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# Advanced biohydrogen production using pretreated industrial waste: Outlook and prospects

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ABSTRACT

In order to address existing environmental concerns as a result of non-renewable energy sources and to meet future energy demands, biohydrogen offers a suitable alternative energy reserve. Discrete as well as integrative methods of biohydrogen production have been analyzed over time, optimized for achieving high yields. In addition, key process parameters such as temperature, pH, hydraulic retention time, substrate concentration etc., which influence the rate of production have been clarified. Several studies have exploited industrial waste as feed sources for the production of biohydrogen; however, lower yields from these add an additional requirement for suitable pretreatment methods. The present communication examines various pretreatment methods used to increase the accessibility of industrial wastewater/waste for biohydrogen production. Furthermore, a brief overview addresses challenges and constraints in creating a biohydrogen economy. The impacts of pretreating wastes on biohydrogen generation and the latest trends are also supplied. This study helps in the critical understanding of agro-industrial wastes for biohydrogen production, thereby encouraging future outcomes for a sustainable biohydrogen economy.

## 1. Introduction

Increasing awareness of environmental impacts of energy production and use has been growing steadily as a result of harmful effects which impact biota and biodiversity, and climate impacts specifically have brought environmental considerations to the fore. Petroleum-derived fossil energy sources are one of the major contributors of such complications. Prevailing issues regarding sustainability due to conventional practices has forced attention towards alternative energy sources including bio-based sources [1]. In this context, biohydrogen stands as an ideal alternative, offering an array of desirable attributes for efficient energy generation. Despite promising research activity, biohydrogen production processes still demand refinement on a broad scale owing to certain inhomogeneities, especially with respect to suitable reactor design and configuration. To devise an efficient method for the production of biohydrogen without compromising economic viability, research also focuses on employing waste matter (i.e. from industry) as a potentially favored substrate [2].

Biohydrogen production is known to be either a light-dependent (photofermentation) or a light-independent (dark fermentation) process (Fig. 1) [3]. Biohydrogen can be produced through different processes, namely: anoxic photosynthesis, fermentation, oxygenic photosynthesis, and cyanobacterial hydrogen biosynthesis through a nitrogenase enzyme complex. The integrative prospects offered by dark fermentation methods are well established despite being less commonly used by industry [4].

It is essential to optimize the key parameters which influence the production process. Studies have analyzed the effects of crucial parameters such as temperature, pH and substrate concentration on biohydrogen generation. For instance, Thanwised et al. [5] showed an inverse relationship between hydrogen production rate (HPR) and hydraulic retention time (HRT) and reported an optimum HRT of 6 h for anaerobic baffled reactor operation. Another variant, an “anaerobic sequencing batch biofilm reactor” has been tested for its effectiveness in biohydrogen production with varying organic loads and feed types [6]. Gomes et al. [7] established the unfavorable effects of lactic acid

