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Effect of ethanol concentration as drying agent to the mechanical properties of oil palm lumber

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ABSTRACT: This study examines the impact of ethanol on oil palm lumber as a drying agent. The mechanical characteristics of oil palm timber were assessed. The ethanol immersion process utilized concentrations of 91%, 70%, 85%, 55%, and 49% for both the internal and external layers of oil palm timber. The treated outside layer of oil palm lumber demonstrated superior strength compared to the untreated control. In contrast, the strength of the treated core layer diminished compared to that of the control oil palm timber. Our research demonstrates that the ethanol drying technique for oil palm trunk was efficacious. It shows that ethanol influenced the mechanical properties of both the outer and core layers of the trunk after 24 hours at 80℃ in an oven with an optimal ethanol concentration of 55% recommended to attain superior mechanical properties.

Keywords: Oil palm trunk, ethanol, treatment, drying agent, mechanical properties

Yağ palmiyesi kerestesinin mekanik özelliklerine kurutma maddesi olarak etanol konsantrasyonunun etkisi

ÖZ: Bu çalışmada etanolün yağ palmiyesi kerestesi üzerinde kurutma maddesi olarak etkisi incelenmektedir.. Yağ palmiyesi kerestesinin mekanik özellikleri değerlendirilmiştir. Etanol ıslatma için, işlem yağ palmiyesi kerestesinin hem iç hem de dış tabakası için %91, %70, %85, %55 ve %49 konsantrasyonları kullanılarak gerçekleştirildi. İşlenmiş yağ palmiyesi kerestesinin dış tabakası, işlenmemiş kontrole kıyasla daha üstün bir dayanıklılık gösterdi. Buna karşılık, işlenmiş çekirdek tabakasının mukavemeti, kontrol yağ palmiyesi kerestesine kıyasla azaldı. Araştırmamız, yağ palmiyesi gövdeleri için etanol kurutma tekniğinin etkili olduğunu göstermektedir. Etanolün, bir fırında 80℃'de 24 saat sonra gövdenin hem dış hem de çekirdek katmanlarının mekanik özelliklerini etkilediğini ve üstün mekanik özellikler elde etmek için %55'lik optimum etanol konsantrasyonunun önerildiğini göstermektedir.

Anahtar kelimeler: Yağ palmiyesi gövdesi, etanol, kurutma maddesi, mekanik özellikler

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1 Introduction

The drying of oil palm lumber (OPL) has consistently limited its broader use. The elevated green moisture content (about 300-500%) and significant density variation throughout the stem render the drying of OPL a laborious and energy-demanding procedure (Rais et al. 2021). No viable commercial drying schedule for OPL has existed until recently. The traditional drying technique of OPL in a kiln dryer requires 30-35 days and it is associated with various drying effects (Nadzim et al. 2021). Consequently, it is imperative to devise an effective technique for expediting the drying of OPL.

Ethanol may serve as a drying agent for OPL due to its volatility. Previous literature indicates that methanol and ethanol have been utilized as drying agents in the drying process of radiata pine (Pang, 2006). This action can avert the development of discoloration and staining in wood referred to as kiln brown stain (KBS), a significant drying fault of wood. The author stated that by drying radiata pine in methanol and ethanol solutions, brighter and KBS-free wood was obtained. Significantly, it permits the utilization of elevated temperatures without inducing surface discoloration, hence it enhances the efficiency of the drying process (Pang, 2006). The research demonstrated the viability of using evaporative agents such as alcohol in the drying process.

Consequently, this study employed ethanol as a desiccant for OPL. The OPL was immersed in ethanol solvent before undergoing the drying procedure. The impact of this drying technique on the mechanical properties of the OPL remains unexplored. There is concern that elevated stress will occur as ethanol enhances intracellular water removal leading to wood fracture and, consequently, detrimental effects on the mechanical properties of wood. This study aims to examine the impact of ethanol as a drying agent for OPL on the bending, shear, and compression strength of the material.

2 Material and Method

2.1 Material

A 25-year-old oil palm tree (OPT) was harvested from the oil palm plantation in UiTM Jengka, Pahang, Malaysia. The trunk was cut 3 m from the bottom of the tree. 95% denatured ethanol (Sigma-Aldrich) was used as a drying agent in this study.

2.2 Sample preparation

The logs were processed and flat sawn into boards with dimensions of 60 cm x 5 cm x 5 cm (length x width x thickness). The first process was cutting the OPT into a wood disc consisting of 60% core layer of the trunk and 40% of the outer layer. After that, the oil palm trunk was cut into two layers using a primary breakdown saw. Then, the lumber was immediately placed into a freezer to avoid fungi attack. Then, the OPL was removed from the freezer and placed into a box filled with different concentrations of ethanol, namely, 91%, 70%, 85%, 55%, and 49%. The ethanol was diluted using distilled water. The OPL was immersed in ethanol for 24 hours to allow proper penetration of the solvent into the OPL. After the immersion process, the sample was dried in an oven for 4 to 5 days at 80°C.

