Eco-Friendly (Watermelon Peels) Alternatives to Wood-based Particleboard Composites.

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ABSTRACT

The aim of this study was to investigate the suitability of using watermelon peels as alternatives to wood-based particleboard composites. The watermelon peels composite boards were produced by compressive moulding using recycled low density polyethylene (RLDPE) as the binder. The RLDPE was varies from 30 to 70 wt% with interval of 10 wt%. The microstructure, water absorption (WA), thickness swelling index (TS), modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding strength (IB) and impact strength properties of boards were determined. The results showed that high modulus of rupture of 11.45N/mm^2, MOE of 1678N/mm^2, IB of 0.58N/mm^2 were obtained from board produced at 60 wt% RLDPE.

The uniform distribution of the watermelon particles and the RLDPE in the microstructure of the composites board is the major factor responsible for the improvement in the mechanical properties. The results showed that the MOE, MOR and IB meet the minimum requirements of the European standards, for general purpose like paneling, ceiling, partitioning. Hence watermelon particles can be used as a substitute to wood-based particleboard for general purpose applications.

(Keywords: board composites, watermelon, particles, recycled low-density polyethylene, mechanical and physical properties)

INTRODUCTION

The demand for wood composites from waste wood has been increasing as timber resources in natural forests decline. The use of renewable biomass as a raw material in composites production was one approach and the use of renewable biomass may result in several benefits such as environmental and socio-economic (Younquist et al., 1994). Today renewable biomass are mostly accepted as waste materials and are mostly ploughed into the soil or burnt in the field. According to the end uses of wood-wastes and their possible reuse products, particleboard has found typical applications as flooring, wall and ceiling panels, office dividers, bulletin boards, furniture, cabinets, counter tops, and desk tops (MacCleery, 1995; Chew et al., 1991), and it seems that the manufacture of particleboard from biomass wastes is the most common way to reuse such waste materials (Kuo et al., 1998; Younquist et al., 1994).

Wood composite industries demand more wood raw material everyday despite the fact that the forest resources are diminishing. The decline in wood material source has led researchers to study non-wood ligno-cellulosic biomass utilization in composite manufacturing including particleboard. Agricultural waste materials and annual plant fiber have become alternative raw materials for the production of particle or fiber composite materials. The most frequently referred alternative non-wood materials are flax, bagasse, hemp, reed, and cereal straws such as rice and wheat straw (Younquist et al., 1994).

Today chemical pulp and panel products using wheat straw and other crop residues are being commercially manufactured in a number of countries including Nigeria (Hall et al, 1984). There is still a growing need to find alternative sources of raw materials for composite manufacturing. Therefore, the aim of this study is to investigate the potential utilization of watermelon peels in particleboard production as supplement and to alleviate the shortage of raw material in forest industry.

MATERIALS/ EQUIPMENT

The watermelon peels used in this work was obtained from 'Sabon Gari' area of Zaria in Kaduna state Nigeria (Figure 1).

Figure 1: Photograph of the Watermelon Peels.

Waste Pure water sachet (RLDPE) used were collected literally from the streets of Zaria and around refuse dumps. Cut in to small pieces with the aid of blades and pair of scissors (Figure 2).

Figure 2: The RLDPE Resin Used.

The equipment used in this research was: metal mould, hydraulic press, Avery Denison impact tester, Rockwell hardness, Instron machine, grinding and polishing machine, and scanning electron microscope (SEM).

METHOD

The particle size analysis of the watermelon peels particles was carried out in accordance with BS1377:1990(ASTM E290, 1990). About 100g of the particles was placed unto a set of sieves arranged in descending order of fineness and shaken for 15 minutes which is the recommended time to achieve complete classification, the particle that was retained in the BS. 100µm was used in this study (Figure 3).

Figure 3: Photograph of the Watermelon Peel Sieve Particles.

Metal molds were used in the production of the board composite samples. Each mold had a cavity to accommodate the board composite samples. The dimensions and shapes of cavities were made according to the size and shape of the samples as per ASTM Standard D 638-90 for tensile testing and ASTM Standard D 790-97 for flexural testing (ASTM E290, 1990). After drying the water melon particles and RLDPE in oven at 105^{o}C, the agro-waste particles and the RLDPE were then compounded in a two roll mill at a temperature of 130^{o}C, into a homogenous mixture. Board production was carried out on an electrical heated hydraulic press. The mixtures were then placed in a rectangular mould. The boards were pressed by varying the RLDPE Resin from 30-70wt% with 10wt% interval. At the end of press cycle the board was removed from the press for cooling.

