COMMERCIAL-SCALE PRODUCTION OF SODA PULP AND MEDIUM PAPER FROM OIL PALM EMPTY FRUIT BUNCHES

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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. The objective of this study was to commercially produce soda pulp and medium paper from empty fruit bunches (EFB) of *Elaeis guineensis*. In this work, EFB fibrous strands collected in Malaysia were shipped to China where they were pulped using a continuous pulping system. EFB soda pulp was shipped back to Malaysia for papermaking at three paper mills in Peninsular Malaysia. The EFB pulp was blended with recycled pulp from old corrugated container (OCC) at different ratios of blending to produce medium paper. Our results showed that EFB could be pulped by the soda process commercially. Evaluation of EFB soda pulp produced in this study had properties similar to pulps from two commercial hardwood species, namely, *Acacia mangium* and *Eucalyptus globulus*.

Keywords: Blending, corrugated container, paper mill, pulp mill, soda pulping

RUSHDAN, I., LATIFAH, J., HOI, W. K. & MOHD. NOR, M. Y. 2007. Penghasilan pulpa soda dan kertas medium secara komersial daripada tandan kosong kelapa sawit. Objektif penyelidikan ini adalah untuk menghasilkan pulpa soda dan kertas medium daripada tandan kosong (EFB) kelapa sawit (*Elaeis guineensis*) pada skala komersial. Dalam kajian ini, lembar gentian EFB dari Malaysia telah dihantar ke China. EFB ini telah dihancurkan dengan proses penghadam berterusan. Seterusnya bagi kajian pembuatan kertas pulpa tersebut telah dihantar ke tiga buah kilang kertas di Semenanjung Malaysia. Pulpa EFB ini telah dicampurkan dengan pulpa kitar semula kertas kotak gelugur (OCC) pada kadar kandungan yang berbeza untuk menghasilkan kertas medium. Keputusan kajian menunjukkan EFB boleh dipulpakan secara proses soda pada skala komersial. Penilaian pulpa yang dihasilkan dalam kajian ini menunjukkan ia mempunyai sifat sama seperti pulpa *Acacia mangium* dan *Eucalyptus globulus*.

INTRODUCTION

Oil palm (*Elaeis guineensis*) solid wastes, especially empty fruit bunches (EFB), have great potential to be used as raw materials for the pulp and paper industries. A non-wood fibre source, EFB is the stalk and spikelets of the fruit bunch after removal of fruits. Malaysia produced 16 million tonnes of EFB in 2000, which were generally used as mulch for oil palms, converted to bunch ash or discarded as waste.

Earlier laboratory works have proven that EFB is a useful raw material for the pulp and paper industries (Rushdan 2002, Rushdan 2003a, b, Rushdan 2005a). EFB possess great potential as raw material due to its availability in large quantity and continuous supply, chemically low lignin and high cellulose content, high fibre content, resemblance to hardwood fibres and good bonding strength and paper properties of handsheets (Mohamad 2000). However, none of the EFB pulp and paper discoveries has been utilized commercially. The objective of this study was to produce medium paper from EFB soda pulp at a commercial-scale and compare it with pulp and paper from two commercial hardwood species.

MATERIALS AND METHODS

Commercial-scale pulping

EFB fibrous strands were collected from various oil palm mills in Perak, Negeri Sembilan and Johore, Malaysia where they were also compressed to recover oil and to remove excess water. Following this the strands were shredded, dried and baled. Commercial-scale pulping was carried out in a paper mill in Baishan, Jingling Province, China because facilities for commercial-scale pulping

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for non-wood materials were not available locally.

Prior to pulping, EFB bundles were cut into short fibres, washed and pre-steamed. Pulping of the EFB was carried out by a continuous pulping system that consisted of two cooking tubes, namely, declining and horizontal digesters. EFB was fed into the digesters at a rate of 1.5 tonnes/hour while NaOH (130 g/l based on Na_2O) and white liquor were fed at a rate of 2.2 m^3/hour. EFB was digested for 45 min at 0.40 Mpa. After cooking, the pulp was washed, made to pulp board and then dried. The EFB soda pulp board was sent back to Malaysia for papermaking.

