

## **Abstract**

Agro-waste pineapple leaf fibre (PALF) was extracted from fresh pineapple leaves for use as a green reinforcement in polypropylene (PP) composites. There is a growing interest in the use of PALF as reinforcement in thermoplastic matrix composites to develop high-performance impact-resistant materials in technical applications. PP undeniably offers economic, ecological, and practical benefits compared to other thermoplastic polymers due to its affordability, environmentally friendly recycling process, and excellent thermal stability. Generally, chemical treatment is used to clean the sun-dried PALF, and the effluents of those chemicals are discharged into nature.

In this study, new mechanical approach (carding) was used to remove the remaining extraneous substances from the scratched and sun-dried PALF instead of using any chemical treatment. Optimum number of passages through carding process did not reduce the fibre length or deteriorate the mechanical properties of fibres and was found to be effective in improving the fibre surface roughness, leading to an improved fibre-matrix interface. The carding process also removed the non-cellulosic materials from PALF, resulting in an increase in the cellulose percentage. Four passages of PALF through carding successfully removed 12 wt.% of non-cellulosic materials.. The percentage of sticky fibres and dust content decreased, and fibre breakage increased with further increase in number of carding passages. The properties of individualized fibres were also influenced by the number of carding passages. The carding process reduced the diameter of PALF due to the removal of extraneous materials and increased the tensile strength and modulus. Scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FTIR) confirmed the elimination of non-cellulosic materials along with other gummy and waxy substances from the surface of fibrillated PALF due to the carding action.

The crystallinity % also increased after the carding process due to the removal of amorphous substances. As the reinforcement-matrix interfacial shear strength (IFSS) strongly influences the physico-mechanical properties of composites, the IFSS of carded PALF-reinforced PP fibre micro-bonded composites was also studied using the single fibre pull-out test (SFPT). PP in the form of fibres, which on melting transforms into matrix, was used. PP fibres of two different fineness values were used to study their influence on composite properties. Composites with PALF, carded four times and finer PP fibre showed the highest IFSS. Additionally, the load extension curves and SEM images of the tensile pulled-out surface were investigated to study the interfacial adhesion between PALF and PP micro-droplets. The increased surface roughness of PALF due to the carding action resulted in an improvement in the IFSS of PALF-reinforced PP composites.

The high melt viscosity of PP hinders its penetration into the composite reinforcement. To overcome this difficulty, the individualized and fibrillated PALF and PP fibres of different fineness were blended (50% by weight) in the carding process to ensure homogeneous distribution of reinforcement and matrix in fibre form within composites. The blended carded sliver was further parallelized through a gill-drawing process, and subsequently, unidirectional composites were fabricated using the compression moulding technique. The drawn sliver was used to produce the composites in a compression moulding machine at 180°C for 15 minutes under 20 bar pressure. The consolidated samples were allowed to cool naturally to 100°C under constant pressure keeping inside the moulds. The fabricated composites were cut into different shapes according to the respective standards for the measurement of void percentage, surface water contact angle, thermal conductivity, dynamic mechanical analysis, tensile, flexural, short beam, and Izod impact strength, thermal conductivity, and water absorbency analysis. SEM was used to examine the fracture surface of the tensile strength-tested samples.

The composite made with four times carded PALF, demonstrated the best physico-mechanical performance among the samples, while those made with finer PP fibres as matrix forming fibres also contributed positively. The thermal insulation performance of the composites improved with shorter PALF carded five times and with coarser PP fibres, but at the same time, the water absorbency of these composites also increased, indicating reduced water resistance of such composites.

The drawn sliver PALF-PP fibres were converted into thermal-bonded sliver by melting the outer layer to keep the reinforcement fibres unidirectional in composite fabrication at 180, 190, 200, and 210°C. The tensile performances, bending rigidity, and weavability of the thermal-bonded slivers were evaluated. Then, the unidirectional composites of the thermally bonded slivers were fabricated according to the above-mentioned process, and their properties were analysed. The thermal-bonded sliver was treated at 200°C, and composites fabricated with this sliver showed the best feasible physico-mechanical properties. Based on the results of this investigation, PALF and PP fibres can be chosen to produce thermal-bonded sliver with improved fibre alignment, as well as the final composites in accordance with the specifications of the intended use.

The thermal-bonded sliver treated at 200°C was used to make cross-laid (0/90°), 1/1 plain, 2/1 twill, and 3/1 twill structures with the same EPM (ends per meter) and PPM (picks per meter) but different patterns of interlacements. These structures were compression moulded into composites according to the same process used earlier. The tensile failure surface morphology and the interlaminar failure of short-beam shear strength (SBS) tested samples were analysed by SEM and micro computed tomography ( $\mu$ CT) images, respectively. The composite sample fabricated with cross-laid structures showed the best mechanical properties and a lower void percentage due to the lower order of interlacements.

According to the findings of this research, PALF and PP fibres can be converted in to thermal-bonded sliver to produce good quality textile-structured composites with aligned fibres. These composites can be tailor-made to have desired specifications, as a viable alternative to conventional and costly materials for protective applications.