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Isothermal Kinetics of Thermal Degradation on Cattle Manure and Wood using Thermogravimetric Analysis

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The increasing volume of animal waste, driven by the growth of the livestock industry, presents environmental and management challenges. Conventional treatment methods, such as land application or composting often lead to nutrient losses and substantial greenhouse gas emissions [1]. As part of carbon neutrality efforts, thermochemical conversion technologies, particularly pyrolysis and torrefaction, have gained attentions as sustainable alternatives. These processes can convert organic waste, including cattle manure, into valuable energy carriers such as methane- and hydrogen-rich syngas, along with biochar as a long-term carbon sink, contributing to renewable fuel production. While the majority of studies [2] have focused on lignocellulosic biomass (e.g., wood, crop residues), non-lignocellulosic biomass like cattle manure presents distinct challenges due to its high ash, nitrogen, nutrient, and mineral content. These properties lead to complicated decomposition behavior during pyrolysis, strongly influenced by feedstock composition, reaction temperature, and residence time. However, the underlying reaction mechanisms and chemical kinetics of the cattle manure remain insufficiently understood.

This study investigates the isothermal kinetics and thermal degradation behavior of cattle manure (non-lignocellulose) and wood (lignocellulose) using thermogravimetric analysis (TGA) at reaction temperatures ranging from 250 to 450 °C. Systematic investigations were carried out to understand the thermal degradation behavior of non-lignocellulosic biomass (cattle manure) and compare with lignocellulosic (wood) biomass. A single-step global reaction model [3], assuming first- or nth-order kinetics, was used with the Arrhenius rate law to derive key kinetic parameters. Conversion data were analyzed to calculate the reaction rate at each temperature. The corresponding activation energy and pre-exponential factor were obtained from the linearized Arrhenius relationship. The comparative kinetic evaluation revealed distinct thermal reactivity between the two biomass types, highlighting the role of feedstock composition in kinetic behavior and its implications for process optimization. To bridge experimental kinetics with simulation-based reactor design, the obtained kinetic parameters is implemented in a gas-solid reactive flow simulations using a CFD-DEM framework (e.g., OpenFOAM and MFiX). These simulations are compared with isothermal tube furnace experiments to evaluate prediction performance.

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