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Thermo-mechanical characterization of PHB/PCL blend incorporated with carbon nanotubes and evaluation of nanocomposite printability

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Polyhydroxybutyrate (PHB) stands out as a widely used polymer in various biomedical applications, especially in bone tissue engineering. Nevertheless, it faces some challenges such as brittleness and low impact resistance. To overcome these limitations, PHB is generally combined with other materials, forming blends or composites, for instance. Among them, polycaprolactone (PCL) is interesting due to its high flexibility, and improved biocompatibility when combined with additional inorganic particles. Therefore, this work aims to evaluate the effect of carbon nanotubes (CNT) in PHB and PCL blends, following the proportion of 70:30 wt% of PHB/PCL, with the addition of 0.5 wt% CNTs. To the best of our knowledge, studies regarding the incorporation of CNT in this blend's composition are unusual, even though PHB/PCL is a very studied blend. The materials were mixed through an extrusion step under the following conditions: 180°C and 40 rpm for 20 minutes. It allowed obtaining PHB/PCL and PHB/PCL/CNT filaments. Then, specimens were produced under hot pressing at 200-210 ºC and 0,5 ton, aiming at the characterization through bending tests, thermogravimetric analysis (TGA), and differential scanning calorimetry (DSC). Through TGA, it was possible to calculate the thermal resistance index (THRI), which estimates the thermal stability of materials. PHB/PCL showed a decrease in THRI compared to neat PHB. However, in the presence of CNT, the index was slightly higher than PHB/PCL, evidencing the incorporation of CNT slightly contributed to the blend's thermal stability. DSC cooling curves showed that PHB, PHB/PCL, and PHB/PCL/CNT presented different crystallization behavior. Blending PHB with PCL resulted in a slow crystallization of PHB, but CNT could improve the crystallization process of both phases (PHB and PCL). The effect of CNT on mechanical behavior was studied through bending tests. The difference in mechanical properties of PHB and PHB/PCL was remarkable. Flexural resistance and elastic modulus of PHB/PCL decreased compared to PHB. In the nanocomposite, a slight tendency of reduction of these mechanical properties was observed compared to the blend, but there was no relevant statistical difference to support this observation. Since the commercial carbon nanotubes were used as received, CNT might have established a weak interface with the polymers, due to poor interaction with the matrix. So, further studies may evaluate the influence of CNT functionalization on the thermo-mechanical properties of PHB/PCL. Finally, preliminary 3D printing tests were carried out and the parameters were optimized at: 0.4 mm nozzle diameter, nozzle temperature at 200°C, bed temperature at 50-60°C, and printing speed at 25 mm/s. The blend and composite had greater printability, resulting in specimens of higher quality and reproducibility than pure PHB.