Effect of Seawater Treatment on The Mechanical Properties of Oil Palm Empty Fruit Bunch Fibre/Poly(vinyl alcohol) Composites

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In this study, the mechanical properties of seawater treated empty fruit bunch filled poly(vinyl alcohol) were investigated as well as to discover an appropriate alternative for chemical modification of natural fibres. The different volumes of filler (1%, 3% and 5%) of untreated and treated composites were prepared by casting method, respectively. The single fibre of oil palm empty fruit bunch has been treated using sea water from day-one until day-thirty. The mechanical effect of the properties of single fibre and oil palm empty fruit bunch filled poly(vinyl alcohol)examined using Universal Testing Machine. The mechanical properties of the single fibre of oil palm empty fruit bunch enhanced when the longer fibre soaked in sea water with 269.3% increase in tensile strength. The tensile strength of composites increased sharply upon the treatment from 67.37% to 224.10%, while the decrease of the tensile modulus showed when the filler decrease from 89.72% to 66.67%. The elongation at break of the composite shows slightly increased when the filler reduced from 21.43% to 41.34%. In conclusion, sea water treatment significantly improved an extra enhancement in mechanical strength. Thus, the result provides alternatives efficiency method of surface modification by nature as low-priced better and safer than chemicals treatment.

Keywords: Empty fruit bunch, sea water treatment, poly(vinyl alcohol)

I. INTRODUCTION

Malaysia alone has been reported to produce around 30 million tons annually of oil palm biomass which including trunks, fronds and empty fruit bunches (Shinoj *et al.,* 2011). Thus, these fibres give benefit in term of economic utilization. Lignocellulosic oil palm empty fruit bunches (EFB) fibres made of approximately of 44.2% cellulose, 33.5% hemicellulose and 20.4% of the lignin (Astimar *et al.,* 2002). Generally, several advantages attributed to the utilization of oil palm EFB such as low in density, has greater deformability, less abrasiveness toward equipment, biodegradability as well as cheaper. Oil palm EFB fibre suitable used in composite application due to high cellulose contained and high strength properties (Chiesa and Gnansounou, 2014). Based on the previous study shows that the addition of filler oil palm EFB into the matrix of poly(vinyl alcohol)(PVA) increased the mechanical properties of tensile strength (Ching *et al.,* 2014). A numerous of studies have been completed utilizing existing fibre surface

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treatment strategies to enhance the interfacial bonding properties of diverse natural fibre reinforced composites (Sreekala and Thomas, 2003; Herrera-Franco and Valadez-Gonzalez, 2005; Van *et al.,* 2003). Conversely, only a few studies have been completed in turn to find a new biological-based treatment, which can to hunt down another organic-based treatment that can replace the chemical treatment, sea water treatment is one of the natural treatments, which can be used as the alternative than chemical treatment.

According to the Ishak *et al.* (2009), they found that sea water treated composites of 20% and 30% fibre content had higher impact value at 18.46 MPa and 14.16 MPa with 5.06% and 4.27% of improvements respectively, when compared to untreated composites. Similar result was reported for flexural strength of 30% fibre content which had higher impact value at 53.87 MPa with 7.35% of improvements. Based on the research conducted by Gu (2009), the sea water treated of glass fibre unsaturated polyester composites showed decrement trend of the bending resistance upon the immersion time. After 30 days of the immersion time, the composites underwent some forms of physical impairment and degradation of chemical composition.

In this study, the mechanical properties of the untreated and sea water treated EFB fibres of the composites were investigated. The outcome of this research serves as the nature surface modification of sea water treatment of fibre which is act as the alternative method, as it is low cost, better and safer than chemical treatment has great potential in biofuel production.

II. MATERIALS AND METHODS

A. Sample Collection

The oil palm EFB fibre obtained from Beaufort, Sabah, Malaysia. Sea water as the treatment agent was taken from Pulau Tiga, Survivor Island, Kuala Penyu, Sabah, Malaysia. The geographical location of the sea water is taken 200 m away from the sea shore to ensure the salinity of sea water (Ishak *et al.,* 2009). Besides, the place was identified with no river mouth nearby in order to maintain the standard salinity of water due to the depth of the sea water influenced the salinity. The salinity of water tested by using Professional plus (Pro Plus) Multiparameter Instrument.

B. Treatment Process

The samples were divided into two categories namely untreated and treated fibre. The untreated fibre was washed using distilled water whereas the treated fibre was soaked in sea water at different soaking time as shown in Figure 1 as modified Leman *et al.* (2008) method. The untreated and treated fibre dried at room temperature for 48 h to ensure there dried and then proceed to the physical characterization. The single fibres of untreated and treated fibre were cut at the size of 100 mm length to use in characterization of the tensile strength.

