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Combined effect of pelleting and pretreatment on enzymatic hydrolysis of switchgrass

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ABSTRACT

Switchgrass was pelleted to evaluate the effect of densification on acidic and alkaline pretreatment efficacy. Bulk density and durability of pellets were 724 kg/m^3 and 95%, respectively. Ground switchgrass (D_{90} = 21.7 mm) was further ground to a fine power (D_{90} = 0.5 mm) in the pellet mill prior to densification. This grinding increased enzymatic hydrolyzate glucose yields of non-pretreated materials by 210%. Pelleting had no adverse impact on dilute acid pretreatment efficacy. Grinding and pelleting increased hydrolyzate glucose yields of switchgrass pretreated by soaking in aqueous ammonia (SAA) by 37%. Xylose yields from SAA-pretreated switchgrass pellets were 42% higher than those from the original biomass. Increases in sugar yields from SAA-pretreated pelleted biomass are attributed to grinding and heating of biomass during the pelleting process. Potential transportation, storage, and handling benefits of biomass pelleting may be achieved without negatively affecting the downstream processing steps of pretreatment or enzymatic hydrolysis.

1. Introduction

Low densities of biomass feedstocks and the associated handling, transportation, and storage costs are major impediments to the utilization of biomass for biofuel production. The densification of biomass into uniform pellets could be one method to reduce these challenges. Pelleting increases the biomass density by almost ten-fold (Tumuluru et al., 2011) thereby facilitating easy handling and decreasing transportation and storage costs (Hess et al., 2007). Significant work has been done to study the densification characteristics of agricultural and woody biomass (Kaliyan and Morey, 2010; Larsson et al., 2008; Mani et al., 2006).

The recalcitrant structure of lignocellulosic biomass is another challenge to commercial bioethanol production. Expensive pretreatment is needed for disruption of cell wall structures to make polysaccharides more accessible to enzymes for effective hydrolysis. Several cost-effective methods including dilute acid (DA) and soaking in aqueous ammonia (SAA) pretreatments have been developed to disrupt plant cell wall structures for efficient bioconversion of lignocellulosic biomass to fermentable carbohydrates (Tao et al., 2011; Wyman et al., 2011).

Chemical pretreatment of biomass increases the biomass surface area and pore volume through delignification, hemicellulose solubilization, and reduction in cellulose crystallinity (McMillan, 1994). Acid treatments are more effective for hemicellulose solubilization while alkaline pretreatments are more effective for lignin solubilization with minimal losses of cellulose and hemicellulose. Physical pretreatments of biomass reduce particle size and cellulose crystallinity in order to increase the specific surface area and reduce the degree of polymerization. Extrusion has been shown to be an effective pretreatment for many forms of biomass (Karunanithy and Muthukumarappan, 2010; Karunanithy et al., 2008), although in one case it negatively affected sugar release from soybean hulls (Lamsal et al., 2010). This effect was attributed to the interaction of lignin with carbohydrate fibers during extrusion.

Pelleting increases biomass bulk density through mechanical and thermal processing similar to extrusion (Larsson et al., 2008). High temperatures generated in the pelleting process soften lignin and enable it to act as a binder to form durable pellets (Kaliyan and Morey, 2010). Because lignin content and distribution has a strong influence on biomass recalcitrance, alteration of lignin during densification could impact pretreatment efficacy or hydrolysis yields. Theerarattananoon et al. (2011) showed that changes in pelleting parameters can influence sugar yields.

Literature on the impact of pelleting under different pelleting and pretreatment conditions of biomass feedstock is limited; the present study used switchgrass as a model substrate to investigate the interaction of densification and pretreatment. Switchgrass is a promising feedstock for bioethanol production (Hu et al., 2010; Isci et al., 2008) because of its high productivity, suitability for growth

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