SUMMARY

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Recyclability of Polystyrene Bead Foams:
Degradation Behaviour over 10 Extrusion Cycles

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New study demonstrates the robustness of EPS recycling under EU regulatory conditions

A recent peer-reviewed study conducted by the Polymer Engineering Department of the University of Bayreuth provides new, robust evidence on the recyclability of expanded polystyrene (EPS) bead foams. Published in *Polymer Engineering & Science*, the research evaluates EPS recycling performance under conditions explicitly aligned with the EU Packaging and Packaging Waste Regulation (PPWR).

By simulating ten consecutive mechanical recycling cycles with a constant recycled content of 35 by weight (wt%), the study offers one of the most detailed assessments to date of how EPS behaves when repeatedly reprocessed. Its conclusions bring important clarity to ongoing discussions on recycled content targets, material performance and the practical implementation of circular economy requirements for EPS packaging.

Testing EPS recyclability under realistic PPWR conditions

The study was designed to mirror future industrial practice under the PPWR, which sets minimum recycled content requirements for packaging applications. Each extrusion cycle incorporated 35 wt% recycled EPS blended with 65 wt% virgin material, reflecting the regulatory framework expected to apply across the EU.

This experimental setup allowed the researchers to assess cumulative effects over time, rather than isolated recycling steps. Crucially, key indicators such as molar mass and melt flow index (MFI) remained nearly constant across all ten cycles. This demonstrates that repeated mechanical recycling, when carried out under controlled conditions and with appropriate blending, does not inherently lead to progressive molecular degradation of EPS.

From a regulatory and industrial perspective, this finding is significant. It confirms that the PPWR recycled content threshold can be technically met without compromising the fundamental processability of EPS over multiple recycling loops.

Understanding mechanical performance: early adaptation, then stability

While molecular indicators remained stable, the study observed a reduction in mechanical properties during the first recycling stages. Over the initial four cycles, compression modulus decreased by 24%, flexural modulus by 14% and flexural strength by 21%.

However, the study provides a possible explanation: these changes are not driven by polymer chain scission. Instead, they are linked to faster diffusion of the blowing agent (pentane), which leads to shorter cycle times during moulding. In other words, the loss in mechanical performance is governed by diffusion behaviour and subtle morphological changes in the foam structure, not by irreversible chemical degradation of the polymer.

After the fourth cycle, both processing behaviour and mechanical properties reached a clear plateau. From this point onwards, no further significant deterioration was observed up to the tenth cycle. This stabilisation demonstrates that EPS reaches a steady and predictable material condition when recycled with a constant 35 wt% recycled content, providing reassurance for long-term industrial use.

Identifying critical points in a full recycling loop

Beyond repeated extrusion, the study also examined a complete post-use recycling loop (referred to as C+1), including prefoaming, welding, compression, shredding and pelletising. This closed-loop scenario represents a full EPS life cycle before reprocessing.

Here, the researchers identified pelletising as the most critical step in terms of material degradation. During this phase, a 15% drop in molar mass and a corresponding increase in MFI were observed. Other stages of the recycling loop had a far more limited impact.

This insight is particularly valuable for industrial optimisation. It shows that EPS recycling performance is not constrained by recycling itself, but by specific processing steps that require careful control. Monitoring pelletising conditions and managing blowing agent diffusion emerge as key levers to further improve circular EPS production.

Conclusion: strong evidence for circular EPS production

Overall, this study delivers clear and actionable conclusions for both industry and policymakers. It demonstrates that EPS bead foams can withstand multiple mechanical recycling cycles when blended with virgin material, in line with PPWR requirements. After an initial adaptation phase, both mechanical performance and processing behaviour stabilise, supporting reliable and repeatable industrial applications.

At the same time, the research identifies where attention should be focused to further strengthen circularity: controlling pelletising intensity and managing blowing agent diffusion. Addressing these aspects will allow the EPS value chain to meet regulatory objectives while maintaining performance, predictability and material quality.

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