The effect of alkaline/hydrogen peroxide pretreatment on hydrogen and methane production from biomasses of different origin: the case of willow sawdust and date palm fibers

M. Alexandropoulou[1], I. Ben Atitallah[2,3], I. Ntaikou[1], G. Antonopoulou[1,*], T. Mechichi[3] ,G. Lyberatos[1,4]

[1]Institute of Chemical Engineering Sciences (FORTH/ICE-HT), 11 Stadiou st., Platani, Patras, GR 26504, Greece.
[2]Laboratory of Enzyme Engineering and Microbiology, National School of Engineers of Sfax, University of Sfax, BP 1173, 3038 Sfax, Tunisia.
[3]Laboratory of Biochemistry and Enzyme Engineering of Lipases, National School of Engineers of Sfax, University of Sfax, BP 1173, 3038 Sfax, Tunisia.
[4]School of Chemical Engineering, National Technical University of Athens, GR 15780 Athens, Greece.

Keywords: date palm fibers, willow, pretreatment, hydrogen, methane
*Corresponding and presenting author email: geogant@chemeng.upatras.gr

Abstract
The present study focuses on the use of agricultural wastes of two different origins, i.e.: willow sawdust (WS) and date palm fibers (DPF) as substrates for methane and hydrogen production, via biological processes using mixed microbial cultures. Both substrates were pretreated using dilute solutions of sodium hydroxide and/or hydrogen peroxide with 5% solids loading, at 80 °C for 24 h in a two-step or one step approach. The results showed that the pretreatment methods used enhanced hydrogen and methane production from both substrates, leading to higher yields when compared with the untreated samples, indicating the effectiveness of alkaline/hydrogen peroxide pretreatment.

Introduction

Nowadays, among the major challenges of the world's economy, is the reduction of the fossil fuels dependence (Su et al., 2020). In this context, several approaches have been considered, including the production of gaseous biofuels such as hydrogen and methane. Gaseous biofuels produce lower pollutant emissions and offer greater greenhouse gas emission reductions than other fuels (conventional or not) while they can be produced from inexhaustible sources such as lignocellulosic biomass. Pretreatment of lignocellulosic biomass is a quite important step before fermentation/ anaerobic digestion to liberate cellulose and hemicellulose from the complex lignocellulosic structure. In this work, sodium hydroxide and/or hydrogen peroxide, were applied on WS and DPF, and the effect of each method on hydrogen and methane productivities and yields was determined.

Materials and Methods

The WS used in this study was collected in the region of Athens, Greece while the DPF were collected during the date harvesting in the region of Kébeli, in southern Tunisia.
Suspensions of air dried WS at 5 % solids loading (5 gTS at 100 mL chemical solution) were treated with A) dilute solution of NaOH (0.5 %w/v) B) dilute solution of H_2O_2 (0.5 %, v/v) and C) mixture of NaOH (0.5 %w/v) and H_2O_2 (0.5 % v/v) at ratio 1:1. All pretreatments were performed at 80 °C for 24 h. In addition, two-step processes, i.e. D) initially to NaOH (0.5 %, w/v) treatment followed by H_2O_2 (0.5 %, v/v) or E) to H_2O_2 (0.5 %, v/v) first, followed by NaOH (0.5 %, w/v) were tested.

Anaerobic Digestion of pretreated biomass was studied in batch mesophilic experiments and the biochemical methane potential (BMP) of all pretreated and raw feedstocks, was assessed measuring the methane production versus time. Anaerobic sludge was used as inoculum, while the initial substrate concentration in the vial was 2 g TS/L. Fermentative Hydrogen Production (FHP) tests were also performed in batch mode, at meshophilic conditions, using heat treated mixed anaerobic sludge, as microbial inoculum, with the addition of commercial enzymes (cellulose blend) via a SSF (simultaneous saccharification and fermentation) process. The initial substrate concentration was equal to 10 g TS/L.

