PROPERTIES OF PARTICLEBOARD MANUFACTURED FROM CULTIVATED OR PLANTED *Acacia mangium*

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THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN SCIENCE

SCHOOL OF INTERNATIONAL TROPICAL FORESTRY
UNIVERSITI MALAYSIA SABAH
2007

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL : **PENGHASILAN PAPAN SERPAI DARIPADA *Acacia mangium* YANG TERPELIHARA ATAU DITANAM**

IJAZAH : SARJANA SAINS

SESI PENGAJIAN : 2003-2007

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The materials in this thesis are original except for quotations, excerpts, summaries and references, which have been duly acknowledged.

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PS03-010-003
JULY 2007

ACKNOWLEDGEMENT

With the blessing of the Al mighty Lord.

I would like to express my great appreciation to my supervisors Prof. Dr. Aminuddin Mohamad and Mr. Awang Ahmad Mohd. Yunus for their guidance and valuable supervision.

I would like to express my gratitude to the Vice Chancellor, Universiti Malaysia Sabah, for his permission to continue my postgraduate study in Universiti Malaysia Sabah.

I would like to express my thanks to the Dean of School of International Tropical Forestry, University Malaysia Sabah, Dr. Mahmud Sudin for providing me support during my research work.

I would like to take this opportunity to thank Mr. Ir. K. K Lee of Jayakuik Sdn. Bhd. and rest of the management team to give me support me to do my master degree.

I would like to express my gratitude to Dr. Lee Ying Foh and Dr. Sining Unchi Forest Research Center Sandakan for their valuable advice and suggestions.

I would like to express my sincere thanks to my colleagues and others whom are not mentioned here for their support and cooperation through out this research work.

Special thank to my loving wife Sindhu and children Vineeth and Amal as without their sacrifice and support I will not have completed this study.

Finally, I dedicate this work to my father who was not with me now but his spirit and support given me all through my life. Thank you.

ABSTRAK

Sampel papan serpai daripada *Acacia mangium* dan kayu Tropika campuran sebelum dan selepas proses pempelasan telah diambil untuk mengkaji kesesuaian *A. mangium* sebagai bahan mentah dalam menghasilkan papan serpai mengikut skala perindustrian. Ciri-ciri fizikal dan mekanikal *A. mangium* dan kayu Tropika campuran sebelum dan selepas proses pempelasan telah di jalankan untuk memastikan papan serpai yang akan dihasilkan adalah memenuhi piawaian jenis 18 JIS 5908-1994. Pembuatan papan serpai telah diuji berdasarkan kepada piawaian ISO 9001-2000. Papan serpai setebal 18mm telah dihasilkan dan ujian fikizal dan mekanikal dikendalikan berdasarkan kepada standard BS dan JIS. Ujian dijalankan melalui 2 cara iaitu sebelum dan selepas proses pempelasan dengan menggunakan *A. mangium* dan kayu Tropika campuran dengan sukatan gam dan tekanan parameter yang sama. *A. mangium* mempunyai kepadatan rendah 690 kg/m^3 bagi papan yang belum diketam dan 679 kg/m^3 bagi papan yang telah diketam. Selain itu *A. mangium* juga mempunyai kekuatan pembengkokan yang tinggi iaitu 30.46 N/mm^2 untuk sebelum pempelasan dan 30.22 N/mm^2 selepas pempelasan. MOE 5479.47 N/mm^2 untuk papan sebelum pempelasan dan 5542.94 N/mm^2 untuk papan selepas pempelasan. Kekuatan skru ialah 106.63 N/mm^2 bagi papan sebelum pempelasan ialah 101.37 N/mm^2. Hasil keputusan yang diperolehi mencadangkan kepada industri bahawa kayu *A.mangium* lebih menunjukkan signifikasi berbanding dengan keputusan kayu tropika campuran dan ini memastikan bahawa kayu *A.mangium* boleh digunakan sebagai alternatif bahan mentah tunggal untuk menghasilkan papan serpai.

