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Advances in Bioresearch

## **REVIEW ARTICLE**

# Hydrogen: A Potential Source of Clean Energy

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#### ABSTRACT

Hydrogen or biohydrogen (H<sub>2</sub>) is one among the most acceptable and sustainable renewable fuels due to continuous lessening of non-renewable fossil fuels. In addition, increasing human population and their existing modern life style including transport and industrial sectors are the reasons for energy obligation. Moreover, using hydrogen as fuel is the best solution to reduce air pollution because it doesn't contaminate the environment once it splits and therefore considered as a clean form of energy. Hence, present review spotlights the production of hydrogen through various methods including both renewable and non-renewable processes. Current review also focuses on the biological hydrogen production method from various sources was emphasized. Overall, this review will be useful for renewable energy sector and also for future research.

Keywords: Renewable, Energy, Hydrogen, Methods, Biological, Enhancement.

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#### INTRODUCTION

Indiscriminate usage of fossil fuels and their regular reduction shifts our focus towards renewable energy resources. The major reasons behind the fossil fuels getting depleted are increasing human population and their needs, transport and industrial divisions [1]. Thus, the demand of energy increasing continuously, thereby rising price in recent days in turn is a serious threat to economy. Additionally, most of the fossil fuels are reasons for environmental pollution which is one of the causes of global warming and climate change, thereby imposing severe threat to health of living organisms including human beings [2]. Therefore, there is an urgent need to look in to alternate sources of energies which are cost effective, causes no side effects to environment and at the same time renewable.

Renewable fuels are generated from natural resources such as sunlight, wind, water, biomass, tidal, geothermal etc. [3]. Among the renewable resources, solar and wind energy are the largest growing industries apart from hydro energy. Specifically, solar energy popularized in entire world at present and practiced in most of the countries. Wind energy is also one of the big renewable energy resources, which is generated from wind. Wind turbines alter kinetic energy into mechanical energy, thereby producing electricity. Hydro energy is again divided into large and small categories. Bioenergy is yet another form of renewable source which come under the category of biofuels [4]. They are mainly produced from biomass of biological organisms including plants and animal and their wastes. In contrast, both tidal and geothermal energies have historically been limited to areas which in turn depend on the location. Tidal energy is also one of the sources of renewable energy that can be utilized to produce electricity.

Biomass-based energy such as bioethanol, biobutatnol, biodiesel and biohydrogen are the popular and last one emerged recently. Biological hydrogen or biohydrogen (H<sub>2</sub>) is assumed to be the most ideal fuel due to its clean form [5, 6]. It is often generated from a variety of resources both by chemical and biological methods. But still the production is insufficient for public usage due to different reasons. Various photosynthetic organisms including plants and certain algae can produce hydrogen from water by with the help of solar energy [7, 8]. Apart from advanced plants, algae are simple group of photosynthetic organisms ranging from single cell to multicellular forms with different alterations in physiological and biochemical pathways particularly with reference to biofuel generation [9].

### Hydrogen production methods

Pure form of hydrogen exists at very low levels (< 1ppm) in our atmosphere and most of the hydrogen (96%) has been generated from non-renewable fossil fuels and water electrolysis contributes the remaining 4% [10]. There are different methods of H<sub>2</sub> production such as steam-methane reforming, thermochemical process, gasification, electrolytic process, pyrolysis and renewable processes such as water splitting by solar energy and biological methods (Fig. 1) [11, 12, 13]. Specifically, several research groups are working chemically for H<sub>2</sub> production and also from different biomass or biowaste as feed but productivity is unsatisfactory [14]. Usage of biological organisms particularly plants have some negative results. The first generation fuels which are produced from food crops such as corn and maize and the second generation fuels which are produced from non-edible crops and their waste. The algae, seaweeds and diatoms are used for third generation fuels. Fourth generation fuels are those produced from advanced technology using algae, bacteria along with non-arable land which include electro fuels and photobiological solar fuels [15].



Figure 1. Different processes involved in H<sub>2</sub> production.

Steam-methane reforming is a popular and widely used method for hydrogen production. In this process, methane reacts with steam at high temperature [16]. Gasification is nothing but reaction of carbonaceous materials with oxygen, air and steam at high temperature. In this method, coal or biomass will be used and further purification step will1 be carried out to separate the hydrogen gas from other gases [17]. Thermochemical process involves chemical and heat reactions to split the water into hydrogen and oxygen. Several materials and noble elements including metal oxides are used as catalysts in the water splitting process [18]. In electrolytic process, water will split using electricity to get hydrogen and oxygen [19]. Pyrolysis process involves heating of hydrocarbons and oils in the absence of oxygen to get the hydrogen [20].

In photoelectron chemical method, hydrogen is generated from water using sunlight and certain semiconductors [13]. The earth covers mostly with water and it is easy to generate hydrogen once the standard protocol establish. A biological method is nothing but generation of hydrogen using biomass of living organisms. Majorly, the photosynthetic organisms have chance to produce more hydrogen due to water splitting process in photosystem II of the photosynthesis [14]. Advanced biofuels including biohydrogen have several advantages over first and second generation biofuels because first generation bio-fuels often lead to rise in food prices and climate change problem. Specifically, algae/microbes are grown in special bioreactors and supplied with nutrients and  $CO_2$  from the air or from conventional gas plants for the hydrogen production in down streaming process [21].

## Biological hydrogen production

Production biohydrogen using biological samples or biowaste is one of the best and sustainable methods. At initial stages, biological researchers worked on hydrogen generation using microbial organisms and plants through fermentation [4]. Biological hydrogen production is the easiest, less expensive and

environment friendly method due to more availability of natural resources. However, hydrogen production was carried out mostly using non-biological methods till date.

Dark fermentation, light fermentation and biophotolysis are the important biological methods. Breakdown of organic substrates into hydrogen without light in the process of fermentation called dark fermentation. In this process, carbohydrates, sugars and biomass were used for fermentation process [11]. In light fermentation, cyanobacteria like organisms used the light and organic compounds to generate biohydrogen. Biophotolysis is one of the best methods where the photosynthetic organisms split the water into hydrogen. Certain primitive including algal species were used for this method [5].

Several decades back researchers observed primitive plants such as algae possess the property of H<sub>2</sub> production in dark anaerobic condition [22]. Apart from other biofuels such as bioethanol, biobutanol and biodiesel generation, biohydrogen production from algae is one of the emerging trends in recent days. Using of algal species in bioreactors without using much space is one of the best options for hydrogen production at industrial scale. Algal species are available in both freshwater and marine areas. Algal species possess high photosynthetic capacity and short life span depends on the species [23]. Based on the pigment content algae are divided into green, red, brown and blue-green types. Algae also generate useful macromolecules such as carbohydrate, protein and lipid for biofuel and other commercial product generation and considered as best feedstocks. Generally certain photosynthetic microalgae generate protons (H<sup>+</sup>) in water splitting stage at photosystem II in photosynthetic process which in turn reduced by hydrogenase enzyme to generate hydrogen gas [6]. This pathway results in the photo-evolution of hydrogen gas by the algae and number of workers working on this topic in the present conditions. Figure 2 highlights the biological materials used for hydrogen production.



Figure 2. Plants and algal samples used for biological hydrogen production.

## CONCLUSION

Continuous reduction of conventional non-renewable fossil fuels urges us to focus on renewable energy such as hydrogen. Hydrogen is one of the clean and sustainable energy sources at present conditions. In this review, hydrogen production methods were emphasized. In addition, this review also highlighted the biological hydrogen production methods. This work will be useful for commercial production of hydrogen and future research.

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