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Research paper

Effects of Dip-treatment in Palm Oil on Dimensional Stability of Particleboard made from Rubberwood and Oil Palm Trunk

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Abstract: Particleboard made from a mixture of rubberwood (RW) and oil palm trunk (OPT) is not a regular practice and dimensional stability of the particleboards produced are poor. Therefore, in this study, particleboard from RW and OPT were immersed in palm oil solution in order to improve its dimensional stability. Palm oil were dissolved in ethanol using the following ratio: 10%, 50% and 100%. The particleboards were dip-treated in the solution and oven-dried. Properties such as thickness swelling (TS), water absorption (WA), equilibrium moisture content (EMC) and moisture excluding efficiency. (MEE) were evaluated. The results revealed that the value of the MEE is corresponding to the EMC values. Positives MEE values indicated the hygroscopicity of the treated samples was greatly reduced. However, no significant difference was found between the samples treated with 10%, 50% and 100% palm oil in term of TS. On the contrary, percentages of oil treatments show high significant effect to the WA of the particleboard. Particleboard made from 100% OPT particles show lowest WA (31.81%). The overall WA values of the treated particleboard were reduced. In conclusion, dip treatment with palm oil has improved the EMC, MEE and WA of the particleboard while TS were not significantly affected.

Keywords: Palm oil; particleboard; oil palm trunk; rubberwood; moisture excluding efficiency.

1. Introduction

Rubberwood is the main raw materials for particleboard industries in Malaysia [1]. Unfortunately, shortage of rubberwood urged the manufacturer to find alternative raw materials in the particleboard production. On that account, utilizing of oil palm trunk would be promising the sustainability future for particleboard processing due to the increasing land area of oil palm plantation in Malaysia. Nevertheless, the practice of using mixed materials in particleboard production is not common in Peninsular Malaysia as the density differences between OPT and RW particles could affect the adhesives consumption and interfere the adhesion between particles [2].

A preliminary study revealed that the thickness swelling (TS) of particleboard made from admixture of OPT and RW at different proportion ratios ranged from 18.99 to 25.69 % [3]. The findings failed to meet the minimum requirement of thickness swelling for particleboard type P3 (12 mm thickness) stated in EN 312 (Particleboards: Specifications), which is 17 %. Therefore, treatment is needed to improve the dimensional stability of the particleboard.

Vegetable oils such as linseed, rapeseed, soybean and palm oil have been used to improve the dimensional stability and biological resistance of wood and wood composite. Application of these vegetable oils has drawn a lot of attention in the recent years because it is environmentally friendly owing to its low-toxicity [4]. Oil absorption during treatment could form a protective layer to inhibit water uptake by the wood. Nevertheless, the cost of using vegetable oils is relatively high and high retention of oil could produce undesirable odors. Therefore, to reduce the application of oil, this study proposed a procedure in which different ratio of palm oil (mass/mass basis) were dissolved in ethanol followed by dip-treatment of the particleboard samples. The effects of dip-treatment in palm oil and ethanol followed by heating on dimensional stability of particleboard were investigated.

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2. Materials and Methods

Rubberwood (RW) particles were obtained from a commercial particleboard plant in Gemas, Negeri Sembilan, while the oil palm trunk (OPT) particles were chipped from felled OPT retrieved from Universiti Putra Malaysia (UPM). The particles were sieved using a vibrator fiber screener. 100 % coarse particles that pass through 20 mm and retain on 10 mm sieve were used for particleboard production. Both particles were dried to 3 % moisture content prior to particleboard fabrication. Commercial Vesawit edible palm oil manufactured in Yee Lee Edible Oils Sdn Bhd, Ipoh were purchased from local groceries store and used for dip-treatment in this study. Urea formaldehyde (UF) resin type E1 were purchased from Aica Sdn Bhd, Senawang and used as adhesive for particleboard production. Wax as water repellent and ammonium chloride as hardener were applied during the blending process.

2.1. Fabrication of particleboard

RW and OPT particles were dried to 3% moisture content at 103 ± 2˚C prior to particleboard fabrication. Single-layer particleboards with target density of 800 kg/m3 were produced using five different proportions of RW to OPT, which are 100 % OPT, 30 % RW: 70 % OPT, 50 % RW: 50 % OPT, 70 % RW: 30 % OPT and 100 % RW. 8 % urea formaldehyde (UF) resin based on the weight of dry particles admixed with 0.5 % of wax and 1 % ammonium chloride were sprayed onto the particles. The spraying was carried out carefully to ensure the mixture of resin and additives spread evenly throughout the particles. Upon the completion of spraying process, the particles were let blended in blender for 3 minutes. After the blending process, the particles were poured into a wooden mould to form a mat. The mat was undergoing hot-press process at 180˚C with 4 Mpa pressure for 270 seconds. After pressing, the boards were conditioned under temperature 20 ± 2˚C and 65 ± 5% relative humidity for 7 days. The test samples were prepared according to EN 312 prior to properties testing. 3 replicates were prepared for each testing.

