

## Mechanical Properties of Betel Nut Husk Fibre Reinforced Oxo-HDPE Composite

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### Abstract

*The mechanical properties of oxo-biodegradable high-density polyethylene (oxo-HDPE) composites reinforced betel nut husk (BNH) fibre were studied in this research. A neat oxo-HDPE laminate and four betel nut fibre reinforced oxo-HDPE composites were fabricated using hot press compression moulding method. The composites contain 7%, 12%, 17%, and 22% fibres volume fraction respectively. The cross section of the composite was observed under scanning electron microscopy (SEM) and all five laminates are put through tensile test and hardness test. The result of the study shows that adding betel nut husk (BNH) fibres as reinforcement increases its tensile strength, specific tensile strength, and hardness of the composites. The good lamination observed under scanning electron microscopy (SEM) enable good transfer and distribution of stresses from the matrix to the fibres.*

**Keywords:** Betel nut, Areca catechu, HDPE, Biodegradable, Composite

### 1. Introduction

For centuries, mankind has been studying natural fibres from different kind of plants and fruits to be used in composite material. Bagasse, cereal straw, palm, corn stalk, sago, cotton stalk, hemp and rice husk are just some of the examples of the more popular natural fibres that have been studied by researchers and scientists alike. Polymer composites are replacing many conventional materials due to their superior advantages [1]. For instance, glass fibres have high strength due to the fact that usually during fabrication process, the internal or surface flaws that normally decrease the quality of the glass are avoided. As for the likes of aramid, its near to perfection alignment of molecular chains with the fibres axis contributes to its high strength and stiffness. These synthetic fibres are man-made, and are usually petrochemical based or derived from nylon, polyester, or polyacrylonitrile fibres. Generally, the use of these synthetic fibres alone is not practical. They are usually “glued” together by a matrix material which also transfers all the loads and stresses exerted to them [2]. The matrix also acts as a protection from abrasion as well as from environmental attack. The interface between the reinforcing agent and the matrix plays an essential role in determining the mechanical properties of composite materials [3].

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The harmful effects of processing and recycling of widely used petroleum-based products on the environment have resulted in a renewed interest in green materials. There are concerns on how petroleum-based products such as resin in thermoset plastics, which is toxic and non-degradable, may harm the ecological balance in the long run. Thus, recyclability and environmental safety are becoming important factors to the introduction of materials and products. Application of green composite is an increasingly popular alternative to counter the environmental issue problem. A green composite combines natural fibres with natural resin to create an environmental friendly material. The resins and fibres used are biodegradable, which means they can be decomposed by the action of microorganisms.

There are extensive studies were done by researchers on the effects of natural fibres as reinforcement in polymer matrix [4-5]. A study on the characterisation of oil palm empty fruit bunch and glass fibre reinforced recycled polypropylene hybrid composite were investigated [6]. In that study, it was found that the fibres can improve the tensile strength and tensile modulus of the composite. Impact test also shown that increasing volume fraction of Pandanus fibre can enhance the toughness of the composite [7]. A study on the mechanical properties of betel nut husk fibres yields promising results in terms of tensile properties and moisture content [8]. The ripe *Areca catechu* fibres were excellent as reinforcement in polymer composite due to their excellent tensile strength. For application requiring good dimensional stability, the dried fibres are the best due to their low moisture content. The main objective of this study is to characterise the mechanical properties of betel nut husk reinforced oxo-HDPE composite. The composites were fabricated using neat oxo-HDPE as reference to the fabricated betel nut husk composites. The fibres were added in volume fraction range between 7 – 22% whilst the composites were fabricated using hot press method.

## 2 Materials and methods

### 2.1 Materials

Local betel nut (*Areca catechu*) husk fibres were used in this research. The nuts were manually extracted by hand after they were soaked in water for at least 3 days. The reason of soaking the fibres in water is to soften the fibre to ease the peeling process. The extracts were then dried in the sun for at least 8 hours. Meanwhile, oxo-biodegradable HDPE was obtained from local supplier and used as the matrix for composite fabrication.

### 2.2 Composite fabrication

Oxo-HDPE films were cut to a dimension of 250 mm × 250 mm to fit in the mould. A total of 150 layers of oxo-HDPE were used neat oxo-HDPE lamination. Each composite was prepared by randomly distributing BNH in between piles of oxo-HDPE films. Any entrapped air was removed carefully with a scrapper. This is to prevent bubble formation. The mould was closed for compression at 3 MPa at 160 °C temperature for 15 minutes. The summary of all the composites investigated in this research are shown in Table 1.

