Influence of Press Temperature on The Properties of Binderless Particleboard

Milawarni1*, Nurlaili2, Sariadi3, Siti Amra1, Yassir1

1Electrical Engineering Departement, Politeknik Negeri Lhokseumawe
2Mechanical Engineering Departement, Politeknik Negeri Lhokseumawe
3Chemical Engineering Departement, Politeknik Negeri Lhokseumawe

*E-mail: milawarni@pnl.ac.id

Abstract. All experimental binderless particleboard were manufactured using coffee husk. In this case, we apply a method so called an oxidation method that uses 15% hydrogen peroxide (H\textsubscript{2}O\textsubscript{2}) and a Ferro-sulphate (FeSO\textsubscript{4}) 7.5% catalyst. The methods refer to JIS A 5908-2003 standard. In this paper, through the test, we evaluate some properties of the panel including density, modulus of rupture (MOR), modulus of elasticity (MOE), internal bond strength (IB), thickness swelling (TS) and water absorption (WA). The panel is made with a target density of 0.75 g / cm\textsuperscript{3} using pressing temperatures of 150,160,170,180 and 190\textdegree C. The result shows that, by increasing pressing temperatures, some parameters such as the modulus of rupture, modulus of elasticity and internal bonding of the particleboards tend to increase while their water absorption and thickness swelling decreased. The best physical and mechanical properties of binderless particleboard from coffee husk were obtained in pressing temperature of 180\textdegree C. Microscopic study using Scanning Electron Microscopy (SEM) revealed that panels made with pressing temperature of 180\textdegree C have bond characteristics that support the improvement of panel properties. Thus, this study addressed that the mechanical and physical properties of the panel were influenced by pressing temperature.

1. Introduction
Particle boards are one type of composite or wood panel made of wood particles or other lignocellulosic materials, which are hot-pressed bound using synthetic adhesives or other binding materials [1]. Making composite products with varied raw materials will be useful for the future. This is due to the emergence of environmental issues that are increasingly degraded, scarcity of resources, consumer guidance for higher quality products, higher knowledge, and mastery of knowledge. In addition, countries that do not have the potential of wood is one of the factors which stimulate the creation of high-quality composite products from low-quality raw materials [2]. Various products based on renewable natural resources are products that are widely accepted in developed countries. Many developed countries require that products entering their country are not environmentally damaging and not derived from raw materials and stages of the production process that pollute the environment [3]. The board can be made from basic pieces of wood or other lignocellulosic materials by heating without the need to use adhesives and hot-pressed, this treatment can cause self-bonding. This occurs by solubility of hemicellulose and lignin from hydrolysis process [4]. Many researchers in the world have studied non-adhesive particle boards from lignocellulose materials such as bagasse waste [5], palm oil leaves [6], oil palm stems [7], sun flower whole plant, [8] and Jatropha [9].
Previous research showed that hemicellulose and lignin had decomposed during the suppression process. The condensation reaction of lignin contributes to the self-bonding mechanism and the sugar content of the board decreases with increasing pressure [10]. Subsequent studies show that binderless boards are developed from sugars containing lignocellulose materials such as sorghum which are given a pressure temperature of 180°C or higher to achieve the desired bond [11]. The research stated that increasing temperature pressure is one of the potential ways to improve the nature of binderless particleboards [12]. The properties of the board using the steam exploded Miscanthus sinensis method by applying pressure at a temperature range of 195 - 245°C and obtaining satisfactory results [13]. Furthermore, the research showed that lignin, carbohydrates (cellulose and hemicellulose) and proteins are believed to be natural binders that can be activated with high pressure at high temperatures to produce binderless particleboard from jatropha seed cake [14]. Proteins can act as internal bonds in fiberboards by forming complex bonds that can improve the cohesion between the surfaces of the fiber. Coffee husk is agricultural biomass waste obtained from coffee processing at the factory. Binderless particle boards can be made from coffee husk with an oxidation method that produces boards with good characteristics. With fiber content, hemicellulose, the usefulness of coffee husk is a very interesting idea to be developed so that it becomes an added value of this biomass waste which can be produced into particle boards without adhesive [15]. In this paper, we will study the effect of temperature pressure on physical and mechanical properties of adhesive-free particle boards made from coffee husks. The morphological form of the panel was obtained after the Scanning Electron Microscopy (SEM) test was carried out to evaluate changes in protein corpuscles and fiber textures during the degradation process.

2. Trial Procedure

The coffee husk used in this study was obtained from a coffee processing plant in a region, Takengon-Aceh, Indonesia. The particles are dried in the open air for a week until the moisture content is less than 8%. After that the coffee was reduced in size using a grinding machine after which the particle powder was filtered with a size of 10/20 mesh sieve. These particles are then oxidized using 15% Hydrogen peroxide (H₂O₂) based on the particle dry weight and 7.5% ferro-sulphate (FeSO₄) based on H₂O₂ weight. After oxidation, the particles were allowed to stand for 20 minutes and hot pressed with temperature variations of 150,160,170,180 and 190°C and a pressure of 25 kgf / cm² for 12 minutes. Determination of the optimal press temperature is carried out based on the results of testing the physical and mechanical properties of the board produced. The tests carried out refer to JIS A 5908 2003. The physical and mechanical properties tested include density, water absorption, thickness development, modulus of elasticity, fracture modulus and firmness of internal adhesives. Each sample is tested for its characteristics based on needs.