2.2 Dip treatment

10% and 50% food grade palm oil were dissolved in ethanol (mass/mass basis) prior to dip-treatment. Particleboard samples having dimensions of 50 x 50 x 12 mm (width x length x thickness) were dip-treated in solution of palm oil and ethanol for 10 minutes. After 10-minute, dip-treated samples were retrieved from the solution and heated in oven. After 24 hours, the samples were conditioned in a conditioning room for 24 h prior to properties evaluation. Dip-treated in pure palm oil (100%) were used for comparison purpose. One set of untreated samples were served as control.

2.3 Properties Evaluation of the Particleboard

2.3.1 Equilibrium Moisture Content (EMC)

The samples were oven dried in an oven. After oven dried, the weights of treated and untreated particleboard were recorded. Then, the oven dried samples were reconditioned in a conditioning room until constant mass was reached. The constant weights of the samples were recorded. The EMC of the sample was calculated by using the Equation 1.

$$\text{EMC (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \qquad \text{Equation 1}$$

Where,
W_1 = oven-dried weight (g);
W_2 = constant weight after reconditioned (g)

2.3.2 Moisture Excluding Efficiency (MEE)

Moisture excluding efficiency (MEE) was determined by using the Equation 2.

$$\text{MEE (\%)} = \frac{E_u - E_T}{E_u} \times 100 \qquad \text{Equation 2}$$

Where
E_U = EMC of untreated samples (%)
E_T = EMC of treated samples (%)

2.3.3 Thickness Swelling (TS)

The thickness of the samples were measured with a veneer caliper. Then, the samples were immersed in water horizontally about 3cm below water surface for 24 hours. After 24 hours, the samples were taken out and the excessive water were wiped off. The thickness was measured again and recorded. Thickness swelling of the samples were calculated by using the Equation 3.

$$TS\ (\%) = \frac{T_f - T_i}{T_i} \times 100 \qquad \text{Equation 3}$$

Where,
T_f = Thickness after immersion (mm)
T_i = Thickness before immersion (mm)

2.3.4 Water Absorption (WA)

The samples were weighed by using an electronic balance. Then, the samples were immersed in water horizontally about 3cm below water surface for 24 hours. After 24 hours, the specimens were taken out and the excessive water were wiped off. The weight of the specimen was measured again and recorded. Water absorption of the specimens were calculated by using the Equation 4.

$$WA\ (\%) = \frac{W_2 - W_1}{W_1} \times 100 \qquad \text{Equation 4}$$

Where,
W_1 = weight before immersion in water (g)
W_2 = weight after immersion in water (g)

2.3.5 Solution uptake

The solution uptake after treatment were recorded and calculated using the Equation 5.

$$\text{Solution uptake}\ (\%) = \frac{W_2 - W_1}{w_1} \text{x}100 \qquad \text{Equation 5}$$

Where,
W_1 = weight before treatment (g)
W_2 = weight after treatment (g)

2.4 Data Analysis

The effect of treatment on the dimensional stability of the particleboard were evaluated by performing one-way analysis of variance (ANOVA) at 95% confident level ($P \leq 0.05$) using Statistical Analysis System (SAS) procedure. The differences between treatment levels were compared by Tukey's honest significance different (HSD) test.