Laboratory pulp evaluation

The untreated pulp was examined for its pH, kappa number, shives content and handsheet properties. A comparative development of pulp and paper properties of EFB was made for two commercial hardwood species, *Acacia mangium* and *Eucalyptus globulus* (Rushdan 1995).

The pH of pulp was examined according to TAPPI T 252 'pH and Electrical Conductivity of Hot Water Extract of Pulp, Paper, and Paperboard'. This procedure measures the level of residual ionic impurities in pulp and shows the effectiveness of washing in the pulp manufacturing process (TAPPI 1994). The kappa number was examined according to TAPPI T 236 'Kappa Number of Pulp' (TAPPI 1994). It measures the quantity of lignin left in pulp. The relationship between kappa number and lignin content is lignin (%) = 0.147 × kappa number (Loras 1980). The degree of lignin dissolved depends on the pulping parameters, namely, chemical, temperature and time. Kappa number indicates the degree of cooking and estimates the chemical requirement for the bleaching process (Gullichsen & Fogelholm 1999). Shives, the fraction of pulp retained on screened plate of 0.20 mm slits, were examined by screening the pulp using a Somerville fractionator. Shives will not contribute to fibre bonding and will appear as black dots or shieve picks on the sheet and make the paper surface uneven. They also decrease the mechanical and optical properties of the paper produced (Gullichsen & Fogelholm 1999).

We examined the pulp for its quality, process ability and suitability for various end uses in order to obtain fibre quality criteria that can be used to predict the properties of papers produced from it. Pulp quality is a function of inherent characteristics modified by processing within a pulp mill. It gives some indication of the papermaking quality of the pulp, which may represent only a relatively small part of total factors defining the quality characteristics of the final product. Pulp evaluation was carried out by subjecting the pulp to mechanical treatment in a laboratory beater after which the pulp was converted into standard test sheets. The handsheets were then pressed before drying and their properties were examined according to TAPPI T 248 'Laboratory Beating of Pulp (PFI Mill Method)', TAPPI T 205 'Forming Handsheets for Physical Tests of Pulp' and TAPPI T 220 'Physical Testing of Pulp Handsheets'. These procedures give some indication of the papermaking quality of a pulp.

Paper mill trials

The pulp was sent to three paper mills in Peninsular Malaysia. These mills uses recycled pulps to produce medium paper. The EFB pulp was washed, screened and refined during stock preparation. EFB pulp at ratios ranging between 6 and 50% was blended with recycled pulp from old corrugated container (OCC) to produce medium paper. The medium paper was tested for its properties, namely, burst according to TAPPI T 403 'Bursting Strength of Paper', corrugated medium test (CMT) according to TAPPI T 809 'Flat Crush of Corrugating Medium', ring crush (RC) according to TAPPI T 818 'Ring Crush of Paperboard', tensile index according to TAPPI T 494 'Tensile Breaking Properties of Paper and Paperboard' and folding endurance according to TAPPI T 511 'Folding Endurance of Paper (MIT tester)' (TAPPI 1994). Results were compared with the control medium paper (unblended paper) used in corrugated board production and also with two commercial hardwood species, *A. mangium* and *E. globulus* pulps (Rushdan 1995).

RESULTS AND DISCUSSION

Pulp properties

The liquor extracted from the pulp for pH measurement was black in colour. The pH of the untreated EFB soda pulp was 13. The high pH obtained in this study showed that the pulp had not been washed properly after cooking.

The kappa number of the washed and screened EFB pulp was 47. There was 6.91% lignin in the EFB soda pulp. The initial content of lignin in EFB was 12–21%. The commercial-scale soda pulping had dissolved about 42 to 67% of lignin from EFB. Rushdan (2002) reported that at laboratory scale, the kappa number was 15 and lignin was dissolved in the range of 59 to 69%.

Shives content of the pulp was 38%. Pulp contained very high shives due to uncooked EFB. Low chemical concentration, short cooking time and low temperature will produce pulp with high shives and kappa number. It has been reported that cooking at 20% NaOH for three hours at 170 °C produced pulp without shives (Rushdan 2002).

