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INTERACTIONS OF OIL PALM FIBRES WITH WOOD PULPS

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ABSTRACT

Oil palm pulps were prepared from frond and empty-fruit-bunch (EFB) by soda process and blended with a hardwood kraft pulp from *Acacia mangium* to produce liner grade paper. The nonwood pulps were also mixed with a softwood thermomechanical pulp (TMP) to produce medium grade sheet. The results suggest that blending of oil palm pulps with wood pulps could produce liner and medium with satisfactory properties.

KEYWORDS: *Elaeis guineensis*, *Acacia mangium*, oil palm frond, oil palm empty-fruit-bunch, sulphate pulping, soda pulping, thermomechanical pulp, PFI beating.

INTRODUCTION

Oil palm (*Elaeis guineensis*) is vastly cultivated as a source of oil in West and Central Africa, where originated, and in Malaysia, Indonesia and Thailand. In Malaysia, oil palm is one of the most important commercial crops. The explosive expansion of oil palm plantation in these countries has generated enormous amounts of lignocellulosic waste, creating problem in replanting operations, and tremendous environmental concerns. In 2006, Malaysia alone produced about 70 million tonnes of oil palm biomass, including trunks, fronds, and empty fruit bunches (Yacob 2007). An estimation based on a planted area of 4.69 million ha (MPOB 2009), and a production rate of dry oil palm biomass of 20.336 tonnes per ha per year (Lim 1998) shows that Malaysian palm oil industry produced approximately 95.3 million tonnes of dry lignocellulosic biomass in 2009. This figure is expected to increase substantially when the total planted hectarage of oil palm in Malaysia could reach 4.74 million ha in 2015 (Basiron and Simeh 2005) while the projected hectarage in Indonesia is 4.5 million ha. Fibres of empty fruit bunches (EFB) has great potential in papermaking and their chemical and morphological has recently been examined (Law et al. 2007). Other studies had shown that oil palm biomass can be transformed into fibres useful for paper and paperboards manufacture (Wanrosli and Law 2011, Rushdan et al. 2007, Gonzalo et al. 2007). Some researchers (Wanrosli et al. 2005, Rushdan et al. 2007, Gonzalo et al. 2007) had reported successful use of EFB soda pulps in combination with recycled fibres (OCC). Since oil palm residues come in various forms (trunk, frond and empty-fruit-bunch) it is economically necessary to process them as a whole, i.e. in mixture of various components and not individually. However, each of these components has different physical and chemical properties; it becomes necessary to evaluate their interactions between them as well as those with wood fibres. As an initial step, we pulped the two main oil palm residues (frond and empty-fruit-bunch, EFB) separately and then blended them together in various proportions. We also mixed them, separately, with wood pulps such as *Acacia mangium* kraft pulp and softwood thermomechanical pulp (TMP). In future studies we will make efforts to pulp the frond and EFB together, simplifying the operation for economic reasons. In this work *Acacia mangium* kraft pulp was also used since it is being utilized to produce liners by some mills such as Sabah Forest Industries (SFI) integrated paper mill. Our targeted products were liner and medium for linerboard. In the latter case we examine the possibility of using EFB pulp and softwood TMP to produce medium grade. TMP has long fibres with high rigidity, which is suitable for producing medium sheet with high bulk and stiffness.

MATERIAL AND METHODS

Material

Industrial fibrous strands of oil palm frond and EFB were obtained from a local company in Perak state, Malaysia. The strands (air dry) were cut into pieces of 2-3 cm in length to facilitate the pulping process.

Two wood pulps were used in the blending study, a hardwood chemical pulp and a softwood mechanical pulp. The chemical pulp was prepared from *Acacia mangium* by a sulphate process in our laboratory while the mechanical pulp was a softwood (mainly black spruce and balsam fir) TMP obtained from a Canadian mill in the province of Quebec.

Pulping

Soda pulping of oil palm frond and EFB was carried out in a 4-L stationary stainless steel digester (NAC Autoclave Co. Ltd., Japan) fitted with a computer-controlled thermocouple. The following conditions were employed basing on our previous experiences (Wanrosli et al. 1998, Wan Rosli et al. 2004): Liquor-to-material ratio- 8:1, time to maximum temperature – 80 (EFB) to 90 (frond) min; NaOH – 25 % (frond), 27 % (EFB); maximum temperature: 170°C (frond), 160°C (EFB), cooking time: 120 min (frond), 100 min (EFB). These conditions produced pulps with a Kappa number of 16-18. At the completion of the cook, the pulps were mechanically disintegrated in a three-bladed mixer for 1 min at 2 % and subsequently screened on a flat-plate screen with 0.15-mm slits, and stored in plastic bags for further use.