The scanning electron microscope (SEM) JEOL JSM-6480LV was used to identify the surface morphology of the board composite samples. The surfaces of the board composite specimens are examined directly by scanning electron microscope JEOL JSM-6480LV. The samples were washed, cleaned thoroughly, air-dried, and coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV. The digitized images were recorded.

The basic method of determining the density of board composite samples was by measuring the mass and volume of the sample used. A clean sample is weighed accurately in air using a laboratory balance and then suspended in water. The weight of the sample when suspended in water was determined and the volume of the sample was determined from the effect of displacement by water (Archimedean principle). The density of the sample was then estimated from equation below (BSI, 1993):

$$Density = \frac{Mass}{Volume}$$

Specimens with dimensions of 50 mm x 50 mm were prepared for evaluation of the thickness swelling. The thickness at the middle of the test specimen was measured with a micrometer. Then the test specimens were place into water in parallel for 30 mm and soaked for 24 h before further measurement of the thickness. The Thickness swelling rate (TS) was determined from the following formula (BSI, 2003).

$$\mathrm{TS}_{24} = \frac{(t_{24} - t_0)}{t_0} \times 100$$

Where TS is the thickness swelling rate (%), t_0 and t_{24} are the thickness at the middle of the test specimen. The values of the WA as percentages were calculated (BSI, 2003).

$$\mathrm{WA}(t) = \frac{\mathrm{W}(t) - \mathrm{Wo}}{\mathrm{Wo}} \times 100$$

where WA(t) is the water absorption (%) at time t, W_0 is the initial weight, and W(t) is the weight of the sample at a given immersion time t.

Bending specimens of 50 mm wide 275 mm long were cut from each full particleboard. A concentrated bending load was applied at the center with a span of 15 times the thickness of the specimen. The bending modulus of elasticity (MOE) and modulus of rupture (MOR) were calculated from load deflection curves according to the following formula (BSI, 2003):

$$\mathrm{MOR} = \frac{3P_b L}{2bh^2}$$

$$\mathrm{MOE} = \frac{P_{bp} L^3}{4bh^3 Y_p}$$

where P_b is the maximum load (N), P_{bp} is the load at the proportional limit (N), Y_p is the deflection corresponding to P_{bp} (mm), b is the width of the specimen (mm), h is the thickness of the specimen (mm), and L is the span (mm).

The tensile strength perpendicular to the surface was determined using three conditioned specimens of 50 mm x 50mm from each particleboard. The rupture load (Ps) was determined and internal bond strength (IB) was calculated using the following formula (ASTM E290, 1990).

$$\mathrm{IB} = \frac{P_s}{bl}$$

where Ps is the rupture load, and l is the length of the specimen.

The impact test of the board composites sample was conducted using a fully instrumented Avery Denison test machine. Charpy impact tests were conducted on notched samples. Standard square impact test sample of measuring 75 x 10 x 10 mm with notch depth of 2 mm and a notch tip radius of 0. 02 mm at angle of 45^o was used(ASTM E290, 1990).

RESULTS AND DISCUSSION

Macrostructural studies of the particleboard revealed a uniform distribution of agro-waste particles with the RLDPE binder. The distribution of particles is influenced by the compounding of the particle and the binder which resulted to good interfacial bonding (Figure 4). However during the production of the boards, RLDPE resin binder of 10-20wt% did not give good bonding, as the RLDPE binder increased beyond 20wt% good bonding of the particles and the resin was obtained.

Figure 4: Photograph of the Developed Particleboard.

The morphologies of the particleboard composites by SEM are show in Figure 5-7 Morphological analysis using SEM clearly show difference in the morphology of the particleboard composites (Figures 5-7). The microstructure clearly shows that when the agro-waste particle was added to the RLDPE resin morphological change in the structure take place.

