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Properties of Fiberboard from Durian Composite with Latex and Alkyl Ketene Dimmer

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Abstract: The new composite of compressed fiberboards with free urea-formaldehyde production from durian fiber composite with latex binder were investigated. The objective of this study is to evaluate the quality of compressed fiberboards bond with durian fiber and latex binder. In this experiment, compressed fiberboards were produced from durian fiber with latex (3:1), silica (30%), azadirachtin (40%) and Alkyl Ketene Dimmer (AKD, 4%) composites. The influence of AKD in reducing water absorption was investigated by varying ratio 0, 2, 3, 4 and 5% while varying titanium dioxide to lacquer ratio from 0, 0.2, 0.3 and 0.4% was studied to improve the mechanical property. Their composite materials were carried out from hot compression molding and examined the mechanical properties following JIS A5905-1994 and ASTM standard. The properties of the resulting mixed latex-fiber-silica azadirachtin and AKD were evaluated and compared with MDF. The new compressed fiberboards showed the good application material for energy conservation, environmental friendly and commercial market.

Key words: Durian fiber-latex composite, fiberboard, AKD, ASTM standard, energy, conservation, Thailand

INTRODUCTION

A highly increasing demand of wood composite products such as particleboards and Medium-density Fiberboard (MDF) for housing construction and furniture manufacturing has been in concern because of a resulting effect on the deforestation which could lead to a shortage of wood resources in the future. Hence, finding new resources as substitution to wood is necessary with the motivation to solve the problems of wood shortage, increasing consumption of wood and decreasing in supplies of wood-based materials. Therefore biomass, such as plants, branch wood and agricultural residues has been highly promoted as an alternative resource to substitute wood-based materials (plywood, MDF and particleboard).

In additional, agricultural residues play more important role as being substitute wood-based materials due to increased awareness on environment concern. As a result there are several studies reporting about making particleboards using rice straw, cotton stalk, sugar cane bagasse (Heslop, 1997; Zhongli and Anna, 2004), coconut shells (Almwdia *et al*., 2002), wheat straw (Han *et al*., 1998; Mo *et al*., 2003; Wang and Sun, 2002) sunflower stalks (Khristova *et al*., 1998) maize husks and cobs (Sampathrajan *et al*., 1992), coconut coir (Khedari *et al*., 2001, 2003, 2004), saline jose tall wheatgrass (Zheng *et al*., 2007), bamboo (Ismail *et al*., 2002a; Rao *et al*., 2010) and durian mixture coconut (Khedari *et al*., 2004).

Ajiwe *et al*. (1998) studied the moisture content, rate of water absorption and tensile strength of ceil boards which were produced from agricultural waste, i.e., rice husks and sawdusts. It was revealed that the products owned similar standards to those commercially available. Durian and coconut have been successfully used for lightweight concrete composite and particleboard production because of its low thermal conductivity (Khedari *et al*., 2004).

Also, new low-cost insulation particleboards from mixture of durian peel and coconut coir have been studied. The results indicated that particleboards have good mechanical properties such as internal bond low and thermal conductivity. In additional, particleboard quality depends on the properties of adhesives and bonding capability with fibers or particles. The contact angel

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between the outer surface of material and the adhesive has been used as an indicator of building capacity (wet ability) of an adhesive on fibers. In fact, Urea-Formaldehyde (UF), Urea-Melamine-Formaldehyde (UMF), Melamine-Formaldehyde (MF) or Phenol-Formadehyde (PF) resins have also become major adhesives for wood-based particleboards production. However, during the process of particleboard production, formaldehyde issue should be taken into consideration, since formaldehyde can be released from hot molding compressed process and emission from particleboards used as building and furnishing material, especially interior material building products. Nevertheless, there is a risk to human's disease and sickness due to Volatile Organic Compounds (VOCs) contaminated in air in offices and houses.

To overcome these problems, the use of low-formaldehyde and non-formaldehyde resins with less expensive and environmentally for particleboards production have been extensively studied.

