Jatropha fruit hulls (JFH) particleboard: Effect of acetic acid treatment and ratio of JFH and non-wood particles

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Abstract. The objective of the experiment was to analyze the effect of acetic acid treatment and JFH/non-wood particle ratio to physical and mechanical properties particleboard. Non-wood particles used in this experiment namely bamboo and sorghum bagasse. For the particle treatment, JFH and non-wood particle immersed in 1% acetic acid solution for 24 hours. The untreated particle also prepared for bamboo and sorghum bagasse. The ratio of JFH/non-wood particles was 100/0, 70/30, 60/40, 50/50, and 0/100. The board size, thickness, and density target were 30 x 30 cm², 1 cm, and 0.70 g/cm³, respectively. Particles sprayed using 10% UF resin (SC: 63%). Afterward it was pressed using the hot pressing machine at the temperature of 130 °C, the pressure of 2.544 N/mm² and 10 minutes time of pressing. Conditioning was conducted around seven days at room temperature before physical and mechanical test. That properties test refers to JIS A 5908 (2003). The results showed that 50/50 (%w/w) JFH and bamboo ratio produced of better thickness swelling value compared to another ratio. Therefore, combination JFH and bamboo acid treated resulted in the best of thickness swelling value. A similar trend also showed in mechanical properties. That treatment produced the best of the modulus of elasticity, modulus of rupture and internal bond value.

1. Introduction
The improvement of physical and mechanical properties of the board had been made using wood particle and veneer to strengthen of board [1,2,3,4]. The result showed that the quality of jatropha fruit hulls (JFH) particleboard had increased in particular at the modulus of elasticity (MOE) and modulus of rupture (MOR) values. The combination of particleboard and stronger materials was expected to increases strength and elastic properties. The use of wood as additional material on non-wood particleboard was able to improve physical and mechanical properties. Further research still needed to find out whether this positive trend is also occurred on JFH’s particleboard.

Bamboo and sorghum bagasse were chosen as additional particles for JFH’s particleboard. Mohmod et al. [5] stated that bending firmness of bamboo is in the range of 2600-8000 N/mm²; Papadopoulos et al. [6], Kasim et al. [7] also expressed that mechanical properties of bamboo with formaldehyde adhesive
(UF) were higher than 2000 N/mm², in particular, the modulus of elasticity (MOE) parameter. As stated by Iswanto et al. [8], the mechanical properties of sorghum bagasse with formaldehyde adhesive (UF) for MOE and MOR values were 1900 N/mm² dan 9 N/mm², respectively. Considering the properties of materials, board and resulted board, bamboo, and sorghum bagasse were eligible to enhance mechanical properties, in particular, MOE parameter. The objective of the experiment was to anályze the effect of bamboo and sorghum bagasse as strengthened materials to physical and mechanical properties of JFH’s particleboard with UF adhesive.

2. Materials and methods

2.1. Materials

We used untreated JFH, treated JFH, string bamboo (Gigantochloa apus) and sorghum bagasse (Sorghum bicolor (L) Monech). The treatment was immersion in 1% acetic acid solution for 24 hours. We also use 10% level of UF adhesive and 63% of SC.

2.2. Methods

2.2.1. JFH, bamboo, and sorghum bagasse pH analysis

The preparation and particle pH analysis based on Krilov and Lasander [9], Johns and Niazi [10] methods. The result presented in Table 1.

| No | Materials                                      | pH          |
|----|-----------------------------------------------|-------------|
| 1  | JFH                                           | 10.20 ± 0.00|
| 2  | JFH (immersing in 1% acetic acid solution for 24 hours) | 5.90 ± 0.00 |
| 3  | Bamboo                                        | 6.53 ± 0.05 |
| 4  | Bamboo (soaking in 1% acetic acid solution for 24 hours) | 5.73 ± 0.05 |
| 5  | Sorghum bagasse                               | 6.98 ± 0.09 |

2.2.2. Board forming

The JFH and non-wood particles ratios were 100/0, 70/30, 60/40, 50/50, and 0/100. The JFH, non-wood particles and UF adhesive at the concentration level of 10% (SC: 63%) were blended. Furthermore, it formed into the size of 300 by 300 by 9 mm, then pressed using the hot pressing machine set on the temperature of 130 °C for 10 minutes. Conditioning was conducted around seven days before to the testing process, followed by board cutting and test referred to JIS A 5908 (2003).

