Effect of Particle Length to The Quality of Particleboard Made from Sorghum Bagasse

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Abstract. The objective of this research was to evaluate the effect of length size particle on physical and mechanical properties of particleboard. Sorghum bagasse was cut into 3, 5, and 7 cm length size. Furthermore, particles were dried until reached of4% moisture content. Amount of 10% urea-formaldehyde (UF) resin used for binding. Hot pressing process conducted in 130□C temperature for 10 minutes and 30 kg cm-2 pressure. The results showed that thickness swelling (TS) and internal bond (IB) did not fulfill of requirement of Japanese Industrial Standard (JIS) A 5908 (2003). According to all parameters, 3 cm length size of particle was resulting in the best properties.

Keyword: Length Size Particle, Particleboard, Sorghum Bagasse, UF Resin.

1 Introduction

The demand of wood as raw materials increases every year, while the wood supply has the opposite condition. This situation has become an issue for Indonesian wood industry. To address this issue, alternate ways need to be identified in terms of utilization of non-wood materials as the replacement of wood materials, especially for the composite industry like particleboard.

Sorghum stalk has been known as potential raw material for particleboard. It is known that chemical composition of sorghum consists of 24 to 38% cellulose, 12 to 22% hemicellulose, 17 to 20% lignin, 1 to 22% starch, and 59 to 66% carbohydrate. One of the important requirements of non-wood material processed for particleboard is having of lignin and cellulose content [1].

Several studies had been conducted to provide database and to examine the feasibility of sorghum stalk as wood substitute for material of particleboard. Study about utilization of sorghum stalk for particleboard material was conducted by [2]. This study was conducted to optimize the use of sorghum stalk as particleboard raw material. The objective of this research was to analyze the effect of particle length to physical and mechanical properties of particleboard made from sorghum bagasse [3].

2   Materials and Methods

2.1   Materials

Bagasse sorghum cut in 3, 5, and 7 cm length. Furthermore, it was dried until reach of less than 5% moisture content.

2.2   Methods

A.   Board Manufacture

The particleboard dimension is 25 cm length, 25 cm width, and 1 cm thickness with board density target of 0.7 g/cm3. Particle mixed with 10% level of UF adhesive using rotary blending machine. After blending, the material The mixture was put on a 25 cm x 25 cm mold then continued by hot pressing process used 130$\square$C temperature, 30 kg/cm^{2}pressure for 10 minutes [3].

B.   Testing

After 7 days conditioning process in room temperature, board was cut into samples size in accordance to JIS A 5908 (2003). Particleboard testing parameter includes density and moisture content (MC), water absorption (WA), thickness swelling (TS) and internal bond (IB), Modulus of Elasticity (MOE), and Modulus of Rupture (MOR).

C.   Data Analysis

Statistical analysis in this study used Completely Randomized Design (CRD). Treatment of particle includes 3 level of particle length namely 3, 5, and 7 cm in triplicate.

3   Result and Discussion

3.1   Density and Moisture Content

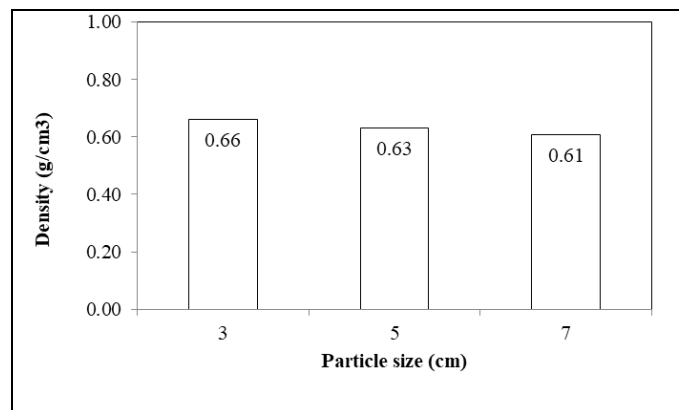Density and moisture content value were presented on Figure 1 and 2.

