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Effects of Chemical Treatment on Mechanical Properties of Oil Palm Empty Fruit Bunch (EFB) with Urea Formaldehyde (UF) Resin Particleboardtype

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Abstract*: Oil palm plant by-product such empty fruit bunches (EFB) are not effectively utilized and in many instances had caused severe pollution problems. It has a potential to replace the wood in the production of particleboard in furniture industry. This research aim is to investigate the effects of the chemical treatment on the mechanical properties of the oil palm empty fruit bunch (EFB) with urea formaldehyde (UF) resin particleboard through Scanning Electron Microscopy (SEM), flexural test – three point bending test and the water absorption test. A single layered oil palm EFB/UF particleboard with the fibres treated with NaOH of 0.5%, 1.0% and 1.5% concentrations were made. Testing procedure was done in accordance with the American Standard Testing Materials - ASTM 1037 standard for testing wood based fibre and particle panel materials. The SEM images of 1.0% NaOH treated fibre shows a rougher surface indicating that more silica bodies are detached from the EFB surface which improves the mechanical interlocking ability of the fiber. Flexural properties the treated EFB/UF particleboard shows an improved quality compared to the untreated board. There is significant increase of 82% and 81% in the flexural strength and flexural modulus respectively of the 1.0% NaOH treated board from 0.5% NaOH treatment. As for the water absorption rate, the treated particle board shows a decrease in water absorption rate after the treatment.

***Keywords* : oil palm empty fruit bunch, particleboard, chemical treatment, urea formaldehyde.**

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I. INTRODUCTION

Oil palm is one of the leading agricultural harvests in Malaysia. In 2013, the oil palm estate covered around 5.23 hectare [1] and these vast zone produced plentiful measure of biomass every year in the form of trunk, frond, pressed fruit fibre (PFF), palm oil mill effluent (POME) and empty fruit bunches (EFB). From the overall oil palm biomass produced, EFB added about 30.5% from the oil palm biomass.

It is important to properly utilize EFB in order to prevent disposal problem of the potentially high commercial value fibre. If proper actions are not taken, these problems might lead to air pollution and other environmental problems especially if they are burned. However, the conventional way will be simply placing the EFB at a landfill to decompose into green fertilizers. The large quantity of this oil palm waste has the potential to be utilize as resources for items with high profitable value [2] as for the production of the particleboard.

Before the EFB can be made into a particleboards, it has to undergo chemical treatments. The most essential part of palm oil processing is the sterilization process which consists of various minor steps. One of them will be the various chemical treatments using sodium hydroxide, silane, acetic acid or benzoic acid. These treatments have critical impact on the EFB which in turn will affect the productivity and reliability of its commercial value [3].

Natural fibres consist of pectins and waxy materials which prevent the hydroxyl groups from reacting with the polymer matrices. This issue will cause and ineffective fibre matrix interface which will later result in the debonding and voids in the composite product. Therefore, chemical treatments plays an important role in removing these non-cellulosic components in the fibres by adding functional groups to provide better bonding in the composite product. On top of that, the chemical treatment has the ability to change the crystalline structure of the cellulose fibre [4]. However, the chemical treatments of the EFB remains a relatively debateable subject field in research and development which will be further discussed in this paper.

II. METHODOLOGY

The EFB were obtained from local palm oil plantation in Bau, Sarawak.

The EFB were cleaned by soaking it in distilled water for 24 hours at room temperature. The cleaned EFB was then dried under the sun until it reaches its constant weight. Sodium hydroxide (NaOH) was used for the alkaline treatment at the concentration of 0.5%, 1% and 1.5% [5]. The EFB fibres were soaked in 0.5% concentration of NaOH at room temperature for 24 hours [6].

The fibres were then filtered out and were rinsed with distilled water. The EFB was sundried until reaches constant weight. The process is repeated with 1% and 1.5% of sodium hydroxide. The treated EFB were then cut into smaller but random sized fibre using a blender.

The EFB particles of random sizes were prepared for the fabrication of the particleboard.The resin urea formaldehyde (UF) was obtained from Hexachem, Sarawak. 55% UF concentration to the amount of EFB was used to fabricate the particleboard.The mass of the EFB particles were measured and placed in a mixing container. The EFB particles were mixed by hand with 55% UF resin to get a homogenous mixture. A mould (220 mm x 240 mm x 6 mm) was coated with wax prior placing the mixed particles to ease the removal process of the particleboard after hot pressing. A hot press machine at a temperature of 165°C and a pressure of 3000 KPa was used to hot press the mat for 6 minutes. The boards produced was then cooled and cut into 195 mm x 50 mm x 6 mm according to ASTM D1037 standard for testing of wood based fibre and particle panel materials [7]. Three Point bending test using M350 Testometric Machine was performed at 3mm/min to obtain the flexural properties of the sample.

