Assessing the Performance of Three Different Sugar Cane Bagasse Pretreatments: Alkaline/NaOH, Alkaline/NH4OH and Organossolv/Ethanol

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Introduction

In Brazil, due to the production of sugar and ethanol from sugar cane, there is a large amount of bagasse that is not consumed for generation of electricity and, therefore, requires other uses. This material is composed by app. 40% of cellulose, 30% of hemicellulose and 30% of lignin. After separation of the other fractions, cellulose can be converted to glucose and fermented to ethanol. Sugar cane bagasse (SCB) is, therefore, the most promising lignocellulosic raw material for ethanol production in Brazil. However, the structure of this material is very stable, preventing its attack by microorganisms. The recalcitrance of this structure is due to the physicochemical interaction between its constitutive polymers, cellulose, hemicellulose and lignin. Hydrolysis of cellulose to glucose can be catalyzed by acids or enzymes. The first one is less expensive, but may degrade the carbohydrates and generate toxic by-products that inhibit fermentation. Several pretreatments have been tested to separate the fractions and increase the accessibility of the enzymes to the substrate, without degradation of the obtained monomers. Two approaches are possible to initiate the separation of the polymers, either using acid water solution to dissolve the carbohydrate fraction and separating lignin as solid, or dissolving lignin and keeping the carbohydrate fraction as solid. Hemicellulose is an amorphous polymer and can be easily attacked by acids. In view of that, even when the second approach is used, it is possible the dissolution of part of the hemicellulose with lignin. The more severe the pretreatment, the more efficient is the separation of the fractions. However, also the higher is the concentration of by-products generated by the degradation of the sugars monomers.

This work focuses on the study of three different pretreatments, alkaline/NaOH, alkaline/NH4OH and organosolv/ethanol. In natura bagasse donated by Centro de Tecnologia Canavieira (CTC, Piracicaba, Brazil) was used throughout this work. Solid samples, which included treated and untreated SCB, were subject to compositional analysis according to NREL standard method. Consecutive saccharification and fermentation of SCB was performed in shake flasks of 250 mL. Saccharification experiments were carried out at 250 rpm and 50oC, 3-10% of solid loading, 20-50 FPU/cellulose (Accellerase 1500, Genencor). SEM of the samples allowed observation of structural modifications of the lignocellulosic matrix.

Results and Conclusions

Experimental conditions and performance indices follow, for each pre-treatment:

1) Alkaline/NaOH: SCB pretreated in autoclave (121C, 2.1 atm), reaction time 15-90 min, 1-7% w/v NaOH solution, using a solid-liquid ration of 1:10 (w/v). The best condition was 7.0% of NaOH, residence time of 30 min: the loss of cellulose was 1.2%, with 81.3% removal of lignin and 83.9% of hemicellulose. Enzymatic assay reached 76.0% of glucose conversion, with a specific productivity of 0.483 (mg-glucose/FPU/h). Fermentation assays reached 90% of the theoretical yield.

2) Organosolv/ethanol: SCB pretreated in a 2.0 L Parr® reactor (300 rpm), reaction time 10-90 min, ethanol 30-70% v/v, temperatures 150, 170 and 190C, using a solid-liquid ratio of 1:10 (w/v). Degree of severity (DS) ranged from 4.2-5.9. The best condition was 190C/10 min/50% ethanol, DS = 5.5: the loss of cellulose was less than 1%, with 78.3% removal of lignin and 86.8% of hemicellulose. Enzymatic assay reached 61.2% of glucose conversion, with a specific productivity of 0.371 (mg-glucose/FPU/h). Fermentation assays reached app. 82% of the theoretical yield.

3) Alkaline/NH4OH: SCB pretreated in a stainless steel cylindrical reactor, reaction time 30-90 min, 4, 10 and 15% w/w NH4OH solution, temperatures 50 and 100C, using a solid-liquid ration of 1:5 (w/w). The best condition was obtained 10% of NH4OH at 100C during 60 min: the loss of cellulose was 1.7%, with 74.9% removal of lignin and 62.1% of hemicellulose. Enzymatic assay reached 69.7% of glucose conversion, with a specific productivity of 0.460 (mg-glucose/FPU/h). Fermentation assays reached app. 90% of the theoretical yield.

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