2.3 Mechanical properties evaluation

The OPL samples were cut into the required size for properties evaluation after drying. The samples were cut into dimensions of 20 mm x 20 mm x 300 mm in accordance with BS 373: for bending strength (1957). Meanwhile, the samples were cut into dimensions of 20 mm x 20 mm x 60 mm according to ASTM D143 for compression parallel to the grain (1991) The shear sample sizes were cut according to ASTM D 143-94 (2000) which is 50.8 mm x 60.5 mm x 50.8 mm. Five replicates were prepared for each test.

2.4 Data analysis

Response Surface Methodology (RSM) is used to determine the influence of individual and interactive parameters on the mechanical properties of the samples.

3 Results and Discussion

3.1 Density

Figure 1 depicts the oven-dried density of the core and inner OPL before and after immersion in ethanol. The outer plexiform layer (OPL) generally exhibits a higher density than the inner OPL. After immersion in several concentrations of ethanol, the density of the oil palm lumber augmented for both inner and outer OPL in comparison to the control (untreated) OPL. The untreated inner and outer OPL exhibited densities of 202 kg/m³ and 303 kg/m³, respectively. The highest density after immersion in ethanol was recorded in OPL treated with 55% ethanol for 5 hours, resulting in a density of 309 kg/m³ for the inner layer and 530 kg/m³ for the outer layer. Ethanol, as a polar solvent, can interact with the substance and alter its molecular structure, perhaps resulting in a change in density.

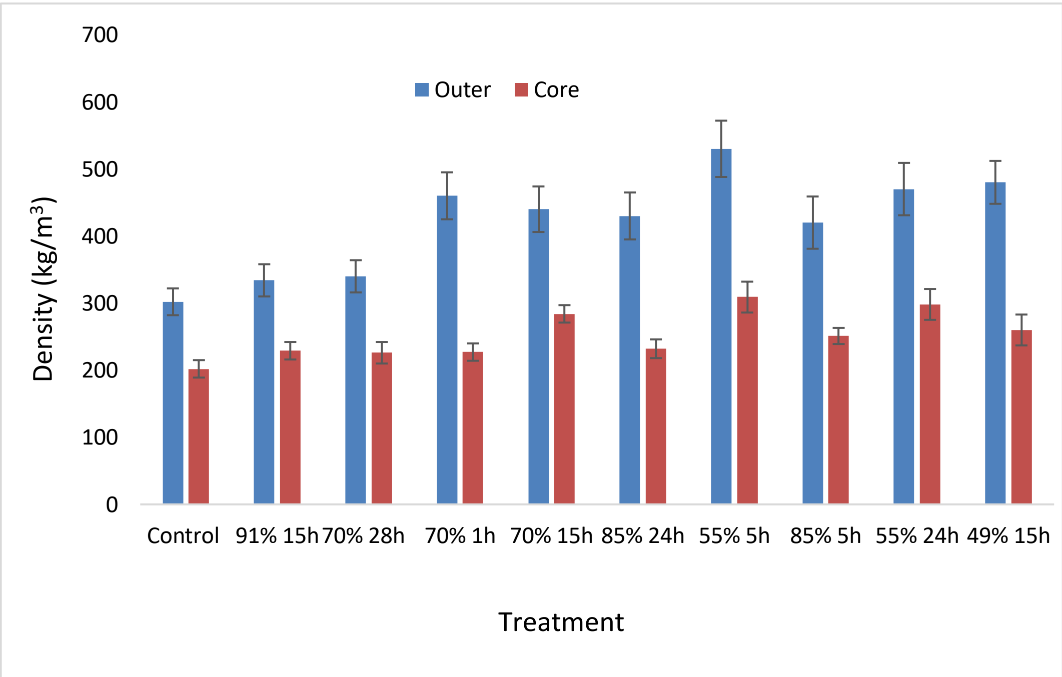

Fig. 1. Density of outer and core OPL samples soaked in different concentrations of ethanol solution and soaking time.

3.2 Mechanical strength

Figure 2 shows the effect of concentration and soaking time on the mechanical properties of OPL.

