On the design of anaerobic bioprocesses for sustainable exploitation strategies from poplar sawdust

G. Antonopoulou[1,*], A. Kampioti[2], G. Lyberatos[1,3]

[1]Institute of Chemical Engineering Sciences, Stadiou 1, Platani, Patras, GR 26504, Greece
[2]Ionian University, Department of Environment, M. Minotou-Giannopoulou, GR 29100, Zakynthos, Greece
[3]School of Chemical Engineering, National Technical University of Athens, GR 15780 Athens, Greece
Keywords: poplar sawdust, anaerobic bioprocesses, exploitation
Presenting author email: geogant@chemeng.upatras.gr

Abstract

In the present study, different pretreatment methods such as alkaline and acid were applied on poplar sawdust (PS) and the effect of each pretreatment method on the fractionation of the lignocellulossic content (cellulose, hemicellulose, lignin) was evaluated. In the sequel, the pretreated feedstocks were further evaluated for 2nd generation biofuels production (biohydrogen, biogas and bioethanol).

Introduction

The residues of wood poplar processing, such as wood cuttings, sawdust and sapwood, account for 10-15% of poplar wood volume, and remain unexploited since are usually burned or discarded causing environmental problems (Yao et al., 2013). By using poplar processing residues such as PS as substrate of different anaerobic processes (such anaerobic digestion (AD), fermentative hydrogen production (FHP) and bio-ethanol production (BP), not only waste minimization, but also bioenergy production, is occurred.

Materials and Methods

Pretreatment

Acid pretreatment was conducted by the use of H_2SO_4 and HCl, at 2,10 and 20 g/100 gTS, at 121°C for 1h while the alkaline one by the use of NaOH at the same concentrations at 80°C for 24h. Blank experiments, in which only thermal treatment (121°C for 1h or 80°C for 24 h) without any chemical addition, were carried out, for comparative reasons. Analysis of the lignocellulosic content before and after pretreatment was performed as presented in Antonopoulou et al. (2016).

Anaerobic bioprocesses

AD of pretreated biomass was studied in batch experiments and the biochemical methane potential (BMP) of all pretreated feedstocks (whole slurry or separated fractions), was assessed. FHP was performed at meshophilic conditions, using heat treated mixed anaerobic sludge, as microbial inoculum, with the addition of commercial enzymes (40 FPU/gTS) via a SSF (simultaneous saccharifiacation and fermentation) process. For the best pretreatment conditions (H_2SO_4 10 g /100 gTS) different schemes were evaluated, such as: a) fermentation without enzymes addition and b) hydrolysis (using enzymes) at a separate step, prior to fermentation (SHF). In addition, the separation of the whole pretreatment slurry and the use of the separated fraction for FHP was also assessed. BP from pretreated feedstocks was studied in batch experiments at 30°C, using the xylose -fermenting yeast of *Pichia stipitis* at SSF concept. For the best pretreatment conditions (10 g H_2SO_4 /100 gTS), the use of *P. stipitis*, *Pachysolen Tannophilus* or the traditional glucose -fermenting yeast of *Saccharomyces cerevisiae* were used either in a SSF or a SHF. In addition, the separation of the whole pretreatment slurry and the use of the separated fraction for BP was also assessed. Analysis of liquid and gaseous biofuels was performed as described in Antonopoulou et al (2016;2020).

Results and discussion

Characterization of pretreated samples

From figure 1, where the effect of pretreatments on the BMPs are presented, it is obvious that 10 or 20 g HCl /100 gTS caused a reduction of hemicellulose by 69.6 and 97.6 %, respectively, while when using H_2SO_4 at the higher concentration of 20 g/100 gTS, the hemicellulose fraction was reduced by 58.5 %. The lignin fraction was significantly affected only by alkaline pretreatment and the higher the NaOH concentration, the higher was the lignin removal efficiency observed.

