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A Mini-review on Dark-Photo Fermentation

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Abstract: Because of the benefits of increased hydrogen yields and greater substrate conversion efficiencies, systematic integration of dark and photo fermentation has gotten a lot of attention recently. This integration can be done in two stages sequentially or in a single stage, with the single-stage integration appearing to be more cost-effective. The primary operating techniques, key factors affecting hydrogen yields, and the overall increase in hydrogen yields realized in the single-stage integration biohydrogen processes are all thoroughly reviewed in this paper. Selection of a more complementary pair of dark and photofermentative microorganisms, optimization of common growing medium composition, and improved tactics for consistent growth pH management and lignocellulosic feedstock facilitation have been recognized as important issues that require more attention and development. Most investigations so far have been performed with batch digesters utilizing unpolluted culture and a sole wastewater, so, the method improvement of the combined two-steps procedure was yet in the early stages. The combination of dark- and photo-fermentation can be used to boost biohydrogen production and substrate utilization, making it the best option for commercial biohydrogen generation. The current status of single-stage integration bio-hydrogen technology has been reviewed, and its potential to become a reliable hydrogen production technology has been factually assessed, based on the insightful talks.

Keywords: Dark-photo Fermentation, Hydrogen, Microorganisms, Anaerobic

1. Introduction

The rapid usage of these resources may result in their depletion in the not-too-distant future, raising a significant task of finding a new and environmentally benign energy source [1]. Hydrogen, with its maximum conversion efficiency of 122 kJ/g and no emissions of greenhouse gases (GHG) during combustion, is seen as a promising energy carrier and, in the long run, may be the ultimate biofuel [2, 3]. "Biohydrogen" is hydrogen (H_2) created biologically from renewable sources (biomass, waste water, organic wastes). Organic contaminants in trash and/or wastewater serve as a carbon and energy source for the bacteria that produce biohydrogen [4, 5]. Every procedure has its own set of benefits and drawbacks. Over the last few years, integrated systems for biological H_2 generation, comprising dark- and photo-fermentation, have gotten a lot of interest [6, 7]. A mixture of distinct microorganisms with varying capacities can be used to leverage their particular strengths and overcome their deficiencies. This review looks at how far integrated dark- and photo-fermentative biohydrogen generation has progressed, as well as the processes and integration strategies that have been developed, as well as the possibilities for increasing H_2 yield.

The purpose of this paper is to give an overview of dark and photo fermentation as a notable alternative feedstock for H_2 synthesis and to compare its importance. The role of numerous processes and enzymes in various fermentation strategies, such as dark fermentation, photofermentation, and mixed (hybrid) dark–photofermentation, has been discussed.

2. Photo Fermentation

Though this system is likely to cure substrates, the amount of hydrogen generated is less than the other procedures [8]. This system is highly susceptible to microbial activity, which inhibits commercial growth. As a result, genetic engineering applications are critical for system improvement. Instead, because the majority of light is absorbed by pigments, light penetration becomes the regulating factor during the treatment of concentrated wastewaters of dark hue [9]. Purple non-sulfur bacteria (Rhodobacter sphaeroides) were used to produce H_2 from various carbon sources. [10] Investigated the production of hydrogen from glucose, fructose, and sucrose in a new species (Rhodopseudomonas sp. nov.) isolated from bio-digester sludge. In a 61 mL digester lit with 150 W/m^2 light, 161 mL hydrogen was produced. Furthermore, this process is expected to produce generations of important compounds. [5] Siddique et al., 2019 used photo-fermentation to produce hydrogen and poly-hydroxybutyrate (468 mL/L and 1500 mg/L, respectively) from winery effluent.

