UNIVERSITI PUTRA MALAYSIA

PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLEBOARD MADE FROM BLENDS OF KENAF (*Hibiscus cannabinus* L.) AND RUBBERWOOD (*Hevea brasiliensis* Müll.Arg.) PARTICLES

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By

NORANI ABD.KARIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science in Wood Science and Technology

March 2011

SPECIAL DEDICATION TO:

My Parents;

Abd. Karim Umar Baki & Hazizah Ator

My supervisor;

Assoc. Prof. Dr. Paridah Md Tahir

And,

All my family members and my friends, who always support me in everything.

Without them I cannot go through all the challenges to complete all this. May Allah bless all my efforts and hopefully this knowledge will be useful for those who need it. Amin

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science in Wood Science and Technology

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Chairman : Paridah Md. Tahir, PhD

Faculty : Forestry

Kenaf (*Hibiscus cannabinus* L.) variety V36 was used to make different types of particleboard. The purpose of this study was to evaluate the mechanical properties and dimensional stability of particleboards made from kenaf bast (KB), kenaf core (KC), rubberwood (RW) particles and a combination of the three. The basic properties of kenaf stem, namely, specific gravity (SG), moisture content (MC), pH and buffering capacity, wettability, and slenderness ratio (SL), were evaluated. Meanwhile, the mechanical properties, which include modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding strength (IB), dimensional stability (thickness swelling (TS) and water absorption (WA), as well as the density profile of the panels were determined according to JIS 5908:2003. Scanning electron micrographs (SEM) were

used to examine the failures occurring between fibres bonding. All the panels were made at a density of 700kg/m^3 using urea formaldehyde (UF) resin as the main binder, and low molecular weight phenol formaldehyde (LmwPF) resin as an additional resin to impart dimensional stability. For this purpose, two levels of resin content were used, namely, 10% UF and 12% UF + 2% LmwPF. A statistical analysis, through the analysis of variance (ANOVA) and Least Significant Different (LSD), was carried out to evaluate the effects of the resin treatment and the types of the particle on mechanical properties and dimensional stability properties.

This study was divided into three parts: (1) evaluation of the basic properties of kenaf stem, (2) evaluation of the effects of kenaf proportion on the physical and mechanical properties of particleboard, and (3) improvement of the performance of kenaf-based particleboard via treatment with a low molecular weight phenol formaldehyde (LmwPF) resin. On the first part of the study, the specific gravity for the kenaf core (0.28g/m^3) was lower as compared to the kenaf bast (1.66g/m^3) and rubberwood (0.57g/m^3). As for the moisture content (MC), the results showed that rubberwood possessed 18% as compared to kenaf bast (12.6%) and kenaf core (11%). The results obtained for their pH revealed that kenaf bast (6.3%) and kenaf core (6.4%) possessed almost similar characteristics, whereas rubberwood showed 5.9%. Thus, it can be concluded that rubberwood is more acidic as compared to kenaf bast and kenaf core. When the two types of fibre were mixed, however, the characteristics were revealed to be more acidic, i.e., kenaf core + rubberwood (5.2%) and kenaf bast + rubberwood (5.1%). In addition, it was found that the two types of fibre were more suitable as a binder which has acid setting characteristics, such as Urea Formaldehyde (UF). The results for the buffering capacity also showed that kenaf bast was the most resistant towards acid and alkali (19 minutes and 11 minutes, respectively) compared to kenaf core (14 minutes and 4 minutes) and rubberwood (10 minutes and 5 minutes). Meanwhile, when kenaf core and kenaf bast were mixed with rubberwood, the results obtained for the buffering capacity revealed that its curing rate was shortened when urea formaldehyde was used in the panel manufacturing and less hardener was also required. In more specific, higher wettability was found in the outer part of kenaf core compared to the other samples. The highest contact angle was found in the sample (1.04^0 for acid, 0.98^0 for alkali and 1.34^0 for distilled water). The finding also showed that kenaf bast had a longer slenderness ratio than kenaf core and rubberwood, with the values of 71.0, 3.5 and 6.8, respectively.