3. Results and Discussion

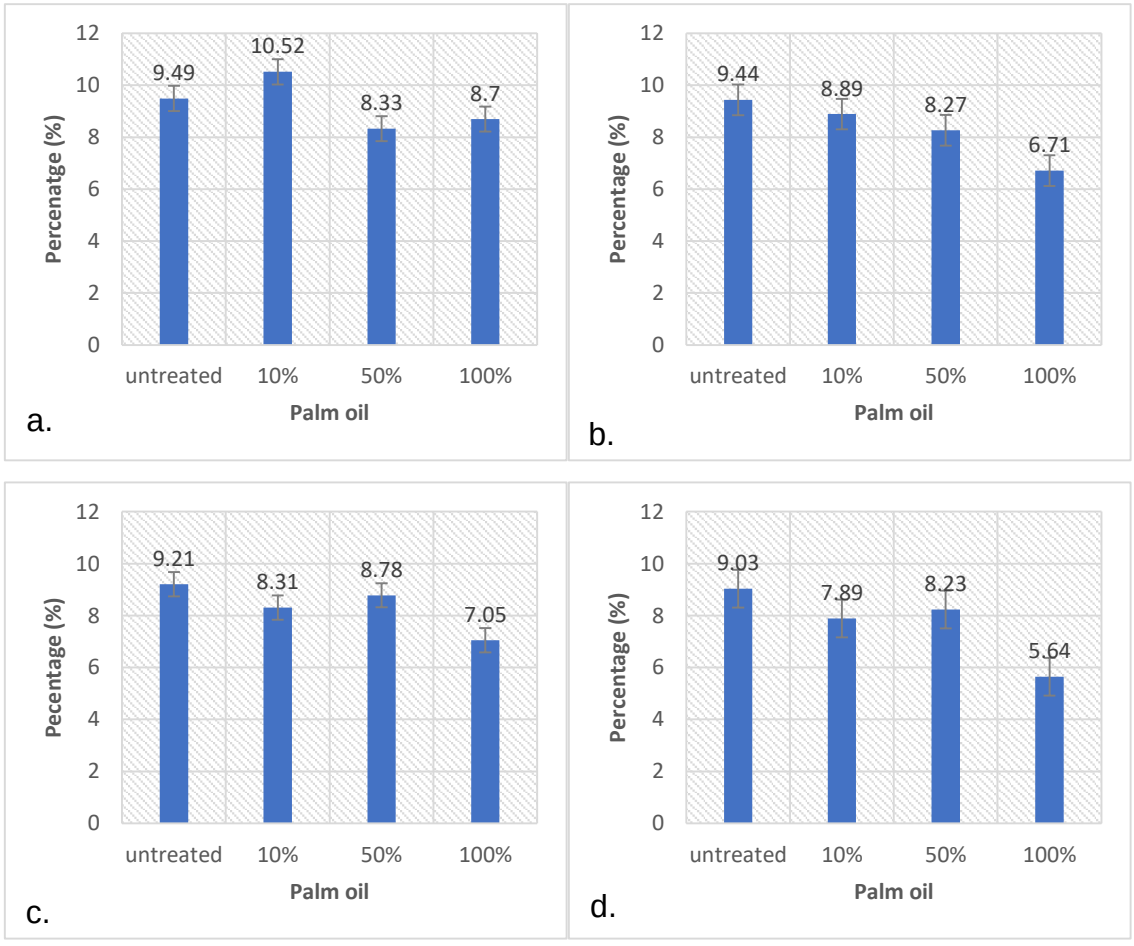
3.1 Equilibrium Moisture Content (EMC)

Figure 1 shows the equilibrium moisture content of particleboard samples dip-treated with different percentage levels of palm oil. From Figure 1, one can see that the EMC of particleboards

reduced after dipped into different percentage of palm oil compared to that of the untreated particleboards. However, there is one exception, the EMC of the 100% oil palm trunk particleboard that treated with 10% palm oil increased from 9.5% to 10.5%, indicated that 10% palm oil are not sufficient to impart better hygroscopic behaviour to the particleboard.

Equilibrium moisture content (EMC) refers to the percentage of the water in wood that absorbs or release moisture from or into the atmosphere. From Figure 1, EMC of the untreated sample were ranging from 8.9% to 10%. After oil dip treatment, the EMC of the treated samples were reduced to 7.3% - 10.1% (10% palm oil), 7.0% - 8.5% (50% palm oil) and 7.0% - 8.7% (100% palm oil), respectively. However, only the particleboard made from 100% oil palm trunk particles show 10.52% of EMC which is higher than the untreated samples. This finding suggesting that 10% palm oil treatment not very effective. In 100% palm oil treatment, particleboard made from 70% rubberwood and 30% oil palm trunk show the lowest EMC as compared to the others treated samples and untreated samples indicating 100% palm oil are effective in reducing the wood hygroscopicity.

According to Lee et al. [3], two-stage treatment which involve oil soaking and heat curing can improve the dimensional stability. The effectiveness of the treatment has proven that EMC was reduced after two stage treatment. After treatments, EMC of untreated samples ranged from 6.6 to 7.0 %. After heat curing, the EMCs of treated samples were reduced to 4.7-5.2 % (180 °C), 4.0-5.0 % (200 °C), and 3.9-4.3 % (220 °C), respectively. As compared to this research, both treatment is effective in reducing the wood hygroscopicity.



