The improvement on physical and mechanical properties of particle board from jatropha press cake

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Abstract. Jatropha press cake (Jatropha curcas L) has high crude fiber which is potential to be utilized as raw material for particle board production. The objective of this study is to assess the physical and mechanical properties of Jatropha press cake particle board and effect of addition of paraffin and sago starch to improve the quality of particle board. The paraffin was added at 0, 1, and 3%, and the sago starch was added at 6, 8, and 10%. The physical and mechanical properties of particle board product were evaluated. The density of particle board ranged at 0.84 – 0.95 g/cm³, moisture content 4.56 – 6.19%, the thickness-swelling for 2h and 24h by soaking in water were 11.67- 20.12% and 16.22-25.70%, respectively. The water absorption of particle board for 2h and 24h by soaking in water were 48.74-62.20% and 63.10-72.75%. The Modulus of Rupture (MoR) and Modulus of Elasticity (MoE) of particleboard were 19.70 – 97.44 kgf/cm² and 1552-7235 kgf/cm², respectively. The addition of paraffin and sago starch can improve the physical and mechanical properties of particle board. The particle board with paraffin addition of 3% and sago starch of 10% passes the MoR in accordance with Japan Industrial Standard (JIS) of A 5908:2003.

Keywords: jatropha press cake, paraffin, particle board, sago starch

1. Introduction

Recently, increase in biodiesel production from Jatropha has caused an increase in production of Jatropha press cake as byproduct producing about 70% of raw materials. The Jatropha press cake contains fiber, carbohydrate and protein that can be utilized for other products, such as particle board. Utilization of Jatropha press cake as raw materials for particle board was reported by Zuanda [1] and Lestari [2]. Particle board is a composite product produced by mixing wood chips or other lignocellulosic materials. The particle board can be used for furniture such as cabinet, table, partition, box or toys. Increase in demand of wood materials for many products cause the composite industrial force to utilize non-wood materials that contain high lignocelluloses [3], such as agricultural waste and filter press cake as byproduct of oil extraction from palm oil [4,5], Jatropha [1,2,6], rice straw [7], bagasse/plastic [8], sun flower [9], and bamboo waste [10,11].

To improve the quality of particle board, production of particle board uses binder based on resin formaldehyde such as urea formaldehyde that is cheaper and has better appearance as binder materials [12]. The urea formaldehyde produced from petroleum is non renewable source, so it will be more expensive following increase in petroleum prices [13] and it is not environmentally sound. The increase
in urea formaldehyde price will increase the production cost of particle board [14]. Another production of particle board uses natural and renewable binder materials, such as cane-sugar starch [15], corn starch [16], starch from palm oil stem [17]. Sago starch is a renewable product in Indonesia which could be used as binder for particle board from Jatropha press cake. Zuanda [1] utilized glycerol from byproduct of biodiesel transesterification from Jatropha, and Lestari [2] utilized protein compound in Jatropha press cake as binder (or binderless). However, their particle board products have still lower quality in physical and mechanical properties. Utilizing sago starch as binder to particle boards from Jatropha press cake could improve their physical and mechanical properties.

The objective of this research is to assess the physical and mechanical properties of Jatropha press cake particle board and effect of paraffin and sago starch addition to the improvement of the quality of particle board.

2. Material and methods

2.1. Preparation of jatropha press cake

The Jatropha press cake (JPC) as raw materials was supplied from Jatropha Oil Producer. The sago starch and paraffin used were from commercial products. The dried-JPC and commercial sago starch were milled to pass through a 40-mesh screen size, respectively. The screened JPC was analyzed to moisture content [18] (AOAC 1995, 950.46), ash [19] (AOAC 1995, 923.03), protein [20] (AOAC 1995, 991.20), oil and grease [21] (SNI 01-2891-1992), fiber [20] (SNI 01-2891-1992), and carbohydrates (by difference).

2.2. Particle board production

The particle board was produced by mixing Jatropha press cake, water, sago starch and paraffin. The sago starch was added at 6, 8, and 10% (w/w). The paraffin was added at 0, 1, and 3% (w/w). The moisture content of JPC was kept at 15% (w/w). All materials were mixed homogenously, poured to a mat with size of 10 cm x 10 cm x 0.5 cm. The mat was pressed at 200 kgf/cm² and temperature at 160 °C for 8 minutes by hydrolic hot press. Before analysis, the particle board samples were conditioned at room temperature for 2 weeks.