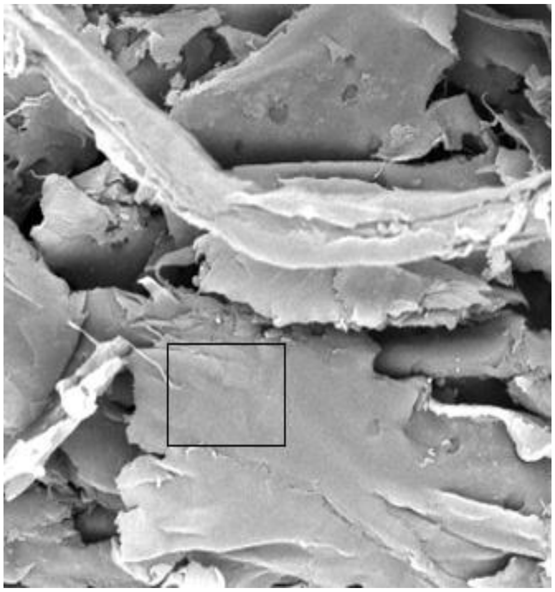

Figure 5: SEM/EDS Microstructure of the Watermelon Peel Particleboard with 30wt% RLDPE Resin.

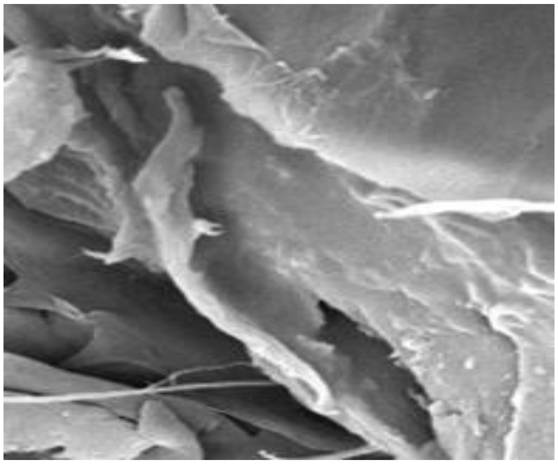

Figure 6: SEM Microstructure of the Watermelon Peel Particleboard with 50wt% RLDPE Resin.

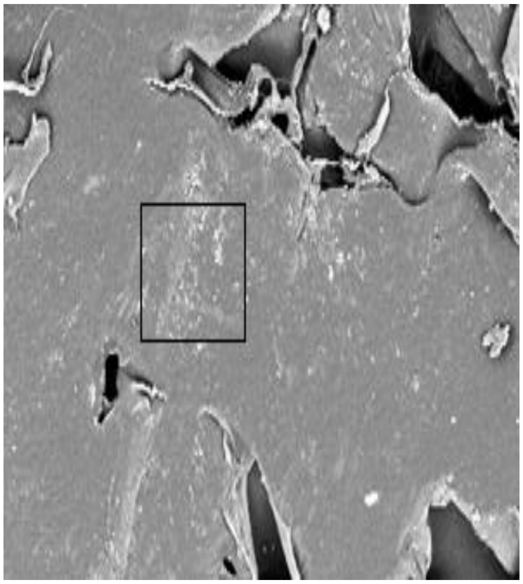

Figure 7: SEM Microstructure of the Watermelon Peel Particleboard with 70wt% RLDPE Resin.

The microstructure reveals that there are small discontinuities and a reasonably uniform distribution of particles and the resin. The particles phase is shown as white phase, while the resin phase is dark. The agro-waste particles are embedded within the amorphous matrix composed of randomly distributed in the matrix planar boundaries. The surface of the agro-waste particles is smooth indicating that the compatibility between particles and the resin was good. It can be seen that the agro-waste particles are not detached from the resin surface as the weight fraction of agro-waste particles increased in the resin, this is due to good interfacial bonding between the resin and the particles(Han et al., 1998; Dalen, 1999). This good bonding was achieved from the compounding of the agro-waste particles and the resin.

The density, thickness swelling (TS) and water absorption (WA) of the particleboards are shown in Figures 8-10. The values obtained for the thickness swelling (TS) and water absorption (WA) of the particleboards were high (Figures 8-9). This is due to not using water repellent agents in the particleboard manufacturing.

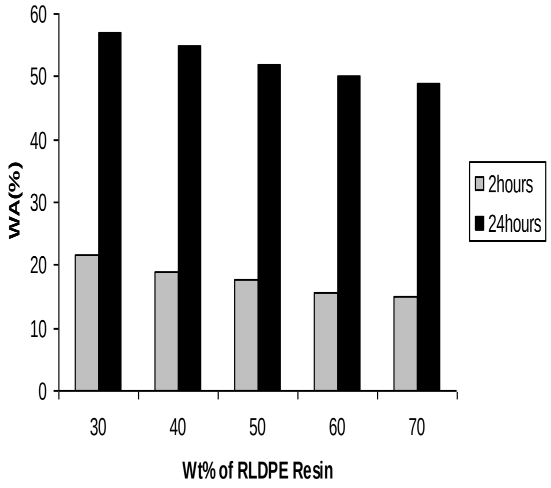

Figure 8: Variation of Water Absorption with RLDPE Addition.

