Tensile and impact strength of alpaca fiber epoxy matrix hybrid composites prepared by injection moulding process

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Abstract: Today, there are many more applications for fibre reinforced polymer composites than there were for metals and alloys a few decades ago. Numerous research projects have focused on improving the mechanical and thermal properties of composite materials, especially when reinforced with environmentally friendly, recyclable, and biodegradable materials. This study combined alpaca fibre (AF), palm seed filler (PSF), and polypropylene (PP) to create composites that have improved properties over traditional polymer composites. Fiber loadings of 35, 30, 25, 20, 15, and 10 percent and filler loadings of 15, 10, and 5 percent were used to prepare the alpaca fiber/palm seed filler polypropylene (PP) composites using a conventional injection moulding technique (0, 5, 10, 15, 20 and 25 wt. percent ). Hydrophilicity and mechanical properties of the hybrid bio-composites were evaluated experimentally. The results showed that 15 lbs. For example, epoxy matrix composites have tensile and flexural strengths of 62 MPa, as well as hardness and impact strengths of 54 and 17.9 kJ/m², respectively.

Keywords: Polypropylene, injection moulding technique, tensile strength, impact strength, palm seed filler.

1. Introduction
Non-renewable sources are used to produce petrochemical-based polymeric materials, which find wide application [1]. As a result of their inability to biodegrade, these petroleum-based materials pose serious environmental risks to future generations[2]. Therefore, due to increased awareness of the environment's sustainability and renewability [3]–[7]. "Go green" is a concept that is currently being researched by researchers [8]–[10]. This has led to the creation of "biocomposites or bio-based fibres" from petroleum-based synthetic textile fibres that have been combined with their natural counterparts to reduce the environmental impact[2], [11]. These fibres have been made from a variety of cellullosic materials such as cotton and lignin, as well as flax and hemp[12], [13]. It is not only more
biodegradable than synthetic fibres that these blended fibres are, but they are also cheaper and reduce natural waste[13]. These bio-based green composite fibres are already being used in food packaging, the automobile industry, aircraft and train interiors, building construction sites, sensors and even storage devices [13]–[22].

2. Materials and Methods

2.1. Composite preparation
Alpaca fiber and palm seed fillers (less than 100 m in size) had to be dried for 10 hours before being mixed. Alpaca fibers of 35, 30, 25, 20, 15, and 10% weight percent and palm seed fillers of 0, 5, 10, 15, and 20% weight percent were used to compare the effects of compounding techniques on mechanical properties. The materials were compounded using two methods: an internal mixer and a twin-screw extruder. All ingredients were loaded into the internal mixer and mixed for 15 minutes at 80 rpm at 190°C. For the twin-screw extruder, this was done at a screw speed of 80 revolutions per minute. Extruder temperatures were set at 180°C (first zone), 185°C (second zone), and 190°C (third zone) (at die). The twin screw extrusion and hot injection molding processes are schematically depicted in Figure 1.

![Twin screw extruder schematic arrangement](Image)

Figure 1. Twin screw extruder schematic arrangement

2.2 Mechanical Testing
A saw cutter was used to cut the fabricated composite plates to the desired shapes for different test specimens. A Universal Testing Machine was used to perform tensile at room temperature. For each weight percentage, three specimens were tested to ensure that the results could be reproduced. Three-millimeter-per-minute crosshead speed was used in the ASTM D638 test standard. Reinforced Polypropylene (PP) composites’ impact strength refers to their ability to absorb energy from impact loads without breaking. If there are voids present, the filler’s influence, and testing conditions all affect impact strength. The Charpy test method was used to determine the impact strength in accordance with ASTM D-256.

3. Results and Discussions

3.1 Tensile Properties
Various bio-composites were tested for tensile strength using a variety of fibre and filler weight percentages. Fiber and filler loading percentages are depicted in Figure 2 as a function of tensile strength.
Figure 2. Effect of fiber/filler loading on tensile strength for PP/AF/PSF composites

Composites filled with 0, 1, 3, 5, 7, and 9 wt. lbs. 35, 40, 46, 53, 62, and 42 percent of palm seeds were used. At 20 wt% filler, the improvement on tensile strength was 45% higher than that of pure Polypropylene (PP)/Alpaca fiber reinforced composite specimens. Meanwhile, when it was increased from 0 wt% to 20 wt%, the tensile strength was drastically increased from 35 MPa to 621 MPa, respectively. At 20 wt% filler weights, the improvement on tensile strength was 45% higher than that of pure Polypropylene (PP)/Alpaca fiber reinforced composite specimens. The tensile strength was suddenly reduced between 41 MPa at 25 wt.% of filler. This was because of the distorted bonding properties between the filler and the matrix and also due to the presence of voids. Bio-composite tensile strength was improved from 35 MPa to 62 MPa by changing the filler weight percentage from 0 to 25 weight percent. The high tensile strength of bio-composite was 62 MPa at 20 wt.% and it was observed as an optimum value. Also, it was 43% higher than that pure Polypropylene (PP)/Alpaca fiber reinforced composite specimens. Figure 3 depicts the tensile stress-strain curves for various filler weight percentages. Furthermore, the percentage of fibre and filler in bio-composites increased by up to 15 wt. As well as a 20 lb. are used to determine the amount of weight. Percentages are expressed as a percentage.

