Evaluation of the sugar production from cellulosic rejections from wastewater treatment plants as valorisation strategy

A. Duque[1], I. Ballesteros[1], M.J. Negro[1], C. Coll[2], M. Latorre-Sánchez[2], J. Hereza[3], R. Iglesias[1]

[1]Advanced Biofuels and Bioproducts Unit, Renewable Energies Department, CIEMAT, Madrid, 28040, Spain
[2]PERSEO Biotechnology SL, Ciudad Darío 13, L´Alcudia, 46250, Spain
[3]Digital Information, Quality and Innovation Service, Waste Prevention and Management Department, AMB, Barcelona, 08041, Spain
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Presenting author email: aleta.duque@ciemat.es

In the modern western society, there is a widespread use of disposable nonwoven wipes as personal or household care products. While this kind of products can clearly ease the daily life, there is a severe problem related to how these materials are disposed of. Particularly, when flushed down the toilets, nonwoven wipes are known to cause sewer blockages and damages to wastewater treatment systems, and they contribute to the microplastics pollution of oceans through their release as wastewater treatment plants (WWTP) effluents (Briain *et al.*, 2020).

Nonwoven fabrics are composed of (modified) cellulose combined with plastics such as polyvinyl alcohol, polypropylene or polyester (Pantoja *et al.*, 2018). The cellulosic fraction could be susceptible of valorisation through transformation into other valuable products such as the biofuel bioethanol. A common accepted route to transform cellulosic biomass into bioethanol includes the release of simple sugars by enzymatic hydrolysis of the carbohydrates and subsequent fermentation to ethanol. This process usually requires some type of pretreatment or conditioning of the biomass to increase the accessibility of enzymes to the biomass and to maximize the concentration of sugars (and so, ethanol) with a view to reduce distillation costs in the last part of the industrial process.

WWTP cellulosic rejections were collected by Àrea Metropolitana de Barcelona (AMB) from the wastewater treatment plant of El Besòs (Barcelona). Samples were managed, pre-treated and sterilized by PERSEO Biotechnology and then sent to CIEMAT where they were characterized upon arrival and then kept frozen until used.

The material received was very heterogeneous and it was difficult to visually identify the content; therefore, an exhaustive characterization of the biowaste was intended in order to gather as much knowledge about the sample as possible. Characterization of WWTP cellulosic rejections in terms of moisture and main structural components was made following NREL’s analytical procedures LAP NREL/TP-510-42618, 42621, 42622 and 42623. Total Kjeldahl Nitrogen was determined by the standard method APHA-AWWA-WEF 4500 and pH of the sample was measured following the EPA method 9045D for soil and waste. Ultimate analysis and major elements in ash of the sample were done following the ISO 1648 method for C, H and N, the European Standard EN 15289 for chlorine and sulfur, and the European Standard EN 15290 for inorganic elements in biomass ash. A summary of the determined main components are found in Table 1 below.

Table 1. Summary of main components of WWTP cellulosic rejections in dry weight basis (dwb), means of triplicates and standard deviation.

Component	(% dry weight basis)
Extractives	17.75 ± 1.17
Glucan	25.82 ± 0.50
Hemicellulose	4.65 ± 0.13
Acid insoluble residue	38.54 ± 0.88
Ash	7.55 ± 0.15
Total Kjeldahl Nitrogen	1.35 ± 0.03

After characterization, a tentative enzymatic hydrolysis (EH) of the biowaste as it was received was carried out at laboratory conditions (5% w/w solids, 15 FPU/g dry matter, 150 rpm, 50ºC) with a commercial cellulolytic cocktail (Cellulase blend, SIGMA-ALDRICH, Co.) to assess the ethanol potential of the untreated waste. The EH yield with respect to glucose was around 90% of theoretical, which means an estimated ethanol potential of 167 L/tn dry feedstock calculated using the stoichiometric coefficient of 0.51.

Despite the high accessibility of cellulose in untreated WWTP cellulosic rejections (around 90% of glucan was easily converted to glucose), the relatively low glucan concentration of the raw substrate (26%) makes it advisable to try to concentrate it to increase the sugars concentration in the fermentation step. Thus, hydrothermal pre-treatment at different conditions was investigated to this purpose. Steam explosion (SE) pre-treatment at temperatures of 150 or 190ºC and liquid hot water (LWH) at 120-130ºC, both acid-catalysed or not, were the methods tested.

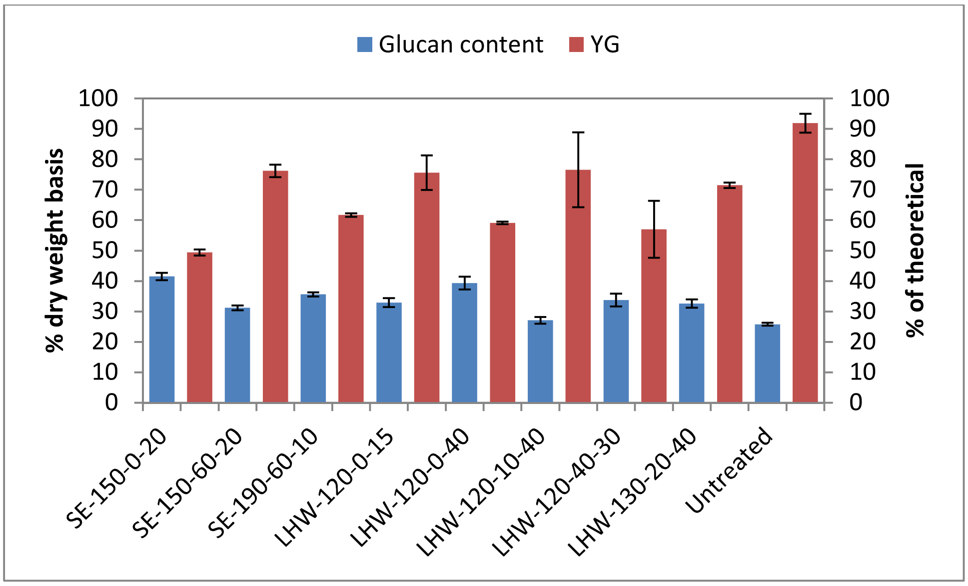

Figure 1. Glucan content and EH yield with respect to glucose (Y_G) of the pre-treated WWTP cellulosic rejections at different conditions: AA-BB-CC-DD. AA: type of hydrothermal pre-treatment (SE or LHW); BB: temperature (in ºC); CC: amount of sulfuric acid (in mg/g dry matter); DD: time (in min).

Although some sugar concentration was achieved by these pre-treatments, the EH yields were lower in the pre-treated materials than in the untreated WWTP cellulosic rejections (Figure 1). After calculating the mass balances, the estimated ethanol potential was also lower for the pre-treated substrates, except for the LHW at 130ºC with 20 mg acid/g dry matter and 40 min, which was 177 L ethanol/tn dry material, but the improvement achieved was minor in comparison to the costs that would be incurred by the pre-treatment.

References

Briain, O.O., Marques Mendes, A.R., McCarron, S., Healy, M.G., Morrison, L. The role of wet wipes and sanitary towels as source of white microplastic fibers in the marine environment. Water Research, 2020, 182, 116021.

Pantoja Munoz, L., Gonzalez Baez, A., McKinney, D., Garelick, H. Characterisation of “flushable” and “non-flushable” commercial wet wipes using microRaman, FTIR spectroscopy and fluorescence microscopy: to flush or not to flush. Environ Sci Pollut Res 2018, 25, 20268–20279.

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