In term of mechanical properties, the results showed that all the kenaf board types fulfilled the JIS for the minimum requirements for MOE (2000 MPa), except for 70%kenaf bast:30%rubberwood, 30%kenaf bast:70%rubberwood and 100%kenaf core. As for MOR, all the panels fulfilled the standard (8 MPa). Nevertheless, all the boards comprising kenaf bast did not fulfil the minimum requirement for IB. Scanning electron micrographs SEM showed that kenaf bast did not bond well with rubberwood. From the dimensional stability tests, the study showed that the most unstable panel was that made from 100% kenaf core, and this was followed by 70%:30% kenaf core:rubberwood and 30%:70% kenaf core:rubberwood. Except for 100%kenaf bast and 30%:70% kenaf bast:rubberwood, the remaining boards have a similar stability throughout the 28 days of exposure in cold water. Only 30%kenaf core:70%rubberwood board was found to have shrunk after 1 h of soaking in water, whilst the rest experienced a significant swelling. Much severe thickness swelling and water absorption were observed as the soaking period reached 3 and 7 days, respectively. Using 10% UF, the particleboards made from blended 100%kenaf core and 100%rubberwood at 30%:70% kenaf core:rubberwood ratio were found to be the most stable, recording only 39% in thickness swelling and 150% in water absorption, after being soaked in cold water for 28 days. In terms of their mechanical properties, 70%kenaf core:30%rubberwood (MOE: 2096 MPa; MOR:16 MPa and IB: O.64 MPa) showed an excellent performance compared to other proportions.

Generally, the addition of LmwPF resin to the furnish did improve the TS and WA, but the strength of the board had slightly been reduced. All the panels produced in this study met the minimum requirements for MOR (8 MPa). On the other hand, increasing the level of resin content did not give significant effect on the IB values. For instance, boards having 100% kenaf core had the lowest IB which did not improve even though the resin level was increased.

The density profile for all the panels showed a U-shape trend which is similar to that of commercial particleboards. Meanwhile, panels containing the pre-treated LmwPF particles were apparently more stable. These boards experienced a mere 22% swelling and 98% water absorption after the same period of soaking. Re-treating the particles with LmwPF resin, prior to the normal blending, was found to have reduced the swelling between 48-64% (respectively for 70%kenaf core:30%rubberwood and 100% kenaf core boards). The percentage of water absorption also improved between 76-114%. The findings of the study proved that soaking the kenaf particles in LmwPF resin could improve the dimensional stability of kenaf boards, particularly for kenaf core. The usage of kenaf core up to 70% produced kenaf particleboards with a good quality.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains dan Teknologi Kayu

KAJIAN KE ATAS KEKUATAN FIZIKAL DAN MEKANIKAL PAPAN SERPAI YANG DIPERBUAT DARIPADA KOMBINASI KENAF (*Hibiscus cannabinus* L.) DAN KAYU GETAH (*Hevea Brasiliensis* Müll.Arg.)

By

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Mac 2011

Pengerusi : Paridah Md.Tahir, PhD

Fakulti : Perhutanan

Kenaf (*Hibiscus cannabinus* L.) dari jenis V36 telah digunakan sebagai bahan utama bagi penghasilan papan serpai dengan kandungan peratusan yang berbeza. Tujuan kajian ini dilakukan adalah bagi mengukur kekuatan mekanikal dan kestabilan dimensi papan serpai yang dihasilkan daripada 3 bahan utama iaitu partikel teras kenaf (KC), gentian kulit kenaf (KB) dan kayu getah (RW) serta kombinasi antara ketiga-tiganya. Eksperimen seperti ujian spesifik graviti kayu (SG), kandungan lembapan (MC), nilai pH dan kadar sensitiviti terhadap asid, alkali serta air, darjah penembusan cecair serta penentuan dimensi ketebalan dan panjang sesuatu partikel (SL) dilaksanakan bagi

penentu ukur kriteria yang ada pada batang kenaf. Sifat mekanikal seperti modulus kerapuhan (MOR), modulus kekenyalan (MOE), kekuatan dalaman (IB), kestabilan dimensi seperti pengembangan ketebalan (TS) dan serapan air (WA) serta profail ketumpatan sesuatu papan serpai diukur mengikut garis panduan yang termaktub dalam JIS 5908:2003. Penelitian melalui peralatan mikrograf elektron (SEM) digunakan bagi membuktikan tahap kegagalan yang berlaku pada kekuatan ikatan partikel bagi setiap kombinasi campuran bahan yang disediakan. Kesemua papan serpai yang dibuat mempunyai ketumpatan sebanyak 700kg/m^3. Perekat Urea formaldehid (UF) dan perekat berjisim molekul rendah (LmwPF) digunakan sebagai perekat tambahan bagi memberikan impak ke atas kestabilan dimensi. Dua tahap kandungan perekat telah digunakan iaitu 10%UF dan 12%UF serta 2% LmwPF digunakan bagi tujuan kajian ini. Data dianalisis dengan menggunakan perisian SAS di mana analisis varian (ANOVA) dan kesan-kesannya dianalisis dengan menggunakan perbezaan minimum yang ketara (LSD) bagi menentukan impak rawatan perekat dan jenis-jenis partikel ke atas sifat kekuatan mekanikal dan kestabilan dimensi.