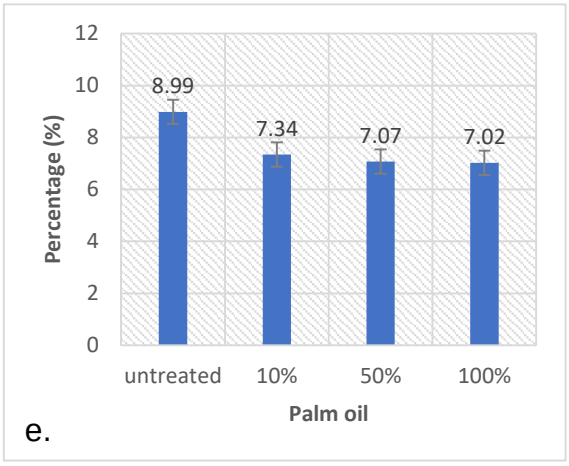
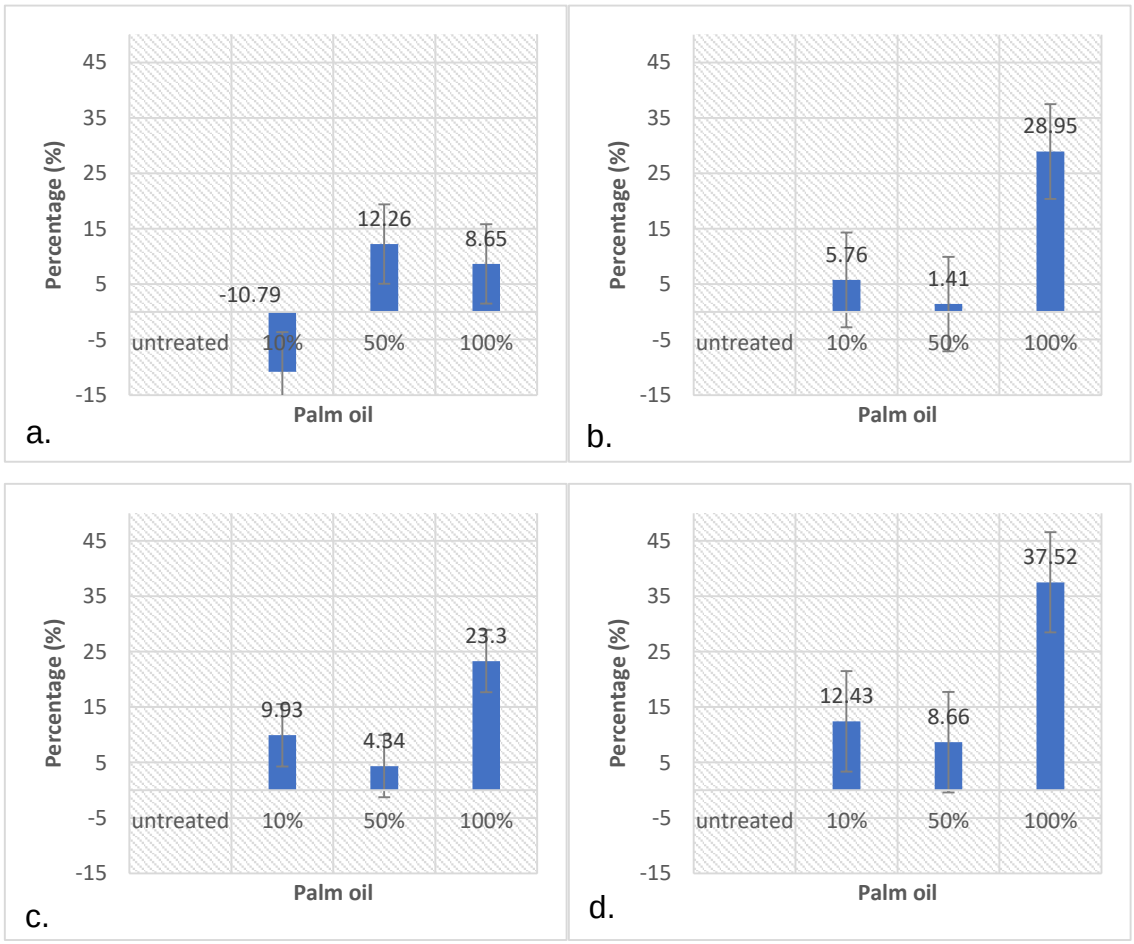


Figure 1. Equilibrium Moisture Content (EMC) of particleboard (a. 100% OPT, b. 30% RW: 70%OPT, c. 50% RW: 50% OPT, d. 70%RW: 30% OPT, e. 100% RW) dip-treated with different percentage of palm oil.

3.2 Moisture Excluding Efficiency (MEE)

Figure 2 exhibits the moisture excluding efficiency (MEE) of the particleboard samples dip-treated with different percentage levels of palm oil. From the results, particleboard made from 30% rubberwood and 70% oil palm trunk show the lowest MEE as compare to others. Positive MEE values indicated that the hygroscopicity of the treated samples was greatly reduced.

The value of the MEE are corresponding to the EMC values recorded. Therefore, 100% oil palm trunk particleboard that dip-treated with 10% palm oil showed a negative MEE value of 10.79% due to its increasing EMC. This can be explained that 10% palm oil treatment did not impart significant effect in improving the MEE of the particleboard.