Acacia mangium trees were procured from Byram Forest Reserves, Penang, Malaysia. They were chipped and screened to remove the oversized particles; the average accepted chip size was about 23, 22 and 6 mm in length, width and thickness, respectively. Kraft puling (Wan Rosli et al. 2009) was conducted using these conditions: 19 % active alkali (expressed as Na_2O), 21.4 % sulfidity, pulping temperature 170°C, pulping time 120 min. After cooking, the treated chips were mechanically disintegrated in a three-bladed mixer at 2 % consistency for 1 min, and screened on a flat-plate screen with 0.15-mm slits (a 6-cut slot screen). The screened pulps were characterized without being further refined. Kappa number (17.2) of the screened pulps was determined by the Tappi method T 236.

Beating

Pulps were used in both beaten and unbeaten forms. They were beaten to freeness (CSF) about 300 mL in a PFI mill, at 10 % consistency, in accordance with Tappi method T 248 wd-97. To obtain the number of revolutions required, the pulps were individually beaten at various revolutions. The required number of revolutions was determined from a freeness-vs-number of revolutions curve. Latency of the beaten samples was removed by shear-disintegration in hot water (≈ 95°C) by means of a laboratory disintegrator before standard handsheets of 60 $g.m^{-2}$ were formed. The freeness (in mL) of pulps was: EFB: 550 (unbeaten), 300 (beaten); frond: 600 (unbeaten), 330 (beaten); *Acacia mangium*: 530 (unbeaten), 290 (beaten); TMP: 290 (not beaten).

Characterization of pulps

All sample pulps were characterized in terms of fiber length. The fiber length measurements (Tab. 1) were performed using a Fiber Quality Analyzer (FQA, Optest Equipment Inc., Canada).

Tab.1: Average fibre length data of difference pulps.

Pulp	Unbeaten			Beaten		
	AFL (mm)	LWFL (mm)	WWFL (mm)	AFL (mm)	LWFL (mm)	WWFL (mm)
Frond	0.81	1.26	1.06	0.72	1.09	0.70
EFB	0.70	1.03	0.81	0.61	0.98	0.76
A. mangium	0.70	1.26	0.84	0.71	1.26	0.81
TMP	1.00	1.68	1.15	0.53	0.75	0.70

The arithmetic fiber length (AFL) is based on the total number of particles measured and, hence, greatly affected by the small-sized particles. The weight-weighted fiber length (WWFL) is influenced by the number of particularly long fiber elements such as fiber bundles. To minimize the effects of both fine and large particles, it is recommended to use length-weighted fiber length (LWFL) for comparison purpose. As seen in Tab. 1, the frond pulp lost about 13 % in fiber length after 3000 revolutions of beating while the EFB fibers were shortened by about 5 % with 4000 revolutions, indicating that the former was easier to break than the latter. Beating with 7000 revolutions had no impact on fiber length of *Acacia mangium* kraft fibers due to their flexibility. On the other hand, the TMP fibers suffered remarkable loss (about 55 %) in fiber length even with only 1000 revolutions of beating, which is attributable to the rigidity of these mechanical fibers, which had high lignin content.

Handsheet formation and testing

Standard handsheets of 60 $g.m^{-2}$ were prepared from various blends of pulps. For the blending experiments the following weight percentages were fixed at 0, 10, 20, 30, 50, 80 and 100 % for the component of EFB or frond; the remainders being made up with wood pulp. The sheets were conditioned at 23°C and 50 % RH for at least 24 h before testing, according to appropriate Tappi standard methods.

RESULTS AND DISCUSSION

Interactions between EFB and frond fibres

Handsheets made from EFB fibres, beaten or unbeaten, had considerably lower density (diamonds in figures) and, as a result, were much weaker in tensile strength (triangles in figure) when compared to the frond counterparts, as shown in Fig. 1a (the subscript b of legends in this and subsequent figures denotes beaten samples). Higher bulk or lower sheet density of EFB suggests that EFB fibers were less conformable and thus had inferior inter-fiber bonding capacity in comparison to frond fibers. Additionally, the shorter fibre length of EFB (Tab. 1) might be partially accountable for the difference. As a result, blending EFB with frond component had a negative impact on the tensile index of the resulting handsheet. However, a 20 % EFB addition could yield acceptable value of tensile index, 50-60 Nm.g^{-1}, which is quite acceptable for making industrial liners. Our results are comparable to those reported by Rushdan et al. (2007) and Gonzalo et al. (2007).

