MODELING FAST PYROLYSIS OF WASTE BIOMASS: IMPROVING PREDICTIVE CAPABILITY

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Unlocking the potential of waste biomass as a source of renewable energy and chemicals is crucial for sustainable development, and fast pyrolysis offers a promising solution. However, the complexity of the process poses significant challenges for accurate modeling. In this study, we discuss the design of predictive and flexible models that can accurately characterize the produced condensates by considering important factors such as biomass characteristics, degradation kinetics, and phase equilibria. Due to the concurrent complex phenomena taking place, modeling the reactor stage is challenging. Commonly used approaches such as black box models and Gibbs energy minimization models fail to provide the necessary predictive and flexible capabilities. Our study shows that kinetic-based primary pyrolysis models, such as those available in the literature, are able to estimate the product distribution of a fast pyrolysis process, with the added benefit of predicting the composition of bio-oil(s). However, our study reveals that the consideration of secondary pyrolysis is critical for achieving accurate predictions (Figure 1).

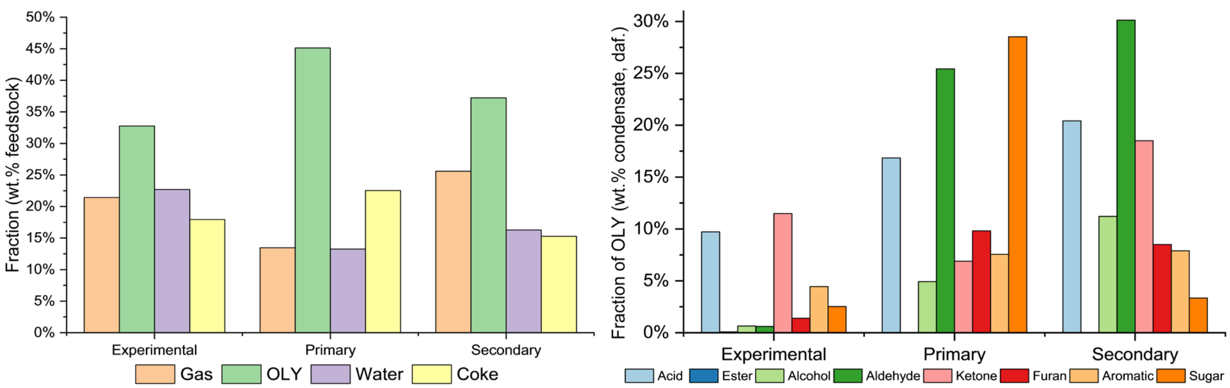

Figure 1 – Contrasting model results using only primary pyrolysis, primary + secondary pyrolysis, and experimental data, using different reactor models, and comparing with experimental results.

Phase equilibria phenomena entail the availability of several thermophysical and interaction parameters for the species present in the mixture, and inherently dynamic phenomena like recirculating quenching of pyrolysis vapors are difficult to model in steady-state, especially when the flow rate of quenching media is much higher than that of incoming vapor. To address this challenging issue, we developed four different loop starter surrogate mixtures based on analyses of bio-oils, and our results demonstrate that more complex surrogates offer better predictions, but may sacrifice some predictive ability when operational conditions are modified (Figure 2). By highlighting the challenges and opportunities in modeling biomass fast pyrolysis processes, our study offers crucial insights for designing more predictive and flexible models.