Bioethanol and biogas production from an alternative valorisation pathway for green waste

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Introduction

Green waste (GW) includes mostly leaves, branches and lignocellulosic debris from grass clippings, hedge cuttings and tree prunings. The amount of this type of biomass continues to increase with the expansion of urban and green space areas. Large quantities are produced in China, USA as well as in the United Kingdom. Given that green waste is a typical lignocellulosic biomass, the energy recovery from this waste is necessary, especially in large urban centers. In this way, the huge amounts of waste that remain unused will be reduced and at the same time the problem of the energy crisis, which is plaguing today, will be reduced as well. However, the chemical composition of the green waste is complex and varies seasonally and locally.

Green waste for energy production has been suggested to be more environmentally friendly. Just a few studies have been carried out on estimating the potential of green waste towards biofuel production. It has been estimated biofuel produced from green waste can offset 1.6–6.5% of the city's transport gasoline demand in Singapore (Shi et al, 2013). The potential and feasibility of using green waste biomass for bioethanol and biogas production shall be explored further within this study.

Materials and Methods

Raw material

Milled green waste utilized in the present study was provided by the Municipality of Zografou, Attica, Greece. It was transferred to the Unit of Environmental Science and Technology (UEST), School of Chemical Engineering, National Technical University of Athens.

Green waste had the following composition (%w/w dry base): Volatile solids 95.50 ± 1.77, water soluble solids 17.73 ± 1.03, cellulose 33.48 ± 2.44, hemicellulose 14.83 ± 4.78, acid soluble lignin 0.23 ± 0.01, acid insoluble lignin 22.28 ± 0.27

Chemical pretreatment

Two pretreatment schemes were applied with either dilute alkaline or dilute acid media in order to examine which chemical pretreatment suits best the feedstock examined. In the first pretreatment scheme, 20 g GW were pretreated in 0.3M dilute NaOH at 50 °C for 96 h while in the second, 20 g GW were pretreated in 0.2M H_2SO_4 at 120°C for 1 h. After the pretreatment period, the samples were used as feedstock for the enzymatic hydrolysis after pH regulation.

Enzymatic hydrolysis

Enzymatic hydrolysis was performed in 250 mL autoclavable bottles. NaOH or H_2SO_4 solution was used to correct the pH to the optimum pH range of 5.0-5.5. Enzymatic saccharification of cellulose was performed at 50oC by the addition of a cellulolytic formulation; Cellic CTec2 (Novozymes, Denmark) for 96h in an Incubator Shaker (IKA-KS 3000i). Dosages of 25 and 75 μL enzyme/g cellulose were adopted.

Alcoholic Fermentation

Bioconversion of the glucose produced to bioethanol via ethanolic fermentation was achieved by the addition of Saccharomyces cerevisiae (2% w/w) in the same autoclavable bottles, at 35°C for 24h.

Anaerobic Digestion

Biomethane potential tests (BMP) were executed in 250 mL autoclavable bottles aiming to assess the anaerobic digestibility of the raw and stillage GW.

Results & Discussion

The production of phenolic compounds during pretreatment was relatively low for both media (136-173mg/L), indicating that phenolic compounds could not stand as an inhibitory factor for the downstream biological processes. On the other hand, the concentration of VFA was quite high for both cases, although it was almost double after alkaline pretreatment (over 14g/L), revealing possible inhibition in the enzymatic saccharification and fermentation steps.

The glucose and total reducing sugars concentrations are higher for both enzyme dosages for the acid pretreatment while the concentration of TOC is higher for the alkaline pretreatment, probably due to the high concentrations of VFA and TOC that were produced after the pretreatment.

The saccharification yield, ethanol yield and glucose conversion efficiency are presented in Figure 1. It is evident that acid pretreatment resulted in higher saccharification (23-26%) and ethanol yields (13-21%), although moderate. It is worth mentioning that after alkaline pretreatment, the glucose conversion was high implying that the fermentation step was not inhibited and the controlling process step was the saccharification.

The results of the BMP tests regarding the raw green waste along with the stillages GW that derived from the optimum experimental conditions for acid (0.2M H_2SO_4, 75μL CellicCtec2/g cellulose) and alkaline (0.3M NaOH, 25μL CellicCtec2/g cellulose) pretreatments are presented in Figure 2.

