Mechanical Performance Evaluation of 3D-Printed TPU and PLA Fibers Compared to Commercial PE/PP Artificial Turf Under Variable Temperature Conditions

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Artificial turf systems are essential for modern sports infrastructure; however, their long-term safety and playability are often compromised by the mechanical qualities of traditional polymers. This research evaluates the temperature dependent effects on elastic recovery and structural resilience of 3D-printed thermoplastic polyurethane (TPU) and polylactic acid (PLA) fibers, compared against industry-standard polyethylene/polypropylene (PE/PP) fibers. To simulate diverse global climates, samples were tested across four controlled thermal environments: 280.15 K, 292.15 K, 296.15 K, and an extreme heat condition of 325.15 K. The study employed two primary metrics: a 90° bending test to measure flexibility and standardized compression cycles using a 400g jig to determine permanent deformation. Results indicate that TPU is the most viable high-performance alternative, consistently maintaining an elite recovery rate of 93–98% across the entire thermal spectrum. In contrast, PLA demonstrated extreme environmental sensitivity, suffering total structural collapse at 325.15 K and significant brittleness at 280.15 K. While the commercial PE/PP controls provided a stable baseline, they were significantly more prone to matting and permanent flattening of fibers compared to the 3D-printed elastomers. Statistical interaction plots confirm that while the mechanical performance of traditional turf is highly dictated by environmental temperature, TPU provides superior thermal stability. Economic analysis reveals that a TPU-fiber field requires only a 3.5% premium in raw material costs, a negligible increase when balanced against its superior lifespan and thermal resilience. These findings suggest that 3D-printed TPU is a promising, resilient, and safer artificial turf.

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