**Economic optimization of ethanol production from corn stover**

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**Highlights**

* A kinetic model for ethanol production including acetic acid inhibition is proposed.
* The kinetic model is used to study the economic potential of ethanol production.
* Energy needs in the purification are reduced by 17-23% using de-acetylation.
* The minimum ethanol selling price achieved was 1.83-2.25 USD/gal.

**1. Introduction**

Ethanol production using corn stover requires physical and/or chemical pretreatment before fermentation. The pretreatment methods that achieve the highest final ethanol concentration (65-90 g/l) have been reported by [1] where, as a precursor to physical pretreatment (mechanical refining), de-acetylation is proposed. As acetic acid is a known inhibitor, its effective removal can increase fermentation performance. After pretreatment, cellulose is partially converted to glucose by enzymatic hydrolysis. Unfortunately, the inhibition of soluble sugars during enzymatic hydrolysis reduces the conversion rate of cellulose to glucose. In addition, it is known that secondary carbon sources (e.g. xylose) are not effectively utilised during fermentation.

The aim of this work is to study the economic potential (EP) of ethanol production from corn stover using a conventional fed-batch reactor with a partial enzymatic hydrolysis step followed by simultaneous fermentation and co-saccharification (SFCS). SFCS offers an interesting means to reduce glucose and xylose inhibition during enzymatic hydrolysis. Two pretreatment strategies are considered; mechanical refining and a de-acetylation step followed by mechanical refining. As ethanol purification is energy intensive, a highly-energy efficient distillation system is also proposed: extractive distillation with vapor compression (ED-VC), as the purification method, as this is known to reduce the energy requirements when compared to a conventional purification system by 55% [2].

**2. Methods**

A kinetic model describing ethanol production using enzymatic hydrolysis and fermentation under atmospheric conditions is developed. This is based upon previously reported work that considered butanol production [3]. The model is validated using experimental data obtained from batch and continuous fermentations reported by [4,5,6]. The kinetic model includes acetic acid inhibition, preferential consumption of glucose over xylose and xylitol inhibition.

The model is used as the basis for the assessment of the EP of the process where hydrolysis and fermentation operating conditions are optimized in order to achieve the maximum EP. The EP cost function incudes the capital and expenditure costs of pre-treatment, hydrolysis, fermentation and the distillation systems. A number of optimization scenarios are considered to include all possible ranges of concentrations of non-soluble solids, insoluble solids, glucan, xylan, acetyls, and lignin reported for corn stover by [7]. It is assumed that the corn-stover capacity is 2000 ton/day on a dry basis. The distillation costs and energy requirements are calculated using Aspen Plus V9®.

**3. Results and discussion**

The proposed kinetic model achieves an average correlation coefficient of 0.995. A typical result is shown in Figure 1a where it may be observed that the model accurately follows the measured experimental data. Through optimisation of the process operating conditions, using the kinetic model as a basis, we have found that the de-acetylation step reduces the energy requirements of ED-VC by 17 - 22.6% (see Figure 1b) which, in turn, reduces the minimum ethanol selling price (MESP) by 10 - 13%.



**Figure 1.** Profiles of the fermentation (initial concentration of acetate of 8 g/l) and energy requirements of ED-VC under optimal conditions. To the left (Figure 1 a) Data points are experimental data: glucose (stars), xylose (diamonds), ethanol (triangle) and biomass (circle). Experimental data was reported by [5]. Continuous lines represent the simulation predictions. To the right (Figure 1b) Fuel requirements of ED-VC. In Figure 1 b the red points represent the base case scenario reported by [7]

**4. Conclusions**

We have developed a kinetic model that describes ethanol production from corn-stover. The full paper will provide a more detailed account of the kinetic model, however, our results indicate that the inclusion of acetic acid (and the modelling of acetic acid inhibition during fermentation) is required as this significantly affects the EP of the process. Further details of the EP cost function and assumptions made to perform the optimisation will also be provided. In summary, our analysis indicates that the energy needs for ED-VC recovery are between 3.1 and 3.4 MJ fuel/kg ethanol (a reduction of 17 - 22.6% when de-acetylation is not considered) resulting in a minimum ethanol selling price of 1.83-2.25 USD/gal (a reduction of 10 - 13%).

**References**

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