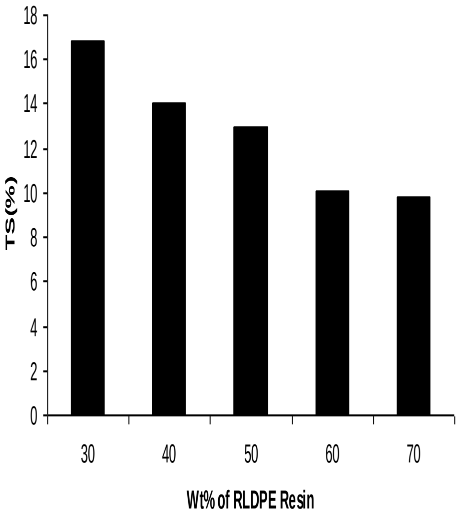

Figure 9: Variation of Thickness Swelling with RLDPE Addition.

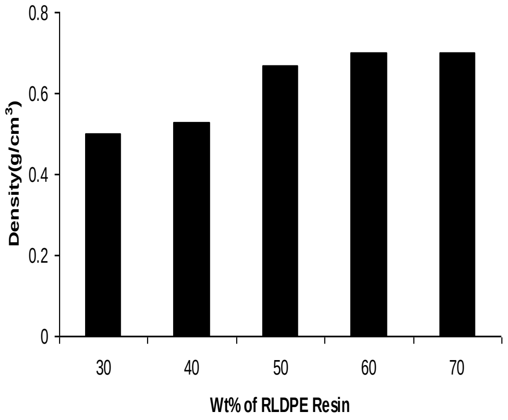

Figure 9: Variation of Density with RLDPE Addition.

The watermelon particles affected the WA and TS properties negatively. Similar results were found by Ntalos and Grigoriou (2002). Decreasing the resin increased the WA and TS of particleboards. This may be due to high solubility values of the particles. In addition, wall thickness of particles was found to be within the ranges of that of common wood species (Wasylciw, 1999).

The density profile of a board is dependent on the particle configuration, moisture distribution in the mat, hot press temperature and rate of closing, resin reactivity and the compressive strength of the particles (Wasylciw, 1999). The boards' density increased with increasing the weight fraction of the RLDPE resin (Figure 10).

Increasing of board density from 0.50 to 0.70 g/ cm^3 decreased the TS and WA for 2 h immersion. This is due to low porosity and difficult diffusion on the high board density. The swelling that occurs is the sum of two components, namely, swelling by hygroscopic particles and the release of compression stresses imparted to the board during the pressing of mat in the hot press (Hall et al, 1984). The release of compression stresses, known as springback, is not recovered when the board is in a dry state.

The values of modulus of elasticity (MOE), modulus of Rupture (MOR), internal bond strength(IB) strength and impact strength(IM) of the boards are shown in Figures 11-13.

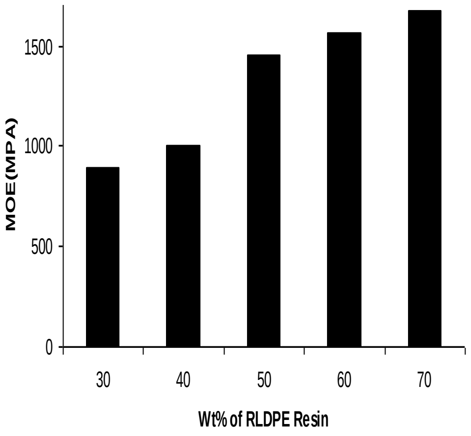

Figure 11: Variation of Modulus of Elasticity with RLDPE Addition.

