Study of the Production of Bioethanol from Switchgrass pretreated by Steam Explosion

Fernando Bonfiglio [1], Fabiana Rey[1], Matías Cagno [1], Silvia Böthig [1], Pilar Menéndez [2], Solange I. Mussatto [3]

[1] Centro de Investigaciones en Biocombustibles 2G, Latitud – Fundación LATU, Montevideo (Uruguay)
[2] Laboratorio de Productos Naturales, Departamento de Química Orgánica, Facultad de Química, Universidad de la República, Montevideo (Uruguay)
[3] Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Kongens Lyngby (Denmark)

Introduction

Switchgrass (*Panicum virgatum*) is a perennial warm season grass highly valued as an energy crop resource for the production of bioethanol due to its high carbohydrate content, fast growth, and ability to grow in lands that cannot support crop or food production.

BIOETHANOL production process:

Raw Material: SWITCHGRASS

Pretreament: STEAM EXPLOSION
- Solubilization of hemicellulose

Hydrolysis (Saccharification)

Fermentation and separation/purification

BIOETHANOL

The recalcitrance of the lignocellulosic material can be overcome by applying steam **at high pressure and temperature** during a certain amount of **time**, and then suddenly releasing the pressure. This opens the fibers solubilizing the hemicellulose and making the cellulose fibers more accessible to the enzymes in the following step of saccharification.

Problem: Steam explosion has been demonstrated to be an efficient technology for biomass pretreatment. However, the efficiency and the selectivity of this process is highly dependent on the feedstock and conditions applied, being the temperature and residence time the two main parameters affecting the results. Therefore, **the aim of the present study** was to evaluate the impact of the temperature and residence time on the pretreatment of switchgrass by steam explosion in a semi-continuous pre-pilot plant able to generate between 3 and 7 kg of pretreated solid material and to produce bioethanol from that exploded material.

Experimental

Raw material:

Switchgrass harvested in Uruguay, dried and milled to approx. 1 cm size Moisture content: 30% humidity

Experimental design:

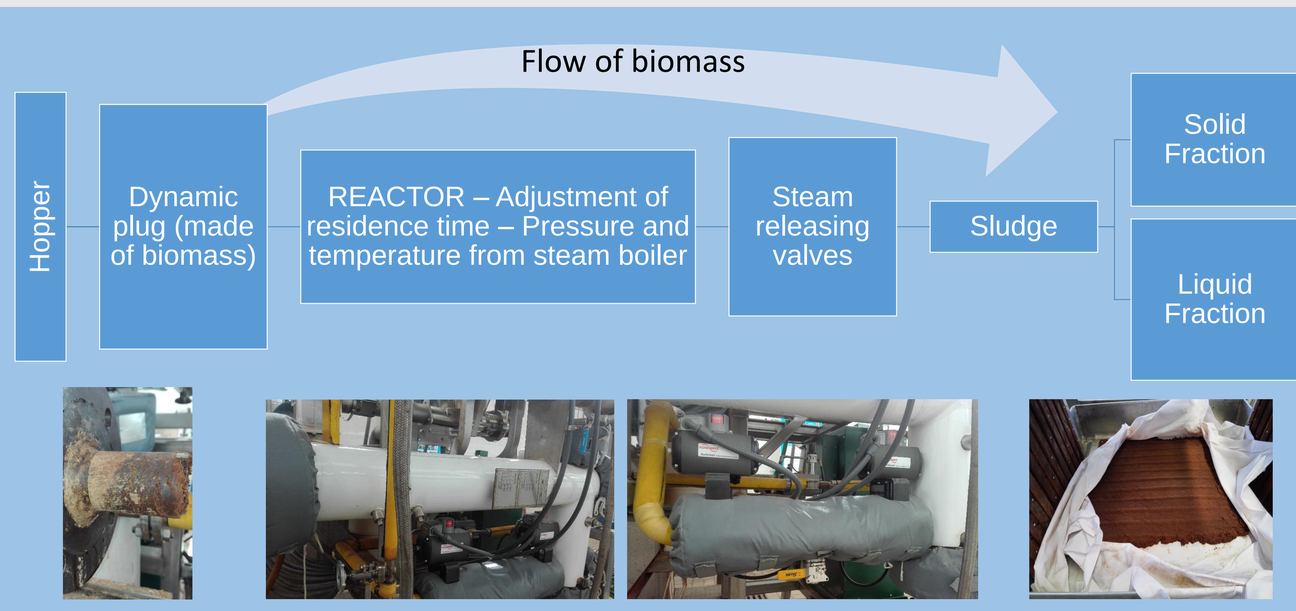
Steam explosion:
Temperature: 170, 185 and 200 ºC
Residence time: 5, 10 and 15 min
Combined through a 2^2 central composite design (11 assays)
Enzymatic Hydrolysis: CellicCTec2, 2% (w/v) biomass, 50 FPU, at 50 ºC and 200 rpm for 96 h
Fermentation: Saccharomyces cerevisiae (Thermosacc DRY), $1x10^7$ cells/mL, 48 hs at 36 ºC