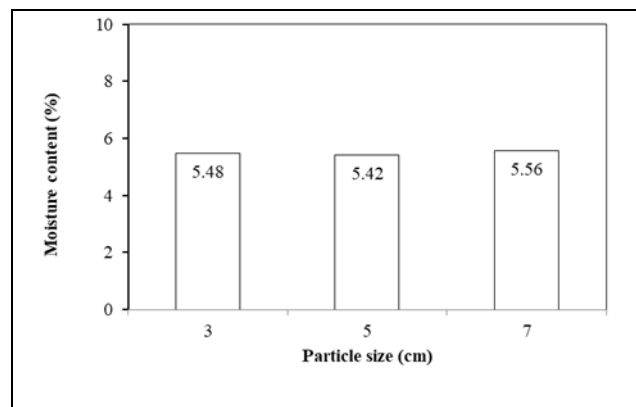**Figure 1** Density of particleboard

Figure 2 Moisture content of particleboard

Density value of particleboard ranged between of 0.61 to 0.66 g/cm^3. The lowest and highest values were produced by particle length 7 and 3 cm respectively. Density value didn't reach of target, where the density target was 0.70 g/cm^3. There are two reasons to explain that, first it caused by the spring back of board after conditioning process. The second reason was loss weight of particle during manufacture of boards according to research conducted by [4]. Several factors affecting of board density include wood type, pressing, amount of particle, amount of adhesive and additive [5]. Analysis of variance in Table 1 showed that particle size did not significantly affected to density [6]. Density of board in this research had fulfilled of JIS A 5908 2003 that required of density value ranged between of 0.40 to 0.90 g/cm^3 [7].

Table 1   Analysis of variance on particleboard density and moisture content

No	Parameter	F Hit	Prob	Remark
1	Density	0.42	0.68	NS
2	Moisture content	0.31	0.75	NS

Note: S = Significantly affecting within confidence rate of 95% or 99%; NS = not significantly affecting

Furthermore, MC value of board ranged betweenof 5.42 to 5.56%. The lowest and highest MC was produced by particle length 5 and 7 cm respectively. Initialmoisture content of particle is

one of factors that determined of particleboard quality. High MC can make particle to have blister. Each adhesive has its own tolerance to different moisture content values. UF adhesive is very sensitive to MC. The moisture content higher than 6% has bigger possibility to cause blister on board bonded with UF adhesive. Furthermore, that moisture content variance on material has important role in determining of final MC of particleboard [6]. Moisture content varies due to species used, the origin of the source, part of the raw material used, and storage mechanism. Particle that resistant to water will have a better dimension stability [6]. Analysis of variance on Table 1 showed that particle size did not significantly affected of MC. The MC values fulfill of JIS A 5908-2003 that required of MC value ranged between of 5 to 13% [7].

3.2   Thickness Swelling (TS) and Water Absorption (WA)

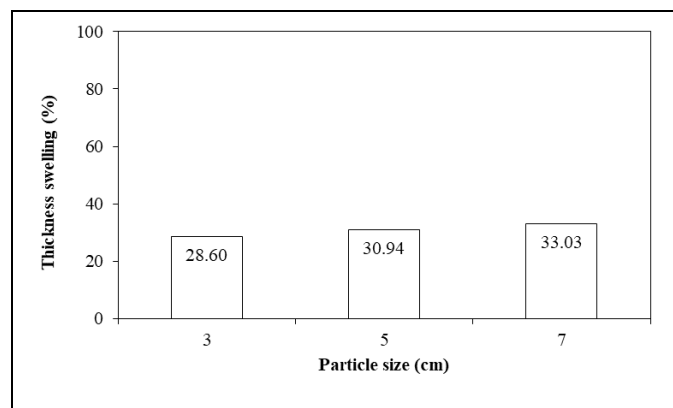The TS and WA value were presented on Figure 3 and 4.