ABSTRACT

Properties of Particleboard Manufactured From Cultivated or Planted Acacia Mangium

Samples of unsanded and sanded particleboard made from A. mangium and mixed tropical hardwood were examined for the suitability of using A. mangium as a raw material to produce particleboard on industrial scale. The physical and mechanical properties of the unsanded and sanded A. mangium and mixed tropical hardwood studied to produce the board to fulfill the requirement as per type 18 JIS 5908-1994. The particleboard production was carried out as per ISO 9001 -2000 standard. The thickness of the board produced was 18mm and the physical and mechanical test carried out as per BS and JIS standard. The research carried out on two stages Unsanded and sanded and both A. mangium and mixed tropical hardwood was produced with the same glue and press parameters. A. mangium have the lower density 690 kg/m^3 for unsanded board and 679 kg/m^3 for sanded boards. Having a higher bending strength of 30.46 N/mm^2 for unsanded and 30.22 N/mm^2 for sanded boards, MOE 5479.47 N/mm^2 for unsanded and 5542.9447 N/mm^2 for sanded and Screw holding strength of 106.63 N/mm^2 for unsanded and 101.3747 N/mm^2 for sanded boards. The results obtained for A.mangium have significant different in comparison with mixed tropical hardwood result. Properties such as thickness swelling 2 hrs and 24 hrs, internal bond and surface bond had no significant difference between A. mangium and mixed wood unsanded and sanded particleboard. The results suggests to the industries that properties of particleboard manufactured from cultivated or planted A.mangium is comparable with mixed tropical hardwood and A.mangium can be used as an alternative raw material for producing particleboard.

ABBREVIATIONS

AFTSC	Asean Forest Tree Seed Centre
AM	Acacia Mangium
ANOVA	Analysis of Variance
BS	Bending Strength
BS	British Standard
CBP	Cement Bonded Particleboard
CFPP	Compensatory Forest Plantation Program
D	Density
IB	Internal Bond
IN	Inch
ISO	International Standard Organization
JIS	Japanese Industrial Standard
LVL	Laminated Veneer Lumber
Max	Maximum
MC	Moisture Content
Min	Minimum
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
MTC	Malaysian Timber Council
MTHW	Mixed Tropical Hardwood
RM	Ringgit Malaysia
SFM	Sustainable Forest Management
SH	Screw Holding
SW	Swelling

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CHAPTER 1

INTRODUCTION

1.1 Wood based Industry in Malaysia

The wood industries serve important roles in socio-economic of the world population. From these industries necessities such as toilet paper, boxes, tissue, construction materials and composite products can be obtained.

The wood based industry in Malaysia has developed tremendously since the early era of logging in our country. The downstream processing has gained much intention and grows rapidly with the modernizing of Southeast Asian economies. The furniture industry is the popular one amongst with Medium Density Fiberboard (MDF) and particleboard industry. Composite wood products have been strongly related with the wood-based sector in Malaysia and significantly been a global player. In 2002, Malaysia emerged as the world's second largest exporter of tropical sawn timber and 10^{th} largest exporter of furniture (primarily wood-based furniture) in the world (Jalaluddin, 2003).

1.1.1 Panel Production and Consumption

Over the last three decades, wood-based panels, veneer and plywood in particular have been the most dynamic wood-based products in the consumption, production and trade in the Asia-Pacific region. The consumption of wood-based panels in the

Asia-Pacific region soared to 24% of the world consumption dominated by plywood, particleboard and fiberboard (Jalaluddin, 2003).

Malaysia, plywood is still and continues to be the important reconstituted wood panel product followed by particleboard and MDF. The production of other wood composite products such as Laminated Veneer Lumber (LVL) is currently small and marginal to the industry. The product particularly significant in developed countries like Europe where LVL have many structural application and used in large quantities (Jalaluddin, 2003).

1.1.2 Particleboard

Composite product is defined as engineered wood product, which is produced through various processes to produce wood based product such as particleboard, fiberboard, oriented strand board, block board, wafer board etc. One of the most distinguish product is particleboard. It's also known as a substitute to solid wood product.

Particleboard can be defined as panel manufactured from lignocellulosic material (usually wood), primarily in the form of discrete pieces or particles, as distinguished from fibers, combine with a synthetic resin or other suitable binder and bonded together under heat and pressure in a hot press by a process in which the entire interparticle bond is created by the added binder, and to which other material may have been added during manufacture to improve certain properties. Particleboards are further defined by the method of pressing (Maloney, 1977). The British Standard describes particleboard as a panel manufactured under pressure, essentially composed of wood particles and/or other lignocellulosic materials with or without the addition of an adhesive (Anon, 1979).

