Effect of PCL/HEC polymer blend composition on degradation mechanisms under different conditions- ACEX260

This study investigates the degradation of polymer blends based on poly(ε-caprolactone) (PCL) and hydroxyethyl cellulose (HEC), prepared with varying amounts of filler (HEC), plasticizer (glycerol), and compatibilizer (ethylene-co-acrylic acid, EAA). The filler content ranged from 0 to 50 wt.%. The effect of individual components on the structural properties and morphology of the blends was analyzed before and after exposure to degradation conditions. Degradation was examined using two methods: the soil burial test, simulating microbial degradation in a soil environment, and accelerated photochemical degradation in a QUV chamber. The results showed significant differences in degradation behavior depending on the blend composition, with the highest degradation observed in samples with higher HEC and plasticizer content. The soil burial test and QUV exposure indicate distinct degradation mechanisms depending on the environment. These findings contribute to a better understanding of biodegradable polymeric systems and their optimization for various applications. To quantitatively assess the changes in the chemical structure of the blends after QUV degradation, the carbonyl index (CI) and degradation index (DI) were used (see Fig. 1 and Fig. 2). The most significant increase in CI was observed in the blend containing 90 wt.% PCL/10 wt.% HEC/30 wt.% glycerol, with notable increases also recorded for blends with 70 wt.% PCL/30 wt.% HEC and 50 wt.% PCL/50 wt.% HEC/30 wt.% glycerol. This trend is attributed to the higher content of hydroxyethyl cellulose (HEC) and glycerol, which increase the hygroscopicity of the PCL-based system. A more pronounced increase in DI was observed for the 70 wt.% PCL/30 wt.% HEC, 90 wt.% PCL/10 wt.% HEC/30 wt.% glycerol, and 50 wt.% PCL/50 wt.% HEC/30 wt.% glycerol blends. This correlates with the high content of HEC and glycerol, which enhance hygroscopicity and accelerate hydrolytic-oxidative degradation processes. In contrast, neat PCL and the blend containing 70 wt.% PCL/30 wt.% HEC/30 wt.% glycerol/25 wt.% EAA showed a decrease in DI, likely due to higher structural stability. For further analysis of changes after QUV degradation, SEM was employed. This method enabled detailed comparison of the surface morphology and fracture structures of the polymer blends before and after degradation, considering various compositions of HEC, glycerol, and EAA. Blends without the compatibilizer EAA exhibited clear signs of degradation, particularly increased porosity, microcracking, and poor interphase adhesion. For example, the 70 wt.% PCL/30 wt.% HEC blend (Fig. 3a) showed fine surface cracking and layered fracture structures, indicating insufficient compatibility and degradation of the hydrophilic HEC component. Upon addition of glycerol (Figs. 3b–c), the material became softened and plasticized, resulting in a smoother but less cohesive fracture surface. Exposure of PCL blends with varying contents of HEC, glycerol, and EAA to QUV conditions led to significant visual and structural changes (Fig. 4). In the case of neat PCL, its expected dimensional stability was not maintained after QUV degradation. Small surface blisters gradually formed, indicating photooxidation. The burial test (Fig. 5) confirmed that the composition of PCL/HEC blends has a critical influence on biodegradability under natural soil conditions. After 180 days of soil exposure, significant differences in weight loss were observed among the samples, reflecting the chemical nature and microstructure of the systems. The smallest weight loss was recorded for neat PCL (13.4%), due to its pronounced hydrophobicity, higher crystallinity, and slower biodegradation mechanism, which primarily occurs through ester bond hydrolysis. Although PCL is a biodegradable polyester, its degradation in soil is slow, particularly in the early stages when changes are limited to the surface. In contrast, blends with higher HEC and glycerol content showed substantially faster degradation.

Conclusion

The conclusion of the work confirms that an appropriate combination of PCL, HEC, glycerol, and EAA can influence the degradation of polymer blends under soil conditions and accelerated aging. HEC and glycerol enhance biodegradability, while EAA stabilizes the structure without preventing decomposition. The results indicate the possibility of optimizing the composition according to specific application requirements.