Development of Composite Fibre Board (CFB) using Coconut Coir Pith and Rice Husk with Phenol Formaldehyde Resin

H.G.I.M. Wijesinghe[1] A.N.R. Weerawansa[2]
[1,2]Department of Export Agriculture
[1,2]Uva Wellassa University, Badulla, Sri Lanka

Abstract— Recently, rice and coconut industries are growing rapidly in Sri Lanka due to utilization of new technology may be after the year 2005. The wastes generated from these industries are mainly rice husks and coconut coir pith. They are only used as potting media in horticultural aspects. But there is a potential to utilize them as an economical and ecofriendly raw material to manufacture composite fibre boards (CFBs) which can be used to replace the wood based medium density fibre boards (MDF). As the bonding agent phenol formaldehyde was used in manufacturing of CBFs. Cold pressed sheets were cured in a hydraulic press at 170 ºC for 20 minutes under the pressure of 25 MPa. Hardness, density, internal bonding and absorption of moisture of CBFs were measured according to ASTM standards compared to the standards of MDF boards by taking it as the control sample. Each sample was replicated 5 times and tests were carried out at room temperature (25°C). Data was analyzed using Minitab 16 statistical software with use of Tukey pairwise comparison. Coir pith based CFBs have shown 477.55 pounds hardness and it is very close to the hardness of MDF boards. Statistically, the rice husk based CFB have also indicated different hardness compared to MDF boards and the value was 419.44 pounds. Density of 723.0 kg/m^3 has achieved by coir based CFB which is higher comparatively to rice husk based CFB (690.2 kg/m^3). Higher internal bonding has indicated by the coir pith based CFB and it does not have shown a significant difference to the standard. Both CFBs have absorbed moisture more than 12% but that absorbance is not significant in comparison to the standards. In conclusion, both rice husk and coir pith can be utilized as a raw material for manufacturing of composite fibre boards. This investigation appears as a better solution for environmental problem associated with these wastes and it is economical to utilize to manufacture composite fibre boards.

Key words: Coir Pith, Rice Husk, Phenol Formaldehyde, Lignocellulosic Materials

I. Introduction

Sri Lanka is one of the countries in the world, is rich in growing coconut and rice extensively. It generates huge amount of waste after taking foods from these two plants. Coconut palm is named as "Tree of life" due to all the parts of the palm have different kinds of uses in routine lives of most Sri Lankan people. Also there are large numbers of industries related to coconut in Sri Lanka. Also as agriculture based country, Sri Lanka produces 2.7 million metric tons of rice per year (Department of Export Agriculture Sri Lanka). Rice is mainly consuming as food of Sri Lankans and some other types of foods are produced. Huge amount of rice husks remove continuously from rice mills as a waste without any effective use.

The fibrous husks coming out as byproducts from several coconut food based industries are used to manufacture coconut fibre based products. Coconut coir pith is accumulated as a waste in coconut fibre based industries.

The coir pith accounts for 50-60% of the total weight of the husk (Ros P. R. *et al*., 2012).It consists 80% of carbon containing organic compounds including cellulose, hemicellulose and pectin etc. Coir pith has about 31% lignin content and about 27% cellulose content and because of the high lignin content, coir pith takes a longer time period to decompose. In the composition of rice husks, it consists of 30% cellulose, 22% hemicellulose and 22% lignin which can be considered as natural fibre (Kumar S. *et al* .,2010). Since these two materials are rich with lignin and cellulose they can be considered as lignocellulosic materials.

Lignocelluloses are inexpensive and renewable natural materials and its main chemical composition consists of cellulose, hemicellulose and lignin in the cell walls which are responsible for the physical and chemical properties of medium density fibre (MDF) boards (Halvarsson, 2010). As rice husk is rich with those chemicals in the cell wall, there is a potential to use rice husk to manufacture MDF boards (Kumar *et al*., 2010). Also as same to the rice husk, coir pith can be utilized as a raw material for manufacture of MDF boards considering its chemical composition as reported above.

A composite material is made of combining two or more materials to give properties according to Verma *et al.*, 2013.According to this combination, phenol formaldehyde like polymer resin with natural fibrous materials were foremost in this investigation to manufacture composite fibre boards (CFBs) that may have a potential to have some appreciable properties compared to conventional MDF boards. As binding agents in making bond between fiber, people use different kinds of adhesives such as methyl diisocyanates (MDI) and phenol formaldehydes. Use of formaldehyde resins is more economical compared to use of isocyanate adhesives. But isocyanates give better panel properties than that of formaldehydes.