As the wood based industry become more developed, it is essential to find alternative raw material due to diminishing of supply from natural forest. One option is by planting fast growing species such *A. mangium*, *Pinus radiata*, rattan, *Tectona grandis*, *Azadirachta excelsa*, etc.

The particleboard industry in Malaysia has started in 1974, with the first plant located in Kuantan, Pahang. It was then developed to another plant established at Muar, Johor in 1981 and expanded with two plants in Pahang, which is in 1983 and 1984. At present there are about 11 particleboard plants in the country with 16 production lines. The total capacity updated is about 2,065,000m^3 annually. Sabah ought to be proud with its own two outstanding particleboard plants, which are Jayakuik Sdn. Bhd. and Samling Sdn. Bhd. The plants have the capacity of 60,000 m^3 and 36,000 m^3 respectively (Anon, 2006).

1.1.3 Demand for Particleboard

In Asia Plywood panels were traditionally used, how ever the consumption of particleboard has grown rapidly in the last decade. The demand for particleboard is soaring especially from the furniture industry, as it can be a substitute for the solid wood utilization. This is due to an easily produced value-added product from particleboard such as laminated board Global wood panel consumption has continued to expand in the past decade and exceeded 170 million m3 in 2002 with particle board demand upward trend with average global annual growth of 4%. (Vroege, 2003).

1.1.4 Demand for Raw Material

Over 90% of the total dry weight of particle board is usually wood. Timber suitable for particleboard manufacture can be divided into five basic groups which are forest/plantation residues, coarse industrial green residues such as slabs, fine industrial green residues such as sawdust, wood chips from machining dry wood, and dry residues such as slabs from furniture manufacture (Kollmann *et al.* 1975)

The ever-increasing demand for particleboard in the markets has increased the demand for raw materials. Since 90% of the board contains wood, it is estimated that between 24 to 33% of total costs are for wood. Generally, raw material costs increase as a percentage of total costs with mill size; with increasing capacity; fixed costs become less significant and efficiency increases (Jayakuik, 1998).

For a plant with capacity of 60,000 m^3 it is estimated that 84,000 tones metric of raw material is needed per year. So for every year the company needs sufficient supply to achieve its targeted production. Nowadays more companies are turning to plantation forest to get their materials instead of depending to other downstream processing residues (Jayakuik, 1998). Through continuous studies has proven that suitable plantation species has become more popular because of its flexibility in the industry. It is possible that the demand for raw material from plantation forest will increase in a few years to come.

1.2 Objectives

In this study the objectives are as follows:

1. To study the physical and mechanical properties of unsanded and sanded particleboard using *A. mangium* as a raw material produced in industrial scale.
2. To compare the physical properties of unsanded and sanded *A. mangium* particleboard with mixed tropical hardwood unsanded and sanded particleboard produced in industrial scale.
3. To compare the mechanical properties of unsanded and sanded *A. mangium* particleboard to mixed tropical hardwood unsanded and sanded wood particleboard produced in industrial scale.

1.3 Need For The Project

All wood industries in Malaysia are facing a serious problem on getting the raw material supply. For the period of 1981-1987 about 233,800 hectare of forest were harvested annually in peninsular Malaysia for the production of about 9,345,000m3 of logs, about 93% of which were consumed by the local wood industries (Anon, 1988). The demand of timber by the various wood based industries in peninsular Malaysia will exceed the timber supply from the existing sources. With the objective of solving the anticipated shortage, the Compensatory Forest Plantation Program (CFPP) was launched by the forestry department in 1981. Under this CFPP, *A. mangium* is the dominant species planted. For the fifth and sixth Malaysian plans 12,000 hectare and 20,200 hectare of this species would have been planted respectively (Johari and Chin, 1986). This happens not only for those industries which using single source of wood as their raw material, but it is also happened to industries which utilize wood waste in their production. Due to that, wood industries in Malaysia should be taking instant action to ensure that their production will run smoothly and does not face shortage of raw material in the future, thus, each of wood industries sector must look into the other possibility by using single wood species or plantation species as the raw material in future. The main purpose of this research is to look into details on using the *A. mangium* as the main wood raw material in particleboard industries.

