iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** XI **Month of publication:** November 2021

DOI: https://doi.org/10.22214/ijraset.2021.38876

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue XI Nov 2021- Available at www.ijraset.com

Hydrogen Generation from Biowaste & Its Application as A Fuel

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Abstract: ***With the rapid decrease in conventional energy sources and serious issues like Global Warming and change in the climate, there is an immediate need to find sources that are renewable and will last for a long time. Hydrogen as a fuel is a good alternative given its abundance. Hydrogen production uses natural gases and electrolysis of water, thus directly or indirectly creating pollution. But this doesn't mean that energy provided by hydrogen is clean in the utmost sense. Hence there is a need to segregate and analyze different Hydrogen production techniques. In this paper, we will briefly discuss the biological methods of Hydrogen production from biomass and applications of hydrogen.***
Keywords: Biological H_2 production, Aerobic Reaction, Anaerobic reactions, Fuel cell.

I. INTRODUCTION

With the progression in time, the need for energy is also increasing and petroleum-based fuels are no longer a viable option given their non-renewable nature and harmful effect on the environment. However there are ways to generate hydrogen from biowaste and for countries like India, cleanliness is already a big concern. The roads are full of biowaste, mud, dirt, etc., which creates a very bad impact on the health and hygiene of people, especially in the rural areas. The developing world of science has provided us with some solutions but their use is confined due to a lack of funds and technology. In this case, Fuel Cells possess the potential for their use on a large scale. Fuel Cells are revolutionizing the way we produce power by finding ways to be used commercially for large-scale domestic use At the minute Fuel Cells use hydrogen as fuel, which offers a sustainable power source, with water as a byproduct making it clean for use. Hydrogen Fuel Cell is seen as a feasible replacement for conventional power production in many applications, especially on-site/off-grid power production. However, Hydrogen is an inert gas, which makes extracting Hydrogen and packing it a difficult and costly affair. Also, hydrogen produced from natural gas is also accompanied by CO2 emissions and since CO2 is a greenhouse gas it is not appreciable for the environment. In addition, hydrogen production using electrolysis requires a lot of electricity which again comes from conventional sources like power plants. So science is working on newer ways which reduce the emissions caused by conventional methods. Biological methods of production of hydrogen by the action of microbes on wastewater and biomass wastes is very important since it consumes waste helping the reduction of garbage volume, it can be applied to wastewater which results in wastewater treatment and the process is free of emissions and is environment friendly. Biological hydrogen production delivers clean hydrogen with an environmentally-friendly technology and is very suitable for the conversion of wet biomass in small-scale applications, thus having a high chance of becoming an economically feasible technology.

II. TYPES OF WASTE MATERIALS

[1]The main concerns of waste materials from which bio-hydrogen will be produced are availability, cost, biodegradability, and carbohydrate content.

A. Carbohydrate Industrial Wastewaters

Industrial effluents from the dairy industry, olive mills, baker's yeast which are biodegradable carbohydrates and non-toxic can be used for bio-hydrogen production. [2] Although to remove undesirable components and for nutritional balancing, waste may require to be pretreated. Fig. 1 shows schematic diagram for bio-hydrogen production from food industry wastewaters by two stage anaerobic dark and photo-fermentations.

B. Waste Sludge of WTP

A large number of carbohydrates and proteins are useful for the production of methane or hydrogen gas, which can be made available from waste sludge generated in wastewater treatment plans.

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C. Agricultural or Food Industry Wastes

Cellulose containing agricultural wastes requires further pretreatment. Agricultural wastes should be ground and then de-lignified by mechanical or chemical means before fermentation. Biodegradability may be affected badly since these wastes are complex in nature.