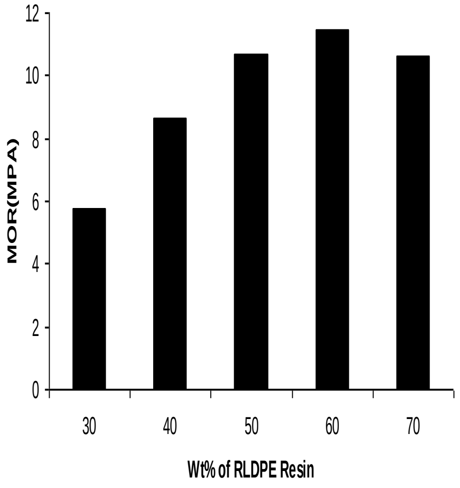

Figure 12: Variation of Modulus of Rupture with RLDPE Addition.

The increase in modulus elasticity with increasing RLDPE resin addition is expected since the addition of resin to the watermelon particles increases the stiffness of the particleboard composites (see Figure 11).

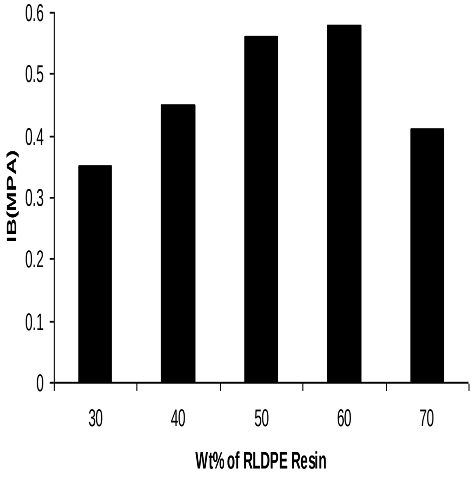

Figure 13: Variation of Internal bonding strength with RLDPE addition

The MOR ranged from 5.78 to 11.6N/mm^2 (Figure 12). The MOR requirements of 11.5 N/mm^2 for general purpose boards by EN 312-2 (1996). Particleboards made from 30wt% RLDPE resin had MOR lower than the requirement for general purpose. In addition, although increasing of RLDPE Resin addition increasing the MOR up to 60wt%, beyond this level no further increased in MOR was obtain.

The range of data in IB was from 0.35 to 0.58 N/mm^2 (Figure 13). The IB requirements of 0.24 N/ mm^2 for general purpose boards, 0.35 N/mm^2 for interior fitments, load-bearing boards and 0.50 N/mm^2 for heavy duty load bearing boards by EN 312-2 (1996), EN 312-3 (1996), EN 312-4 (1996), EN 312-6 (1996), respectively.

The internal bond strength is comparable with values reported by Razali and Kuo (1991) and Chew *et al.* (1991). The watermelon peel board surpassed the mechanical strength requirements for general purpose applications specified by European standard. All of the particleboards produced from are within the recommended standard (i.e., for general purpose, interior fitments, load-bearing boards and heavy-duty load bearing boards).

The results of the impact strength shows that the impact strength of the board composites slightly increased with increases in RLDPE resin addition (Figure 14).

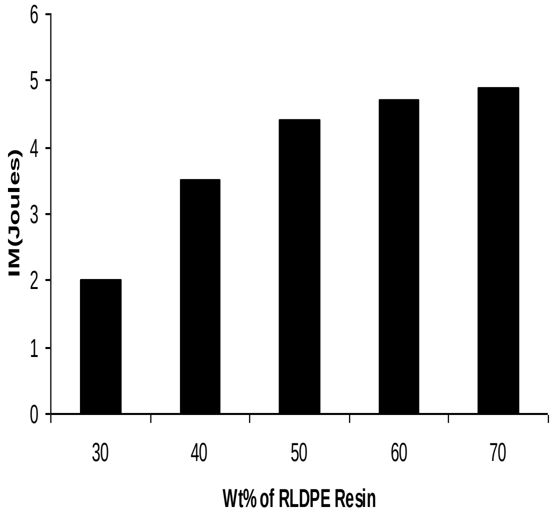

Figure 14: Variation of Impact Strength with RLDPE Addition.

High strain rates or impact loads may be expected in many engineering applications of particleboard composite materials. The suitability of a particleboard composite for such applications should therefore be determined not only by usual design parameters, but by its impact or energy absorbing. The steep increased in the impact strength board composites could be attributed to the presence of particles well bonding by the RLDPE resin this factor leads to increase in impact energy

In general, the boards produced with the agro-waste particles at 50-60% RLDPE resin addition conform to the BIS specifications of density particleboards for general purpose requirements like paneling, ceiling, partitioning, etc. (interior decoration).