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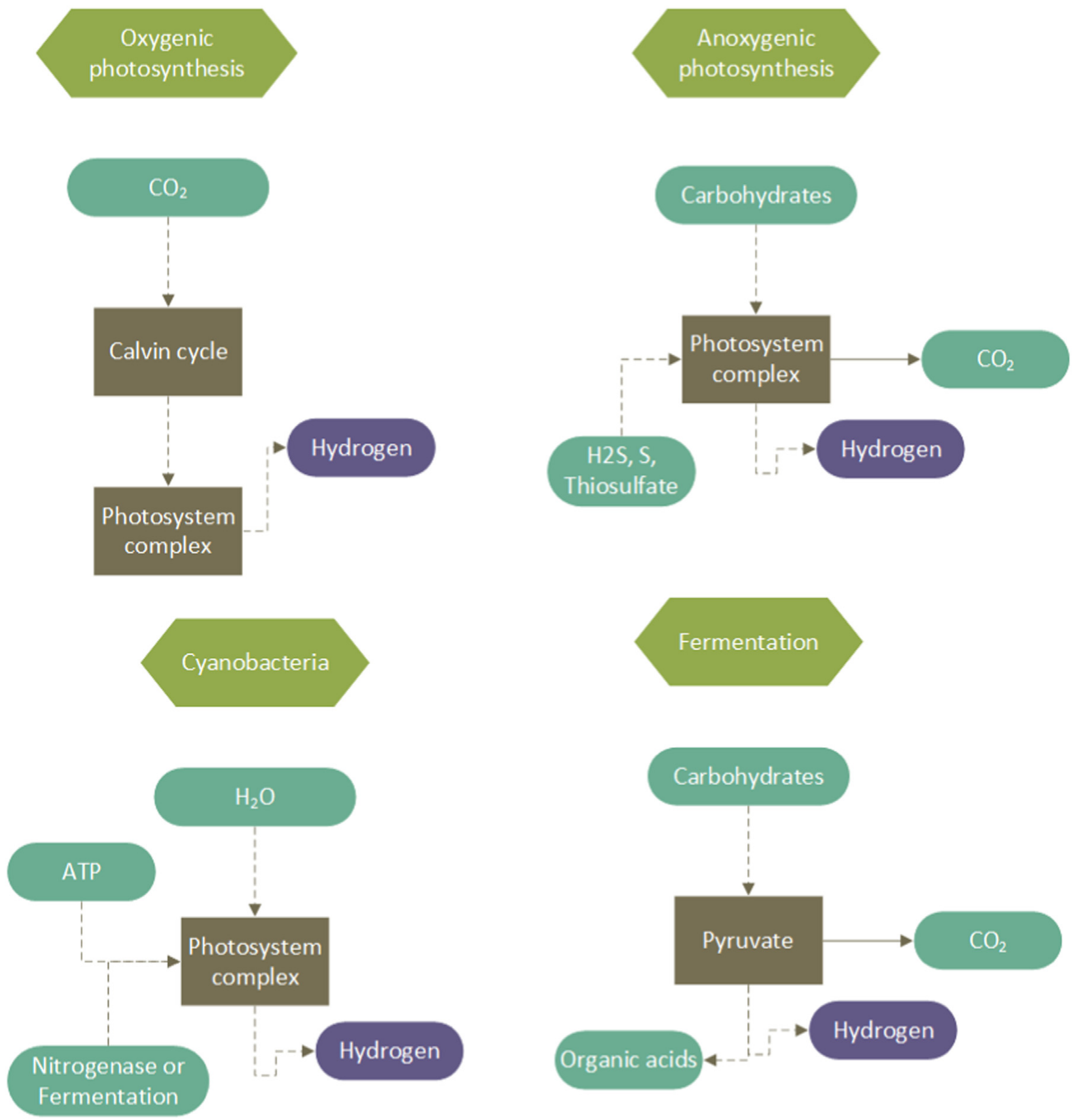


**Fig. 1.** Intracellular pathways for biohydrogen production involving essential metabolites and processes.

bacteria hindering hydrogen production using continuous multiple tube reactors. Hernández et al. [8] showed anaerobic co-digestion of substrates as an essential strategy for enhanced biohydrogen production with varying organic loads. Experiments reveal the importance of optimizing the carbon to nitrogen (C/N) ratio in order to attain desirable yields. Amidst such influencing factors, substrates hold a top priority owing to their role as energy source for adequate functioning of microbial metabolisms. In this context, cost-effective substrates are generally preferred, with special regard to industrial waste and wastewater.

Among studies utilizing agro-industrial waste for biohydrogen production, Venkata Mohan et al. [9] reported a hydrogen production of 6.076 mmol $H_2/m^3$/min using the composite chemical wastewater as a substrate, highlighting the benefits of simultaneous hydrogen production and wastewater treatment. High strength brewery industrial wastewater [10] showed a hydrogen yield of 259.6 mL $H_2$/g COD at a concentration of 5 g/L. Recently, mushroom farm waste has shown a peak hydrogen production rate of 6.84 mmol $H_2$/L/d at pH 8 and a substrate concentration of 60 g MW/L under batch fermentation conditions [11]. Strategies for simultaneous use of two different categories of wastewater as a nutrient source have also been explored. A combination of brewery wastewater (BW) and paper and pulp mill effluent (PPME) yielded 0.69 mol $H_2$/L medium at 10% BW + 90% PPME [12]. Nevertheless, biohydrogen yield obtained from the direct consumption of industrial waste is low unless incorporating an additional pretreatment.

Numerous studies have been conducted on the feasibility and effects of implementing pretreatment strategies to improve biohydrogen yield. He et al. [13] tested the solubilizing capacity of hydrothermal pretreatment (HTT) using rice straw for anaerobic production of biohydrogen. A maximum soluble substrate of 80 mg/g of volatile solids (VS) (210 °C and 0 min holding time) resulted in a 28 mL/gVS yield of biohydrogen, i.e., 93-fold higher than the control. In a recent study, real textile desizing wastewater was pretreated using a fused coagulant, GGEFloc-653 (montmorillonite, polyacrylamide and activated carbon) to achieve increased hydrogen yields [14]. Results illustrated an increase in the hydrogen production capability by 120% ((11–5 mL)/5 mL) with a yield of 3.9 L $H_2$/L/d, highlighting the potential of coagulation pretreatment generally. Further, combined pretreatment approaches such as chemical pretreatment followed by microbial electrolysis are well established [15]. For example, the highest hydrogen