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Characterization of composite boards made of oil palm trunk flour/maleic anhydride grafted polypropylene

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Abstract. The aim of this study was to evaluate and characterize various properties of composite board prepared from oil palm tree flour (KK), maleic anhydride grafted polypropylene (PPd-g-AM), divinyl benzene (DVB) and benzoil peroxide (BPO). The oil palm oil trunk was floured with a size of 80 mesh and dried in an oven so that the water content reaches 2% and then soaked in 3 % sodium hydroxide solution at room temperature for 24 hours. The flour was then filtered, washed repeatedly with water until free of sodium hydroxide. Flour of oil palm trunk flour that had been treated with sodium hydroxide solution was determined lignin levels and extractive substances. Furthermore, the oil palm tree flour was made into a composite board by blending of KK, PPd-g-AM, DVB and BPO in various compositions and casted at 170°C, 10 minutes and 40 bar pressure. The composite boards obtained were stored for 2 weeks and then characterized by physical properties (moisture content, density and thickness development), mechanical properties (MoR and MoE), and morphology. The results shown that the optimum composition of the composite boards was in the KK: PPd-g-AM: DVB: BPO (60: 24: 8: 2%) or KK33.

1. Introduction

Oil palm plantations are one of the important natural resources in Indonesia that provide direct benefits in the form of palm oil. The productive age of oil palm trees ranges from 20-25 years and after that the trees become not productive anymore and are felled and replaced with new plants. Usually, the trees that have been cut down are left to rot or be burned and underutilized as an alternative source of wood, although the efforts to use them were conducted, the results were not satisfactory.

According to the data, the area of oil palm plantations in Indonesia is about 11.7 million Ha.[1] In 1 Ha of land, there are 125-135 oil palm trees[2]. If there is a 10% rejuvenation of oil palm plantation every year, so as many as 146 million palm trees will be produced and this is equivalent to 73 million tons of timber. So palm oil will always be available throughout the year due to sustainable rejuvenation. One way to utilize the oil palm that some researchers have done is to make it into a composite board or a particle board. Most of binder used in preparation of composite boards is formaldehyde-based binder although other binder share used such as corn starch and tannins and cassava starch [3,4,5]. It was reported that the quality of the composite board produced has not been good yet because it was easily bent, insect-edible and moldy and easy to absorb water [6].
To overcome this deficiency and to avoid the dangerous nature of formaldehyde emissions, an action to replace a formaldehyde-based adhesive material with a modified polypropylene adhesive is needed. The main problem of using polypropylene (PP) as a composite board is the weak adhesive force between the PP and the oil palm particles, it is only physical interactions, does not form chemical bonds and the difference of polarity so that the mixture cannot mix homogeneously. The oil palm I of the major components of cellulose is hydrophilic (polar) and polypropylene adhesive is hydrophobic [7].

The way to solve this problem is to modify (functionalize) the polypropylene (PP). It is by reacting PP with benzoyl peroxide (BPO) in order to degrade PP and to obtain a PP with shorter chain (PPd), and then the PPd is grafted with maleic anhydride (AM) using BPO initiator to produce maleic anhydride grafted polypropylene (PPd-g-AM) and adding divinyl benzene as cross linkers. It is expected that with modified polypropylene, its polarity will increase, so that the adhesive power with the wood particles of palm oil is stronger. Also, an esterification reaction occurs between the PPd-g-AM and flour of oil palm wood so that the composite board produced is having better mechanical properties, strong, termite proof, resistant to water and without formaldehyde emissions.

2. Materials and Methods

2.1. Materials
The oil palm trunk used was rejuvenated oil palm tree from oil palm plantation in Southeast Aceh. Polypropylene (Innovex, PT Petrokimia Nusantara), divinyl benzene (Schcharot OUG 85662, Germany), benzoyl peroxide (Aldrich Chemical Company, Inc. USA) and maleic anhydride (Merck) were used.

2.2. Thermal Degradation of Polypropylene with Benzoyl Peroxide
A total of 85% PP and 15% g of BPO was inserted into the internal mixer and heated at temperature of 170 ºC for 5 minutes. The sample was removed from internal mixer and inserted into the beaker, then it was cooled and stored in the indicator. The result was called as PPd.