Results and discussion

Results of BMP tests
In figure 1, the BMPs of pretreated WS and DPF, are presented. In the case of WS, the methane yield was equal to 219.03 ± 3.74 L CH_4/kg when WS was pretreated either only with the NaOH solution or

with the mixture of NaOH/H_2O_2 and 215 L CH_4/kg in the case of two-stage pretreatment approaches (D and E). Low yield was observed in the case of H_2O_2 (149.78 ± 11.2 L CH_4/kg). The same trend was also observed for DPF, with the H_2O_2 pretreatment leading to the lower yield of 167.86 ± 7.2 L CH_4/kg, while the other pretreatment approaches lead to the production of almost 233 L CH_4/kg

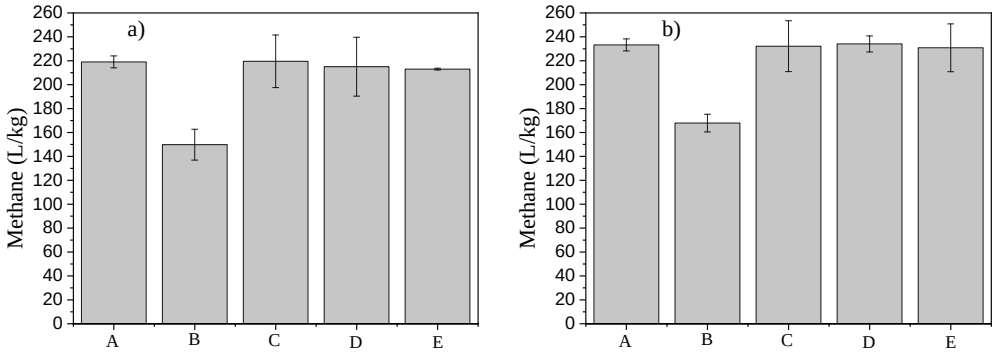

Figure 1: BMPs of a) willow sawdust (WS) and b) date palm fiber (DPF)

Results of FHP tests

Regarding the hydrogen yields (figure 2), high values were observed when WS was pretreated with NaOH (A) or with the mixture of NaOH/H_2O_2 (C) or with the two-stage pretreatments (D and E) (approximately 120 LH_2/kg). Low hydrogen yield was observed in the case of H_2O_2 (20 L/kg), which was similar to the yield of untreated WS at SSF. No hydrogen was produced from untreated WS (without enzymes). The same trend was observed for DPF, with the two-stage pretreatment E (H_2O_2 first, followed by NaOH) giving the maximum hydrogen yield of 136.4 ± 9.8 L H_2/kg, which was similar to the pretreatment A, C and D. Low hydrogen yields were achieved when DPF was pretreated with H_2O_2, being the same with the yield of untreated DPF in SSF, indicating that the addition of hydrogen peroxide did not really increase hydrogen yields.

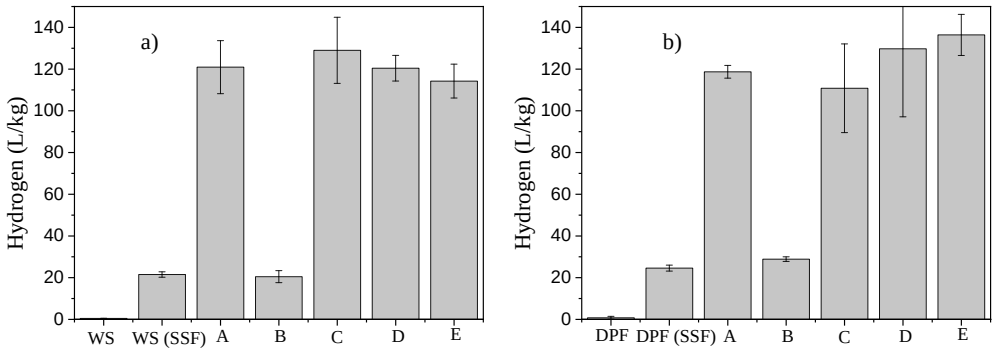

Figure 1: FHP tests of a) willow sawdust (WS) and b) date palm fiber (DPF)

Acknowledgements

We acknowledge financial support of this work by the project “Research infrastructure for Waste Valorization and Sustainable Management of Resources, INVALOR” (MIS 5002495) which is implemented under the “Action for the Strategic Development on the Research and Technological Sector”, funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

References

Su, T., Zhao, D., Khodadadi, M., Len, C., 2020. Lignocellulosic biomass for bioethanol: Recent advances, technology trends, and barriers to industrial development. Current Opinion in Green and Sustainable Chemistry. 24, 56-50