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Pulp from oil palm fronds by chemical processes

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Abstract

To enhance the use of the abundant biomass generated by the palm oil industry in Malaysia a study was conducted in view of exploring the papermaking potential of this industrial byproduct. Fiber strands from the frond of oil palm trees were examined relative to their physical and chemical characteristics and their response to chemical pulping such as sulfite, soda-sulfite and soda processes. Morphologically, the frond fibers are comparable to those of hardwood. They contain high content of holocellulose but low in lignin. Chemical pulps of 45–50% yield produced either by soda-sulfite or soda process exhibit acceptable papermaking properties comparable to those of hardwood kraft pulps. The study showed that frond pulp might be used as a reinforcement component in newsprint production using softwood thermomechanical fibers.

Keywords: Oil palm fronds; Chemical pulping; Sulfite; Soda-sulfite; Soda; Reinforcement fibers

1. Introduction

Presently, wood is the most widely used raw material for production of pulp and paper in the world. However, increasing concerns over future fiber supplies and potential increases in wood costs have caused the pulp and paper industry to search for alternative fiber sources such as non-wood fiber plants. Within the mixed portfolio of non-wood fibers, oil palm (*Elaeis guineensis*) is one that shows great potential as a papermaking raw material, particularly for Indonesia and Malaysia (Fuad et al., 1999). It is an agricultural plant, which originates from West Africa and cultivated in Malaysia for its oil producing fruit. Besides palm oil, the industry also generates massive amounts of lignocellulosic residues such as trunks, fronds and the empty fruit bunches (EFB), with an estimated amount of 30 million tonnes (MPOB, 2001). The suitability of this abundant, inexpensive and renewable raw material for papermaking resource has been explored using a variety of pulping methods (Akamatsu et al., 1987; Khoo and Lee, 1991; Wan Rosli et al., 1998; Mohd Yusof, 1997), with most studies using oil palm trunks, and to a lesser amount on fronds and EFB. It is reported in an earlier work (Wan Rosli et al., 1998), that soda pulping of EFB appears to be the most interesting process when its efficacy and environmental friendliness is taken into consideration. Being an important fibrous source, this paper investigates the potential of another byproduct, viz. fronds, as raw material for pulp and papermaking by assessing the fiber characteristics, pulpability and papermaking characteristics of the obtained pulp.

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2. Experimental

2.1. Material

Processed oil palm frond fiber strands used in this study were obtained from a local palm oil mill in Perak, Malaysia. Before pulping, the raw material was washed, cleaned, sorted to remove foreign matters and air-dried.

2.2. Fiber morphology and chemical analysis

Fiber lengths were determined from the actual pulp produced using a Fiber Quality Analyzer (FQA, OpTest Equipment, Canada), whilst the fiber length distribution curve was obtained by plotting the fiber frequency data generated. The FQA uses optical imaging of fiber to yield length, coarseness and shape, etc. In the measure, a very dilute fiber suspension was used, about 800 mL with continuous stirring. Its concentration was not actually determined but was usually fixed at about 20 fibers passing through a small tube (where the fibers are imaged) per second. The total fiber count could range from 5000 and up. Fiber diameter, cell lumen width and cell wall thickness were measured directly from the magnified image with 100 measurements made on each property. Proximate chemical analyses of the raw material in relation to ash, extractives and lignin, were carried out following the appropriate Tappi standards, whereas, the holocellulose and α-cellulose were determined using the method described in Wise et al. (1946) and the Japanese Standard Method JIS 8101, respectively. Polysaccharide composition of the raw material was analysed by using gas chromatography (GC) according to Tappi standard T249 with slight modification. Acetic anhydride–pyridine mixture was employed for acetylation of polysaccharide instead of the usual standard of acetic anhydride–sulphuric acid. The GC system used in this study is the Hewlett Packard HP6890 Plus, equipped with a flame ionization detector (FID) and the column used is of the capillary type Supelco SP-2380 (30 m × 0.25 mm i.d. × 0.20 μm).

2.3. Pulping and pulp characterization

Pulping trials were carried out in a 4 L stationary stainless steel digester (NAC Autoclave Co. Ltd., Japan) fitted with a computer-controlled thermocouple. The conditions employed were as follows: liquor-to-material ratio of 6:1, time to maximum cooking temperature of 90 min, time of cook of 120 min, with variations in the white liquor chemical composition (Table 1). After cooking, the pulps were mechanically disintegrated in a three-bladed mixer for 1 min at 2% consistency and screened on a flat-plate screen with 0.15 mm slits (a six-cut slot screen). Rejects and screened yield were determined on oven-dry weight basis. The screened pulps were characterized without being further refined. Kappa number of the screened pulps was determined using Tappi method T 236. Handsheets were prepared and conditioned at 23 °C and 50% RH for at least 24 h before testing in accordance with the appropriate Tappi standard methods.

Table 1
Pulping process variables

Pulping type				
Sulfite				
Cook no.	A1	A2	A3	
Na_2SO_3 (%)	100	20	20	
NaOH (%)	100	30	40	
Soda				
Cook no.	B1	B2	B3	B4
NaOH (%)	20	30	40	50

3. Results and discussion

3.1. Morphological analysis

The mean length of the fronds fibers (Table 2) are given by three modes of calculations; arithmetic (AFL), weight weighted (WWFL) and length weighted (LWFL). Each value is obtained through the following

Table 2
Fiber characteristics of oil palm fronds

Fiber property	Oil palm fronds	Trembling aspen[a]
Mean fiber length (mm)		
Arithmetic	0.59	0.73
Length weighted	1.13	0.96
Weight weighted	1.54	1.07
Coarseness (mg/m)	0.098	data not available
Bauer–McNett fractions (%)		
R14	0.4	
R28	38.7	
R48	22.9	data not available
R100	16.4	
R200	6.8	
P200	14.8	
Fiber dimensions (μm)		
Fiber diameter (D)	19.6	20.8
Lumen width (L)	11.66	16.94
Cell wall thickness (T)	3.97	1.93
Rigidity index ($(T/D)^3 \times 10^4$)	83.16	7.99

[a] From Law and Jiang (2001).