2.3. Grafting of PPd with Maleic Anhydride (AM) with BPO Initiator
PPd was grafted with maleic anhydride with BPO initiator at 170 ºC. The weight ratio, (w/w) of PPd: AM: BPO was 92: 6: 2%. Then, 92% PPd and 6% AM were inserted into an internal mixer apparatus and heated to melt. As many as 2% BPO was added and left to react for 5 minutes. The sample was removed and allowed to cool and stored in desiccator. The result was called maleic anhydride grafted polypropylene (PPd-g-AM).

2.4. Purification of PPd-g-AM
A total of 2 g PPd-g-AM was inserted into in the flask. Then, a total of 100 mL of xylene was added and refluxed until they were dissolved. After that, the mixture was deposited by adding 40 mL of acetone. Then, it was filtered with filter paper connected to a vacuum pump. The precipitate was washed with methanol repeatedly. Then, the sediment was dried in oven at a temperature of 120 ºC for 6 hours.

2.5. Determination of PPd-g-AM Grafting Degree
A dried and pure PPd-g-AM was inserted into a flask and then refluxed with 100 mL of xylene until homogeneous. After the mixture dissolved, it was added with 3 drops of water and the reflux was continued for another 15 minutes. Then, 3 drops of phenolphthalein 1% indicator was added and titrated with KOH 0.05 N in methanol in hot conditions. Titration was stopped when the color change to red rose and the volume of KOH 0.05N used was recorded.
2.6. Provision of Palm Oil Powders
The part of the oil palm that is used was the stem with above 2 m in height. Furthermore, the palm oil was cutted into pieces and the middle part was taken and made into flour with the size of 80 mesh and dried in the oven, until the water content was 2%. After that, the flour was soaked in 3% of sodium hydroxide for 24 hours. Furthermore, the filtrate was filtered, washed with water until the sodium hydroxide was removed and dried. Finally, the lignin and extractive agent content were determined.

2.7. Preparation of composite Boards
At this step, the sample composition was made as listed in table 1 and table 2 below. Oil palm flour, PPd-g-AM, DVB and BPO were inserted into a container and stirred until evenly distributed. Then, the mixture was inserted into a mold with a size of 25 cm x 25 cm x 1 cm and molded using a hydraulic press for 15 minutes at a temperature of 170°C with 40 bar of pressure. The resulting board was stored for 2 weeks at room temperature and then, its physical properties, mechanical properties and morphology were characterized.

Table 1  The composition of composite boards without the NaOH 3 % immersion, (% w/w)

| Sample code | KK  | PPd-g-AM | DVB | BPO |
|-------------|-----|----------|-----|-----|
| KK1         | 80  | 8        | 8   | 2   |
| KK2         | 70  | 16       | 8   | 2   |
| KK3         | 60  | 24       | 8   | 2   |
| KK4         | 50  | 32       | 8   | 2   |
| KK5         | 40  | 40       | 8   | 2   |
| KK6         | 64  | 28       | 0   | 2   |

Table 2  The composition of composite boards with the NaOH 3 % immersion, (% w/w)

| Sample code | KK  | PPd-g-AM | DVB | BPO |
|-------------|-----|----------|-----|-----|
| KK13        | 80  | 8        | 8   | 2   |
| KK23        | 70  | 16       | 8   | 2   |
| KK33        | 60  | 24       | 8   | 2   |
| KK43        | 50  | 32       | 8   | 2   |
| KK53        | 40  | 40       | 8   | 2   |
| KK63        | 64  | 28       | 0   | 2   |

3. Results and Discussions

3.1. FTIR Spectrum
The obtained PPd-g-AM grafting degree was 9.73 %. The figure 1 below is showing the the FTIR spectra of PPd, PPd-g-AM before and after the purification process. The FTIR spectra indicate that the grafting process between maleic anhydride and polypropylene was occurred. Before the purification, there was an absorption of the wavelength of 1635.64 cm⁻¹ it indicated the occurrence of the double bond of the maleic anhydride. This indicated that before the purification, there was still maleic anhydride which did not react. Then, after the purification, this adsorption peak was disappear. The typical adsorption of wave number before the purification at 1705.07 cm⁻¹ was refer to asymmetrical carbonyl group from the carbonyl group of maleic anhydride from PP-g-AM, and after the purification, the wavenumber was 1712.79 cm⁻¹. The indication of the formation of PP-g-AM is also supported with C-O group at a wave number of 1296.16 cm⁻¹ from the maleic anhydride.
3.2. Lignin and Extractive Content After Immersion With Hydroxide Solutions

After immersion of oil palm flour with 3% of sodium hydroxide solution was conducted, the lignin content was measured by Klason method. It was found that the lignin content was decreased from 16.70 to 1.34% (92%). Moreover, the extractives was also decreased from 22.07 to 15.06% (32%).

