Studies on Fibrous Biocomposites Prepared with Nettle Yarn and Fabric Reinforcements in Poly(Lactic Acid) Matrix

Parna Nandi

ABSTRACT

In this study, a series of nettle/PLA unidirectional biocomposites was prepared by varying the weight content of nettle yarn preform and woven mat; and the biocomposites were tested for physical, mechanical, thermal, and biodegradation properties with a focus on automotive dashboard and door panel applications. As the preform/mat content increased, the static and dynamic mechanical properties of the biocomposites increased initially and decreased afterwards. The biocomposites prepared with equal weight fraction of nettle preform/mat and PLA demonstrated the highest tensile strength, flexural strength, impact strength, and Young's modulus. The same biocomposites showed the highest storage and loss moduli and the lowest damping factor. The micromechanical analysis revealed that the tensile strength and Young's modulus of the biocomposites could be anticipated by considering the tensile properties of the constituent materials. The morphological and thermal analyses of the biocomposites prepared with 50 % preform/mat content demonstrated good reinforcement wettability, thermal stability, and high crystallinity. The same biocomposites showed remarkable biodegradability and enrichment of soil nutrients during soil burial tests. Overall, these biocomposites were found to be very promising for dashboards and door panels applications.

Also, this research work witnessed improved reinforcement-matrix interface by silanisation of the reinforcement surfaces, and the resulting nettle/PLA biocomposites showed enhancement in mechanical, thermo-mechanical, and biodegradation properties. Tri-ethoxy silyl propyl methacrylate (TES-PM) and amino propyl tri-ethoxy silane (APTES) were grafted onto cellulosic nettle reinforcement at various concentrations. The morphological, structural, chemical, and mechanical properties of the nettle woven reinforcement and the degree of silanisation were determined to ensure a high-quality grafting. Functional moiety and concentration of silane coupling agent were found to affect interfacial strength of the biocomposites. It was shown that an appropriate coupling agent with an optimal concentration improved the static mechanical, dynamic mechanical, and biodegradation properties of the biocomposites without changing the thermal properties much.

Further, this work employed n-octyl coupling agent (TEnOS) to obtain a stronger interface between the nettle reinforcement and the PLA matrix. This resulted in higher static and dynamic mechanical strengths of the biocomposites, with a low concentration of TEnOS. The low density of grafted TEnOS guaranteed a complex design of the biocomposite. The developed process and the obtained end-product could be more economical. Moreover, TEnOS altered fibre cell walls, resulting in an increased dimensional stability, fungal resistance and thermally stability of the biocomposites. All products were recyclable and biodegradable.

Lastly, PLA fiberwebs and multi-ply nettle woven reinforcement were employed in this work to develop nettle/PLA biocomposites with varied reinforcement orientations. Piling of nettle fabrics resulted in improved tensile, flexural, impact, and thermal properties of the biocomposites. The best among all the biocomposites developed in this study was found to be the three-layered woven fabric reinforced PLA biocomposite with a reinforcing orientation of 0°/45°/90. Though thermal stability of biocomposite was found to be unaffected, the crystallinity rose by 25.84 %. The degradation kinetics and the activation energy of the biocomposite were determined by employing differential fitting of Arrhenius model. This biocomposite lost 15.06 % weight and 50.56 % strength after 20 days of burial in soil.#