Thermomechanical Densification Coupled With Partial Delignification for Enhancing The Bending Performance of Sengon (*Falcataria falcata)* Wood

Program Riset ITB Skema Riset Unggulan ITB

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Abstract

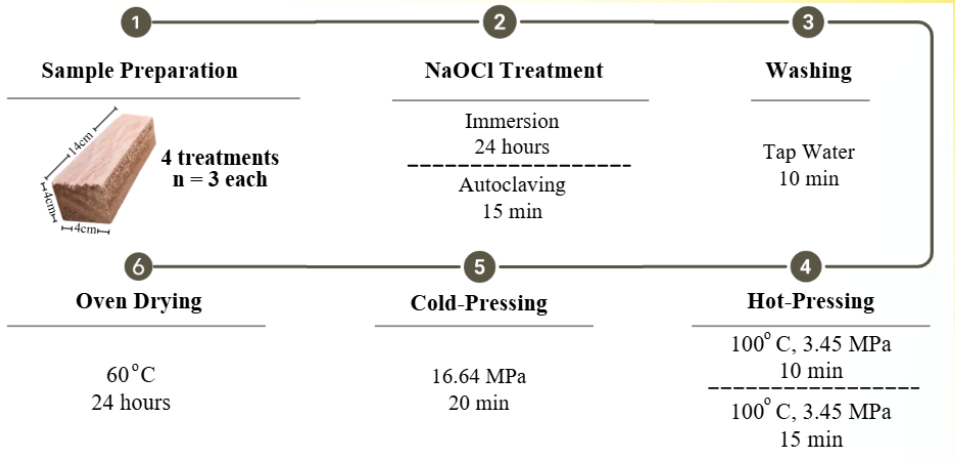
Low-density fast-growing wood species often exhibit limited mechanical performance, restricting their application in structural and engineered wood products. Thermomechanical densification offers a means of enhancing wood strength by reducing cellular voids and increasing cell-wall contact, while partial delignification may facilitate cell-wall deformation and structural rearrangement during compression. This preliminary study investigated the effects of sodium hypochlorite (NaOCl) treatment and subsequent hot-press densification on the density, mass loss, chemical composition, modulus of rupture (MOR), and modulus of elasticity (MOE) of *Falcataria falcata* wood. Solid wood specimens (14 × 4 × 4 cm) were subjected to 5% NaOCl treatment through either 24 h immersion or autoclaving at 121 °C for 15 min, followed by hot pressing at 100 °C and 3.45 MPa for 10 or 15 min. The specimens were subsequently cold pressed at 16.64 MPa for 20 min and oven dried at 60 °C for 24 h. NaOCl treatment combined with hot pressing substantially increased wood density from 0.32–0.39 g cm-3 in the untreated wood to 0.46–0.77 g cm-3 after treatment. Mass loss ranged from 11.01% to 32.56%, with greater losses generally observed following immersion treatment. The highest density (0.77 g cm-3) was obtained with 24 h immersion followed by 10 min hot pressing. Bending performance also improved, with MOR increasing from 33.78 MPa in the untreated control to 53.42 MPa following immersion and 15 min hot pressing, and to 51.74 MPa following autoclaving and 10 min hot pressing. MOE reached a maximum of 1576.54 MPa after immersion followed by 15 min hot pressing. This treatment also resulted in the lowest lignin content (10.86 ± 0.13%) and the highest extractives content (17.74 ± 0.68%). FTIR analysis confirmed changes in hydroxyl, aliphatic, lignin-related, and carbohydrate functional groups following modification. Overall, the combination of partial NaOCl-induced delignification and thermomechanical densification enhanced the density and bending performance of *F. falcata*. Among the evaluated treatments, 24 h immersion followed by 15 min hot pressing provided the most favorable overall mechanical performance. These findings demonstrate the potential of coupled chemical modification and thermomechanical processing for upgrading low-density fast-growing wood species into higher-performance wood materials.

Keyword: partial delignification, thermomechanical densification, sodium hypochlorite pretreatment, fast-growing wood, lignocellulosic material.

Introduction

Low-density fast-growing wood species often exhibit limited mechanical performance, restricting their application in structural and engineered wood products. **Thermomechanical densification offers a means of enhancing wood strength** by reducing cellular voids and increasing cell-wall contact, while partial delignification may facilitate cell-wall deformation and structural rearrangement during compression. This preliminary study investigated **the effects of sodium hypochlorite (NaOCl) treatment and subsequent hot-press densification on the density, mass loss, chemical change, modulus of rupture (MOR), and modulus of elasticity (MOE) of Falcataria falcata wood**.