CHAPTER 2

LITERATURE REVIEW

2.1. History of Particleboard

The idea to create particleboard had started in Germany in the year 1941. It was then developed tremendously with the invention of special machines such as dryers, blenders, mat forming devices; hydraulic presses etc which had erect the production into technical scale. In the following years urea-formaldehyde resins in colloidal solutions were used as binding agents. They were cheaper and cured at low temperatures than phenolic resin glues (Kollmann *et al.* 1975).

For the platen-pressed particleboard industry as it is now known, an early reference for producing this type of board occurred when Ernst Hubbard in 1887, in a publication, "*Die Verwertung Der Holzabfalle*" (Utilization of Wood Waste), proposed to manufacture artificial wood from sawdust and blood albumin under application of pressure and heat, which illustrates the early conceptualization of the particleboard process (Maloney, 1977).

Beckman, a German, in 1918 suggested making a board with chip or wood dust in the center and surface veneers on the outside. This particular formulation is now coming into the market as a "new" type of structural building panel. Another German, Freudenberg, in 1926 talked about utilizing planer shavings with the adhesives available at that time for making a board. He noted that the adhesive level should be between 3% and 10% which, interestingly enough is about the range for the present-day particleboard (Maloney, 1977).

Nevin an American, in 1933 recommended the mixing of coarse sawdust and waste wood shavings with an adhesive and then forming and compressing them under the application of heat. A Frenchman, Antoni, in 1933 discussed boards of a mixture of wood fibers and particles and large elements such as excelsior or even metal netting in a board that was to be bonded with phenolic or urea glues. This, of course, was about the time of the development of these two new synthetic resins (Maloney, 1977).

Samsonow, another Frenchman, in 1935 recommended using lengthy stripe made from veneers in a board. These were to be arranged in a cross-lap manner, again much in the same fashion as conventional plywood. This is a forerunner of the development of oriented flake board, which is going into production in the United States at this time. A Japanese, Satow, in 1935 obtained an American patent for making board with 75mm-long (3 in.) chips arranged randomly within the board to prevent warping. The German, Roher, in 1935 discussed pressing particles onto the surface of a plywood core in a single operation (Maloney, 1977).

Carson, an American, was awarded a patent in 1936, which he applied for initially in 1932, for establishing a regular production line for producing particleboard. He proposed using a splintery type of sawdust with moisture content of about 12%, which was to be first sized, impregnated against fungi growth, and applies with a fire retardant. A binding agent, which was to be a urea-formaldehyde-condensation product dilutable in water, was to be sprayed onto the wood particles in a rotarydrum blender. Before hot pressing, a pre-pressing operation was to take place, and he proposed covering the final board with a thermoplastic coating of synthetic resin (Maloney, 1977).

Another American, E. C. Loetscher, in a 1936 patent, provided interesting data on how to produce a particleboard in an automated system. In 1937 he discussed the production of a board made of sawdust with unconnected individual flakes on the surfaces to provide a decorative effect. These patents were the result of research initiated in 1933. Of great interest is the Farley & Leotscher Manufacturing Co., a millwork firm, which started pilot plant production in1935 in Dubuque, Iowa, based on this research. Hammermilled particles were blended with liquid phenolic resin in an adapted concrete mixer. Four 1/8-in.–thick (3.2 mm) mats were formed for each press opening, pre-pressed, and then assembled into a package using metal caul plates between the mats. An 11 opening press was used; thus 44 boards were pressed at a time. Board specific gravity ranged from 1.2 to 1.3. Finished boards, trade named Leotex, were trimmed, sanded, and then used for core material to which a high-pressure thermosetting plastic was applied. The trade name Farloex was used for the board surfaced with a decorative laminate. Perhaps this could be called the first operational particleboard plant. The firm performed research on boards ranging from 0.70 to 1.8 in specific gravity with wood particle varying in size from coarse "hog chips" to fine wood flour. Many different species were investigated. Research also covered a variety of water-resistance additives and extenders (Maloney, 1977)

In 1938 and 1940, Torfitmerke G. A. Haseke obtained patent on methods of producing particleboard. The first one covered the use of liquid adhesive with a postdrying step, after application of the adhesive, to reduce the moisture content. The second patent covered gluing in the press before removing the board to prevent the blows in a high-density board (Maloney, 1977).

