hot pressing for application in furniture manufacturing. Furthermore the MC reduce by 10% which are 80-70% moisture content with microwave re-drying and less thickness give better or optimum appearance. Therefore initial thickness of 15 mm and 80-70% MC are the optimum for wood to bend. Other than that, the thinner the thickness of the wood is, the less movement in wood occurs and gives perfect appearance. Lastly80-70% MC is suitable for bend curve oil palm wood whereby less movement, defect, deformation and suitable elasticity for wood to bend perfectly.

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References

C. R. Frihart, (2005). Wood Adhesion and Adhesives.Chapter 9 Forest Product Laboratory, Madison, Wisconsin. (pp. 216-251).

E. S. Bakar, & Y. S. Hadi,(2001). Quality Improvement of Oil Palm Wood: Impregnated with Phenolic Resin. Journal Teknologi Hasil Hutan, 14(2):24-31

E. S. Bakar, (2000). Pemanfaatan Batang Kepala Sawit (Elaeisguineensisjacq) Sebagai Bahan Bangunan dan Furniture Laporan Penelitian Hibah Bersaing (VI) Perguruan Tinggi. Jurusan Teknologi Hasil Hutan, 120p. Institut Pertanian Bogor. Unpublished.

E. S. Bakar, F. Febrianto, I. Wahyudi, & Z. Ashaari, (2006). Polygon Sawing: An Optimum Sawing Pattern for Oil Palm Stems. Journal of Biological Science. 6(4): 744–749.

E. S. Bakar, O. Rachman, M. Y. Massijaya, & Bahruni, (2000). Pemanfaatan Batang Kelapa Sawit (ElaeisguineensisJacq.) sebagai Bahan Bangunandan Furniture. Menuju Kemandirian Teknologi Pertanian Unggul. Edisi 2000, p.150-152. JurusanTeknologi Hasil Hutan. Bogor: Institut Pertanian Bogor.

E. S. Bakar, O. Rachman, M. Y. Massijaya, & Bahruni, (2003). Pemanfaatan Batang Kelapa Sawit sebagai Bahan Bagunan dan Furniture. Menuju Kemandirian Teknologi Pertanian Unggul. Edisi 2003, (pp. 169-170). Bogor: Institut Pertanian Bogor.

E. S. Bakar, O. Rachman, W. Darmawan, & I. Hidayat. (1999). Utilization of Oil Palm Trees as Building and Furniture Material (II): Mechanical Properties of Oil Palm Wood. Journal Technology HasilHutan12(1):10-20

E. S. Bakar, P. Md. Tahir, & M. H. Sahri, (2005). Properties enhancement of oil palm wood through the Compreg Method. Proceedings International Symposium of Wood Science and Technology.

Gaddafi Bin Ismaili, 2015 'Engineering Properties of Fast Growing Indigenous Timber in Sarawak Compare to Acacia Mangium: Aras'. International Journal of Innovative Science and Modern Engineering (IJISME)', Volume-3 Issue-2, pp 8-12, ISSN: 2319–6386

Gaddafi, I., Badorul Hisham, A. B., Alik, D., Khairul Khuzaimah, A. R. and Iskanda, O., 2013, 'Domination of grain bearing on the strength properties of Engkabang jantong as fast growing timber in Sarawak', Iranica Journal of Energy & Environment 4 {(3) Geo-hazards and Civil Engineering)}: pp 311-315, 2013 ISSN 2079-2115

Malaysia Palm Oil Board.(2008). In "Annual Statistic" as in www.mpob.gov.my. Accessed on 12-1-2010

W. Killmann, & S. C. Lim, (1985) Anatomy and properties of Oil Palm Stem.Procedings of the

National Symposium Of Oil Palm By-product for Agro-based Industries, Kuala Lumpur. PORIM Bulletin No.11: (pp.18-44).