Abstract

Title:

Validation and Commercial Readiness Acceleration of Polymer-Free Home Compostable Lignocellulosic Biomaterial Products under Indian Ambient Conditions

India is undergoing a regulatory transition away from plastic-based food packaging under the Solid Waste Management (SWM) Rules 2016 and subsequent Plastic Waste Management (PWM) amendments. While compostable alternatives are increasingly promoted, most commercially available materials are certified under industrial compostability standards such as EN 13432:2000 (CEN), ASTM D6400-21 (ASTM International), and ISO 17088:2021 (ISO). These standards require aerobic biodegradation under controlled industrial composting conditions at elevated temperatures (typically 55–60°C), with defined disintegration and ecotoxicity thresholds. However, industrial composting infrastructure remains limited across India.

Organic waste processing predominantly occurs through decentralized, ambient condition composting systems at household, community, and institutional levels. Current international standards do not adequately reflect degradation behaviour under these lower-temperature, mixed-waste composting environments.

For home composting, the only internationally recognized certification framework is TÜV Austria's "OK Compost HOME" scheme, which evaluates biodegradation and disintegration at lower temperatures (~20– 30°C) and includes ecotoxicity and plant growth testing. While this provides a benchmark for ambient compostability, it is not contextualized to Indian climatic variability, decentralized waste composition, or integration with informal compost ecosystems. Moreover, India currently lacks a dedicated BIS (Bureau of Indian Standards) protocol for validating polymer-free, compression moulded lignocellulosic packaging under ambient home-composting conditions.

This regulatory and scientific gap creates a significant commercialization barrier for regenerative biomaterial products designed to integrate into decentralized composting systems. Without validated mechanical performance data, ambient compostability benchmarking, soil compatibility assessment, and carbon pathway quantification

aligned with recognized standards, such innovations face delays in certification, institutional procurement, investor confidence, and regulatory acceptance.

Circularbee has developed a polymer-free, agro-waste–based compression moulded beverage cup utilizing lignocellulosic residues such as coffee and coconut biomass. The product is engineered to deliver structural performance under hot beverage conditions while enabling biological reintegration through composting or biochar pathways. The technology is currently positioned at TRL 5 (prototype validated in relevant environment), demonstrating functional structural integrity, thermal usability, and intended home compostability behaviour along with kitchen waste (aligned with upcoming solid waste management rules 2026). To advance toward TRL 7 (system prototype demonstrated in operational environment), structured third-party validation aligned with global benchmarking standards is required.The proposed academia–industry collaboration under the URP framework will address this commercialization bottleneck through independent validation and performance benchmarking, without disclosure of proprietary formulation chemistry.

The first component of the project will focus on mechanical performance validation of finished compression-moulded products. Standardized material testing protocols will evaluate tensile strength, compressive load capacity, and thermal resistance under hot-liquid exposure. Performance metrics will be benchmarked against pulp-based and plastic-based alternatives. Although EN 13432 and ASTM D6400 primarily address compostability rather than mechanical performance, compliance with such standards requires minimum structural integrity prior to compost testing. Generating reproducible mechanical datasets will strengthen regulatory positioning and procurement

The second component will develop and validate an ambient-condition compostability framework reflective of Indian decentralized composting systems. Degradation kinetics, disintegration timelines, and compost maturity indicators will be documented and compared against international criteria outlined in EN 13432, ASTM D6400, ISO 17088, and TÜV OK Compost HOME. While industrial standards require 90% biodegradation within six months under thermophilic conditions, this project will evaluate biodegradation under mesophilic Indian ambient conditions (25–40°C), generating India relevant validation data. Compost maturity and soil safety assessments