Chemical Engineering Journal 218 (2013) 191–203

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Multivariable feedback linearizing control of *Chlamydomonas reinhardtii* photoautotrophic growth process in a torus photobioreactor

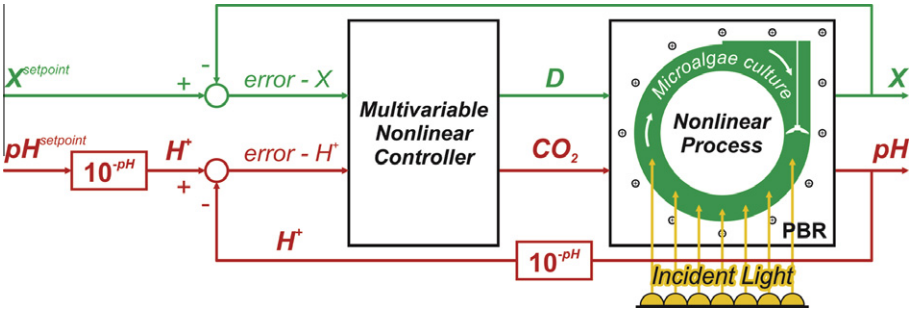
George Adrian Ifrim [a,b], Mariana Titica [a,*], Marian Barbu [b], Lionel Boillereaux [a], Guillaume Cogne [a], Sergiu Caraman [b,*], Jack Legrand [a]

[a] LUNAM, Université de Nantes, GEPEA, UMR-CNRS 6144, University Bd. CRTT-BP 406, 44600 Saint-Nazaire, France
[b] "Dunărea de Jos" University of Galaţi, Domnească Street, no. 47, 800008, Galaţi, Romania

HIGHLIGHTS

- A nonlinear multivariable controller for the microalgae growth process was designed.
- Biomass concentration and pH were simultaneously controlled in a microalgae culture.
- A systemic analysis of the process led to a reduced model proper for control purposes.
- A dynamic time-varying expression for the concentration of hydrogen ions was obtained.
- A centralized MIMO controller was used with excellent results on a photobioreactor.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 26 July 2012
Received in revised form 26 November 2012
Accepted 30 November 2012
Available online 10 December 2012

Keywords:
pH control
Turbidostat
Nonlinear multivariable control
Model reduction
Feedback linearizing control
Photobioreactor

ABSTRACT

The objective of this paper is to design and to validate a nonlinear multivariable controller, based on the exact feedback linearization technique, which has the capacity to stabilize the photoautotrophic microalgae growth in photobioreactor regardless of the operation point or the transient trajectory. Two measurable outputs were selected, namely the biomass concentration and the pH, whose simultaneous control can be realized by manipulating the dilution rate and the injected carbon dioxide gas flowrate. A mechanistic dynamical model describing the interactions between physicochemical and biological phenomena inside the photobioreactor was used as a starting point for the controller design. Given its complexity, the model was reduced by differentiating the states with slow dynamics from the ones with fast dynamics that were converted into algebraic expressions. In addition, a dynamic time-varying expression was derived for the concentration of hydrogen ions (negative antilogarithm of pH) thus obtaining an appropriate I/O model for control purposes. The degree of interaction between I/O channels was determined through a relative gain array analysis, in order to establish if the system allows the implementation of decentralized SISO controllers or requires a centralized MIMO controller. The feedback linearization method was associated with a model based technique to furnish the immeasurable variables required by the nonlinear control algorithm. The nonlinear controller was implemented on a laboratory torus photobioreactor piloted at constant incident light flux intensity throughout the photoautotrophic growth of a *Chlamydomonas reinhardtii* culture, its efficiency being proved under several operating points.

* Corresponding authors. Tel.: +33 240 17 26 11; fax: +33 240 17 26 18 (M. Titica), tel. :+40 745 13 19 09; fax: +40 236 47 09 05 (S. Caraman).
E-mail addresses: mariana.titica@univ-nantes.fr (M. Titica), sergiu.caraman@ugal.ro (S. Caraman).

1385-8947/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cej.2012.11.133