2.3. Particle board samples and analysis

The particle board samples were cut according to analytical procedure of Japan Industrial Standard (JIS) A 5908:2003 [22]. The physical-chemical test for particle board samples were density, water content, thickness-swelling for 2 h and 24 h by soaking in water, and water absorption for 2 h and 24 h. The mechanical test was modulus of rupture (MoR) and modulus of elasticity (MoE) by Universal Testing Machines.

2.4. Data analysis

The design experiment of completed random factorial was applied for treatments of addition of sago starch and paraffin. All data were processed by MatLab and presented by Microsoft excel.

3. Result and discussion

3.1. Jatropha press cake

The proximate composition of JPC is shown in table 1. The percentage of moisture, ash, crude protein, crude fat, and crude fiber is 3.54, 6.15, 6.86, 3.31 and 48.43 %, respectively. The crude protein is only 6.86% of total compound, whereas the protein compound was known as natural binder which makes complex compound to enhance the cohesion bonding between fibers in JPC as reported by Evon et al. [9] in particle board manufacture from sunflower and Kurniati et al. [23] in binderless particleboard
production from castor press cake. Meanwhile, the crude fiber content was very high because the seeds were not dehulled.

**Table 1.** Proximate analysis of jatropha press cake.

| Analytical Test               | Value (% dry bases) |
|-------------------------------|---------------------|
| Water content                 | 3.54 ± 0.07         |
| Ash                           | 6.15 ± 0.11         |
| Protein                       | 6.86 ± 0.34         |
| Oil and grease                | 3.31 ± 0.03         |
| Fiber                         | 48.43 ± 0.69        |
| Carbohydrate (by difference)  | 28.05 ± 0.55        |

3.2. **Physical and mechanical properties of particle board.**

The product of Jatropha press cake particle board was tested on density, water content, thickness-swelling and water absorption by soaking in water. Figure 1 shows the effect of starch and paraffin addition on the density of JPC particle board. The average density of the obtained particle board was in the range of 0.84 - 0.95 g/cm³. The average density of the produced particle board complies with density requirement of JIS A 5908:2003 standard (0.4 - 0.9 g/cm³). Kelly [24] reported that density of particle board was influenced by wood density, addition of binder, and binder material. The higher the density of particle board, the higher the mechanical properties of strength and rigidity [25].

![Figure 1. The effect of starch and paraffin addition on density of JPC particle board.](image)

The analysis of variance indicated that treatment of sago starch and paraffin addition influenced the density of particle board. The Duncan test indicated that the particle board with addition of paraffin 3% and 1% was different from that with no addition of paraffin (0%). The Duncan test indicated that the particle board with addition of sago starch 8% and 10% was different with that with addition of sago starch 6%.
Figure 2 shows the moisture content of particle board ranged from 4.56 to 6.19%. In general, increase in density of particle board caused decrease in moisture content. Moisture content is very important to stabilize the particleboard dimension. The moisture content of raw materials used before pressing was 15%. Moisture content increased with respect to the augmentation of the sago starch and 3% of paraffin. The moisture content of particle boards was higher than that of raw materials of JPC. It may be caused by water addition in its mixing formula and conditioning the particleboard at room temperature.

The thickness-swelling for 2 h ranged at 11.67-20.12% (figure 3.a), and for 24 h at 16.22-25.70% (figure 3.b). The thickness swelling (TS) values of obtained JPC were very high and did not meet JIS A 5908:2003 standard at maximum 12%, except the particleboard with sago starch addition of 8% and paraffin of 3%. Increase in paraffin addition caused decrease in TS. The lowest TS were the best requirement of particle board. This low value was caused by slow water absorption by particle board via porous and void volume at inside particle. The analysis of variance indicated that treatment of paraffin addition influenced the thickness-swelling by soaking in water for 2 h. The Duncan test indicated that the particle board with paraffin addition of 3% was different with paraffin addition of 0 and 1%. The Duncan test indicated that the particle board with sago starch addition of 8% and 10% was different with sago starch addition of 6%.

The analysis of variance indicated that treatment of paraffin addition influenced the thickness-swelling by soaking in water for 24 h. The Duncan test indicated that the particle board paraffin addition
of 0% was different with paraffin addition of 1 and 3%. The particle board product indicated that increasing in paraffin addition caused decreasing in thickness-swelling by soaking in water. The lowest of thickness-swelling by soaked in water was the best product of particle board. This low value was caused by slow water absorption by particle board via porous and void volume at inside particle [26]. Erniwati et al. [27] reported that paraffin addition of 3% could withstand the thickness-swelling in water of particle board and almost meet the standard value of JIS A 5908:2003 (figure 3b).