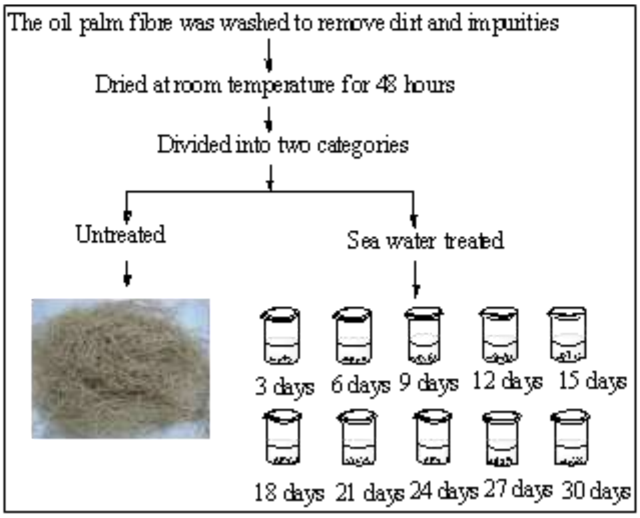


Figure 1. The treatment process of the single fibre of oil palm.

C. Fabrication of Composites

Poly(vinyl alcohol)(PVA) powder (5-10 g) mixed with distilled water (50-100 ml) using hot plate at the consistent temperature of 90 °C for 2 h until it fully dissolved and became viscous and transparent, the blending formulation as shown in Table 1. Untreated and treated EFB were milled at the size of ±3 mm and transferred on the PVA solution for three different loading of 1%, 3% and 5%. These composites were prepared by casting method with PVA as a matrix and oil palm EFB as filler, the mixture of filler and polymer placed in open mould with dimension (24 cm length x 12 cm witdh x 1 cm thick) and dried consistently at room temperature for 3 days. Finally, the composite was cured 24 h by compressing the top with the glass plate in order to maintain the uniform thickness and avoid air from entering the mould.

Table 1. Blending formulation of oil palm EFB on the respective fillers loading.

Component	PVA (g)	Water (mL)	Treated EFB (g)	Untreated EFB (g)
Neat	10.0	100.0	-	-
1%	9.0	90.0	1.0	1.0
3%	7.0	70.0	3.0	3.0
5%	5.0	50.0	5.0	5.0

D. Mechanical Characterization

The tensile test was conducted according to ASTM D5083 using Universal Testing Machine (UTM) model GOTECH AI-7000-M equipped with a load capacity of 10 kN (Ibrahim *et al.*, 2003). The group of 15 samples of each treated and untreated of oil palm EFB single fibre were tested with crosshead of 10 mm min^{-1} for tensile strength. The composites of the oil palm EFB filled PVA cut for 10 mm (width) and 50 mm (length) with five replicates for each of the sample loading. The diameter of the fibres was determined using a calliper.

The sample kept in desiccator at room temperature for 24 h prior to be used in characterization by using UTM.

III. RESULTS AND DISCUSSIONS

A. Mechanical Properties of Single Fibers

The mechanical strength of the fibres depends on the chemical structure, cellulose content, microfibrillar angle and so on. Hemicelluloses and lignin play as a glue to the fibre three-dimensional network structure (Sreekala *et al.*, 2000). From the result obtained, it can be shown in Figure 2, which single fibre of treated oil palm EFB of day 30 shows the highest tensile strength of 166.35 mPa due to decreasing of the microfibrillar angle upon the sea water treatment (Sreekala *et al.,* 2000). Thus, as the diameter of the oil palm EFB decreased, the mechanical strength of the fibre improved.

The result indicated that the tensile strength of the single fibre increased upon the treatment time. The untreated single fibre displays the lowest tensile strength of 70.61 mPa followed by 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 days shows the highest of 89.11, 103.34, 126.87, 136.40, 137.35, 151.34, 155.76 and 166.35, respectively. The result pattern indicated same as the research done by Ishak *et al.*, (2009), where the sea water treated fibre at day 30 shows the highest tensile strength. According to the Ishak *et al.,* (2009) the sea water treatment for the duration of 30 days of sugar palm fibres showed the improvement of the interfacial bonding between the matrix due to the removal of the outer layer of hemicellulose and lignin due to the salinity behaviour of the sea water that helps the removal process. Salinity known as the amount of dissolved material in sea water, common sea water has about 35% of salinity, which means by 35 g of dissolved salts. Sodium chloride, (NaCl) is the most abundant salts found in the sea water (Melorose *et al.,* 2015).