Significant efforts are being made to bring particleboard and fiberboard further into the structural building panel market in direct competition with plywood. Some large breakthroughs have already occurred, most notably in the mobile home decking market, where urea-bonded particleboard has supplanted plywood for the floor membranes. Structural flake board is approved for use in Canada. Other particleboards are used structurally throughout the world (Maloney, 1977).

The development of this particular segment of the board industry has been phenomenal since World War II. Many different of board plant have been built around the world, based not only on wood waste and round wood cut especially for particleboard but also from other lignocellulosic materials such as bagasse and flax. The ability to use the heretofore-wasted raw material has been a boon to all of society (Maloney, 1977).

Otto Kreibaum initially developed the extrusion method of producing particleboard in Germany in the years 1947-1949. This production process has been expanded over the years in Europe to the extent that at least one manufacturer is producing both boards and factory-built houses in a single manufacturing complex (Maloney, 1977).

REFERENCES

Ahmed, N.A.J. 2001. Commercialization of products from oil palm biomass-potential and constraints. *Paper presented at the Oil palm Biomass Opportunities for Commercialization seminar.* Hotel Istana, Kuala Lumpur, Malaysia 15-16 October.

Anonymous. 1979. *Tropical Legumes: Resources for the Future*. National Academy of Science. National Research Council, Washington DC.

Anonymous. 1988. *Forestry in Malaysia*. Ministry of Primary industries Malaysia.

Anonymous. 1997. Experience of Forest Plantation Projects in Malaysia. *Paper presented in Asia Pacific Plantation Forestry Conference. 1997, Kuala Lumpur.*

Anonymous. 1998. Malaysian Timber Industrial Board. *Particleboard An Investment Opportunity in Kedah Darulaman*, Malaysia.

Anonymous. 2006. Particleboard Supply Overview Data in Mala*ysia. Minutes of meeting in the 6th Thailand-Malaysia-Korea particleboard manufactures meeting.* Katathani, Phuket, Thailand. 24 March 2006.

Awang, K. & Taylor, D, 1993. *Acacia mangium: Growing and utilization*. Winrock International and FAO, Bangkok, Thailand.

Chew, L.T., Nurulhuda Mohd. Nasir, Ong, C.L. & Rahim Sudin, 1989. *Acacia mangium* For Manufacture Of Panel Products And Adhesive. Nos 51/60. Kuala Lumpur, Malaysia. *Forest Research Institute Malaysia report 1989/1992.*

Edward, B.J. 2004. *An Applied Statistical Reliability Analysis of the Internal Bond of Medium Density Fiberboard.* Thesis Of Master Science (Unpublished): The University Of Tennessee, Knoxville.

Forestry Department Annual Report 2004. *Sabah Forestry Department.* Sandakan, Sabah.

Jayakuik Glue and press parameter setting report, 2000. *Glue and press parameter setting report. Jayakuik Sdn. Bhd.* Sandakan.

Jayakuik Technical Report, 1998. *Technical report, Jayakuik Sdn. Bhd.* Sandakan.

Jalaluddin, H. 2003. Bio-Composite Industry: Challenges in Utilising Non–Conventional Fiber Resources in Malaysia. *Paper presented at the 11th WoodmacAsia 2003 International Conference.* September 9-10, 2003. Singapore.

Johari B. & Chin, T.Y. 1986. Review of plantation experience in Peninsular Malaysia. *Processdings of the 9th Malaysian Forestry Conference.* October 12-14, 1999. Kuching, Sarawak.

Kollmann, F.P., Kuenzi, W.E. & Stamm, A.J. 1975. *Principles of Wood Science and Technology II Wood Based Materials.* Springer – Verlag: New York City.

Leong. D.C.T. 2002. Applications of Plantation Timbers in Value – Added Processing. *Paper presented at the Seminar on Application of Plantation Timbers.* September 3, 2002. Kota Kinabalu, Sabah.

Lynam, F.C. 1968. Effects of Fibrous Raw Materials on Board Properties and Production Technology. *In*: Mitlin, L.(Ed.). *Particleboard Manufacture & Applications.*pp29-33.Pressmedia Limited Borough Green Kent, Louisiana, U.S.A.