Figure 3. Tensile strain vs tensile stress curves for PP/AF/PSF composites
Fiber and filler reinforcement carried the tensile load more effectively than the matrix, which caused the matrix to break. It has a higher stiffness and strength. Hence, it was observed that when fiber and filler weight percentage was increased beyond 15 wt. % and 20 wt. %, the strength of bio-composites decreased. This continued in sinusoidal pattern with the further increase in filler weight percentage. At a higher filler percentage, this is due to insufficient bonding between the filler and the Polypropylene (PP) matrix. It resulted to voids and weaker strength during tensile testing. Figure 4 depicts the tensile load-displacement curves for the various fiber and filler weight percentages. The percentage of elongation between 0 wt. % and 20 wt. % ranged from 1.18 to 3.7 % correspondingly.

![Figure 4. Displacement vs load curves for PP/AF/PSF composites](image)

As well as a measure of stiffness, the tensile modulus is used to characterise materials. The effect of different weight percentage addition of filler material into the fiber and Polypropylene (PP) combination is illustrated in figure 5.

![Figure 5. Effect of fiber/filler loading on tensile modulus for PP/AF/PSF composites](image)
Moreover, the addition of filler weight from 0 wt% to 25 wt% increased or enhanced the modulus value from 1.5 GPa to 2.7 GPa. Polypropylene (PP)/palm-seed filler/Alpaca-fiber composites had an optimal tensile strength of 62.5 MPa, which was comparable to coconut shell powder reinforced epoxy, oil palm shell powder reinforced polyester, and kenaf-coconut-kenaf fibre reinforced polyester composites. However, it was still higher than tamarind seed filler reinforced vinyl ester composites of 34.32 MPa, date palm wood flour and glass fibre reinforced polypropylene composites of 25.31 MPa, boiled egg shell powder and coir fibre reinforced vinyl ester composites of 24.37 MPa, and groundnut powder and coir fibre reinforced vinyl ester composites of 28.12 MPa. This comparative analysis on mechanical behaviour (tensile and other properties) of the palm seed filler/Alpaca fiber/Polypropylene (PP) composite shows that the palm seed filler/Alpaca fiber/Polypropylene (PP) is a promising material for engineering structures.

### 3.2 Impact Strength

Pendulum-broken composites of notched palm seed/Alpaca fiber/polypropylene (PP) were held in an Izod Charpy instrument. It is shown in Figure 6 that the composites with different filler loadings recorded average impact energy values. An increase in filler loading increased impact strength in composites made from palm seed, alpaca fibre, and polypropylene (PP). When the filler content was increased by 20 weight percent, impact energy increased by 23.67 percent. Importantly, the palm seed/Alpaca fiber/Polypropylene (PP) composites exhibited a maximum impact strength of 17.9 kJ/m² at 20 wt.% of filler loading, and it was 23.67 % higher than the Alpaca fiber/Polypropylene (PP) composites. While Alpaca fiber/PP composites were capable of absorbing high energy, palm seed/Alpaca fiber/PP composites were capable of halting crack propagation.

![Figure 6. Effect of fiber/filler loading on impact strength for PP/AF/PSF composites](image)

The higher impact strength of palm seed/Alpaca fiber/Polypropylene (PP) composites recorded was due to the excellent homogeneous dispersion of filler in the matrix, and it produced an excellent interfacial adhesion. Hence, the crack propagation was prevented and energy was easily absorbed, thus improving impact strength. On the other hands, poor dispersion of filler increased the tendency to agglomerate the particle, thus minimising their surface areas. Therefore, the crack propagation was increased, and the energy absorption was also less. The phenomenon has explained the decrease in impact strength of 25 % weight loadings of the composites. An increase in impact strength was more pronounced when the filler loading was increased up to 20 wt.%. 

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4. Conclusions
From this study's promising results, the following conclusions can be drawn. The percentages of fibre and filler in Polypropylene (PP)/Alpaca fiber/palm seed composites were found to affect mechanical properties, with 15 and 20 percent, respectively, being optimal.

- According to the manufacturer, polypropylene (PP)/Alpaca fiber/palm seed composites had maximum tensile strength and modulus of around 62 MPa and 2.7 GPa.
- PP/Alpaca fiber/palm seed composites with a filler loading of 20 wt.% also showed maximum strengths of 17.9 kJ/m² in impact tests.
- Therefore, with tensile and impact strength of the Polypropylene (PP)/Alpaca fiber/palm seed composites increased by 44 and 25%, respectively.

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