Table 1. Summary of designation of composites investigated in this study

Composite	Sample	Volume of BNH $v_f$ , (%)
H	Oxo-HDPE	0
C1	Oxo-HDPE/10g fibre	7
C2	Oxo-HDPE/15g fibre	12
C3	Oxo-HDPE/20g fibre	17
C4	Oxo-HDPE/25g fibre	22

### 2.3 Tensile test

Five laminates for each of the composite type were tested and the samples were prepared according to ASTM D3039 at a crosshead rate displacement of 1 mm/min. Tensile strength and tensile modulus were calculated on the basis of initial sample dimensions.

### 2.4 Hardness test

Shimadzu HMV-G21 Micro Vickers Hardness Tester was used to conduct Vickers hardness test on the laminates. The machine can perform up to thirteen tests, with nine test force levels and 4 arbitrary values across a range of 98.07 mN to 9.861 N. The Vickers indenter is a quadrangular pyramid diamond with an angle of 136 degrees between opposite faces. The indentation force applied was set to be 1.961 N while the magnification is set to be 10 MX.

Five samples for each of the composite composition were tested so that the average results can be obtained. The samples were prepared according to ASTM E384 where the laminate size is 250 mm  $\times$  250 mm.

### 2.5 Preparation of Scanning Electron Microscopy (SEM)

The cross section of the samples was observed using the scanning electron microscopy (SEM). The sample was cut into the dimension to fix on an aluminium plate. The laminate was then coated using gold powder before being placed under the scanning electron microscopy for inspection.

## 3 Results and discussion

### 3.1 Tensile test

The composites were prepared into the dimension of 150 mm  $\times$  25 mm. Before testing, the width and thickness of each composites are recorded. Figure 1 shows the tensile strength for each laminate with different fibre volume fractions. As observed from the figure, laminate H which is neat oxo-HDPE exhibit the lowest tensile strength. The addition of 7% betel nut husk fibres increased the tensile strength of oxo-HDPE from 18.20 MPa to 19.18 MPa. Further addition of fibres in the composites increased the tensile strength gradually, with composite C4 exhibited the highest tensile strength with 21.00 MPa. The use of BNH as fibre reinforcement in oxo-HDPE matrix shows that introducing extracted betel nut husk will lead to a higher tensile strength in the laminates. Increasing the volume fraction of betel nut husk fibres will increase the strength of the composites and ascertain a good interlaminating bonding between the fibre and polyethylene matrix with fibre not greater than 22% volume fraction.

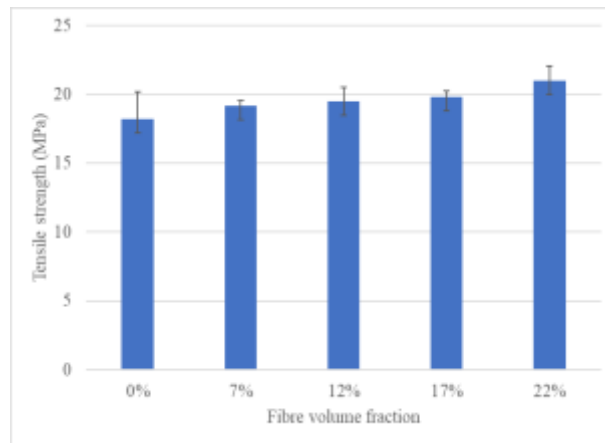


Figure 1. Tensile strength for each composite with different BNH fibres volume fraction.

The specific tensile strength of the composite is shown in Figure 2. The specific tensile strength is the lowest for laminate H, with 0.0182 MPa.m<sup>3</sup>/kg. Adding 7% of fibres volume fraction in the composite increases the specific tensile strength to 0.0189 MPa.m<sup>3</sup>/kg. The specific tensile strength for laminates C2, C3 and C4 are 0.0185 MPa.m<sup>3</sup>/kg, 0.0188 MPa.m<sup>3</sup>/kg, and 0.0199 MPa.m<sup>3</sup>/kg, respectively. Generally, all the composites have better specific tensile strength compared to neat high-density polyethylene, laminate H.

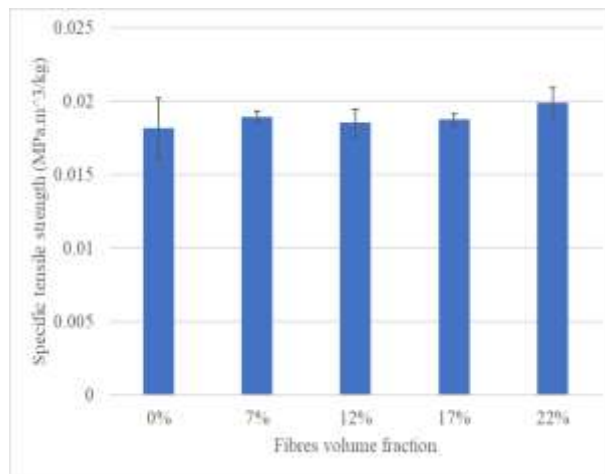


Figure 2. Specific tensile strength for each composite with different BNH fibres volume fraction.