3.3. Mechanical Properties of Composite Boards: MoR and MoE

The number of MoR and MoE composite boards without immersion is descibed in table 3. The number of MoR composite board increased with the increase of PPd-g-AM and reached the maximum value of 175.40 kgf/cm² when the number of PPd-g-MA reached 24% (KK3). The increase of this MoR value was the result of the ester bonding between the maleic anhydrous group and the hydroxyl group from the palm oil powder cellulose.\(^\text{[10]}\) The increasing of the PPd-g-AM number lead to a decrease in the number of the MoR. It is estimated that PPd-g-MA excess has occurred so it will cause two phases, namely the powder phase of KK and PPd-g-AM phase. This phase separation will affect the bending strength of the composite board.

| Sample Code | MoR (kgf/cm²) | MoE (10³ kgf/cm²) |
|-------------|---------------|------------------|
| KK1         | 95.02         | 12.70            |
| KK2         | 120.06        | 18.25            |
| KK3         | 175.40        | 19.80            |
| KK4         | 153.28        | 18.10            |

Table 3. The mechanical properties of composite boards without the NaOH 3 % immersion
Divinyl benzene (DVB) has a major effect in increasing the number of MoR. This can be seen by comparing the number of MoR without the presence of DVB (KK6); 90.70 kgf/cm² and the presence of DVB (KK3); 175.40 kgf/cm². It can be seen that the increase in MoR was almost doubled. This significant increase was estimated due to the occurrence of divinyl benzene and PP-g-AM cross-linked in particle board. The existence of these cross linking will increase the strength of the composite board. When compared to the number of MoR in SNI 03-2105-2006, the minimum MoR requirement is 107 kgf/cm², then, not all of the the composite boards produced were eligible. The eligible particle board was a sample of KK2, KK3, KK4 and KK5 with KK3 possessed a maximum value. The role of PPd-g-AM adhesive was highly significant in increasing the MoR value. In other hand, without the PPd-g-AM, the value of MoR was significantly decrease [11,12].

Moreover, table 3 also shows the modulus of elasticity value. The MoE of composite board changed with the increasing of PPd-g-AM content. Initially, the value of MoE increased with the increase of PPd-g-AM content and reached the maximum value when the amount of PPd-g-MA reached 24%; 19.80 x 10³ kgf/cm² (KK3). Then, there was a decrease in the value of MoE if the number of PPd-g-AM increased. Based on SNI 03-2105-2006, the minimum MoE requirement is 20.40 x 10³ kgf/cm², and the boards produced had not met the minimum standard requirement [12].

### Table 4. The mechanical properties of composite boards with the NaOH 3% immersion

| Sample code | MoR (kgf/cm²) | MoE (10³ kgf/cm²) |
|-------------|---------------|------------------|
| KK13        | 103.86        | 15.58            |
| KK23        | 138.15        | 19.19            |
| KK33        | 182.40        | 22.80            |
| KK43        | 163.52        | 21.59            |
| KK53        | 134.10        | 17.34            |
| KK63        | 93.90         | 12.57            |

Table 4 shows the value of MoR and MoE composite board with immersion of KK with 3% of NaOH solution. If the value of MoR before and after immersion is compared, there is an increase in the value of MoR from 160.40 kgf/cm² (KK3) to 182.40 kgf/cm² (KK33). There was an increase for the value of MoR by 22%. Similarly, the value of MoE has increased from 19.80 x 10³ kgf/cm² (KK3) to 22.80 x 10³ kgf/cm² (KK33). There was an increase in MoE value by 15 %. The increase in mechanical properties was due to the reduction of lignin content and extractive substances in the wood flour of oil palm, so that lignocelluloses were more easily bound to PPd-g-AM. Finally, the composite board of KK33 had met the predefined standards.

