Tensile Properties of Hybrid Pomegranate/Moringa Peel Reinforced Polyester Composites

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Abstract. The demand for polymers escalates as a result of its expansive applications in industries such as automotive, aerospace, electronics, packaging and medical. In a reinforced polymer, synthetic fillers have been introduced to modify its mechanical properties. As part of a sustainable development effort, organic fillers are currently used instead of the synthetic type. The current work explored the potential of incorporating pomegranate peel combined with Moringa oleifera pods as a hybrid filler in the polymer to study its effect on the properties of polyester. Samples of polyester composites at different compositions of organic fillers were prepared. The composition of pomegranate peel and Moringa oleifera pods was varied from 0 to 4 wt%. A comparison study was conducted between two hybrid compositions; 4 wt% and 8 wt%. It was observed that incorporating 4 wt% of the hybrid fillers showed better characteristics. This composition of polyester recorded 6.26 MPa, 227.80 MPa and 2.91% of tensile strength (σ), Young’s modulus (E) and elongation at break (ɛ), respectively.

1. Introduction
The term polymer originates from the Greek word where “poly” means many and “mer” means unit. Polymer is known as a molecule that has long repeating units of monomer [1]. Polyester is a polymeric material that contains ester groups in polymeric main chains of macromolecules [2]. Typically, polyester is used in making containers, film, fabrics and textiles. Polyester can be further specified into two main categories which are thermoplastic and thermoset. Thermoplastic is a type of plastic that can be reformed all over again once heated. On the contrary, thermoset degrades directly when heat is applied. This distinct characteristic provides opportunities for polyester to be utilized according to their specific use [3].

Filler is added into the polymer formulation to enhance its mechanical properties. Filler is divided into two categories; organic and synthetic. Organic filler is used due to its biodegradable property, acceptable specific strength and low cost [4,5]. Organic filler is able to reduce the weight of the polymer [6]. However, organic filler is hydrophilic in nature which might cause incompatibility, adhesion and dispersion problems in the polymer composite [7]. There are reports on the application of various organic fillers and its effects towards polymer’s properties. Many reported on the enhancement of the polymer’s properties, but some reported otherwise. As an example, Abdullah [8] incorporated natural particles into the unsaturated polyester resin of polymer matrix composite. The author observed the tensile strength of the polymer and claimed that sunflower husk increases the
tensile strength of the polymer. Meanwhile, the influence of organic fillers on physico-mechanical properties of Luffa cylindrica incorporated polyester composites was studied by Dhanola et al. The tensile strength of the polymer showed counterproductive results as the filler is added. However, ground nut filled composites recorded promising results [9]. Mahmood [10] studied the effect of addition of mixture of pomegranate peel and licorice to the epoxy. It was found that epoxy resin hardness improved with the addition of the organic fillers. On the other hand, Agarwal et al. [11] investigated the mechanical properties of jute fiber reinforced composites with polyester and epoxy resin matrices. The authors highlighted high tensile strength of the polymer with addition of low percentage of treated jute fiber.

The current research intended to utilise pomegranate peel combined with Moringa oleifera pods as hybrid organic fillers in the polyester. These materials were chosen due to its availability as waste. For instance, pomegranate is widely used for production of beverages. The juice making process generates waste that contains high amount of peels [12]. It has become an environmental challenge nowadays to utilize industrial or agricultural waste and residues in any product or invention [13]. On the other hand, most of Moringa oleifera parts such as root, bark, gum, leaf, fruit, flowers, seed and seed oil have been used for various ailments in the indigenous medicine [14]. Rather than use it solely on medicinal purposes, alternative uses of the plant should be explored. The effect of incorporating hybrid filler in polyester on its strength will be looked. In this research, tensile strength, elongation at break and Young’s modulus will be studied to showcase the mechanical strength of the polymer composites.