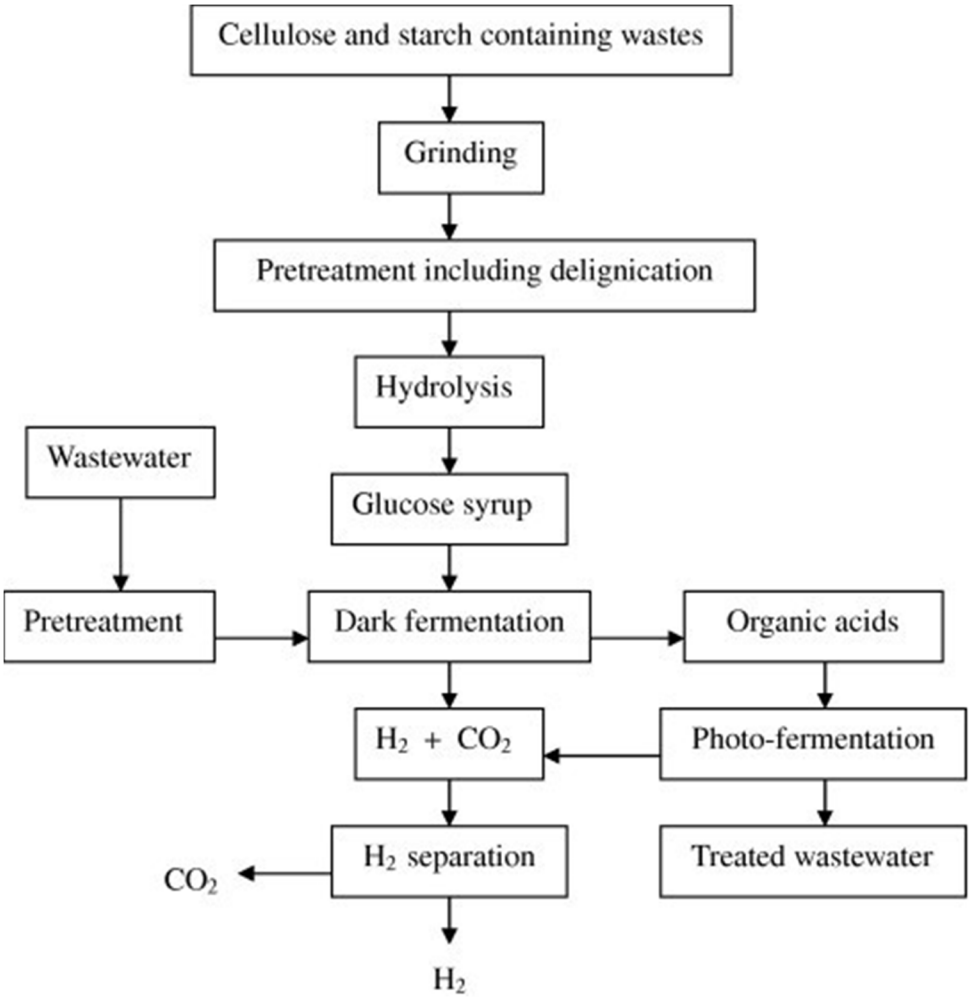


Fig.1

III. BIOLOGICAL HYDROGEN GAS PRODUCTION

Hydrogen has a very high energy content per unit mass and is considered clean fuel because it produces water on combustion. [3]Although currently only 40% of hydrogen is produced from natural gas, 30% from heavy oils and naphtha, 18% from coal, 4% from coal, and 1% is produced from biomass. [4]The method used today uses natural gas as input and hence produces CO2 and other waste gases which cause emissions.

Electrolysis of water looks like a cleaner solution but it requires a very amount of electricity which is provided by conventional sources like thermal or nuclear power plans that indirectly create pollution. In the coal gasification process, a lot of waste gases are produced containing sulfur compounds, thus highly polluting. [5]To meet the emission standards by the Kyoto protocol, hydrogen should be produced from renewable energy sources.

Many biochemical reactions create hydrogen as a by-product mainly in anaerobic fermentation processes. [6] In addition, many microorganisms create enzymes that also produce H2 from water if an outside energy source like sunlight is present. Hydrogen is produced anaerobically caused by the process of anaerobic digestion in enzymes.

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Thermophilic bacteria are selected over mesophilic bacterial, for the production of hydrogen from renewable sources due to higher hydrogen production efficiency. For this purpose, the feedstock can range from crop wastes of high sugar content and waste streams of domestic organic waste, paper sludge, and potato steam peels, etc.

Nutrient requirements and inhibitory effects differed depending on the strain and the feedstock applied. Specific ways in which microbes can produce H2 are described below:[6]

1) Biophotolysis of water using green & blue-green algae (cyanobacteria)
2) Direct biophotolysis
3) Indirect bio-photolysis
4) Photo-fermentation
5) Dark fermentation
6) Hybrid systems
7) Using dark fermentative and Photo-fermentative bioreactors
8) Bio-electrochemically assisted microbial bioreactors

A. Direct Biophotolysis

Direct Biophotolysis is a biological process to create hydrogen using solar energy and photosynthetic systems of algae to convert water into chemical energy.[7]

