Physical and mechanical properties of urea formaldehyde and phenol formaldehyde-bonded particleboards made from corn stalk

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Physical and mechanical properties of urea formaldehyde and phenol formaldehyde-bonded particleboards made from corn stalk

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Abstract. Biomass from annual fibers and agricultural wastes as a raw material to produce particleboard or other composite panels has gained increased popularity. The purpose of this study was to investigate the suitability of corn stalk as a material for particleboard manufacturing. The effect of adhesive type and concentration on the physical and mechanical properties of particleboard manufactured from corn stalk was evaluated. Particleboards were produced using hot-pressing machine at temperature of 130 °C for urea formaldehyde (UF) and 150 °C for phenol formaldehyde (PF) adhesives until 10 min. The size of particleboards and target density were 25 mm x 25 mm x 0.9 mm and 0.8 g/cm^3, respectively. The adhesive content was varied from 8, 10 and 12 wt%. The results showed that the physical and mechanical properties of particleboards had better values with increasing the adhesive concentration. The board bonded with PF adhesive showed better physical and mechanical properties than the board bonded with UF adhesive. The modulus of rupture, modulus of elasticity and internal bond of the board bonded with 12 wt% of PF fulfilled the requirement of the JIS A 5908 (2003) for type 13 particleboard.

1. Introduction

Particleboard is known as one of the most important products of the composite industry. Commonly, particleboard is produced from the wood particle. Nath and Mwchahary [1] argued that the wood supply for particleboards industry has been decreased due to the deforestation of natural forest. Considering this condition, the particleboard industry struggles to obtain a sufficient amount of raw material for particleboard production. There is still an outgoing research interest to find alternative sources of raw materials for composite manufacture [2]. Therefore, alternative raw materials such as annual plants and agricultural wastes will play an important role in the composite industry [3, 4].

Many researchers have studied properties of agro-based particleboard made from wide variety of annual plants and agricultural wastes such as hazelnut husk [5], eggplant stalks [2], wheat straws and corn pith [6], sunflower stalks [5], grass clipping [3], kenaf stalks [7], rice straw [8], bamboo [9] and sweet sorghum [10].

As an information, corn production in 2015 was recorded 19.61 million tons which was increased from 2014 with the production of 19.01 million tons [11]. The increase of corn production is also followed by the increase of its solid waste such as corn stalks, so it will take effort in handling it. Corn stalks can be used as a raw material for particleboard production because they are abundance, cheap, renewable lignocellulosic sources and suitable for producing natural cellulose fibers based on

chemical composition, type and number of fiber cells [12]. More than 90% of particleboards manufacturing is bonded with urea formaldehyde (UF) and phenol formaldehyde (PF) adhesives. In addition, among other adhesives used in particleboard manufacture, UF and PF are the most economical and useful glue because of its low cost and easy application.

This research aimed to determine the suitability of corn stalks particle as a raw material for particleboard. The specific objectives of this research were to study the physical and mechanical properties of particleboard from corn stalk particle and to evaluate the influence of different adhesive type and various content of UF and PF on physical and mechanical properties of corn stalks particleboard.

2. Materials and methods

Corn stalks were obtained from the field in Cibinong, Bogor region. They were cleaned from dust and soil. Corn stalks were coarsely chipped using ring flaker and chipper machine into small particles. The particles were then screened by utilizing a horizontal vibration sieve. Particles size used in this research was 1.5-2 cm. All particles used in this research were dried at 100-105 °C in a technical oven until reaching 8% of moisture content.

Corn stalks particles were blended with liquid urea formaldehyde (UF) and phenol formaldehyde (PF). The solid content of PF is 45% and UF is 50%. Based on oven dry particle weight, 8%, 10% and 12% of UF and PF adhesives were applied for particleboard manufacture, respectively. The dimensions of particleboards were 25 cm x 25 cm x 0.9 cm. The pressing conditions were as follows: hot-press temperature (130 °C for UF adhesive and 150 °C for PF adhesive), press pressure (2.5 Mpa), press time (10 min), and target density of corn stalks particleboard bonded PF and UF adhesives (0.8 g/cm^3).