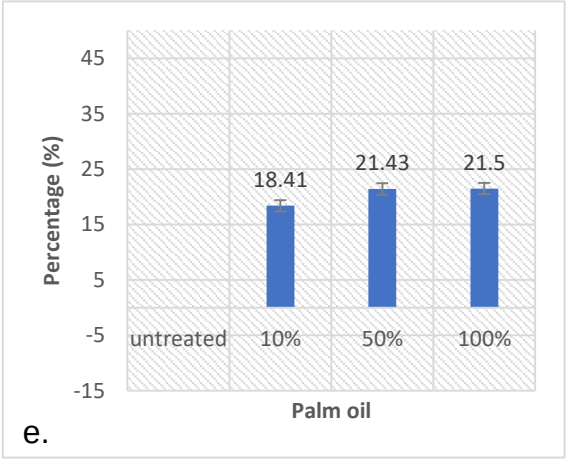


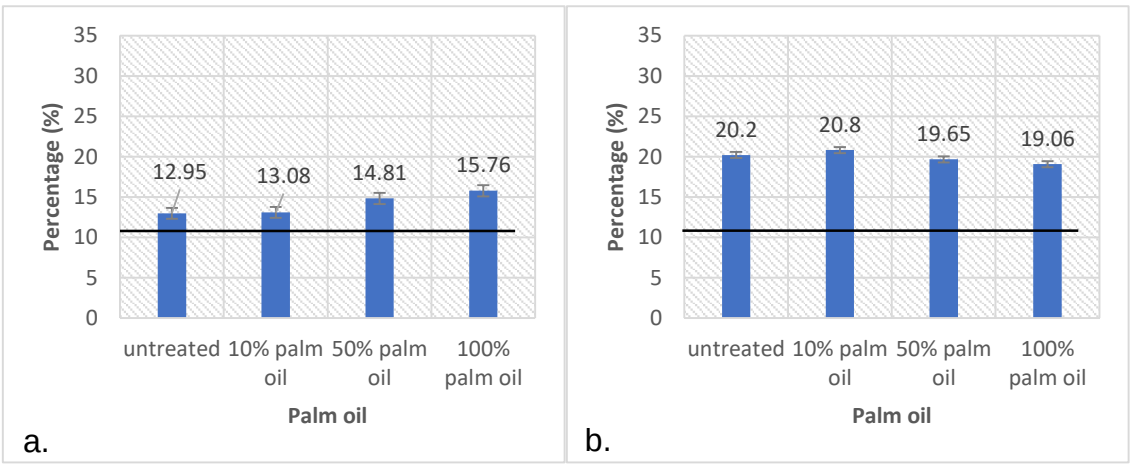
Figure 2. Moisture Excluding Efficiency (MEE) of particleboard (a. 100% OPT, b. 30% RW: 70%OPT, c. 50% RW: 50% OPT, d. 70%RW: 30% OPT, e. 100% RW) dip-treated with different percentage of palm oil.

3.3 Thickness Swelling (TS)

Figure 3 shows the thickness swelling (TS) of the particleboards made from different mixture ratio of rubberwood and oil palm trunk dip-treated in different percentage levels of palm oil. As for mixing ratio, particleboard made from 100% OPT particles showed the lowest thickness swelling (12.95%) compared to the particleboard made with 100% RW and with RW in a mixture with 70%, 50% and 30% OPT.

As for oil percentage for treatment, no significant different were found between the samples treated with 10%, 50% and 100% palm oil, respectively. In fact, some of the samples exhibited increment in thickness swelling after dip-treated in palm. The findings suggesting the dip treatment with palm oil are not effective in improving the thickness swelling of the particleboard.

According to Lee et al. [3], heat treatment in palm oil at 220 °C has improved the dimensional stability of treated samples. The findings were in agreement with Welzbacher et al. [5] who reported that oil heat treatment at 220 °C for 4 h had completely eliminated the compression- set recovery of treated Norway spruce. However, without the application of heat, oil dip treatment in this study failed to improve the thickness swelling of particleboard, suggesting that oil treatment solely is not sufficient in improving the thickness swelling of the particleboard.



