Effect of Resin Content and Density on the Properties Three Layer Particleboard from Kelempayan (*Neolamarckia cadamba*) and Wood Shaving

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Abstract

Particleboard is a composite panel product consisting of cellulosic particle of various sizes that are bonded together with a synthetic resin or binder under pressure and heat. The species of Kelempayan (*Neolamarckiacadamba*) with diameter 40 cm at breast height 25m height, from 1 log diameter was converted into particle by using scale knife ring flaker. The target densities were 500 kg/m^3, 600 kg/m^3 and 700 kg/m^3. The particle that was used in this process is unscreened and was dried to certain moisture contain. The particleboard was produced in different densities and resin contents; 8%, 10% and 12% with addition 1% of wax using adhesive urea formaldehyde (UF). This research is to determine the physical and mechanical properties of particleboard and effects of resin contents and density on Kelempayan and shavings on particleboard properties. The particleboard testing followed JIS Standard to determine the physical properties. Collected data was analysed by using Microsoft Excel and Statistical Packages for the Social Science (SPSS). From the result, Wood ratio showed significant effect to all board properties. Whereas for resin content, there were significant impact on MOR, TS and WA.

Keywords: *kelempayan*, woodshaving, resin content, layered particleboard

1. INTRODUCTION

Timber is a valuable natural renewable material that has helped countries leads sustainable development over hundreds of years. Modern plywood, as an alternative to natural wood, was invented in the 19th century, but by the end of the 1940s there was not enough lumber around to manufacture plywood affordably. Particleboard was intended to be a replacement composite. It is any combinations of two or more materials, in any forms and for any use (Cheetham, 1978).

The development of the particleboard industry has been characterized by large and dramatic changes in equipment, resins and levels of automation since its inception in the early forties. Particleboard is wood composite manufactured from wood particles, such as saw mill shavings, chips, or even sawdust, and pressed with a synthetic resin or other suitable binder. It has found typical applications as furniture, cabinets, flooring, table, counter and desktops, office dividers, wall and ceiling, stair treads, home constructions, interior signs, bulletin boards, and other industrial products (Tabarsa, Ashori, & Gholamzadeh, 2011).

The developing countries have poor resources of wood for particleboard manufacturing. As a result, non-wood fibres play a major role in providing the balance between supply and demand. It would seem that with suitable treatment almost any agricultural residue could be a suitable raw material for particleboard. Therefore the fast-growing species like *Kelempayan* provide an opportunity to satisfy the demand of wood and wood products (Taghiyari, Bari, & Schmidt, 2014). According to Chaowana (2013), with the rapid development of the global economy and constant increase in population, the overall demand for wood and wood based composites is rising.

Composite product like particleboard and plywood must use adhesive. Urea formaldehyde was selected for this research. Urea formaldehyde resins have been greatly used in the production of particleboard and other wood based panel industries. The colour of urea formaldehyde is white. The use of urea formaldehyde resin as a major adhesive by the forest products industry is due to low cost, low cure temperature, water solubility and ease of use under a wide variety of curing conditions (Akyüz, et al., 2010).

2. MATERIALS AND METHODS

2.1 Field Procedure

The *Kelempayan neolamarckia cadamba* (Kelempayan) was obtain from UiTM Jengka Forest Reserves, the trees were harvested using a chain saw and has the diameters are 26.1 cm and 23.2cm. The logs were debarked as the bark will affect the manufacturing process of particleboard. After felling, both logs were moved to factory and were cut into plain sawn logs by making a series of parallel cut on the logs. Next, the sawn logs ware cut into smaller dimension using band saw machine for easy handling during chipping. Chipping turns the sawn logs to particle size or chips suitable for manufacturing of particleboard. Next flaking is done to refine the size of the chips. This process produces smaller size of chip by using Knife Ring Flaker Machine. It can produced thickness in range from 0.1 mm to 1.0 mm and length from 0 to 20mm (Sari, et al., 2012). After flaking and chipping, Vibrator Screening Machine was used to screen the particles. The screening have 4 type sizes which is 0.5 mm, 1.0 mm, 2.0 mm and 5.0mm in thickness. The sizes used were less than 5.0 mm. The dust was discarded. The particles were then air-dried, followed by the oven drying to reduce the moisture content (MC) to below 5%. This reduce board blow caused by the presence of water in the particles up in the hot press section. The temperature was around 80°C and kept for 24 hours.