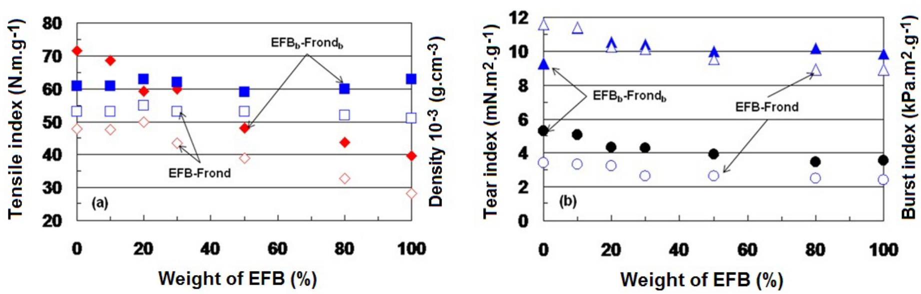

Fig. 1: Effect of blending of EFB and Frond fibers on paper properties a) Tensile (diamonds) and density (squares), b) Tear (triangles) and Burst (Circles).

EFB had slightly lower tear index (triangles shown in figures) compared to the frond for its slightly shorter mean fibre length (Tab. 1); mixing these two fibrous components showed small reduction in tearing resistance (Fig. 1b). Nonetheless, mixtures of these two pulps could produce excellent industrial liners.

Comparatively, EFB was weaker than the frond counterpart in terms of burst index (Fig. 1b; circles in figure). However, blending the beaten EFB (up to 30 %) with the beaten frond fibres (CSF about 300 mL in both cases) gave excellent burst resistance of approximately 4 kPa.m^2.g^{-1}.

Interactions between EFB and *Acacia mangium*

Beating had significantly increased fiber flxibilty and improved considerably the sheet formation, resulting in substantial increases in sheet density and tensile index, particularly for the kraft pulp of *Acacia mangium* (Fig. 2a). This hardwood kraft pulp had excellent tensile index (60 Nm.g^{-1}) as compared to the soda pulp of EFB (30 and 40 Nm.g^{-1}), unbeaten and beaten respectively). It is well known that kraft pulping produce pulps with high physical properties. However, the fact that *Acacia mangium* had longer average fibre length (1.26 mm) than the EFB had (about 1 mm) could also be partially responsible for the difference in tensile strength between the two pulps. However, adding EFB, up to 30 %, to *Acacia mangium* pulp had no noticeable impact on tensile index. Such mixtures of furnish would be suitable for producing liners.

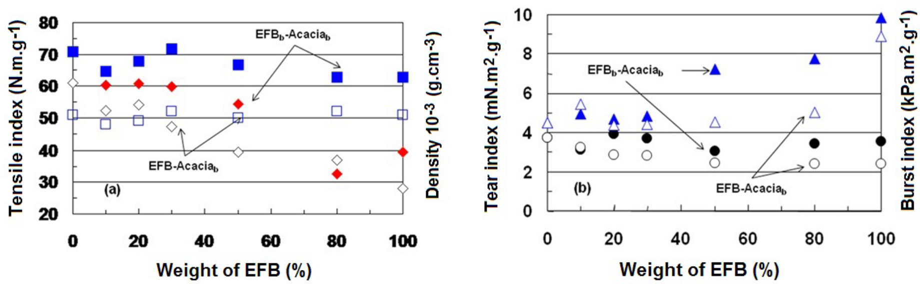

Fig. 2: Effect of blending of EFB and Acacia mangium fibers on paper properties a) Tensile (diamonds) and density (squares), b) Tear (triangles) and Burst (circles).

Acacia mangium pulp had much lower tear index (4.5 mN.m^2.g^{-1}) compared to that (about 9 mN.m^2.g^{-1}) of EFB (Fig. 2b) despite its longer mean fibre length (1.26 mm vs. 1 mm). This characteristic might be attributable the high inter-fiber bonding of *Acacia mangium* fibers, resulting in more fiber breakage during the tearing test. Strongly bonded fibers tend to yield rather than being pulled out of the fibrous network. It appears that blending of EFB with *Acacia mangium* kraft would yield beneficial effect on tearing resistance of the resulting sheet.

