Effect of Water Content and Particle Size on Sawdust Liquefaction f or Adhesive Material

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Effect Of Water Content And Particle Size On Sawdust Liquefaction For Adhesive Material

Budy Rahmat, Suharjadinata, Rudi Priyadi

Abstract: The aim of this study was to determine the effect of water content and particle size of sawdust on its liquefying into wood adhesives. The water content and particle size of the sawdust as the respective treatment factors were arranged in a randomized block design, namely: (i) water content was varied as w_1 (22%), w_2 (19 %); and w_3 (14 %); and (ii) the particle size was varied as s_1 (sieved in 0.5 mm), s_2 (sieved in 1 mm); and s_3 (sieved in 1.5 mm). Experimental data were analyzed by Anova and continued with Duncan's multiple range test. The results of the experiments showed that, no interaction between the water content and the particle size of the sawdust to the volume of adhesive as the liquefying yield and the weight of the residue, but the interaction occured on the bonding strength of the adhesive. Sawdust size of 0.5, 1.0, and 1.5 were not affected on the liquefying process. While the water contents were affected to : (i) reduce volume of adhesive, which the highest by 22 % for 59.89 mL; and (ii) rise weight of the residue, which the highest was for 74.75 g. The highest bonding strength was obtained at a water content of 22% and size of sawdust between of 1 to l .5 mm.

Index Terms: liquefaction, particle size, moisture content, sawdust, adhesive

1 INTRODUCTION

Abundant wood waste generated from the processing of agricultural and forestry products in general has not been handled well. Examples are mostly found in Tasikmalaya City, West Java, Indonesia, industrial wood waste from furniture home industry just piled up in landfills, where it did not get burned then transported by a fleet of municipal waste and dumped in landfill [1]. The wood waste from the sawmill industry consists of: bark, wood chips and sawdust, each for 22, 8, and 10% of the volume of logs. These figures do not include the volume of waste generated at the level of the final processing such as furniture, namely shavings, dust and pieces of wood [1, 2]. Burning of wood waste impact rising CO2 emissions that contribute to global warming. Similarly, the landfill biomass on the surface or in the soil will occur anaerobic decomposition process that produces methane gas (CH4), which qualitatively have a stronger impact on global warming than CO2 [3,4,5]. Actually, with the conversion technology, all fresh lignocellulose (virgin biomass) and lignocellulosic waste (waste biomass) have prospects in the supply of raw materials to produce: (i) biomaterial (food, feed, fertilizer, fibers, adhesives, biocides, chemicals, forest produce etc.); and (ii) bioenergy (charcoal, bioethanol, biogas) [6]. Products from mild liquefaction can be applied as fuels and fuel additives or materials to make resins and polyurethane films [7, 8]. The general condition of the water content and particle size of sawdust is varied. Thus, it is important to know the water content and particle size suitable as a feedstock that process, so it can be the result of efforts to improve the process of liquefaction. This study aims to determine the effect of water content and particle size of sawdust in the liquefaction process of wood waste into a natural adhesive.

2 EXPERIMENTAL SECTION

2.1 Experimental Design

The experiment to determine the effectiveness of water content (K) and particle size of the sawdust (S) variations were arranged in a randomized block design (RBD) factorial pattern. Both these factors have to some extents, namely: the water content was varied as w_1 (22% or without drying), w_2 (19% after drying for 30 minutes); and w_3 (14% after drying for 60 minutes); and the size particel was varied as s_1 (sieved in 0.5 mm), s_2 (sieved in 1.0 mm), and s_3 (sieved in 1.5 mm). The composition of all the treatments that were formed in Table 1.

TABEL 1: *COMPOSITION OF TREATMENT WHICH ARE FORMED BY THE SIZE (S) AND THE WATER CONTENT (K)*

Sawdust water content (%)	Sawdust particle size (mm)		
	s_1 (0,5)	s_2 (1,0)	s_3 (1,5)
k_1 (22,0)	k_1s_1	k_1s_2	k_1s_3
k_2 (18,9)	k_2s_1	k_2s_2	k_2s_3
k_3 (14,2)	k_3s_1	k_3s_2	k_3s_2

2.2 Experimental Procedurs

Preparation of materials

Teak (*Tectona grandis*) wood sawdust was obtained from four different locations (10 kg from each) representing industry prepare in the home furniture industry center, Cibeureum subdistrict, Tasikmalaya. The sawdust was mixed homogeneously and then dried for 0, 30, and 60 minutes and filtered with a filter size of 0.5, 1, and 1.5 mm in accordance with the treatments. The feedstock were prepared for the liquefaction process.Teak wood-sawdust (150 g) use as feedstock per experiment unit was added by 100 mL of phenol, 5 g technical grade H_2SO_4 as liquefaction catalyst. Temperature of the process were: 110 °C, and the processing

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time of 60 minutes. After the completion of the liquefaction process, filtration was done with fine plastic-mesh size of 0.1 mm to obtain two results, namely: (i) the filtrate as residual unreacted sawdust; and (ii) liquid filtran as reacted sawdust. The liquid filtran were separated, and subsequently used as adhesive.

