UNIVERSITI PUTRA MALAYSIA

OPTIMIZATION OF KRAFT AND BIOKRAFT PULPING FOR KENAF V36

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OPTIMIZATION OF KRAFT AND BIOKRAFT PULPING FOR KENAF V36

By

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Chairman: Associate Professor Jalaluddin Harun, PhD
Institute: Institute of Tropical Forestry and Forest Products

To realise the full potential of kenaf derived products to the wood industry more research needs to be done. This study examines the suitability of kenaf V36 to the pulp and paper industry using various pulping processes for future paper manufacturing considerations. The effectiveness of fungal pre-treatments to improve the production of Kraft pulp and paper properties was investigated. The study comprised characterization of kenaf fibres, assessment of pulping conditions, morphological characterisation of selected fungi, pre-treatments and biokraft pulp and paper evaluations.

The characterization of kenaf V36 fractions covered the botanical aspects, anatomical structure, fibre morphology and chemical compositions. Anatomically, it was found that the bast fibre consisted of long fibre bundles (2.6 mm) and the core with short fibres (0.64 mm). Vessel elements including axial and ray parenchyma were observed

in the composition of the core structure. Bast was composed of 59.7% cellulose with a lower percentage of lignin (13.2%) compared to the core with 34.5% and 19.4%, respectively. The chemical composition showed that kenaf had higher cellulose and lower lignin contents compared to wood. Kraft pulping of kenaf stem using different cooking conditions showed that a combination with 17% of active alkali, 25% sulphidity, a wood to water ratio of 1:7 and a cooking temperature of 170□ C for 2 hours yielded 47.2% pulp and produced the optimum paper properties. Beating operation enhanced almost all paper properties of kenaf pulps except for tearing strength.

Fungal pre-treatments were carried out for a period of 1, 2, 3 or 4 weeks. The results obtained from SEM and TEM micrographs revealed that each fungus had a different morphology and a unique growth pattern. In degrading kenaf chips each fungus involves a different selection of chemical compounds. The results showed that *Coriolus versicolor* was a lignin degrader with 38% reduction; *Pycnoporus sanguineus* fed on holocellulose (22.03%) and cellulose (33.50%) as sources of food whilst *Phanerochaete chrysosporium* was a milder decomposer on lignin and cellulose throughout the duration of treatments. Treatments with a mix of two fungi indicated a drastic loss of all chemical contents especially on cellulose and lignin contents.

Pre-treatments for biokraft pulping required a two-week incubation period. Biokraft pulping treated with single fungus, with different inoculum sizes and nutrient adjuvants were done to investigate the optimal properties of the pulp and paper produced. Pre-treatments yielded a higher percentage of pulp and lower reject values

than untreated pulp. The inoculum of 6 x 10^6 mL/spores and 6:300 v/v nutrients adjuvant is the best condition that improved all pulp and paper properties. Bio-kraft pulping treated with PS produced the highest yield of pulp at 52.6%. Treated pulps tend to have greater conformability and compressibility which resulted in better fibre-to-fibre bonding of paper. Thus, higher quality hand-sheets were produced relative to their untreated counterparts. Among the hand-sheets produced, the *C. versicolor* treated yielded superior paper properties compared to *P. chrysosporium* and *P. sanguineus* except on folding endurance. Biokraft pulping using a mix of two fungi pre-treatments showed better brightness with lower kappa number as compared to single fungal treatments. The treated handsheets showed severe losses in pulp yields and lesser paper strength properties. The reduction in strength was as much as 94% - 96% when compared to the untreated pulps.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah doktor falsafah

PROSES MEMPULPA KRAFT DAN BIOKRAFT YANG OPTIMA BAGI KENAF V36

oleh

RASMINA HALIS

Disember 2010

Pengerusi: Profesor Madya Jalaluddin Harun, PhD
Institusi: Institut Perhutanan Tropika dan Tropika Produk

Untuk mengetahui potensi keseluruhan mengenai produk penghasilan kenaf kepada industri perkayuan maka lebih banyak kajian perlu dilakukan. Kajian ini adalah menyelidik kesesuaian kenaf V36 kepada industri pulpa dan kertas menggunakan pelbagai jenis proses mempulpa untuk perhatian pembuatan kertas di masa akan datang. Keberkesanan pra-rawatan kulat dalam membantu penghasilan sifat pulpa dan kertas kraft yang lebih baik telah diteliti. Kajian ini meliputi pencirian terhadap sifat-sifat kenaf, penghasilan mempulpa kraft yang optimum, morfologi kulat, pra rawatan kulat dan mempulpa secara biokraft.

