A PRELIMINARY STUDY OF MALAYSIAN WOOD WASTES AS SECONDARY RAW MATERIAL FOR PULPING

I. Rushdan*

Forest Research Institute Malaysia, 52109 Kepong, Selangor Darul Ehsan, Malaysia. E-mail: rushdan@frim.gov.my

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RUSHDAN, I. 2006. A preliminary study of Malaysian wood wastes as secondary raw material for pulping. In this work, we used waste wood from three Malaysian tropical hardwoods to understand the effects of species on the size of chips and pulp properties. The three species were kekatong (*Cynometra* spp.), merbatu (*Parinari oblongifolia*) and nyatoh (*Madhuca laurifolia*), categorized as heavy, medium and light hardwoods respectively. Results showed that wood species had an effect on the distribution of size of chips and on the quantity of chips accepted for kraft pulping. Wood species and chip size had an effect on pulp yield and properties. Screened yield increased as the wood density decreased and kappa number increased as wood density increased. The effects on pulp properties varied depending on wood species and/or chip size. This study showed that the three tropical hardwood wastes studied were not suitable for pulp because of their low yield and strength.

Keywords: Chip diameter, chip thickness, *Cynometra* spp., kraft pulping, *Parinari oblongifolia, Madhuca laurifolia*, wood chip, wood density, yield

RUSHDAN, I. 2006. Kajian awal ke atas sisa kayu Malaysia sebagai bahan mentah sekunder untuk penghasilan pulpa. Kami mengkaji sisa kayu daripada tiga spesies kayu keras tropika Malaysia untuk memahami kesan spesies terhadap saiz serpih dan ciri pulpa. Tiga spesies tersebut ialah kekatong (*Cynometra* spp.), merbatu (*Parinari oblongifolia*) dan nyatoh (*Madhuca laurifolia*), yang masing-masing tergolong sebagai spesies kayu keras berat, sederhana dan ringan. Keputusan menunjukkan spesies kayu memberi kesan terhadap taburan saiz serpih dan kuantiti serpih diterima untuk pempulpaan kraf. Kajian ini juga mendapati spesies kayu dan saiz serpih mempengaruhi hasil pulpa dan sifat-sifatnya. Hasil terskrin meningkat apabila ketumpatan kayu menurun dan nombor kappa meningkat apabila ketumpatan kayu meningkat. Kesan ke atas sifat-sifat pulpa bergantung pada spesies kayu dan/atau saiz serpih. Penyelidikan ini menunjukkan bahawa ketiga-tiga sisa kayu yang dikaji tidak sesuai untuk penghasilan pulpa dan kertas. Ini kerana keputusan menunjukkan hasil pulpa dan kekuatan kertas yang rendah.

INTRODUCTION

The greatest challenges of wood industries in Malaysia are to address and overcome declining supplies of raw material, to fully utilize available resources, and to take advantage of innovations in wood processing. It is thus not surprising that logging and mill residues are emerging as major sources of raw material. Moreover, dumping of waste and residues is now prohibited or very costly, and now restrictions on open burning are being enforced more rigorously in Malaysia. Mill residues comprise bark, sawdust, slabs, ribs, peeler cores, grading off-cuts, sander dust, shavings, and rejects. In 1999, there were 5300 timber processing mills in Malaysia including sawmills, plywood and veneer mills, furniture mills, and factories for timber preservation, kiln drying facilities, particleboard, MDF, laminated board, prefabricated housing, woodchip, wood cement boards and flooring (MTIB 2001). These mills produced 5 million m^3 wood wastes per year (Hoi 2000). These wood wastes can be used for energy production and secondary raw material, e.g. in pulp and paper production. In industrial countries, a large share of wood-processing residues is used by the pulp industries (Hoi 2000).

Wood of different species may vary widely in physical and chemical properties. The importance of wood properties to the final product is well known. Wood wastes are

* Rushdan Ibrahim

characterized by six dominant attributes, namely, species, segregation, purity, moisture, storage and size (Anonymous 1998). In the pulp and paper industry, wood density is of key importance because it has a major effect on both yield and quality of fibres. Malaysian hardwoods are categorized into three groups according to density: light hardwoods (250–450 kg m^{-3}), medium hardwoods (451–650 kg m^{-3}), and heavy hardwoods (651–850 kg m^{-3}).

