SUITABILITY OF *Yushania alpina* FOR ORIENTED PARTICLEBOARD

By

SEYOUM KELEMWORK HAILE

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

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DEDICATION

Dedicated to my mother the late Yesharege Zerfu, my brother the late Ashagrea Deme and my elder sisters Teseme and Negat

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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Chairman: Associate Professor Paridah Md Tahir, PhD

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Highland bamboo *(Yushania alpina*) and lowland bamboo (*Oxytenanthera abyssinica)* are widespread in Ethiopian. Both covering approximately 1 million hectare of land. No commercial importance has been found for these lignocellulose materials. It is thus the main objective of this study is to determine the suitability of *Yushania alpina* for the manufacture of oriented particleboard.

Yushania alpina from three major bamboo growing areas, namely Ambo, Bore and Masha of three age groups of bamboo (one, two and three year-old) were used for this study. The effects of bamboo growing sites and age variation on mensurational attributes (i.e., culm basal diameter, culm wall thickness, culm volume and weight) and on basic properties (i.e., moisture content, density, anatomical characteristics, buffering capacity and wettability of bamboo) were statistically analyzed using completely randomized design. The analysis indicated that mensurational attributes and basic properties of vary with respect to growing sites, ages and culm height.

Homogenous, three-layered oriented from fine particle sizes, three-layer oriented from coarse particle sizes and three-layered oriented conventional (a mixture of fine and coarse particles) bamboo particleboards were manufactured using 10% urea-formaldehyde resin to evaluate the effects of particleboard processing parameters such as board density, particle size, particle orientation and particle layering on mechanical properties and dimensional stability. The completely randomized design with factorial experiments was used in the analysis.

The results show that the mechanical properties and dimensional stability of homogenous boards made from three-year old bamboo varied among the growing sites. Age of bamboo did not show significant effects on strength and stiffness properties of homogenous bamboo particleboards. It was also found that the internal bond strength of bamboo particleboards decreased as the bamboo gets older whilst thickness swelling increased.

The modulus of rupture (MOR) and modulus of elasticity (MOE) of three-layered oriented bamboo particleboards produced from fine particle sizes and three-layered oriented bamboo particleboards produced from coarse particles were significantly affected by particle alignment and sizes. Both types of particleboards made from fine and coarse particle sizes and parallelly aligned to the longitudinal axis of the boards had superior strength (about 15%) compared to random oriented boards. Similar comparisons of the MOE between oriented and random boards showed that MOE of parallelly aligned boards to the longitudinal axis of the boards was higher by 28% and

37%, respectively for both fine and coarse particle size oriented boards than those of random boards. The internal bond strength, thickness swelling and water absorption of oriented bamboo particleboards showed insignificant variation with particle alignment. However, boards made from fine particle sizes gave 35% higher IB strength and 12% dimensionally stable oriented boards than those made from coarse particle. The screw withdrawal resistances of oriented bamboo particleboards were affected by particle alignment and particle size. Boards made from coarse particles that were randomly oriented particles had superior screw withdrawal resistance than that made from fine particles.

The properties of three-layered conventional oriented bamboo particleboards were affected by the density profile of the boards. As fine particles at face layer was increased from 20% to 30% (based on the weight of the board) the MOR and MOE of the boards increased from 27 MPa to 41 MPa and 4.9 GPa to 6.1 GPa, respectively. The thickness swelling (TS) decreased from 7.5 to 5.8 % and the internal bond (IB) strength increased from 0.60 MPa to 0.69 MPa. The presence of high amount of fine particle at the face layers and high internal bond strength increased significantly screw withdrawal resistance.

In general, vertical density profile has significant impact on strength and stiffness properties of three-layered boards. Three-layered boards that have steeper density gradient (higher average face layer density and low core density) have high strength and stiffness properties than three-layered boards which have relatively more uniform density

profile. Regression equations of three-layered boards relating the proportion of fine particles on the face layer to coarse particles in the core layer may be used to predict the MOR, MOE, IB strength and TS of three-layered particleboards produced in this study. Generally, the strength and dimensional stability of particleboards manufactured from *Yushania alpina* bamboo met the ISO standards ISO/DIS 16978, ISO/DIS 16984 and ISO/DIS 16983 for high performance general purpose particleboards.

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

KESESESUAIAN PAPAN SERPAI BERORIENTASI DARI SEPSIS BULUH *Yushania alpina*

Oleh

SEYOUM KELEMWORK HAILE

Februari 2005

Pengerusi: Profesor Madya Paridah Md Tahir, PhD

Fakulti: Perhutanan

Buluh tanah tinggi (*Yushania alpina*) dan buluh tanah rendah (*Oxytenanthera*) tersebar luas di Ethiopia. Kedua-dua spesis ini merangkumi kawasan vegetasi yang luas yang mana lebih dari 1 juta hektar. Walau bagaimanapun, tidak ada kepentingan komersil didapati pada bahan lignoselulosa ini. Oleh itu, objektif kajian ini adalah untuk menentukan kesesuaian buluh ini untuk pembuatan papan serpai berorientasi.

Batang *Yushania alpina* daripada tiga kawasan utama pertumbuhan buluh seperti Ambo, Bore dan Masha dan batang daripada tiga kumpulan umur (1, 2 dan 3 tahun) digunakan dalam kajian ini. Kesan daripada kawasan pertumbuhan buluh dan perbezaan umur terhadap sifat pengukuran (contohnya, diameter pangkal batang, ketebalan dinding batang, isipadu batang dan berat) dan sifat asas (contohnya, kandungan lembapan (MC), ketumpatan, sifat-sifat anatomi, kapasiti penahan dan kebasahan buluh) dianalisis menggunakan rekabentuk rawak lengkap. Analisis menunjukkan bahawa sifat pengukuran dan sifat asas *Y. Alpina* berbeza pada kawasan pertumbuhan, umur dan ketinggian batang.