3. Results and discussion

3.1. Physical properties

Overall board density values had met the standard requirement JIS A 5908 (2003) and categorized as medium density. Kelly [11] reported some influencing factors to board density value such as wood type, pressure, the number of particles, the amount of adhesive and additive.

The combination of JFH and bamboo particle without treatment resulted in better dimension stabilization compared to the combination of JFH and sorghum bagasse without treatment. The use of bamboo and sorghum bagasse without treatment was not able to enhance the board’s dimensional stabilization. However, the bamboo particle immersing on 1% acetat acid for 24 hours was able to fix the dimension stabilization. The increase of bamboo particle ratio resulted positive response on dimension.
stabilization enhancement. One of the limits of the UF use as the interior adhesive is its non-waterproof properties. Bektas et al. [12] stated that the panel’s thickness swelling depended on some factors such as the amount of adhesive, the spreading of adhesive, water content of furnish, compatibility of furnish and adhesive, the chemical composition of furnish, etc. Hsu [13] stated that water absorption and thickness swelling occurred because of thickness swelling properties of additional materials, spring back due to tension during conditioning process and furnish separation. The overall thickness swelling result has not met the JIS A 5908 (2003) standard requirement.

Figure 1. Particleboard used in the study

Table 2. JFH/non-wood particle ratio on physical properties

| Type of Particleboard | Ratio     | Density (g/cm³) | MC (%)   | TS (%)   | WA (%)   |
|-----------------------|-----------|-----------------|----------|----------|----------|
| JFH-ac                | 100/0     | 0.67±0.05       | 8.69±0.82| 23.85±0.04| 87.01±6.60|
| JFH-ac/bamboo         | 70/30     | 0.68±0.01       | 8.61±0.64| 28.58±0.26| 95.38±5.52|
|                       | 60/40     | 0.73±0.03       | 9.07±0.36| 25.10±1.24| 74.39±4.52|
|                       | 50/50     | 0.72±0.03       | 8.51±0.27| 20.51±0.61| 66.16±6.85|
|                       | 0/100     | 0.72±0.05       | 9.14±0.79| 13.49±0.08| 52.60±3.62|
| JFH-ac/Sorghum        | 70/30     | 0.68±0.03       | 8.45±0.69| 32.84±1.46| 104.00±12.28|
|                       | 60/40     | 0.72±0.03       | 8.52±0.50| 31.46±1.56| 106.97±14.62|
|                       | 50/50     | 0.74±0.01       | 8.57±0.48| 28.99±0.92| 102.94±3.61|
|                       | 0/100     | 0.72±0.05       | 8.00±0.67| 21.39±1.51| 48.97±4.49|
| JIS A 5908 (2003)     |           | 0.5-0.9         | 4-13     | Max 12   | NA       |

Table 3. Acetic acid treatment on physical properties

| Type of Particleboard | Density (g/cm³) | MC (%) | TS (%) | WA (%) |
|-----------------------|-----------------|--------|--------|--------|
| JFH-ac                | 0.67±0.05       | 8.69±0.82| 23.85±0.04| 87.01±6.60|
| JFH-ac/Bamboo         | 0.68±0.01       | 8.61±0.64| 28.58±0.26| 95.38±5.52|
| JFH-ac/Bamboo-ac      | 0.70±0.05       | 9.18±0.38| 19.80±0.53| 60.68±3.27|
| JFH-ac/Sorghum        | 0.68±0.03       | 8.45±0.69| 32.84±1.46| 104.00±12.28|
| JFH-ac/Sorghum-ac     | 0.67±0.02       | 8.18±0.48| 35.58±3.53| 95.23±0.48|
| JIS A 5908 (2003)     | 0.5-0.9         | 4-13    | Max 12 | NA     |
### Table 4. Variance analysis of physical properties

| Source                          | Density | MC      | TS       | WA       |
|---------------------------------|---------|---------|----------|----------|
| Type of particleboard (I)       | 0.04ns  | 3.27ns  | 256.19** | 33.78**  |
| Ratio (II)                      | 2.89ns  | 0.26ns  | 187.70** | 44.57**  |
| Interaction of I and II         | 0.31ns  | 1.10ns  | 5.00*    | 9.12**   |