Fig. 1. *From left to right: **(i)** glass of sawdust; **(ii)** liquefaction process; and **(iii)** liquefaction product*

Measurement of adhesion was done by using the tool tensometer following the procedure of Gintaka [9]. Substrate (adherent) test was used on two pieces of albasia (*Paraserianthes falcataria*) wood-boards which has been planed (thickness x width x length = 1 cm x 2.5 cm x 10 cm). The adhesive was applied with a brush on each substrate contact-surface facing 2 mL dose, then they were leaved to infuse for 10 minutes. Both the substrate board was glued in pairs and vise pressed on for 30 minutes. After drying, both ends of the substrate-board was detained on tensometer, then both ends drawn by the electricmotor and the load generated by the pull was measured in units of kg/cm^2.

Observations Variable and Data Analysis
The volume of liquefaction product, that the fluid was passed from the filter after the liquefaction process. The weight of the residue, that the mass weight of unreacted components that was not passed the filter after liquefaction process. Tenacity of adhesion was the value of the bonding strength test (kg/cm^2) of liquefaction product that was applied as an adhesive on a pair of wooden board substrate. The data were obtained from observations done with the statistical analysis, including ANOVA (F-test) and Duncan's multiple range test [10].

3 RESULTS AND DISCUSSION

3.1 Weight of Residues

The results of statistical analysis showed there was no significant interaction effect between water content (W) and particle size (S) factor to the weight of sawdust that did not react as a residue. But independently, the water content of sawdust significantly to the weight of the residue, while the particle size was not significantly to the weight of the residue as presented in Table 2.

TABLE 2: *EFFECT OF WATER CONTENT (W) AND PARTICLE SIZE (S) ON WEIGHT OF RESIDUE (g)*

Water Content (%)	Particle size (mm)			Average
	s_1 (0.5)	s_2 (1.0)	s_3 (1.5)	
w_1 (22.0)	41.27	41.66	43.55	42.16 a
w_2 (18.9)	75.42	74.10		71.67 b
w_3 (14.2)	70.66	82.59	71.00	74.75 b
Rata-rata	62.45 A	66.12 A	60.01 A	

Note: numbers followed by the same small letters in the vertical direction and the same capitalization in the horizontal direction indicate no significant differences according Duncan's multiple range test at a confidence level of 5%. Based on Table 2, the weight of residue generated by the treatment of w_1 (water content 22%) was lower compared to the treatment w_2 (water content 18.9%) and w_3 (water content 14.2%). While between w_2 and w_3 treatment showed no significant differences. This proves that the decrease in water content will increase the weight of the residue, ie sawdust with a moisture content of 22%, 19% and 14% respectively weighs consecutive residues 42.16, 71.67 and 74.75 g. Lignocellulose with a specific water content was expected to help the of lignocellulose liquefaction process. As opinion of Gaurav and Shiro [11] treatment of Japanese beech in water-added subcritical phenol at different ratios of water/phenol revealed that the degradation products of cellulose and hemicelluloses are in the water-soluble portion and those of lignin are in the phenol-soluble portion. Treatment at 270 ° C and 3.1 MPa with water-phenol ratio of 25:75 gives the best results. The combined results of phenol and phenolated wood increases with longer treatment time in the range between 3 and 30 minutes. Considering the total energy balance, the shorter reaction time of approximately 10 min is more advantageous. Bagase liquefaction residue mainly consisted of undissolved cellulose and some lignin or lignin derivatives, whose higher heating value (HHV) was higher than that of bagasse. Based on infrared (IR) and gel permeation chromatography (GPC) analyses, the acetone-soluble fraction mainly contained lignin degradation products with high molecular weights. Its predicted HHV value was much higher than that of bagasse, therefore the dissolved products in this fraction could be interesting as fuel components [7].

3.2 Volume of Adhesive as liquefaction product

Statistical analysis showed no significant interaction occurs between water content (W) and particle size (S) to the adhesive as a liquefaction product volume. As shown in Table 3, independently, water content factor has significant effect on the volume of adhesive. While the size of sawdust no significant effect on the volume of adhesive.

