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Suitability of *Melia dubia* and *Eucalyptus tereticornis* for particleboard production

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Abstract
In this study the production of particleboard using two fast growing tree species *viz.*, *Eucalyptus tereticornis* and *Melia dubia* and using Urea Formaldehyde as adhesive. This experiment was conducted in Centaury plywood industry, Chennai. The physical and mechanical properties of two tree species were assessed for the suitability of particleboard production. Based on the physical and mechanical properties of the wood, Particleboards were produced using *Eucalyptus* tereticornis (100%) and *Melia* dubia (100%) as raw material. Physical and Mechanical properties of both the particleboards were recorded. Particleboard using *Eucalyptus tereticornis* has recorded maximum density of 642 Kg/m^3 with lower moisture content of 5.08%, observed minimum water in both 2hrs (18.26%) and 24hrs (51.45%) and also recorded minimum thickness swelling of 12.91%. In other hand *Eucalyptus tereticornis* based Particle board has Minimum Modulus of Rupture (MOR) of 12.30 N/mm^2, minimum Screw withdrawal strength load of 1825Kg/m^3 in face and 992 Kg/m^3 in edge. Observed maximum Modulus of Elasticity (MOE) of 2098 N/mm^2 with more Internal Bonding of 0.36 N/mm^2. From this study, results clearly showed that, both fast growing tree species having good physical and mechanical properties for the production of particleboard but compare with these two tree species *Eucalyptus tereticornis* is highly suitable for production of good quality particleboards.

Keywords: Particleboard, *Melia dubia*, *Eucalyptus tereticornis,* Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

Introduction

Wood is a material of great economic importance and it is found throughout the world and can be sustainably managed as a renewable resource. Rising world population is the driving force of increasing consumption of wood and wood-based products. The most effective way to meet the growing demand for wood are establishment of fast-growing tree plantations using the underutilized tree species and fibrous agricultural residues. These resources can play a key role in providing balance between supply and demand and decrease the demand on natural forest (Hegazy *et al*., 2010) [11]. Greater attention to short-rotation forestry on agricultural land and on fertile forest soils could offer a way to provide wood-based industries with enough wood resources and people in the developing world with enough fuel, while conserving natural forests.

The shortage of timber from natural forests has therefore created a need for a substitution of new resources in the current timber industry. Growing social demands for various wood-based panel products leads to the continuous efforts to find new wood resources as an alternative to solid wood from natural forests (Ramadan Abdel-Sayed Nasser, 2012). Wood composites include a range of different derivative wood products which are produced by binding the strands, fibres or boards of wood together and different types of wood composites are plywood, core board, sandwich board, particle board, laminated board. Particleboards are widely used because they enable wood particles or non-wood particles from relatively useless small size and or low-grade timber to be transformed into useful large panels. When phenolic resins are used as binders, particleboards are characterized by good physical and mechanical properties (Lubi and Thachi, 2007) [6]. The Particleboard production forms about 57% of the total production of wood-based panels and is growing at a rate of 2 to 5 percent annually.

The durability of particleboard panels has always been a major concern as demonstrated by the increasing use of chemicals for preserving against decay and termite attacks. The geometry and homogeneity of the particles, the types of thermosetting resin, the density and the fabrication processes can be modified to produce products that are suitable for specific application (Silva *et al*., 2013) [16]. The selection of species based on an evaluation of their physical and mechanical properties, as well as their potential to supply wood in adequate quantities, are also relevant criteria for industrial production. Compaction ratio is the relationship between panel density and wood density, and it should be at least 1.3 to ensure sufficient compaction for panel formation (Moslemi, 1974) [1]. Panels with a higher compaction ratio contain a larger amount of wood particles and consequently present greater compaction, resulting in improved hygroscopic swell of the wood and better release of the compression tension generated during the pressing process (Iwakiri *et al*., 2010) [12]. In this juncture, two important fast growing tree species were selected for assess the suitability of particleboard production based on their Physical and Mechanical properties.

Melia dubia belong to the family Meliaceae and has its trade name as Malabar Neem. Large deciduous and fast-growing tree with wide spreading branches on a stout, straight, tall bole. Young shoots with inflorescence covered with mealy stellate hairs. It is indigenous to the Western Ghats of Southern India and is common in moist deciduous forests of Kerala. Outside India, it is found in Sri Lanka, Malaysia, Java, China and Australia (Parthiban *et al*., 2013) [17]. *Melia dubia* grows up to 40 feet within two years of planting and has the potential of yielding up to 40 tons of biomass on an average per acre per annum of 10-year-old plantation.