Conventionally, people use wood based raw material for manufacture of MDF boards. Plant fibres like Flax, Hemp, Jute, bagasse, Bamboo and Corn have been researched extensively for manufacturing fibre boards (Halvarsson, 2010).

Manufacturing of CFBs using large scale natural waste generated from the rice and coconut based industries would be a value addition to that industry and may have the potential to replace some conventional fibres used to manufacture MDF or composite fibre boards (CFBs).

The objectives of this study were to develop a fibre composite board (FCB) using coconut coir pith and rice husk and to discuss the physical properties of fibre composite board (FCB) comparing with the medium density fiber (MDF) boards available in the market.

II. METHODOLOGY

A. Materials

Fresh coconut coir pith was collected from a coconut fiber processing factory located in Dunkannawa, belonging to Coconut Research Institute, Sri Lanka and fresh rice husk was collected from a rice mill located in Kurunegala, Sri Lanka.

B. Method

Collection of samples was done in a way as reported by Ross P.R. *et al*., (2012). According to that, the surface layer of the mount was scrapped out and around 1kg of unexposed coir pith was collected randomly at five places. Then all the samples were mixed and stored in polyethylene containers. Also same procedure was followed to collect samples of rice husk.

Both coconut coir pith and rice husks were dried on a clean surface at room temperature (25ºC) under the sunlight for two days. Dirt materials such as stones and sand were sorted out and removed. An amount of 300 grams of coconut coir pith and the same amount of rice husk were mixed with 30 grams of phenol formaldehyde (PF) resin as the experiment one (E_1). Similar to that, rice husk and PF resin composite was prepared (E_2).

The application of liquid resin was done by a spraying equipment to optimize the even distribution of resin. Then mold was filled with mixture and the sheet was shaped pressing by hand. Then samples were pressed at 25 MPa pressure and 170°C temperature using the hydraulic press for 20 minutes.

Density, tensile strength which is related with the internal bonding, hardness and water absorption of fibre composite boards were measured according to the American standards for Testing and Material (ASTM) standards. Each sample was replicated 5 times and tests were carried out at room temperature (25°C). Analysis of data was done using Minitab 16 statistical software with use of Tukey pairwise comparison.

III. RESULTS AND DISCUSSION

Composite fibre boards were successfully prepared by dry process having a fibre moisture content of less than 20%, and having a density of ≥ 450 kg/m^3 as reported by Halvarsson, in 2010.

Experiment	Hardness in Pounds	Density (kg/m^3)	Internal bonding (MPa)	Moisture content (%)
E_1	477.55^a	723.0^a	1.0565^{ab}	13^a
E_2	419.44^b	690.2^a	1.0121^b	14^a
Control	500.00^a	750.0^b	1.2000^a	12^a

Table 1: Phsysio-mechanical properties of CFB

As shown in Table 1 the highest hardness has achieved by the CFB made out of coir pith (E_1) and it is not significantly different to control sample. Densities of CFBs are significantly different to control sample in both CFBs according to the statistical analysis. Internal bonding of both CFBs is not significantly different but only the CFB made out of coir pith has not indicated a significant difference to the control sample. Moisture content of both CFB samples have not significantly different to the control sample and the moisture content of coir pith and rice husk based samples are not significantly different to each other. According to the results in Table 1 coir pith based sample has achieved better properties compared to rice husk based CFB sample.

These boards are produced under application of pressure and heat with the addition of Phenol formaldehyde synthetic bonding agent. Use of thermosetting resinous adhesives may have an effect to retain the dimensions under applied stresses such as bending and extension. According to Verma *et al*., the use of thermosetting polymers such as epoxies, alkyds, vinyl esters, alkyl resins, amino plastics, urethanes and silicones have better properties which can withstand to high heat and also for high stresses applied on the CFBs.

Sometimes the use of isocyanates and urethanes give high impact resistance to the board by absorbing the impact energy through vibrating the flexible segments of the polymer chains. It may improve the hardness as well as the elasticity of the boards.

