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Series of packed bed biofilm reactors: experimental and model.

Francesca Raganati[1]*, Alessandra Procentese[2], Giuseppe Olivieri[1], Maria Elena Russo[2], Piero Salatino[1], Antonio Marzocchella[1]

1 Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione Industriali - Università degli Studi di Napoli Federico II, P.le V. Tecchio 80, 80125 Napoli – Italy;

2 Istituto di Ricerche sulla Combustione, Consiglio Nazionale delle Ricerche, P.le V. Tecchio 80, 80125 Napoli – Italy

**Corresponding author: Francesca.raganati@unina.it*

Highlights

- Butanol production was performed by immobilized cells of *C. acetobutylicum*.
- The process was performed in 4 biofilm packed bed reactors connected in series.
- An unstructured-unsegregated kinetic model was used to describe cells.

1. Introduction

Acetone-Butanol-Ethanol (ABE) fermentation by clostridia is drawing new interest as a way to turn renewable resources into valuable base chemicals and liquid fuels. Although the high industrial potential interest for the butanol production by the biotechnological route, some features of the ABE fermentation process hinder its success on the industrial scale. Indeed, the ABE fermentation is characterized by low yield, the acid-solvent two phase path, and final low concentration of butanol due to its inhibiting effect on the fermentation [1]. The reactor design and the selection of the optimal operating conditions play a key role in fermentative productions and they may take advantages from reactor modeling. Process intensification may be obtained by increasing cell concentration in the reactor: cell immobilized reactors and retention membrane reactors are two potential solutions [2]. Simulations of the fermentation process gives an insight into the characteristics of the process and supports the identification of key variables of the overall process.

This study reports an innovative immobilized cell reactor system: an experimental campaign and the model developed to describe the reactor system.

2. Methods

PBBR SYSTEM. The anaerobic solventogenic commercial *Clostridium acetobutylicum* DSM 792 was used for the fermentation process. The conversion was carried out in 4 packed bed biofilm reactors (PBBRs) connected in series (Figure 1; details regarding the operating conditions of the system are reported in Raganati et al. [3]): the first reactor (fed with a 100 g/L glucose solution) was operated under acidogenesis conditions, and the three successive reactors were operated under solventogenesis conditions.
The overall dilution rate (D) ranged between 0.05 and 1.4 h^{-1}.

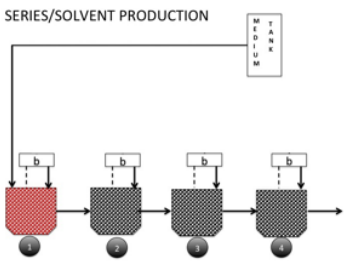

Figure 1. Outline of the apparatus used for the continuous butanol production. b: pH measure/control device [3].

MODEL. A mathematical model of the PBBRs system was developed with reference to glucose kinetics assessed experimentally [4,5]. The proposed model included an unstructured-unsegregated kinetics and summarizes biochemical as well as physiological issues of growth and metabolite synthesis by the selected

strain. The main assumptions are: i) the PBBR system was assumed as a series of CSTR; ii) the biomass (free and immobilized cells) in each PBBR was a heterogeneous cell population consisting of acidogenic, solventogenic, and spore cells; iii) the kinetics of cell growth and butanol production did not depend on the free/biofilm cell status; iv) cells attachment and detachment processes were considered.

3. Results and discussion

Fig. 2 A reports the concentration of butanol and glucose in the four PBBRs measured under steady state conditions at D=0.15 h^{-1}. The gradual decrease in glucose concentration (Fig. 2B), and the gradual increase in solvent concentration (Fig. 2A) along the PBBR series reproduce the typical behavior of batch fermentation. As expected, the formation of a stable biofilm in the four units and the selection of the operating conditions lead to a successful reactor system that behaves like a PFR with continuous inoculum.

Fig. 2C and D reports the estimated concentration of butanol and glucose in the four PBBRs at D=0.15 h^{-1}. The developed model succeeded in reproducing the behavior of the PBBRs system.

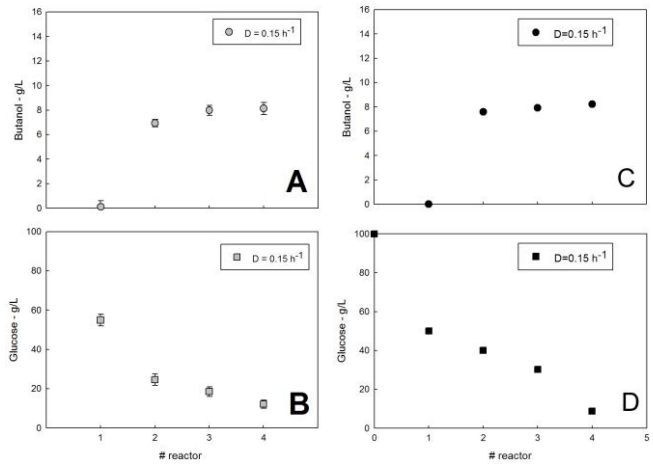

Figure 2. Measured and estimated butanol and glucose concentration along the PBBR series at D=0.15 h^{-1}.

4. Conclusions

Butanol production was carried out in 4 packed bed biofilm reactors (PBBRs) connected in series. An unstructured-unsegregated kinetic was included in the proposed that succeeded in reproducing the behavior of the PBBRs system.

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Keywords
Butanol; *Clostridium acetobutyilicum*; Modeling; Biofilm.