cbecimat26
26° Congresso Brasileiro de Engenharia e Ciência dos Materiais
22 a 26 de novembro de 2026
Costão do Santinho
Florianópolis-SC

ROLE OF MECHANICAL RECYCLING OF PLASTIC WASTE IN ENVIRONMENTAL SUSTAINABILITY: A CASE STUDY OF THE SEMENTE DO AMANHÃ ASSOCIATION

Flávia Gonçalves[1]; Thaís Helena Sydenstricker Flores-Sahagun[1]
[1]Federal University of Paraná (UFPR) – Polymer Laboratory (LAPOL)

Introduction

In 2025, the Semente do Amanhã Association received 1,307,714.01 kg of materials, of which 286,619.00 kg (22%) were classified as rejects (non-recyclable materials). These materials are not sent to landfills; instead, they are sold for approximately BRL 0.03/kg (BRL 30.00 per metric ton) and directed to energy recovery in industrial processes. Importantly, this amount represents all rejects, not only the S/Al and C/Al packaging investigated here (the polymeric fraction).

Objectives

To assess the technical feasibility of laboratory-scale mechanical recycling of post-consumer polymer waste considered unsuitable for conventional recycling, comprising transparent packaging without an aluminum layer (S/Al) and colored packaging containing an aluminum layer (C/Al), through thermal, mechanical, and morphological characterization of the processed materials, while discussing their potential contributions to environmental sustainability and solid waste management.

Methodology

Material preparation and specimen fabrication were performed at the Polymer Laboratory (LAPOL), Federal University of Paraná (UFPR). Source: post-consumer waste from the Semente do Amanhã Association. Classification: transparent packaging without aluminum (S/Al) and colored packaging with aluminum (C/Al). Preparation: sorting, washing, air drying, and shredding. Processing: extrusion, pelletizing, and hot-compression molding, retaining the aluminum layer in C/Al samples. Formulations: commercial virgin PP (180 °C; compression-molded only; independent reference); S/Al (200 °C); C/Al and the 50/50 blend (210 °C), with the latter three extruded and compression-molded. Characterization: tensile testing (ASTM D638), Differential Scanning Calorimetry (DSC), and Scanning Electron Microscopy (SEM).

Results and Discussion

The S/Al, C/Al, and 50/50 blend formulations were extruded and subsequently hot-compression-molded at 200 °C (S/Al) and 210 °C (C/Al and blend), yielding test specimens for all three formulations. The results demonstrate the initial technical feasibility of laboratory-scale mechanical recycling, including aluminum-containing packaging, and suggest that packaging characteristics may influence processability. Differential Scanning Calorimetry (DSC): The recycled samples showed thermal transitions consistent with a polypropylene (PP)-based semicrystalline phase, with melting temperatures of 168.4 °C (S/Al), 163.2 °C (C/Al), and 166.1 °C (50/50 blend), close to commercial virgin PP (169.2 °C). Apparent crystallinity values were 42.56% (S/Al), 37.25% (C/Al), and 37.37% (blend), compared with 48.74% for virgin PP. C/Al had the lowest melting enthalpy and apparent crystallinity, closely resembling the blend despite the addition of 50% S/Al. This similarity may reflect compositional heterogeneity and the materials crystallization characteristics.

Tensile Testing and Scanning Electron Microscopy (SEM): As shown in Figure 1, S/Al exhibited the highest tensile strength among the recycled materials (28.82 MPa), corresponding to 86.5% of commercial virgin PP (33.30 MPa), indicating its potential for material recovery. C/Al showed the lowest strength (8.65 MPa), whereas the 50/50 blend displayed an intermediate value (13.53 MPa).

