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# Empty Fruit Bunch (EFB) Fibers as Reinforcement in Polypropylene

Nuramirah Binti Che Lah[1,a], Noor Mazni binti Ismail[1,b]

*Correspondence

[a]amirahchelah@gmail.com
[b]drmazni@ump.edu.my

[1] Faculty of Manufacturing Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.

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**ABSTRACT**

In this work, EFB fibers / Polypropylene matrix were prepared using hot pressing tool at 3 different ratio (5%, 10%, and 15% EFB/PP). Tensile test and impact test were done according to ASTM standard, ASTM D638 and ASTM D256, respectively. The results from tensile test and impact test showed that the prepared specimens of EFB/PP composite have slightly higher elastic modulus (1.95 GPa - 2.1 GPa) compared to pure PP (1.91 GPa) but at the same time they are lack of ductility and have low impact strength, at a range of 4.6 kJ/m2 to 5.5 kJ/m2 compared to pure polypropylene with impact strength value of 18.18 kJ/m2. From the fractured surface analysis, the initial micro cracks were seen mostly occurred at the interface of the EFB/PP and air voids which act as a crack propagation site.

## INTRODUCTION

Oil palm (Elaeis guineensis) was first introduced to Malaysia as an ornamental plant in 1870. Since 1960, planted area had increased at a rapid pace. In 1985, 1.5 million hectares were planted with palm tree, and it had increased to 4.3 million hectares in 2007. Today, there are 4.49 million hectares of land in Malaysia under oil palm cultivation; producing 17.73 million tonnes of palm oil and 2.13 tonnes of palm kernel oil. Malaysia is now one the largest producers and exporters of palm oil in the world, accounting for 11% of the world's oils & fats production and 27% of export trade of oils & fats [1]. Driven by significantly expanded of palm oil cultivation, billions tone of palm oil by-products in the form of empty fruit bunches, fibers and shelle, as well as liquid effluent were produced annually. One of these palm oil by-products, empty fruit bunch (EFB) is found to be an attractive alternative for the most widely applied fiber in the composite technology due to its well-known availability and high strength to weight ratio.

The use of EFB fiber as a reinforcement in composite materials has attracting many scientists and researchers. Among the pioneer works are thorough study on the morphology, surface modifications, chemical composition and also the mechanical properties of oil palm fibers. EFB is a natural fiber that has high potential as an effective reinforcement in thermoplastics material. The reinforcement gives the rigidity and strength which is help to support the structural load [2, 3]. In this current work, EFB fibers were used as a reinforcement in polypropylene (PP) polymer matrix. The effect of the fibers on the mechanical properties of polypropylene were studied thoroughly.

## METHODOLOGY

Figure 1 shows a simplified methodology for overall experiment.

