

## Fundamental Technique of Pre-blending of Bio-matrix with Commercial HDPE

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**Abstract.** The effect of bio-polymer as bio-matrix material with HDPE for the blending process is described in this study. 10%, 20%, 30%, 40% and 50% of bio-polymer was added to the HDPE and then blended by using Brabender Plastograph machine using mixer and roller screw and the test specimens were prepared by injection moulding. The compatibility of the origin bio-polymer (VOP), HDPE and the bio-matrix of bio-polymer/ HDPE (BioPE) were observed during the injection moulding process. Dumbbell shape of tensile test specimens were produced according to ISO 527-2 (5A) from the injection moulding process. Mixing process was successfully conducted based on two different matrix which is lab scale bio-polymer and production of commercial thermoplastic materials.

### Introduction

Polymers are a group of materials made up of long covalently bonded molecules, which are obtained either from natural or synthetic sources. Polymers, in the form of plastics, are used in making articles of daily use, such as knobs, handles, switches, pipes, heart valves, and so on. An overwhelming percentage of the polymers to make these commodities are synthesized from petroleum sources or natural gas raw materials. The key petrochemicals for polymer synthesis are produced largely from naphtha, one of the distillation fractions of crude oil or from natural gas. Once synthesized, the polymer materials, such as polyethylene, polypropylene, polystyrene, and polyvinyl chloride, are passed to major consuming industries. These synthetic polymers are, however, often not environmentally friendly because they typically do not undergo the process of biodegradation and, of course, are dependent on a limited petroleum resource.

The urgent need of today is to develop polymers that are biodegradable so that they become environmentally friendly [1]. The most important aspect of synthesizing biodegradable polymers relates to their ability to undergo degradation within the biosphere on coming into contact with micro-organisms, enzymes, or under natural environmental conditions. Many of the biodegradable polymers have good film forming properties, making them suitable for applications in high performance applications as well as in traditional commodity uses. Some applications include food containers, soil retention sheeting, agriculture film, waste bags and the use as packaging material in general. When used as non-wovens, these biopolymers can also be used in agriculture, filtration, hygiene and protective clothing [2]. In this study, HDPE was used as synthetic polymer while biodegradable polymer was produced from palm oil known as origin bio-polymer (VOP).

### Methodology

**Materials.** Injection grade HDPE (HI1600) was supplied by Titan Petchem (M) Sdn. Bhd, having density of 0.94 to 0.965 g/cm<sup>3</sup> and the melting point of HDPE is >120°.

The origin bio-polymer (VOP), Vesawit Palm oil was used as original palm oil. The monomer conversion begins with the catalyst preparation to generate the epoxies from the unsaturated fatty compound, and second reaction is the acid-catalyst ring opening of the epoxies to form polyols or bio monomer. The bio-monomer mixed with cross linking agent that is 4, 4'-Methylene Diphenyl

Diisocyanate (MDI) and Toluene as the solvent. The proportion ratio is 1:0.5 for bio-monomer and MDI respectively. The mixture stirred at 50°C for 15 minute until the mixture become high viscous compound then the compound casted into the mould to produced solid polymer known as VOP [3-7].

The preparation of polymer matrixs materials was started by mixing the HDPE with 10% bio-polymer (wt/wt ratio) by using Brabender Plastograph<sup>®</sup> EC machine from Germany at 130°C with 30 rpm speed rate for 20 mint. Then, the percent of bio-polymer were increased to 20%, 30%, 40% and 50% respectively. This polymer/ biopolymer compound named as BioPE

**Casting Process.** Tensile test samples for VOP were designed according to the BS EN ISO 527-2:1996. Bio-monomer was mixed with cross linking agent and was stirred for 30 minutes at 50°C and the resulting viscous compound was poured into the tensile mould and left at room temperature until the material became tack-free and was clamped at 55 °C by using Heat Transfers Machine, Fukutomo type, with 50 Pound load. Five samples of VOP were prepared.

**Injection Moulding.** The compounding materials were then fed to injection moulding machine (Nissei Horizontal Screw Type Injection Moulding NP7 Real Mini from Japan). The mold was designed according to ISO 527 (5A) to produce tensile test specimens. Barrel temperature set points of nozzle zone, front zone, middle zone, rear 1 zone, rear 2 zone and feed zone were 170°C, 165°C, 160°C, 155°C, 150°C and 70°C respectively.

**Tensile Test.** The tensile tests sample was prepared according to ISO 527-2 (5A). The testing was divided into three groups and each group consists of five samples. Universal Tensile Machine AG-I, Shimadzu, 10 kN types with 5 mm/min crosshead speed were used for this testing.

**Scanning Electron Microscopy (SEM).** The morphological study based on the fracture surface of tensile test of VOP, BioPE, and HDPE was examined using a SEM (JSM-6380LA Analytical Scanning Electron Microscope manufactured by JEOL Company Japan). The samples were cut into 1cm x 1cm x 1cm and was ultrathin coated with gold to produce electrically conductive specimens by JFC-1600 Auto Coater manufactured (JEOL Company Japan). The gold deposited on the sample either by low vacuum sputter coating or by high vacuum evaporation. Samples were examined after coated with ultrathin platinum, at 10kV voltage supplied by the SEM.