As seen in Fig. 2b, EFB had somewhat lower burst resistance when compared to the *Acacia mangium* sample. However, mixing these two components we still can maintain a relatively acceptable burst index, about 2.5 kPa.m^2.g^{-1}.

Interactions between frond and *Acacia mangium*

The beaten frond pulp was considerably stronger than the beaten *Acacia mangium* kraft pulp in tensile index (e.g. 72 Nm.g^{-1} vs. 60 Nm.g^{-1}) despite the fact that *Acacia mangium* pulp had higher sheet density (71 g.cm^{-3}) than the frond counterpart (60 g.cm^{-3}), as revealed in Fig. 3a. But the frond had rather poor performance in tensile strength when it was used in unbeaten state.

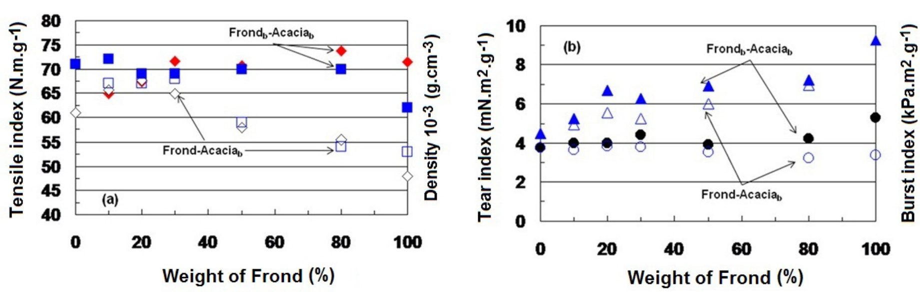

Fig. 3: Effect of blending of Frond and Acacia mangium fibers on paper properties a) Tensile (diamonds) and density (squares), b) Tear (triangles) and Burst (circles).

Mixing frond fibres, particularly the beaten ones, with *Acacia mangium* pulp improved noticeably the tearing resistance of the resulting sheets (Fig. 3b). Such blends of furnish would be suitable for producing liners with excellent tear index.

Blending of frond and *Acacia mangium* fibres gave excellent burst index of approximately

4 kPa.m^2.g^{-1} (Fig. 3b), indicating that the soda oil palm fibres could maintain good burst resistance of paper when they were combined with *Acacia mangium* kraft fibres.

Interactions between EBF and TMP

Using TMP in medium production might be of great interest due to the long and rigid fibres of TMP, yielding high bulk and stiffness to the product. When high proportion (e.g. 80 %) of beaten frond fibres were blended with the unbeaten TMP, one could obtain relatively good tensile strength (about 30 Nm.g^{-1}), Fig. 4a indicates. The freeness of the TMP employed here was too high (290 mL) to yield good properties. Had it been refined to about 100 mL CSF (e.g. for newsprint grade), it should normally have a tensile index around 40-50 Nm.g^{-1}.

Fig. 4b shows that the rate of EFB addition to TMP had little influence on both tear and burst indices, regardless of the freeness levels of EFB (i.e. beaten or unbeaten). The values of tear and burst indices could be greatly improved by beating the TMP to lower freeness because the specific surface of TMP fibres is expected to augment upon refining, improving these strength properties.

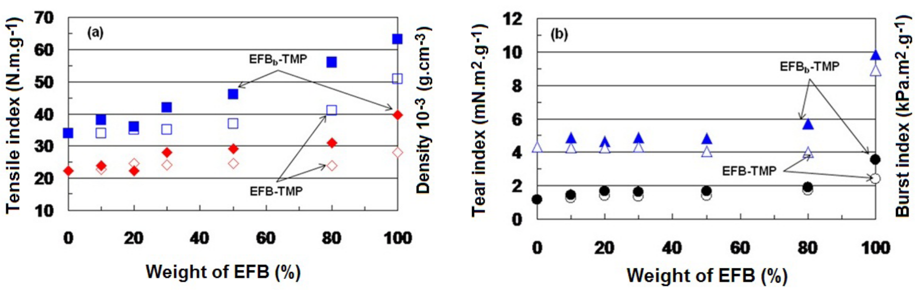

Fig. 4: Effect of blending of EFB and TMP fibers on paper properties a) Tensile (diamonds) and density (squares), b) Tear (triangles) and Burst (circles).

Interactions between frond and TPM

Blending 50-80 % of frond fibres (beaten or unbeaten) with 20-50 % TMP gave excellent tensile strength of 40-60 Nm.g^{-1} (Fig. 5a). The corresponding tear index was about 7 mN.m^2.g^{-1} and burst index was 2-3 kPa.m^2.g^{-1} (Fig. 5b), which is quite suitable for producing corrugated medium.