Using wood chips of uniform size will ensure highest pulp quality with the most efficient use of pulping chemicals and the least environmental impact (Biermann 1996). Dimension of chips depends on the condition and maintenance of chipper, stability at wood-knife interface, wood moisture content, presence of decay, and wood temperature (Smith & Javid 1992, Uhmeier 1995).

Wood wastes from Malaysian tropical hardwoods have never been tried as raw material for the pulping industry and thus, the importance of this work. The objective of this study was to determine the effects of density of hardwood wastes on size of chips and on kraft pulping. We carried out the pulping process on various sizes of chips to compare the properties of the pulp obtained. This is especially important because the current size limits are based on temperate species and none on tropical hardwood species. Furthermore, currently there is no literature available on the effects of size of chips on pulping properties for tropical hardwood. From this study, we also hope to find out if wood wastes from Malaysian tropical hardwood can be utilized for pulp.

MATERIALS AND METHODS

In this preliminary study, long off-cuts of three species of wood wastes representing the commercial heavy, medium and light Malaysian tropical hardwoods were used; they were kekatong (*Cynometra* spp.), merbatu (*Parinari oblongifolia*) and nyatoh (*Madhuca laurifolia*) respectively. Samples of kekatong and merbatu were construction wastes while nyatoh, furniture manufacturing. Species were confirmed using a hand lens (Sosef *et al.* 1998, Menon 2004). Basic density and moisture content were determined according to TAPPI T258 (TAPPI 1994). The dimensions, basic densities and moisture contents of woods are shown in Table 1.

The woods were chipped at the Forest Research Institute Malaysia (FRIM), Kepong using a drum chipper (30 kW, two knives and operated at 1465 rpm). The chips were classified into five different size fractions by vibrating them through a series of screen slots of 30, 25, 20 and 15 mm diameters. The diameter and thickness of wood chips were measured using a calliper. Following temperate species, we also considered chips that passed 30-mm diameter slots and those retained on the 25-, 20- and 15-mm screen as acceptable for pulping. The rest of the chips were considered as either oversize (retained on 30-mm screen) or undersize (passed 15-mm screen). All chips were kept in polyethylene bags and weighed.

A total of 500 g oven-dried chips of each species, grouped into accepted, oversize and undersize diameters, were pulped by kraft process in a four-litre rotating digester at the Universiti Sains Malaysia (USM), Penang. The pulping conditions were 20% active alkali (expressed as Na_2O), 25% sulphidity (expressed as Na_2O), 170 °C maximum temperature, 1.5 hours to maximum temperature, 2 hours at maximum temperature, and 1:5 of wood to liquor ratio. At the end of digestion, the softened pulp was disintegrated for 5 min in a hydrapulper, washed on a screen and screened using Somerville fractionators. The total pulp yield was calculated as the sum of screened pulp and shives or screened reject yields. Kappa number was determined according to TAPPI T236 (TAPPI 1994).

Screened pulps of accepted kekatong,

Table 1 The dimensions and properties of woods used for chipping

Wood species	Length (mm)	Width(mm)	Thickness(mm)	Density (kg m^{-3})	Moisture content (%) o.d.
Kekatong (*Cynometra* spp.)	500	47	11	730	17.3
Merbatu (*Parinari oblongifolia*)	500	47	25	630	13.9
Nyatoh (*Madhuca laurifolia*)	500	80	18	430	13.9

merbatu and nyatoh were refined using Lampen ball mill at five different degrees, namely, 1000, 2000, 4000 and 16 000 rpm, and a consistency of 3%. We used the Lampen ball mill as it was the only refiner available at USM and also it was acceptable for comparative studies.

Handsheets were made and their physical properties tested under controlled temperature and humidity following TAPPI T220 and T420 (TAPPI 1994).

RESULTS AND DISCUSSION

Chip diameter and thickness

The distribution of diameter and thickness of chips are shown in Table 2. The quantity and quality of chip sizes among species are different. Wood chips retained on the screens had diameters and thickness in the range of 119.64 to 17.06 mm and 19.48 to 1.73 mm respectively. Kekatong had the biggest size and nyatoh, the smallest. The average diameter of kekatong, merbatu and nyatoh were 35.64, 39.01 and 32.49 mm respectively and their average thickness were 5.66, 5.84 and 4.59 mm respectively. The quantity of chips retained according to size varied among species; more than 50% of the chips were retained on the 15-mm screen, i.e. 51.3, 58.3 and 51.8% for kekatong, merbatu and nyatoh hardwoods respectively (Figure 1).