Eucalyptus tereticornis is a fast-growing, evergreen tree with a large, open or fairly dense crown. *Eucalyptus tereticornis*, commonly known as forest red gum is a species of tree that is native to eastern Australia and southern New Guinea. It grows from 18-45metres tall or taller. The bole is usually straight; when growing in the open it will often branch from low down, otherwise it can be unbranched for more than half the tree's height and from 100-180cm in diameter (Hassan *et al*., 2020) [23]. This tree is potential of yielding up to 30 tons of biomass on an average per acre per annum of 6-year-old plantation.

Materials and methods

The experiment procedures of this work were carried out using wood of *Melia dubia* (Malabar neem) and *Eucalyptus tereticornis* (Red gum tree) collected from farmer's plantation. The following accepted standard procedures were used to assess the physical and mechanical properties of the particleboard.

Physical properties

Moisture Content - IS 2380 (Part 3)-2005

The initial weight of wood is weighed (W_1) and dried in hot air oven at 103 ± 2°C for 4 hours until a constant value is obtained. The final weight (W_2) of the wood is determined and moisture content was calculated as below:

$$\text{Moisture Content} = \frac{W_1 - W_2}{W_2} \times 100$$

Density - IS 2380 (Part 3) - 2005

The mass of the wood was determined to an accuracy of 0.2% and volume was determined using length, breadth and thickness of the wood. The density of the wood is calculated with mass in grams and volume in cm^3.

Volume = Length (cm) x Breadth (cm) x Thickness (cm)

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

Water Absorption after 2 and 24hrs: IS 2380 - Part 16: (2005)

Each specimen of dimension 30 x 30cm is prepared and all four edges are smoothly trimmed. The four edges of the specimens shall be covered with wax coating and submerged horizontally under 25 mm water at a temperature of 27 ± 2ºC. The quantity of water absorbed shall be calculated from the increase in mass of the specimen during the submersion and water absorption shall be expressed in percentage. The formula for determining water absorption is as:

$$\text{Water Absorption (\%) after 2 hrs.} = \frac{W_2 - W_1}{W_1} \times 100$$

$$\text{Water Absorption (\%) after 24 hrs.} = \frac{W_3 - W_1}{W_1} \times 100$$

Thickness Swelling: IS 2380 - Part 17: (2005)

The thickness of the sample edge is measured at three points along one long edge approximately 50mm, 100mm and 150mm from one end. Each test specimen shall be immersed in fresh clean water having a temperature of 27 ± 2°C, and water renewed for each test. After 2hours, each test sample was withdrawn from water and wiped with damp cloth. The sample thickness is measured at the same point as before and thickness increased is recorded as the formula given below:

$$\text{Thickness Swelling (\%)} = \frac{T_2 - T_1}{T_1} \times 100$$

Where

T_1 = Initial thickness of sample (mm).

T_2 = Final thickness of sample after two hours dipping in water (mm).

Mechanical Properties

Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

This test is intended to determine the strength (modulus of rupture), stiffness (modulus of elasticity) and other properties related to flexural stress. The preconditioned samples are tested on Universal Testing Machine as per procedure laid out in IS 2380 Part 4-(2005). The dimensions of test specimen are as below;

Grain direction is parallel to grain -62.6cm x 5cm x 1.2cm

Grain direction perpendicular to grain -33.8cm x 5cm x 1.2cm

The Modulus of rupture (Parallel and Perpendicular to grain) and Modulus of Elasticity (Parallel and Perpendicular to grain) were calculated using following equations;

$$\text{MoR (N/mm}^2) = 3\frac{P'L}{2bh^2}$$

$$\text{MoE (N/mm}^2) = \frac{PL^3}{4bh^3\Delta}$$

Where

In both the equation, b is the width of the sample in (mm); h is sample thickness in (mm); P' is the maximum load (N); Δ is deflection at proportional limit in (mm); L is length of span (mm); P is the static bending maximum load (N); MoR is Modulus of Rupture and MoE is Modulus of Elasticity.

Tensile strength perpendicular to Surface (Internal Bond Strength)

The tensile strength perpendicular to the surface was determined using thirty square conditioned specimens of 5 x 5cm from each panel according to IS 2380 part-06:2005.

Internal bond (IB) strength was calculated from the formulae:

$$\text{Internal Bond} = \frac{P_s}{b \times l}$$

Where

P_s is the rupture load, and

L is the length of the specimen

Nail and screw holding power test: -Test method: IS 2380 part-14: (2005)

The length and width of the test specimen shall be 150 mm and 75mm respectively. The thickness shall not be less than 12 mm. The specimen holding fixture shall be attached to the lower platen of the testing machine. The specimen shall be inserted in the fixture with the head of the screw or nail up. The maximum load required to withdraw the screw or nail shall be the measured.