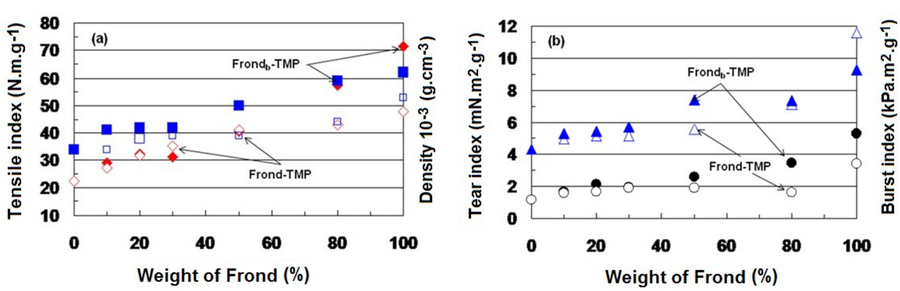

Fig. 5: Effect of blending of Frond and TMP fibers on paper properties a) Tensile (diamonds) and density (squares), b) Tear (triangles) and Burst (circles).

CONCLUSIONS

This study indicates that oil palm pulps produced from frond and empty-fruit-bunch (EFB) by means of a soda process have great potential in producing liners and medium. These pulps, which have a Kappa number of 16-18, can be used in combination or in mixtures with a hardwood kraft pulp of *Acacia mangium* to make liners with satisfactory tensile, burst and tear indices. This work also suggests that the oil palm pulps can also be blended with a softwood thermomechanical pulp (TMP) to make good quality medium. To simplify the pulping operation of oil palm materials, and for economic reason, we recommend that further studies be made to optimize a pulping technique to treat the frond and EFB together as a whole.

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REFERENCES

1. Basiron, Y., Simeh, M.A., 2005: Vision 2020 - The palm oil phenomenon. Oil Palm Industry Economic J. 5(2): 1-10.
2. Gonzalo, A., Sanchez, J.L., Escudero, E., Marin, F., Fuertes, R., 2007: Pulp and paper production from EFB using a semichemical process. TAPPI Engineering, Pulping and Environmental Conferece, (Jacksonville-USA), October 21-24, 2007. www.tappi.org/content/events/07epe/papers/07epe82.pdf.
3. Law, K.N., Wan Rosli, W.D., Ghazali, A., 2007: Morphological and chemical nature of fiber strands of oil palm empty-fruit-bunch (OPEFB). BioResources 2(3): 351-362.
4. Lim, K.O., 1998: Oil palm plantations – A plausible renewable source of energy. RERIC International Energy J. 20(2): 107-116.
5. MPOB, 2009: Malaysian Palm Oil Board. Overview of the Malaysian Oil Palm Industry 2009. http://econ.mpob.gov.my/economy/overview_2009.pdf accessed on 13th September, 2010.
6. Rushdan, I., Latifah, J., Hoi, W.K., Mohd, Nor, M.Y., 2007: Commercial-scale production of soda pulp and medium paper from oil palm empty fruit bunches. J. Tropical Forest Sci. 19(3): 121-126.
7. Wan Rosli, W.D., Law, K.N., Zainuddin, Z., Asro, R., 2004: Effect of pulping variables on the characteristics of oil-palm frond-fiber. Bioresource Technol. 93(3): 233-240.
8. Wan Rosli, W.D., Mazlan, I., Law, K.N., 2009: Effects of Kraft pulping variables on pulp and paper properties of *Acacia mangium* Kraft pulp. Cellulose Chem. Technol. 43(1-3): 9-15.
9. Wanrosli, W.D., Law, K.N., 2011: Oil palm fibres as papermaking material – potential and challenges. Bioresources 6(1): 901-917.
10. Wanrosli, W.D., Law, K.N., Valade, J.L., 1998: Chemical pulping of oil palm empty fruit bunches. Cellulose Chem. Technol. 32(1-2): 133-143.

11. Wanrosli, W.D., Zainuddin, Z., Roslan, S., 2005: Upgrading of recycled paper with oil palm fiber soda pulp. Industrial Crops and Products 21(3): 325–329.
12. Yacob, S., 2007: Progress & challenges in utilization of palm biomass. Advanced agriecological research Sdn. Bhd. http://www.jst.go.jp/asts/asts_j/files/ppt/15_ppt.pdf accessed on 27th November, 2008.

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