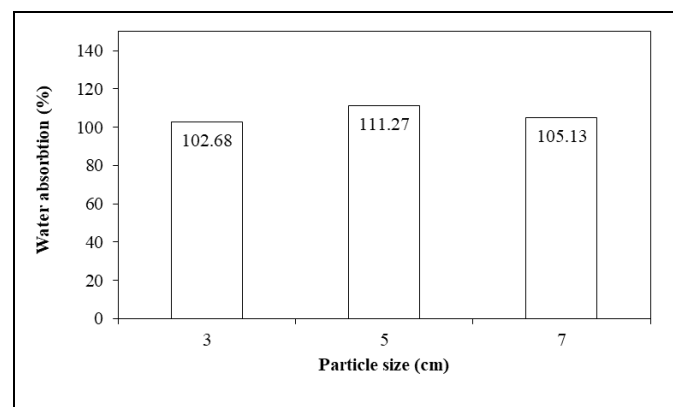**Figure 3** Thickness swelling of particleboard

Figure 4 Water absorbtion of particleboard

The TS value of board was ranged between of 28.60 to 33.03%. The lowest and highest TS values were produced by particle length 3 and 7 cm respectively. Thickness swelling in this research was still quite high, it was presumed due to the UF adhesive used, where that adhesive mostly applied for interior products. UF had not durability to water. High TS value was also due to the internal bond (IB) of board produced has not fulfill the standard. According to [8] that

there is negative correlation between IB and TS, the higher of IB value of a board, the lower its TS value. WA and TS of a board is a result of spring back characteristic of material, where is the inner stress is released during of board conditioning and furnish separation [9]. The TS of a board is determined by several factors, such as density, adhesive level and distribution, moisture content of furnish, furnish and adhesive compatibility, chemical composition of furnish, etc [10].

Analysis of variance in Table 2 showed that particle size did not significantly affected to TS. Thickness swelling did not fulfilled of JIS A 5908 2003 that requires of TS maximum value is 12 % [7].

Table 2 Analysis of variance on thickness swelling and water absorption of particleboard

No	Parameter	F Hit	Prob	Remarks
1	TS	0.64	0.56	NS
2	WA	0.37	0.71	NS

Note:S = Significantly affecting within confidence rate of 95% or 99%; NS = not significantly affecting

The WA value of board was ranged between of 102.68 to 111.27 %. The lowest and highest WA values were produced of particle with 3 and 5 cm long. The WA value was still too high, as the processing did not utilized of water repellent additive. Hemicellulose plays the biggest role on water absorption; however, cellulose, lignin and the surface of crystal cellulose also contribute [11]. Analysis of variance on Table 2 showed that particle length did not significantly affected to WA.

3.3 Modulus of Rupture (MOR), Modulus of Elasticity (MOE), and Internal Bond (IB)

The mechanical properties including of modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding (IB) were presented on Figure 5, 6 and 7.
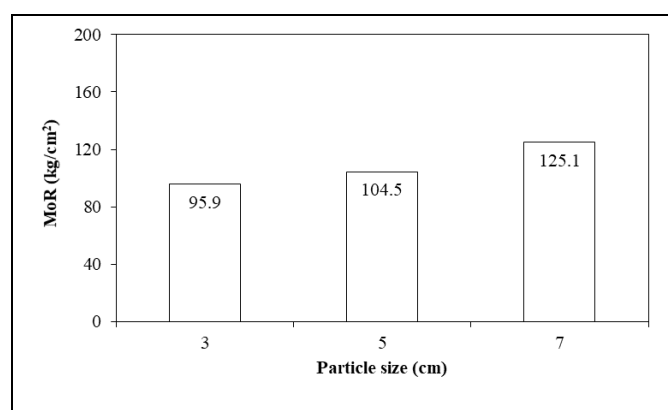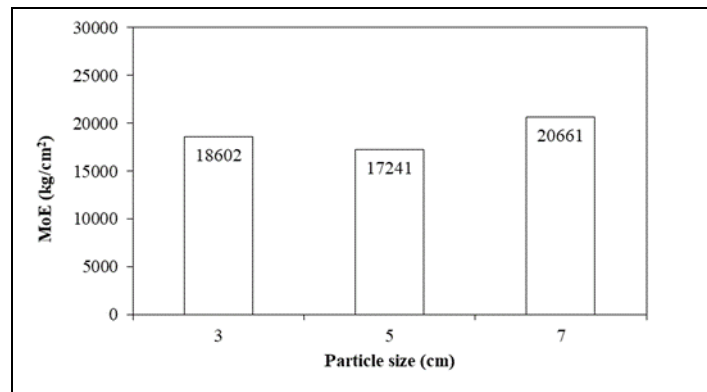

