Contribution ID: **405** Type: **Presentazione orale**

ASSESSING THE POTENTIAL OF OPUNTIA FICUS-INDICA SPINES FOR BIODEGRADABLE COMPOSITES

Thursday 3 September 2026 15:15 (15 minutes)

Natural reinforcements derived from *Opuntia ficus-indica* have attracted increasing attention for biodegradable composite applications, particularly in agriculture and packaging. While cladode fibers, flours, mucilage, and their combinations have already been investigated, spines used as standalone reinforcements remain largely unexplored despite their hierarchical structure and potentially favorable mechanical properties.
This study assesses the potential use of *Opuntia ficus-indica* spines as reinforcements for biodegradable composites, using polylactic acid (PLA) as a reference matrix. After providing a detailed overview of the current state of research in this field, integrating available experimental data and highlighting the main trends governing the mechanical behavior of plant-based reinforcements, the study develops and applies a comparative micromechanical predictive framework based on mechanical and morphological data available in the literature.
Within this framework, the mechanical response of PLA-based composites reinforced with *Opuntia* spines is predicted and compared with that of related systems based on other *Opuntia*-derived constituents. The comparison is further extended to potential composite systems incorporating spines from other cactus species. A unified micromechanical approach is adopted to estimate elastic modulus and tensile strength as a function of reinforcement type and volume fraction.
The results indicate that *Opuntia* spines exhibit a high potential for mechanical reinforcement, with the micromechanical predictions showing higher stiffness and strength than those associated with the other plant-derived constituents considered in this study. These trends are consistent with their high cellulose crystallinity, aligned microfibrillar structure, and favorable geometry. Preliminary experimental observations, although limited and exploratory, showed trends consistent with the micromechanical predictions.
Overall, the proposed micromechanical framework provides a structured basis for comparing different reinforcement strategies and supports the potential of *Opuntia ficus-indica* spines as promising candidates for biodegradable composite applications.

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Session Classification: Compositi

Track Classification: Meccanica dei Materiali