The highest hardness has achieved by E_1 composite fibre board (CFB) made of coconut coir pith as shown in the Table 1. Statistical analysis has shown that CFB made out of coir pith is not significantly different from the standard but in rice husk based CFB has shown a significant difference to the standard. Hardness of CFBs increases when the density of CFBs is increased. As reported by Kumar A. *et al*., (2012) rice husk contains 20% of silica and that silica may have some reinforcing effect in CFBs made out of rice husks because silica is also used as a filler in rubber based products to get the stiffness.

The density of coconut coir pith based CFB is 723 kg/m^3.Compared to rice husk based CFBs, density is higher in coir pith based CFBs. The reason for this behavior may be the effect of particle sizes as reported above. Particle size has some effect on density because coarse particles normally show a poor packing compared to packing of fine particles. In coir pith, the particles are fine compared to rice husks and therefore that could be one reason to have a high density and hardness in E_1 coconut coir pith based CFB. Sometimes there could be an effect of Silica stored in plant cells to increase the hardness of CFBs.

Also fine particles can enhance the bonding among particles because they have high surface area to volume ratio. Coconut coir pith has the fine particles and it has shown high internal bonding compared to bonding of particles of rice husk.

Phenol formaldehyde (PF) was used as the bonding agent and with the best action of that, the coconut and rice husk based composite boards have indicated the required values for internal bonding. In relation to internal bonding, there is no significant difference of manufactured CFBs compared to the specifications of standard MDF board.

As reported by the Torkaman J., (2010) PF resin is incompatible with partially hydrophobic rice husks. Replacing of PF bonding agent in E_2 by inexpensive Sodium Silicate binder, better internal bonding properties could have to be achieved but those performance are lower than in the boards made out of isocyanate resins. Also isocyanates are toxic and expensive.

Coconut coir pith has lengthy fibers compared to rice husks. Cheng et al., has described that use of lengthy fibres can improve the bending properties and modulus of rupture that correlates with internal bonding and this is one reason to have high internal bonding in E_1.

Verma et al., has reported that the total lignin and cellulose content in coir as 45.84% and 43.44% respectively. Lignins are amorphous, highly complex, mainly aromatic, polymers of phenyl propane units (Rowell et al., 1997). Due to its aromatic nature it may have a better compatibility with PF resin. According to that the chemical bonding between coir and resin can be improved, obviously, it has improved the internal bonding in CFBs.

In rise husks the content of lignin and cellulose are less therefore; it has indicated less internal bonding. According to Nadazi et al., (2006), physio-mechanical properties of the composite board made out of wood materials can be improved by treating them with steam and some chemicals such as NaOH. To enhance the internal bonding some other bonding agents such as isocyanates can be used. Or modifications such as acetylation can be used to improve the internal bonding.

Some chemical structures such as cellulose can absorb moisture therefore; the moisture content even after manufacturing of CFBs can be increased in the products with the time. Both CBFs have shown equal moisture contents that are statistically on par with control sample according to the statistical analysis.

Normally, acceptable moisture content of MFD boards is 10-12%. Moisture can affect to the dimension stability of MDF board. Moisture content in the board and relative humidity in the environment has an effect on the dimensional stability of CFBs according to Ganev S. (2001). According to these authors, it is obvious that there is a relationship between relative humidity of environment and the dimension stability of MDF boards.

According to EWPAA group, changes in relative humidity can change the length about 0.03-0.06% and thickness by 0.3-0.5% for every 1% change in moisture content. In this study the moisture content is about 12% and there is no significant change in dimensions.

Also the moisture content can lead the MDF or CFB for attack of fungus and termites as they are wood products. High moisture content and some transition metal ions in coir pith and rice husk can increase the fungal growth on boards. According to EWPAA, the moisture contents over 18% must be maintained to have fungal attack. Therefore, to protect the CFBs from those attacks, preservatives, waxes are used. CFBs in this study have moisture content below 18% therefore; these CFBs are not affected by such attacks.

After the use of CFBs, the biodegradation is possible as reported by other authors. Some of cyanobacteria such as Phormidium Sp. and Oscillatoria sp. can be used. But degradation of PF resin will take a certain time. Since there is a high lignin content in coir and rice husks it is more durable. Verma et al., says that increasing emphasis on fuel efficiency, coir based composites have broader applications in automobiles and many areas of transport systems due to light weight and appreciable other mechanical properties. Therefore, these composite boards have different kinds of applications.

