

Recycled Polypropylene Raffia Waste for Injection Molding: Processability and Life-Cycle Impact

Angie Mendoza^{a,b}, Irina Ñacato^{a,c}, Estephany Adrian^{a,b}, Sebastian Ponce^d and Andrés Rigail-Cedeño^{a,b,*}

^aFacultad de Ingeniería en Mecánica y Ciencias de la Producción, Escuela Superior Politécnica del Litoral, ESPOL, Campus Gustavo Galindo Km 30.5 Vía Perimetral, Guayaquil, Ecuador

^bLaboratorio de Procesamiento de Plásticos, Escuela Superior Politécnica del Litoral, ESPOL, Campus Gustavo Galindo Km 30.5 Vía Perimetral, Guayaquil, Ecuador

^cLaboratorio de Evaluación de Materiales (LEMAT), Escuela Superior Politécnica del Litoral, ESPOL, Campus Gustavo Galindo Km 30.5 Vía Perimetral, Guayaquil, Ecuador

^dDepartamento de Ingeniería Química, Colegio de Ciencias e Ingenierías, Universidad San Francisco de Quito (USFQ), Quito 170901, Ecuador
arigail@espol.edu.ec

Abstract

This study examines the utilization of polypropylene raffia (RPP) waste from the shrimp industry as a viable feedstock for injection molding, addressing one of the most abundant post-consumer residues in Ecuador's coastal sector. Ecuador is the world's leading shrimp exporter, with over 120 million polypropylene sacks distributed annually across agribusiness, aquaculture, food, and construction sectors, making the shrimp industry the most significant consumer. Blends of post-consumer raffia polypropylene sacks with virgin polypropylene (PP), recycled low-density polyethylene (rLDPE) sacks, and isotactic polypropylene-based additives (IPE, Vistamaxx 8880 and 6502) were compounded using a torque rheometer. These blends were then characterized through melt flow index measurements, tensile testing, and life cycle assessment (LCA). Incorporating 5–10 wt% IPE significantly reduced peak torque and specific energy consumption by over 40%, stabilized fusion behavior, and lowered processing temperatures and fusion time. These improvements would facilitate faster melt flow, shorter cycle times, and enhanced processability of heterogeneous waste-derived inputs. Compatibilization with IPE enhanced the homogeneity of the material and partially restored tensile strength that had been compromised due to contamination. The tensile strength improved to values ranging from 8 to 12 MPa, consistent with the Young's modulus increase from 600 MPa to 1100 MPa, as reported in the recycled raffia composites. By integrating transportation, end-of-life scenarios, and Ecuador's specific electricity mix, the assessment would provide a robust benchmark for circular economy strategies. In fact, embodied energy was reduced by up to 37% and carbon footprint by 32% for a representative drawer case study. The dominant contributions to impact reduction stem from decreasing virgin resin production, lower processing demands, and closed-loop substitution potential at end-of-life. These findings provide scientific and industrial evidence that shrimp raffia waste can be transformed into sustainable, cost-efficient injection-molding feedstock, contributing to circular economy strategies in Ecuador and similar contexts. The inspiring environmental benefits of this research underscore its potential to impact sustainability and resource conservation significantly.