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ORIGINAL ARTICLE

# Characteristics of binderless particleboard made from jabon wood using several oxidation pretreatments

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**Abstract** The aims of this study were to evaluate the characteristics of the binderless particleboard made from jabon wood, using several combinations of hydrogen peroxide ($H_2O_2$) and ferrous sulfate ($FeSO_4$) in an oxidation process. Jabon wood obtained from a community forest was chipped into particles. The particles were then dried to about 10% moisture content. Binderless particleboards with a target density of 0.75 g cm$^{-3}$ were manufactured using $H_2O_2$ and $FeSO_4$ to activate the wood particles. Eight combinations of $H_2O_2$ (H) and $FeSO_4$ (F) were used: H5:F5, H10:F5, H15:F5, H20:F5, H5:F7.5, H10:F7.5, H15:F7.5, and H20:F7.5, where the numerical values indicated the percentage of each. The boards were then tested based on Japan Industrial Standard A 5908-2003. The results showed that the binderless particleboard made with $FeSO_4$ at 5% and $H_2O_2$ at 20% exhibits best, with the physical and mechanical properties meeting the requirements of the standard.

**Keywords** Jabon wood · Binderless particleboard · Oxidation process

## Introduction

Jabon (*Anthocephalus cadamba*) is a fast-growing species that is widely cultivated in community forests in Indonesia. It produces a light wood that is used for light construction, ceilings, and carving and as a raw material for making plywood, flooring, pulp and paper, matches, and pencils (Krisnawati et al. 2011). Yunianti et al. (2015) found that jabon wood has a low density (0.36 g cm$^{-3}$), unstable dimensions (tangential/radial ratio of > 2), and a high content of cellulose and lignin (50.32% and 23.82%). Based on these characteristics, jabon has potential raw material for particleboard manufacture. Low-density wood is preferred for particleboard, and medium-density wood may be used if prices are appropriate, but high-density wood is not recommended (Shmulsky and Jones 2011).

Ruhendi and Putra (2011) investigated the use of jabon as a raw material for particleboard. They made particleboard from the stems and branches of jabon using urea formaldehyde adhesives. However, the boards had an inadequate modulus of elasticity (MOE). Moreover, they still used formaldehyde-based adhesives, which are widely known to be harmful to health and the environment.

Binderless particleboard is expected to be able to overcome these problems. First, this board does not use adhesives, and second, this technology has been shown to increase the physical and mechanical properties of sengon (*Paraserianthes falcataria*) particleboard. In addition, the quality of binderless particleboards can be influenced by many factors, one of which is pretreatment (Widyorini et al. 2011). Based on research by Suhasman et al. (2011), binderless sengon particleboard made with an oxidation pretreatment showed good results and met the Japan Industrial Standard (JIS) A5908-2003 standard (JIS 2003). The oxidation pretreatment was also developed for manufacturing composite plywood (Saad et al. 2019; Suhasman et al 2019) and plywood (Suhasman and Agussalim 2019). Auza (2018) found that sengon particleboard made with urea–formaldehyde adhesive had weaknesses in its mechanical properties, especially the MOE and the modulus of rupture (MOR). However, boards made with

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particles that were pretreated with heat immersion and steaming had an increased MOR, although the MOE was not changed.

Sengon or jabon is a fast-growing species with somewhat similar characteristics, one of which is low-density wood. Jabon has never been used as a raw material for binderless particleboard produced with an oxidation method. Therefore, the aim of study was to evaluate the characteristics of binderless particleboard made from jabon species wood using oxidation pretreatments based on several combinations of hydrogen peroxide ($H_2O_2$) and ferrous sulfate ($FeSO_4$).

## Research method

### Sample preparation

Jabon wood was obtained from a community forest in South Sulawesi, Indonesia. The wood was then made by shaving particles and dried to achieve about 10% moisture content.

## The boards manufacturing

The particles were then oxidized, using eight different combinations of H2O2 and FeSO4, namely H5:F5, H10:F5, H15:F5, H20:F5, H5:F7.5, H10:F7.5, H15:F7.5, and H20:F7.5. H5:F5 means 5% $H_2O_2$ based on the particle weight and 5% $FeSO_4$ based on $H_2O_2$ weight. The oxidations were conducted by spraying $H_2O_2$ first and subsequently $FeSO_4$ to the particles gradually. The oxidized particles were conditioned for 15 min. After that, the particles were formed to be mats for manufacturing the boards with a dimension of 30 cm × 30 cm × 0.7 cm (length, width, and thickness, respectively). The boards were hot-pressed at 180 °C and 25 kg $cm^{-2}$ of pressure for 12 min to achieve a target density of 0.75 g $cm^{-3}$. The boards were then conditioned for two weeks before testing.