IV. Conclusion

According to the results obtained for two of above composite fibre boards, there is a big potential to use coconut coir pith as a raw material to manufacture composite fibre boards easily. Rice husks have also shown the same possibility to use as a raw material for CFBs even though it has been reported some of lower results for measured properties compared to coir based CFB. Some chemical treatments have been reported by other authors indicating that it could have the potential to use to improve the functional properties of surfaces of raw materials and it could improve the internal bonding like properties.

In conclusion, both rice husk and coir pith can be utilized as a raw material for manufacturing of composite fibre boards (CFBs) as such as MDFs. The results of this investigation appears as a better solution for environmental problem associated with coir pith and rice husk wastes and it may economical to use for manufacturing of composite fibre boards. Also it is easy to degrade biologically after use and therefore it is environmental friendly.

References

[1] ANSI A208.2-2002 Medium Density Fiberboard (MDF) for Interior Applications, Composite Panel Association, 18922 Premiere Court, Gaithersburg, MD 20879-1569
[2] Atchison, J.E. (1997). XVII. Data on non-wood plant fibers. In. Pulp and Paper Manufacture. Vol. 1. Properties of fibrous raw materials and their preparation for pulping. M.J. Kocurek and C.F.B. Stevens, Editors. CPPA. Montreal, Canada: 157-169.
[3] Cellulose moisture absorption, retrieved on 06th December 2015 from http://www.fibersource.com/f-tutor/cellulose.htm
[4] Cheng et al., (2013). “Oriented Structural Boards from Split Wheat Straw: Effect of Straw Length, Panel Density and Resin Content”,Bio Resources 8(3), 4497-4504
[5] Facts about Particleboard and MDF – EWPAA,Published by the Australian Wood Panels Association Incorporated, PO Box 158, CoolangattaQld 4225, February 2008
[6] Ganev S.et al., (2001). Effect of Panel Moisture Content and Density on Moisture Movement in MDF Wood and Fiber Science, 35(1),pp 68-82
[7] Halvarsson S. (2010). Manufacture of Straw MDF and Fibre Boards, Thesis for the degree of Doctor of Technology, Sundsvall 2010, Fibre Science and Communication NetworkDepartment of Natural Sciences, Engineering and Mathematics, Mid Sweden University, SE-851 70 Sundsvall, Sweden
[8] Halvarsson S. et al., (2010). “Wheat Straw as Raw Material for Manufacture of Medium Density Fiberboards (MDF)”, Bio Resources 5(2), 1215-1231
[9] Kumar A. et al., (2012). Properties and Industrial Applications of Rice husk:A review in International Journal of Emerging Technology and Advanced Engineering, Website: www.ijetae.com Volume 2, Issue 10
[10] Kumar P.S.,et al. (2010). Thermodynamic and kinetic studies of cadmium adsorption from aqueous solution

onto rice husk, Brazilian Journal of Chemical Engineering, On-line version ISSN 0104-6632 Chem. Eng. vol.27 no.2 Sao Paulo Apr./June 2010 from http://dx.doi.org/10.1590/S0104-66322010000200013

[11] Mendis A., Information courtesy, Global Agricultural Information Network, report dated 04.17.2012 www.gain.fas.usda.gov retrieved on 5th December, 2015 from http://nipunarice.com/rice-o-pedia/rice-production-and-consumption-trends-in-sri-lanka/

[12] Nadazi B.S., et al., (2006). Chemical and physical modifications of rice husks for use as composite panels, Volume 38, Issue 3, March 2007, Pages 925–935

[13] Ross P.R., et al., (2012). Determination Of Physico-Chemical Properties Of Coir Pith In Relation To Particle Size Suitable For Potting Medium in International Journal of Research in Environmental Science and Technology, Universal Research Publications,2(2): 45-47 retrieved on 28 November,2015 from htttp://www.urpjournals.com

[14] Rowell et al., (1997). Paper and composites from agro-based resources, CRC Lewis Publishers, Boca Raton RL,301-336

[15] Technical data sheet 'Medium Density Fiberboard Moisture Resistant Grade,' from Engineered wood.pdf

[16] TorkamanJ. (2010). Improvement of Bondability in Rice Husk Particleboard Made With Sodium Silicate, Second International Conference on Sustainable Construction Materials and Technologies in June 28-June 30,2010, UniversitaPolitenicadelle Marche, Ancona, Italy.

[17] Verma D et al., (2012) Coir Fibre Reinforcement and Application in Polymer Composites: A Reviewin JMESN p 263-276.