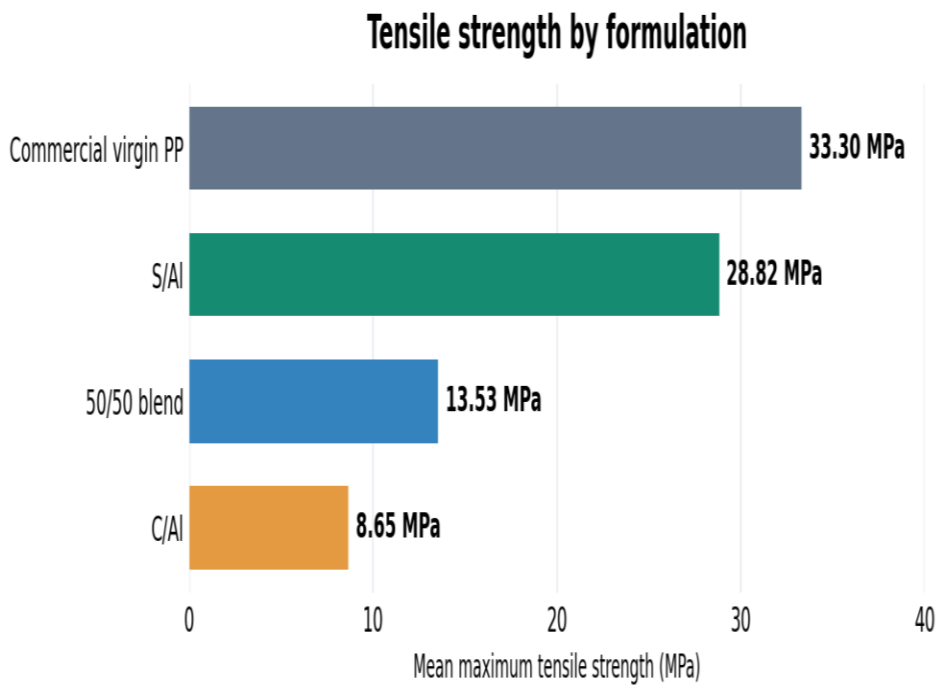


Figure 1. Tensile test results.

SEM micrographs of the recycled specimens, obtained after tensile testing, revealed morphological differences in fracture regions. S/Al showed relatively continuous regions, whereas C/Al exhibited more irregular features, including cavities and localized fibrillar structures. The 50/50 blend displayed intermediate, heterogeneous characteristics. These features are consistent with the different mechanical performances but do not establish aluminum as their sole cause.

Conclusions

The study demonstrated the initial technical feasibility of laboratory-scale mechanical recycling of post-consumer packaging considered unsuitable for conventional recycling, including aluminum-containing materials. The S/Al formulation exhibited the best mechanical performance, whereas the C/Al formulation showed greater limitations associated with the characteristics of the packaging materials. The results indicate potential for material recovery from waste currently directed to energy recovery, underscoring that separate collection alone does not ensure effective recycling. The study acknowledges the role of the Semente do Amanhã Association and environmental workers, connecting the technological investigation to the circular economy, Brazil's National Solid Waste Policy (PNRS), and the Sustainable Development Goals (SDGs), particularly SDG 11 - Sustainable Cities and Communities and SDG 12 - Responsible Consumption and Production.

Further research involving Life Cycle Assessment (LCA), techno-economic feasibility, and recovery indicators is needed to verify environmental and socioeconomic benefits and compare mechanical recycling with current energy-recovery routes.

References and Acknowledgments

ABOLPOUR, B.; ABBASLOU, H.; ZARE, Sh.; KHOJASTEHNEZHAD, M. Optimizing Circular Economy in Electric Arc Furnace Steel Production: a comprehensive 4Rs approach. Circular Economy and Sustainability, v. 5, n. 5, p. 4055–4073, 2025.

AMARIEI, Georgiana; ROSAL, Roberto. Plastic circularity: challenges, opportunities, and future pathways. Cambridge Prisms: Plastics, v. 3, e39, 2025. Published: Oct. 28, 2025. Accessed: Apr. 26, 2026.

FORLIN, Flávio J.; FARIA, José de Assis F. Considerações sobre a reciclagem de embalagens plásticas. Polímeros: Ciência e Tecnologia, v. 12, no. 1, pp. 1–10, 2002. Accessed: Apr. 28, 2026.

Acknowledgments: Semente do Amanhã Association; UFPR; CNPq (grant no. 302459/2023-5); and CAPES.