Kajian ini mengandungi 3 bahagian di mana; (1) Menentukan kriteria dan sifat asas bagi batang kenaf; (2) Menentukan impak kombinasi campuran di antara kenaf dan kayu getah ke atas kekuatan fizikal dan mekanikal papan serpai; dan (3) Penambahbaikan ke atas prestasi papan serpai berasaskan kenaf melalui kaedah rawatan ke atas partikel teras kenaf (KC) sahaja dengan menggunakan perekat LmwPF.

Pada peringkat pertama kajian ini, kadar ketumpatan (SG) teras kenaf ialah 0.28g/m^3 adalah lebih rendah berbanding dengan ketumpatan kulit kenaf iaitu 1.66g/m^3 dan kayu getah pula merekodkan 0.57g/m^3. Manakala kandungan lembapan (MC) pula merekodkan kayu getah menunjukkan lebih tinggi keputusannya iaitu 18% berbanding gentian kulit kenaf (12.6%) dan teras kenaf (11%). Nilai pH bagi teras kenaf dan kulit kenaf menunjukkan nilai yang hanpir sama iaitu 6.4 dan 6.3. Nilai ini menunjukkan bahawa kenaf hampir sensitif kepada bahan alkali, berbanding kayu getah merekodkan nilai pH 5.9. Walau bagaimanapun, apabila kedua-dua gentian ini dicampurkan, sifatnya lebih menunjukkan asidik. (Contohnya: teras kenaf + kayu getah (5.2), manakala gentian kulit kenaf + kayu getah (5.1). Kesimpulan yang boleh dibuat hasil dari penemuan ini adalah kedua-dua gentian yang dicampurkan amat sesuai menggunakan perekat seperti Urea formaldehid (UF) sebagai pengikat gentian kerana UF lebih sesuai dengan bahan yang lebih bersifat asidik.

Kadar sensitivity terhadap asid, alkali dan air pula telah menunjukkan bahawa gentian kulit kenaf lebih tahan terhadap asid dan alkali, di mana kadar sensitiviti terhadap asid dan alkali telah mengambil masa 19 minit dan 11 minit, berbanding dengan teras kenaf yang mana kadar sensitivitinya lebih singkat iaitu 14 minit dan 4 minit sahaja. Manakala kayu getah mengambil masa selama 10 minit dan 5 minit. Apabila teras kenaf, gentian kulit kenaf dicampurkan dengan kayu getah, keputusan telah menunjukkan bahawa kadar pengeringan sesuatu perekat lebih singkat jika Urea formaldehid (UF) digunakan di dalam pembuatan papan panel serta kadar bahan pengeras juga dapat dikurangkan.

Kadar ketelapan yang tinggi dicatatkan oleh bahagian atas permukaan teras kenaf berbanding dengan sampel-sampel yang lain iaitu 1.04^0 bagi asid, 0.98^0 bagi alkali dan 1.34^0 bagi air suling. Hasil penemuan ini juga menunjukkan bahawa saiz fiber bagi gentan kulit kenaf adalah yang paling panjang berbanding dengan saiz gentian bagi teras kenaf dan kayu getah. Nilai yang dicatatkan ialah 71.0 bagi gentian kulit kenaf, 3.5 bagi partikel teras kenaf dan 6.8 bagi kayu getah.