So, far many formaldehyde-free wood adhesives from natural source have been studied such as Soy Flour (SF) (Prasittisopin and Li, 2010). Moreover, latex is one of several interesting formaldehyde-frees which could be used as an adhesive for composites material based on cellulose fibers (Ismail *et al*., 2002b; Jun *et al*., 2009; Abdelmouleh *et al*., 2007; Wang *et al*., 2007). Latex is the matrix and the fibers as reinforcing elements. The natural fibers such as pineapple, jute, coir, coconut and oil palm have been used for reinforcing latex rubber. These composite materials show behavior of the soft, elastic rubber matrix and the stiff, strong fibrous reinforcement. However, this research area is still opened.

The objective of this study is to examine the possibility of using durian fiber from durian peel as raw material and latex for developing the durian fiberboard reinforced with latex composite. Durian fiber was selected as reinforcement because durian peel is an abundant agricultural residue in Thailand. The durian's fiber-latex composites forming compressed fiberboards can be achieved by application of hot compression molding. The physical and mechanical properties; moisture content, density, specific gravity, water adsorption and thickness swelling, tensile strength, elongation at break, hardness shore A, thermal conductivity and contact angel have been investigated. Moreover, the influence of Alkyl Ketene Dimmer (AKD) has been examined.

MATERIALS AND METHODS

Latex concentrates 60%; type low ammonia was used as adhesives for making the compressed boards in this study. It was purchased from Rubber Research Institute of Thailand. Sodium Hydroxide (NaOH) was purchased from Merck. Sodium Silicate ($NaSiO_3$), Magnesium Sulfate ($MgSO_4$), Titanium dioxide (TiO_2) was obtained from Sigma-aldrich. Silica oxide (SiO_2) was purchased from Evonik industries. AKD was received from SCG. Azadirachtin was (40%) was commercial grade.

Sample preparation: The fresh durian peels were reduced into smaller particles and dried to remove water following general methods (Khedari *et al*., 2004). The chips were boiled in compressed boiler with 0.65 M NaOH for 10 h to treat the surface of durian peels. The treated fresh durian peels were washed three to four times using water until the pH value of washing water was about 7 followed spinning, retted fiber with H_2O_2 20%, $NaSiO_3$ 2%, $MgSO_4$ 0.05% and NaOH 1% in water bath at temperature 70-80°C for 3 h and oven-dried to 7% moisture content oven dried at 100°C 2 h. Four mixing ratio between durian fiber and latex were investigated as follows; 1:1, 2:1, 3:1 and 4:1 by weight, respectively.

The varying of AKD from 0, 2-4% were studied. The silica and titanium dioxide to lacquer ratio were 30% of latex and 0.4 of durian fiber, respectively. Azadirachtin (40%) was used as additive to improve the physical property for termites. Latex concentrates 60% were used as adhesion instead of Urea Formaldehyde (UF). After mixing durian fiber, chemical substances, latex and placing the mixture into rotary drum mixer. The mixture was then put to hot compression to form composite fiber boards at pressure 15 ton and a temperature of 150°C. Total pressing time was 12 min. Fiberboard samples were pre-conditioned at 25°C for 24 h to adjust moisture before testing the physical and mechanical properties. Compressed fiberboards size of $13\times13.5\times0.5$ cm^3 were cut into $50\times50\times0.5$ mm^3 and have been determined for mechanical properties according to ASTM standard method and JIS A5905-1994.

Evaluation of compressed fiberboard properties: Mechanical properties including moisture content, density, specific gravity, water adsorption and thickness swelling, tensile strength, elongation at break, hardness shore A, thermal conductivity and contact angel were measured to evaluate the properties of particleboards. The specific gravity of compressed fiberboard was determined according to ASTM D2395-07a while moisture content, density and tensile stress were determined according to JIS A 5905-1994.

Compressed fiberboards size of $13\times13.5\times0.5$ 5 cm^3 for water adsorption and thickness swelling, compressed fiberboards were cut into $50\times50\times0.5$ mm^3 and soaked in water lower 20 mm at room temperature for 24 h. Compressed fiberboard's thickness and weight were measured before and after 24 h of water immersion according to JIS A5905-1994. Tensile test and elongation at break were performed in accordance with ASTM 638 and ASTM D2240 for hardness shore A testing. Contact angle of compressed fiberboard was measured using ASTM D5946-04. Thermal conductivity was performed in accordance with ASTM C 177.