Shavings were obtained from the Wood Industry workshop in UiTM Pahang. The shavings were screened to obtain various sizes except for the fines, because the fine can affect the particleboard. Then, shaving were oven dried with the temperature of 80-90°C at 24 hours. The drying process will reduce the moisture content (MC) below 5%.

2.2 Board Manufacture

Three-layer particleboard were produced using Kelempayan as a core and shaving as the face and back with three different densities 500 kgm^{-3}, 600 kgm^{-3} and 700 kgm^{-3}.

Urea formaldehyde (UF) was used as binder with combination of resin content (core:face:back), 8%:10%:8%, 10%:10%:10% and 12%:10%:12%. The dried particles were placed in the blender where the calculated resins dosages were mixed.

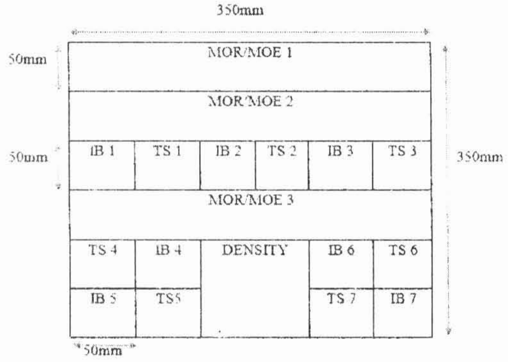
After blending with resin, the particles were manually distributed into a wooden mould to form a particleboard mat. Before forming, mould release agent is sprayed onto the tray to avoid the particle sticking on the tray and mould. In hot press machine, the mats were placed between a pair of heated platens, one sheet at a time. The hot press was set at three stage pressure cycle as per Table 2.1. The process is to cure the particleboard and increase the board strength.

Table 2.1: Hot press time and pressure

Steps	Times(minutes)	Pressure(psi)
1	3	1800
2	2	1200
3	1	800

After hot press, the board was separated from metal plate after several minutes and cooled at 24°C about 4 to 6 minutes for conditioning.

The board were trimmed and sized into accurate dimension for testing process using the table saw machine. The lines were drawn on the board face for standard size of each test (Figure 2.1). This is standard specifying method of test for determining dimensions and properties of wood based panels. The test include bending strength or modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding (IB), thickness swelling (TS) and water absorption (WA).



Note: MOR= Modulus of rupture, MOE= Modulus of elasticity, IB= Internal bonding, TS= Thickness swelling

Figure 2.1: Particle board sampling pattern

3. TESTING METHODS

3.1 Bending Strength

The objective bending test is to measure the strength of the particle. MOR is measurement of the rate rupture pieces of the particleboards simple and MOE is to measure the resistance to bending from stiffness of a beam. The board are tested using Universal Instron Machine with the marks number of samples, the board is tested until it broken and the result are measured in MPa. MOE and MOR calculation follows.

MOE (N, mm^{-2}) $= PL^3/48ID$

Where: P: load deflection at midspan in inches/mm

L: span in inches

I: moment or inertia, a function of beam size

D: (width x depth^3)/12 for beams with rectangular cross section

MOR (N, mm^{-2}) $= 1.5PL/bd^2$

Where: P: breaking (maximum) load

L: distance between support or span (mm)

d: depth of the beam (mm)

b: width of the beam (mm)

3.2 Internal Bonding

Internal bonding (IB) determined the tensile strength of the board. For internal bonding, the board was sized to 50 mm x 50 mm. The surface of the board was sanded to avoid failure the test. It was then glued the steel block using an epoxy: hardener mixed ratio of 1:1. The test block was allowed to cure for 24 hours. Test was by using Universal Instron machine i.e. the machine will pull the two sides of block until it break at the middle of sample. IB is calculated as follows:

$$\text{Internal bond } (N/mm^2) = \frac{P'}{2bL}$$

Where: P' = Maximum load (N) at the time of failing for

b = Width (mm) of sample

L = Length (mm) of sample

3.3 Thickness Swelling

The purpose of this testing is basically to determine how much the particles absorbs the water. This thickness swelling testing also indicates how durable the particleboard is to the water. The measurement for the sample is 50 mm x 50 mm. Firstly all the data must be recorded, and the all samples were soaked into water for 24 hours. All of the samples must be carefully soaked into the water to make sure that the overall of the samples were properly soaked. The formula used in thickness swelling is as follow:

$$\text{Thickness swelling: } \frac{\text{Final dimension - Initial dimension}}{\text{Initial dimension}} \times 100$$

