Mini Review
Volume 11:10, 2022

Journal of Industrial Engineering and Management

ISSN: 2169-0316 Open Access

Improved Product Yield from Pathway Engineering in Yeast-Based Industrial Ethanol Production

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Abstract

A crucial performance indicator for industrial ethanol production using the yeast Saccharomyces cerevisiae is product yield on carbohydrate feedstock's. By altering the ratio of ethanol production, yeast growth, and glycerol formation in anaerobic yeast cultures, this paper examines pathway engineering strategies for increasing ethanol yield on glucose and/or sucrose. Strategies for altering redox-cofactor coupling in carbon and nitrogen metabolism, which aim to reduce or eliminate the role of glycerol formation in anaerobic redox metabolism, and strategies for altering alcoholic fermentation's energy coupling receive particular attention. We discuss context dependence, theoretical impact, and the potential for industrial application of various proposed and developed strategies in addition to providing an overview of scientific advancements.

Keywords: Ethanol production • Glycerol formation • Theoretical impact

Introduction

In the absence of growth, survival of yeast cells requires cellular maintenance metabolism, which encompasses use of ATP for growth-independent processes that maintain structural integrity and viability. In anaerobic yeast cultures, this ATP is exclusively generated via alcoholic fermentation In contrast, growth of yeast cells not only requires ATP but also organic precursors for biomass components, whose biosynthetic pathways compete for carbon with ethanol production Anaerobic growth occurs in all current industrial processes for ethanol production and the resulting surplus yeast biomass is valorized by its inclusion in a by-product stream sold as an animal feed supplement [1-3].

Literature Review

Redox-cofactor metabolism links growth to the production of glycerol, another important byproduct of anaerobic yeast metabolism. This paper aims to review the current body of knowledge on pathway engineering strategies that focus on maximizing ethanol yields on glucose or sucrose by altering the ratio of ethanol, biomass, and glycerol formation in S. cerevisiae. The formation of biomass by S. cerevisiae from sugar, ammonium or urea, and other nutrients is coupled to a net reduction of NAD+ to NADH. This scope leaves out a significant amount of metabolic engineering research that aims to expand the sugar- and polysaccharide substrate range of S. cerevisiae in order to facilitate its nascent application for industrial-scale fermentation of lignocellulosic hydrolysates generated from agricultural residues or energy crops. The growth of anaerobic laboratory cultures of wild-type S. cerevisiae strains under various conditions revealed how distribution of sugar over biomass, glycerol [4,5].

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Received: 01 October, 2022, Manuscript No. Iem-23-86305; **Editor assigned:** 03 October, 2022, Pre QC No. P-86305; **Reviewed:** 16 October, 2022, QC No. Q-86305; **Revised:** 21 October, 2022, Manuscript No. R-86305; **Published:** 27 October, 2022, DOI: 10.37421/2572-0813.2022.11.173

Discussion

By altering the conditions under which the cultures are grown, it is possible to increase the proportion of the sugar substrate that is fermented into ethanol by actively growing anaerobic cultures in order to meet the requirements for maintenance energy rather than lowering the specific growth rate. It was found that adding weak organic acids like lactate, acetate, propionate, or benzoate to low-pH anaerobic batch and chemostat cultures decreased biomass yields while increasing ethanol yields. Due to an influx of protons into the yeast cytosol as a result of weak acid diffusion, these findings indicate an increased maintenance energy requirement for intracellular pH homeostasis.

Conclusion

Experiments on disaccharide metabolism by anaerobic S.cerevisiae cultures provided a first demonstration that ethanol yields can be modified by changing the mechanism of sugar import. In contrast to transport of glucose, which occurs via facilitated diffusion by Hxt transporters During growth on ammonium or urea, a significant part of the 'surplus' NADH generated in biosynthesis is derived from the synthesis of amino acids from these nitrogen sources and sugar. Several studies reported lower glycerol yields and higher ethanol yields on sugar in anaerobic cultures grown with amino acids or yeast extract as the nitrogen source. Although use of amino acids as industrial nitrogen source is not an economically viable proposition, these observations highlighted the potential for engineering redox-cofactor metabolism to improve ethanol yields.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Khan, Jaheer. “Improved Product Yield from Pathway Engineering in Yeast-based Industrial Ethanol Production.” J Ind Eng Manag 11 (2022): 173.