The specific tensile modulus for each composite with different betel nut husk (BNH) fibres volume fraction is shown in Figure 3. The trend of the graph show that with the increase of fibres volume fraction, the specific tensile modulus decreases. The values of specific tensile modulus of laminate H, composite C1, composite C2, composite C3, and composite C4 are 0.513 MPa.m<sup>3</sup>/kg, 0.511 MPa.m<sup>3</sup>/kg, 0.494 MPa.m<sup>3</sup>/kg, 0.496 MPa.m<sup>3</sup>/kg, and 0.495 MPa.m<sup>3</sup>/kg, respectively. Laminate H has the highest specific tensile strength value. As for the other composites, they all have specific tensile strength value less than neat high-density polyethylene. This shows that neat high-density polyethylene material has better elastic properties compared to the composites reinforced with betel nut husk (BNH) fibres. Increment of betel nut husk fibres further reduce the extent to which the composites can deform elastically.

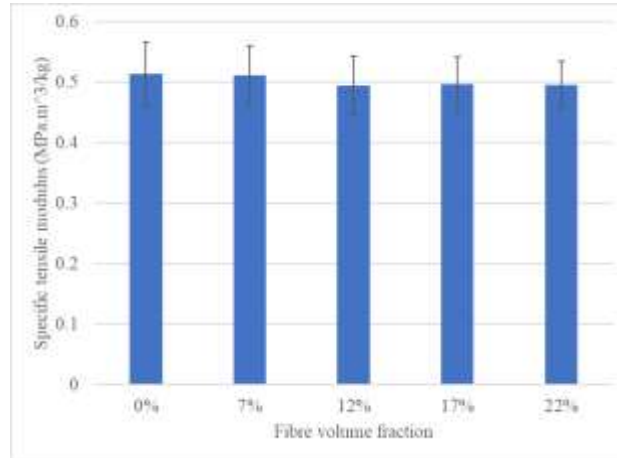


Figure 3. Specific tensile modulus for each composite with different BNH fibres volume fraction.

### 3.2 Hardness test

The Vickers hardness of the fabricated laminates are compared and shown in Figure 4. From the figure, laminate H has the lowest hardness with 6.06 HV. When 7% of betel nut husk fibres was added to the polyethylene, the hardness number increases to 6.23. Further addition of 17% fibres increases the hardness number. With the composition of 22% fibres volume fraction, the hardness number of the composite is highest at 6.69 HV.

Generally, from Figure 4, the composites are harder compared to laminate H which contains neat oxo- HDPE. As for the composites, the Vickers hardness number increases as the fibres volume fraction increases. The trend is true for fibres volume fraction of up to 22%, as hardness increases gradually from 6.234 to 6.687 HV.

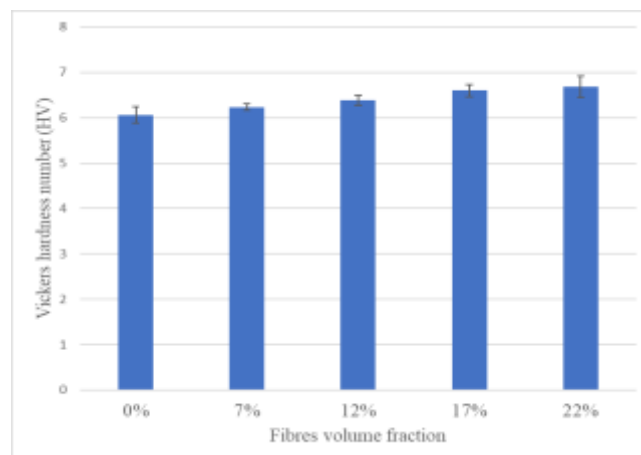


Figure 4. Average Vickers hardness number for each composite with different BNH fibres volume fraction

As hardness of a material usually has a collinear relationship with its tensile strength [9], the results of the hardness test for the composites agrees with the statement. Laminate H has the lowest hardness number of 6.06 HV. As fibres are added, the composite becomes harder. Meanwhile, better surface polishing exposes crystalline region to the indenter and will produce better results.