The water absorption is physical properties of particle board which demonstrates the ability to absorb water [28]. The water absorption by soaking in water for 2 h ranged at 48.74-62.20% (figure 4.a), while for 24h was 63.10-72.75% (figure 4.b). The lowest water absorption of particle board was a particle board with paraffin addition of 3% and sago starch of 10%. Sago starch addition increased the density of JPC due to compactness of particleboard and less WA.

Mardikanto et al. [29] described that modulus of rupture (MoR) is an elastic maximum of such materials until the materials fractures. The JPC particle board have MoR value ranged of 19.70-97.44 kgf/cm² (figure 5.a.). The particle board produced generally does not comply with JIS A 5908:2003 standard at 80 kgf/cm², except to that particle board with paraffin addition of 3% and sago starch of 10% at MoR value of 97.44 kgf/cm². The analysis of variance indicated that treatment of paraffin and sago starch additions influenced to MoR value of particle board. The Duncan test indicated that the particle board addition of paraffin 3% was different from that with addition of paraffin (0 and 1%). Increase in paraffin addition caused the increase in MoR value. The Duncan test indicated that the particle board with sago starch addition of 10 % was different from that with sago starch addition of 6 and 8%. Increase in sago starch addition caused the increase in MoR value.

Maloney [30] reported that paraffin addition at more than 1 % will decrease the mechanical properties of particle board. However, this result shows that addition of paraffin until 3% could not decrease the MoR value. Addition of sago starch up to 8% did not influence the MoR value (figure 5.a). The MoR value tends to enhance as increase in paraffin addition as described by Hermawan [31]. The amylase and amylpectin compounds were contained in sago starch. Both molecules become granule semi crystalline. During heating, the granule will be opened to improve of a binding ability caused by interaction of water and heat. Both molecules will phase change in gelatinization process [32]. The hydric hot press of particle board at 160 °C caused the amylase and amylpectin compounds to be swelling and gelatinous, so the molecule of sago starch will bind any particle of JPC.
Figure 5. Effect of sago starch and paraffin addition on modulus of rupture (MOR) (a) and modulus of elasticity (MOE) (b) of JPC particleboard.

The modulus of elasticity (MoE) is mechanical strength value of wood to maintain change in deformation caused by loading [24]. The Jatropha press cake particle board performed at 1552 -7235 kgf/cm² (figure 5.b). This MoE value is lower than The JIS A 2908:2003 standard at 20394 kgf/cm² or 200 N/mm² [21]. The analysis of variance indicated that treatment of paraffin and sago starch additions influenced the MoE value of particle board. The Duncan test indicated that the particle board paraffin addition of 3% was different from that with paraffin addition of 0 and 1%. Increase in paraffin addition caused the increase in MoE value. The Duncan test indicated that the particle board sago starch addition of 10 % was different from that with sago starch addition of 6 and 8%. Increase in sago starch addition caused the increase in MoR value.

The paraffin addition at 1-10% tended to increase the MoE, but decrease the MoR value in particle board [31]. Amount of particle and starch in particle board has higher density due to the interaction of intra particle and starch during pressing of particle board. The structure of particle board becomes more compact and stronger [33].

Compared with other Jatropha press cake particle boards, this result is better than what reported previously [1,2]. The quality of particle board product made from Jatropha press cake with sago starch and paraffin addition was better than that it is with glycerol addition [1] or binderless [2] for thickness-swelling in water. The thickness-swelling in water within 2h of this research achieved 11.67%, better than Jatropha cake particle board with binderless by 12.39% [2]. The MoR value of this product was at 97.44 kgf/cm², higher than Jatropha cake particle board with binderless of 65.99 kgf/cm² [2] or glycerol addition of 60.15 kgf/cm² [1]. The MoE value of 7235 kgf/cm² by this research was higher than that Jatropha cake particle board with binderless of 5150 kgf/cm² [2] or with glycerol addition of 5120 kgf/cm² [1].

In general, addition of sago starch and paraffin to Jatropha press cake particle board indicated that it could improve the physical and mechanical properties. This particle board product made from Jatropha press cake with sago starch and paraffin additions do not meet JIS A 5908:2003 standard yet, except the particle board with sago starch addition of 8% and paraffin of 3% for MoR value of 97.44 kgf/cm².

