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Role of resin content in MDF board fabricated from lignocellulosic fibre of *Bambusa polymorpha* Munro

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Abstract
In order to better utilization of agricultural fibers as an alternative source for making composite panels, several variables were investigated to improve mechanical and physical properties of agro-based fiberboard. The objective of this study was focused on the role of resin content in the manufacturing of MDF (Medium Density Fiber) board made from lignocellulosic fibre of *Bambusa polymorpha* Munro. The MDF boards were made as per IS: 2380 (1998) using 6, 8 and 10% Phenol Formaldehyde resin and were subsequently hot pressed at 250 lbs/inch^2 (17.5 kg/cm^2) specific pressures and temperature of 150°C for 12 minutes. The physical and mechanical properties of the particle boards were tested as per IS: 12406 (2003). The results revealed that there was an increase in the density, MOR (modulus of rupture) and internal bonding strength of the fiberboard as increase resin content from 6% to 10%. Hence, the MDF board made 10% resin content meets the minimum requirement of IS: 12406 (2003) except some moisture related properties i.e., surface absorption, water absorption, thickness swelling due to general absorption etc, which can be controlled by suitable treatment.

Keywords: *Bambusa polymorpha*, density, moisture, mechanical, physical, pressure, resin content

Introduction

The study and practices of science & technology of adhesive, plywood, laminated wood & other building boards & allied subject come under "composite wood". There have been many new panel products introduced and modifications done to the existing ones but still in India the main composite wood products include plywood, particle boards and fibre board. There is a considerable increase in demand for such products because such products have advantage over solid wood in addition to some of its physical and mechanical properties; they inherit from their main constituent wood.

Bamboo represents one of the greatest potential alternative source of lingo-cellulosic raw materials, since it is the fast growing plant, found mostly in tropical and sub-tropical zones (Pannipa *et al.* 2011) [13]. Many studies have evaluated the properties of bamboo based composites such as oriented strand board (Lee *et al.* 1997) [14], medium density fiberboard (Yusoff *et al.* 1994, Zhang *et al*. 1997) [22, 23], bamboo fiber reinforced cement boards (Sulastiningsih *et al.* 2002) [20] and bamboo fiber/thermoplastic composites (Jindal 1986, Jain *et al*. 1992) [10, 9]. Higher benzene-ethanol extractives of some bamboo species could be an advantage for decay resistance (Feng *et al.* 2002). The strength of MDF depends on its fibres and on the adhesive bonds between them Halvarsson *et al.*, (2008) [6]. Refining process is an important parameter for MDF production by affecting fibre properties Fang *et al*. (2013) [5]. It is generally accepted that longer fibers obtain an increased network system by themselves and result in increased bending properties of composites (Mobarak *et al.* 1982; Li *et al*. 2000) [16, 15].

Medium Density Fiberboard (MDF) is a panel with a density range of 600-900 kg/m3 and manufactured from fibers of wood and other lingo-cellulosic materials with the primary bond deriving from the felting of the fibers and their inherent adhesives properties (IUFRO, 2002). MDF has become one of the most popular composite materials in recent years, because MDF is uniform, dense, smooth and free of knots and grain patterns, it makes an excellent substitute for solid wood in various applications. MDF is a composite wood product similar to particleboard. It's made out of wood waste fibers glued together with resin, heat and pressure. It's very smooth because the wood fibers used in its manufacture are uniform and fine.

This makes it have low "tear out," which means that when sawed, the end has a smooth cut instead of a jagged edge. This also means that a coat of primer and a couple of coats of paint take well, leaving an attractive, finished surface unlike other composite wood products. MDF also has a mild reaction to moisture, meaning it won't warp or swell in high-humidity applications like a bathroom cabinet. Since MDF is strengthened with resin containing formaldehyde, those at exposure try to reduce their risk of inhalation, or use special MDF with lower formaldehyde levels. The objective of this study was focused on the role of resin content in the manufacturing of MDF board made from lignocellulosic fibre of *Bambusa polymorpha*.

Materials and Methods

Procurement of raw material

The ligno-cellulosic raw material i.e., Bamboo (*Bambusa polymorpha* Munro) fibers were collected from forest Research Institute (latitude: $30^0$19'N and longitude: $78^0$04'E) Dehradun, India. The air dried bamboos culms were converted into small chips. These chips were converted into fibres in a condux mill. The fibres were separated from each other by refining them in a refiner. The refined fibres were screened to 0.5-2.0 mm mesh size and then dried up to 5% Moisture Content (MC) prior to manufacturing the MDF.

