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Comparison of laboratory delignification methods, their selectivity, and impacts on physiochemical characteristics of cellulosic biomass

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HIGHLIGHTS

- Delignification was performed employing sodium chlorite–acetic acid and peracetic acid.
- Various raw and pretreated biomass solids and pure cellulose were used.
- Delignification selectivity and effects on cellulose structure were determined.
- Peracetic acid was more selective than sodium chlorite–acetic acid.
- Cellulose MW, reducing ends, and CrI were affected less in delignification with PAA.

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ABSTRACT

Two established delignification methods employing sodium chlorite–acetic acid (SC/AA) and peracetic acid (PAA) are often used, and are reportedly highly selective. However, these reports are mostly for highly recalcitrant and unpretreated softwoods and hardwoods species, and information for less recalcitrant lignocellulosic feedstocks and pretreated biomass is scarce. Furthermore, the effects on cellulose structure are not documented. Thus, in this study, delignification kinetics and selectivity were evaluated when SC/AA and PAA were applied to untreated switchgrass, poplar, corn stover, and pine sawdust; poplar subjected to AFEX, controlled pH, lime, and SO_2 pretreatments; and the cellulose model compounds. Both methods proved effective in removing >90% lignin, but selectivity for lignin and carbohydrates removal was substrate and pretreatment dependent. For untreated biomass, PAA was more selective in removing lignin than SC/AA; however, both methods were less selective for pretreated solids. Cellulose characterizations revealed that PAA had less pronounced impacts on cellulose structure.

1. Introduction

Cellulose, hemicellulose, and lignin are three major components of lignocellulosic biomass, with amounts varying with biomass types (hardwood, softwood, agricultural residues, and energy crops), primary vs. secondary cell walls, ages, and locations (Chundawat et al., 2010; Wyman, 1990). Lignin is believed to surround cellulose and hemicellulose as a complex structure that makes cellulosic biomass highly recalcitrant to enzymes, pathogens and microorganisms (Lynd et al., 1991; Studer et al., 2011). To understand the complex structure of cellulosic biomass and the impact of biomass features on its enzymatic digestibility, delignification is often performed by two common laboratory methods: acidified sodium chlorite or peracetic acid (Chang and Holtzapple, 2000; Ding et al., 2012; Ishizawa et al., 2009; Naran et al., 2009). The sodium chlorite–acetic acid (SC/AA) method, originally known as the Wise method (Wise et al., 1946), is usually performed at 60–70 °C for 4–8 h with successive addition (every hour or two) of fresh sodium chlorite and acetic acid at loadings of 0.3–0.6 g sodium chlorite/g dry biomass and 0.1–0.6 ml acetic acid/g dry biomass (Ahlgren and Goring, 1971; Hubbell and Ragauskas, 2010; Timell, 1961). Whereas, peracetic acid (PAA) delignification is performed at more moderate conditions: 25°C with PAA loadings of 4–5.5 g/g dry biomass and times of 24–48 h (Chang and Holtzapple,

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