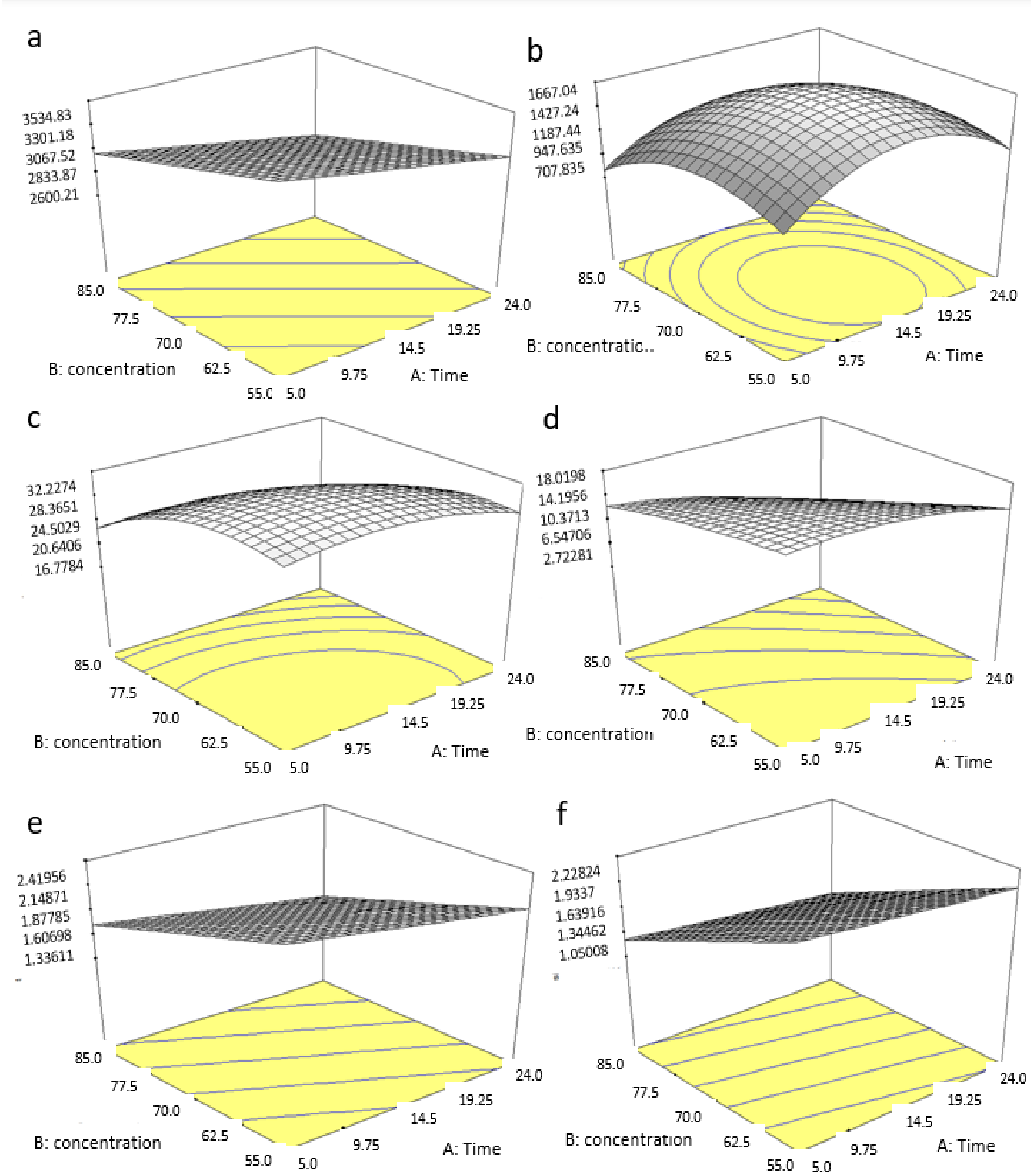

Fig. 2. The 3D-surface plots of (a) MOE of outer layer; (b) MOE of inner layer; (c) MOR of outer layer; (d) MOR of inner layer; (e) shear strength of outer layer; and (f) shear strength of inner layer, as function of alcohol concentration and soaking time

3.2.1 Modulus of elasticity (MOE)

Figure 2a illustrates the impact of concentration and soaking duration on the MOE of OPL. The MOE diminished with rising ethanol content and prolonged soaking duration. This may be due to the elevated concentration of ethanol employed as a drying agent, which could have compromised some parenchyma components in the outer layer of the oil palm trunk. Meanwhile, quadratic effects are demonstrated for the inner layer (Figure 2b). This finding indicates that the concentration of ethanol predominantly influenced the MOE, rather than the duration of soaking.

3.2.2 Modulus of rupture (MOR)

Figure 2c illustrates a quadratic effect on the MOR of the outer layer. MOR continues to rise with increasing ethanol content until it attains a maximal point. Beyond this threshold, the MOR value diminished in relation to concentration and soaking duration. The reduction in bending MOR was likely due to the medium concentration of ethanol adequately drying the outer layer of OPL, thereby stabilizing the vessel and fiber structure and potentially averting collapse and deformation post-soaking. A comparable observation was noted for the inner OPL, as illustrated in Figure 2d.