The chemical raw material is Phenol Formaldehyde. Phenol formaldehyde resin was prepared using phenol, formalin and sodium hydroxide which act as a binding material in the preparation of MDF board.

Preparation of medium density fiberboard

The MDFs were manufactured in the Composite wood Division, Forest Research Institute (FRI) at Dehradun (India). The dried fibers were blended with PF resin in a rotating drum-type mixer fitted with a pneumatic spray gun. Based on oven-dry particle weight, the PF resin was applied to the fibers at three percentages: 6, 8 and 10%. The blended fibres were then distributed manually in a wooden mould through a wire mesh. The hand-formed mats were then cold-pressed. Afterwards, these mats were hot-pressed at 150°C for 12 min under a press pressure of 250 lbs/inch^2 (17.5 kg/cm^2). Twelve boards of the dimensions 508X508X12mm were manufactured. The samples were conditioned in a chamber at 20°C and a relative humidity of 65+2% for a week.

Physical and mechanical properties of MDF

After conditioning, the test samples were cut into prescribed size and to evaluate the moisture content, Water Absorption (WA), Thickness swelling (TS), density, strength properties Internal Bonding (IB) strength and Screw withdrawal resistance as per IS: 12406 (2003) [8]. A total of 108 specimens with six replicate, were used in these tests. The density and Moisture content of specimens were determined using sample cut from the remnants of the static bending test specimens.

A static bending test was performed on 250x50x12 mm specimens using an Universal Testing Machine (UTM). Both the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) values were calculated. The IB strength was determined by the tensile perpendicular to surface test using specimens of size 50x50x12 mm. Twenty-four-hour soaking test was employed to obtain thickness swell data. A direct screw withdrawal test was used to evaluate the screw holding capacities in the face and edge. The procedures of the tests are detailed in the IS: 12406 (2003) [8].

Statistical analysis

The effects of resin content (%) on different properties of MDF board were analysed by means of analysis of variance (ANOVA) using SPSS16.0 version. Duncan homogeneity test was carried out to test the significance and mean separation of the treatments.

Results and Discussions

Physical and mechanical properties: The findings related to average physical and mechanical properties of the MDF fabricated from *B. polymorpha* fibers bonded with different level of PF resin are summarized in table-1. The ANOVA results shows that there is significant interaction effect between the resin levels, both on mechanical and physical properties of MDF Board. This implies that the resin level is synergistically affecting the board properties.

Table 1: Physical and Mechanical properties of medium density fiberboards prepared from *Bambusa polymorpha* at different content of PF resin (35% solid content)

Resin content (%) Wt	Moisture Content (%)	Density g/cm3	Water Absorption %		Thickness swelling due to surface absorption after 2 hrs. (%)	MOR N/mm2	Tensile strength	Screw withdrawal strength (N)	
			After 2 hrs	After 24 hrs				Face	Edge
6	10.50^a	0.63^d	95.37^g	114.37^j	16.85^m	10.63^p	0.284^s	1141.7^v	1014.3^y
8	8.42^b	0.70^e	70.09^h	89.72^k	8.00^n	15.77^q	0.404^t	1602.3^w	1411.2^z
10	6.51^c	0.75^f	57.93^i	70.29^l	3.58^o	18.91^r	0.521^u	1832.6^x	1592.5^z

Mean Square Error (MSE) of Moisture content = 0.65, density = 0.002, WA (2hr) = 4.02, WA (24hr) =8.09, TS due to surface absorption= 0.74, MOR = 2.72, Internal Bonding = 0.002, Screw Withdrawal (Face) = 10247.2, Screw Withdrawal (Edge) = 2483.4 respectively at ($P \leq 0.05$) Level. Different letters denote significantly different groups.

The results of moisture content were ranged from 10.50% to 6.51% at lower (6%) and higher (10%) resin content MDF Board. Further, density is one of the most important factors affecting the properties of MDF board. Figure 1 shows that the resin content has significantly improved the board density i.e., increases gradually (0.63 to 0.75 gcm^{-3}) with increase in resin content from 6% to 10%. Further, as increasing the density of the board the mechanical strength increased which is confirmed by Eslah *et al*. (2012) and Lias *et al*. (2014) [4, 12]. The reason of such increase is that when the board density increases, it causes an increase in compression rate and contact between wood fibers and results in improvement of the mechanical properties.

