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Dimensional Stability Properties of Medium Density Fibreboard (MDF) from Treated Oil Palm (*Elaeis guineensis*) Empty Fruit Bunches (EFB) Fibres

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Abstract

The aim of the study was to investigate the effect of pre-treatments by using sodium hydroxide (NaOH) and acetic acid on oil palm Empty Fruit Bunch (EFB) fibres for the production of Medium Density Fibreboard (MDF). The EFB fibres were treated with chemicals in the concentration range of 0.2%, 0.4%, 0.6% and 0.8% prior to refining. Single-homogenous layer MDF with 12 mm thickness and density of 720 kg/m^3 was produced. Urea-Formaldehyde (UF) was applied at 10% loading (based on dry weight of dry fibres) as a binder. The physical properties (Water Absorption (WA) and Thickness Swelling (TS)) of the produced panels were tested according to European Standard, EN 622-5:2006. The results show that types of chemical used had greater effects than concentration on the dimensional stability of the MDF. EFB fibres treated with acetic acid produced MDF with better dimensional stability compared to the MDF NaOH treated fibres. High concentration of NaOH produced poor dimensional stability in the panels.

Keywords

Empty Fruit Bunch, Sodium Hydroxide, Acetic Acid, Dimensional Stability, Thickness Swelling, Water Absorption

1. Introduction

Natural fibers are lignocellulosic materials that have good potential to be used in any composite materials. The advantages such as availability, light weight, specific strength and good modulus properties make the natural fibres the preferred option as the main raw material, filler or as reinforcement, in composite panels. However, the main disadvantage of natural fiber is the structural compositions that allow easy absorption of water which leads to poor bonding and strength. Thus, in order to improve the fibre properties, treatment is necessary. The principle of treatment is to modify the fibre structures and change the composition [1] and also to alter the structure of cellulosic material to make the cellulose more accessible with the goal of modifying the surfaces of the fibres [2]. Abdelmouleh *et al.* [3] has suggested chemical treatments such as mercerization and acetylation that resulted in the modification of fibre chemistry.

Oil palm is one of the most important agricultural crops in Malaysia. Oil palm belongs to the species *Elaeis guineensis* under the family of *Palmaceae* and it is a monocotyledons plant. The oil palm tree is planted for oil production, and the oil is used in food, detergents and cosmetic. Based on Sumathi *et al.* [4] and Alam *et al.* [5], the oil palm industries in Malaysia generated about 8.2 million tonnes of Oil Palm Trunk (OPT), 12.9 million tonnes of Oil Palm Frond (OPF), and 15.8 million tonnes of Empty Fruit Bunch (EFB). In addition, Wahid [6] estimated based on 4.69 million ha planted area, the total oil palm biomass was 95.3 million tonnes of dry lignocellulosic material. Furthermore, more than 30 million metric tons of entire oil palm productions in the world are considered as agricultural material, and about 8 million metric tons are EFB materials.

Pre-treatment of the EFB fibres is needed in order to produce fibres of acceptable properties suitable for Medium Density Fibreboard (MDF) production. The treatment process and the properties of the fibres are belonging to the many factors of critical importance to the performance of MDF panels. Most of the reports indicated that treatments influenced the final properties of MDF [7]-[10]. Lignocellulosic materials are hydrophilic and readily absorb water that leads to swelling of the fibres and affects the dimensional stability of MDF. Li *et al.* [7] concluded that the acid treatment of wood chips led to decreased WA and TS of MDF up to 16.9% and 23.8%, respectively, compared to untreated fibre attributed from the removal of hemicelluloses by the treatment. Thickness Swelling (TS) of the panel is defined as the additional swelling in the thickness direction after exposure to water for a certain period of time and mainly cooperates with fibre bonding, where good bonding between fibres resultes in low TS [11].

The purpose of this study is to evaluate the effect of fibre treatment on the physical properties of MDF. In this part, two types of chemicals were used: 1) sodium hydroxide (NaOH) and 2) acetic acid, with different concentrations. The physical properties analysed were Thickness Swelling (TS) and Water Absorption (WA) of the panel as functions of chemical treatments and concentrations.