### 3.2. Mechanical properties

Both bamboo particle and sorghum bagasse combinations were able to enhance the bending properties (MOE and MOR), but the bamboo mixture was better due to its high bending firmness. Mohmod et al. [5] studied that bamboo’s bending strength with UF adhesive was reaching 8000 N/mm². This value was four times compared to bamboo particleboard. The immersing in 1% acetic acid for 24 hours was able to increase MOE and MOR values from 1300 N/mm² to 2040 N/mm². Thus, the particleboard bending value had met the standard requirement of JIS A 5908 (2003). The increasing of the shelling ratio also increased the MOE and MOR values. The combination jatropha fruit hulls and bamboo particleboard on the ratio of 60/40 resulted in almost two times as much as MOE value compared to the non-combination board. Akbulut (1995) cited in Nemli [14] expressed that the increase of shelling ratio had enhanced physical and mechanical properties. Overall MOR values had met the JIS A 5908 (2003) standard requirements. The combination of JFH and treated bamboo particle had met the JIS A 5908 (2003) standard requirements for MOE value.

The combination of bamboo particle and JFH resulted in better IB value than sorghum bagasse combination. The immersing treatment of bamboo particle in 1% acetic acid solution for 24 hours was able to increase the IB value from 0.16 N/mm² to 0.32 N/mm². We assumed this caused by the compatibility of mixing materials based on their acid levels. According to Table 1, the initiate pH level of bamboo was 6.53. After acetic acid immersing treatment, the bamboo pH level decreased to 5.73, almost similar to JFH pH level was 5.90. The urea formaldehyde adhesive was optimum in acid condition. Nawawi et al. [15] and Malanit et al. [16] studied the influence of material acidity to UF adhesive effectiveness and found out that the UF bonding strength would increase as the high of wood’s acidity. The increase of shelling ratio was also increase the IB value. Akbulut (1995) cited in Nemli [14] stated that the raise of shelling ratio had enhanced the physical and mechanical properties. The type of added particle, shelling ratio, and their interactions were significantly different for IB values. Overall values of IB had met the JIS A 5908 (2003) standard requirements.

### Table 5. JFH/non-wood particle ratio on mechanical properties

| Type of Particleboard  | Ratio  | MOE (N/mm²) | MOR (N/mm²) | IB (N/mm²) |
|------------------------|--------|-------------|-------------|------------|
| JFH-ac                 | 100/0  | 1006.52±101.25 | 10.65±0.86 | 0.25±0.03 |
| JFH-ac/bamboo          | 70/30  | 1346.57±58.69 | 9.13±0.14  | 0.16±0.02 |
|                        | 60/40  | 1900.71±215.64 | 14.86±1.09 | 0.42±0.08 |
|                        | 50/50  | 1622.87±170.81 | 12.89±0.23 | 0.34±0.02 |
|                        | 0/100  | 2139.92±91.35  | 16.45±0.46 | 0.60±0.22 |
| JFH-ac/sorghum         | 70/30  | 1178.73±110.60 | 6.17±0.27  | 0.16±0.01 |
|                        | 60/40  | 1158.30±84.82  | 7.06±1.02  | 0.15±0.01 |
|                        | 50/50  | 1450.98±55.70  | 8.15±0.27  | 0.17±0.03 |
Table 6. Acetic acid treatment on mechanical properties

| Type of Particleboard | MOE (N/mm²)       | MOR (N/mm²)       | IB (N/mm²)    |
|-----------------------|-------------------|-------------------|--------------|
| JFH-ac                | 1006.52±101.25    | 10.65±0.86        | 0.25±0.03    |
| JFH-ac /bamboo        | 1346.57±58.69     | 9.13±0.14         | 0.16±0.02    |
| JFH-ac /bamboo-ac     | 2040.99±126.99    | 13.74±0.53        | 0.32±0.03    |
| JFH-ac /sorghum       | 1178.73±110.60    | 6.17±0.27         | 0.16±0.01    |
| JFH-ac /sorghum-ac    | 1032.08±66.35     | 4.62±0.48         | 0.05±0.02    |
| JIS A 5908 (2003)     | 2000              | 8                 | 0.15         |