2. Methodology

2.1 Materials
Pomegranate peel and Moringa oleifera pods used in this study were obtained locally. Meanwhile, polyester and methyl ethyl ketone peroxide were supplied by S&N Chemical Sdn Bhd, Johor. Once obtained, the pomegranate peels and Moringa oleifera pods were dried in an oven at temperature of 120 °C in 5 hours to completely remove the moisture from the organic compound. After that, the dried pomegranate peel and Moringa oleifera pods were grind and sieved to obtain uniform size at 63 µm.

2.2 Sample preparation

| Table 1. Composition of the polymer and hybrid composite. |
|---------------------------------|----------------|----------------|----------------|
| Polyester (wt%) | Pomegranate Peel (wt%) | Moringa oleifera pods (wt%) | Methyl Ethyl Ketone Peroxide (wt%) |
|-----------------|-----------------|-----------------|-----------------|
| 100             | 0               | 0               | 4               |
| 96              | 0               | 4               | 4               |
| 96              | 4               | 0               | 4               |
| 96              | 2               | 2               | 4               |
| 92              | 4               | 4               | 4               |

The dried pomegranate peel and Moringa oleifera pods were weighed according to the desired composition of materials as shown in Table 1. The organic fillers were mixed before adding them to the polyester. 4 wt% of methyl ethyl ketone was added subsequently as the hardener. The composition of methyl ethyl ketone peroxide was kept constant for the entire experiment. The mixture was then poured into a mold to produce a dumbbell-shaped sample. 5 samples were prepared for each composition of the organic fillers. Only average value data is presented.
2.3 Mechanical testing

2.3.1 Tensile test. Shimadzu AG-100kNXplus universal testing machine was used to determine the tensile strength of the polymer composite. The procedure was conducted at ambient temperature at which the crosshead speed was set to 3mm/min. The tensile strength of the samples was calculated by using equation (1).

\[ \sigma = \frac{F}{A} \] (1)

where \( \sigma \) represents tensile strength (N/mm\(^2\) or MPa), \( F \) is the applied load (N) while \( A \) is the original area (mm\(^2\)) of the sample. Data of standard deviation of the tensile strength of the sample will be presented as 5 samples were tested for each composition of the polymer. In this study, samples of gauge of 40 mm length and 3 mm thickness were analyzed.

2.3.2 Young’s modulus.

Young’s modulus is the ratio between tensile strength and strain in the proportional limit zone and the value was determined by using equation (2).

\[ E = \frac{\sigma}{\varepsilon} \] (2)

Where \( E \) is the Young’s modulus (Mpa), \( \sigma \) is the tensile strength of the sample as calculated by using equation (1) and \( \varepsilon \) is strain (dimensionless). Calculation of strain is discussed in the subsequent section.

2.3.3 Elongation at break.

Elongation at break, \( \varepsilon(\%) \) also known as strain is the measure of the deformation at the point of final fracture. It was calculated by using equation (3).

\[ \% \varepsilon = \frac{\Delta L}{L_0} \times 100 \] (3)

where \( \Delta L \) and \( L_0 \) is the length change of the sample (mm) and original length (mm), respectively.

3. Result and discussion

3.1 Tensile strength

The effect of polyester’s composition on tensile strength is presented in Figure 1. The figure clearly shows that polyester reinforced with 4 wt% Moringa oleifera pods, 4 wt% pomegranate peel and 4 wt% hybrid recorded lower tensile strength than the pure polyester. Pure polyester exhibited the highest tensile strength (9.56 MPa) as compared to the reinforced type. Imperfect interfacial bonding is the cause of the low tensile strength recorded [15]. In fact, low tensile strength is due to the incapability of particles to transferring load which resulted in accumulation of stress at certain points of the composite [16].

However, the figure also depicts that 4 wt% hybrid reinforced polyester has higher tensile strength compared to 4 wt% Moringa oleifera pod reinforced polyester and 4wt% pomegranate peel reinforced polyester. The results obtained showcases that 4 wt% hybrid reinforced polyester has distinguished properties that reflect its potential to be utilized in specific uses. Poor fiber-matrix interaction is highly likely to be the cause of the poor performance of the other two organic fillers incorporated...
polymers. Poor fiber-matrix interaction is a result of different chemical nature of the matrix and the fiber reinforcement [17].