Of the total chipper output, certain portions are not acceptable as raw material for the pulping process because of size limitation. Chips of 10 to 30 mm long and 3 to 6 mm thick are prime materials for pulping. Chips of these dimensions will produce long, sound fibres, allow quick penetration of steam or cooking liquid, and are easily handled and transported (Smook 1992, Broderick *et al.* 1998). Chips > 30 mm long are considered as oversize while that of < 10 mm long, undersize. Oversize chips can be rechipped and returned to the screens. Undersize, consisting of sawdust, small bark particles and very small chips, are removed and used as fuel. Based on diameters and thickness, kekatong had the highest portion of accepted chips (81.45%), followed by nyatoh and merbatu with 80.4 and 74.8% respectively (accepted chip size is the sum of chips retained on 25, 20 and 15 mm screens).

The variation in diameter and thickness of chips are due to the difference in their wood density (Koch 1972, Tsoumis 1991). The mechanical properties of the wood being cut strongly influence the type of chips formed and the cutting forces. Types of chips depend on wood resistance to cleavage and bending. The cutting force is positively correlated with wood density. The mechanical properties of wood are not equal in the transverse, radial, and tangential planes. Consequently, when a chipper knife passes through a wood, the shearing forces are not equally transferred in all directions. As a result, chip dimensions have a distribution around a statistical mean value.

Pulp yield and kappa number

The yields of pulp and kappa numbers of the three hardwoods are shown in Table 3. Merbatu undersized chips had the highest total yield (47.6%) and merbatu oversize chips the lowest total yield (35.9%). Merbatu undersize and nyatoh accepted chips gave the highest screened yields (38.9%) while kekatong oversize chips, the lowest (16.3%). Kekatong oversize chips had the highest rejects (26.1%) and nyatoh undersize, the lowest (0.5%). Kekatong oversize chips

Table 2 Average diameter and thickness of chips by species and fractionation of size

Wood species	Retained on screen slot				Biggest size	Smallest size
	30-mm	25-mm	20-mm	15-mm	retained	retained
Kekatong						
Diameter	62.10	27.59	22.86	18.55	119.64	16.89
Thickness	7.06	5.08	4.50	4.06	19.48	3.01
Merbatu						
Diameter	55.75	27.67	23.24	19.34	109.34	19.30
Thickness	7.02	5.03	4.73	3.76	18.03	2.83
Nyatoh						
Diameter	39.69	27.26	23.11	18.40	57.60	17.06
Thickness	5.26	3.86	3.91	3.38	9.28	1.73