## Discussions

Fig. 1 shows the solid bio-polymer samples produced from the casting and clamping process while Fig. 2 shows the samples produced from the injection moulding process of HDPE and BioPE. Referring to Fig. 3, HDPE shows the highest mechanical property of tensile strength result that is 20.98 MPa. The tensile property of pure HDPE specimen was characteristic as cold drawing polymer. At the yield point, the polymer forms a neck at particular zone of the specimen and elongated further to grow this necking region. As the deformation continues, the neck region becomes larger until the entire specimen has been drawn out into new shape with the cross-sectional area that of the original neck zone. The molecular chains get highly oriented in the stressed neck region [9-10]. Meanwhile, the average tensile strength for VOP shows the lowest result that is 5.69 MPa compared to BioPE that is 17.47 MPa. BioPE gives increment to the tensile strength of VOP as the origin. This shows the influence of HDPE as the matrix polymeric materials is to enhance the mechanical strength of origin bio-polymer. The strength increment of BioPE from the origin starting biopolymer is more than 207% indicating that this dwi matrix of biopolymer and commercial synthetic polymer is a highly combination or good combination of thermosetting and thermoplastic in producing acceptable property of bio-materials.



Fig. 1: Tensile test specimens of solid bio-polymer (VOP) fabricated by simple casting process

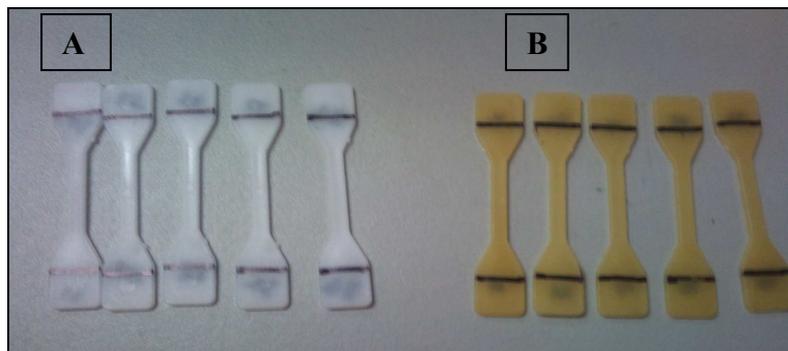


Fig. 2: Tensile test specimens of (A) HDPE and (B) BioPE sample produced from injection moulding process