2. Materials and Methods

2.1. Materials

The EFB fibres were obtained from Sri Langat Oil Palm Mill Sdn. Bhd. in Selangor, Malaysia. The fibres were further reduced in length of 4 to 5 cm using a drum chipper. Chemical used in this study were NaOH and acetic acid supplied by a local chemical supplier. Urea formaldehyde (UF) with 64% solid content was used as the binder.

2.2. Fibre Production

The EFB fibres were soaked in the solution of NaOH and acetic acid at 0.2%, 0.4%, 0.6% and 0.8% concentration levels. The EFB fibres were immersed in the separate solutions for 24 hours, after that the treated EFB were filtered out and washed with water to remove impurities. The treated EFB then were air dried for 5 hours. The EFB were chipped using a drum chipper and then were refined by the Sprout-Bauer (ANDRITZ) refiner at the MDF pilot plant located in MPOB-UKM Research Station. The refined EFB fibres were oven-dried until the moisture content (MC) was about 4% - 5%.

2.3. Fibreboard Production

The treated dried fibres were blended with 10% of UF resin in a rotary-drum blender. The resinated EFB fibres were collected and placed in a 300 × 300 mm size wooden box template and formed manually into a mat. The mats were then cold press followed by hot press at 200˚C for 5 minutes under a pressure of 170 kg/cm^2. Boards with dimensions of 300 × 300 × 12 mm and density of 720 kg/m^3 were manufactured. Prior to testing, the produced panels were conditioned in a chamber at 65% relative humidity and 20˚C temperature for a week.

2.4. Dimensional Stability Evaluation

The weight and thickness of the test specimens were measured by immersing in water at 20˚C temperature. The final thickness and weight of the test specimens were determined and recorded after 24 hours. The absorbed water and thickness swelling of the samples were calculated as a percentage according to the procedure of EN 317. The percentage of absorbed water was calculated using Equation (1) and the thickness swelling was calculated using Equation (2) below.

$$\text{WA}(\%) = \frac{W_2 - W_1}{W_1} \times 100 \tag{1}$$

where W_1 is the weight before and W_2 is the weight after immersion in gram.

$$\text{TS}(\%) = \frac{T_2 - T_1}{T_1} \times 100 \tag{2}$$

where T_1 is the thickness before and T_2 is the thickness after immersion.

2.5. Statistical Analysis

The effect of chemical treatment and concentrations on the physical properties were evaluated by Analysis of Variance (ANOVA) using the Statistical Analysis Software (SAS). The Least Significant Difference (LSD) method was used to test for the level of significant differences between the different MDF panels.

3. Result and Discussion

The effect of different chemical treatments and concentrations on the MDF physical properties; Thickness Swelling (TS) and Water Absorption (WA) were determined. Table 1 shows the analysis of variance (ANOVA) for the effects of treatments and concentrations on physical properties of the panels.

High significant interactions between treatment and concentration were observed for all board in both physical properties at a significant level of 10 percent. Between the two variables, treatment has more dominant effect on the physical properties of MDF compared to the concentration, which is only has effect in TS but not significant in WA.

3.1. Thickness Swelling

Figure 1 shows the mean values of TS for MDF with treated EFB fibres. The figure illustrates both treatments reduced the TS value of the panels. Significantly higher TS were found in the boards made from fibres that were treated with NaOH as compared to boards treated with acetic acid. With the NaOH fibre treatment, the TS of the boards reduced as the concentration was increased from 0.2% to 0.4%. In addition, with in-

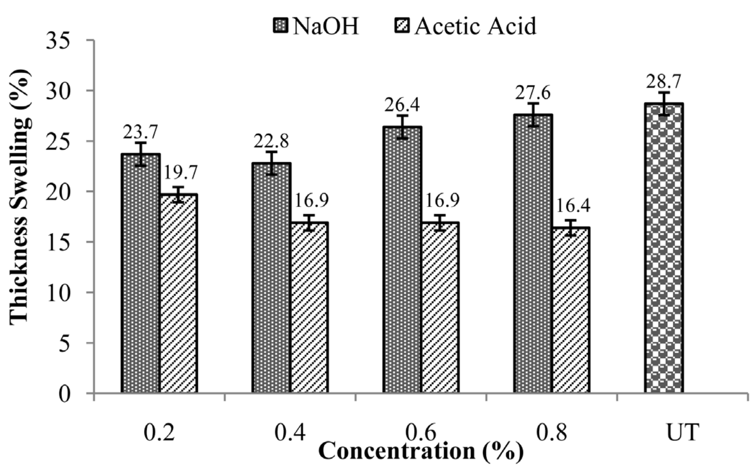

Figure 1. The mean values of TS of MDF from treated empty fruit bunch (EFB) fibres.

