

CHAR:ME: biochar and biomass-derived waste products as sustainable and safe domestic fuel

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Abstract

The CHAR:ME project (Polisocial Award 2022) tackles pressing environmental and social issues for Sub-Saharan Africa, with a particular emphasis on Madagascar, by creating sustainable alternatives to conventional wood and charcoal cooking practices. Targeting the Antsiranana region, the project transforms organic waste into biochar, a solid renewable fuel with the aim of halting deforestation and alleviating health issues linked to conventional cooking. Characterization of the locally available biomass wastes, predominantly carpentry sawdust, using elemental analysis and thermogravimetry was carried out. The wastes were mechanically compressed and bio-dried to form biomass briquettes, where various compositions were analyzed for mechanical property maximization. Semi-detailed kinetic mechanisms and particle-scale simulations were employed as sophisticated modeling approaches for predicting the degradation behavior and pyrolysis product distribution. Both 0D and 1D models simulated biomass degradation characteristics, including the exothermic charring reactions and product yields of the selected feedstock. The models were subsequently integrated with full-scale CFD reactor simulations to design an optimal Top-Lit-Up-Draft (TLUD) pyrolytic stove, which efficiently produces both thermal energy for cooking and biochar as a byproduct. The TLUD design, through strategic placement of air inlets, enables clean burning with fewer pollutants being produced, making it far safer than open flames or clay stoves. Comparative testing confirmed that the heating values and yields of biochar produced were similar to that of traditional Malagasy charcoal, making it a viable alternative. A full-text Life Cycle Assessment (LCA) detected profound environmental advantages concerning the CHAR:ME method compared to conventional processes, including -97.54% global warming potential and -68.14% land use impact. The novel process amplifies the entire workflow from the generation of biomass wastes to stove functionality, facilitating waste valorization and transformation while safeguarding Madagascar's distinct biodiversity.