## Testing and analysis

Physical and mechanical properties, namely density, moisture content, thickness swelling, modulus of rupture, modulus of elasticity, and internal bond, were determined based on JIS A5908-2003 (JIS 2003). The characteristics of the boards were then analyzed descriptively.

## Results and discussion

Table 1 shows the physical properties of the binderless particleboards created for this study. The target board density was 0.75 g $cm^{-3}$. The range required by JIS A5908:2003 is from 0.4 to 0.9 g $cm^{-3}$. The boards produced varied in density, however, with values ranging from 0.65 to 0.73 g $cm^{-3}$ and no boards reaching the target. A possible reason for this result is the degradation of the cell walls of the wood during the manufacturing process. Oxidation can degrade the chemical components of wood particles, which can then be lost during both the oxidation and the compression processes (Suhasman et al. 2011).

Board density tended to increase with increasing $H_2O_2$ concentration and particularly when the $FeSO_4$ was 5%. Meanwhile, at 7.5% $FeSO_4$ boards had nearly the same density, except with 15% $H_2O_2$ concentrations, which were associated with higher densities. At the two $FeSO_4$ concentrations, the board densities of 7.5% were higher than 5%, but the density was lower with the 20% $H_2O_2$ concentration.

The density of the boards was inversely related to their moisture content. Moisture content tended to decrease with an increasing concentration of $H_2O_2$, indicating that the ability of the board to bind water was decreasing. Boards with the combination of H20: F5 had the lowest moisture content (4.51%). A similar relationship was found between moisture content and the levels of $FeSO_4$, with the boards produced with 7.5% $FeSO_4$ having a lower water content compared to those produced with 5% $FeSO_4$. In general, the increase in board density was associated with a decrease in moisture content.

The thickness swelling of the boards also showed a good appearance at higher concentrations of $H_2O_2$. As shown in Table 1, with 20% $H_2O_2$ boards reached thickness swelling of 11.60%. With regard to the two levels of $FeSO_4$, the board with 7.5% resulted better in thickness swelling than that with 5%. However, at 20% $H_2O_2$ concentration, the use of 7.5% $FeSO_4$ yielded better results. The best results for thickness swelling were achieved with this combination, and it was the only board that fulfilled the JIS requirement.

The MOR values ranged from 60 to 117 kg $cm^{-2}$ as shown in Fig. 1. The MOR values tended to increase as $H_2O_2$ levels increased, mainly with the 5% $FeSO_4$ concentrations. Meanwhile, at the level of 7.5% $FeSO_4$, the MOR value decreased when the $H_2O_2$ concentrations were 15% and 20%.

MOE and internal bonding of boards had similar trends as shown in Figs. 2 and 3. Both the MOE and internal bonding increased with increasing $H_2O_2$ concentrations at 5% $FeSO_4$. As with the MOR at the 7.5% $FeSO_4$

**Table 1** Physical properties of binderless particleboard made with various combinations of H2O2 and FeSO4

| $H_2O_2$ (%): $FeSO_4$ (%) | Particleboard characteristics | | |
|---|---|---|---|
| | Density (g/cm$^3$) | Moisture content (%) | Thickness swelling (%) |
| H5:F5 | 0.65 | 10.66 | 50.64 |
| H10:F5 | 0.67 | 5.67 | 30.35 |
| H15:F5 | 0.68 | 6.26 | 29.33 |
| H20:F5 | 0.72 | 4.51 | 25.28 |
| H5:F7.5 | 0.69 | 8.57 | 55.58 |
| H10:7.5 | 0.68 | 5.62 | 38.51 |
| H15:F7.5 | 0.73 | 4.98 | 48.43 |
| H20:F7.5 | 0.68 | 5.20 | 11.60 |
| JIS A 5908 (2003) | 0.4–0.9 | 5–13 | 13 max |