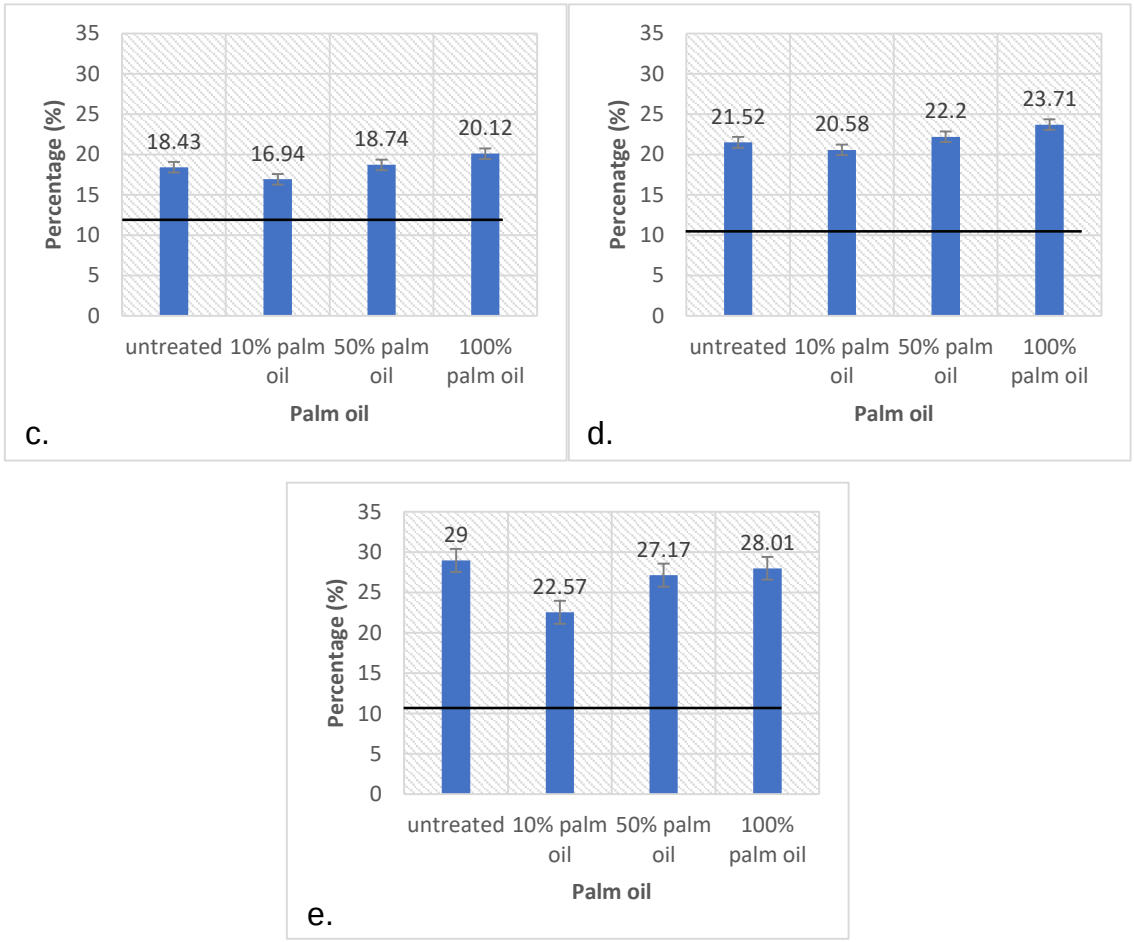


Figure 3. Thickness swelling (TS) of particleboard (a. 100% OPT, b. 30% RW: 70%OPT, c. 50% RW: 50% OPT, d. 70%RW: 30% OPT, e. 100% RW) dip-treated with different percentage of palm oil.

3.4 Water Absorption (WA)

Figure 4 shows the water absorption (WA) of the particleboards made from different mixture ratio of rubberwood and oil palm trunk dip-treated in different percentage levels of palm oil. In contrast to the results of thickness swelling, percentage of oil treatment is the main factors that affected the water absorption of the particleboards. The percentage of water absorption of the treated particleboard were ranging from 31% to 77%, which are lower than the untreated particleboard (73% to 86%), probably due to the oil have deposited in the wood cell wall and subsequently inhibited the water uptake.

The hemicellulose and the non-crystalline region of cellulose present in the rubberwood particles are rich in hydroxyl groups which will easily react with water molecules by hydrogen bonding. However, wood treated with palm oil has lower the water absorption. From Figure 4, water absorption of treated particleboard was decreased probably due to decreasing in hydroxyl groups on carbohydrate chains, mainly for the hemicellulose and non-crystalline region of cellulose during the treatment of particleboard. Thus, this caused the particleboards have lower ability to absorb water when soaked in the water.

According to Yingprasert et al. [7], the amount of the water absorbed (WA) by the cinnamon oil treated particleboard was 59.52% which was lower than the untreated particleboard (62.4%). We can see that the WA of the particleboard decrease after the treatment. As compare to this research, we can conclude that oil treatment is a relatively influential factor in affecting the water absorption of the particleboard.

