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Dynamic model of temperature impact on cell viability and major product formation during fed-batch and continuous ethanolic fermentation in *Saccharomyces cerevisiae*

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ABSTRACT

The impact of the temperature on an industrial yeast strain was investigated in very high ethanol performance fermentation fed-batch process within the range of 30–47 °C. As previously observed with a lab strain, decoupling between growth and glycerol formation occurred at temperature of 36 °C and higher. A dynamic model was proposed to describe the impact of the temperature on the total and viable biomass, ethanol and glycerol production. The model validation was implemented with experimental data sets from independent cultures under different temperatures, temperature variation profiles and cultivation modes. The proposed model fitted accurately the dynamic evolutions for products and biomass concentrations over a wide range of temperature profiles. R^2 values were above 0.96 for ethanol and glycerol in most experiments. The best results were obtained at 37 °C in fed-batch and chemostat cultures. This dynamic model could be further used for optimizing and monitoring the ethanol fermentation at larger scale.

1. Introduction

Alternative energy sources must be developed to cope with fossil energy depletion and to reduce greenhouse gas emissions and global warming. Biofuels, derived from renewable resources are realistic substitutes to fossil fuels. Bio-ethanol, the main biofuel produced by fermentation of several feedstocks, constitutes a rapid and significant answer to these problems (Sánchez and Cardona, 2008).

Temperature is one of the main technological factors known to impact both the metabolism and the activity of *Saccharomyces cerevisiae (S. cerevisiae)* at industrial scale due to inhomogeneities in large scale bioreactor (Torija et al., 2003). An optimal temperature, different for growth and ethanol production, exists for each yeast species, and a suboptimal temperature can decrease production kinetics and yields (Aldiguier et al., 2004; Torija et al., 2003). Moreover, a temperature raise alters the cell viability and decreases the ethanol tolerance (Aldiguier et al., 2004; Torija et al., 2003). Besides, the rate of temperature variation significantly impacts the viability, thermal shocks being much more drastic than weak variations (Beney et al., 2000; Gervais and Martínez De Marañón, 1995; Guyot et al., 2005; Marechal et al., 1999; Martínez De Marañón et al., 1999).

Besides ethanol and CO_2, glycerol is the main by-product of the alcoholic fermentation and may account for up to 5% of the carbon in some industrial processes (Oura, 1977). The production of glycerol was reported to be coupled to an increase of the fermentation temperature (Aldiguier et al., 2004; Berovic et al., 2007; Omori et al., 1996; Torija et al., 2003). Moreover, on different *S. cerevisiae* strains a 10–20% higher production was reached when the temperature was shifted for 10 min from 27 to 45 °C or 50 °C (Omori et al., 1996). The glycerol on glucose yields obtained from cultures regulated at 36 and 39 °C were found 4 to 6-fold higher than those obtained at 30 °C (Aldiguier et al., 2004). In a range between 27 and 33 °C a coupling phenomenon was reported between growth and glycerol production in *S. cerevisiae*. Above 36 °C, a decoupling phenomenon was shown (Aldiguier et al., 2004) *i.e.* glycerol was still produced in absence of growth. It is reported that temperature leads to protein unfolding and then in a loss of enzyme functionality, and that glycerol limits heat damages. This metabolite, *in vitro*, was shown to stabilise and renature inorganic pyrophosphatases, involved in lipid anabolism and DNA synthesis (Zancan and Sola-Penna, 2005).

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