Papan serpai buluh sama jenis, tiga lapis berorientasi daripada patikel bersaiz halus, tiga lapis berorientasi daripada partikel bersaiz kasar dan tiga lapis berorientasi biasa (campuran partikel bersaiz halus dan kasar) dibuat untuk menilai kesan parameter pembuatan papan serpai seperti ketumpatan panel, saiz partikel, orientasi partikel dan lapisan partikel terhadap sifat mekanikal dan kestabilan dimensi. Rekabentuk rawak lengkap dengan eksperimen faktorial digunakan dalam analisis ini.

Keputusan menunjukkan bahawa sifat mekanikal dan kestabilan dimensi panel sama jenis diperbuat daripada buluh berumur tiga tahun berbeza dengan kawasan pertumbuhan. Umur buluh tidak mempunyai perbezaan bererti pada sifat kekuatan dan kekakuan papan serpai buluh sama jenis diperbuat daripada kumpulan umur yang berbeza. Kekuatan dalaman (IB) papan serpai buluh juga didapati menurun apabila buluh semakin tua manakala pengembangan ketebalan (TS) meningkat.

Modulus Kehancuran (MOR) dan Modulus Kekenyalan (MOE) papan serpai buluh tiga lapis berorientasi daripada partikel bersaiz halus dan papan serpai buluh tiga lapis berorientasi mempunyai perbezaan bererti pada susunan dan saiz partikel. Papan serpai buluh tiga lapis berorientasi diperbuat daripada partikel bersaiz kasar dan halus serta disusun selari dengan pada paksi membujur panel mempunyai nilai kekuatan lebih kurang 15% berbanding dengan panel yang mempunyai partikel yang disusun secara rawak. Perbezaan yang sama didapati pada modulus kekenyalan (MOE) antara panel berorientasi dan rawak menunjukkan bahawa kekakuan panel yang disusun selari pada

paksi membujur panel masing-masing meningkat lebih kurang 28% dan 37% untuk partikel bersaiz halus dan kasar panel berorientasi berbanding panel rawak. Kekuatan dalaman (IB), pengembangan ketebalan (TS) dan penyerapan air (WA) papan serpai buluh berorientasi menunjukkan tidak ada perbezaan bererti dengan susunan partikel. Namun, panel yang dibuat daripada saiz partikel halus memberikan kekuatan dalaman (IB) 35% lebih tinggi dan 12% lebih tinggi untuk kestabilan dimensi panel orientasi daripada partikel bersaiz kasar. Panel yang diperbuat daripada partikel kasar yang mana disusun secara rawak mempunyai ketahanan pengeluaran skru yang lebih tinggi berbanding partikel halus.

Sifat papan serpai buluh tiga lapis berorientasi biasa adalah dipengaruhi oleh profil ketumpatan panel. Apabila partikel halus pada permukaan lapisan meningkat daripada 20% kepada 60% (berdasarkan pada berat panel), modulus kehancuran (MOR) dan modulus kekenyalan (MOE) panel masing-masing meningkat daripada 27 MPa kepada 41 MPa dan 4864 MPa kepada 6114 MPa. Pengembangan ketebalan (TS) menurun daripada 7.5 kepada 5.8% dan kekuatan dalaman (IB) meningkat daripada 0.600 MPa kepada 0.685 MPa. Kehadiran lebih banyak partikel halus pada lapisan permukaan dan kekuatan dalaman (IB) yang tinggi juga mempunyai kesan yang bererti pada ketahanan pengeluaran skru.

Secara amnya, profil ketumpatan tegak mempunyai perbezaan bererti pada sifat kekuatan dan kekakuan panel tiga lapis. Panel tiga lapis mempunyai kecerunan ketumpatan yang tinggi (purata ketumpatan permukaan lapisan tinggi dan ketumpatan tengah rendah)

mempunyai sifat kekuatan dan kekakuan yang tinggi berbanding panel tiga lapis yang mana mempunyai profil ketumpatan yang seragam. Persamaan regresi panel tiga lapis mungkin digunakan untuk meramal modulus kehancuran (MOR), modulus kekenyalan (MOE), kekuatan dalaman (IB) dan pengembangan ketebalan (TS) papan serpai tiga lapis mengandungi partikel halus dalam lapisan permukaan daripada 20% kepada 40%.

Amnya, kekuatan dan kestabilan dimensi papan serpai diperbuat daripada buluh *Yushania alpina* mencapai piawaian ISO/DIS 16978, ISO/DIS 16984 dan ISO/DIS 16983 untuk pelaksanaan papan serpai untuk tujuan am.

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I certify that an Examination Committee met on February 18 2005 to conduct the final examination of Seyoum Kelemwork Haile on his Doctor of Philosophy thesis entitled "Suitability of Ethiopian highland Bamboo for Oriented particleboard '' in accordance with Universiti Pertanian Malysia (Higher Degree) Act 1980 and Universiti Pertanian Malysia (Higher Degree) regulation 1981. The committee recommended the candidate to be awarded the relevant degree. Members of the examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at UPM or other institutions.

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SEYOUM KELEMWORK HAILE

Date:

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