3. Results and Discussion

3.1. Mechanical Properties

The effect of the pressure temperature on the modulus of rupture (MOR), and modulus of elasticity (MOE) values of the adhesive-free particle board made from the coffee husk are shown in Figures 1a and 1b, respectively. The MOR and MOE values of the board tend to increase with increasing temperature. At a pressure temperature of 180°C, the highest MOR value is 3.85 MPa and the highest MOE value is 787.67 MPa. Meanwhile if the pressure temperature is greater than 180°C then the MOR and MOE values will decrease. The best MOR value is related to denaturation of husk coffee protein at temperatures of 170-175°C. At a pressure temperature above 180°C, the protein becomes partially degraded to small fragments which cannot be enhanced by adhesion of the fiber board. Overall, the average MOR and MOE values of non-adhesive particle boards obtained did not meet JIS A 5908 (2003) standards [16]. The low value proves that high temperatures are not enough to achieve self-bonding power through the activity of natural bonds (such as protein and fiber) in the board. The occurrence of a bonding mechanism in an adhesive-free particle board without the help of synthetic
resin can occur due to the presence of natural bonds such as proteins, hemicellulose, lignin and cellulose where these bonds can be activated through high temperature pressure [17]. In this study, the temperature pressure was made at a range of 150-190°C, at which time the protein has been denaturized and hemicellulose degraded. But that is not enough to increase the bond strength between fibers.

Conversely, at a pressure temperature above 190°C lignin and cellulose will be activated but the protein will degrade. In this study, high temperatures are needed to activate natural bonds to increase the strength of the particle board without adhesive. Like the research report where at high pressure
temperatures, the activity of natural bonds is obtained from mechanical bonding (interlocking by protein penetration through porous fibers surface) and molecular attractive force (Van der Waals force, hydrogen bonds) [18].

The MOE value is almost the same as the MOR value. Where the value of MOE increases with increasing temperature pressure. The same reason for the MOE value where the pressure temperature activates protein increases its strength. When the temperature pressure is above 180°C, the MOE value tends to begin to decline. Strength of particle board without adhesive from coffee husk can be seen from its chemical and physical properties. The MOR, MOE and IB values are not only dependent on the bond strength between fibers but also by the strength of the fiber itself, fibers and fiber or particle geometry.

Figure 1c shows the effect of the pressure temperature on the internal bond strength (IB) of the particle board without adhesive. The IB value is used to calculate the bonding strength of the interface between the fibers / particles in the board. IB is associated with the ability of adhesion between fibers. In general, the value of IB tends to increase with increasing temperature pressure. At temperatures of 180°C the maximum IB value decreases when the pressure temperature rises to 190°C. At 180°C the maximum protein activity is a natural bond, where at this temperature the adhesion between the fibers on the board reaches the optimum value. Adhesion ability decreases when the pressure temperature rises to 190°C this is due to the gradual degradation of the protein. This situation can be seen from SEM analysis.

3.2. Physical Properties

Thick development values (TS) and water absorption capacity (WA) of the boards produced after 24 hours of immersion ranged between 11-15% and 80-84% as shown in Figures 1d and 1e. TS and WA values at high pressure will reduce their values. Values that meet the standards are at 180°C, this is because at this temperature there is a very good style of adhesively, compatibility and spread of protein along the surface of the fiber.

3.3. Morphology of binderless particleboards

The morphology of the board is seen as a function of pressure temperature. Test analysis Scanning Electron Micrographs (SEM) were carried out on a board made at 180°C because at this temperature the optimum physical and mechanical test characteristics were obtained. At a pressure temperature of 180°C it has been led to improve the denaturisation ability of protein and then the corpuscles of the binderless particleboard protein disappeared after the treatment temperature and the fibers were embedded in a continuous matrix.

Figure 2. SEM results at pressure temperature

4. Conclusion

A research has been conducted on the effect of pressure temperature on the physical and mechanical properties of adhesive-free particle boards made from coffee husks. The test results show the pressure temperature has an influence on the nature of the board. In general, the MOR and MOE values
increase with increasing temperature pressure but do not meet the JIS standard. Pressure temperature affects the physical properties of the board. Meanwhile the IB values at 170 and 180°C meet the JIS minimum standard. With increasing pressure temperature, it decreases the value of TS and WA. TS value at a pressure of 180°C meets the standard.

5. Acknowledgement
The author would like to express their gratitude to Kemenristek DIKTI for its funding to conduct this research thought a competitive research grant program in 2017-2018.

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