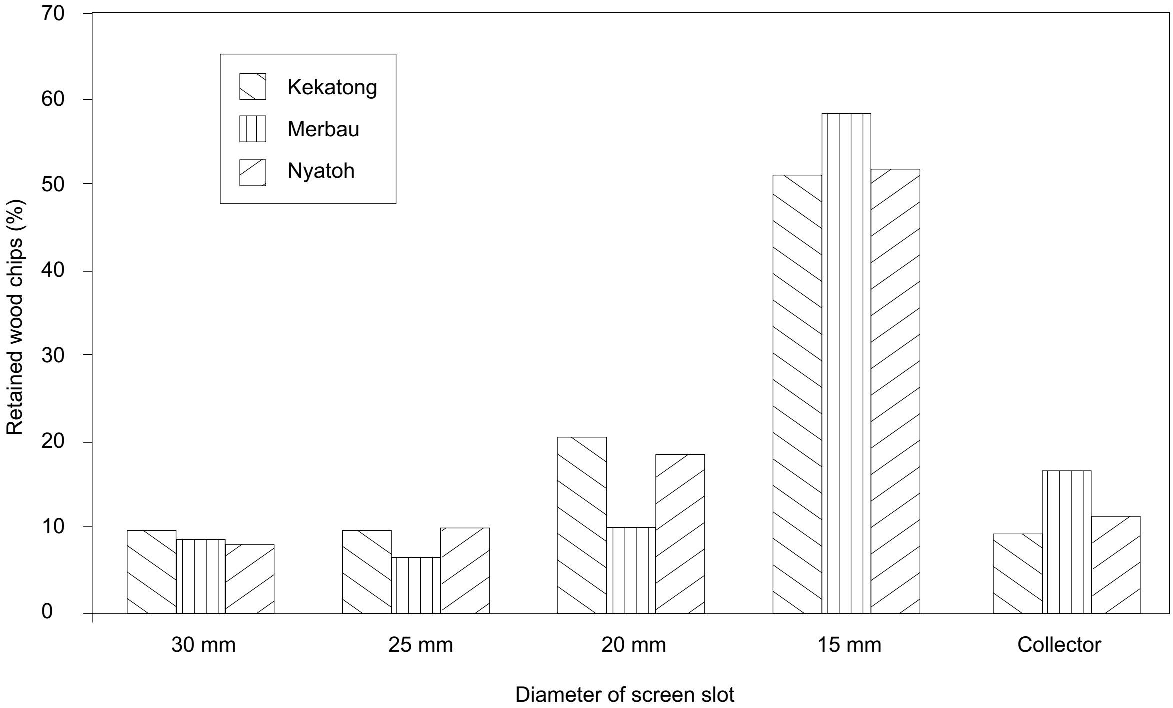


Figure 1 Percentage of wood chips retained on screen slots by species

Table 3 Pulp yields and kappa numbers of three Malaysian tropical hardwoods

Wood species	Chip size	Screened yield (%)	Rejects or sieves (%)	Total yield (%)	Kappa no.
Kekatong	Undersize	22.65	23.46	46.11	50.9
	Accepted	28.15	9.15	37.30	60.7
	Oversize	16.33	26.11	42.44	122.0
Merbatu	Undersize	38.89	8.67	47.56	61.3
	Accepted	27.39	11.29	38.68	66.1
	Oversize	22.75	13.16	35.91	92.6
Nyatoh	Undersize	38.08	0.47	44.35	50.5
	Accepted	38.89	3.91	42.80	59.3
	Oversize	30.74	13.61	44.35	65.9

exhibited the highest kappa number (122.0) and nyatoh undersize chips had the lowest kappa number (50.5). The differences in yields and kappa numbers between the species are due to their chemical and physical characteristics, which affect the topochemical and diffusion processes during pulping process (Minor 1996). This study showed that pulps of the three hardwood species all had kappa numbers > 20; these made them unsuitable for bleaching (Peh *et al.* 1986). Some optimization studies should be done to reduce the kappa number and rejects content.

High values of screened yield and low rejects are due to high lignin dissolution. Kappa number measures the quantity of lignin left in pulp. The lower the kappa number, the more lignin dissolved, and thus, more fibres were separated and fewer fibres were bonded together (Figure 2).

The selectivity of the delignification is linked to the chip size distribution (Hartler 1996, Broderick *et al.* 1998). Chip size strongly determines the mass transfer properties. Undersize chip overcook to a lower yield because liquor penetrates more quickly and reactions proceed more thoroughly. Delignification was retarded as the chip size increased (Figure 3).