Maloney, T.M. 1977. *Modern Particleboard & Dry-Process Fiberboard Manufacturing.* Miiler Freeman Publications, Inc. San Francisco, California: 280 pp.

Malaysian Timber Industry Board 2005a. *Acacia mangium* in Downstream Processing. *MASKAYU* **8**:24-29.

Malaysian Timber Industry Board 2005b. *Acacia* timber for Wood-based Industry in Malaysia. *MASKAYU* **10**:7.

Malaysian Timber Industry Board 2005c. Export of Major Timber Products by Sabah. *MASKAYU* **12**:24.

Maslin, B.R. 1995. *Systematic and phytogeography of Australian species of Acacia:* an overview. *IFA Newsletter,* **36**(2):2-5.

Maslin, B.R., & McDonald, M.W., 1996. *A key to useful Australian Acacias for the seasonally dry tropics.* Melbourne, Australia: CSIRO Publishing. 80 pp.

Mead, D.J. & Speechly, H.T. 1989. Growing *Acacia mangium* For High Quality Sawlogs in Peninsular Malaysia. Recent Development In Tree Plantation Of Humid/Subhumid Tropics Of Asia. *Proceedings of a Regional Symposium. June, 5 – 9 1989.* Universiti Putra Malaysia. pp 54- 65.

Mohd. Zin J.D., Jewan, & Mohd. Hamami S. 1989. Physical and Mechanical Properties Of *Acacia mangium* Wild. Of Selected Ages Grown In Malaysia. Recent Development In Tree Plantation Of Humid/Subhumid Tropics Of Asia. *Proceedings of a Regional Symposium. June, 5 – 9 1989.* Universiti Putra Malaysia. pp 774-778.

Nigel, P.T.L. 2003. *Particleboard Manufacture From Baby Small Keruing.* Timber Research & Technical Training Centre, Forest Department Sarawak.

Nigel, P.T.L., & Pek, Y.K. 2003. *Assessment of Four Sarawak reforestation species for manufacture of particleboard.* Timber Research & Technical Training Centre, Forest Department Sarawak.

Ong, S.H. 1984. *Moisture content of wood in Acacia mangium living trees.* Forest Research Center Pub. No. 16. Sandakan, Sabah. Malaysia.

Ong, S.H. 1985. *Physical and mechanical properties of Acacia mangium timber from Ulu Kukut in Sabah.* Forest Research Center Pub. No. 23 . Sandakan, Sabah. Malaysia.

Peh, T.B. & Khoo, K.C., 1984. Timber Properties of *Acacia mangium, Gmelina arborea,* and *Paraserianthes falcataria* and their utilization aspects. Malay. *Forester.* **47**(4):285-303.

Razali, A.K. 1985. *Origins of Thickness Swelling in Particleboards,* Thesis of Philosophies Doctor (Unpublished).United Kingdom: University of Wales.

Razali, A.K. & Kuo, H.S. 1989. Properties of Particleboards Manufactured from Fast-Growing Plantations species. Recent Development In Tree Plantation Of Humid/Subhumid Tropics Of Asia. *Proceedings of a Regional Symposium. June, 5 – 9 1989*. Universiti Putra Malaysia. pp 685-690.

Razali, A.K. & Mohd. Hamami Sahri, 1993. Properties and Utilization Of *Acacia mangium*. *Acacia mangium: Growing and Utilization, MPTS. Monograph 3*. Bangkok, Thailand: Wynrock International and FAO.

Salleh, M.N. & Wong, W.C., 1991. Utilization Of Forest Plantation Trees. Recent Development In Tree Plantation Of Humid/Subhumid Tropics Of Asia. *Proceedings of a Regional Symposium. June, 5 – 9 1989*, Universiti Putra Malaysia. pp 672-684.

Wong, W.C., Ho, K.S., & Wong, C.N., 1988. *Acacia mangium* from Sabah for plywood and decorative manufacture: *Initial trials. J. Trop. For. Sci.* **1**(1): 42-50.

Vroege, M. 2003. Impact of Chinese demand in the local and regional wood panel markets. *Paper presented at the 11th WoodmacAsia 2003 International Conference*. September 9-10, 2003. Singapore.