Laboratory pulp evaluation

Pulp properties changed as the degree of beating increased (Table 1). Compared with *A. mangium* and *E. globulus*, EFB had the lowest apparent density and burst index, highest freeness and was second in tensile and tear indices. The changes in pulp and handsheet properties were due to the change in fibre properties. All fibre morphology parameters decreased as the degree of beating increased (Rushdan 2003b).

Freeness decreased as the beating degree increased due to the increase in pulp wetness, fibre shortening and fines production (Rushdan 2003b). The strength of paper with randomly oriented fibres is dependent on the strength of individual fibres and the strength and number of bonds between them. The number of bonds is the number of bonding area and is influenced by fibre flexibility. A flexible fibre will have more surface area for bonding. Fibre flexibility and the relative bonding area can be determined indirectly by the paper apparent density. Apparent density is one of the most significant properties of paper. It influences almost all mechanical, physical, and electrical properties. As apparent density increased burst index and tensile index also increased (Figures 1 and 2).

Table 1 Development of properties in soda pulped EFB due to beating compared with *Acacia mangium* and *Eucalyptus globulus* pulps

(a) Empty fruit bunches (EFB) of *Elaeis guineensis*

	Refining (rev.)				
	0	1000	2000	4000	8000
Freeness (CSF)	623	528	479	414	320
Apparent density (g/cm^3)	0.47	0.52	0.54	0.57	0.60
Tear index (mNm^2/g)	5.85	6.73	8.35	7.71	7.84
Tensile index (Nm/g)	21.37	27.58	30.98	34.39	36.86
Burst index (kPa.m^2/g)	1.41	1.90	2.11	2.45	2.80

(b) *Acacia mangium**

	Refining (rev.)			
	0	750	1500	2250
Freeness (CSF)	650	375	100	45
Apparent density (g/cm^3)	0.49	0.65	0.62	0.59
Tear index (mNm^2/g)	3.28	7.39	6.34	5.71
Tensile index (Nm/g)	2.53	10.23	10.34	10.29
Burst index (kPa.m^2/g)	6.76	7.20	7.25	7.44

(c) *Eucalyptus globulus**

	Refining (rev.)			
	0	750	1500	2250
Freeness (CSF)	550	500	400	275
Apparent density (g/cm^3)	0.54	0.70	0.78	0.83
Tear index (mNm^2/g)	4.33	13.47	12.39	11.34
Tensile index (Nm/g)	24.84	91.40	91.40	92.62
Burst index (kPa.m^2/g)	0.13	6.02	6.71	6.65

* Rushdan (1995)

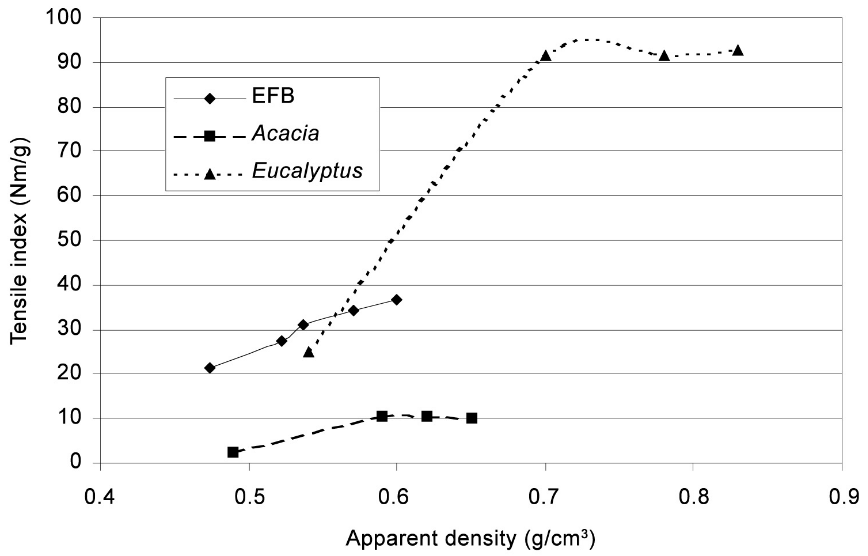

Figure 1 The effect of apparent density on tensile index for a soda pulped EFB compared with *Acacia mangium* and *Eucalyptus globulus* pulps