All the boards were conditioned for one week at room temperature. of 27 °C and a relative humidity of approximately 60%. Test samples were prepared and tested based on JIS A 5908:2003 standard for physical and mechanical properties.

3. Results and discussion

The results of physical properties such as thickness swelling (TS) and water absorption (WA) of corn stalks particleboards for 24 h water immersion test are shown in figure 1 and 2. Both figures reveal similar trends of thickness swelling and water uptake in all types of boards. It can be seen that the values of TS and WA of the samples decreased with the increase of adhesive content. TS and WA values of particleboards with UF adhesive were higher than particleboard with PF adhesive, ranging from 14.56% to 25.83% and 56.29 to 77.96%, respectively. The TS value of the particleboard bonded with 10% wt and 12% wt PF adhesive were 11.73% and 8.01%, respectively. The values fulfilled JIS A 5908:2003 [13] requirements of Type 8 Particleboard, maximum of 12%.

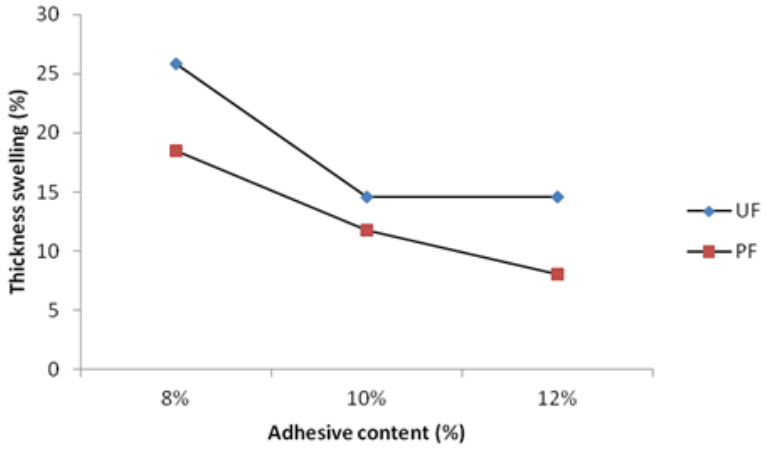

Figure 1. Thickness swelling value of particleboard.

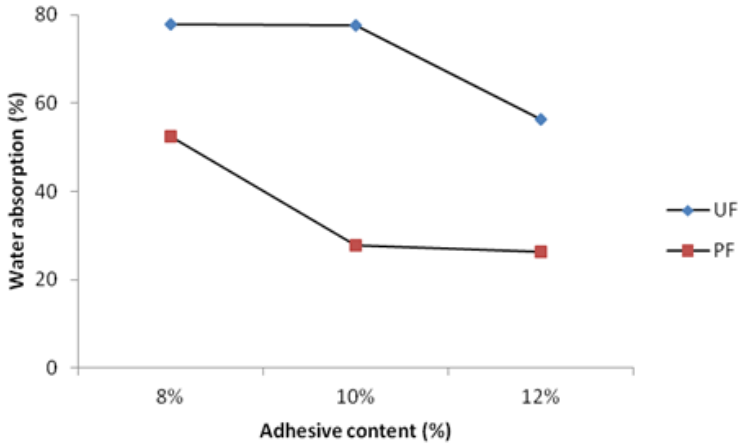

Figure 2. Water absorption values of corn stalk particleboard.

Generally, increasing the adhesive content could improve the thickness swelling and water absorption properties of particleboards. The TS and WA values of particleboards using PF was better than particleboards using UF. This may be due to interference in the curing of PF adhesive that resulted in the reduced wettability of the particle surface or limitation of diffusion and/or the spreading of the adhesive within the particles and over the particle surface. It is due to the major disadvantages of UF adhesive that occurs in damage to the bond which is mainly caused by water and moisture [14]. In addition, The principal factors affecting the TS value of particleboards are the type of adhesives used and the resin content and compressibility of the boards [15].

