BIOFUELS FROM LIGNOCELLULOSIC RESIDUES: BIOMASS PRETREATMENT TECHNOLOGIES, ENZYMATIC HYDROLYSIS AND SUGARS BIOCONVERSION INTO BIOFUELS

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In the recent decades, the use of new fuel sources has been widely studied due to the increasing environmental, economic and politic problems related to fossil fuel consumption and the predicted decrease of its production. Among these new fuel sources under research, the greatest interest focuses on the renewable ones or biofuels, as a result of their availability and environmentally friendly nature.

Lignocellulosic residues appear as a promising alternative raw material for biofuel production. These residues derive from industrial processes using agricultural sources and from the harvesting of conventional crops. They are abundant, have a low cost and their valorisation often entails the mitigation of an environmental problem, since their accumulation frequently generates soil contamination by compounds derived from their natural degradation. Alcohols, such as ethanol or butanol, and biogas can be produced from lignocellulosic materials.

Fig. 1 Pilot scale plant of steam explosion.

The use of lignocellulosic materials for biofuels production requires three steps in most of cases. The first step is the pretreatment, which is responsible for opening the biomass structure and releasing the carbohydrates polymers from lignin. The second is the enzymatic hydrolysis to convert the carbohydrates polymers into monomeric fermentable sugars. Finally, the third step is the bioconversion of the hydrolysates obtained in the target product, alcohols like ethanol and butanol by alcoholic fermentation, or methane by anaerobic digestion.

The technology to achieve an effective lignocellulosic-to-biofuel conversion process has been studied since the 50's, but so far unsuccessfully. The three main process stages are strongly interrelated. High severity pretreatments are effective opening the lignocellulose structure and facilitate high sugar release yields but degrade biomass generating large amounts of byproducts which inhibit the next stages on the sequential process: enzymatic hydrolysis and/or the sugar fermentation. On the other hand, a mild pretreatment requires in most of cases the use of a large amount of enzymes, which makes the process excessively expensive.

This project, applying the biorefinery concept, proposes to use all sugars contained in two abundant lignocellulosic wastes, cereal straw and sugarcane bagasse, with the integration of alcohols (butanol or ethanol) and methane production processes. Methane production allows exhausting all sugars and proteins contained in the waste streams while operating under mild pretreatment conditions or in the presence of potential inhibitors. The results are analyzed comprehensively considering the technical, economic and environmental feasibility of each process. In this way, this work focuses on the study of the different sequential stages and their interrelation:

-Pretreatments (ozonolysis, steam explosion, thermal and thermochemical). The project studies, for each pretreatment, the effect of the process conditions and type of lignocellulosic biomass used on the changes in lignocellulosic structure, sugar solubilization and type and concentration of possible inhibitory compounds generated.

-Enzymatic hydrolysis of pretreated biomass. The use of new fungal enzymatic extracts and their comparison with commercial enzymes; the best hydrolysis conditions linked to the type of pretreatment used and its effect on the sugar yields and composition; the concentration of inhibitory compounds on the hydrolysates and its relation to the bioconversion step are investigated.

-Bioconversion of sugars into biofuels (ethanol fermentation, ABE (acetone-butanol-ethanol) fermentation and biochemical methane potential). The effect of generated degradation compounds on the microorganisms selected for fermentation processes is investigated: *Clostridium acetobutylicum* for butanol production by ABE fermentation, *Pichia stipitis* for the biotransformation of pentoses and hexoses to ethanol, *Saccharomyces cerevisiae* for the transformation of only hexoses to ethanol, and mixed cultures for methane production.

The alternative of process that allows an optimal use of the energy available in the lignocellulosic materials is selected through analysis of compositions of all the process streams.

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