Mechanical performance of oil palm empty fruit bunches fibre reinforced polyester resin

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Abstract. Studies on natural fibers reinforced composite has been growing rapidly due to abundant and availability of wide variety of natural fibers. One of the most promising and readily available natural fiber is oil palm empty fruits bunch (EFB), a side product of palm oil industries. This fiber could be converted into useful materials by combining them with other polymer, such as polyester resin, to produce biodegradable composite. Based on other research about empty fruit bunch (EFB), there is no research about empty fruit bunch reinforced polyester resin. Thus this research was conducted to investigate the performance of Polyester-EBF composite as well as their biodegradability. The composite was prepared by mixing certain amount of EFB (of 2-4 mm length) to polyester resin and hardened with methyl ethyl ketone peroxide (MEKP). The resulted composite were characterized for their mechanical properties, water absorptivity and weight reduction over time. Polyester-EBF 50 have the highest value of tensile strength which is about 22.31 N/mm². This result of Polyester-EBF 50 shows that the tensile properties of composites are markedly improved by adding fibers to a polymer matrix since fibers have much higher strength and stiffness values than those of the matrices.

1. Introduction

Natural fibre such as empty fruit bunch, jute, cotton, flax, kenaf, pineapple leaf, banana and sisal fibre are increasingly in demand across the globe for making a wide range of polymer-composites materials [1]. This natural fibre originated from plants, animal, agro waste, crops or other natural sources, has many advantages of such as low density, have a better thermal and insulting properties and low energy consumption during processing [7]. According to Kyoto protocol, natural fibre are natural with respect to the emission of CO² and this put lignocellulosic fibre as material [11].

Empty fruit bunch (EFB) is belongs to the species Elaeis guineensis and planted mostly in Southeast Asian countries such as Malaysia and Indonesia. It was estimated Malaysia produce 30 million tons of oil palm biomass annually, including trunks, fronds, and empty fruits bunches (EFB). Therefore, utilization of this fibre would be economically beneficial due to readily available raw material sources all over the country [1]. EFB was produce after the removal of oil seeds from fruit bunch for oil extraction. An average yield of empty fruits bunch that produce from oil palm is about 400g per bunch. This fibre is non-hazardous, biodegradable and environmental friendly lignocellulosic raw material and possesses good physical and mechanical properties as shown in Table 1 [5] [17] [18].
Table 1. Mechanical properties of oil palm empty fruit bunch fibre (EFB)

| Chemical constituents (%) |          |
|----------------------------|----------|
| Cellulose                  | 65       |
| Hemi cellulose             | -        |
| Lignin                     | 19       |
| Ash content                | 2        |

Table 2. Physical properties of oil palm empty fruit bunch fibre (EFB)

| Physical properties of oil palm fibers |          |
|----------------------------------------|----------|
| Diameter (mm)                          | 0.15-0.50|
| Density (g/mm³)                        | 0.7-1.55 |
| Linear density (denier)                | 2150     |
| Tensile strength (MPa)                 | 100-400  |
| Young’s Modulus (MPa)                  | 1000-9000|
| Elongation at break (%)                | 14       |
| Microfibrillar angle (°)               | 46       |

The objectives of this research is to fabricate new biocomposites from mixture of empty fruit bunch (EFB) fibre reinforced polyester resin and determine mechanical properties of empty fruit bunch (EFB) fibre reinforced polyester resin. Based on studied Mohammed et. al, [12] composites were fabricated from oil palm empty fruit bunch (OPEFB) fiber and poly(lactic) acid (PLA) matrix. At the end of this research, mechanical testing showed an improvement of up to 23.5% and 33.6% respectively for tensile strength (TS) and tensile modulus (TM) of treated fiber composites above untreated fiber composite.

2. Material and Methods

2.1. Preparation of composite

Raw materials used in this study were polyester resin, EFB and Methyl ethyl ketone peroxide (MEKP) as hardener. Different percentage of empty fruit bunch and polyester resin used to prepare composites are indicated in Tables 3. Definite amount of various percentages of EFB and polyester resin were weighed, mixed and stirred for about 15 minute in a bowl, followed by addition of 1 ml MEKP. Next, the mixture was poured into the closed and open mold and was kept for 4-5 hours until dried and hardened. All composites samples then were released from the mold for characterization.