Sago starch is used for various processes in industry such as adhesives in paper making, additives in cement and as a binder in gypsum fiberboard [34]. The addition of paraffin will increase the good water resistance and high dimensional stability on the board, so that it will provide protection during immersion or exposure to water after construction (Maloney 2003). The addition of paraffin greater than 1% will reduce the strength of the board, but this can be prevented by the addition of adhesives.

Sulaiman et al. [17] reported that the use of raw materials in the form of wood produces high MoR and MoE values. By mixing of Jatropha press cake with wood particles, it is expected to improve the mechanical properties of the resulting particle board.
4. Conclusion
The obtained particleboard revealed that the addition of sago starch and paraffin has an influence on the properties of the samples. Generally, the modulus of rupture increases with addition of sago starch and paraffin, but it remains insufficient to meet the standard, except the particle board with 3% of paraffin and 10% of sago starch. The properties of Jatropha press cake particle board were density of 0.84-0.95 g/cm$^3$, water content of 4.56-6.19%, thickness-swelling by soaking in water for 2h and 24h were 11.67-20.12% and 48.74-62.20%, respectively, and the water absorption by soaking in water for 2h and 24h were 16.22-25.70% and 63.10-72.75% respectively. The physical and mechanical properties of MoR at 19.70-97.44 kgf/cm$^2$ and MoE at 1552-7235 kgf/cm$^2$. The best particle board product with highest MoR (97.44 kgf/cm$^2$) was produced with addition of paraffin 3% and sago starch 10%.
To meet the JIS Standard, Jatropha press cake particle can be added with wood particle, with optimum sago starch, and minimum paraffin.

5. References
[1] Zuanda R 2012 Kajian Pembuatan papan partikel dari ampas jarak pagar (Jatropha curcasL) hasil proses transesterifikasi in situ [skripsi]. (Bogor: Departemen Teknologi Industri Pertanian, Fakultas Teknologi Industri Pertanian, Institut Pertanian Bogor)
[2] Lestari S, Kartika I A 2012 Pembuatan papan partikel amas biji jarak pagar pada berbagai proses. E-J Agroind. Indon 1 11-17
[3] Guntekin E, and Karakus B 2008 The manufacture of particleboard using mixture of hull (Arachis hypogaea L.) and European Black pine (Pinus nigra Arnold) wood chips Bioresource Technology 99 2893-2897
[4] Jumhuri N, Hashim R, Sulaiman O, Wan Nadhari W N A, Salleh K M, Khalid I, Saharudin N I, Razali M Z 2014 Effect of treated particles on the properties of particleboard made from oil palm trunk Materials and Design 64 769-774
[5] Nadhari W N A, Hashim R, Sulaiman O, Sato M, Sugitomo T, and Selamat M E 2013 Utilization of oil palm trunk waste for manufacturing of binderless particleboard: optimization study. Bioresources 8 675-1696.
[6] Hidayat H, Kejisers E R P, U. Prijanto, van Dam JEG, HJ Heeresc. 2014. Preparation and properties of binderless boards from Jatropha curcas L. seed cake Ind. Crops. Prod. 52 245-254
[7] Kurokochi Y, Sato M 2015 Properties of binderless board made from rice straw: The morphological effect of particles Ind. Crops. Prod. 69 55-59
[8] Talavera F J F, Guzm’ an J A S, Richter H G, Due’ nas R S, Quirarte J R 2007 Effect of production variables on bending properties, water absorption and thickness swelling of bagasse/plastic composite boards. Ind Crops Prod. 26 1-7.
[9] Evon P, Vanderbossche V, Pontailer P, Rigal L 2010 Thermo-chemical behaviour of raffinate resulting from aqueous extraction of sunflower whole plant in twin-screw extruder : manufacturing of biodegradable agromaterials by thermo-pressing. Adv. Mater. Res. 112 63-72
[10] Laemlaksakul V 2010 Physical and mechanical properties of particleboard from bamboo waste. WASET 40 566-570
[11] Biswas D, Bose S K, Hossain M M 2011 Physical and mechanical properties of urea formaldehyde-bonded particleboard made from bamboo waste Int. J. Adhes. and Adhes. 31 84-87
[12] H’ng P S, Lee S H, Loh Y W, Lum W C, and tan B H 2011 Production of low formaldehyde emission particleboard by using new formulated formaldehyde based resin. Asian J. of Scientific Res. 4 264-270
[13] Konnerth J, Hahn G, and Gindl W 2009 Feasibility of particleboard production using bone glue Eur. J. Wood Prod. 6 243-245
[14] D’ Amico S, Hrabalova M. Muller U, and Berghofer E 2012 Influence of ageing on mechanical
properties of wood to wood bonding with wheat lour glue. Eur. J. wood Prod. 70 679-688

[15] Tondi G, Wieland S, Wimmer T, and Schnabel T 2011 Starch-sugar synergy in wood adhesion science: basic studies and particleboard production. Eur. J. Wood Prod. 70 271-278.