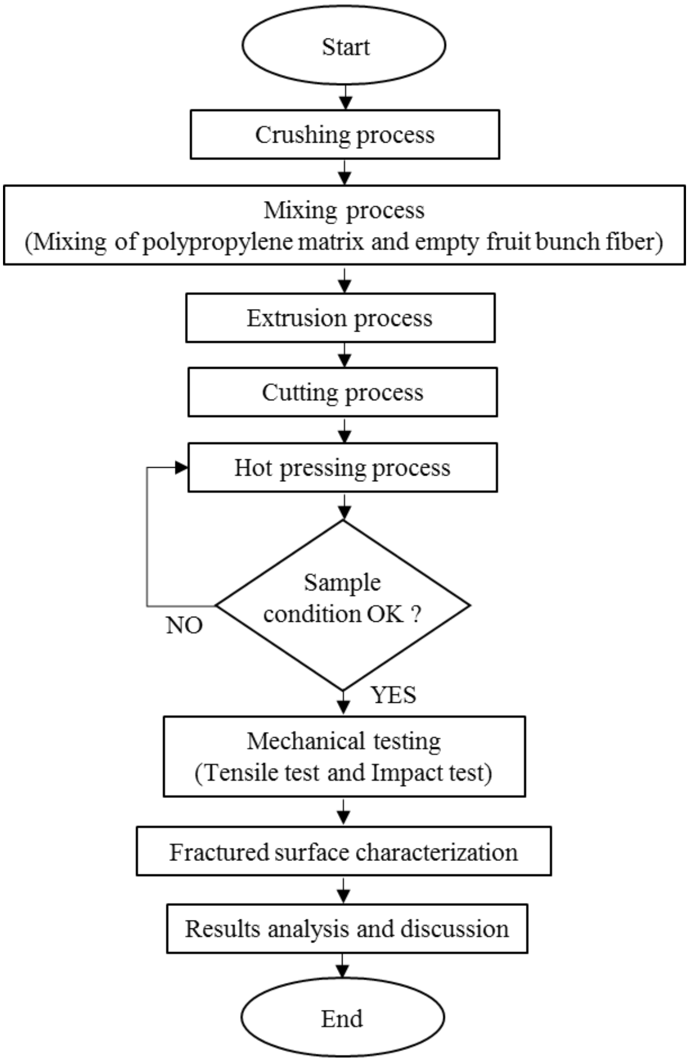


**Figure 1** Simplified flow of the project methodology

### i) Crushing process

The empty fruit bunch (EFB) fibers that was used in the research study were from Makmur Bio-Organik, LKPP Corporation Sdn. Bhd., Kilang Lepar, Kuantan. Prior starting the experiment, empty fruit bunch (EFB) fibers were cleaned by water to remove any foreign materials. After the process of cleaning finished, EFB fibers were crushed by using crushing machine into smaller size, as shown in Figure 2. The small size of EFB fibers will help to reduce the blending process with PP polymer matrix in the extruder.

**Figure 2** Crushing machine

**ii) Mixing and extrusion process**

After the crushing process, the EFB fibers were mixed with the Polypropylene (PP) and Maleic Anhydride grafted Polyethylene (MAPE) at the desired amount of ratio as listed in Table 1. Maleic anhydride grafted polyethylene (MAPE) was used as a compatibilizer agent to enhance the adhesion between EFB fiber and PP matrix. Figure 3, Figure 4, and Figure 5 show the image of pure PP, crushed EFB fibers, and the mixture of EFB fibers, PP granules and MAPE, respectively.

***Table 1:*** *Mixture percentage of EFB fibers, PP and MAPE.*

| Specimen Number | Mixture percentage |
|---|---|
| Specimen 1 | 100% PP |
| Specimen 2 | 95 % PP + 5 % EFB + 5% MAPE |
| Specimen 3 | 90 % PP + 10 % EFB + 5% MAPE |
| Specimen 4 | 85 % PP + 15 % EFB + 5% MAPE |

**Figure 3** Pure polypropylene

**Figure 4** EFB fiber

**Figure 5** Mixture of EFB fibers, PP and MAPE

Extrusion process was used to improve homogeneity of the mixture and reduce separation of fiber from polymer during hot pressing process. The extrusion process starts by feeding the mixture of PP, EFB and MAPE into the barrel of the extruder through a hopper. The mixture was gradually mixed and melted by the mechanical energy generated by turning screws and by heaters arranged along the barrel. The molten EFB/PP composite was then forced into a die, which shapes the polymer into a shape that hardens during cooling. Figure 6 shows the image of extrusion machine, while Figure 7 shows the EFB/PP composite after the extrusion process, with a long rope shape.

**iii) Cutting process**

After the extrusion process, the EFB/PP composites were cut into granule shape by using cutter machine. Figure 8 shows the image of cutter machine, while Figure 9 shows the image of EFB/PP composite in granule shape after the cutting process.

**Figure 8** Cutter machine

**Figure 9** EFB/PP composite (granules) after cutting

**iv) Hot pressing process**

In the hot pressing process, EFB/PP granules were placed into a mould, then pressed into a 3 mm thickness of sheet shape by using hot press machine. The temperature of hot pressing plates were set at 185oC for top plate, and 200oC for bottom plate. Preheating time for each specimens was set for 5 minutes. Figure 10 shows the specimens after the hot pressing process.

