A Framework for Optimization of Bioprocess Operation under Uncertainties: A lignocellulosic Ethanol Production Case Study

Morales Rodriguez, Ricardo; Mauricio Iglesias, Miguel; Meyer, Anne S.; Gernaey, Krist; Sin, Gürkan

Publication date: 2011

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
I. Introduction

This study presents the development and application of a systematic model-based framework for bioprocess optimization. The framework relies on the identification of sources of uncertainties via global sensitivity analysis, followed by the quantification of their impact on performance evaluation metrics via uncertainty analysis. Finally, stochastic programming is applied to drive the process development efforts forward subject to these uncertainties.

II. Objective:

To develop a framework to solve the optimization problem of bioprocesses subject to uncertainties in particular identify the significant sources of uncertainties and optimize production cost of lignocellulosic ethanol.

III. A Framework for Bioprocess Optimization under Uncertainty

The framework is generic and can be applied to analyze the impact of market as well as political uncertainties (e.g. subsidies) on bioprocess development efforts.

With stochastic optimization, operation ideas generated to bring down the production costs further (up to 21%)

The uncertainty analysis is carried out using the Monte-Carlo technique. The sensitivity analysis is done by Morris screening.

Morris method relies on estimating the distribution of the elementary effects (EE) of each input parameter (i) on the kth model output (Ei,j).

IV. Case Study: Lignocellulosic Ethanol Production

To enhance the bioprocess performance the two optimization techniques are applied to the existing bioprocesses.

Optimization results under uncertainty (SNLP)

V. Screen and Identify Significant Sources of Uncertainty

The uncertainty analysis is carried out using the Monte-Carlo technique. The sensitivity analysis is done by Morris screening.

Uncertainty Analysis

Relative improvements in consumption of additives

VI. Optimization under Uncertainty

Formulation of the optimization problem under uncertainty (Stochastic NLP)

\[
\min \left[ \sum_{k=1}^{N} f(x_k) \right] \text{subject to} \ x_k \geq 0 \quad \forall k \in \mathbb{N}
\]

Obj is to minimize unit production Cost

\[
\text{C_{mean,Ethanol}, g/L} = \frac{\text{USD/gal-Ethanol}}{\text{C mg-Enz/g-cellulose g/L}} - \text{USD/gal-Ethanol}
\]

VI. Discussion and Concluding Remarks

- A model-based approach for bioprocess optimization under uncertainties: identify them, quantify them, optimize under them & iterate
- The most significant sources of uncertainties affecting unit production cost of ethanol: (i) feedstock composition, (ii) degree of hydrolysis of cellulose and (iii) ethanol yield on glucose and xylose. These uncertainties leads to an uncertainty of 0.26 USD/gal-eth in unit production cost.
- With stochastic optimization, operation ideas generated to bring down the production costs further (up to 21%)
- The framework is generic and can be applied to analyze the impact of market as well as political uncertainties (e.g. subsidies) on bioprocess development efforts.