Hasil dapatan daripada kajian telah menunjukkan, hampir kesemua papan serpai kenaf telah memenuhi keperluan garis panduan di dalam JIS bagi modulus kekenyalan (MOE) kecuali bagi kombinasi campuran 70%:30% kenaf bast: rubberwood ; 30%:70% kenaf bast:rubberwood dan 100%kenaf core. Modulus kerapuhan (MOR) pula menunjukkan bahawa kesemua papan panel berkenaan memenuhi tahap minima standard yang ditetapkan (8 MPa). Apa yang disimpulkan daripada penemuan di atas, kewujudan kulit kenaf di dalam kombinasi campuran telah melemahkan kekuatan dalaman (IB) sesuatu papan serpai. Keputusan dari hasil penelitian SEM juga membuktikan bahawa tidak berlaku percampuran di antara kulit kenaf dan partikel kayu getah. Dapatan daripada ujian kestabilan dimensi pula, memunjukkan bahawa papan serpai daripada 100% teras kenaf; 70%:30% teras kenaf : kayu getah dan 30%:70% teras kenaf : kayu getah yang paling kurang stabil kerana sifat teras kenaf (KC) itu sendiri yang mempunyai kadar penyerapan yang tinggi telah menyumbang kepada keputusan tersebut. Kesemua papan serpai mengalami kadar pengembangan ketebalan yang sama selepas proses rendaman selama 28 hari kecuali pada 100% gentian kulit kenaf dan 30%:70% gentian kulit kenaf :kayu getah. Papan serpai yang mempunyai kombinasi 30%:70% teras kenaf: kayu getah (KCR1) sahaja yang menunjukkan pengecutan berlaku selepas 1 jam rendaman manakala papan panel yang lain mengalami proses pengembangan ketebalan (TS). Kadar pengembangan ketebalan dapat dilihat dengan jelas setelah proses rendaman selepas 3 hari dan 1 minggu proses rendaman berlaku. Penggunaan 10%UF pada kombinasi campuran 30%:70% teras kenaf : kayu getah dilihat paling stabil dengan hanya merekodkan kadar pengembangan ketebalan (TS) sebanyak 39% dan 150% bagi kadar serapan air (WA) selepas melalui proses rendaman selama 28 hari. Secara keseluruhannya, papan serpai yang diperbuat daripada 70%teras kenaf:30% kayu getah dilihat mempunyai prestasi paling cemerlang dari segi sifat kekuatan mekanikal (MOE:2096 MPa; MOR:16 MPa dan IB: O.64 MPa). Walau bagaimanapun, dari segi kestabilan dimensi, kombinasi 30%:70% teras kenaf : kayu getah merupakan yang paling efisyen berbanding kombinasi yang lain.

Kebiasaannya, penambahan jenis resin seperti LmwPF kepada campuran bahan telah meningkatkan kestabilan dimensi tetapi mengurangkan sifat kekuatan mekanikalnya. Kesemua papan serpai yang dihasilkan di dalam penyelidikan ini telah mencapai had minimum bagi modulus kerapuhan (MOR). Penambahan kadar resin tidak mempengaruhi kekuatan dalaman (IB) walaupun kadar resin yang digunakan bertambah.

Profail ketumpatan papan serpai yang telah dibuat penelitian telah menunjukkan bentuk `U` sama seperti profail pada papan serpai yang telah komersil di pasaran. Papan serpai yang dirawat dengan LmwPF dilihat yang paling stabil bagi sifat kestabilan dimensi.

Panel tersebut hanya mengalami proses pengembangan ketebalan sebanyak 22% dan 98% kadar serapan air selepas menjalani proses rendaman yang sama. Kaedah rawatan dengan perekat LmwPF ke atas teras kenaf (KC) telah berjaya mengurangkan kadar pengembangan di antara 48 – 64% bagi panel 70%:30% teras kenaf : kayu getah dan 100% teras kenaf. Kadar serapan air juga berjaya dikurangkan sehingga 76 – 114%.

Hasil kajian telah membuktikan penggunaan perekat LmwPF yang dirawat ke atas teras kenaf telah berjaya meningkatkan prestasi di dalam kestabilan dimensi terutamanya teras kenaf (KC). Penggunaan teras kenaf (KC) sehingga 70% juga berjaya menghasilkan papan panel partikel yang berkualiti.

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I certify that Examination Committee has met on **16 March 2011** to conduct the final examination of **Norani Abd.Karim** on her Master of Science thesis entitled "**Physical and Mechanical Properties of Particleboard Made From Blends of Kenaf (*Hibiscus cannabinus* L.) and Rubberwood (*Hevea Brasiliensis*) Particles"** 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 candidate be awarded the Degree of Master of Science in Wood Science and Technology.

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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 it is has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

____

NORANI ABD KARIM

Date: 16 March 2011

I certify that Examination Committee has met on **16 March 2011** to conduct the final examination of **Norani Abd.Karim** on her Master of Science thesis entitled "**Physical and Mechanical Properties of Particleboard Made From Blends of Kenaf (*Hibiscus cannabinus* L.) And Rubberwood (*Hevea Brasiliensis* MOLL.ARG.) Particles"** 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 candidate be awarded the Degree of Master of Science in Wood Science and Technology.

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