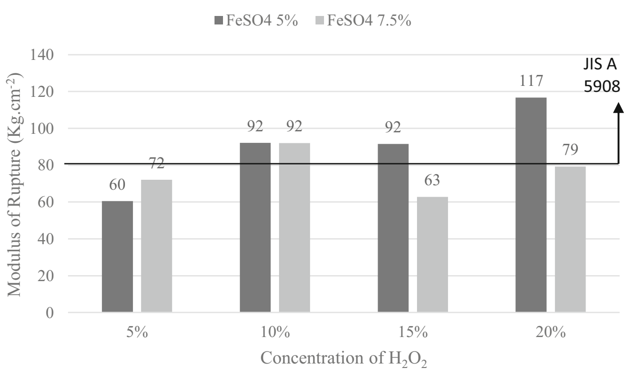


**Fig. 1** Modulus of rupture (MOR) of binderless particleboard

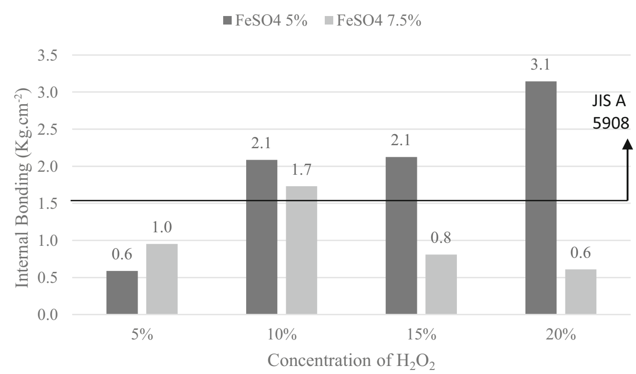


**Fig. 3** Internal bonding of binderless particleboard

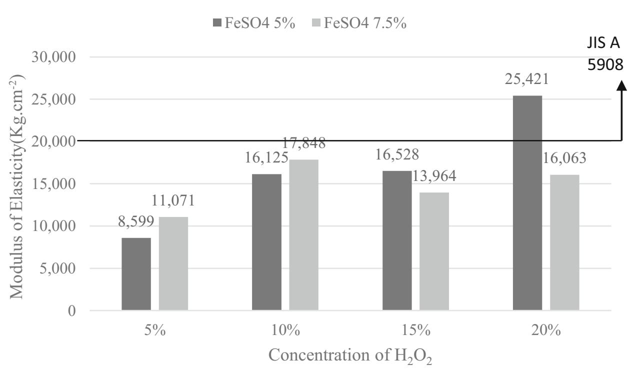


**Fig. 2** Modulus of elasticity (MOE) of binderless particleboard

concentration, MOE and internal bonding also decreased at the 15% and 20% $H_2O_2$ concentrations. H20:F5 combination was the only board for which MOE met the JIS requirement, namely 25,421 kg cm$^{-2}$. In general, this study showed that the increase in $H_2O_2$ concentration produced boards with better mechanical properties, but only when $FeSO_4$ was at 5%.

As reported by Shmulsky and Jones (2011), the higher the density of particleboard, the better the strength. We found the same result in binderless particleboard made from jabon, especially with the use of 5% $FeSO_4$. An increase in all mechanical properties was associated with an increase in board density. The boards made using 7.5% $FeSO_4$ had different characteristics. Even though its density was higher, the boards had lower strength after oxidation with 15% and 20% $H_2O_2$ levels. It likely occurred because of greater damage to the chemical components of the cell walls of the wood particles compared with lower concentrations.

Based on JIS A 5908 (JIS 2003), none of the boards in the current study met all the required physical properties. However, 20% $H_2O_2$ and 5% $FeSO_4$ provided the optimum combination for making particle board without adhesive from jabon wood. All the mechanical properties met the standards, although the physical properties fell short, especially the moisture content and thickness swelling. These results differ from those achieved by Suhasman et al. (2011), who used sengon as the raw material for binderless particleboard. All boards in that study had excellent characteristics, and almost all the properties met JIS requirement at all oxidation combinations, other than moisture content. Within the oxidation process, lignin plays a significant role, particularly syringyl lignin. The hydroxyl radicals generated react with lignin to form reactive components that will form a covalent bond to the others that activate the low molecules (Nasir et al. 2019). Syringyl is more reactive than guaiacyl (Widsten et al. 2003), and sengon wood has a higher syringyl/guaiacyl ratio than jabon (Fitriana 2015). Consequently, the oxidation process produces more binding between particles in boards made with sengon.

## Conclusion

The physical properties of the board showed an increase with a growing number of $H_2O_2$ used and a decrease with an increasing number of $FeSO_4$. Mechanical properties showed the same indication at the use of 5% $FeSO_4$, where they increased with a rising number of $H_2O_2$. While the use of 7.5% $FeSO_4$, mechanical properties decreased after using $H_2O_2$ above 10%. In general, there were no boards fulfilled the JIS A 5908. However, the optimum oxidation combination was 20% $H_2O_2$ and 5% $FeSO_4$ in this study.

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