Furthermore, good polishing procedure will remove surface sample that caused the exposure of inner crystalline polymeric region, making the surface become more crystalline [10].

### 3.4 Scanning Electron Microscopy (SEM)

Figure 5-6 show the scanning electron microscopy (SEM) images of the laminated composite with fibres volume fraction of 12%. Figure 5 shows the image of the composite cross section with magnification of 50 $\times$ , while in Figure 6, the closed-up image of the bonding between fibres and the polyethylene matrix can be observed with the magnification power of 500 $\times$ . From the scanning electron microscopy (SEM) images, the surface adhesion between the polyethylene (PE) matrix and the betel nut husk (BNH) fibres is good. There are merely significant voids between the matrix and fibres, allowing for maximum transfer of load from the matrix to the fibres. This explains the better tensile properties of the composites compared to the neat high-density polyethylene laminate. The good adhesion allowed for excellent stress transfer, resulting in better tensile properties.

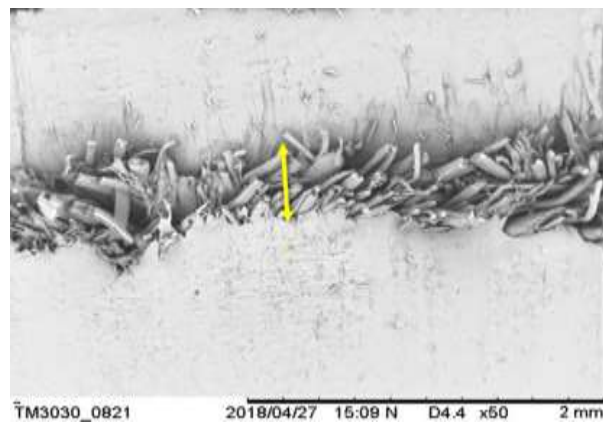


Figure 5. The image of the composite cross section with magnification of 50 $\times$ .

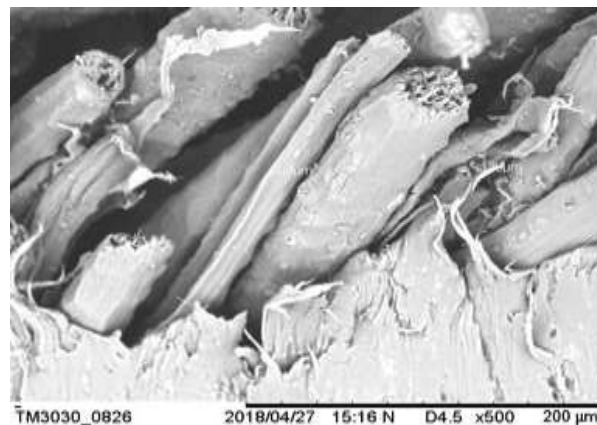


Figure 6. The closed-up image of the bonding between fibres and the polyethylene matrix observed with the magnification power of 500 $\times$ .



As in Figure 6, the non-uniformity observed is due to the betel nut husk (BNH) fibres being inherently polar and hydrophilic whereas the matrix is non-polar. This resulted in compounding difficulty, leading to the non-uniform fibre distribution [11].

## 4 Conclusion

A total of five laminates were fabricated throughout this project to study the effects of betel nut husk (BNH) fibres as reinforcement in a composite. Laminate H is a neat oxo-high density polyethylene laminate, and it was used as a basis for comparison. Four composites were fabricated with 7%, 12%, 17%, and 22% fibres volume fraction respectively.

In terms of tensile strength, the composites containing betel nut husk (BNH) fibres are proven to be stronger than neat high-density polyethylene (HDPE). Among all the composites, the higher the content of fibres in them, the higher their tensile strength. In terms of tensile modulus, the neat high-density polyethylene sample has the highest modulus. Increment of fibres volume fraction in the composites however, decreases the tensile modulus. This shows that neat HDPE can deform elastically better than the composites with fibres reinforcement. Other than that, the composites with higher fibres volume fraction starts deforming plastically at lower applied load.

From the results of the Vickers hardness testing, the composite with 22% fibres volume fraction has highest resistance to surface deformation. All the composites have relatively higher hardness number than the neat oxo-HDPE. Due to the fact that the hardness depends on the crystallinity of the indented region, the result indicates that the surface of the composites has more crystalline region compared to the neat HDPE. The consistency of polishing the surface to be tested for hardness is important in getting the best result. The scanning electron microscopy shows that there are no significant voids between the matrix and fibres, allowing for maximum transfer of load from the matrix to the fibres. This explains a better tensile properties of the composites compared to the neat high-density polyethylene laminate.

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