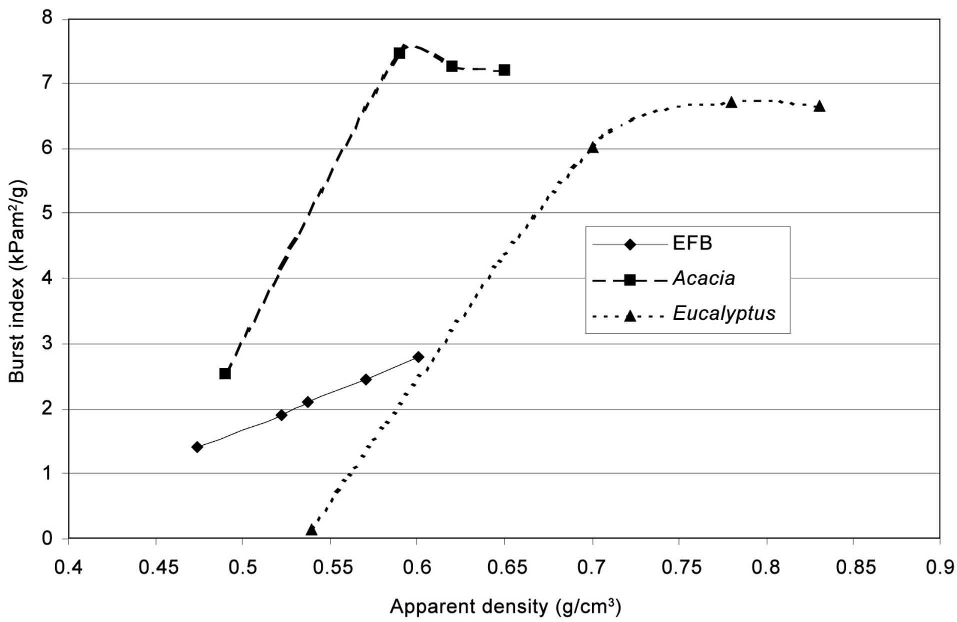

Figure 2 The effect of apparent density on burst index for a soda pulped EFB compared with *A. mangium* and *E. globulus* pulps

Paper mill trials

The properties of medium papers made from mixtures of the EFB soda pulp and recycled pulp from OCC papers are shown in Table 2. In comparison with the control (100% recycled pulp), the paper properties were greatly affected by the percentage of blending with EFB pulp. Strength properties of the blended recycled papers were not linearly related with those of the EFB paper. Changes are in the range of -32 to 512% (Table 3).

The addition of EFB pulp improved the burst, corrugated medium test, ring crush, tensile index and folding endurance but had adverse effects on the thickness, bulk and tear index. EFB virgin pulp was more ready to collapse and the fibres were more flexible compared with those of the recycled paper pulp. Flexible fibres fill voids in sheets. The flexibility and collapsibility of fibres decrease paper thickness and consequently decrease bulkiness. At the same time, the flexibility and collapsibility increase fibre bonding of a paper sheet. The increase in

Table 2 Paper properties of blended pulp of oil palm EFB soda pulp and recycled pulp from old corrugated container

