UV/H_2O_2 pretreatment for the enhancement of methane from olive tree pruning biomass

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Abstract

Lignocellulosic biomass including olive tree pruning (OTP) could be used as feedstock for anaerobic digestion (AD). Although being abundant, especially in Mediterranean countries, like Greece, the main obstacles of their use are the low yields attained, due to the recalcitrant nature of their lignocellulosic content. The application of a pretreatment process prior to AD could improve the hydrolysis and the total methane yield.

Different methods have been employed for the pretreatment of lignocellulosics and among them, alkaline hydrogen peroxide (H_2O_2) pretreatment, is a very promising one (Alexandropoulou et al., 2023). The mechanism of H_2O_2 pretreatment appears to involve the production of highly reactive oxygen species and subsequent oxidative depolymerization of lignin in the lignocellulosic biomass. In a UV/H_2O_2 system, ultraviolet radiation enhances the in situ production of % OH radicals through photochemical reactions over a very short period of time (Zhang et al., 2017) and thus it could be considered as an efficient pretreatment method in removing lignin and hemicellulose from lignocellulosic feedstocks, promoting their utilization for subsequent bioprocesses (Yang et al., 2018).

In the present study, H_2O_2 in combination with ultraviolet (UV) radiation (UV/H_2O_2) at ambient temperature was used as pretreatment method for enhancing methane production from OTP. Three different concentrations of H_2O_2 (0, 1 and 3 % w/w) alone or in combination with UV radiation, at different retention times (8, 14 and 20 h) were evaluated to enhance OTP solubilization and depolymerization as well as methane generation. In addition, the combination of UV/H_2O_2 with alkali was evaluated and compared with the typical alkaline pretreatment in terms of fractionation of lignocellulosics and methane generation.

Materials and Methods

Pretreatment

OTP was chopped, milled and then sieved to a powder, before being air-dried at ambient temperature. For all pretreatment methods used, the solids loading, expressed as total solids (TS), was 5% w/v, (5 g of TS in 100 mL water). A UV lamp emitting UV irradiation (TUV T8, Philips, Netherlands) was used in the experiments. Three different concentrations of H_2O_2 (0, 1 and 3 % w/w) in combination with UV irradiation, at different retention times (8, 14 and 20 h) were tested. In addition, 1 and 3 % w/w H_2O_2 was applied for 20 h, without UV irradiation. UV/1% w/w H_2O_2 was combined with 1% w/v NaOH for 20 h ($UV/NaOH/H_2O_2$) and compared with the typical NaOH pretreatment (1% w/v of NaOH, 20 h at 80^{o}C). After pretreatment, the whole pretreated biomass was separated through vacuum filtration (0.7 μm pore size) and two fractions (a liquid and a solid one) were obtained. A detailed physicochemical and structural characterization was performed in both fractions based on Antonopoulou et al. (2015). Both fractions, as well as the whole pretreatment slurry (without separation) were used for the production of methane, through batch biochemical methane potential (BMP) tests.

BMP tests

BMP tests were performed either at the whole slurry or at the separated fractions, obtained after pretreatment, based on Antonopoulou et al. (2020). Briefly, in all experiments, 20 % v/v of anaerobic sludge was used as inoculum in serum bottles of 160 mL, with a working volume of 100 mL. For the experiments with the whole slurry, 20 mL mixed anaerobic culture, 76 mL water and 4 mL of the whole slurry at a solid loading of 5% w/v, were used. For the experiments with the solids obtained after pretreatment, 20 mL mixed anaerobic culture, 80 mL water and appropriate amounts of samples were added, in order to acquire the desirable TS content of 2g TS / L. For the experiments with the hydolysates, 20 mL mixed anaerobic culture were seeded with water and appropriate volumes of hydrolysates, so as their final COD concentration, being 2 g/L.

Results and Discussion

The composition of OTP used in the present study was: total solids (TS) (%) =92.03 ± 0.1, volatile solids (VS) (g/100 gTS)= 91.91 ± 0.25, cellulose (g/100 gTS)= 24.05 ± 0.47, hemicellulose (g/100 gTS)= 15.88 ± 1.5, lignin (g/100 gTS)= 41.28 ± 0.12, extractives (g/100 gTS)= 16.93 ± 0.26. Figure 1 summarises the effect of different pretreatments on the fractionation of biomass in terms of lignin, cellulose and hemicellulose. It is obvious that a slight lignin reduction occurred in the case of pretreatment with UV/3% H_2O_2 for 14 h and the reduction was more intense at UV/3% H_2O_2 for 20 h or under the combination of UV/ NaOH/ H_2O_2 for 20 h. However, the highest lignin reduction was observed for alkaline (NaOH) pretreatment (37.96%).