Pencirian bagi kenaf V36 meliputi aspek botani, anatomi, moforlogi gentian dan kandungan kimianya. Didapati sifat anatomi bagi gentian bastnya (luar) tersusun dalam kelompok-kelompok gentian dan mempunyai purata gentian sepanjang (2.6 mm) dan bahagian terasnya (dalam) bersifat seperti struktur kayu keras yang mempunyai gentian yang lebih pendek (0.64 mm) dan berliang salur, parenkima

menegak dan parenkima ruji pada strukturnya. Bast mempunyai 59.7% kandungan selulosa dan lignin yang rendah 13.2% berbanding dengan teras dengan 34.5% dan 19.4%. Kandungan selulosa dan lignin menunjukkan bahawa kenaf lebih baik daripada kayu. Mempulpa secara kraft dijalankan dengan memasak pada pembolehubah yang berbeza-beza dan sifat pulpanya ditentukan. Kenaf menunjukkan bahawa mempulpa pada 17% alkali aktif dan 25% sulfiditi dengan nisbah kandungan air dan kayu 1:7 dan dimasak pada suhu 170□ C selama 2 jam menghasilkan pulpa sebanyak 47.2% dan memberi sifat kertas yang paling baik. Proses pemukulan (beating) telah menambahbaik sifat kertas dari pulpa kenaf V36 kecuali pada kekuatan koyak pada kertas.

Pra rawatan kulat dijalankan pada minggu 1, 2, 3 dan 4. Keputusan yang diperolehi daripada mikrograf SEM dan TEM menunjukkan bahawa ketiga-tiga kulat mempunyai moforlogi dan corak pertumbuhan berbeza pada cip kenaf. Setiap kulat juga memilih untuk mengdegradasikan kandungan kimia dalam cip kenaf yang berbeza-beza. Keputusan menunjukkan bahawa *Coriolus versicolor* adalah penyahlignin dengan 38% pengurangan, *Pycnoporous sanguineus* pula memilih untuk mendegradsikan holoselulosa (22.03%) dan selulosa (33.50%) sebagai sumber makanannya. Sebaliknya *Phanerocheate chrysosporium* adalah bersifat sederhana dalam mengkomposkan lignin dan selulosa dalam tempoh rawatan. Pra rawatan menggunakan campuran dua kulat menunjukkan kehilangan yang keterlaluan pada kandungan kimia terutama pada kandungan selulosa dan lignin.

Pra rawatan untuk biokraft telah dijalankan untuk pengeraman selama 2 minggu. Mempulpa secara biokraft dengan satu spesis kulat pada saiz inokulum dan

pertambahan nutrisi yang berbeza telah dilakukan bagi mendapatkan keputusan yang optima pada sifat pulpa dan kertas. Pulpa terawat mengasilkan peratus pulpa yang tinggi dan rendah sisa terbuang daripada pulpa tanpa rawatan. Saiz inokulum 6 x 10^6 mL/spora dan 6:300 i/i nutrisi tambahan adalah kondisi terbaik dan telah menambahbaik kesemua sifat-sifat pulpa dan kertas. Mempulpa biokraft dengan *P. sanguinues* menghasilkan pulpa yang paling tinggi iaitu 52.6%. Pulpa terawat memberi pembentukan dan kemampatan kepada kertas yang menghasilkan prerekatan gentian kepada gentian yang baik kepada kertas. Di antara kertas yang dihasilkan, kertas terawat dengan *C. versicolor* menghasilkan sifat kertas yang terbaik berbanding *P. sanguinues* and *P. chrysosporium* kecuali sifat penglipatannya. Mempulpa biokraft dengan campuran dua kulat menghasilkan kertas yang lebih cerah dengan nilai nombor kappa yang rendah berbanding rawatan dengan satu spesis kulat. Kertas terawat yang dihasilkan menunjukkan penurunan sifat-sifat penghasilan pulpa dan kekuatan kertas yang tinggi dengan nilai penurunan 94 - 96% apabila dibandingkan dengan kertas tanpa rawatan.

DEDICATION

In the Name of Allah, the Most Beneficent, the Most Merciful

This thesis is written with love and gratitude to **ALLAH**,

My **lord**, My **Master** and **My Protector**,

Who has always loved me taken care of me,

Glory to the **Lord, Praise** the **Lord**, **ALLAH** is **Great**.

In the name of **ALLAH, Most Gracious, Most Merciful**

The Holy Quran: Surah 26:

Who created me, and

It is He who guides me;

Who gives me food and drink,

And when I'm ill,

It is He who cures me;

Who will cause me to die,

And then to live (again);

And who, I hope,

Will forgive me my faults;

On the Day of Judgement

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I certify that an Examination Committee met on **29 December 2010** to conduct the final examination of **Rasmina Halis** on her Doctor of Philosophy thesis entitled "**Optimization of Kraft and Biokraft Pulping for Kenaf V36**" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded Doctor of Philosophy.

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This thesis was submitted to Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledge. I also declare that it has not been previously, and not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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RASMINA BINTI HALIS

Date: 29 December 2011

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