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Process investigations of extreme thermophilic fermentations for hydrogen production: Effect of bubble induction and reduced pressure

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HIGHLIGHTS

- ▶ The addition of bubble inducting materials is beneficial for inert gas reduction.
- ▶ For optimal bacteria growth in dark fermentation cysteine is required in the medium.
- ▶ Reduced pressure is an alternative method to inert gas sparging.
- ▶ For large scale application vacuum-sealed systems are necessary.

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ABSTRACT

Hydrogen production via thermophilic dark fermentation is considered a sustainable way to produce renewable hydrogen. For industrial scale an optimisation of hydrogen production is of highest importance. The aim of this work was to evaluate induced bubble formation and applying reduced pressure as methods of removing produced hydrogen instead of external gas stripping. Evaluation was carried out in a continuously stirred tank reactor using the extremely thermophilic bacterium *Caldicellulosiruptor saccharolyticus*. The addition of a bubble formation inductor was able to maintain the fermentation, but only at low hydrogen production rates and yields. Applying reduced pressure at a level of 305 mbar, nitrogen stripping could be omitted and hydrogen yields of around 72% of the theoretical maximum were achieved. It was proven, that application of reduced pressure is a promising alternative to inert gas stripping to obtain high hydrogen productivities and yields for thermophilic dark fermentations.

1. Introduction

Hydrogen will be an important energy carrier in the future. Hydrogen as an alternative motor fuel is seen as a market coming to maturity in 2015–2020. To make the future hydrogen economy fully sustainable, renewable resources instead of fossil fuels have to be employed for hydrogen production. Biological hydrogen production is less energy intensive and more environmental-friendly than conventional thermochemical and electrochemical processes (Das and Veziroğlu, 2001). Different concepts were introduced to meet this approach. One promising and intensively investigated concept is the so called dark fermentation, where hydrogen is produced by heterotrophic anaerobic microorganisms.

Many microorganisms are able to produce hydrogen directly from carbohydrates, under anaerobic conditions via so called dark fermentation, whereby a mixed biogas is produced containing primarily H_2 and CO_2. In dark fermentation 1 mol of glucose is converted theoretically to 4 mol of hydrogen and 2 mol of acetic acid as the main by-product (Thauer et al., 1977). In known pathways and experiments at most 2–3 mol of hydrogen (Hallenbeck and Benemann, 2002) or approximately 70–90% of the maximum hydrogen yield can be obtained from different substrates (De Vrije et al., 2007). Thermophilic fermentation at 70 °C is superior concerning hydrogen yield as compared to fermentations at moderate temperatures (Hallenbeck, 2005).

However, there are specific constraints with biohydrogen fermentation in the dark, which have to be reconsidered for development of a stable process. Hydrogen production and growth for *Caldicellulosiruptor saccharolyticus* is inhibited by product

Abbreviations: CDW, cell dry weight; CSTR, continuously stirred tank reactor; DSMZ, Deutsche Sammlung von Mikroorganismen und Zellkulturen/German Collection of Microorganisms and Cell Cultures; FT-IR, Fourier tansformed infrared; OD, optical density; R^2, coefficient of determination; TCD, thermal conductivity detector.

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