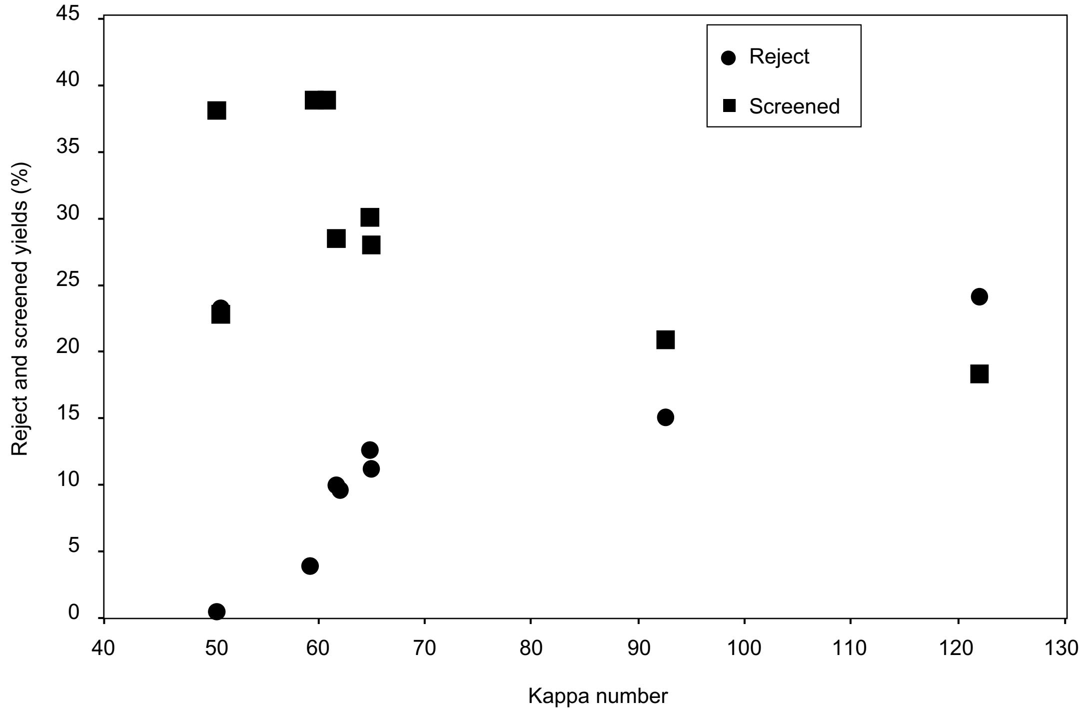
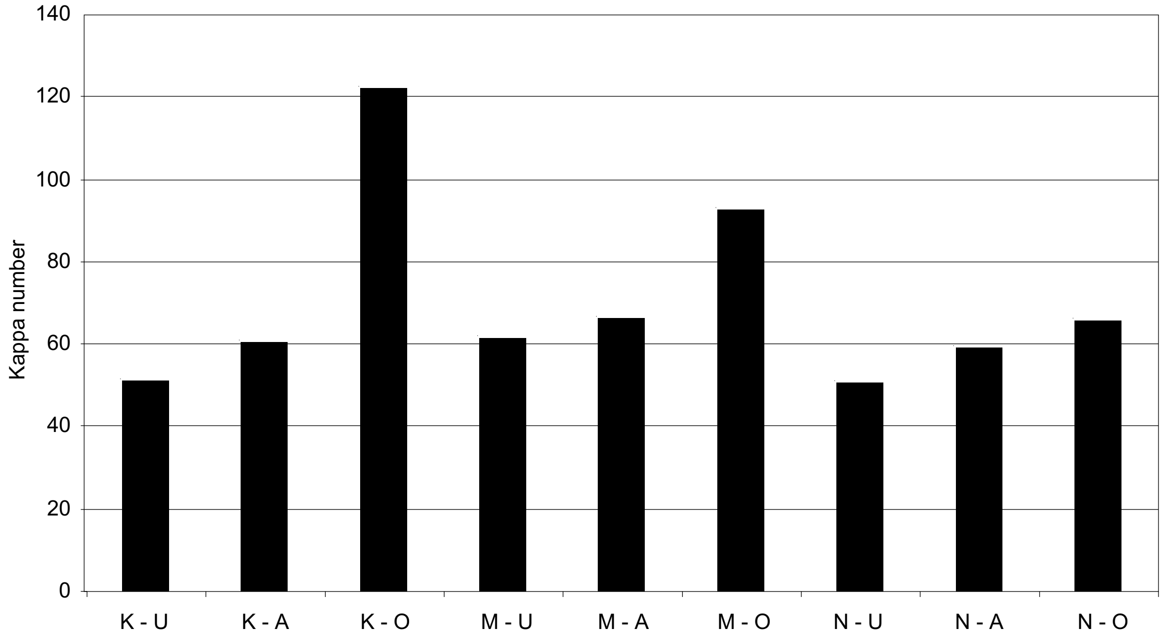


Figure 2 Relationship between kappa number and screened yield and rejects



Note : K = kekatong, M = merbatu, N = nyatoh, U = undersize, A = acceptable, O = oversize

Figure 3 The effects of wood species and size on kappa number

Pulp properties

Pulp properties of the three species are shown in Table 4. Among the pulps, nyatoh oversize handsheets had the highest apparent density (0.49 g cm^{-3}). Apparent density indirectly measures the flexibility of pulp. Heavy hardwood fibres are stiffer so they do not easily fill the gap in the sheet compared with medium and light hardwood fibres (Horn 1978).

For mechanical properties, kekatong undersize had the highest tensile index (15.8 N m g^{-1}) and merbatu oversize, the lowest (7.1 N m g^{-1}). Handsheets made from kekatong chips of acceptable chip size gave the highest tear index (3.9 mN m^2 g^{-1}) and folding endurance (5). Merbatu undersize and oversize chips had the lowest burst and tear indices (1.8 kPa m^2 g^{-1} and 1.1 mN m^2 g^{-1}) respectively.