Scanning electron microscopy of durian fiber: The morphology of durian fiber before and after treatment with H_2O_2 was studied by SEM (model JEM-6400 Jeol Ltd., Japan). The surfaces of samples were coated with gold and analyzed by SEM which was operated in the Back Scattering Electron (BSE) mode at 15 kV.

RESULTS AND DISCUSSION

Surface treatments: Lignocellulose in durian fiber was treated by alkaline treatments. Figure 1 a, b showed the morphology of fibers before and after the durian shell surface with a solution of hydrogen peroxide. It was found that when the skin had a reaction with hydrogen peroxide at the concentration 15% (w/v) at 30 min which is the reaction of hydrogen peroxide in the isolated lignin from the fiber durian. The increasing of surface area and porous with effective adhesion between the fiber shell with latex and durian alkyl compounds was observed. A comparison between the native fiber and the alkaline treated one displays a formation of a rougher surface.

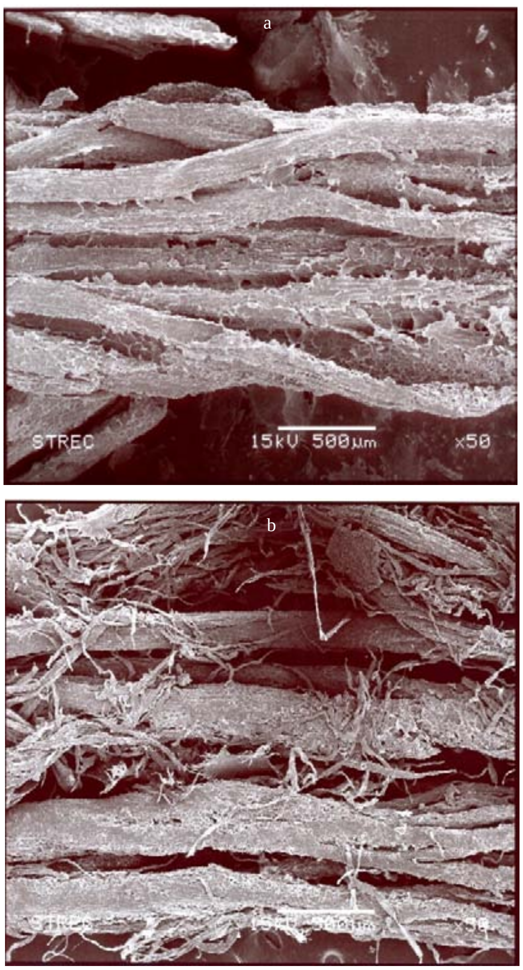

Fig. 1: SEM images of; a) durian fibers before treatment with a solution of hydrogen peroxide and b) durian fiber surface after treatment with a solution of hydrogen peroxide

Effect of mixing ratio of durian fiber with latex: Fiberboard manufacture fibers were mixed with latex and durian fiber ratio. From Table 1, it was found that the ratio of fiber per durian latex 1:1 and 4:1 can not produce fiberboard because there is a ratio of 1:1 and 4:1 fibers do not tire more grip as well as they should have. The small amount of latex fiberboard 2:1 ratio is approximately 4 mm thick and flexible latex-like fibers because the ratio of durian is similar to latex. The fiberboard of a 3:1 ratio by about 5 mm thickness and the hardness is similar to the fiberboard's thickness which is considered very similar. The ratio of 3:1 fiber per latex is suitable for the production of fiberboard.