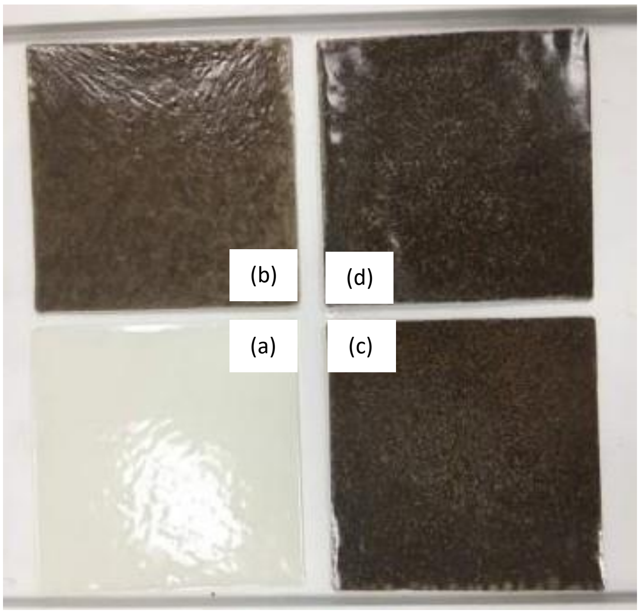


**Figure 10** Specimen after hot pressing process, a) 0% EFB/PP, b) 5% EFB/PP, c) 10% EFB/PP, d) 15% EFB/PP

**v) Tensile test and impact test**

After the hot pressing process, the EFB/PP composite sheets were shaped into a test specimen for tensile test and impact test. The tensile test was carried out according to ASTM D638 by using universal testing machine (UTM) and impact test was carried out according to ASTM D256 by using Izod impact test.

## RESULT AND DISCUSSION

### i) Elastic modulus of the EFB/PP composites

Figure 11 represents the graph of elastic modulus from the tensile test for the four different EFB/PP specimens; 0% EFB/PP, 5% EFB/PP, 10% EFB/PP, and 15% EFB/PP. From the graph in Figure 11, it was observed that all specimens with EFB fibers have higher elastic modulus compared to pure PP, with the highest value of elastic modulus of 2.2 GPa seen in 15% EFB/PP specimen. High value of elastic modulus suggested that the EFB/PP specimens are stiffer and have less tendency to being deformed elastically when force is applied, resulted from the addition of EFB which act as a reinforcement in EFB/PP specimens [4, 5].