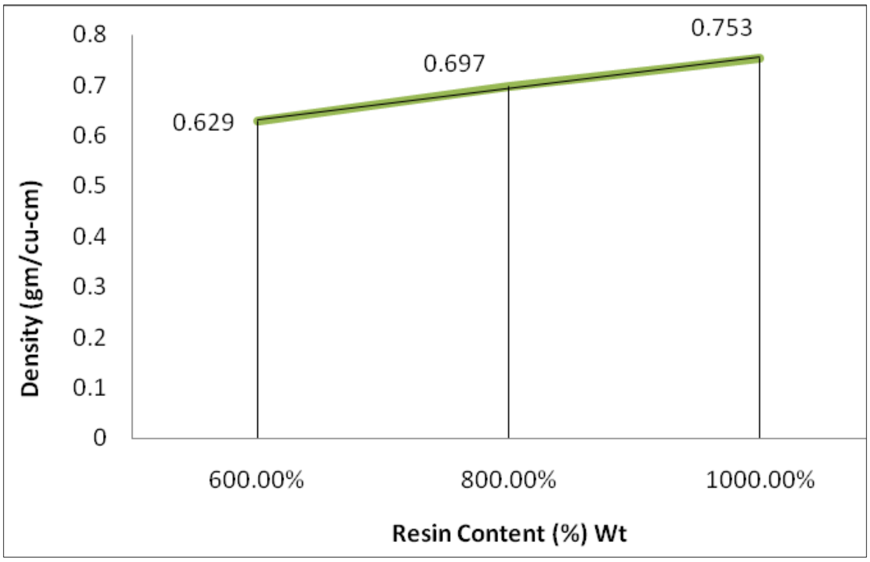

Fig 1: Effect of resin content (%) wt on density of the MDF boards

The MOR strength of specimens were ranges from 10.63 to 18.91 N/mm^2 whereas, IB strength 0.28-0.52 N/mm^2 at lower and higher resin content respectively. The results of MOR and internal bonding (IB) strength were also showed linear model of improvement ($P \leq 0.05$) with increase in resin content in MDF boards (Fig 2 & 3).