Result and Discussion

The physical and mechanical properties of raw materials affect the quality of particle board produced using Melia and Eucalyptus. The moisture content of panel was higher in *Melia dubia* (6.90%) and lowest in *Eucalyptus tereticornis* (5.08%) respectively as in Table 1. This variation in moisture content may be due to the presence of chemical composition of raw materials as *Eucalyptus tereticornis* which contain high concentration of allelochemicals may lead to lower moisture content of panel (Maloney 1993) [4]. The panel moisture content of both *Melia dubia* and *Eucalyptus tereticornis* were lower when compared to panels of *Eucalyptus grandis* (8.3%) and rice husk (8.6%), (Melo *et al* 2009) [9].

Density is one of the important characteristics that shows better physical and mechanical properties of the particle panel. Higher compaction ratio in the board is influenced by increase in board density (Lias *et al*., 2014) [19]. The mean value of density varied from 621kg/m^3 in *Melia dubia* and 642kg/m^3 in *Eucalyptus tereticornis*. The difference in density might be due to greater volume of particles, resulting in large release of compressing tension enforced during the pressing time. Similar mean board density value was reported by (Gebrewahid *et al*., 2019) [22].

Water absorption

The water absorption percent of particleboard was observed at 2hours and 24hours' time interval. Panel made from *Melia dubia* shown highest water absorption percent at 2 and 24 hours with 25.44 and 73.77% and lowest values in *E. tereticornis* with 18.26% and 51.45% respectively. The variation in absorption may be due to particle orientation and the mixture of chemicals and materials, which was higher than those of *Sequoia sempervirens* and *Pinus taeda* (range between 26.3 and 55.4%) at 24-hour time period (Iwakiri *et al*., 2014) [12]. Low absorption of water by panel may be due to low porosity on the board surface resulting from the higher density made diffusion of water difficult to the Particle board.

Thickness Swelling

Particle board had thickness swelling values ranging from 12.91 to 16.14 after 2 hours water soaking as shown in (Table 1). The highest value of thickness swelling was shown by *Melia dubia* (16.14) and lowest value by *Eucalyptus tereticornis* (12.91) respectively. The thickness swelling of *Melia dubia* after 2 hours immersion increased above the standard value (12%) and did not satisfy the requirement. The differences in thickness swelling of the particle board produced may be due to the chemical composition of the wood (Akgül and Tozluoğlu 2008, Nemli *et al*., 2009) [8, 10]. Lower compaction of particles increases water penetration into the particle board and consequently requires shorter time to diffuse into the panel (Chiang *et al*., 2014) [20]. Particle geometry and structure also leads to internal swelling of panel and cause deformation (Sotannde *et al.*, 2012) [15].

Table 1: Physical Properties of particleboards using *Melia dubia* and *Eucalyptus tereticornis*

Sl. No.	Species	Density (kg/m^3)	Moisture Content (%)	Water absorption (%)		Thickness swelling (%)
				2 hrs.	24 hrs.	
1.	Melia dubia	621	6.90	25.44	73.77	16.14
2.	Eucalyptus tereticornis	642	5.08	18.26	51.45	12.91

Table 2: Mechanical Properties of Particleboards using *Melia dubia* and *Eucalyptus tereticornis*

Sl. No.	Parameters		Species	
			Melia dubia	Eucalyptus tereticornis
1.	Modulus of Rupture (MOR) N/mm^2		15.01	12.30
2.	Modulus of Elasticity (MOE) N/mm^2		2090	2098
3.	Internal Bond (IB) N/mm^2		0.30	0.36
4.	Screw withdrawal strength Load (kg/cm^2)	Face	2353	1825
		Edge	1198	992

Mechanical Properties

Mechanical properties i.e., Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Internal Bond strength (IB) and Screw withdrawal strength (SWS) of Particle boards from *Melia dubia* and *Eucalyptus tereticornis* are shown in Table 2.

Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

The Modulus of Rupture (MOR) was highest in *Melia dubia* (15.01 Nmm^{-2}) and higher Modulus of Elasticity (MOE) was shown by *Eucalyptus tereticornis* (2098 Nmm^{-2}) as shown in

Table 2. Panel performance and binding quality is influenced by the type and quality of resin (Ratkha *et al*., 2012) and higher density of wood affects correspondingly higher bending strength of manufactured panel (Franz *et al*., 1975) [2].

Internal Bond Strength (IB)

Internal bonding is one of the most important parameters for qualitative characterization of Particle board. This property indicates how significantly the bonding performed between the particles and resin used (Melo *et al*., 2014) [9], and directly influence all other physio-mechanical parameters determined in the study. The board made from *Eucalyptus tereticornis* (0.36Nmm^{-2}) had higher internal bonding compared to *Melia dubia* (0.30 Nmm^{-2}) panel. The internal bond of *Eucalyptus tereticornis* and *Melia dubia* is higher than Particleboards of *Bambusa vulgaris* (0.22 N mm^{-2}), *Oryza sativa* (0.04 N mm^{-2}) and *Eucalyptus grandis* (0.24 N mm^{-2}) (Melo *et al.*, 2014) [9]. The higher mean value of internal bond for the panels made from *E. tereticornis* and *M. dubia* may be due to higher resin content (Rathke *et al.*, 2012) [14], low moisture content and higher amount of adhesive available per particle (Winistorfer and Dicarlo 1988) [3].