TABLE 3: *EFFECT OF WATER CONTENT (W) AND PARTICLE SIZE (S) ON VOLUME OF ADHESIVE (mL)*

Water Content (%)	Particle size (mm)			Average
	s_1 (0.5)	s_2 (1.0)	s_3 (1.5)	
w_1 (22.0)	61.67	58.33	59.67	59.89 a

w_2 (18.9)	40.00	37.67	45.00	40.89 b
w_3 (14.2)	45.67	35.67	43.67	41.67 b
Average	49.11 A	43.89 A	49.44 A	

Note: numbers followed by the same small letters in the vertical direction and the same capitalization in the horizontal direction indicate no significant differences according Duncan's multiple range test at a confidence level of 5%. In Table 3 shows that w_1 treatment (water content 22%) provide the largest volume of adhesive, and it is different to the treatment of w_2 (18.9) and w_3 (14.2). While between w_2 and w_3 did not show a different effect in generating volumes of adhesive. This proves that, lowering the water content material of 22%, 19%, and 14% also reduced the volume of adhesive are respectively 59.89, 40.89, 41.67 mL. The reason of this phenomenon is the moisture content of the sawdust are increasing the volume of adhesive, as should the liquefaction process takes place at higher temperatures, so that the water content has been out since evaporated. As noted by Yoshioka *et al.* [12] that the liquefaction of lignocellulosic also be carried out at a temperature of 240-270 °C even without the catalyst. Zhang *et al.* [7] found that the water soluble fraction mainly contained saccharides, alcohols, aldehydes, ketones, phenols and especially some acids and their esters, which are promising to be separated and used as chemicals. Liquefaction kinetics of corn stover in the presence of ethylene glycol (EG) using sulfuric acid as a catalyst was studied. The microwave liquefaction rate of corn stover at 160 °C was seven times greater than that of conventional liquefaction with external heating [13].

3.3 Bonding Strength

Statistical analysis indicated the presence of significant interaction between water content (W) with a particle size (S) against the bonding strength.

TABLE 4: *EFFECT OF WATER CONTENT (W) AND PARTICLE SIZE (S) ON THE BONDING STRENGHT (kg/m^2) OF ADHESIVE*

Water content (%)	Particle size (mm)		
	s_1 (0.5)	s_2 (1.0)	s_3 (1.5)
w_1 (22.0)	32.625 c A	43.5 c B	43.5 c B
w_2 (18.9)	10.88 a B	14.50 b C	8.90 a A
w_3 (14.2)	17.83 b B	10.88 a A	36.25 b C

Note: numbers followed by the same small letters in the vertical direction and the same capitalization in the horizontal direction indicate no significant differences according Duncan's multiple range test at a confidence level of 5%. Based on Table 4, the highest bonding strength was obtained on consecutive treatment as follows: $w_1s_2 = w_1s_3 > w_3s_3 > w_1s_1 > w_3s_1 > w_2s_2 > w_2s_1 = w_3s_2$, and the smallest w_2s_3. Sawdust with a moisture content of about 22% on particle size of 1 to 1.5 mm generates higher adhesion than others. The water content and different sizes will vary the viscosity adhesive, so it will give a different adhesive qualities. Corresponding opinion of White *et al.* [14] and Nugroho *et al.* [15] that the viscosity of the adhesive affect the value of the adhesive. The low viscosity of the adhesive is very beneficial in the implementation process of gluing a substrate, because the adhesive can be spread evenly throughout the field of adhesiveness, thus providing better adhesion. This is evidenced by the high value of the bonding strength of the adhesive which has a low viscosity grades. Adhesion is one of important quality parameters for determining the adhesive properties of the bonding strength. Measurements done by testing the adhesion strength of adhesion, which is the magnitude of the force acting to separate the surfaces of materials are glued together by the adhesive per unit area (kg/cm^2) [15].

CONCLUSION

There was no interaction between the water content and the size of the sawdust on the volume of adhesive and the weight of residue results, but there was an interaction in the bonding strength of the adhesive produced. The size of sawdust which include 1.0, 1.5 and 2.0 mm no influence on the liquefaction process. The water content of sawdust at 22%, 19% and 14% respectively there were influence to the liquefaction process, namely: (i) increase the weight of residue, ie respectively amounted to 42.16, 71.67 and 74.75 g; and (ii) decrease the volume of adhesive was obtained, which respectively amounted to 59.89, 40.89 and 41.67 mL. The highest adhesion strength were obtained at a water content of 22% and the size of the sawdust on a 1 to 1.5 mm.

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