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A Hybrid Film: $NiFe_2O_4$ Nanoparticles in Poly-3-Hydroxybutyrate as an Antibacterial Agent

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Abstract : In this work, a hybrid film based on poly-3-hydroxybutyrate (P3HB) and nickel ferrite ($NiFe_2O_4$) nanoparticles (NPs) was obtained by a simple and reproducible methodology in order to study its antibacterial and cytotoxic properties. The motivation for this research is the current antimicrobial resistance (RAM). This is a threat to human health and development worldwide. RAM is caused by the emergence of bacterial strains resistant to traditional antibiotics that were used as treatment. Due to this, the need to investigate new alternatives for preventing and treating bacterial infections emerges. In this sense, metal oxide NPs have aroused great interest due to their unique physicochemical properties. However, their use is limited by the nanostructured nature, commonly obtained by chemical and physical synthesis methods, as powders or colloidal dispersions. Therefore, the incorporation of nanostructured materials in polymer matrices to obtain hybrid materials that allow disinfecting and preventing the spread of bacteria on various surfaces. Accordingly, this work presents the synthesis and study of the antibacterial properties of the P3HB@$NiFe_2O_4$ hybrid film as a potential material to inhibit bacterial growth. The $NiFe_2O_4$ NPs were previously synthesized by a mechanochemical method. The P3HB and P3HB@$NiFe_2O_4$ films were obtained by the solvent casting method. The films were characterized by X-ray diffraction (XRD), Raman scattering, and scanning electron microscopy (SEM). The XRD pattern showed that the $NiFe_2O_4$ NPs were incorporated into the P3HB polymer matrix and retained their nanometric sizes. By energy dispersive X-ray spectroscopy (EDS), it was observed that the NPs are homogeneously distributed in the film. The bactericidal effect of the films obtained was evaluated in vitro using the broth surface method against two opportunistic and nosocomial pathogens, Staphylococcus aureus and Pseudomonas aeruginosa. The bacterial growth results showed that the P3HB@$NiFe_2O_4$ hybrid film was inhibited by 97% and 96% for S. aureus and P. aeruginosa, respectively. Surprisingly, the P3HB film inhibited both bacterial strains by around 90%. The cytotoxicity of the $NiFe_2O_4$ NPs, P3HB@$NiFe_2O_4$ hybrid film, and the P3HB film was evaluated using human skin cells, keratinocytes, and fibroblasts, finding that the NPs are biocompatible. The P3HB film and hybrids are cytotoxic, which demonstrated that although P3HB is known and reported as a biocompatible polymer, under our work conditions, P3HB was cytotoxic. Its bactericidal effect could be related to this activity. Its films are bactericidal and cytotoxic to keratinocytes and fibroblasts, the first barrier of human skin. Despite this, the hybrid film of P3HB@$NiFe_2O_4$ presents synergy with the bactericidal effect between P3HB and NPs, increasing bacterial inhibition. In addition, NPs decrease the cytotoxicity of P3HB to keratinocytes. The methodology used in this work was successful in producing hybrid films with antibacterial activity. However, future challenges are generated to find relationships between NPs and P3HB that allow taking advantage of their bactericidal properties and do not compromise biocompatibility.

Keywords : poly-3-hydroxybutyrate, nanoparticles, hybrid film, antibacterial
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