The effects of the chemical treatment on the EFB fibre was observed from the Scanning Electron Microscope (SEM) images. The specimen was held by a round shaped aluminium plate before coated with JEOL JFC-1600 Auto Fine Coater machine for 30 seconds. The sample is then placed in the SEM machine that is the Hitachi Model TM3030. The specimen was then scanned and analysed with magnifications of x1000, x2500 and x5000.

The water absorption test was carried out to determine the extent of deviations and the rate of water absorption after being submerged after 24 hours. The specimens were cut into sample sizes of 50 mm x 50 mm x 6 mm and were then oven dried, weighed and submerged in 3 cm underwater for 5 different durations that is 1 hour, 2 hours, 4 hours, 6 hours and 24 hours. After every duration, the specimens were taken out, wiped with a tissue paper prior to reweighing and measurement of the thickness .

III. RESULT AND DISCUSSION

A. Surface Morphology

The images obtained from the Scanning Electron Microscope (SEM) can be observed in Fig 1. It can be seen that on the surface of the untreated EFB in Fig 1a are silica bodies still embedded on the surface. The SEM images of the 0.5% of NaOH treated fibre in Fig. 1b shows that most of silica bodies are still attached to the surface resulting in appearance of voids. As silica bodies were still found attached to the fibre, this observation signifies that a higher concentration of NaOH is needed to successfully eliminate the silica bodies and other substances like waxes or lignin. SEM images of the EFB fibre treated with 1.0% NaOH in Fig. 1c however, shows that more silica bodies are detached from the EFB surface and more voids are present. At 1.5% NaOH treatment in Fig. 1d displays an image with a coarse and uneven surface as well as images of deposition of residues from the fibre degradation due to a higher NaOH concentration. If the NaOH concentration used was higher that the optimum condition, excess delignification of the fibre will occur, damaging the fibre [8]. Detachment of the silica body exposes that the region beneath the silica voids is perforated which would improve chemical penetrations in pulping [9]. A similar research by [10] claimed that the presence of the silica bodies will give rise to the strength and rigidity of the EFB fibre.

B. Flexural Test – Three Point Bending Test

Fig. 2a shows the flexural strength of the particleboard with different concentration of NaOH treatment. The highest value is possessed by the 1.5% NaOH treated EFB/UF particle board with a value of 16.02 MPa. The flexural strength then experience a decrease in value from 14.29 MPa for 1.0% NaOH, 7.86 MPa for 0.5% NaOH followed by the untreated sample with the lowest flexural strength of 6.97 MPa. From the graph plotted, the alkaline treatment has shown a positive increment in the flexural strength of the EFB/UF particleboard.

As for flexural strain (Fig. 2b), it was shown that the highest value is possessed by the 1.5% NaOH treated EFB/UF particleboard with a value of 14.3 mm/mm The ductility then experience a decrease in value from 13.3 mm/mm for 1.0% NaOH, 12.7 mm/mm for 0.5% NaOH followed by the untreated sample with the lowest ductility of 5.9 mm/mm. From the graph plotted, alkalization has displayed a significant positive increment in the ductility of the EFB/UF particle board.

Fig. 2c shows the flexural modulus of the EFB/UF particle board. The 1.5% NaOH treated EFB/UF particleboard shows the highest value of flexural modulus that is 272.52 MPa followed by the 1.0% NaOH treated EFB/UF particleboard with a lower value of 260.17 MPa. The flexural modulus then experienced a further decrease in value as can be seen from the 0.5% NaOH EFB/UF particleboard showing 143.95 MPa of flexural modulus and 142.06 MPa by the untreated sample. The flexural modulus follows the same trend as the flexural strength and flexural strain after alkalization that is experiencing a significant increase in value.

It can be clearly seen that the flexural properties of the NaOH treated samples are gradually enhanced as compared to the untreated samples due to the improvement in the bonding strength after the treatment with NaOH. It causes fibrillation in the EFB surface, causing an increase in the effective surface area available for contact with the matrix. This action also decreases the diameter of the fillers and enhanced the roughness of the filler's surface as compared to the untreated fillers [11].