Figure 5 Modulus of rupture of particleboard

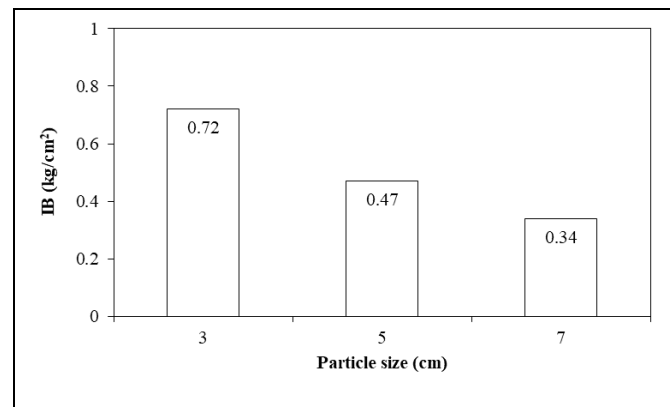**Figure 6** Modulus of elasticity of particleboard

Figure 7 Internal bond of particleboard

The average value of MOR was ranged between of 95.9 to 125.1 kg/cm². The lowest and highest MOR was produced by particle length 3 and 7 cm respectively. Particle with 7 cm length has the highest slenderness ratio (SR) of 44.5. SR is ratio between of particle length and its thickness. SR is one of factors determining of particle orientation and bending strength [6]. Particle with high SR is easier to orient so the strength is better and needs less surface extension adhesive to hold particle. The ideal SR value in the form of flake is 150 [6]. A longer particle size corresponds with its mechanical strength if compared with a shorter particle. High SR value could increase the possibility of surface area availability extension for resin coverage. However, this increase will reduce IB strength value [12]. SR increment will also increase the particleboard cavity percentage and resin coverage percentage on particle surface [13, 14]. Particle with extended surface has higher resin coverage and increases of mechanical strength [6, 12].

Analysis of variance on Table 3 showed that particle size did not affected significantly to MOR. All particles produced fulfill JIS A 5908 (2003) that requires of minimum MOR value is 82 kg/cm² [7].

Table 3 Analysis of variance MOR, MOE, and IB of particleboard

No	Parameter	F Hit	Prob	Remarks
1	MOR	0.93	0.45	NS
2	MOE	12.48	0.01	NS
3	IB	3.70	0.09	NS

Note:S = Significantly affecting within confidence rate of 95% or 99%; NS = not significantly affecting

The average value of MOE was ranged between of 17,241to 20,661 kg/cm^2. The lowest and highest MOE was produced by particle length 5 and 7 cm respectively. MOE value is determined by composition and type of adhesive used, adhesive strength and fiber length [6]. Sorghum stem has fiber length of 1324 µm that classified into medium category (900-1600 µm) [2].

Analysis of variance in Table 3 showed that particle size significantly affected to MOE value. MOE produced from particle sized 3 and 7 cm fulfilled of JIS A 5908 2003 that requires of minimum MOE is 20,500 kg/cm^2 [7].

The IB value of board was ranged between of 0.34 to 0.72 kg/cm^2. The lowest and highest IB values were produced by particle length 7 and 3 cm respectively. Particle length 5 and 7 cm had a lower IB compared to 3 cm length because they had higher SR, which are 29.6 and 44.5 while 3 cm board had SR of 19.3. A high slenderness ratio value causes a higher percentage of resin closure so that it has a negative impact on IB [13]. Therefore, when length and width increase, the distribution of resin on surface become uneven.

Analysis of variance in Table 3 showed that particle size did not significantly affected to IB. The IB value did not fulfilled of JIS A 5908 2003 that requires of minimum IB is 1.5 kg/cm^2 [7]. The low IB was due to by: 1) Sorghum bagasse was contain of bark, where it has smooth and less porous surface so that these made inter-particle bond weak, 2) Sorghum bagasse had a low acidity with pH 6.8 [8], so the performance of UF adhesive was not optimimum because UF resin was categorized as acid based curing. The environmental condition for processing should be acidic.

4   Conclusion

Generally, particle length 3 cm produced the best physical and mechanical properties of board. Thickness swelling and internal bond of particleboard had not fulfilled the requirement of JIS A 5908 (2003).

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