3.4 Water Absorption

The purpose of this testing is basically to determine how much the particleboard absorbs water. This thickness swelling testing also indicates how durable the particleboard is to the water. The formula that is used in calculation to know the percentages of water absorption is:

$$\text{Water absorption: } \frac{\text{Final weight} - \text{Initial}}{\text{Initial weight}}$$

4. RESULTS AND DISCUSSIONS

4.1 Mechanical and physical properties of particleboard from *Kelempayan* spp

Table 4.1 show the average result of mechanical and physical properties of the three layer particleboards made from Kelempayan and shaving. The results were compared based on resin contents and particleboard densities. The results were evaluated for Type 13 JIS A 5908:2003 particle Board. Particleboard of density 700 kg/m³ with solid resin contents 8%, 10% and 12% achieved the standard. The MOE however did not achieve the standard for all boards. Next, for internal bonding, density 600 kg/m³ and 700kg/m³ with resin content 10% and 12% achieved the standard. While the physical properties of three layer particleboard from Kelempayan and shaving on thickness swelling on particleboard density 500kg/m³ with solid resin content 10% and 12% achieved the standard.

Table 4.1 Average result of mechanical and physical properties of three layer particleboard from Kelempayan and shaving

Board density	Resin content %	MOR (MPa)	MOE (MPa)	IB (MPa)	TS %	WA %
	8:10:08	4.971	758.872	0.0695	20.915	143.282
500	10:10:10	7.327	1,196.55	0.1011	8.8287	110.47
	12:10:12	6.477	1,035.49	0.0678	9.7416	101.292
	8:10:08	12.768	1,880.47	0.0393	14.4905	76.0466
600	10:10:10	12.361	1,862.02	0.2729	14.3037	80.5965
	12:10:12	8.135	1,219.02	0.2294	19.599	100.985
	8:10:08	15.096	2,092.55	0.1389	22.131	79.8982
700	10:10:10	15.597	2,340.70	0.22	16.6295	73.1701
	12:10:12	17.008	2,390.67	0.2218	18.4736	72.4205
JIS 2003		>13..00	> 2500	>0.2	< 12	n.a
type 13						

(Sources: JIS A 5908:2003)

Note: MOR =Modulus of rupture, MOE= Modulus of elasticity, IB= Internal bonding, TS=thickness swelling, WA=water absorption

4.2 Statistical significant for Particleboard

Table 4.2 shows the summaries of ANOVA of effect on density and solid resin content for three layer particleboard made from Kelempayan and shaving. Density and solid resin content of particleboard shows the significant of effects on all board properties. The relationship between density and solid resin content were shown to have significant difference.

Table 4.2: Summaries of variance (ANOVA) Of the effects density and solid resin content.

Source of variance	DF	MOR	MOE	IB	TS	WA
Density	2	230.341**	259.369*	25.446**	6.989*	117.976**
Resin content	2	5.289*	12.744*	20.249**	12.826**	9.481*
Density*resin content	4	14.114**	19.361**	8.334**	7.112**	22.367**

Note: MOR =Modulus of rupture, MOE= Modulus of elasticity, IB= Internal bonding, TS=thickness swelling, WA=water absorption

4.3 Effect of density on mechanical and physical properties

Three different densities (500kg/m³, 600kg/m³, 700kg/m³) were used in this study. Densities effects were tested by determining the mechanical properties of the boards. Figure 4.1 showed the value of MOR, MOE and IB. The values show increase in MOR and MOE with the increase density from 500kg/m³, 600kg/m³ and 700kg/m³ for MOR and MOE. The trend is different for IB. Internal bonding for density 600kg/m³ is highest compared to densities 700kg/m³ and 500kg/m³. The increase of the mechanical properties was due to the availability of more particle at higher density thus increasing the bonding ability of the particles (Baharoğlu, et al., 2012).

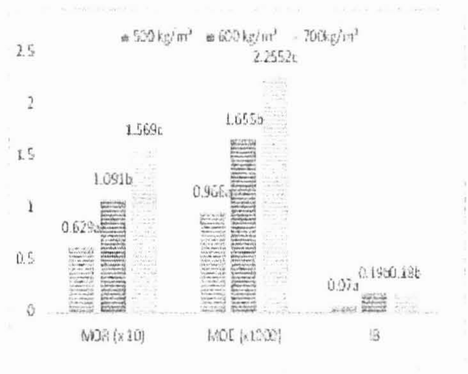


Figure 4.1 Effect of density no mechanical properties.