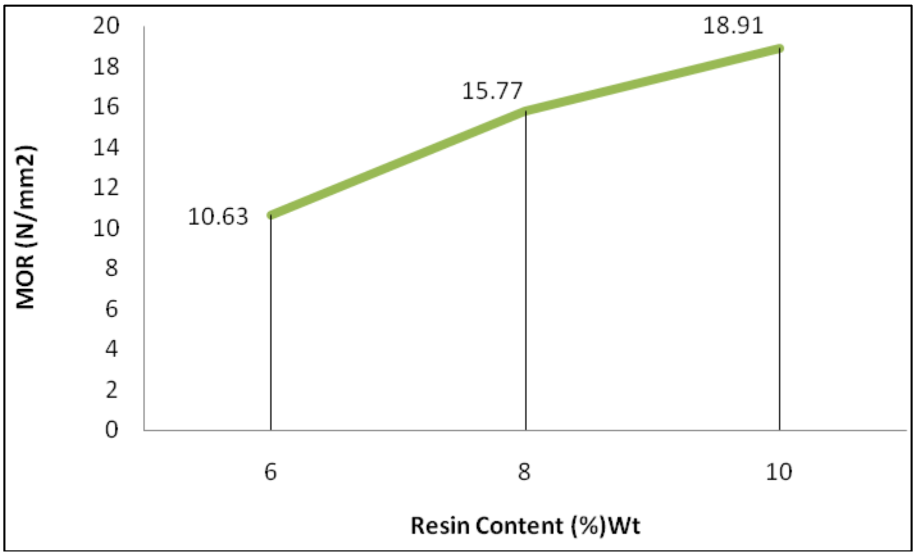

Fig 2: Effect of Resin content on MOR of the MDF boards

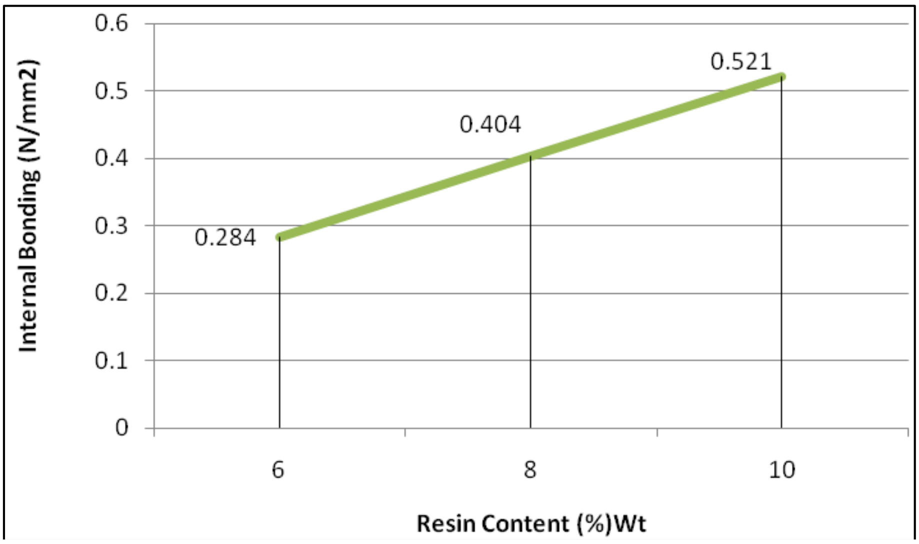

Fig 3: Effect of Resin content on internal bonding strength of the MDF boards

The screw withdrawal strength also increased with increasing resin content and the increment was significant when content was raised to 10% from 6% afterwards it showed more gradual trend as shown in figure 4.

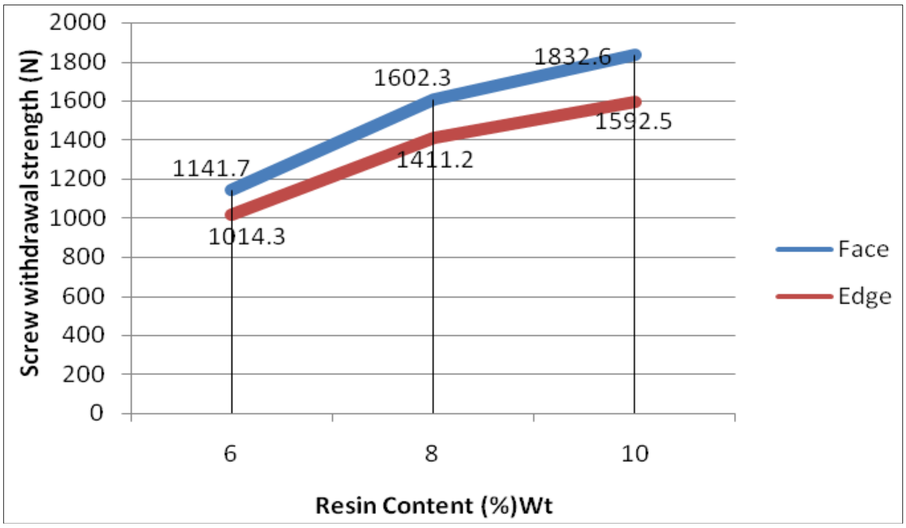

Fig 4: Effect of Resin content (%) on Screw withdrawal strength of the MDF boards

These findings demonstrate that there were improvements in all tested mechanical properties as the resin level was increased from 6 to 10%. These results were expected and are in line with the results of some previous studies (Chow and Zhao, 1992; Ashori and Nourbakhsh, 2008) [3, 1]. Similar Observations on the relationship between resin content and strength properties were also reported by other researchers on wood (Moslemi, 1974) [17], bamboo (Chen *et al*., 1991) [2] and oil palm fibres. At high resin content further bonding sites are available, thus improving the strength properties of MDF board.

The hydrophilic properties of lingo-cellulosic materials and capillary action induce intake of water during soaking and thus increase the TS and water absorption of the panel. Thickness swelling is normally related to the inter-particle/fibre bonding. A good bonding would result in low TS and vice versa. The results for water absorption, thickness swelling due to surface absorption showed a decrease in the values with the increase in resin content from 6% to 10%. The figure-5 & 6 also illustrates, the higher resin content (10%) were much more improved the dimensional stability of the board. The statistical analysis revealed that there is significant improvement ($P \leq 0.05$) in board properties as increase in resin content i.e., decrease in water absorption and TS of MDF board. Hence, the board manufactured with higher resin content generally result in better dimensional stability means lower TS and WA than boards fabricated with lower resin content. These results are in agreement with other researcher on natural fiber composites (Norul Izani *et al.*, 2012; Kapil *et al.*, 2017) [18, 11]. Nugroho and Ando (2000) [19] concluded that higher resin levels could enhance the inter-fibre bonding and reduce the void spaces, thus resulting in lower WA. Tangjuank and Kumfu (2011) [21] also concluded the MDF board fabricated with higher resin content, the binder is cured more effectively in the void spaces of the board and there is less water absorption.