Table 3 Polyester-EFB composites percentage ratios

| Composites   | EFB (%) | Polyester resin (%) |
|--------------|---------|---------------------|
| Polyester-EFB 0 | 0       | 100                 |
| Polyester-EFB 5 | 5       | 95                  |
| Polyester-EFB 30 | 30      | 70                  |
| Polyester-EFB 50 | 50      | 50                  |
| Polyester-EFB 70 | 70      | 30                  |
2.2. Characterization of EFB-polyester composites

The water absorption test of the composites was carried out according to ASTM D570-98 (Standard Test Method for Water Absorption of Plastic) with repeated immersions method in distilled water at room temperature (25°C) at 24 hours (ASTM). The test specimens were in the forms of rectangular bars 6 mm long by 28 mm wide by the thickness of the material. It was measured by soaking the samples in five glass beaker for 0%, 5%, 30%, 50% and 70% w/w EFB fiber of water for different periods (up to 336 hours). The percentage of water absorption was determined by using the Equation (1) [14]:

\[
\text{Weight absorbed, WA (\%)} = \frac{W_t - W_0}{W_t} \times 100
\]  

Where \( W_t \) and \( W_0 \) are the weight of the sample after and before soaking in water.

The tensile tests were performed using Universal testing machine model Gotech Ai-7000M. The specimens were cut into sizes of 100mm (length, L) x 20 mm (width, W) x 5 mm (thickness, T). The gauge length was 50 mm and the cross head speeds used were 1mm/min. Biodegradability was determined by measuring weight loss of specimens buried in compost soil. The samples (20x50mm) for each Polyester-EFB 0%, 5%, 30%, 50% and 70% composite were buried at moisture controlled conditions. Each samples was dug out from the soil after 30 days, then, washed, dried and weighed. The weight loss was calculated using Equation (2) below:

\[
\text{Weight Loss (\%)} = \frac{W_0 - W_t}{W_0} \times 100
\]  

Where \( W_t \) and \( W_0 \) are the weight of the sample after and before buried in soil.

3. Result and discussion

3.1 Physical properties

3.1.1 Water absorption. The result of water absorption test of Polyester-EFB composites prepared from various amount of EFB (0%, 5%, 30%, 50% and 70%) is shown in Figure 2. The composites were soak in water about 336 hours. It reveals that the water absorption value is influenced by the amount of EFB and immersion of time for all Polyester-EFB composites. Results shows that the water absorption increased with increasing percentage of EFB. It is evident that the percentage of water absorption is higher for 70% EFB and lower for 0% EFB composites [13]. The rate of water absorption is very low with time. This is due to the fact that reduction in the cured polyester and the degree of cross-linking reaction, which diminishes the void spaces with the increase of molding load, the composite becomes more dense or reinforced materials are distributed properly eliminating all voids. Mineral fillers are hydrophobic in nature (the incapability of filler to absorb water is known to be hydrophobic filler), however because of hydrophobic nature of EFB is very small, amount of water intake in the composites are higher [10] [4]. Figure 1 below show the water absorption test of Polyester-EFB composites.
3.1.2 Biodegradability Test. Samples of Polyester-EFB composite for 0%, 5%, 30%, 50% and 70% were buried for about 30 days as shown in Figure 4. At the end of biological test, it was found that the weight of Polyester-EFB 70 was reduce 41.47% compared to the other composites. Polyester-EFB 5 shows the lowest weight loss that is about 6.25%. While, 14.28% weight loss in Polyester-EFB 30 and 34.59% in Polyester-EFB 50. This condition was caused by the degradation of EFB in polyester matrix. Figure 3 shown the graph for result of weight loss (%) of Polyester-EFB composites.

Other involving factor includes EFB fibre which is readily biodegradable and naturally acts as nutrients source for many microorganisms such as bacteria and fungi. This attributes to more biodegrability by EFB fibre as it is a target for fungal and bacterial growths [15]. Based on research Shanks and Kong [11], disintegration of starch through partial solubility happens due to its biodegradability properties. This shows that partially degradation EFB fibre is more readily biodegraded by enzymes derived especially from microorganism.
3.2 Mechanical properties

3.2.1 Tensile Strength. The variations in tensile properties of EFB-polyester composites (of 0, 5, 30, 50 and 70% of EFB) are given in Figure 5 shows the mechanical properties of Polyester-EFB composites. It is shows that starting from composites Polyester-EFB 5 to Polyester-EFB 50 the tensile strength value is increase based on the increasing EFB fiber content in Polyester-EFB composite. Morever, for tensile strength of composite Polyester-EFB 0 is higher than composite Polyester-EFB 5, this is because the percentage of EFB in composite is to small and effect the tensile strength. So, the parameter in this experiment were increase to 70 wt% to get the best result. Polyester-EFB 50 have the highest value of tensile strength which is about 22.31 N/mm². This result of Polyester-EFB 50 shows that the tensile properties of composites are markedly improved by adding fibers to a polymer matrix since fibers have much higher strength and stiffness values than those of the matrices [9]. While the values of tensile...
strength for Polyester-EFB 5 and Polyester-EFB 30 is 12.48 N/mm² and 16.71 N/mm². Beside that, Polyester-EFB 70 has the lowest values of tensile strength which is 6.11 N/mm². The weight of EFB fiber in this composites is 70% and polyester resin only 30%. According to [2], higher amount of filler content may cause difficulties in achieving homogeneous mixture process.