$$2H2O + \text{solar energy} \rightarrow 2H2 + O2$$

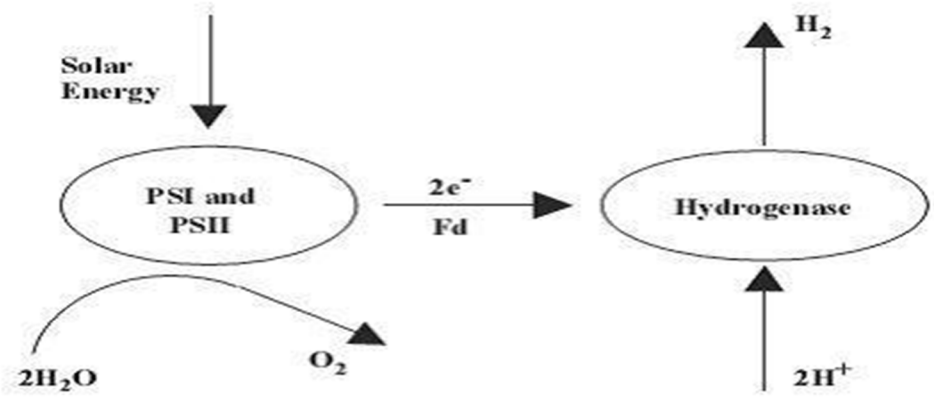
In the above process, two protons (H+) are released. In the presence of the "Hydrogenase" enzyme, these two protons can produce one molecule of H2. Hydrogenase enzyme is present in green algae and cyanobacteria, thus they possess the ability to generate hydrogen.[8]

$$H2O \rightarrow PSII \rightarrow PSI \rightarrow Fd \rightarrow \text{Hydrogenase} \rightarrow H2$$
$$\downarrow O2$$

It is necessary to keep Oxygen content to a low level (under 0.1%) so that hydrogen production can be sustained since hydrogenase is sensitive to oxygen. This condition can be obtained by the use of green algae, Chlamydomonasreinhardtii, which can deplete oxygen during oxidative respiration. However, the reaction is very short-lived and the rate of hydrogen production is very low, less than one-tenth than that of other photosynthetic reactions.

B. Indirect Bio-photolysis

In indirect bio-photolysis, the problem of sensitivity of the H2 evolving process to O2 is usually circumvented by separating O2 and H2. In this process, CO2 is intermittently fixed and released serving as the electron carrier between the O2producing (water splitting) reaction and the O2 sensitive hydrogenase reactions.



In such concepts, the algae undergo a cycle of CO2 fixation into storage carbohydrates (starch, glycogen) followed by its conversion to H2 by dark anaerobic fermentation processes. In a typical indirect bio-photolysis H2 is produced as follows:[9]

$$12H2O + 6CO2 \rightarrow C6H12O6 + 6O2$$
$$C6H12O6 + 12H2O \rightarrow 12H2 + 6CO2$$

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C. Photo-fermentation

H2 production by purple non-sulfur bacteria is mainly due to the presence of nitrogenase under oxygen-deficient conditions using light energy and reduced compounds (organic acids). The reaction is as follows: C6H12O6 + 12H2O + Light energy → 12H2 + 6CO2 The overall biochemical pathways for the photofermentation process can be expressed as follows: (CH2O)2→ (NADPH) Ferredoxin → Nitrogenase ↑ ATP ↓ H2 Many types of green algae and cyanobacteria, besides having the ability to fix CO2 via photosynthesis, also can fix nitrogen from the atmosphere and produce enzymes that can catalyze the second H2 generating step. Since these nitrogen-fixing enzymes, nitrogenase, are localized within the heterocyst, they provide an O2 free environment to carry out the H2 evolution reactions. [10]The advantage of this method is in the versatile metabolic capabilities of these organisms and the lack of Photosystem II (PSII), which automatically eliminates the difficulties associated with O2 inhibition of H2 production. Major bottlenecks of the process involve low photochemical efficiencies (3-10 %). Moreover, inhomogeneity of the light distribution in the reactor also contributes to lowering the overall light conversion efficiency.

IV. APPLICATION OF HYDROGEN

[11]Hydrogen works as a replacement for fossil fuels in various industries and across various use-cases such as jet engines, internal combustion engines, turbines, etc. Hydrogen is also used in modern electric cars to run fuel cells which primarily convert hydrogen to electricity in an efficient manner. Currently, research and development on hydrogen to make it an alternative as a fuel to power our daily energy needs.

The application of fuel cells is not limited and can be across a lot of different industries. They have the potential of becoming the primary energy reservoir for combustion engines, trucks engines, buses, power plants, etc.

A. Hydrogen Fuel Cell

Hydrogen fuel cells work on compressed hydrogen which is used to power fuel cell stack that produces electricity for electric vehicles to provide zero emissions. This electricity produced combined with an electric motor can allow people to drive an electric car. The hydrogen fuel cell is made of a fuel cell stack that produces power as long as hydrogen (the fuel) is available. Each and every fuel cell which is present in the fuel cell stack has an anode, a cathode, and a proton exchange membrane in between the anode and the cathode.

For the reaction to take place, oxygen is pulled from the air to the cathode side and hydrogen is pulled from the gas tank onto the anode side. As the hydrogen enters the membrane, a catalyst divides hydrogen into a proton (H+) and an electron (e-). The proton goes through the fuel cell and the electron is used to provide electricity to the engine's circuit hence providing current to the electric motor before combining again with oxygen to form water as a tailpipe emission.

