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Kinetics of switch grass pellet thermal decomposition under inert and oxidizing atmospheres

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HIGHLIGHTS

- Switch grass pellets have higher ash and chlorine content compared to wood.
- Thermogravimetric analysis (TGA) has been conducted of grass pellets.
- Two major loss process: volatilization and burning or slow oxidation.
- Activation energy and pre-exponential factors were high for oxidizing environments.
- During pyrolysis, the activation energy was 314 kJ/mol.
- In air the activation energy was 556 kJ/mol.

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ABSTRACT

Grass pellets are a renewable resource that have energy content similar to that of wood. However, the higher ash and chlorine content affects combustion. Thermal degradation analysis of a fuel is useful in developing effective combustion. Thermogravimetric analysis (TGA) of the thermal degradation of grass pellets under inert (nitrogen) and oxidizing (air) atmospheres was conducted. Non-isothermal conditions were employed with 4 different heating rates. Kinetic parameters (activation energy and pre-exponential factors) were estimated using the iso-conversional method. Both pyrolysis and oxidative atmospheric thermal degradation exhibited two major loss process: volatilization of cellulose, hemicelluloses and lignin and burning or slow oxidation of the residual char. The activation energy and pre-exponential factors were high for the oxidizing environment. During pyrolysis, major decomposition occurred with 40% to 75% conversion of the mass to gas with an activation energy of 314 kJ/mol. In air the decomposition occurred with 30% to 55% conversion with an activation energy of 556 kJ/mol. There was a substantial effect of heating rate on mass loss and mass loss rate. The TG shifted to higher temperature ranges on increasing the heating rate. In both pyrolyzing and oxidizing conditions, average combustion and devolatilization rates increased. Enhanced combustion takes place with higher activation energy in oxidizing atmosphere compared to the inert atmosphere due to presence of air.

1. Introduction

Biomass based fuels have found renewed interest because of the rising cost of oil (Luque et al., 2008). Common sources of biomass include wood, agricultural crops and their residues (Vassilev et al., 2010). Although more research is being done on wood as a fuel, there is a growing interest in alternative, fast growing plants like grasses. Grasses have several advantages over other feedstocks for biomass-based fuel production because they are a local resource that can support local economic models. The energy content from grass pellets is similar to that of wood pellets and is a rapidly renewable resource with multiple harvests per year. Grasses can be grown on marginal farmlands that would otherwise not be used. In New York State, there are about 1.5 million acres of underutilized agricultural land that could be used to grow grass (Cherney, 2006). However, there are issues that need to be resolved with respect to the high ash and chlorine content of grass pellets (Van Loo and Koppejan, 2008). These issues could possibly be addressed using soil management techniques or by using better, advanced staged combustion units (Cherney, 2006; Van Loo and Koppejan, 2008).

The thermal conversion process is generally conducted in a chamber in one of the three ways; pyrolysis, gasification, and combustion (Van Loo and Koppejan, 2008). Pyrolysis is defined as the

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