Table 7. Variance analysis of mechanical properties

| Source                        | MOE    | MOR    | IB     |
|-------------------------------|--------|--------|--------|
| Type of particleboard (I)     | 64.77**| 369.22**| 37.31**|
| Ratio (II)                    | 28.84**| 46.88**| 10.64**|
| Interaction of I and II       | 8.10** | 15.31**| 5.43** |

4. Conclusion
The addition of bamboo and sorghum bagasse particles on JFH’s particleboard was able to increase the board’s quality, in particular on modulus of elasticity and modulus of rupture values. Therefore, combination JFH and treated bamboo on the same ratio were better than the combination of sorghum bagasse. Immersing in 1% acetic acid solution had increased the dimension stabilization and mechanical properties compared to the untreated boards. Particle board with bamboo addition and treated on acid was the best and had met the JIS A 5908 (2003) standard requirement.

References
[1] Iswanto AH, Febrianto F, Wahyudi I, Hwang WJ, Lee SH, Kwon JH, Kwon SM, Kim, NH, Kondo T 2010 J. Fac. Agr. Kyushu Univ 55 (2) 371–377
[2] Iswanto AH, Febrianto F, Hadi YS, Ruhendi S, Hermawan D 2012. J. Ilmu dan Teknologi Kayu Tropis 10(2) 103-111
[3] Iswanto AH, Aritonang W, Azhar I, Supriyanto, Fatriasari W 2017 J Indian Acad Wood Sci 14(1) 1–8
[4] Iswanto AH, Sucipto T, Nadeak SSD, Fatriasari W 2017 1st Annual Applied Science and Engineering Conference IOP Conf. Series: Materials Science and Engineering 180 (2017) 012015 doi 10.1088/1757-899X/180/1/012015
[5] Mohmod AL, Ariffin WTW, Ahmad F 1990 J. Tropical Forest Science 2(3) 227-234
[6] Papadopoulos AN, Hill CAS, Gkaraveli A, Ntalos GA, Karastergiou SP 2004 Holz Roh- und Werkstoff 62(1) 36-39
[7] Kasim J, Ahmad AJ, Harun J, Mohmod ZAAL, Yusof MNM 2001 Pertanika J. Trap. Agric. Sci. 24(2) 151-157
[8] Iswanto AH, Fatriasari F, Supriyanto  2012 Pemanfaatan Limbah Batang Sorghum (*Sorghum bicolor* (L) Monech) Sebagai Bahan Baku Papan Partikel, Makalah pada Workshop on the Current Status and Challenges in Sorghum Development in Indonesia, Bogor 25-26 September 2012.

[9] Krilov A and Lasander WH 1988 *Holzforschung* **42**(4) 253-258

[10] Johns WE and Niazi KA 1980 *Wood and Fiber Sci* **12**(4) 256-263

[11] Kelly MW 1977 Critical Literature Review of Relationship Between Processing Parameter and Physical Properties of particleboard, General Technical Report FPL-10, US Department of Agriculture Forest Service and Forest Products Laboratory University of Wisconsin

[12] Bektas I, Guler C, Kalaycioglu H, Mengeloglu F, Nacar M 2005 *Composite Materials* **39**(5) 467-473

[13] Hsu, WE 1987 A process for stabilizing waferboard/OSB, Proceedings of the 21st International Particleboard Symposium, (IPS’87), Washington State University, Pullman, pp: 219-236.

[14] Nemli G 2003 *Turk J Agric For* **27**: 99-104

[15] Nawawi DS, Rusman D, Febrianto F, Syafii W 2005 *J. Teknologi Hasil Hutan* **18**(2) 47-52

[16] Malanit P, Barbu MC, Fruhwald A 2009 *J. Tropical Forest Science* **21**(4) 361-368