CONCLUSIONS

This present research is centered on the development and characterization of the microstructure and properties of particleboard composites using watermelon peels and RLDPE as binder. From the above results and discussion the following conclusions are made:

1. This work shows that successful fabrication of watermelon peel particleboard composites by simple compressive moulding techniques.
2. The density increased as the percentage of resin increases in the particles.
3. The percentage of thickness swelling and water absorption increased in decreasing the weight fraction of the RLDPE resin.
4. The tensile properties obtained are in agreement with the results obtained from the analysis of and impact strength.
5. The uniform distribution of the particles and the resin in the microstructure of the board composites is the major factor responsible for the improvement in the mechanical properties.
6. The developed particleboard composites can be use in density particleboards for general purpose requirements like paneling, ceilings, partitioning, etc. Since the properties of particleboard composites used in this area compared favorably with the properties of the developed board composites at 50-60 wt% RLDPE resin.

REFERENCES

1. ASTM E290. 1990. *Physical Testing Standards and Mechanical Testing Standards*. ASTM: New York. 1234-1345.
2. BSI. 1993. *Wood-Based Panels—Determination of Modulus of Elasticity in Bending and of Bending Strength*. The British Standards Institution: London, UK. 67-90.
3. Chew, L.T., M.N. Nurulhuda, C.L. Ong, and S. Rahim. 1991. *Particleboard from Some Plantation Species*. In: Abod SA et al. (eds.). *Proceedings of a Regional Symposium on Recent Developments in Tree Plantations of Humid/Subhumid Tropics of Asia*. 5−9 June 1989. Serdang. Universiti Putra Malaysia, Serdang. 708−724.
4. Dalen, H. 1999. "Factors to take into Consideration when Producing Particleboard from Straw". *Proceedings of the Meeting of the Eastern Canadian Section of the Forest Products Society*. 456-462
5. EN 312-2. 1996. "Particleboards-Specifications-Part 2: Requirements for General Purpose Boards for use in Dry Conditions". European Standardization Committee: Brussels, Belgium.

6. EN 312-3. 1996. “Particleboards-Specifications-Part 3: Requirements for Boards for Interior Fitments (including furniture) for use in Dry Conditions”. European Standardization Committee: Brussels, Belgium.

7. EN 312-4. 1996. “Particleboards-Specifications-Part 4: Requirements for Load-Bearing Boards for use in Dry Conditions”. European Standardization Committee: Brussels, Belgium.

8. EN 312-6. 1996. “Particleboards-Specifications-Part 6: Requirements for Heavy-Duty Load-Bearing Boards for use in Dry Conditions”. European Standardization Committee: Brussels, Belgium.

9. Hall, H.J., R.O. Gertjajensen, E.L. Schmidt, C.G. Carl, and R.C. DeGroot. 1984. “Preservative Effect on Mechanical and Thickness Swelling Properties of Aspen Wafer Board”. In: *Proceedings of a Workshop on Durability of Str. Panels*. Pensacola, FL. 234-247

10. Han, G., C. Zhang, D. Zhang, D. Umerra, and S. Kawai. 1998. “Upgrading of Urea Formaldehyde Bonded Reed and Wheat Straw Particleboard using Silane Coupling Agents”. *J. Wood Sci*. 44: 282-286.

11. MacCleery, R. 1995. “Resiliency, the Trade Mark of American Forests”. *Forest Prod. J.* 45:19-28.

12. Ntalos, G.A. and A.H. Grigoriou. 2002. “Characterization and Utilisation of Wine Prunings as a Wood Substitute for Particleboard Production”. *Industrial Crops and Products*. 16(1):59-68.

13. Razali, A.K. and H.S. Kuo. 1991. “Properties of Particleboards Manufactured from fast growing Plantation Species”. In: Abod, S.A. et al. (eds.) *Proceedings of a Regional Symposium on Recent Developments in Tree Plantations of Humid/Subhumid Tropics of Asia*. 5−9 June 1989. Serdang. Universiti Putra Malaysia, Serdang. 685−691.

14. Wasylciw, W. 1999. “The Utilization of Industrial Hemp Stalks in Composite Panels”. *Proceedings of the Meeting of the Eastern Canadian Section of the Forest Products Society*. May 19-20. Winnipeg, Manitoba, Canada.

15. Yamashita, Y., H. Watanabe and S. Takeda. 1999. “Rubberwood: Characteristics of its Supply and Development of its Utilization”. *Forest Research*. 71:65−70.

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