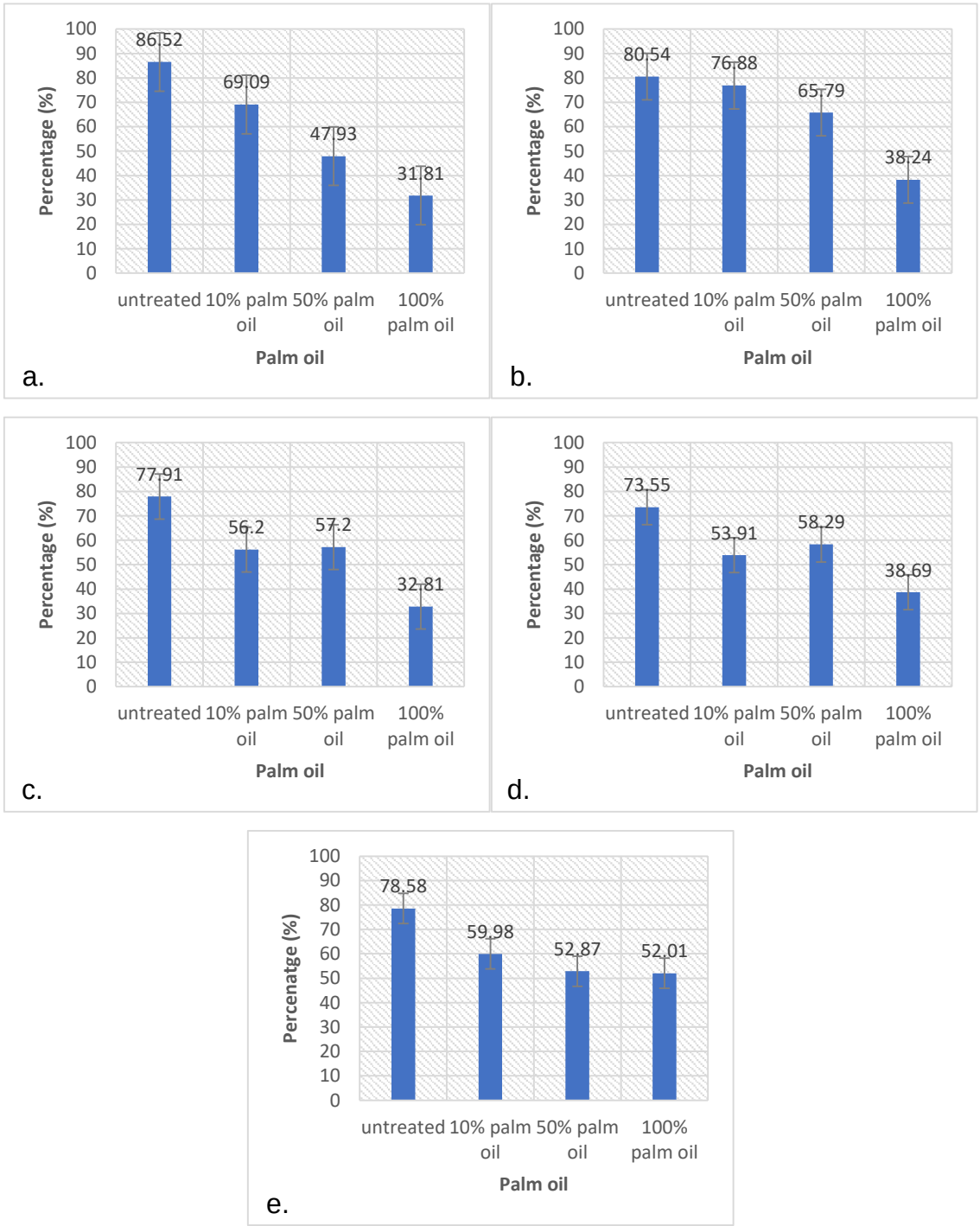


Figure 4. Water Absorption (WA) of particleboard (a. 100% OPT, b. 30% RW: 70%OPT, c. 50% RW: 50% OPT, d. 70%RW: 30% OPT, e. 100% RW) dip-treated with different percentage of palm oil.

3.5 Solution Uptake

Figure 5 shows solution uptake of the treated and untreated particleboards made from different mixture ratio of rubberwood and oil palm trunk. Particleboard make from 100% OPT showed the highest solution uptake (41.05%) when dip-treated with 10% palm oil while 100% RW of particleboard show solution uptake of 29.66%. Particleboard make from 30% RW and 70% OPT showed the highest solution uptake of 40.49% when dip-treated in 50% palm oil while the 100% RW particleboard show 24% of solution uptake. Particleboard make from 30% RW and 70% OPT show the highest solution uptake of 53.04% when dip-treated in 100% palm oil treatment while 100% RW particleboard show 30.92%.

