Abstract. In general, the weakness of particleboard using urea formaldehyde (UF) resin has a low dimensional stability. This reasearch intends to improve its properties by post-treatment technique using several water repellent materials. The post-treatment effect on dimensional stability and durability properties of particleboard against to subterranean and dry termites has been evaluated. Sample was dipped into water repellent solution namely parafin, palm oil, silicon and water proof for 3 minutes. Furthermore, they were oven dried at 50°C for 24 hours. The results showed that the density varied of 0.60 to 0.74 g/cm$^3$. The post-treatment of particleboard increases the density value. Water absorption and thickness swelling of board were varied of 29.35% to 114.99% and 13.23 to 37.31%, respectively. This treatment also improved up the thickness swelling to 65%. The best durability of board to subterranean and dry termite attack has found on silicon and waterproof treatment, respectively.

1. Introduction

Current forest conditions are unfavorable for the development of wood industries. Lack of raw materials has been the reason for wood industries to be closed down. Non-wood particleboard technology is one of the alternative efforts to solve the problem.

Particleboard was one of composite product/wood panel made of wood particles or lignocellulosic materials which bounded by synthetic adhesive or other materials, then heat compressed [1]. Urea Formaldehyde (UF) was one of the common adhesives used on particleboard industry. It was a thermosetting adhesive that was applied for interior use. However, it had low dimension stability. Particleboard was also vulnerable to termite attack and other wood-destroying organisms. There were already many studies conducted in aim to improve particleboards dimension stability using UF adhesive. Some techniques were using paraffin [2], acetylation [3,4,5] and steam treatment [6] to enhance of dimension stability commonly using pre-treatment technique. Iswanto et al [6] reported that strand pretreatment using steam, soaking in hot water and preservative solution resulted in improvement the dimension stability, bending and durability of oriented strand board. Haygreen and Gertjejansen (1971) cited in Zaidon and Paridah [7] stated that hygroscopicity and wood durability properties to destroying organisms could be decreased by resin impregnating (injecting preservative) on fiber or wood particles.

This study applied water repellent materials using post-treatment technique on processed board. The board then soaked in water repellent materials such as liquid paraffin, liquid silicone, waterproof and
cooking oil. We examined the post-treatment method effectivity using these materials to improve board dimension stability.

2. Materials and Methods

2.1. Materials

The physical properties examination was using 5 by 5 cm\(^2\) samples, while the durability examination was using 2 by 2 cm\(^2\) samples. Both samples were made of sorghum bagasse particleboard and UF adhesive. Other materials were 100% liquid paraffin, 100% liquid silicon, 100% waterproof dan 100% cooking oil.

2.2. Methods

2.2.1. Sample Treatments. Samples were measured and weighed. Each dipped into containers that contain dimension stability enhancer, which were 100% liquid paraffin, 100% liquid silicon, 100% waterproof and 100% cooking oil for 3 minutes. Samples then drained and processed inside an oven for 24 hours with temperature 50°C. Particleboards volume was obtained by measuring its length, width and thickness.

2.2.2. Physical evaluation. The physical properties examination was density and water absorption of each sample, based on JIS A 5908 (2003) [8].

2.2.3. Durability evaluation. The durability examination against subterranean termite (Cryptotermes Cynocephalus Light.) and drywood termite (Coptotermers curvignathus Holmgren.) attack was conducted based on Indonesia National Standard (SNI) 01-7207-2006 [9].

2.3. Data Analysis

This research was using Completed Randomized Design (CDR). The treatments in this research were soaking the samples in liquid paraffin, liquid silicone, water glass, waterproof and cooking oil for three minutes each. Each treatment then repeated three times.

3. Results and Discussion

3.1. Physical Properties

3.1.1. Density

![Figure 1. Density of particleboard](image-url)
Data showed that board density value increased after water repellent coatings due to weight increment was higher than dimension change. Mean value of weight increment after post-treatment was 20.39% while volume change was 3.99%. According to Geimer et al. [10], coating on board surface causing board density value to change.

The statistical analysis of board density showed that water repellent coating did not significantly influence board density value. The result also showed that the particleboard density value had met the JIS A 5908 (2003) standard which requirement of density value ranged between 0.4 to 0.90 gr/cm³.

3.1.2. Thickness Swelling

Boards coated with water repellent materials tended to have dimension stability value improvement. Result showed that board coated with waterproof had the best dimension stability compared to the other treatments and untreated, shown by its swelling value curve which was relatively flat. The waterproof layer coated or closed particleboards hollow spaces thus prevent water absorption. It is known that waterproof functions as damp proofing material. Antoni [11] stated that main material of waterproof was acrylic and cement, consisted of two components of powder and liquid which when mixed evenly would form wet cement paste then transformed into waterproof and strong thin layer when dried.