B. Application as Liquid Hydrogen

Hydrogen has the lowest possible molecular structure and burns with very high intensity in liquid form. Liquid Hydrogen is considered one of the most significant accomplishments of science. It has applications as a powerful rocket propellant because of its small molecular weight. It is combined with liquid oxygen to get the highest efficiency in terms of propellant used, out of all the rocket propellants.

V. CONCLUSION

In this study, we reviewed various processes that are available and are being used to generate hydrogen in a completely environment-friendly process based on microbial activities. Adopting these techniques to generate hydrogen with no harm to the environment and can also redirect the organic wastes and water being produced by various industries as raw materials. Another use of the process can be found in the waste disposal methods.

VI. ACKNOWLEDGEMENT

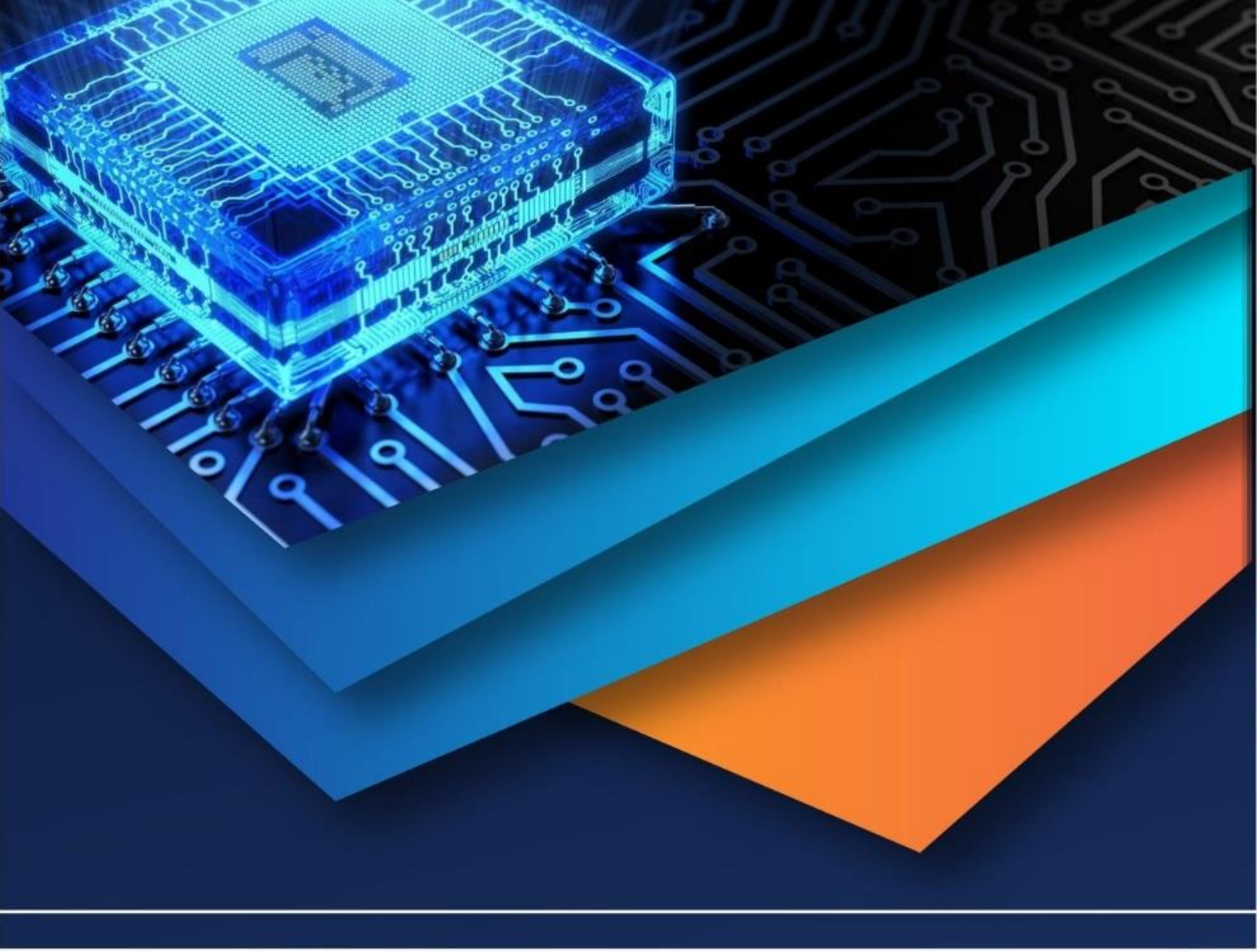
The authors wish to acknowledge Dr. J.P Kesari and Delhi Technological University for their complete support throughout their work.

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