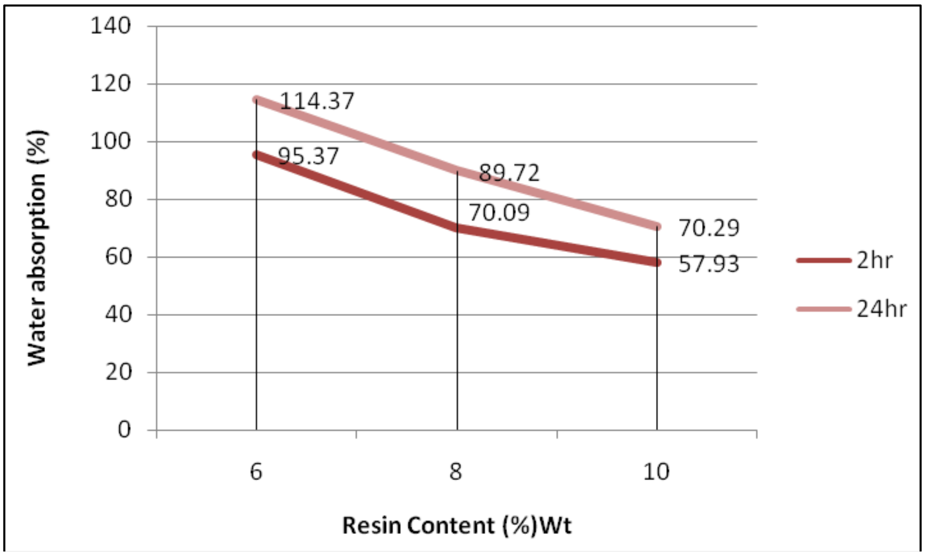

Fig 5: Effect of resin content (%) on water absorption of the MDF boards at 2 hrs and 24 hrs.

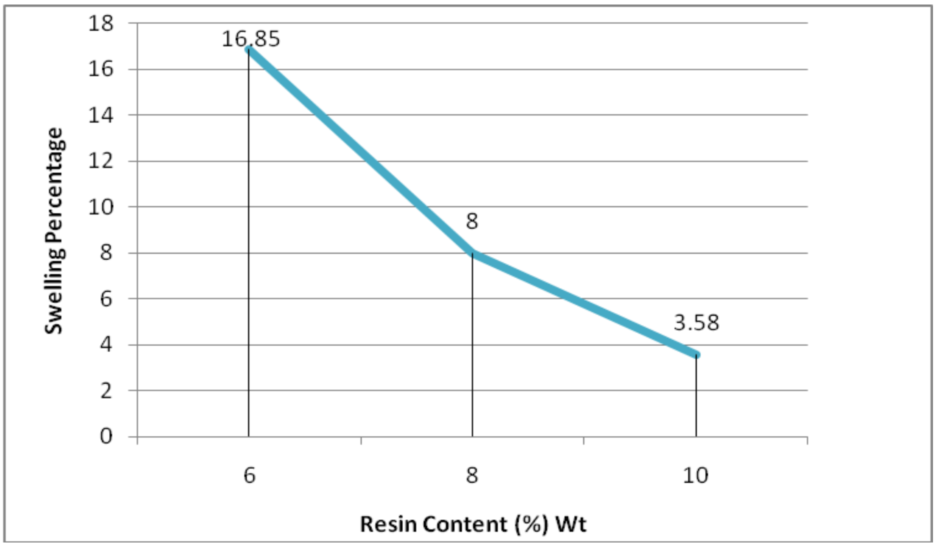

Fig 6: Effect of Resin content on thickness swelling (TS) due to surface absorption of MDF boards.

The furthermore improvement in physical/mechanical properties can be achieved by adding sizing material such as paraffin wax. Thus, it is observed that the most of the properties of the MDF board were fabricated with higher resin i.e., 10% meet as per the IS specification 12406 (2003).

Conclusion

From the above study, it is concluded that *B. polymorpha* can be utilized for producing medium density Fiber boards. The boards produced with phenol formaldehyde resin confirmed to IS specification for MDF board. In this investigation varying amount of phenol formaldehyde resin were used for making MDF boards from *B. polymorpha*. As the amount of resin increased, density of the boards was increased while, moisture content, water absorption and thickness swelling properties were reduced. Satisfactory boards were prepared by using 10 per cent phenol formaldehyde resin met the requirement in respect of IS: 12406 (2003) [8].