Effect of mixing ratio of AKD with durian fiber: The study, the ratio of durian fiber with latex durian to alkyl ketene dimmer was shown in Table 2 and 3. The ratio between durian fibers mixed with latex, the alkyl ketene dimmer percent 0, 2-4 when tested by the absorption of water and found water absorption, 214.31, 182.15, 169.29 and 158.14, respectively (Table 2). The alkyl ketene dimmer at 4% to fiberboard pulled minimal water absorption. Table 3 shows the results for the ratio between durian fiber mixed with latex, the substance alkyl ketene dimmer-percent 0, 2-4 and 10 when tested by the

Table 1: Mixing ratio of durian fiber with latex

	Durian fiber:Latex (g)			
Raw material	1:1	2:1	3:1	4:1
Durian fiber	25	50	75	100
Latex	25	25	25	25

Table 2: Water absorption of mixing ratio of AKD with durian fiber

	Alkyl ketene dimmer (%)			
Durian fiber board	0	2	3	4
Water absorption	214.31	182.15	169.29	158.14

Table 3: Thickness swelling of AKD with durian fiber

	Alkyl ketene dimmer (%)			
Durian fiber board	0	2	3	4
Thickness swelling	169.57	125	109	107

Table 4: Properties of composite composed boards

Material properties	MDF	Durian fiber board
Specific gravity	0.79	0.70
Moisture content	5.46	4.12
Density	0.84	0.74
Water absorption	9.17	109.38
Swelling thickness	9.13	49.05
Tensile strenge	17.19	4.50
Elongation at break	5.46	5.75
Hardness (Shore A)	90.40	81.50
Thermal conductivity	0.14	0.10

swelling when immersed in water. It was found to have swelling on water 169.57, 125, 109 and 107, respectively which showed that the ratio between fibers durian mixed with rubber; the substance alkyl ketene dimmer at 4% was chosen. From the results, compressed fiberboards showed that the water adsorption and thickness swelling significantly decreased when AKD content was increased.

The presence of AKD could have positive effect on durian fiber and latex because AKD contains hydrophilic such as more OH groups and hydrophobic which can cross link between latex and fiber. The hydrogen bonding sites in the latex structure link OH group of AKD structure whereas rich hydrophobic in durian's fiber link hydrophobic of AKD structure, resulting in good matrix formed during the compounding process which is a good ability to resist water. The 4% of AKD results in the good for low water adsorption and thickness swelling. The adsorption and thickness swelling properties decreased with the increase of titanium dioxide in mixture ratio. At 0.4% is good for adsorption and thickness swelling properties. Additional of AKD and titanium dioxide can increase the resistance termite and reflect the sunshine, including of water repellant.

Physical and mechanical properties: The results of physical and mechanical properties are shown in Table 4. The reporting specific gravity, moisture content and density value of the compressed particleboard were 0.7, 4.12 and 0.74, respectively. The specific gravity, moisture content and density value of compressed fiber board was similar to wood Medium Density Fiber Board (MDF).The moisture adsorption and thickness swelling are higher than MDF because of binder and porous, void among the fibers. However, these values are better than control because of AKD. The tensile strength and hardness shore (A) obtained was significantly different from MDF because of using latex binder instead of UF and effect of durian's fiber. Elongation at break obtained was higher than MDF but thermal conductivity are better than MDF. Thermal conductivity of durian fiberboard was 0.10 whereas MDF was 0.14.

Contact angel: The result studied water droplets on the surface of the fiberboard durian fiber mixed latex and alkyl ketene dimmer-coating the surface with lacquer mixed with titanium dioxide. The initial contact angel of fiberboard durian fiber mixed latex was 75°C. Considering the contact angle at the same time, it was found that the measured contact angle is decreased over time because of the additive alkyl ketene dimmer.

CONCLUSION

The experimental investigation indicated that the optimum fiberboard properties are obtained with a mixture ratio of 3:1 (durian fiber and latex by weight) and AKD was 4%, the ratio of the suitability of titanium dioxide on lacquer is 0.4% of the fiber. The results indicated that latex could be used as binder instead of UF. Addition of AKD can significantly improve the mechanical properties, especially resistant water adsorption and thickness swelling of compressed fiberboards. The thermal conductivity of particleboards from durian fiber and latex is low, 0.10 W mK^{-1}. The results showed that these composite materials are suitable for gym, yoka, hospital, children playground such as soft floor wall or furniture and insulation including the building material to add environmental and energy friendly qualities. Besides, these composite materials could be used for cushioning material in packaging. In additional, the UF-free in processing is very interesting. However, these new composite material and parameters of the processing will be further developed in the future.

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