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Parametric Investigation of Fast Pyrolysis of Cotton Stalk: Influence of Carrier Gas Flow Rate and Biomass Loading on Product Yield

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Abstract

The present study evaluates the influence of carrier gas flow rate and biomass loading on the fast pyrolysis of cotton stalk in a fixed-bed reactor to optimise product distribution and enhance bio-oil quality. Comprehensive feedstock characterisation revealed high volatile matter (86.49 wt.%) and low ash content (0.62 wt.%), along with significant lignin (28%) and extractives (48.6%), indicating strong suitability for thermochemical conversion (Yang et al., 2007; Demirbas, 2004). Pyrolysis experiments conducted at 500°C with a heating rate of 50°C/min demonstrated that product yields are highly sensitive to operating parameters, with maximum bio-oil yield (~20.26 wt.%) achieved at higher biomass loading (60 g) and lower nitrogen flow rate (5 L/min), attributed to prolonged vapour residence time favouring condensation reactions (Bridgwater, 2012). In contrast, higher flow rates increased syngas yield (up to ~66 wt.%) due to enhanced secondary cracking of volatiles (Mohan et al., 2006; Shen et al., 2010), while a moderate flow rate (7.5 L/min) provided an optimal balance between heat transfer and residence time, improving overall conversion efficiency (Di Blasi, 2008). GC–MS analysis revealed dominance of oxygenated aromatic compounds (up to ~70%), primarily derived from lignin decomposition, alongside significant formation of fatty acid alkyl esters (~40%) at higher flow rates, indicating enhanced esterification and volatilisation pathways (Pandey et al., 2015; Zhang et al., 2019). Furthermore, the FT-IR analysis confirmed the presence of phenolics, carbonyls, and hydrocarbons, with reduced oxygenated functionalities at higher flow rates, suggesting improved bio-oil quality (Oasmaa & Czernik, 1999). Overall, lower carrier gas flow rates favour bio-oil production, whereas higher flow rates promote gas formation, and an optimal combination of moderate flow rate with higher biomass loading is identified for producing high-quality bio-oil enriched with valuable chemical intermediates, providing key insights for sustainable biodiesel production from agricultural residues.

ACCEPTED

Keywords: Fast pyrolysis, Cotton stalk, Fatty acids alkyl esters (FAAEs), Carrier gas flow rate, Biomass loading