Research Method



Discussion & Result

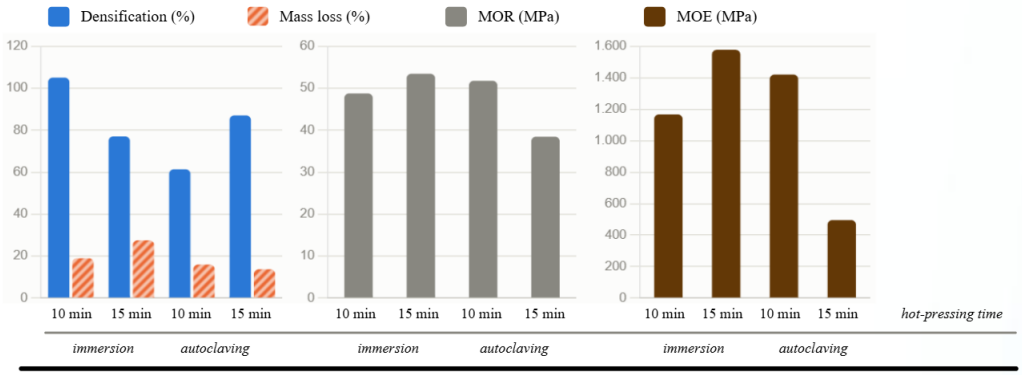


Table 1. Physical and bending properties of F.falcata wood after NaOCl treatment and hot-press densification

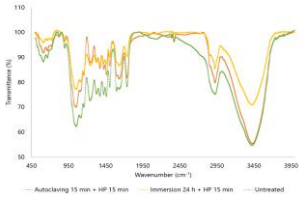


Fig 1. FTIR spectra of untreated wood specimens and specimens subjected to autoclaving for 15 min followed by hot-pressing for 15 min and NaOCl immersion for 24 h followed by hot-pressing for 15 min.

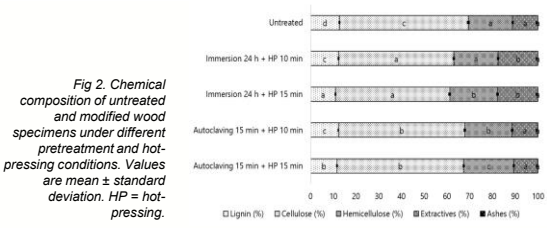


Fig 2. Chemical composition of untreated and modified wood specimens under different pretreatment and hot-pressing conditions. Values are mean ± standard deviation. HP = hot-pressing.

NaOCl immersion followed by hot-pressing reduced lignin content in all treatments, with the lowest value after 24 h immersion and 15 min pressing (10.86%, compared with 12.66% in untreated wood). Cellulose also decreased to around 50%, while extractives increased to about 17.5%. Autoclaving produced smaller changes, keeping cellulose close to untreated levels and only increasing the relative proportion of hemicellulose. Ash content was not affected by any treatment. These results show that oxidative and hydrothermal pretreatments modified the wood constituents in different ways.FTIR spectra supported these differences. NaOCl-treated wood had the highest transmittance at the O–H (3454 and 3226 cm^{-1}), C–H (2883 cm^{-1}), and carbohydrate (974 cm^{-1}) bands, indicating changes in hydroxyl groups and hydrogen-bonding environments in the cell wall. **Partial delignification may expose more carbohydrate-rich surfaces and allow closer contact between cell walls during pressing,** which could explain the higher MOR after NaOCl immersion with 15 min pressing.

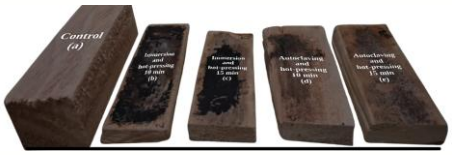


Fig 3. F. falcata wood specimens: (a) untreated control, (b) immersion and hot pressing for 10 min, (c) immersion and hot pressing for 15 min, (d) autoclaving and hot pressing for 10 min, and (e) autoclaving and hot pressing for 15 min. Treated specimens show reduced thickness and surface darkening.

Conclusion

These findings show potential for upgrading low-density fast-growing wood species into higher performance wood materials through chemical modification and thermomechanical process.

Immersion caused higher mass loss than autoclaving, indicating more extensive cell-wall degradation. This treatment also resulted in the greatest reduction in lignin content and increased extractives content, indicating substantial chemical modification of the wood cell wall. FTIR analysis further confirmed changes in hydroxyl, aliphatic, lignin-related, and carbohydrate functional groups.

24 hours immersion followed by 15 minute hot-pressing gave the best bending performance and the higher mass loss. Bending performance is not determined by density alone, so higher density did not always mean higher bending performance.