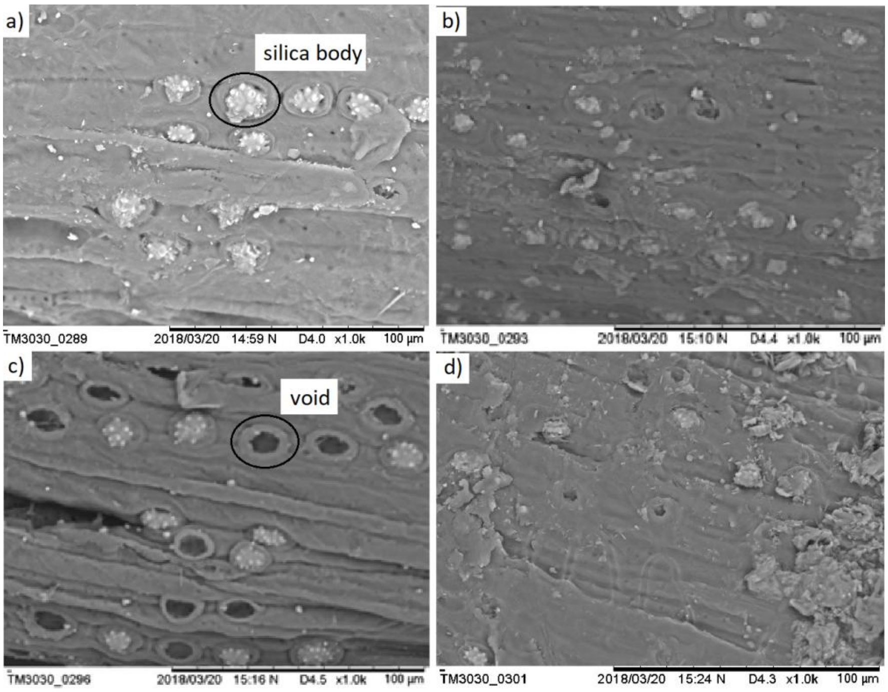
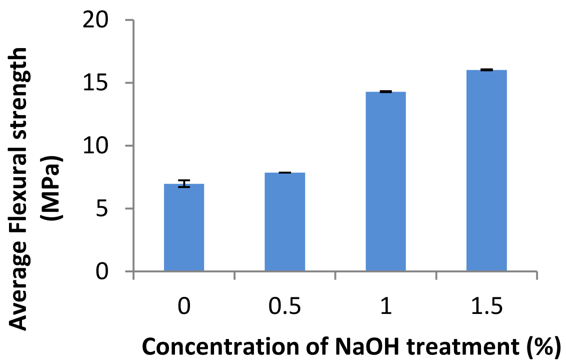
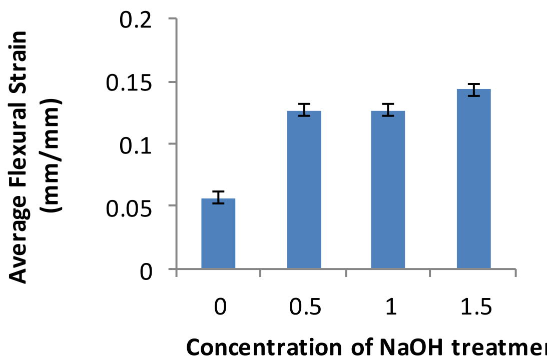


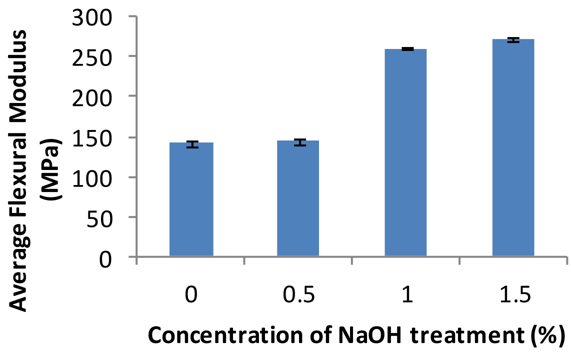
Fig. 1: SEM images showing the surface morphology of Oil Palm Empty Fruit Bunch Fibre (EFB) a) of Untreated , b) 0.5% NaOH, c) 1% NaOH, d) 1.5 %



(a)



(b)



(c)

Fig. 2 Flexural properties of the particleboard at different concentration a) Flexural Strength, b) Flexural strain, c) Flexural Modulus

From the graphs plotted and values calculates, in terms of the flexural properties which consist of flexural strength, flexural strain and flexural modulus, the treated EFB/UF particleboard shows an improved quality compared to the untreated board.

The alkaline treatment decreases the lignin bonds in between the fibres and partly hydrolyses the hemicellulose in it.

The lower amount of hemicellulose contributes to a fibreboard with better strength. The alkaline treated EFB fibre's surface is cleaner and rougher. This improves the mechanical interlocking and bonding reaction between the fibre and resin during compounding due to the hydroxyl groups being exposed to after the treatment. The increment in the flexural modulus may be due to the stress transfer between the treated EFB fibre and the matrix. It is also stated by [12] that it is due to even dispersion or mixing between the fibre and the matrix.