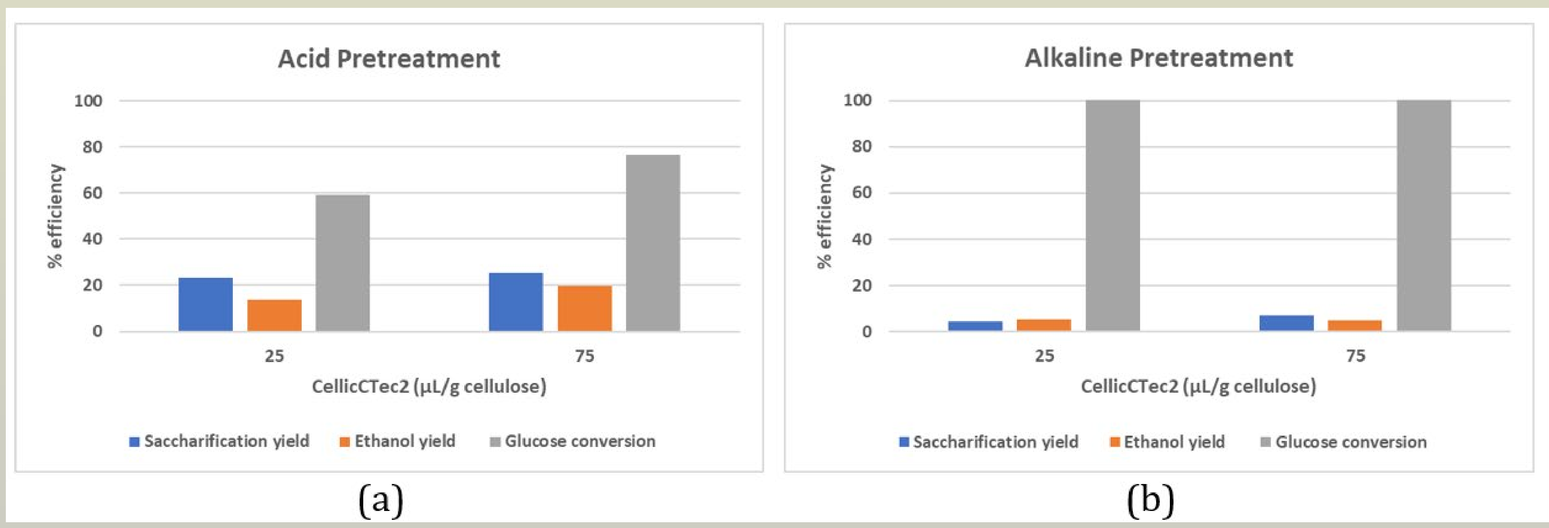

Figure 1: Saccharification yield, ethanol yield and glucose conversion after acid (a) and alkaline (b) pretreatments

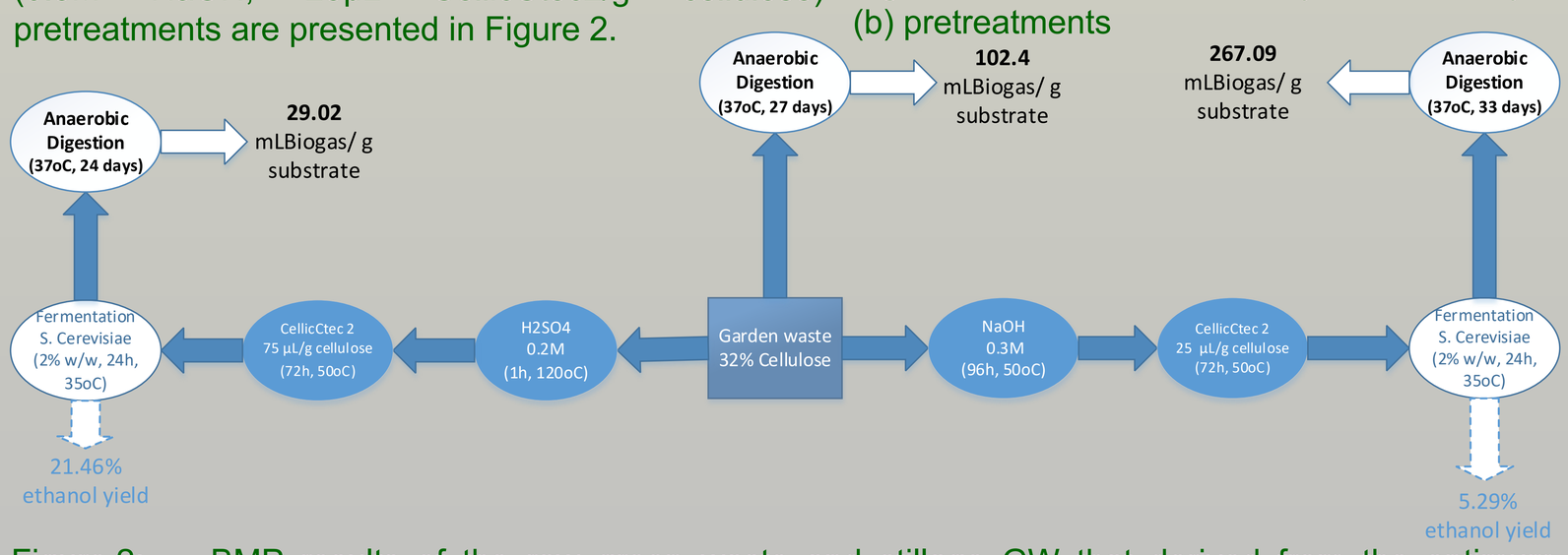

Figure 2: BMP results of the raw green waste and stillage GW that derived from the optimum experimental conditions for acid and alkaline pretreatments

From Figure 2, it can be concluded that alkaline pretreatment promotes anaerobic digestibility of the substrate while acid pretreatment enhances the ethanol yield.

Conclusions

Green waste as an abundant but recalcitrant lignocellulosic waste stream should be suitably pretreated in order to reach its full valorisation potential. A combination of chemical pretreatment with enzymatic hydrolysis could promote different bioenergy pathways; biogas and bioethanol.

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