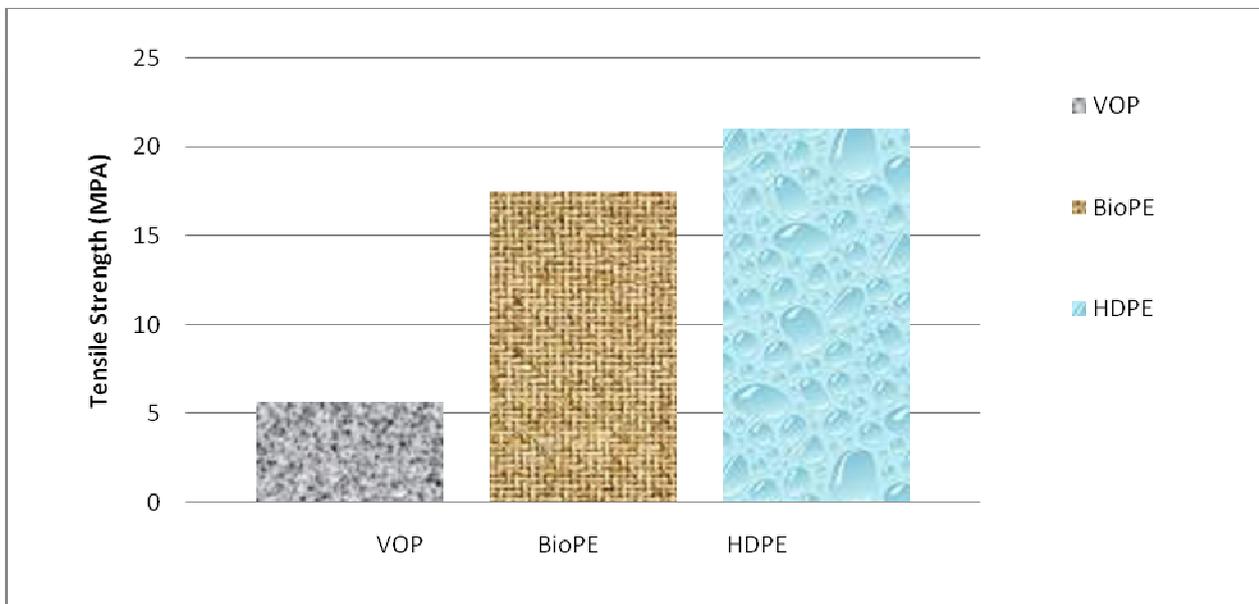


Fig. 3: Tensile strength of VOP, BioPE, and HDPE

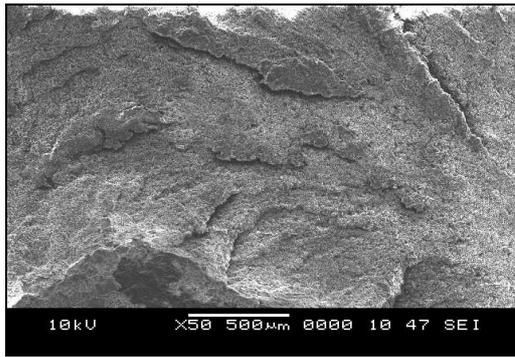


Fig. 4: SEM morphology of fracture surface cross-section of solid VOP

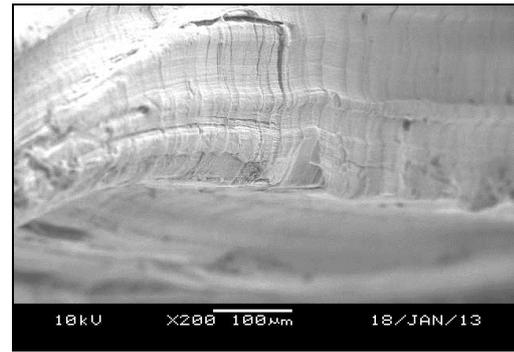


Fig. 5: SEM morphology of fracture surface cross-section of HDPE

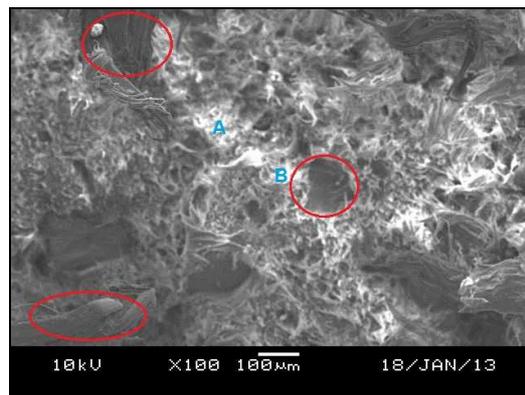


Fig. 6: SEM morphology of fracture surface cross-section of BioPE

Fig. 4 shows the morphological results of fracture surface of solid VOP after tensile test. The SEM microstructure shows a brittle fracture characterized by rapid crack propagation. This type of fracture have glassy smooth surface, flat, bright, shiny and having minimum plastic deformation. As a general rules, the mode of fracture in thermosetting polymers is brittle. In the simple term, it is associated with the fracture process is the formation of crack at regions where there is a localized stress concentration (i.e., scratches, notches, and sharp flaws). The covalent bonds in the network or crosslinked structure are severed during fracture [9].

As shown in Fig. 5, the fracture surface of the HDPE classified as ductile fracture appeared to be comprised of a less textured structure and interior cavities relatively clean also comprised of a lamellar type structure with highly plastic deformation. Ductile materials normally typically exhibit substantial plastic deformation with high energy absorption before fracture. Ductility may be qualified in term of percent elongation and percent reduction in area [10]. Ductile fracture is characterized by extensive plastic deformation in the vicinity of an advancing crack. Furthermore, the process proceeds relatively slowly as the crack length is extended as indicated in Fig. 5.

Referring to Fig. 6, the fracture surface of BioPE has two characteristic as shows in part A and part B. From Fig. 6, A can be classified as a brittle fracture while for B is ductile fracture. SEM result for BioPE shows the structure in part A have interconnected and twisted fibrils with large interfibrillar separation. Meanwhile, part B shows ductile fracture with numerous spherical 'dimples' resulting from uniaxial tensile failure. Each dimple is one half of a microvoid that formed and separated during the fracture process. It's also appears fibrous or dull and it have very rough surface compared to the VOP matrix. As looking at the fracture surface of BioPE, it's undergo a moderate amount of necking. The fracture process normally occurs in several stages. First, after necking begins, small cavities, or microvoids, form in the interior of the cross section. Next, as deformation continues, these microvoids enlarge, come together, and coalesce to form an elliptical crack, which has its long axis perpendicular to the stress direction. The crack continues to grow in a direction parallel to its major axis by this microvoid coalescence process. Finally, fracture ensues by

the rapid propagation of a crack around the outer perimeter of the neck, by shear deformation at an angle of about 45° with the tensile axis which is this is the angle at which the shear stress is at maximum. Sometimes a fracture having this characteristic surface contour is termed a *cup and-cone fracture* because one of the mating surfaces is in the form of a cup, the other like a cone [9].

### Conclusion

As the conclusion, by adding 10% of bio-polymer to the HDPE was contributed to the improvement of the mechanical strength of origin bio-polymer. The original tensile strength of VOP is 5.69 MPa while by adding HDPE to produced BioPE was revealed higher tensile strength of 17.47 MPa. This shows 207 % increment of tensile strength of BioPE which indicated that this dwi matrix biopolymer commercial synthetic polymer is a good combination of thermosetting and thermoplastic in producing acceptable bio-materials. BioPE were also improved the fracture mechanism properties of origin bio-polymer (VOP) from brittle to high plasticized effect of the BioPE samples.

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