Table 1. Analysis of variance (ANOVA) on the MDF physical properties for difference EFB treatment effects.

Variables	d.f	p-value	
		TS	WA
Treatment (T)	2	***	***
Concentration (C)	4	***	n.s
Interaction (T × C)	8	***	***

creasing the concentration from 0.6% to 0.8%, increased the TS significantly. Conversely, the TS of panel with acetic acid treated fibre decreased significantly with increased concentration. The lowest TS value ranging of 16.4% to 16.9% was found for panels made using acetic acid for 0.4%, 0.6% or 0.8% concentration levels.

The NaOH may have removed the residual oils, thus, removing the barrier against water uptake and consequently improving the TS of the panels. This finding was supported by Ridzuan *et al.* [10] who also highlighted the treatment of EFB fibre with NaOH removed the residual oil, therefore, influencing the dimensional stability of MDF. Paridah *et al.* [12] reported that the presence of residual oil in the EFB fibres resulted in lower wettability of MDF making it more difficult to be bonded with adhesive. Evidently, the residual oil contributed to the production of boards with poor fibre bonding. The presence of oil reduces the wetting of the surface of the fibre and prevent adhesive to penetrate, thus reducing the absorption rate of adhesive into fibres.

A greater increase in TS value was observed of boards with fibres treated with 0.6% and 0.8% of NaOH compared to those TS of boards treated with NaOH at 0.2% and 0.4%. The higher bulk density was found in the boards with fibres treated at 0.6% and 0.8% NaOH a result of accumulation of excessive NaOH reagents on the fibre surface. Similar finding was observed in the study by Yusoff *et al.* [13] who reported that alkali treatment generates poor fibre with high bulk density, thus affecting the TS properties of the fibres. Other than that, treated EFB fiber at high concentration of NaOH resulted in the formation of fibre lump, hence, introducing another problem during fibre blending and mat pressing process. These fibre lumps required more forces to deform during hot pressing as a result more stresses were built in the panels due to the poor distribution of resin and fibres. According to Abdul Khalil *et al.* [14] and Gillah *et al.* [15] these excessive stresses were released when exposed to moisture and caused pronounced reversed densification, lead to high TS value.

In addition, it was observed that the lowest TS were obtained in the panels from acetic acid treated fibre. This was because treatment using acetic acid produced lower pH fibres compared to the pH of NaOH fibres. Different pH values of fibres were observed to give different resin curing times during hot pressing [16]. As an acid-curing adhesive, UF is cured at an acidic condition [17]. It is expected that the more highly acidic fibres would result in a higher degree of curing rate in the MDF production, promoted better bond ability between treated EFB fibre and the UF, and thus the fibre to fibre bonding. Good fibre bonding resulted in better TS value as moisture are not allowed to penetrate into the fibres due to effectively wetting between fibres and adhesive.

3.2. Water Absorption

The WA of panels depends on the ability of the fibres to absorb water due to the presence of hydroxyl groups [14]. WA depends on the affinity of the fibres to attract water and hence does not rely much on the bonding strength. **Figure 2** shows the mean values of WA for MDF made from EFB treated fibres.

As shown in **Figure 2**, both treatments increased the WA of the panels with acetic

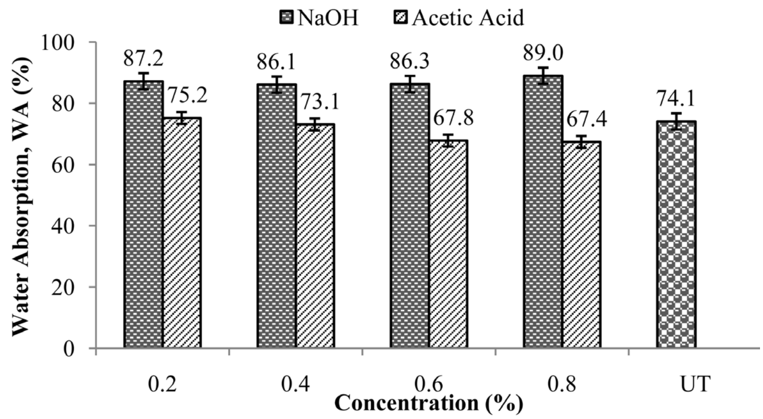

Figure 2. The mean values of WA of MDF from treated empty fruit bunch (EFB) fibres.