Figure 3-6 shows the results of mechanical properties such as modulus of elasticity (MOE), modulus of rupture (MOR), internal bond (IB) and screw holding power (SHP) for produced particleboards. Increasing the adhesive content in the particleboard manufacturing improved the mechanical properties.

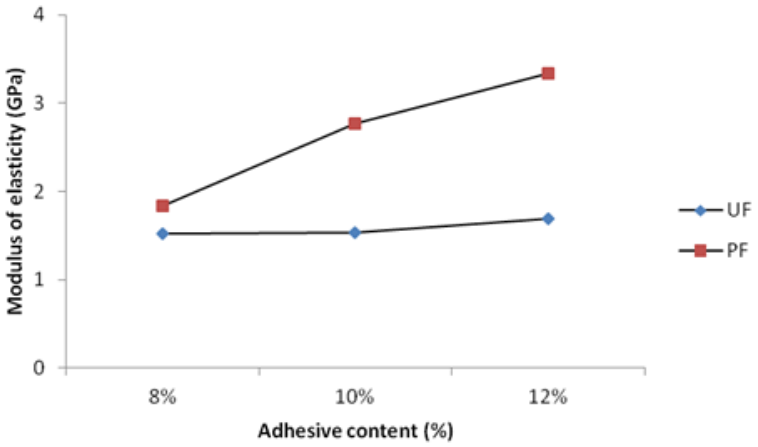

Figure 3. Modulus of elasticity of corn stalk particleboard.

Generally, the bending strength (MOE and MOR) values of corn stalk particleboard using PF adhesive are better than particleboard using UF. The highest MOE (3.34 GPa) and MOR (18.5 MPa) values were obtained for particleboard manufactured using 12% wt PF adhesive.

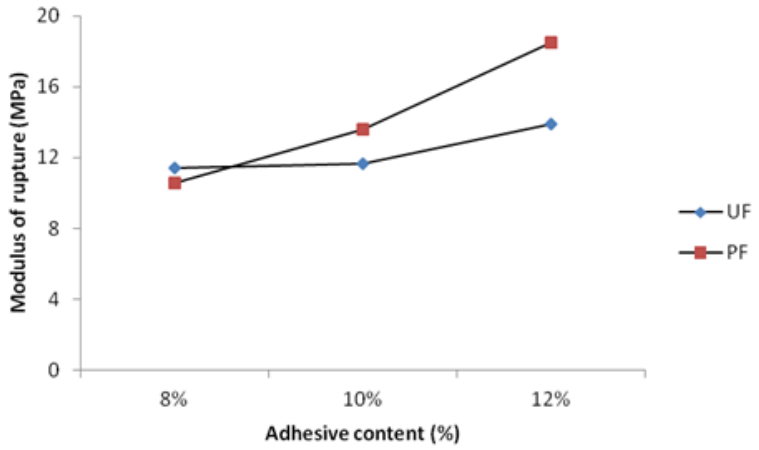

Figure 4. Modulus of rupture of corn stalk particleboard.

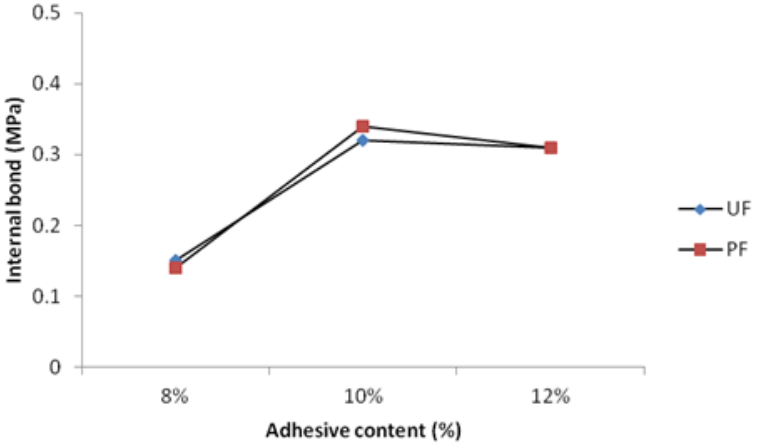

Figure 5. Internal bond values of corn stalk particleboard.

