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Review Article

A review on single stage integrated dark-photo fermentative biohydrogen production: Insight into salient strategies and scopes

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ABSTRACT

In recent times, systematic integration of dark and photofermentation has attracted a lot of attention due to the advantage of enhanced H_2 yields and better substrate conversion efficiencies. This integration is done either in a sequential two stage or in a single stage manner, between which the single stage integration (SSI) seems more cost effective. This article thoroughly reviews the salient operational strategies, key factors affecting the H_2 yields and overall increment in H_2 yields attained in the SSI biohydrogen processes. Selection of more complementing pair of dark and photofermentative microbes, optimization of composition of common growth medium, better strategies for consistent pH control and facilitation of lignocellulosic feedstocks have been identified as major areas requiring in-depth focus and subsequent improvements. Based on the insightful discussions, the current state-of-the-art of SSI bio-H_2 technology has been evaluated and its potential to become a reliable hydrogen production technology has been factually assessed.

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Introduction

Regular and excessive consumption of the conventional fossil fuels worldwide during the last few decades has led to continuous and rapid depletion of the limited reserves [1–3]. In addition, concomitant emission of several noxious green house gases (GHG) from the combustion of these carbonaceous fuels have polluted the air to extremely alarming levels [4,5]. The consequences of these two issues coupled together will be a world with severe energy deficiency and degraded environment, if alternative measures are not adopted right now with immediate effect. The current scenario of global pollution demands severe curtailment of GHG emissions from combustion of fossil fuels [6]. This cognizance has motivated the worldwide research quest for environmentally cleaner, energy efficient and completely renewable options of biofuels viz., bioethanol [7,8], biobutanol [9], biodiesel [10], biogas/biomethane [11–13] and biohydrogen [14–18]. Molecular biohydrogen, which is long been recognized as the future green-fuel is the most attractive alternative of the soon to be scarce pollution causing fossil fuels. Biohydrogen as a fuel has several advantageous attributes, including; carbon-neutral or carbon-zero nature, easy renewability, eco-efficient productivity (via biological routes), eco-friendly conversion and highest energy content among all existing fuels [14,19]. Undoubtedly, hydrogen is the most reliable future biofuel in terms of energy efficiency as well as being environmentally benign. Biological production of fuel grade hydrogen from various waste feedstocks has emerged as a very promising technology in the recent years [16,17,20–23]. This globally uprising research field is continually exploring the newer avenues in search for low cost and economically feasible biohydrogen production processes with higher hydrogen yields to make the employability of biohydrogen as the efficient future fuel a reality soon. Currently, biohydrogen production processes are being combined with waste recycling through utilization of abundant and cheap phytobiomass and wastewaters as feedstock materials to reduce the high cost of production along with reduction of pollutant load on environment [20,23–27]. Multivariate features of these integrated bioprocesses are indeed alluring with regard to - savings in energy expenditure, reutilization of energy rich resources discarded as waste, combating environmental decay etc. and needed to be strategized scientifically for ultimate betterment.

Most of the previous research studies reported on biohydrogen production from complex wastes including starchy and ligno-cellulosic feedstocks, focused majorly on either dark or photo-fermentative processes. The earlier researchers identified high production cost, low H_2 yield and low energy recovery from the feedstocks as the main disadvantages of these processes [28–30]. In case of photofermentation, low light conversion efficiency (LCE) has been reported as a major drawback by many of the researchers [31,32]. Probably, due to these issues encountered in individual fermentative processes, the recent trend of research on biohydrogen production is directed towards the possibility of integration of heterotrophic dark fermentation with phototrophic light fermentation either by using sequence of two reactors or by using a single reactor [28,33–35]. In the integrated systems the carbon-rich by-products of dark fermentation is utilized by the photofermentative microorganisms. Overall, there is an increase in carbon conversion efficiency and enhancement of hydrogen yield over the conventional systems either using dark or photofermentative bacteria [28,33–35]. Based on the stages of reactor operation the integrated bio-H_2 systems are classified into two main classes; two stage integration (TSI) and single stage integration (SSI). In the single stage integrated system, both the dark and photofermentation processes occur in the same reactor. Therefore, the initial investment and running cost of energy for pumping of the by-product of dark fermentation step from 1st to 2nd stage, as required in TSI, are eliminated. Hence, the SSI system is cost-effective and is becoming more attractive in comparison to TSI for the user-friendly revamping of the biohydrogen production. The purpose of this article is to review the recent advances particularly made in SSI biohydrogen production from either simple carbon sources or complex waste streams from both applied and fundamental aspects. Special emphasis has been given on information related to integrated dark and photo fermentative processes and on principles of arrangement used for augmentation of overall hydrogen productivity. Based on a simple techno-economic comparison between the TSI and SSI systems, the superiority of SSI over the TSI has been

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