Strength of paper with randomly oriented fibre is dependent on the strength of individual fibres as well as 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 a larger surface area for bonding. Fibre flexibility and relative bonding area can be determined by the apparent density and light-scattering coefficient of the paper. Apparent density is one of the most significant properties of paper. It influences almost all mechanical, physical, and electrical properties. Paper light-scattering coefficient is a function of both internal and interfibre bonded area. Light-scattering coefficient indicates the extent to which an area of component fibres is bonded and is generally accepted as a measure of the degree of bonding (Clark 1985).

Pulp yield, tensile index and burst index are the main parameters used to judge whether a species is good or poor for pulp and papermaking. The tensile index and burst index of wood waste pulps after beating are shown in Figures 4 and 5. Screened yields of pulp were in the range of 16.3 to 38.9%, tensile index 10 to 32 N m g^{-1}, and burst index 2.5 to 3.5 kPa m^2 g^{-1}. Based on guidelines (yield < 40%, tensile index < 65 N m g^{-1} and burst index < 5 kPa m^2 g^{-1}) by Peh *et al.* (1986), we conclude that the wood waste species used in this study were not suitable for pulp and paper making.

CONCLUSIONS

Wood species affected the chip distribution size. The quantity and quality of chips are different between species. Kekatong produced more acceptable chip for kraft pulping compared with merbatu and nyatoh. Some optimization studies should be done in order to reduce kappa number and rejects content. Kekatong gave the highest mechanical paper properties. As secondary raw material for pulping, wood wastes should be processed separately according to their density because uniform chips and pulp properties can be attained. In this study, we found that the three Malaysian tropical wood wastes were not suitable for pulp because of its low yield and strength.

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Table 4 The effects of species and chip size on properties of handsheets

Species	Chip size	Apparent density (g cm^{-3})	Tensile index (N m g^{-1})	Burst index (kPa m^2 g^{-1})	Tear index (mN m^2 g^{-1})	Folding endurance	Scattering coefficient (cm^2 g^{-1})
Kekatong	Undersize	0.38	15.81	2.43	2.43	3	24.61
	Accepted	0.39	12.89	2.08	3.85	5	25.28
	Oversize	0.33	7.27	2.96	2.05	2	21.70
Merbatu	Undersize	0.43	12.63	1.82	1.15	2	27.64
	Accepted	0.33	8.62	1.94	1.53	2	28.27
	Oversize	0.40	7.14	2.52	1.13	2	26.83
Nyatoh	Undersize	0.37	9.47	2.15	1.49	2	23.97
	Accepted	0.39	10.53	2.21	1.78	3	23.56
	Oversize	0.49	11.49	2.68	1.62	2	22.91

