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Effects of Ionizing Radiation on the Physical and Mechanical Properties of Polylactic Acid: The Presence of Moisture

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Background of the Study:

Polylactic acid (PLA) is a biodegradable polymer widely used in various applications due to its environmental benefits. However, its mechanical properties including brittleness and low thermal stability, limit its broader adoption. Ionizing radiation (gamma irradiation, electron beam) is known to modify polymer properties by inducing chain scission and crosslinking reactions. The impact of radiation on PLA has been mainly investigated in blends, while research on pure PLA remains limited. Additionally, the effect of moisture content on radiation-induced changes has yet to be explored.

Methodology:

This study aimed to analyze the effect of gamma irradiation on the mechanical properties of PLA samples with different moisture contents. Three types of PLA with varying D-lactide contents were tested. Samples were produced by injection molding. Prior to irradiation, some specimens were stored in ambient humidity conditions, while others were dried and kept in a low-moisture environment. These were subjected to gamma irradiation at doses of 50, 100, and 150 kGy. Mechanical properties were assessed using tensile testing, Charpy impact testing, dynamic mechanical analysis (DMA), and differential scanning calorimetry (DSC). Scanning electron microscopy (SEM) was used to examine fracture surfaces.

Results:

The findings indicated that gamma irradiation significantly altered the properties of PLA. At 100 kGy, a substantial decrease can be observed in tensile strength, and at 150 kGy, brittle fracture occurred. Charpy impact tests confirmed reduced toughness at higher doses. DMA results revealed no significant change in storage modulus or glass transition temperature. DSC analysis showed only minor alterations in thermal properties, while crystallinity changes were not substantial. The presence of moisture before irradiation did not significantly affect the measured properties.

Conclusion:

Gamma irradiation induced degradation in PLA, with chain scission being the dominant effect over cross-linking. The most pronounced impact on mechanical properties was observed at higher doses, while thermal properties remained relatively stable. Moisture presence prior to irradiation had no significant influence on the degradation trends. These findings contribute to the deeper understanding of PLA's behaviour under radiation stress, providing insights for controlled degradation applications.