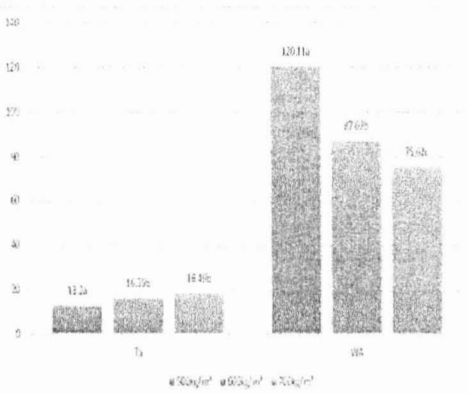


Figure 4.2 Effect of density on physical properties of the board

Figure 4.2 shows the effect of density on physical properties of the board. There is a difference between the water absorption and thickness swelling based on results. The thickness swelling is lowest for 500kg/m³, followed by 600kg/m³ and highest swelling on density 700kg/m³. The opposite is seen with water absorption. Water absorption starts with lowest value from 700kg/m³ to 600kg/m³ and the highest on 500kg/m³.

4.4 Effect of resin content on mechanical and physical properties

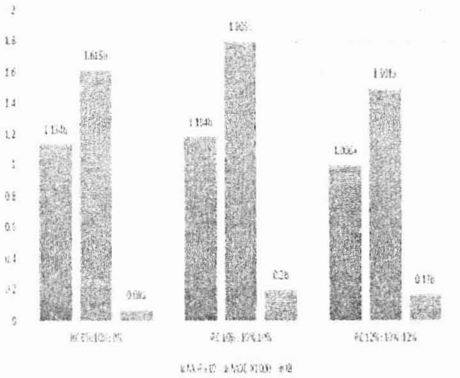


Figure 4.3 Effect of resin on mechanical properties

Different solid resin content (8%:10%:8%, 10%:10%:10% and 12%:10%:12%) for (core:face:back) were used in this study to evaluate the effect of solid resin content on mechanical properties. Figure 4.4 showed the value of MOR, MOE, and IB. The values for MOR and MOE show the increase with solid resin content increase from 12% solid resin content to 8% solid content and the highest MOR and MOE is seen for resin solid content of 10%. The internal bonding was different from MOR and MOE in that the 8% was the lowest compared to 12% and the highest was again 10% solid resin content.

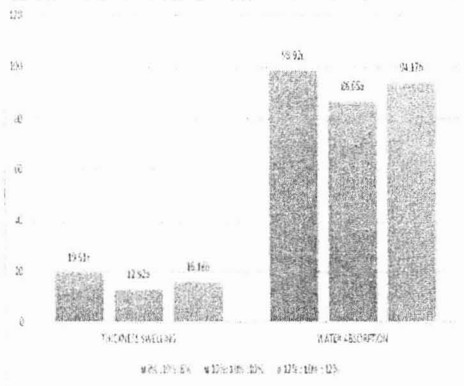


Figure 4.4 Effect solid resin content on physical properties.

Figure 4.4 shows the effect of resin content on thickness swelling and water absorption of board. For thickness swelling at solid resin content 8% give higher value 19.51% and it was decreased at 12% and 10% at the value 12.92% and 16.18%.While, the water absorption of board are directly increased when solid resin content used were decreased. Lowest resin content 8% gives highest (poor) value of water absorption 98.92% followed by 12% and 10% at the value 86.65% and 94.17 % respectively. High resin content give good physical properties of board on thickness swelling on a similar study conducted by Akyüz et al., (2010).

5. CONCLUSIONS

According to the result, when board densities increased from 500kg/m³ to 700kg/m³, values of MOR, MOE were increased but for physical properties (TS and WA) the values were decreased significantly. All the final values of this test were referred to Japan Industry Standard (JIS A 5908:2003) Type 13. Wood shaving has low bulk density compared to particle from Kelempayan and the low bulk density need the smaller quantity of particle to fulfil the space. The low bulk density is good to produce particleboard where if the space is reduced it can make board more compact and stable Generally all boards' combination could not achieve the MOE requirement for Type 13 JIS A 5908:2003. The results particleboard of density 700 kg/m³ with solid resin content 8%, 10% and 12% were able to achieve the standard for MOR. For internal bonding, densities 600 kg/m³ and 700kg/m³ with resin content 10% and 12 % achieved the standard.

Surprisingly, the thickness swelling of particleboard with density 500kg/m³ and resin content 10% and 12% passed the standard requirement.

6. RECOMMENDATION

Kelempayan a fast-growing tree, which shows potential as sources of new raw material to produce wood product. For wood shaving, this will be an innovation to make board, from waste. Utilisation of these materials may help the industries to reduce the wastage and minimize cost of production.

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