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Electron Beam Pretreatment of Lignocellulosic Biomass

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Background:
Cellulose is the major structural component of wood and plant fibers and is the most abundant polymer synthesized by nature. Despite this great abundance, cellulosic biomass has seen limited application outside of the paper industry. Its use as a feedstock for fuels and chemicals has been limited because of its highly crystalline structure, inaccessible morphology and limited solubility. Any economic use of lignocellulosic resources for the production of fuels will require a "pretreatment"technology to enhance the accessibility of the biomass to enzymes and/or chemical reagents. Most pretreatment techniques either are energy intensive or require the use of toxic chemicals. In this study electron beam irradiation was used as a pretreatment technique.

Methodology:
Samples were irradiated at IBA Industrial, Edgewood, New York USA, using a 90 kW, 3 MeV Dynamitron. Most samples were less than 0.5 cm thick with a bulk density of <0.6 g/cc, thus giving equal in equal out dose. Thick (2.5 cm) wood boards were irradiated from both sides giving a uniform dose profile. The dose was determined with cellulose triacetate films.

Molecular weight was determined using a Waters Breeze size exclusion chromatography system fitted with a Waters 2414 refractive index detector, and two Polymer Laboratories Polypore columns (330×7.5 mm2).

The relative1 crystallinity was determined using a Rigaku DMAX-1000 X-ray diffractometer with Ni-filtered Cu Kα radiation (λ=0.15418 nm).

All other tests were conducted in accordance with ASTM or TAPPI standards and gravimetric analysis.

Results:
As the dose was increased from 0 to 1,000 kGy, the molecular weight decreased from 80,000 to 5,000 Da and the relative crystallinity decreased from 0.87 to 0.45. The wood toughness and energy required for milling was decreased by about an order of magnitude. The solubility of irradiated wood in water, 0.2N NaOH and 2.0N NaOH increased with increasing dose with 95% of the wood soluble in 2.0N NaOH after 1,000 kGy. The hot water extraction of hemi cellulose and lignin increased along with dose. The extracted lignin also showed an increase in solubility in acidic solutions.

Most importantly, the rate and total sugar yields from enzymatic hydrolysis increased with increasing dose. There did not appear to be any "poisoning"of fermentation to ethanol due to the presence of furfurals. Sugars extracted from irradiated wood shows an increase in the rate of fermentation.

Conclusion:
Electron beam irradiation of lignocellulosic biomass appears to be an excellent pretreatment technique to reduce the recalcitrance of the biomass. Electron beam treatment is less energy intensive and does not use or produce toxic chemicals than other pretreatment techniques. Electron beam treatment reduces the crystallinity and molecular weight of cellulose, increases hot water extraction of lignin and hemicellulose, and increases the rate and total sugar produced by enzymatic hydrolysis.

Country/Organization invited to participate

United States of America

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