acid treatment produced lowest WA, fell in the range of 67.4% to 75.2%. Similar to the trend in TS, the WA of the panel made from NaOH treated fibres slightly improved from 87.2% to 86.1% when the concentration increased from 0.2% to 0.4%, respectively. However, in the case of the MDF made from fibres treated with NaOH of 0.6% to 0.8% concentration, the WA increased from 86.3% to 89.0%, respectively. The WA was significantly different when fibres were treated with acetic acid, concentration apparently has more effect on reducing WA from 0.2% to 0.8%. Increasing the concentration of acetic acid, the WA improved from 75.2% to 67.4%.

The improvement of WA in the NaOH treatment at 0.2% and 0.4% of concentration can lead to more degradation of hemicelluloses in the fibres. Hemicellulose have hydrophilic characteristic, which tends to absorb water [7] thus removal of this compound significantly affect the absorbent of moisture and water. Additional NaOH used during treatment resulted in more degradation of hemicellulose compounds, and the reduction in the WA was observed. The removal of hemicellulose causes comprehensive conversion in the formation of cellulose that becomes more vulnerable [18]. In addition, Vilaseca *et al.* [19] also claimed that more OH groups are accessible on surface of the fibres, thus creating more surface area and better fibre-adhesive bonding.

The reduction of WA as the concentration of NaOH was increased was noted. As a swelling agent, NaOH is able to penetrate the crystalline region in the cellulose. At high concentration, more severe penetration of NaOH molecules occurred in the crystalline region of fibres structure, freeing more OH groups in the cellulose that led to increase rate of absorption. Any reduction in the volume of amorphous region in the cellulose, where less OH groups are free in the cellulose will produced more stable boards due to the increasing the cellulose crystallinity [20] [21].

The panel from acetic acid treated fibre had better WA properties compared to NaOH panel indicated that the fibre absorb less water. This was due to the removal of hemicellulose component which has hydrophilic properties and lignin constituent from the treated fibre. This explanation also was in agreement with a study by Rowell *et al.* [22] who stated that treatment with acetic acid improved moisture resistance properties resulting from removing hemicellulose and increasing the crystallinity of cellulose.

The significant decrease in water uptake for panels treated with acetic acid was also associated with the change in the water-soluble characteristic of the fibers. The reaction of fibre and acetic acid produced acetylated fibres and water molecules. The reaction was as follows:

$$\text{Fibre–OH} + CH_3COOH \rightarrow \text{Fibre–O} - \overset{\overset{\displaystyle O}{\|}}{C} - CH_3 + H_2O$$
$$(\text{Acetylated fibre})$$

Acetic acid treatment of fibres enhances resistance to absorption of water due to the O-acetyl groups in aceylated EFB fibres. The reaction between O-acetyl groups with free OH groups in the cellulose molecules of the fibres took place, thus the fibres became more hydrophobic. Higher concentration of acetic acid in the treatment resulted in more hydrophobic property of the fibres and reduced the water uptake, producing more stable boards. Sreekala *et al.* [23] proved that the chemical modification occurred when fibres were treated with acetic acid. The chemical modification contributed by the acetic acid produced hydrophobic fibres and this was observed by infrared studies. They found that several chemical reactions took place during the treatment [10] [11] [23].

4. Conclusions

1. The treatment parameters (types of chemical and concentrations) apparently affected the panel physical properties. Treatment types had more pronounced effects on the panel physical properties as compared to concentration levels.
2. Fibre treated with acetic acid produced panels with better dimensional stability compared to those panels made from fibres treated with NaOH.
3. Alkaline treatment at concentration more than 0.6% produced relatively lower physical properties of the sample.
4. The fibres treated with 0.4% of NaOH produced the ideal panels with the lowest TS compared with other concentrations.
5. Fibres treated with acetic acid at 0.4% resulted in boards with the optimised physical properties where the values satisfied the minimum requirements of the standard.

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