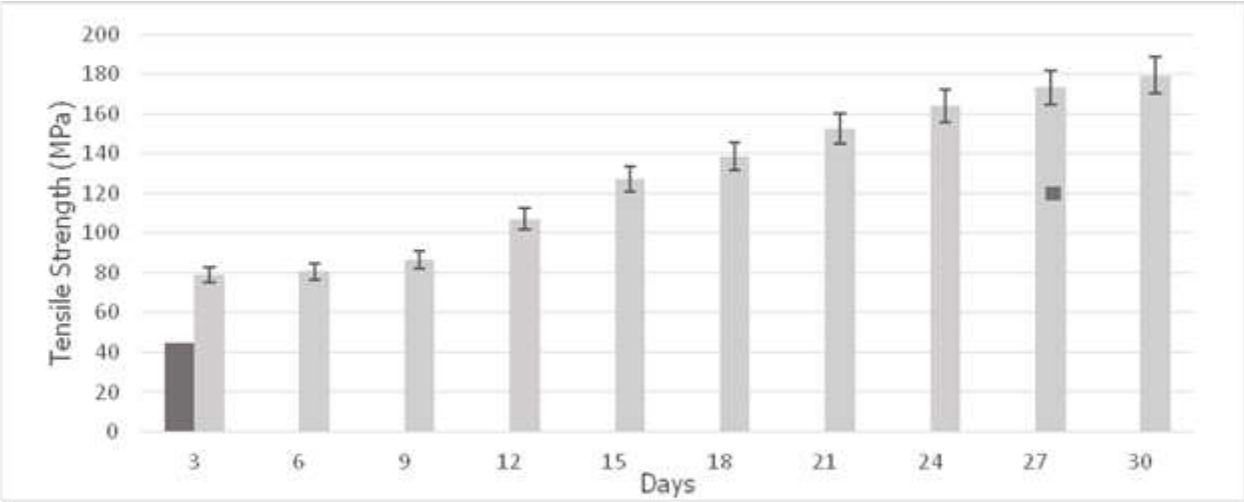


Figure 2. Tensile strength of the untreated and treated single fibres of oil palm EFB

B. Mechanical Properties of Composites

The mechanical properties of the composites of oil palm EFB filled PVA shows in Table 2, generally the tensile strength of oil palm EFB composites decreased with fibre loading. The tensile strength of untreated and treated oil palm EFB at the fibre loading of 1% presents 1.12 mPa and 3.63 mPa respectively, while declined tensile strength from 121% to 38% recorded at the fibre loading of 3% and 5% for untreated and treated oil palm EFB correspondingly. Zailuddin and Husseinsyah (2016), stated that, as the increasing of the fibre loading, the tensile strength decreased due to the aggregation of the oil palm EFB particles. The untreated EFB filled PVA composite shows the lowest tensile strength of due to the weak fibre-matrix interaction since the hydroxyl groups may be engaged in the hydrogen bonding inside the cellulose molecules thus decreasing the activity to the matrix (Sreekala *et al.,* 2000).

The presence of the impurities at the surface and the large amount of hydroxyl groups caused weak interfacial bonding between untreated oil palm EFB fibres and PVA. The decreased in tensile strength cause by the broken ends of short fibres of oil palm fibre that formed during tensile deformation generated fractures in the matrix (Shinoj *et al.,* 2011).

Table 2. Mechanical properties of the oil palm EFB/PVA composite at different fibre loading

Mechanical properties	Fibre content (%)	Composites (MPa) Untreated	Treated
Tensile strength	1	1.12 ± 0.01	3.63 ± 0.44
	3	1.97 ± 0.01	2.48 ± 0.11
	5	1.61 ± 0.07	1.54 ± 0.04
Tensile modulus	1	0.12 ± 0.01	0.21 ± 0.01
	3	0.13 ± 0.01	0.23 ± 0.01
	5	0.12 ± 0.01	0.34 ± 0.04
Elongation	1	16.75 ± 0.23	20.47 ± 2.26
	3	8.37 ± 0.30	11.52 ± 0.54
	5	5.63 ± 0.15	6.23 ± 0.07