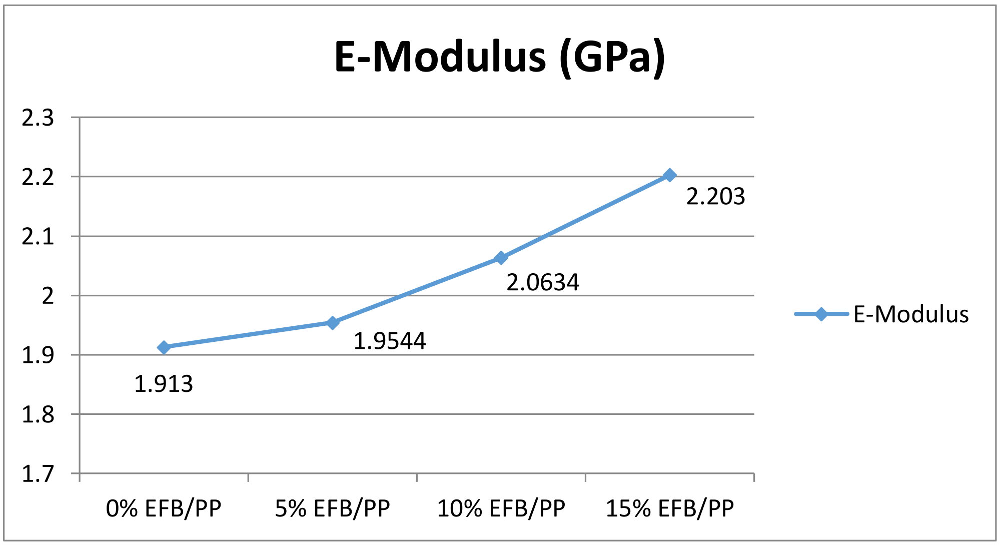


**Figure 11** Elastic modulus (GPa) of 0% EFB/PP, 5% EFB/PP, 10% EFB/PP, and 15% EFB/PP.

### ii) Impact properties of the EFB/PP specimens

Table 2 shows the impact properties of four different EFB/PP specimens, 0% EFB/PP, 5% EFB/PP, 10% EFB/PP, and 15% EFB/PP. From the data in Table 2, it was observed that the highest impact energy obtained from pure PP specimen with the impact strength of 18.18 kJ/m2 and the energy absorbtion percentage of 6.30 %. Meanwhile, the lowest impact strength was seen in the specimen with 15% EFB/PP which ha the impact strength of 4.64 kJ/m2. Figure 12 shows the difference in impact strength between pure PP and EFB/PP specimens

**Table 2:** Impact properties of 0% EFB/PP, 5% EFB/PP, 10% EFB/PP, and 15% EFB/PP.

| *Specimen* | *Absorb Energy (%)* | *Re (kJ/m$^2$)* | *Energy (J)* |
|---|---|---|---|
| *0% EFB/PP* | *6.30* | *18.18* | *0.693* |
| *5% EFB/PP* | *1.90* | *5.48* | *0.209* |
| *10% EFB/PP* | *1.66* | *4.79* | *0.183* |
| *15% EFB/PP* | *1.61* | *4.64* | *0.177* |

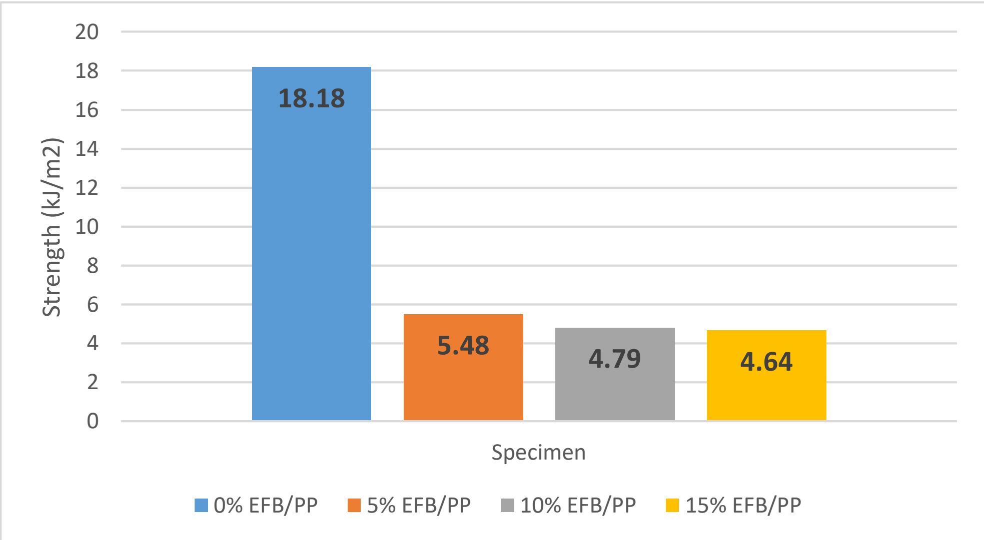


**Figure 12** Impact strength of 0% EFB/PP, 5% EFB/PP, 10% EFB/PP, and 15% EFB/PP.

### iii) Fractured surface of the EFB/PP composites

Figure 13 and Figure 14 show the fractured surface after tensile test and impact test, respectively. By referring to the result in Figure 13 and Figure 14, it can be suggested that the initial microcracks mostly occurred near to the interface between the EFB fibers and PP matrix and air voids which act as a crack propagation site [6,7].