![Figure 1. Effect of compositions of polyester on tensile strength.](image1)

Other than that, the data presented shows that polyester reinforced with 4 wt% Moringa oleifera pods has higher tensile strength as compared to 4 wt% pomegranate peel reinforced polyester. This is due to the lightweight property of the Moringa oleifera pods itself. More particles are required to obtain the same weight as the pomegranate peels. The high quantity of Moringa oleifera pods allows more contact with the polyester and as a consequence, higher tensile strength was obtained. Besides, high cellulose content has significant influence on the strength of the fiber [18]. Content of cellulose in the filler also contributes to the behaviour of the reinforced polyester.

![Figure 2. Effect of composition of hybrid reinforced polyester on tensile strength.](image2)
3.2 Young’s modulus
The relationship between composition of polyester and Young’s modulus can be seen from Figure 3. 4 wt% of hybrid reinforced polyester showed significant value of Young’s modulus (227.80 MPa). High Young's modulus value is due to slipping prevention of the polyester chains by the particles [8]. The figure also illustrates that both 4 wt% Moringa oleifera pods and 4 wt% pomegranate reinforced polyester has low value of Young’s modulus. This indicates that they are more flexible compared to the others.

**Figure 3.** Effect of compositions of polyester on Young's modulus.

Based on Figure 4, the Young’s modulus value decreases with increasing composition of hybrid component in the polyester. 4 wt% of hybrid reinforced polyester has high value of Young’s modulus (227.80 MPa) while 8 wt% hybrid reinforced polyester has lower value (75.40 MPa). The higher value of Young’s modulus indicates that the composite exhibit as rigid materials.

**Figure 4.** Young's modulus for varying hybrid reinforced polyester composition.
3.3 Elongation at break

Influence of composition of polyester on the elongation at break is presented in Figure 5. It was reported that fibers with high tensile strength and Young’s modulus values have lower elongation value [19]. However, data recorded in the current study showed slightly different trend. 4 wt% Moringa oleifera pods reinforced polyester showed the highest value of elongation at break (8.83%) although it has higher tensile strength than 4wt% reinforced pomegranate peel polyester. This phenomenon could be influenced by the orientation of fiber in polyester that was placed randomly rather than transversely or longitudinally. Other than fiber length, fiber orientation is also fundamental in determining composite final properties [20].

![Figure 5. Effect of compositions of polyester on elongation at break (%).](image5)

Figure 6 illustrates the data of elongation at break obtained at two different compositions of the hybrid fillers. Significant increment in the elongation at break percentage value can be observed for polymers made by incorporating more hybrid fillers. Low percentage value of elongation at break

![Figure 6. Effect of different composition of hybrid reinforced polyester on elongation at break (%).](image6)
(2.91%) is shown by 4 wt% hybrid reinforced polyester. The results obtained was expected as it showed high tensile strength. On the other hand, 8 wt% reinforced polyester recorded high percentage of elongation at break (3.77%) whereas the tensile strength value is low.

4. Conclusion
Polyester reinforced with hybrid organic fillers have been prepared in this study. Results which have been obtained from this study reveal that the tensile strength of the hybrid filled composites decreases as the composition of the hybrid fillers increases. In fact, the same trend has been observed for the data of Young’s modulus. However, in a comparison study made between 4 wt% and 8 wt% hybrid reinforced polyester, it has been recorded that the lower compositions of hybrid have higher tensile strength as well as Young’s modulus. The elongation at break data shows that by increasing the hybrid component into the polyester would increase the percentage of elongation at break. Therefore, fibers with low tensile strength and Young’s modulus values have been indicated to possess high elongation value.

Acknowledgement
Facilities provided by Universiti Teknologi MARA and financial support by Fundamental Research Grant Scheme (FRGS/1/2017/TK02/UiTM/03/11) from Ministry of Higher Education Malaysia are greatly acknowledged.

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