UNIVERSITI PUTRA MALAYSIA

PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLEBOARD MANUFACTURED FROM KENAF (Hibiscus cannabinus L.) AND RUBBERWOOD (Hevea brasiliensis Mull)

JULIANA BINTI ABDUL HALIP

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By

JULIANA BINTI ABDUL HALIP

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

May 2013

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DEDICATION

Specially dedicated to all people that always understand and support me…
And to my beloved supervisor,
Professor Dr. Paridah Md. Tahir

Thank you….

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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May 2013

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Institute : Institute of Tropical Forestry and Forest Products

This study evaluates the technical feasibility of producing particleboard from kenaf (*Hibiscus cannabinus* L.) stem. The work comprises evaluation of basic properties of kenaf namely moisture content, specific gravity, and adhesion characteristics through contact angle of wettability study and buffering capacity determination. The evaluation of basic properties, namely moisture content and specific gravity, was done on three sections of stem height (bottom, middle, and top) and also two parts (core and whole stem) of the kenaf stem. Findings show that stem height had no significant differences but the sections do have significant differences in terms of moisture content and specific gravity of kenaf stem, where the kenaf whole stem produced a specific gravity of 22% higher than that of the core. Interestingly, the specific gravity of both kenaf whole stem and kenaf core was found to increase from the bottom to top parts of the stem height; which is opposite of that found in

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woody tree. This was contributed by the smaller vessel diameter at the top. Meanwhile, kenaf's inner core had high wettability in both acidic and alkaline condition, and low initial contact angle of 41.2˚ compared to kenaf's outer bast, with initial contact angle values of 65.6˚. In buffering capacity study, kenaf bast and kenaf core have the highest and lowest buffering capacity in acidic conditions, respectively. Buffering capacity measures the resistance of the wood to change in pH level. A wood with high buffering capacity make it more difficult to cure UF resin, thus requires additional amount of acid catalyst to reduce the pH level to the level required for optimum resin cure.

Three types of 100% homogeneous kenaf boards were fabricated from kenaf whole stem (KWS), kenaf core (KC), and kenaf bast (KB), and their mechanical and physical properties were evaluated. For comparison purposes, 100% homogenous rubberwood (RW) particleboard was fabricated and used as a control. Meanwhile, urea formaldehyde resin was used as the binder. Apart from control panel, panel made from 100% kenaf whole stem was found to exhibit the highest results either in MOR, MOE, IB, TS, and WA, with the values of 15.1 N/mm^2, 1559 N/mm^2, 0.51 N/mm^2, 28%, and 77%, respectively. Kenaf whole stem was observed to be the best form of kenaf raw material for particleboard manufacture. Kenaf core can also be used as a raw material in particleboard, but it requires the use of more resin due to high absorbent property. Conversely, kenaf bast is not suitable to be

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used alone due to the lack of adhesive penetration, resulting in low strength and dimensional stability.

After screening, the particle size distribution of KWS, KC, KB and RW were 74%, 62%, 68% and 59%, respectively. Based on the findings, 75% of kenaf core particles were of rectangular or nearly rectangular in shape, in which the study identified the kenaf core (ten classes), kenaf bast (seven classes), and rubberwood (seven classes) of particles geometries. Analysis of the aspect ratio showed that kenaf bast is much more slender as compared to the kenaf core and rubberwood. Particleboards made from combination of 30% KWS and 70% RW (70RW-30KWS) resulted in superior performance in terms of MOR (17 N/mm^2), MOE (1756 N/mm^2), IB (0.90 N/mm^2). The dimensional stability of such panels also increased about 28% and 77% in terms of TS and WA, respectively. In this study, the panels consisting of slender, rectangular or nearly rectangular shape of rubberwood particles were shown to increase the strength, stiffness, and stability properties. Under the SEM observation, the panel made from 70RW-30KWS gave a better compaction and the lowest void compared to others, suggesting the compatibility among the RW, KC, and KB particles.

Three-layer particleboards were manufactured to improve the elasticity properties of kenaf particleboard. Six types of three-layer particleboard consist of KWS or KC in the middle layer, and RW particles on the two-face

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layers. The MOE values of the three-layer (35RW-30KWS-35RW) panel was 56% and 79% higher than those of the panels comprising single-layers of 100% KWS and 100% KC, respectively. The findings show that the panels produced with 70% shelling ratio have higher MOE, MOR and IB, but lower TS and WA than those of the panels with 30% shelling ratio. After taking all into consideration, kenaf whole stem is the preferred material to be used in particleboard manufacture incorporated with rubberwood as admixture or three-layer panels. Kenaf core may be good for producing lightweight panel, while kenaf bast was found to be unsuitable for particleboard manufacture.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk memenuhi ijazah Doktor Falsafah

KAJIAN FIZIKAL DAN MEKANIKAL PAPAN SERPAI DARIPADA KENAF (*Hibiscus cannabinus* L.) DAN KAYU GETAH (*Hevea brasiliensis* Mull)

Oleh

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Kajian ini menilai kebolehgunaan batang kenaf (*Hibiscus cannabinus* L.) dalam pembuatan papan serpai. Kerja-kerja penilaian merangkumi ciri-ciri asas batang kenaf termasuk kandungan lembapan air, spesifik graviti, dan ciri perekatan menggunakan kajian pembasahan (sudut sentuhan) dan kapasiti penimbal. Penilaian kandungan lembapan air dan spesifik graviti adalah mengikut tiga ketinggian batang (bawah, tengah, dan atas), dan dua bahagian batang berbeza (teras dan keseluruhan batang). Keputusan menunjukkan bahawa tinggi batang kenaf tidak menunjukkan perbezaan ketara, tetapi bahagian (teras dan keseluruhan) batang memberikan perbezaan ketara terhadap kandungan lembapan air dan spesifik graviti, dimana keseluruhan batang memberikan 22% lebih tumpat berbanding teras kenaf. Menariknya, spesifik graviti keseluruhan batang kenaf dan teras kenaf