The particleboard made of bagasse sorghum using urea formaldehyde (UF) adhesive has very high thickness swelling value (Iswanto et al. [12], [13], [14]. We suspected the porous characteristic of bagasse sorghum resulting to high water absorption. Maloney [1] also stated that the main weakness of urea formaldehyde adhesive was bond breaking caused by water and dampness. According to Youngquis [15]; Irle and Barbu [16], UF adhesive was not weather proof, so it was not suitable for exterior use. The statistical analysis of variance after 24 hours of soaking showed significant influence of thickness increment value on confident interval 95%. However, overall the thickness swelling value had not yet met the JIS A 5908 (2003) which requirement of the maximum value was 12%.

![Figure 2. Thickness swelling of particleboard](image-url)
3.1.3. Water Absorption

The results of the measurement of water absorption after 24 hours showed that water absorption value of particleboard ranged between 38.72–114.99%. Rofii and Widyorini [17] stated that thickness swelling and water absorption were physical properties that related to particleboard’s response to soaking conditions. The highest and lowest water absorption values were on control and waterproof treatments. We presumed the waterproof properties of waterproof resisted water to penetrate to particleboard. Waterproof also had negative response to water absorption value. Waterproof coating decreased water absorption almost three times compared to untreated. The statistical analysis of water absorption showed that the treatments were significantly influence the water absorption value for 24 hours on confidence interval 95%.

3.2. Durability properties

3.2.1. Subterranean Termite (Coptetermes curvignathus Holmgren.)

Fig. 4 shows that weight loss value on all treatments are lower than untreated. We presumed of paraffin, silicone and waterproof had toxic properties which subterranean termites dislike. However this
condition was not occurred on samples using cooking oil. The classification of particleboards durability against termite attack according to Indonesia National Standard 01.7207–2006 is shown on Table 1.

Table 1. The durability classification to subterranean termite

| No | Treatments  | Weight loss (%) | Level        |
|----|-------------|-----------------|--------------|
| 1  | Untreated   | 23.16           | Very durable |
| 2  | Paraffin    | 8.60            | Durable      |
| 3  | Silicon     | 4.90            | Moderate     |
| 4  | Waterproof  | 10.30           | Durable      |
| 5  | Cooking oil | 16.40           | Very durable |

The result of analysis of variance showed that all treatments were not significantly influence the weight loss on confident interval 95%. Paraffin, silicone, waterproof and cooking oil were not categorized as preservative, but water repellent. We concluded that treatments using these materials did not show significant difference for these reasons. However, the silicone use slightly increased of durability against subterranean termite.

Termite’s mortality was one of indicators to determine the active level of toxic materials by counting the percentge of dead termites after the application on a period of time. The lowest and the highest mortality value were control and silicone treatments, as much 64.89% and 96.89%, respectively. The mortality on all treatments were higher than control, which means the treated boards were toxic or emitting odor disliked by termites so they uninterested to consume the board. Hadi [18] reported that termite mortality was caused by rejecting behavior to food with strong scent. Thus, result to antifeedant characteristic of termites. Termites also had cannibalism behaviour, eating their own species that were weak, ill, on food lack condition, and fellow carcasses. Nandika et al [19] stated that a 2.5 mg termite needed 0.24 mg food everyday, so when food became unavailable the cannibalism occured. The statistical analysis of mortality value showed that the treatments on boards were insignificant on confident interval 95%.

The antifeedant was determined based on loss weight percentage ratio on untreated and treated samples. Antifeedant is feeding activity inhibitor value that made termites dislike food and weaken. The lowest and highest antifeedant were cooking oil and silicone, as much as 17.10% and 65.10%.

Feeding rate value on treated boards was lower than untreated boards. The feeding rate value was inversely with antifeedant value. If termites liked the food, feeding rate value would high. The lowest and highest feeding rate value was on silicone and untreated treatments were 37.39 and 150.33 \( \mu g/termite/day \). The statistical analysis of subterranean termite mortality showed that treatments did not significantly influence the feeding rate on confident interval 95%.
3.2.2. Drywood Termite (Cryptotermes cynocephalus Light.)

Figure 5. Board durability to drywood termite’s attack

As is the case with subterranean termite, the sample’s weight loss was lower on treated boards than untreated. We presumed paraffin, silicone and waterproof were toxic to drywood termite, or their chemical properties prevented drywood termite to consume treated samples. According to Nandika et al. [19], termite’s consumption activities commonly influenced by food availability, termite’s desirable level of food and environment condition. The statistical analysis showed that all treatments did not significantly influence the weight loss on confident interval 95%.