Label	EFB pulp (%)	Old corrugated container (%)	Thickness (mm)	Grammage (g m^{-2})	Bulk (cm^3 g^{-1})	Burst index (kPam^2 g^{-1})	Corrugated medium test (kN m^{-1})	Ring Crush (kN m^{-1})	Tensile index (Nm g^{-1})		Tear index (mNm^2 g^{-1})		Folding endurance No.	
									CD*	MD#	CD	MD	CD	MD
SANYEN6	6	94	0.18	123.58	1.49	2.54	1.6	1.4	23	61	9.31	8.22	45	312
SANYEN13	13	87	0.18	121.90	1.51	2.30	1.6	1.5	22	59	8.88	7.28	33	168
SANYEN20	20	80	0.18	118.39	1.55	1.92	1.5	1.4	22	52	7.53	6.50	18	99
SANYEN26	26	74	0.19	118.77	1.58	1.95	1.5	1.3	19	49	7.37	6.15	16	57
SANYEN40	40	60	0.19	121.45	1.56	1.55	1.6	1.4	21	52	7.15	6.37	20	80
SANYEN50	50	50	0.22	114.87	1.87	1.59	1.0	1.1	21	38	8.16	7.03	20	40
TRIO25	25	75	0.24	122.53	1.93	1.71	1.2	1.3	21	42	8.09	8.50	26	59
TRIO45	45	55	0.23	124.62	1.82	1.67	1.2	1.2	21	38	8.51	7.45	18	60
TRIO50	50	50	0.22	122.55	1.76	1.75	1.1	1.2	21	39	8.39	7.43	25	60
PASCORP20	20	80	0.19	113.21	1.68	1.40	1.0	1.2	13	35	9.27	7.67	12	71
PASCORP25	25	75	0.19	112.05	1.82	1.25	1.1	1.3	14	46	9.49	8.20	17	93
CONTROL	0	100	0.22	121.90	1.79	1.54	1.1	1.3	19	44	9.06	8.57	12	51
100% *A. mangium*	0	0	0.20	113.28	1.79	1.24	n.a.	n.a.	39	88	8.53	1.03	n.a.	n.a.
100% *E. globulus*	0	0	0.26	137.82	1.92	1.71	n.a.	n.a.	34	57	7.88	6.36	n.a.	n.a.

*CD = machine cross direction, #MD = machine direction, n.a. = not available

Table 3 Percentage (%) of change in paper properties after incorporating oil palm EFB soda pulp into recycled pulp from old corrugated container

Label	Thickness	Bulk	Burst	Corrugated medium	Ring crush	Tensile index		Tear index		Folding endurance	
						CD*	MD#	CD	MD	CD	MD
SANYEN6	-18.18	-16.76	64.94	45.45	7.69	21.05	38.64	2.76	-4.08	275.00	511.76
SANYEN13	-18.18	-15.64	49.35	45.45	15.38	15.79	34.09	-1.99	-15.05	175.00	229.41
SANYEN20	-18.18	-13.41	24.68	36.36	7.69	15.79	18.18	-16.89	-24.15	50.00	94.12
SANYEN26	-13.64	-11.73	26.62	36.36	0.00	0.00	11.36	-18.65	-28.24	33.33	11.76
SANYEN40	-13.64	-12.85	0.65	45.45	7.69	10.53	18.18	-21.08	-25.67	66.67	56.86
SANYEN50	0.00	4.47	3.25	-9.09	-15.38	10.53	-13.64	-9.93	-17.97	66.67	-21.57
TRIO25	9.09	7.82	11.04	9.09	0.00	10.53	-4.55	-10.71	-0.82	116.67	15.69
TRIO45	4.55	1.68	8.44	9.09	-7.69	10.53	-13.64	-6.07	-13.07	50.00	17.65
TRIO50	0.00	-1.68	13.64	0.00	-7.69	10.53	-11.36	-7.40	-13.30	108.33	17.65
PASCORP20	-13.64	-6.15	-9.09	-9.09	-7.69	-31.58	-20.45	2.32	-10.50	0.00	39.22
PASCORP25	-13.64	1.68	-18.83	0.00	0.00	-26.32	4.55	4.75	-4.32	41.67	82.35

*CD = machine cross direction, #MD = machine direction

fibre bonding increases the burst, corrugated medium test, ring crush, tensile index and folding endurance of the recycled paper but it decreases the tear index (Rushdan 2005b).

CONCLUSIONS

The study showed that EFB could be commercially pulped via the soda process. Pulp evaluation of the commercially produced EFB soda pulp had properties comparable with *A. mangium* and *E. globulus* pulps. EFB soda pulp can be blended with recycled pulp from old corrugated container and converted into medium paper commercially.

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