Functionality of cellulose nanofiber as bio-based nucleating agent and nano reinforcement material to enhance crystallization and mechanical properties of polylactic acid nanocomposite

ABSTRACT

Polylactic acid (PLA), a potential alternative material for single use plastics, generally portrays a slow crystallization rate during melt-processing. The use of a nanomaterial such as cellulose nanofibers (CNF) may affect the crystallization rate by acting as a nucleating agent. CNF at a certain wt.% has been evidenced as a good reinforcement material for PLA; nevertheless, there is a lack of information on the correlation between the amount of CNF in PLA that promotes its functionality as reinforcement material, and its effect on PLA nucleation for improving the crystallization rate. This work investigated the nucleation effect of PLA incorporated with CNF at different fiber loading (1–6 wt.%) through an isothermal and non-isothermal crystallization kinetics study using differential scanning calorimetry (DSC) analysis. Mechanical properties of the PLA/CNF nanocomposites were also investigated. PLA/CNF3 exhibited the highest crystallization onset temperature and enthalpy among all the PLA/CNF nanocomposites. PLA/CNF3 also had the highest crystallinity of 44.2% with an almost 95% increment compared to neat PLA. The highest crystallization rate of 0.716 min–1 was achieved when PLA/CNF3 was isothermally melt crystallized at 100 °C. The crystallization rate was 65-fold higher as compared to the neat PLA (0.011 min–1). At CNF content higher than 3 wt.%, the crystallization rate decreased, suggesting the occurrence of agglomeration at higher CNF loading as evidenced by the FESEM micrographs. In contrast to the tensile properties, the highest tensile strength and Young's modulus were recorded by PLA/CNF4 at 76.1 MPa and 3.3 GPa, respectively. These values were, however, not much different compared to PLA/CNF3 (74.1 MPa and 3.3 GPa), suggesting that CNF at 3 wt.% can be used to improve both the crystallization rate and the mechanical properties. Results obtained from this study revealed the dual function of CNF in PLA nanocomposite, namely as nucleating agent and reinforcement material. Being an organic and biodegradable material, CNF has an increased advantage for use in PLA as compared to non-biodegradable material and is foreseen to enhance the potential use of PLA in single use plastics applications.

Keyword: Cellulose nanofiber; Nucleating agent; Crystallization rate; Polylactic acid; Organic nanofiller