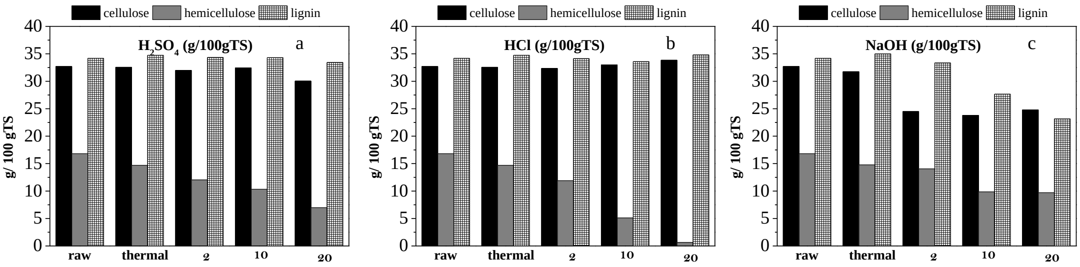

Figure 1. The lignocellulosic content (g/100 gTS $_{initial}$) of the raw, thermally pretreated, acid pretreated (H_2SO_4 (a), HCl (b)) and alkaline pretreated (NaOH (c)) PS, at the concentrations of 2, 10 and 20 g/100 gTS.

Effect of pretreatment on anaerobic bioprocesses

From Figure 2, where the effect of different pretreatment methods on the BMP of PS when the whole pretreatment slurry (Fig.2a) or the separated fractions obtained after pretreatment (Fig.2b) are presented, it is obvious that alkaline pretreatments enhance the methane production, at both cases.

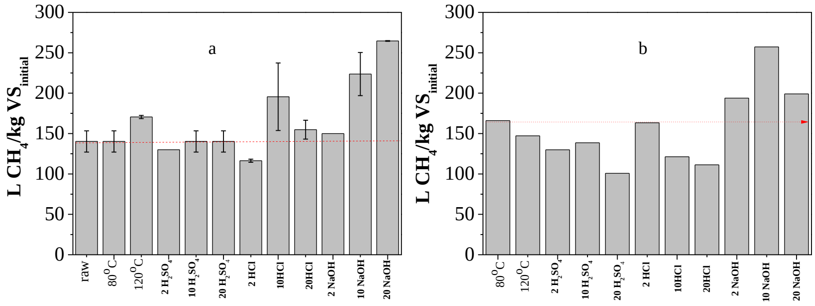

Figure 2. The sum of BMP of liquid and solid fractions obtained after pretreatment (a) and that of the whole pretreatment slurry (b) expressed in L CH_4/ kg VS $_{initial}$.

Regarding the fermentation technologies, indicative results from FHP and BH at the best pretreatment conditions, are presented in tables 1 and 2.

Table 1. FHP yields for the different concepts for PS pretreated with 10 g H_2SO_4/ 100 gTS

Scheme		**L H_2/kgTS**
Whole biomass	No enzymes	14.81 ± 0.89
Whole biomass	40 FPU /gTS at SHF	134.61 ± 14.56
Whole biomass	40 FPU /gTS at SSF	223.16 ± 14.68
Separation of both fractions	Solids with 40 FPU /gTS at SSF	76.24 ± 5.70

Table 2. BH yields for the different concepts for PS pretreated with 10 g H_2SO_4/ 100 gTS

Scheme			**L Ethanol/kgTS**
Whole biomass	SSF	*P. stipitis*	130.42
Whole biomass	SHF	*P. stipitis*	80.45
Whole biomass	SHF	*S. cerevisiae*	80.00
Separation of both fractions	SSF	*P. stipitis, S. cerevisiae*	78.71
Separation of both fractions	SHF	*P. stipitis, S. cerevisiae*	70.98

References

- Antonopoulou, G., Vayenas, D and Lyberatos, G. (2016) Ethanol and hydrogen production from sunflower straw: The effect of pretreatment on the whole slurry fermentation. Biochem. Eng. J.116: 65-74
- Antonopoulou, G., Vayenas, D and Lyberatos, G. (2020) Biogas production from physicochemically pretreated grass lawn waste: comparison of different process schemes. Molecules,25, 296
- Yao, Y., He, M., Ren, Y., Ma, L., Luo, Y., Sheng, H., Xiang, Y., Zhang, H., Li, Q., An, L., (2013). Anaerobic digestion of poplar processing residues for methane production after alkaline treatment. Bioresour. Technol , 134, 347–352