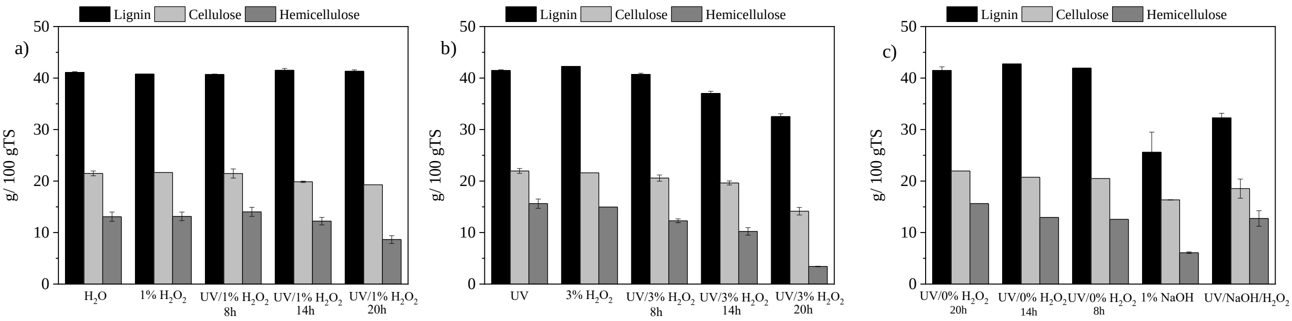

Figure 1: Lignocellulosic fractionation under the different pretreatment schemes

Effect of pretreatment on the BMP

In Figures 2 and 3, the effect of different pretreatment schemes on the BMP of the whole slurry, solid and liquid fractions, respectively, is presented.

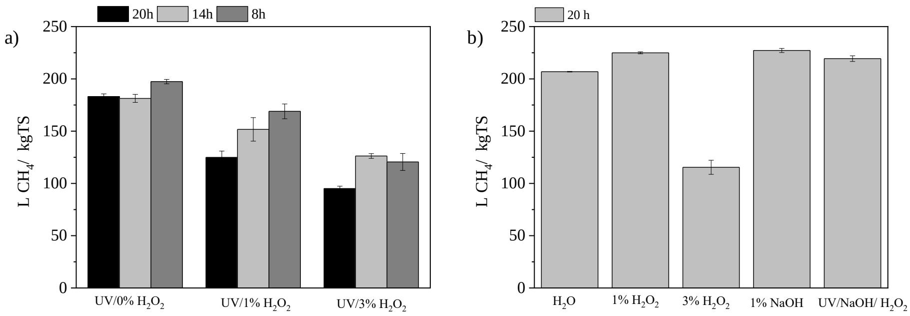

Figure 2: BMP of the whole slurry under different pretreatment schemes

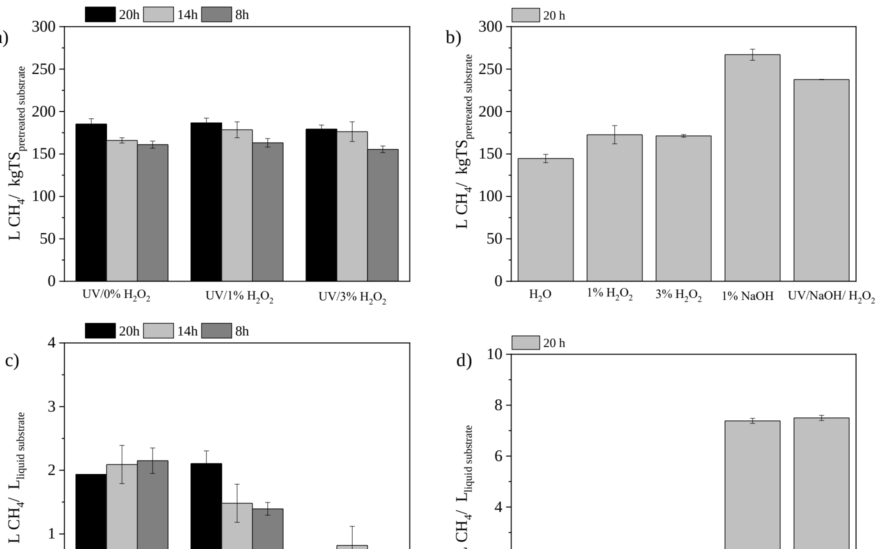

Figure 3: BMP of the solid (a,b) and liquid (c.d) fractions, under different pretreatment schemes

From the figures, it is obvious that alkaline pretreatment alone, or in combination with the UV/H_2O_2 led to the higher methane potential, either when applied in the whole slurry or in the two separated fractions. This can be attributed to the lower lignin content, under the later conditions. In the case of the whole slurry, the lowest BMP was observed for the 3% UV/H_2O_2 (20 h), followed by the same pretreatment at 14 and 8 h, respectively.

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