5th World Conference on Sustainability, Energy and Environment

Prague, Czech Republic 18 – 20 September 2025

Enhancing Recycling Efficiency for Fibre-based Composite Packaging

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ABSTRACT

Cellulose fibre-based multi-layer packaging (MLP), such as beverage cartons, coffee cups and food trays, has gained significant attention as a sustainable alternative to plastic due to the biodegradable nature of cellulose fibers. Take beverage carton as an example, in 2023, global consumption exceeded 250 billion—demanding around 5 million tons of slowgrowing softwoods. Yet only 20–30% of these fibers are successfully recycled, exacerbating resource depletion. The core challenge is the polyethylene (PE) barriers which sandwiched papers and impeded water penetration, extending disintegration times from 2-4 minutes (plain paper) to 20-40 minutes. Prolonged processing not only escalates energy consumption but also contaminates fibers with residual plastics, diminishing pulp quality. Current study investigates the delamination and disintegration mechanisms underlying hydropulping, highlighting the critical influence of hydrodynamic cavitation. By inducing cavitation through ultrasonic and thermal treatments, its damage effect on interfacial bonds between PE and paper was demonstrated. Building on this insight, a pretreatment system was proposed to separate the MLP through intensive cavitation pretreatment. Experimental trials validated a 90%+ reduction in disintegration time which is comparable to current industrial processing time. By elucidating the role of cavitation in beverage carton recycling, this work provides actionable strategies for advancing circular economy initiatives, especially given mandates such as the EU PPWR's requirement of 70% packaging recycling by 2030. The pretreatment solution can potentially integrate with existing recycling infrastructure, necessitating only minimal retrofitting, and offer a scalable means to mitigate reliance on slow-growth softwood resources while decreasing water and energy consumption.

Keywords: hydropulping; beverage carton; multi-layer packaging; recycle; paper