Screw withdrawal strength (SWS)

The screw-withdrawal strength was higher in *Melia dubia* for both face (2353kg cm^{-2}) and edge (1198kg cm^{-2}) and lower Screw withdrawal strength was recorded in *E. tereticornis* for face (1825kg cm^{-2}) and edge (992kg cm^{-2}) respectively. Cunha *et al*., (2014) reported that for panel produced with *Eucalyptus benthamii*, *Eucalyptus dunnii* and *Eucalyptus grandis* average values of screw withdrawal resistance on the surface and edge, in the range of 1042 N to 1472 N. Chaharmahali *et al*., 2008 [7] reported that increase in screw withdrawal strength may be due to low fibre content and higher internal bond strength.

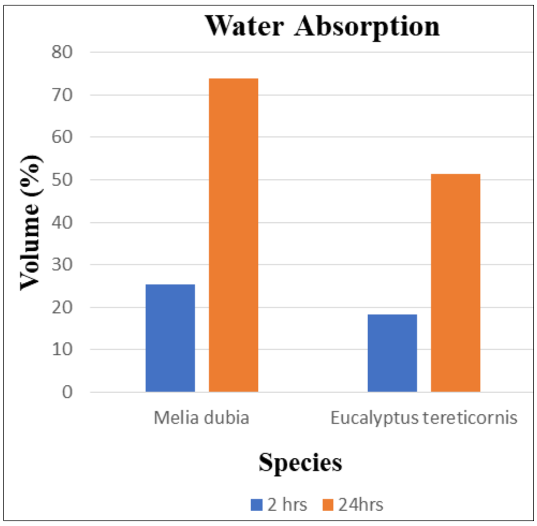

Fig 1: Water absorption percentage of Particle board from Melia dubia and Eucalyptus tereticornis

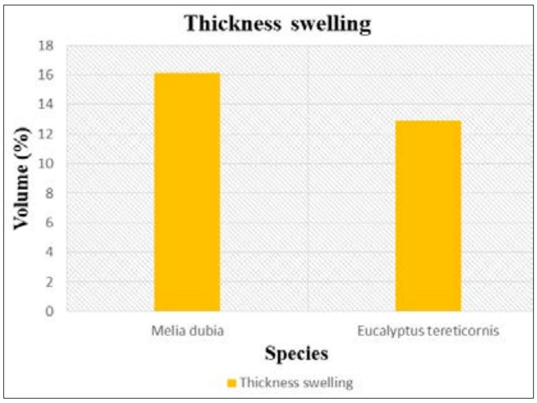

Fig 2: Thickness swelling percentage of Particle board from Melia dubia and Eucalyptus tereticornis

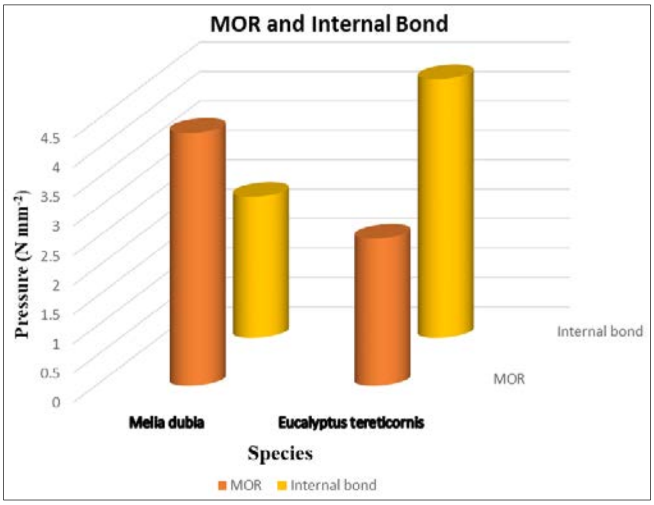

Fig 3: Static Bending strength and Internal Bond strength of Particle board from Melia dubia and Eucalyptus tereticornis

Conclusions

This study assessed some of the mechanical and physical properties of experimental particleboard panels manufactured from *Melia dubia* and *Eucalyptus tereticornis*. Density and Internal Bond strength were the main parameters influencing the physical and mechanical properties of the panels. Based on the result of work, *Melia dubia* and *Eucalyptus tereticornis* trees found to be suitable for Particle board production. *Eucalyptus tereticornis* is the highly suitable fast growing short rotation tree species for production of high quality particleboard compare with *Melia dubia* in terms of both physical and mechanical properties of the panel.

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