Table 2. The durability classification to drywood termite

| No | Treatment    | Weight loss (%) | Durability     |
|----|--------------|-----------------|----------------|
| 1  | Untreated    | 19.74           | Very durable   |
| 2  | Paraffin     | 6.39            | Moderate       |
| 3  | Silicone     | 7.62            | Moderate       |
| 4  | Waterproof   | 0.02            | Very durable   |
| 5  | Cooking oil  | 6.26            | Moderate       |

The lowest and the highest mortality value were on untreated and waterproof treatments, which were 76.00% dan 99.33% respectively. High anti-termite property was found on samples treated with waterproof. We presumed that waterproof contained chemical compound which drywood termite dislike. The result of analysis of variance showed that all treatments did not significantly influence the mortality value on confident interval 95%.

The lowest and the highest antifeedant (consumption activity inhibitor) for drywood termite were silicone and waterproof treatments, which were 45.95% dan 99.76% respectively. The lowest and the highest feeding rate were waterproof and untreated treatments, which were 0.14 and 58.69 µg/termite/day.

In nature, termites chose their environment and food sources. On the contrary, in laboratory the environment was made by human, thus termites on forced condition and would eat only provided food.
The statistical analysis showed that all treatments did not significantly influence the feeding rate on confident interval 95%.

4. Conclusions

The post treatment using water repellent materials such as paraffin, cooking oil, waterproof and silicone was able to improve the dimension stabilization of particleboard. Waterproof was the best material to decrease the thickness swelling value of particleboard up to 65%.

The post treatment using water repellent materials such as paraffin, cooking oil, waterproof and silicone was also able to enhance the durability of particleboard against subterranean termite (Coptetermes curvignathus Holmgren.) and drywood termite (Cryptotermes cynocephalus Light.) infections. Silicone coating was the best treatment and was categorized as moderate durable class against the subterranean termite infection. As for drywood termite, waterproof coating was the best treatment and categorized as very durable class.

References
[1] Maloney TM 1993 Modern Particleboard and Dry-Process Fiberboard Manufacturing (USA: Miller Freeman Inc. San francisco)
[2] Baharoğlu M, Nemli G, Sari B, Ayirilmis N, Bardak S, Zeković E 2014. Science and Engineering of Composite Materials 21(2) 191–195
[3] Houts JHv, Winistorfer PM, Wang S. 2003 Forest Products Journal 53(1) 82-88
[4] Oduor N, Vinden P, and Kho P. 2013 International Journal of Applied Science and Technology 3(3) 153-159
[5] Kwon JH, Ayirilmis N 2015 European Journal of Wood and Wood Products 73(6) 845-847
[6] Iswanto AH, Febrianto F, Wahyudi I, Hwang WJ, Lee SH, Kwon JH, Kwon SM, Kim, NH, Kondo T 2010 J. Fac. Agr. Kyushu Univ 55 (2) 371–377
[7] Zaidon and Paridah 2006 J.Tropical Forest Sci 18 (3) 166-172
[8] Japanese Industrial Standard 2003 JIS A 5908 Japanese Standard Association Particleboard (Japan).
[9] Indonesia National Standard 2006 Uji Ketahanan Kayu dan Produk Kayu Terhadap Organisme Perusak Kayu. SNI 01-7207-2006. (Indonesia: Badan Standardisasi Nasional. Jakarta)
[10] Geimer RL, Montrey H, and Lehmann WF 1975 Forest Products Journal 25 (9)19-29
[11] Antoni 2001 Bahan Waterproofing Semen yang Semi Fleksibel (Indonesia: Ultrachem Super. Jakarta)
[12] Iswanto AH, Febrianto F, Hadi YS, Ruhendi S, Hermawan D 2013 Makara Seri Teknologi 17(3) 145-151
[13] Iswanto AH, Azhar I, Supriyanto, Susilowati A 2014 Agriculture, Forestry and Fisheries 3(2) 62-66.
[14] Iswanto AH, Azhar I, Susilowati A, Supriyanto, Ginting A 2016 International Journal of Materials Science and Applications 5(2) 113-118
[15] Yongquist J A 1999 Wood-based Composites and Panel Product. Wood Hand Book: Wood as an Engineering Material. (USA: Washington DC)
[16] Irle M, Barbu MC 2010 Wood-Based Panels-an Introduction for Spesialists, Heiko Thoeman, editor Ingris (GB) Mark Irle, Milan Sernek, (London: Brunel University Press)
[17] Rofii MN and Widyorini R 2012 Proc of Seminar Nasional Mapeki XV. (Indonesia: Makasar)
[18] Hadi, M 2008 Bioma 6(2) 12-18
[19] Nandika D, Rismayadi Y, and Diba F 2003 Rayap: Biologi dan Pengendaliannya (Indonesia: Muhammadiyah University Press. Surakarta)