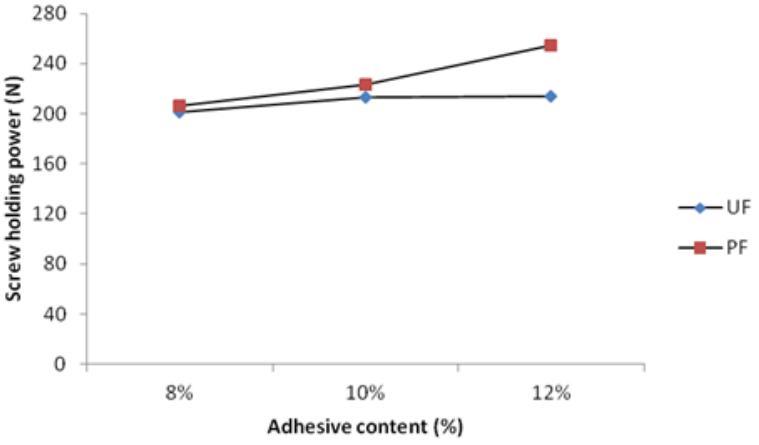

Figure 6. Screw holding power values of corn stalk particleboard.

The MOR and MOE values of the particleboard fulfilled JIS A 5908:2003 requirements of Type 8 Particleboard, Type 13 and 18. The difference of MOE and MOR values of corn stalk particleboard obtained was also influenced by the chemical reaction between adhesive type and lignocelluloses materials, PF adhesive reacts better with corn stalks particles therefore the MOE and MOR value is higher compare to those with UF. As we know that corn stalks have the potential as a source of

lignocellulose material because they have high levels of α-cellulose (32.4%), holocellulose (55.6%), hemicellulose (23.2%) and lignin (16.3%) [16]. Another factor that influence MOE and MOR is moisture content of particle. Using particle with a high moisture content would result in particleboards with inferior mechanical properties due to the poor adhesion between adhesive and particles [17].

Figure 5 shows the relationship between adhesive content and IB properties of corn stalks particleboards. The IB value of particleboards increased in line with the increase of adhesive content from 8 to 10 wt% and then it slightly decreased afterward. The IB values of corn stalk particleboards bonded 10 wt% UF or PF were slightly higher and fulfilled JIS A 5908:2003 than particleboards manufactured with 8 and 12 wt% adhesive content.

The results of screw holding power (SHP) of the corn stalk particleboard is shown in figure 6. Increasing the adhesive content improved the value of SHP of the particleboard. The value of SHP ranged from 201.17 to 254.95 N. This value could not meet JIS A 5908:2003. However, the SHP value of particleboard with PF adhesive is better than particleboard with UF adhesive. The lower value of SHP was also influenced by the density and surface bonding area from the particle. Particles with surface bonding area were caused by the contact between the particles with the adhesive which was to be larger and caused the value of SHP to increase [18].

4. Conclusion

The results of this research showed that it is possible to produce particleboard using corn stalk particle bonded UF and PF adhesive. The physical and mechanical properties of particleboards were enhanced by increasing adhesive content. Generally, corn stalk particleboard with PF adhesive had better properties than particleboards with UF adhesive. The particleboards bonded with PF 12 wt% had the best physical and mechanical properties and fulfilled the minimum requirements in JIS A 5908:2003 standards for particleboards except for the SHP.

Acknowledgement

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