### Table 5. The physical properties of composite boards without the NaOH 3 % immersion

| Sample code | Density (g/cm³) | Water Content (%) | Thickness Development (%) |
|-------------|-----------------|------------------|---------------------------|
| KK1         | 0.56            | 0.63             | 0.54                      |
| KK2         | 0.58            | 0.60             | 0.50                      |
| KK3         | 0.61            | 0.56             | 0.45                      |
| KK4         | 0.58            | 0.58             | 0.50                      |
| KK5         | 0.56            | 0.62             | 0.50                      |

3.4. Physical Properties of Composite Boards (Water Content, Density and Thickness Development)
The value of moisture content, density and thickness of the board before and after immersion is listed in table 5 and table 6. Based on table 5 and table 6, it can be seen that density, moisture content and thickness development of the composite board were relatively similar and there was no significant difference. The water content of composite board is in the range of 0.55-0.64% and this is still in accordance with the range of SNI 03-2105-2006, which is the maximum value is 14%. Based on the previous research, the average density of oil palm flour is 0.27 g/cm³. This increase was also due to PPd-g-AM and DVB presence. The range of density of obtained was from 0.56 g/cm³ to 0.65 g/cm³, and it is still within the range of SNI 03-2105-2006; 0.4-0.9 g/cm³.

Table 6. The physical properties of composite boards with the NaOH 3% immersion

| Sample code | Density (g/cm³) | Water Content (%) | Thick Development (%) |
|-------------|----------------|-------------------|-----------------------|
| KK13        | 0.58           | 0.62              | 0.48                  |
| KK23        | 0.60           | 0.58              | 0.46                  |
| KK33        | 0.65           | 0.55              | 0.40                  |
| KK43        | 0.62           | 0.57              | 0.45                  |
| KK53        | 0.60           | 0.60              | 0.50                  |
| KK63        | 0.56           | 0.64              | 0.52                  |

If it is referred to SNI 03-2105-2006, the value of the thickness of the resulting composite boards still meet the standards.

3.5. Composite Board Morphology

The SEM micrograph of the most optimum composite board is shown in figure 2(a). The interaction between KK with PPd-g-AM and DVB was good and homogeneous and the cavity between composite board component was very small. This is also supported by the most optimum MoR and MoE value.

Figure 2 (b) shows that the composite board is not yet homogeneous and there is still a larger cavity when compared to figure 2 (a). In figure 2 (c), it shows a composite board without DVB. The cavity between oil palm flour trunk with PPd-g-AM is getting bigger and less homogeneous and the cross-linking between powder and PPd-g-AM could not be found.

Figure 2. The SEM micrograph of (a) composite board KK33, (b) composite board KK3, and (c) composite board KK6
4. Conclusions
The immersion of oil palm powder with 3% of NaOH solution was very significant in improving the mechanical properties of composite boards. PPd-g-AM and DVB was very good for making composite board of oil palm flour because its physical, mechanical and morphology properties are good. The MoR and MoE value, moisture content, density, thickness development and morphology of KK33 composite board has already meet the standard and is a composite board with the most optimum composition.

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References
[1] BPS-Statistic Indonesia 2016
[2] PT Aero Geosurvey Indonesia 2017
[3] Zhang Y et al 2011 BioResource, 6 464
[4] Moubarik A et al 2010 Journal of Maderas Ciencia Tecnologia, 12 189
[5] Monteiro S et al 2016 J. Polymer, 8 354
[6] Gerege I et al 2018 J. Material Science & Engineering 13 104
[7] Gosselin R and Rodigue D 2006 Journal of Thermoplastic Composite Materials 19 659
[8] Eddyanto 2007 Functionalization of Polymer: Reactive Processing (United Kingdom: Aston University)
[9] Sclavons M et al 2000 J. Polymer 41 1989
[10] Caufield D F 2005 Wood Thermoplastic Composite: Handbook of Wood Chemistry and Wood Composite (New York: CRC Press)
[11] Cuk N et al 2011 J Material and Technology 45 241
[12] Standar Nasional Indonesia 2006 Mutu Papan Partikel (SNI- 03-2105-2006: Jakarta)