Analyses:

- Characterization of exploded switchgrass (Solid Fraction) according to NREL standard protocol for lignin, cellulose, and hemicellulose
- Glucose from Enzymatic Hydrolysis and Ethanol from Fermentation determined by HPLC

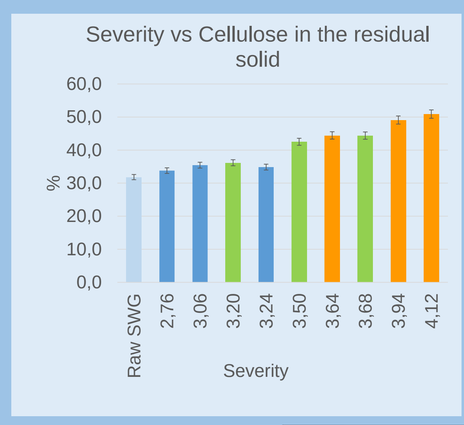
Experimental (cont.)

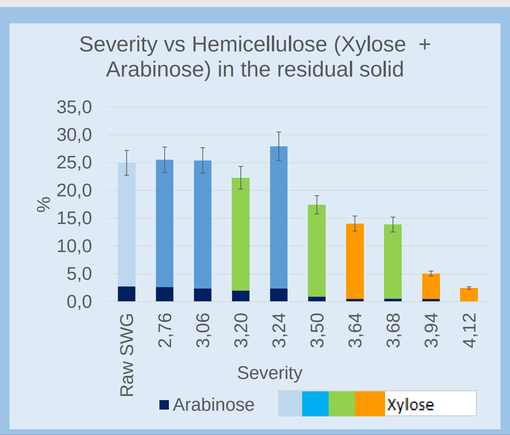
Steam Explosion Equipment

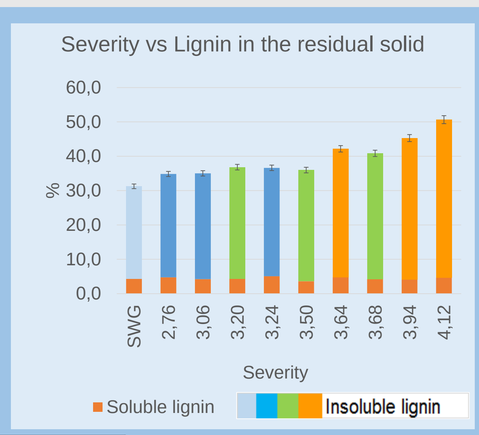


Results

Solid fraction composition



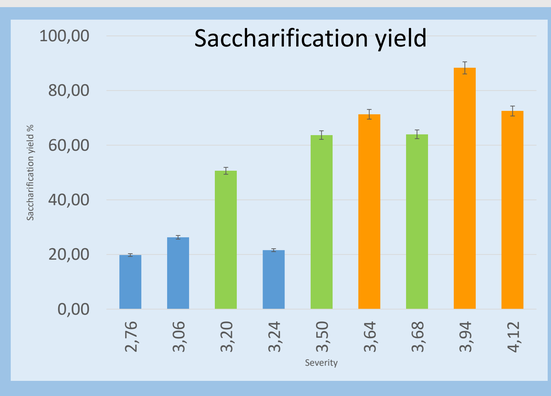


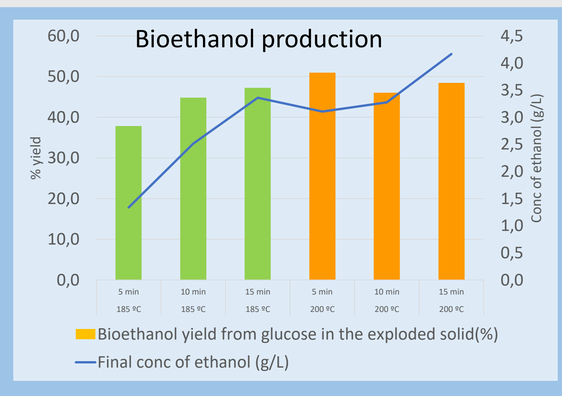


Explosion at 170 ºC | Explosion at 185 ºC | Explosion at 200 ºC

- Steam explosion at 170 ºC had little effect in the composition of the residual exploded solid material. However, increasing the severity factor favored the hemicellulose removal from the feedstock, while increased the amount of cellulose and lignin in the residual solid material. On the other hand, there was no clear correlation between the amount of soluble lignin and the severity factor employed, suggesting that the mildest conditions were already enough to recover this fraction from the feedstock.
- Temperature had a more significant effect than the residence time to overcome the recalcitrance of feedstock.

Separate Hydrolysis and Fermentation (SHF)





Conclusions

Statistical tools were used to optimize the conditions able to result in maximum hemicellulose solubilization in the liquor (with minimal generation of inhibitory compounds) and maximum amount of cellulose in the residual solid material, being **200 ºC and 10 min** of residence time the selected. The obtained results, already in a pre-pilot scale, are very promising and contribute to the development of an ethanol biorefinery using switchgrass as a feedstock.