3. Dark Fermentation

The dark fermentation system uses anaerobic microorganisms to convert organic molecules into H_2 in the absence of light [11]. The use of microbial biocatalysts, pretreatments, and appropriate wastewaters can all help to boost hydrogen generation. Enzymes are used by microorganisms to produce H_2. Dark fermentation uses a variety of microorganisms, including anaerobes (Clostridia and thermophiles), facultative anaerobes (Enterobacter), and complete aerobes (Alcaligenes and Bacillus) [8]. Sugar, amino acids, glucose, sewage wastewater, dairy wastewater, distillery effluents, and other wastewaters are often used to create H_2 [12]. Hydrogens, as well as volatile fatty acids and alcohols, are produced in the dark fermentation method [14]. Different scientists use this technique because of its simplicity and ability to decompose substrates in a way that other systems cannot. Because this system is unaffected by light, it can handle a larger volume of garbage with more efficiency [15]. The utilization of anaerobic states makes it simple to remove O_2 from the dark-fermentation reactor. Scientists' primary goal in constructing the dark reactor is to achieve stable commercial H_2 production. Dark fermentation systems promote microbial growth and are less reliant on environmental conditions [5]. Additional benefits of this system include the ability to manufacture H_2 continuously without the use of light, decreased energy input, and the use of wastes as substrates [8]. An increase in H_2 production can be accomplished in a dark fermentation reactor, which will be detailed further down. In general, batch reactors are preferred for dark fermentation reactors due to their productivity and cost-effectiveness [13]. However, to work continuously, the system must perform inappropriate bio-digesters. These digesters are suitable for soluble wastewaters, however, insoluble wastewaters should be treated using an immobilized reactor.

4. Conclusions

Biological hydrogen generation offers various advantages over chemical and physical hydrogen synthesis, including the use of sunlight and organic wastes as substrates, which aids in bioremediation, and the ability to operate at moderate temperatures, making the process very cost-effective (Figure 1). Combining dark- and photo-fermentation for biological H_2 production appears to be the most promising technique. Individual system issues can be solved, and total performance can be increased, by combining dark- and photo-fermentation systems. Individual systems will be far less efficient than integrated systems, it can be concluded. In addition, combining dark- and photo-fermentation might be more effective for waste minimization. Most investigations so far have been conducted in batch reactors utilising pure cultures and a single substrate, therefore the technology development of the integrated two-step process is still in the early stages. Hydrogen production yield may be efficiently boosted by taking into account all of the system requirements and physical characteristics. The utilisation of high BOD/COD wastes from wastewater treatment systems in the dark-fermentation process by mixed anaerobic cultures could reduce the cost of hydrogen production. When using dark fermentation effluents rich in organic acids for photo-fermentation, the pH and composition of the effluent must be adjusted for the best growth of photo-fermenting organisms in order to produce outstanding hydrogen output. The combination of dark- and photo-fermentation can be used to boost biohydrogen production and substrate utilisation, making it the best option for commercial biohydrogen production.

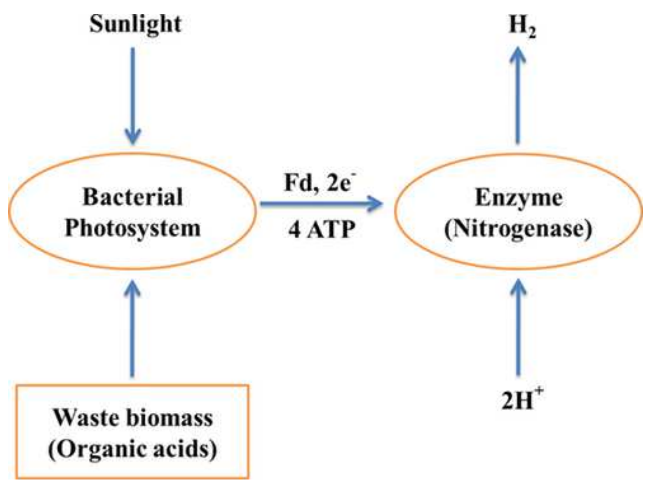

Figure 1. *Schematic diagram of the photofermentation process for biohydrogen formation [16].*

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