3.2.3 Shear Strength

Figure 2e illustrates the influence of ethanol content and immersion duration on the shear strength of the OPL outer layer. The ethanol concentration had relatively minimal effect on shear strength in comparison to soaking duration. The maximum concentration gave the lowest shear strength parallel to the grain, and this gradually increased with increasing soaking time. This was anticipated to result from the disparity in the quantity of parenchyma cells and vascular bundles across the layers with the peripheral zone (outer layer) consisting of a limited number of parenchyma cells and numerous vascular bundles which enhances the mechanical stability of the palm trunk (Lim and Gan 2005). Figure 2f illustrates that the inner OPL was influenced by both the ethanol content and the soaking duration similar to the outer layer. Nonetheless, the inner layer was more profoundly affected as evidenced by the steeper slope in Figure 2f.

3.2.4 Discussion

Ethanol as a polar solvent can interact with the material and change its molecular structure potentially leading to a change in density. This observation aligns with previous studies on the impact of solvents on material properties (Renders et al. 2016). In a study by Conner et al. (1993), the researchers explored the changes in wood extractives from oak cask staves during the maturation of Scotch malt whisky. Their investigation revealed that repeated exposure to aqueous ethanol led to compositional alterations in the lignin present in the wood. In a recent study by Wu et al. (2020), a novel approach utilizing eutectic solvents was introduced to prepare softened wood with several enhanced properties. This method yielded wood with a highly porous network structure, a reduction in lignin, hemicellulose, and cellulose content, a change in colour, decreased hardness, superior mechanical flexibility, and an impressive compression rebound rate of approximately 90%. The changes in chemical composition and density inevitably affected the mechanical properties of the OPL as discussed above.

4. Conclusion

The work described in this paper demonstrates that ethanol can effectively be a drying agent for oil palm lumber. From this overall research, it can be concluded that:

- The outer layer of OPL after treatment had more strength compared to control OPL.
- The strength of the treated core layer decreased compared to the control OPL.
- The drying method by soaking the OPL in ethanol for 24 hours at 80℃ was successfully performed and only 55% of ethanol concentration was required to achieve optimal properties of OPL.
- Nevertheless, the utilization of alcohol must be approached with caution due to its great flammability. Additional research is required to alleviate this risk.

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Author Contributions

Ahmad Fauzi Awang Othman: Conceptualization, Data curation, Writing – original draft, Mohd **Fadzil Arshad:** Formal Analysis, Methodology, Supervision, Writing – review & editing, **Junaiza Ahmad Zaki:** Methodology, Resources, Writing – review & editing, **Nik Hazlan Nik Hashim:** Methodology, Resources, Writing – review & editing, **Nur Hannani Abdul Latif:** Methodology, Resources, Writing – review & editing, **Amran Shafie:** Investigation, Methodology, Resources

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Conflict of interest statement

The authors declare no conflict of interest.

References

Conner, J., Paterson, A., & Piggott, J., (1993). Changes in wood extractives from oak cask staves through maturation of scotch malt whisky, *Journal of the Science of Food and Agriculture*, 62, 169-174.

Lim, S.C., & Gan, K.S., (2005). Characteristics and utilisation of oil palm stem, Timber Technology Bulletin No.35. Forest Research Institute Malaysia: Kepong, Selangor.

Nadzim, M., Edi, S.B., Mojtaba, S., Zaidon, A., & Lee, S.H., (2021). Drying of oil palm lumber by combining air force drying and modified super-fast drying methods, *Journal of Oil Palm Research*, 33(3), 482-492, DOI: DOI: 10.21894/jopr.2021.0002

Pang, S., (2006). Using methanol and ethanol vapours as drying media for producing bright colour wood in drying of radiata pine, 15th International Drying Symposium (IDS 2006), Budapest, Hungary, 20-23 August 2006.

Rais, M.R., Bakar, E.S., Ashaari, Z., Hua, L.S., Soltani, M., Ramli, F., & Bawon, P., (2021). Drying performance, as well as physical and flexural properties of oil palm wood dried via the super-fast drying method, *BioResources*, 16(1), 1674-1685, DOI: 10.15376/biores.16.1.1674-1685

Renders, T., Van den Bosch, S., Vangeel, T., Ennaert, T., Koelewijn, S.F., Van den Bossche, G., Courtin, C.M., Schutyser, W., & Sels, B.F., (2016). Synergetic effects of alcohol/water mixing on the catalytic reductive fractionation of poplar wood, *ACS Sustainable Chemistry & Engineering*, 4(12), 6894-6904, DOI: 10.1021/acssuschemeng.6b01844

Wu, Y., Yang, L., Zhou, J., Yang, F., Huang, Q., & Cai, Y., (2020). Softened wood treated by deep eutectic solvents. *ACS Omega*, 5, 22163-22170, DOI: 10.1021/acsomega.0c02223