References

1. Ashori A, Nourbakhsh A. Effect of press cycle time and resin content on physical and mechanical properties of Particleboard panel made from the underutilized low quality raw materials. Ind. Crop. Prod. 2008; 28:225-230.
2. Chen FW, Jamaludin K, Chew LT. Particle board from Bamboo. Forest Research Institute Malaysia. Report No.56, Kepong Malaysia, 1991, 35-44p.
3. Chow P, Zhao L. Medium density fiber board made from phenolic resin and wood residue of mixed species. For. Prod. J. 1992; 42:65-67.
4. Eslah F, Enayati AA, Tajvidi M, Faezipour MM. Regression models for the prediction of poplar particleboard properties based on urea formaldehyde resin content and board density, Agricultural Science and Technology J. 2012; 14:1321-1329.
5. Fang H, Q Wu, Y Hu, Y Wang, X Yan. Fiber. Polym. 2013; 14:436
6. Halvarsson S, Edlund H, Norgren M. Ind. Crop. Prod. 2008; 28:37
7. IS: 2380. Methods of test for wood particleboards and boards from other ligno-cellulosic materials, IS: 2380 (Part- I- XXI), Bureau of Indian Standard, New Delhi, 1998.
8. IS: 12406. Specification for medium density fibre board for general purposes., Bureau of Indian Standard, New Delhi, 2003.
9. Jain S, Kumar R, Jindal UC. Mechanical behavior of bamboo and bamboo composite. J Mater Sci. 1992; 27:4598-4604.
10. Jindal UC. Development and testing of Bamboo-Fiber Reinforced Plastic Composites. J Composite Mater. 1986; 20:19-29.
11. Kapil Sihag, Anil Negi, Pawan Kumar Poonia, DP Khali. Physical and Mechanical properties of MDF board from Bamboo (*Dendrocalamus strictus*) using Needle Punching Technique International Journal of Chemical Studies. 2017; 5(6):2028-2030
12. Lias H, Kasim J, Johari NAN, Lyana I, Mokhtar M. Influence of board density and particle sizes on the homogenous particleboard properties from kelempayan (*Neolamarckia cadamba*), International Journal of Latest Research in Science and Technology. 2014; 3(6):173-176
13. Pannipa M, Marius CB, Arno F. Physical and mechanical properties of oriented stand lumber made from an Asian Bamboo (*Dendrocalamus asper* Backer) Eur. J. Wood. Prod. 2011; 69:27-36.
14. Lee AWC, Bai X, Bangi AP. Flexural properties of bamboo-reinforced southern pine OSB beams. Forest Prod J. 1997; 47(6):74-78.
15. Li Y, Mai YW, Ye L. Sisal fibre and its composites: a review of recent developments. Compos Sci Tech. 2000; 60:2037-2055
16. Mobarak F, Fahmy Y, Augustin H. Binder less lignocellulose composite from bagasse and mechanism of self-bonding. Holzforschung. 1982; 36:131-13.
17. Moslemi AA. particleboard, Material Vol.I, Southern Illinios University Press, USA. ISBN-13 9780809306558, 1994, 256p.
18. Norul Izani MA, Paridah MT, Astimar AA, Mohd Nor MY, Anwar UMK. Mechanical and Dimensional Stability Properties of Medium-Density Fibre board Produced from Treated Oil Palm Empty Fruit Bunch. Journal of Applied Sciences. 2012; 12:561-567. http://dx.doi.org/10.3923/jas.2012.561.567
19. Nugroho N, Ando N. Development of structural composite products made from bamboo I: Fundamental properties of Bamboo zephyr board. J. Wood Sci. 2000; 46:68-74.

20. Sulastiningsih IM, Nurwati1 SM, Kawai S. The effects of bamboo: cement ratio and agnesium chloride (MgCl2) content on the proper-ties of bamboo–cement boards. ACIAR Proceedings No. 107, Canberra, Australia, 2002.
21. Tangjuank S, Kumfu S. Particle Boards from papyrus fibers as thermal insulation. J. Applied Sci. 2011; 11:2640-2645.
22. Yusoff MNM, Kadir AA, Mohamed AH. Utilization of bamboo for pulp and paper and medium density fiberboard. In: Proceedings of national bamboo seminar I, Kuala Lumpur, Malaysia, 1994.
23. Zhang M, Kawai S, Yusuf S, Imamura Y, Sasaki H. Manufacture of wood composites using lingo cellulosic materials and their properties III. Properties of bamboo particleboards and dimensional stability improvement by using a steam-injection press. Mokuzai Gakkaishi. 1997; 43(4):318-3.