C. Water Absorption and Thickness Swelling Test

Table I shows that the alkaline treatment resulted in a positive effect on the water absorption ability of the EFB/UF particleboard. It is observed that on the 0.5% treated particleboard, the weight gain percentage starts to decrease to 20% as compared to the untreated EFB/UF particleboard. This is then followed by a gradual decrease of the weight gain percentage on 1.0% and 1.5% of sodium hydroxide treated EFB/UF particleboard that is 13% and 12% respectively. There is 5% decrease in water absorption rate from the untreated sample to the 0.5% NaOH sample whereas a significant decrease with 40% percentage from the 0.5% NaOH to 1.5% NaOH treated sample. This signifies that there are presence of voids on the outer surface of the untreated fibre. These voids will cause an increase on the weight of the particleboard as water molecules are easily trapped inside the voids [13].

The water absorption ability of polymer composites is dependent on the capability of fibres to take in water due to the existence of the hydroxyl groups which absorbed water via the formation of hydrogen bonding within the fibre cell wall. The removal of hemicellulose, lignin and impurities lead to an abundant elimination of hydroxyl groups on the outer surface of the EFB fibre [9]. This causes fewer interactions between the fibre and the water molecules as a more crystalline and stiff packed of cellulose is left. Removal of these chemical components will result in a surface that is rougher and of higher porosity [19]. NaOH, having the capability to disrupt the hydrogen bonding within the cellulose structure can therefore increase fibre surface's roughness [17]. This allows water molecules to flow through the pores on the surface of the fibre rather than being retained in the composite [17]. This will then lead to declination of water retention performance in the alkaline treated particleboard.

The results show that all of the samples experienced expansion throughout the 5 durations. The thickness swelling of the samples shows a gradual decrease from 18% (untreated), 16% (0.5% NaOH), 15% (1.0% NaOH) and down to 11% (1.5% NaOH). From Table II, it can be seen that the untreated particle board shows the highest thickness swelling with the value of 18% as compared to the other samples. This has pointed out that due to the higher porosity on the surface of the untreated EFB fibre, the dimensions of particle board will experienced more changes particularly in its thickness as compared to the other samples [18].

As for the treated particleboard, the thickness swelling was seen to be decreasing as well as the percentage of NaOH treatment increases. The treatment increases the number of potential reaction sites on the surface of the fibre. This will promote an improved mechanical interlocking in the treated particleboard. The enhancement of the adhesive ability between the treated fibres are able to create a composite with a better dimension stability [15]. This phenomena is as such because when water molecules diffused into the cellulose network, the treated fibre is able to handle the swelling process well while providing a rigid growth of thickness swelling as can be seen from Table II. This ability will also retain the structure of the particleboard preventing disintegration of the structure.

Boards which are treated with a higher concentration of NaOH has the lowest thickness swelling. This is due to the increased internal bonding compared to the untreated boards. A low thickness swelling value signifies a higher consistency between the EFB fibres which resulted in an improved dimensional stability.

IV. CONCLUSION

This study investigated the effects of chemical treatment using sodium hydroxide (NaOH) on the mechanical properties of oil palm empty fruit bunch (EFB) urea formaldehyde (UF) particle board. The alkaline treatment has shown that it is effective in getting rid of the impurities on the surface of the fibre constructing a fibre with rougher surface which promotes fibre adhesion. The research has also revealed that the alkalization of the EFB prior the fabrication process shows a positive effect improving the flexural properties of the particleboard from the results obtained in the flexural test. As for the water absorption ability, the treated EFB/UF particleboard improved the resistance of the board towards water absorption by decreasing the nature of the EFB fibre being hydrophilic. Therefore, from the study, it can be concluded that the chemical treatment with NaOH has improved the mechanical properties of the EFB/UF particleboard.

Table I Weight Gain Percentage of Samples.

Sample Conditions	Weight (g)						Weight Gain Percentage (%)
	Initial	*1 hour*	*2 hours*	*4 hours*	*6 hours*	*24 hours*	
Untreated	13.458	13.536	13.989	14.278	15.596	16.279	**21 ± 0.60**
0.5%	13.470	14.627	15.434	15.441	15.538	15.556	**20 ± 0.67**
1.0%	15.816	15.991	16.554	16.746	17.234	17.989	**13 ± 0.86**
1.5%	16.408	17.568	17.571	17.759	18.289	18.541	**12 ± 0.73**

Table II Thickness Swelling Percentage of the Samples

Sample Conditions	Thickness (mm)						Thickness Swelling Percentage (%)
	Initial	*1 hour*	*2 hours*	*4 hours*	*6 hours*	*24 hours*	
Untreated	6.07	6.35	6.47	6.62	6.96	7.18	**18**
0.5%	6.06	6.17	6.31	6.34	6.81	7.04	**16**
1.0%	6.03	6.19	6.37	6.63	6.85	6.97	**15**
1.5%	6.06	6.06	6.08	6.22	6.52	6.76	**11**

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