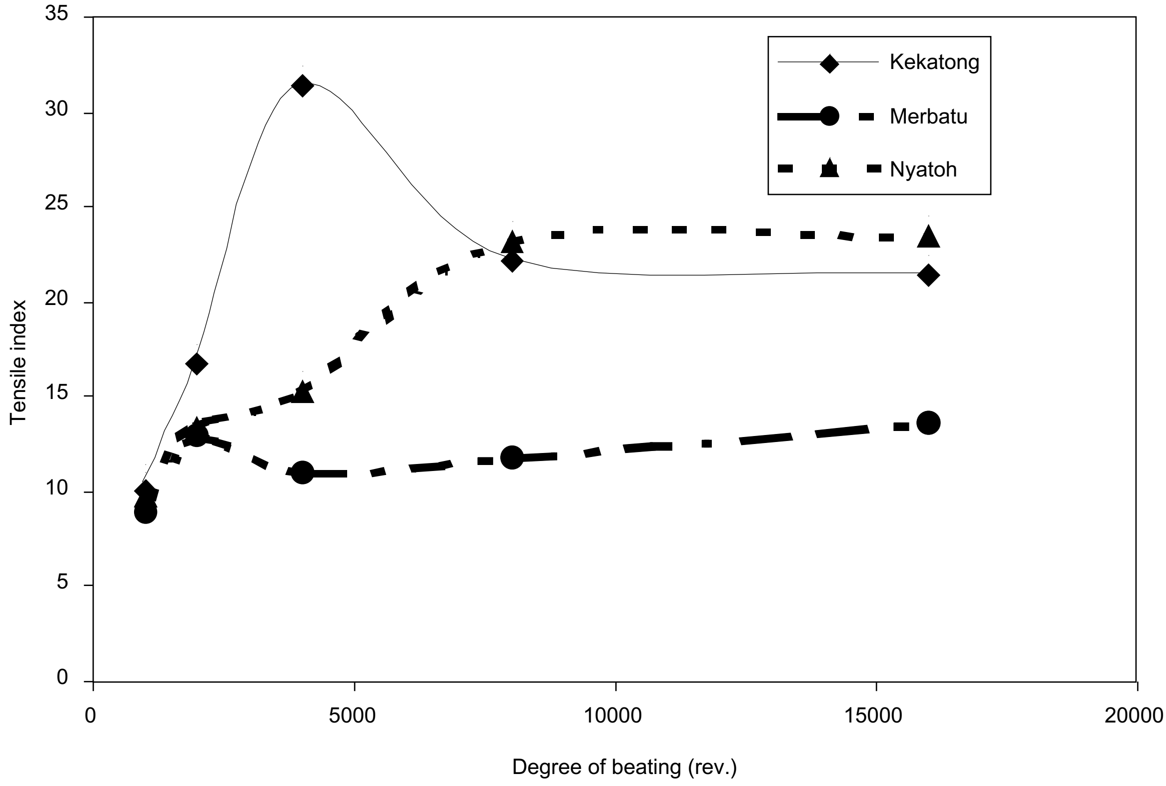

Figure 4 Tensile index (N m g^{-1}) of three wood waste kraft pulps

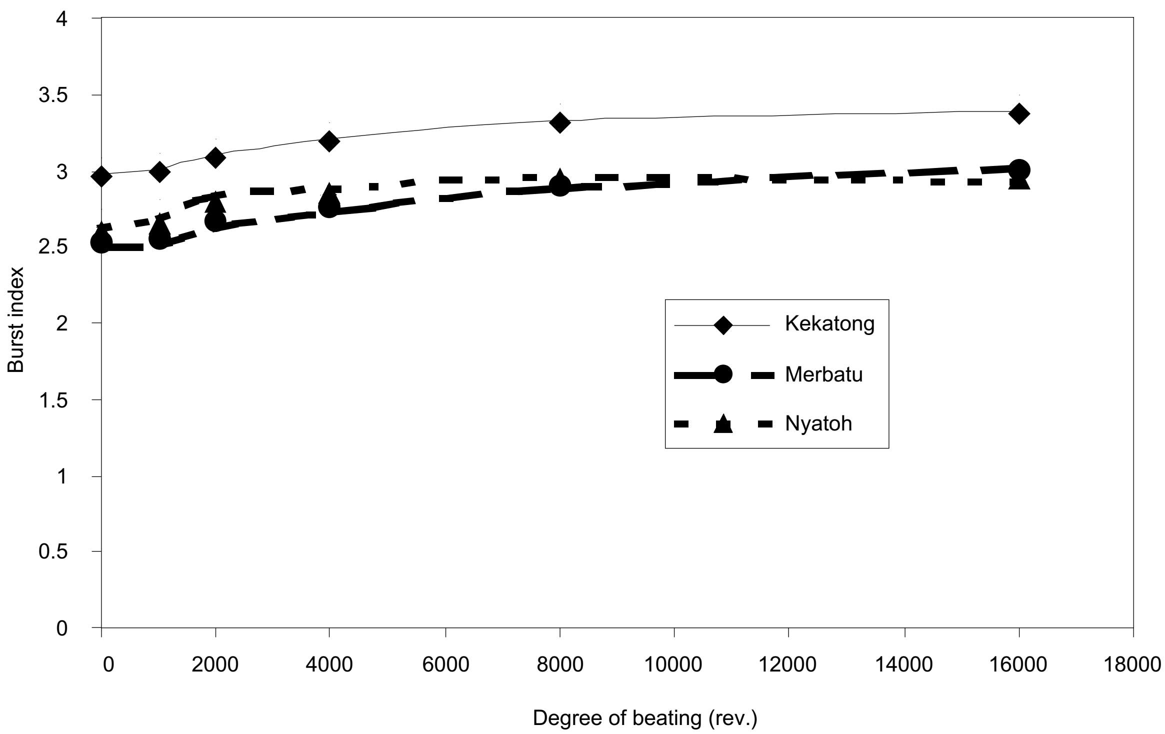

Figure 5 Burst index (kPa m^2g^{-1}) of three wood waste kraft pulps

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