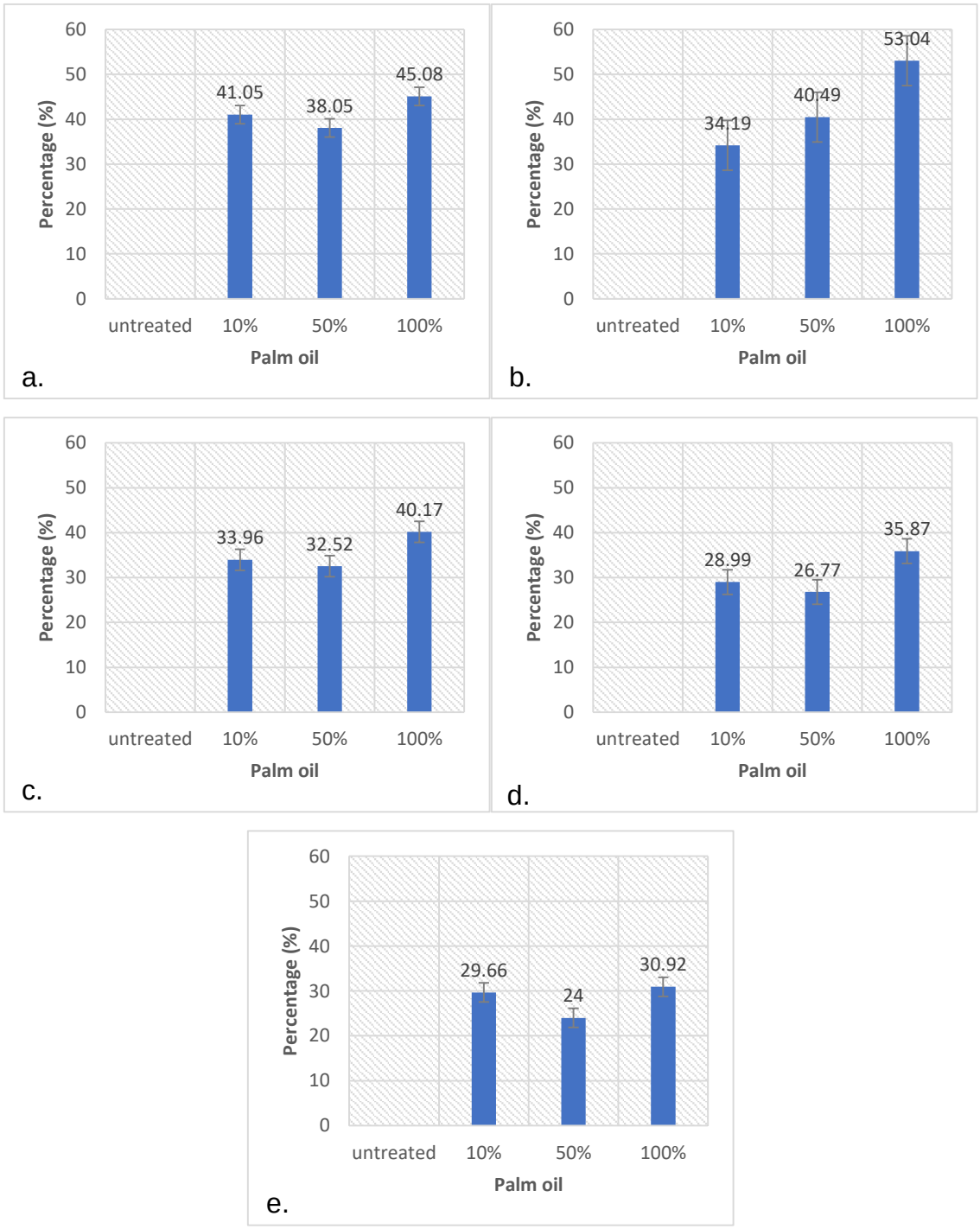


Figure 5. Solution uptake of particleboard (a. 100% OPT, b. 30% RW: 70%OPT, c. 50% RW: 50% OPT, d. 70%RW: 30% OPT, e. 100% RW) dip-treated with different percentage of palm oil.

4. Conclusions

In this research, particleboard made from 70% RW 30% OPT dipped with 100% palm oil had shown lowest EMC (5.64%) compare to the particleboard made with other mixing ratios. This indicates that oil treatment is effective in reducing the wood hygroscopicity. The value of the MEE is corresponding to the EMC values. Positives MEE values indicated the hygroscopicity of the treated samples was greatly reduced. In 10% palm oil treatment, 100% OPT particleboard show negative value which indicate that 10% palm oil is not effective in improving the MEE of particleboard.

As for mixing ratio of the particleboard, particleboard made from 100% OPT particles show lowest thickness swelling (12.95%). However, as for oil percentage used for the treatment, no significant difference was found between the samples treated with 10%, 50% and 100% palm oil. This indicates that the oil treatment is not effective in improving the thickness swelling of the particleboard. In contrast to the results of thickness swelling, percentages of oil treatments show high significant effect to the water absorption of the particleboard. Particleboard made from 100% OPT particles show lowest WA (31.81%). The overall water absorption values of the treated particleboard were reduced.

In conclusion, particleboard made with higher proportion of OPT had better dimensional stability compared to that with higher proportion of RW. Dip treatment with palm oil has improved the EMC, MEE and WA of the particleboard while TS were not significantly affected.

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