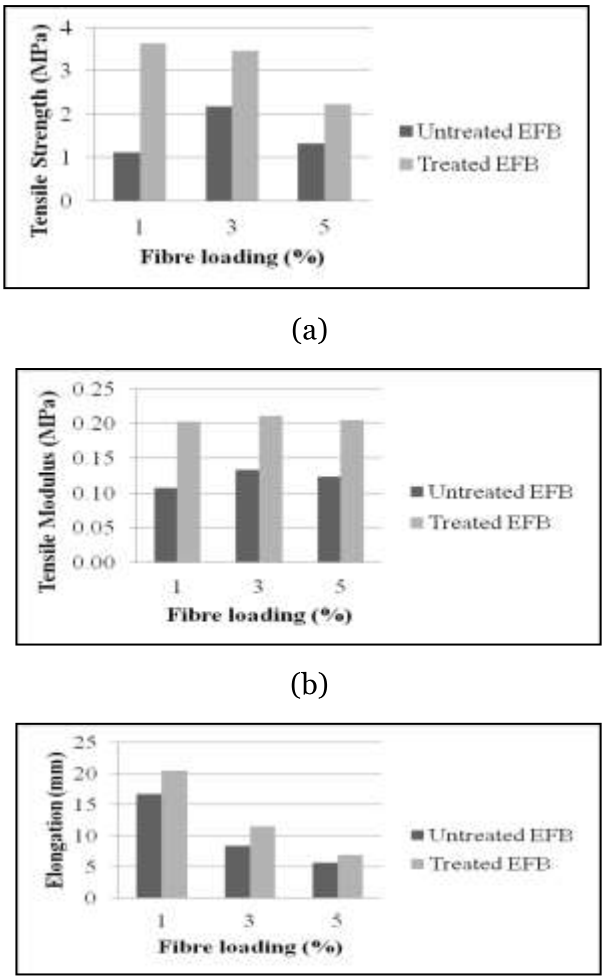
The reduction of tensile strength was the failure of oil palm fibre to support the stress given off from the matrix is also one of the factor caused the decrement in tensile strength due to its uneven shape and spreading problems which caused by formation of agglomerate. Besides, oil palm EFB fibre has nature irregular in shape and size (Hariran, 2005). Wide range error bars indicated at the oil palm EFB composites than the neat PVA due to the nature of the palm fibres which could not efficiently separated individually during the milling process as well as the large portion of fibres were still attached as one bunch (Yeow & Lik, 2015).

Figure 3 (b) represent the effect of the oil palm EFB loading on the modulus of elasticity of oil palm EFB composites films. The overall trend of modulus of elasticity decreased at 1% of fibre loading of treated fibre with 0.15 mPa, however increased at the fibre loading of 3% and 5% at 0.169 mPa and 0.183 mPa, respectively. Nevertheless, the treated oil palm composites give greater value than the untreated oil palm composites.

The untreated oil palm EFB composites give 0.121 mPa, 0.127 MPa and 0.121 MPa for 1%, 3% and 5% of fibre loading, correspondingly The enhancement of the tensile modulus of oil palm EFB composites is due to the high rigidity applied by the oil palm EFB particles (Zailuddin & Husseinsyah, 2016). Figure 3 illustrated that the increasing of the fibre loading cause the increasing of the brittleness of the oil palm EFB composites (Yeow & Lik, 2015). Figure 3 (b) shows the effect of the fibre loading on the elongation at break of oil palm EFB composites.

The elongation at break of treated fibre tends to increase at 1% fibre loading with 15.1 MPa and decreased at 3% (10.61 MPa) and 5% (6.23 MPa) fibre loading. However, the elongation at breaks showed slightly different after the sea water treatment conducted. Low elongation at breaks of the untreated fibre composites with 16.75 MPa (1%), 8.373 MPa (3%) and 5.633 MPa (5%), this may due to the crossinked of three-dimensional network of cellulose and lignin (Sreekala *et al.,* 2000)

The decreased of elongation at break at 3% and 5% fibre loading due to the presence of the oil palm EFB which strain the slippage movement during the deformation and thus decrement in chain mobility of the oil palm EFB composite films (Zailuddin & Husseinsyah, 2016).



(a)

(b)

(c)

Figure 3. The oil palm EFB composites based on (a) Tensile strength; (b) Tensile modulus; and (c) Elongation

IV. SUMMARY

In this work, the tensile strength of single fibres at day 30 shows the highest result compared to the others while the composites of the oil palm EFB decreased as the fibre loading increased. It is found that 1% of the fibre loading shows the optimum loading for the composites. The tensile modulus of the fibre composites increased as the fibre loading increased due to the high rigidity of the oil palm EFB fibre, whereas the elongation at break reduced as the filler loading increased.

V. ACKNOWLEDGMENT

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