![Figure 5. Tensile strength of Polyester-EFB composite](image)

4. Conclusion
In summary, for all the composites, the water absorption increases with increase amount of fiber and soaking time. Based on the graph of tensile strength of Polyester-EFB composite, the tensile strength starting from Polyester-EFB 5 also found to increase constantly with an increase of EFB fiber content in which Polyester-EFB 50 has the highest tensile strength value of 22.31 N/mm². While for biodegradability test, Polyester-EFB 70 had the highest weight loss % after buried in soil for 30 days.

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References
[1] Abdul Khalil, H.P.S., Kang, C.W., Khairul, A., Adawi, T.O. (2009). Reinforced Plastic Composites, 28: 1123-1137.
[2] Ahmad, A., Prayitno, A. & Satoto, R. (2012). Morphology and mechanical properties of palm based fly ash reinforced dynamically vulcanized natural rubber/ polypropylene blends. Procedia Chemistry, 4, 146-153.
[3] ASTM Designation: D 570-98,” Standard Test Methods for Water Absorption of Plastic”.
[4] Chandrasekhar, S. Satyanasayana, K., Pramada, P. and Majeed, J. (2006). Effect of calcinations temperature and heating rate on the optical properties and reactivity of rice husk ash, Journal of Materials Science (Norwell), Vol. 41, No. 1, 7926-7933.
[5] Jacob, M., S. Thomas, and K. T. Varughese. (2004). Mechanical properties of sisal/oil palm hybrid fiber reinforced natural rubber composites. Composites Science and Technology 64 (7-8):955-965.
[6] Jawaid, M., Abdul Khalil, H.P.S. and Abu Bakar, A. (2010). Mechanical performance of empty fruit bunch/jute fibers reinforced epoxy hybrid composites. *Materials and Engineering A*, 527: 7944-7949.

[7] Joshi, SV., Drzal, L.T., Mohanty, A.K. and Arora, S. (2004). Are natural fiber composites environmentally superior to glass fiber reinforced composites? Composites Part A 35: 371-376.

[8] Kabir, H., Gafur, M. A., Ahmed, F., Begum, M. and Qadir, R. (2014). Investigation of physical and Mechanical Properties of Bamboo Fiber and PVC Foam Sheet Composites. *Universal Journal of Materials Science*, Vol. 2, No. 6, 119-124.

[9] Ku, H., Wang, H., Pattarachaiyakoop, N. and Trada, M. (2008). A review on the tensile properties of natural fiber reinforced polymer composites. *Composites: Part B*, 42, 856-873.

[10] Kuriger, R. J. and Khairul Alam, M. (2002). BSME-ASME International Conference on Thermal Engineering, Dhaka, Bangladesh.

[11] Mohanty, A.K., Mishra, M. and Drzal, L.T. (2002). *Journal Polymer Environment*, 10:19-26.

[12] Mohammed MAA, Salmiaton A, Azlina WWAKG, Amran MSM, Fakhru AR, Taufiq YH (2011) Hydrogen rich gas from oil palm biomass as a potential source of renewable energy in Malaysia. *Renew Sustain Energy Review* 2011;15(2):1258e70

[13] Murali, K. Mohan Rao and Mohana Rao, K. (2007). Extraction and tensile properties of natural fibres: Vakka, date and bamboo, *Composite Structures*, Vol. 77, 288-295.

[14] Naznin, M., Abedin, Md. Z., Khan, M.A. and Ga-fur, A. (2012). Influence of Acacia catechu Extracts and Urea and Gamma Irradiation on the Mechanical Properties of starch/PVA-Based Material, *International Scholarly Re-search Network (ISRN), Polymer Science*, Vol. 2012, Article ID: 348685.

[15] Sahari, J. and Sapuan, S. M. (2011). Natural fiber reinforced biodegradable polymer composites. *Review Advance Material Science*, 30: 166-174.

[16] Shanks, R. and Kong, I. (2012). Thermoplastic Elastomers. Rijeka: InTech.

[17] Sreekala, M. S., M. G. Kumaran, and S. Thomas. (1997). Oil palm fibers: Morphology, chemical composition, surface modification, and mechanical properties. *Journal of Applied Polymer Science*. 66 (5):821-835.

[18] Sreekala, M.S., Kumaran, M.G., Reethamma, J. & Thomas,S. (2001) Stress-relaxation behaviour in composites based on short oil-palm fibre and phenol formaldehyde resin. *Composites Science and Technology*, 61: 1175-1188.