[16] Moubarik A, Allal A, Pirzi A, Charrier F, and Charrier B 2010 Preparation and mechanical characterization of particleboard made from maritime pine and glued with bio-adhesive based on cornstarch and tannins Maderas-Cienc. Tecnol. 12 189-197

[17] Sulaiman NS, Hashim R, Aminni MHM, Sulaiman O and Hiziroglu 2013 Evaluation of the properties of particleboard made using oil palm starch modified with epichlorohydrin. Bioresources 8 298-301

[18] AOAC 1995 Official Methods of Analysis of AOAC International, 16th edition. Methods 950.46, Washington (D.C.)

[19] AOAC 1995. Official Methods of Analysis of AOAC International, 16th edition. Methods 923.03, Washington (D.C.)

[20] AOAC 1995 Official Methods of Analysis of AOAC International, 16th edition. Methods 991.20, Washington (D.C.)

[21] SNI (Indonesian National Standard): SNI 01-2891-1992. Proximate analysis for food and drink. [http://sisni.bsn.go.id] [Accessed 4 July 2011]

[22] Japanese Standards Association [JSA]. 2003. Japanese Industrial Standards JIS A 5908 : 2003. Particleboard.

[23] Kurniati M, Fahma F, Amalia Kartika I, Sunarti TC, Syamsu K, Hermawan D, Saito Y, Sato M. 2015 Binderless particleboard from castor seed cake: effect of pressing temperature on physical and mechanical properties. Asian J. Agric. Res. 9 180-188

[24] Kelly MW 1977 Critical literature review of relationships between processing parameters and physical properties of particleboard. USDA For. Serv. Gen. Tech. Report FPL-10. (Madison: Forest Products Laboratory)

[25] Bowyer JL, Shmulsky RS, Haygreen JG 2007 Forest Products and Wood Science, an Introduction fifth edition (USA: Blackwell Publishing)

[26] Widiyanto A 2002 Kualitas papan partikel kayu karet (Heava Brasiliensis Muell. Arg) dan bambu tali (Gigantochlon apus Kurz.) dengan perekat likuida kayu [skripsi] (Bogor: Departemen Hasil Hutan, Fakultas Kehutanan, Institut Pertanian Bogor)

[27] Erniwati, Hadi Y S, Massijaya M Y, Nugroho N 2008 Pengaruh suhu dan waktu kempa terhadap kualitas papan komposit berlapis anyaman bambu. RIMBA Kalimanat Fakultas Kehutanan Unmul 13 106-111

[28] Gintting S H 2009 Oriented strand board dari tiga jenis bambu [skripsi] (Bogor: Departemen Hasil Hutan, Fakultas Kehutanan, Institut Pertanian Bogor)

[29] Mardikanto T R, Karlinasari L, Bahtiar E T 2009 Sifat Mekanis Kayu (Bogor: Bagian Rekayasa dan Desain Bangunan Kayu, Departemen Hasil Hutan, Fakultas Kehutanan, Institut Pertanian Bogor)

[30] Maloney T M 2003 Modern Particleboard and Dry Process Fiberboard Manufacturing. (San Fransisco: Miller Freeman Inc.)

[31] Hermawan D 2005 The Quality of Kenaf (Hibiscus cannabinus L) Particle Board with in paraffin addition. Jurnal Teknologi Hasil Hutan 18 39-45.

[32] Lelievre J 1974 Starch gelatinization J. App. Polym. Sci. 18 293-296

[33] Yimsamerjit P, Surin P, and Wong-on J 2007 Mechanical and physical properties of green particle board produce from corncob and starch binder composite In International Conference on Engineering and Environment-ICEE: Phuket, Thailand.

[34] Burrel M M 2003 Starch: The need for improved quality or quantity-An overview. J Exp. Botany 54 451-456