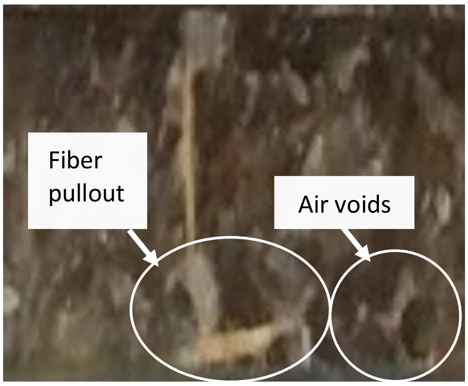


**Figure 13** Tensile fractured surface of 15% EFB/PP.

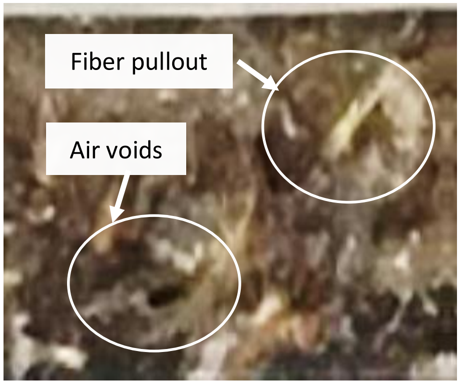


**Figure 14** Impact fractured surface of 15% EFB/PP

## CONCLUSION

In views of the results obtained from the discussion, several conclusions can be drawn as per below:

i. The addtion of EFB fibers into polypropylene increased the elastic modulus EFB/PP composites (1.95 GPa - 2.1 GPa) compared to pure PP (1.91 GPa).

ii. Impact strength of the EFB/PP composites are low, at a range of 4.6 $kJ/m^2$ to 5.5 $kJ/m^2$ compared to pure polypropylene with impact strength value of 18.18 $kJ/m^2$.

iii. From the fractured surface analysis, the initial microcracks seen mostly occurred at the air voids site and near the interface of the EFB/PP composites which causing fiber pullout.

## FUTURE RECOMMENDATIONS

Recommendations for further study can be suggested as the following:

i. Study the effect of different types and different amount of compatibilizer agent on the mechanical properties of EFB/PP composites. Suitable amount and type of compatibilizer expected can increase the interfacial bonding between EFB fibers and PP matrix.

ii. Expend the investigation by using different pattern of EFB fibers such as lamellar layer or mat layer to use as a reinforcement in the PP matrix.

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## REFERENCES

[1] Malaysia Palm Oil Council, http://www.mpoc.org.my/Overview.aspx
[2] H. P. S. Abdul Khalil, et.al. (2007). Agro-hybrid Composite: The Effects on Mechanical and Physical Properties of Oil Palm, 1-16.
[3] Abu Bakar, A. Hassan, A.F. Mohd Yusof, et. al. (2005). Mechanical and Thermal Properties of Oil Palm Empty Fruit Bunch-Filled Unplasticized Poly (Vinyl Chloride) Composites, 1-11.
[4] M.K. Faizi, Shahriman A.B.,M.S. Abdul Majid.et. al. (2016). An Overview of the Oil Palm Empty Fruit Bunch (OPEFB) Potential as Reinforcing Fiber in Polymer Composite for Energy Absorption Applications, 1-9.
[5] Rahman, S. A. et. al. (2010). Reinforcement Of Plastic using Empty Fruit Bunch (EFB) of Palm Oil Waste, 1-25.
[6] Suradi, S. et. al. (2010). Oil Palm Bio-Fiber Reinforced Thermoplastic Composites - Effects of Matrix Modification on Mechanical and Thermal Properties, 1-7.

[7] Ghazali, F. A. et.al. (2013). The Effects Of Recycled Polypropylene Mixing Ratio on the Tensile Strength of Polypropylene, 1-24.