Chapter 7
Fundamental Theories and Kinetic Models for the Pyrolysis of Lignocellulosic Biomass Wastes

Olagoke Oladokun
University of Maiduguri, Nigeria

Bemgba B. Nyakuma
Universiti Teknologi Malaysia, Malaysia

Arshad Ahmad
Universiti Teknologi Malaysia, Malaysia

ABSTRACT

Biomass agricultural waste has a great potential for meeting part of the world energy need and is completely environmentally friendly. One conversion method is thermochemical processes and specifically, pyrolysis. Pyrolysis converts the lignocellulose waste to fuel and essential chemicals into three products: biogas, bio-oil, and biochar. However, performance issues limit the potential of lignocellulose pyrolysis such as design and operation of pyrolysis reactor for effective heat transfer from the heat source to the biomass feedstock. Therefore, this study presents the necessary tools for pyrolysis scientists and engineers in determining the optimal operation and design of lignocellulose agricultural waste pyrolysis. The tools consist of mathematical equations that govern the lignocellulose kinetics (model and model-free) and pyrolysis reactor macro and micro models. A practical model for hydrogen production from pyrolysis bio oil solidifies the viability of biomass as an energy source.

DOI: 10.4018/978-1-7998-0369-0.ch007

INTRODUCTION

Biomass is an abundant, renewable and sustainable source of energy for the future. Biomass typically includes agricultural waste residues, forest waste products, municipal solid waste and energy crops such as perennial grasses (Hayes, 2013; Liew, Hassim, & Ng, 2014; Mohammadi et al., 2011). Biomass has been burnt directly to generate heat for household, gasified to power engines or converted to biofuels and syngas by pyrolysis and other thermochemical processes (Ahmed et al., 2015; Basu, 2013; A. V. Bridgwater, 2012; Miller & Bellan, 1997). A vast amount of biomass is produced every year and of that only 5% (13.5 billion metric tonnes) are effectively converted to energy, which is equivalent to about 26% of the world's energy consumption (Basu, 2013). Figure 1 gives the biomass resources and their energy contribution (Balat, 2008; Demirbas, 2007; L. Zhang, Xu, & Champagne, 2010)).

However, the conversion of agroforest and agricultural product into bioenergy and biofuels presents significant challenges for the environment and human food supply (Oladokun et al., 2017; Sims, Mabee, Saddler, & Taylor, 2010). Consequently, the search for alternative biomass feedstocks such as perennial energy grasses must continue. Numerous studies have investigated the carbonization, torrefaction, gasification and pyrolysis potential of energy grasses such Miscanthus, Switchgrass, and Canary Reed (Floudas, Elia, & Baliban, 2012; Heaton et al., 2010; Lemus et al., 2002; Moutsoglou, 2012; Woli et al., 2011; Yang, Yan, Chen, Lee, & Zheng, 2007). Other potential energy grasses such Elephant grass, and *Imperata cylindrica* found around the world can also be utilised for bioenergy applications.

The conversion of biomass resources into solid, liquid and gaseous products such as biohydrogen through biochemical or thermochemical routes is widely reported in the literature (Monlau et al., 2013; Nyakuma et al., 2014; X. Zhang, Wang, Ma, Zhang, & Jiang, 2013). The biochemical route involves the breakdown of biomass molecules by enzymes or acid (enzymatic or acid hydrolysis) into sugar and subsequent fermentation to bioethanol (Balan et al., 2012; Basu, 2013). The process is well established and cost effective due to advances in research and optimisation of fermentation. However, biochemical processing of biomass into fuels cannot be easily integrated into existing commercial refining operation compared to thermochemical routes (Anthony V. Bridgwater, 2012). Combustion, pyrolysis and gasifi-

Figure 1. Biomass resources and energy contribution