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meningkat dari (ketinggian) bahagian bawah ke atas, dimana ini adalah bertentangan dengan apa yang dijumpai dalam pokok berkayu. Ini disebabkan saiz vesel yang lebih kecil pada bahagian atas. Bahagian dalam teras kenaf memberikan nilai pembasahan yang tinggi dan sudut sentuhan yang rendah iaitu 41.2˚ berbanding bahagian luar kulit kenaf dengan nilai sudut sentuhan 65.6˚. untuk kajian kapasiti penimbal pula, kulit dan teras kenaf masing-masing menunjukkan kapasiti penimbal yang paling tingi dan paling rendah dalam keadaan berasid.

Tiga jenis 100% homogen papan serpai kemudiannya dihasilkan daripada keseluruhan batang, teras, dan kulit kenaf dan ditentukan kekuatan mekanikal dan fizikalnya. Papan serpai 100% homogen kayu getah juga dihasilkan sebagai perbandingan menggunakan urea-formaldehid sebagai pengikat. Selain daripada papan kawalan, papan serpai yang diperbuat daripada 100% batang kenaf memberikan kekutan yang paling tinggi dalam ujian MOR, MOE, IB, TS, dan WA dengan nilai masing-masing adalah 15.1 N/mm^2, 1559 N/mm^2,0.51 N/mm^2, 28%, dan 77%. Keseluruhan batang kenaf dilihat sebagai bentuk bahan mentah yang paling sesuai untuk digunakan dalam pembuatan papan serpai. Teras kenaf juga boleh digunakan sebagai bahan mentah dalam pembuatan papan serpai, tetapi ia memerlukan lebih banyak resin disebabkan ciri penyerapan yang tinggi pada teras kenaf. Namun begitu, kulit kenaf adalah tidak sesuai untuk

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digunakan kerana kekurangan kadar penembusan perekat yang menyebabkan kekuatan dan kestabilan yang rendah.

Selepas penyaringan, kebolehgunaan serpai untuk KWS, KC, KB, dan RW masing-masing adalah 74%, 62%, 68% dan 59%. Daripada hasil kajian, 75% daripada teras kenaf menunjukkan bentuk segiempat atau menghampiri segiempat dimana kajian geometri serpai mengklasifikasikan terdapat teras kenaf (sepuluh kelas), kulit kenaf (tujuh kelas), dan kayu getah (tujuh kelas). Papan serpai yang diperbuat daripada nisbah 30% dan 70% untuk KWS dan RW (70RW-30KWS) mempersembahkan prestasi terbaik dari segi MOR (17 N/mm^2), MOE (1756 N/mm^2), dan IB (0.90 N/mm^2). Kestabilan papan tersebut juga meningkat dengan nisbah 28% dan 77% masing-masing dari segi pembengkakan ketebalan (TS) dan serapan air (WA). Dalam kajian ini, papan yang mengandungi bentuk serpai RW yang runcing, bersegiempat atau menghampiri segiempat memperlihatkan peningkatan dalam ciri kekuatan, sifat elastik, dan kestabilan. Di bawah SEM, papan yang diperbuat daripada 70RW-30KWS memberikan mampatan yang cantik dan nilai lubang yang paling rendah berbanding papan-papan yang lain dimana ini menunjukkan kesesuaian antara serpai-serpai RW, KC, dan KB.

Papan serpai tiga lapis juga dibuat untuk meningkatkan ciri elastik papan serpai kenaf. Enam jenis papan serpai tiga lapis yang mengandungi serpai batang kenaf atau serpai teras kenaf di bahagian tengah, dan serpai kayu

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getah dipermukaan. Nilai modulus elastik papan serpai tiga lapis (35RW-30KWS-35RW) masing-masing adalah 56% dan 79% lebih tinggi daripada papan satu lapis yang diperbuat daripada 100% KWS dan 100% KC. Kajian menunjukkan papan yang mempunyai 70% nisbah permukaan mempunyai nilai MOE, MOR dan IB paling tinggi, dan nilai TS dan WA yang rendah berbanding papan yang mempunyai nisbah permukaan sebanyak 30%. Selepas dinilai dari segala aspek, keseluruhan batang kenaf adalah pilihan yang paling sesuai untuk digunakan dalam pembuatan papan serpai dan digabungkan bersama kayu getah sebagai papan serpai campuran atau papan serpai tiga lapis. Teras kenaf mungkin sesuai digunakan untuk penghasilan papan berketumpatan rendah, manakala kulit kenaf adalah tidak sesuai digunakan dalam pembuatan papan serpai.

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I certify that a Thesis Examination Committee has met on 17th May 2013 to conduct the final examination of Juliana binti Abdul Halip on her thesis entitled "**Physical and Mechanical Properties of Particleboard Manufactured from Kenaf (*Hibiscus cannabinus* L.) and Rubberwood (*Hevea brasiliensis* Mull)**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Degree of Doctor of Philosophy.

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DECLARATION

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

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Date: 17 May 2013

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