A STUDY ON SUSTAINABLE AND EFFICIENT PRODUCTION OF HYDROGEN FROM BIOLOGICAL FEEDSTOCKS.

Sheela K K

Lecturer in Chemical Engineering
Government Polytechnic College, Kalamassery
Technical Education Department, Kerala, India

Abstract- **Hydrogen as an energy carrier is considered one of the results of the current energy challenge and represents one of the most promising ways for sustainable energy application. Still, renewable, CO2-neutral hydrogen product is veritably precious, and the utmost of the hydrogen produced and the consumed moment is still deduced from reactionary sources. The technology enables sustainable and effective products of hydrogen from different natural feedstocks. Biological mass or Biomass is used as a renewable energy source, which includes material similar to wood from timbers, material left over from agrarian and forestry processes, and organic artificial, mortal, and beast wastes. Biomass energy is a type of renewable energy generated from natural (similar to anaerobic digestion) or thermal conversion (for illustration, combustion) of biomass offers. Hydrogen product from biomass is the only direct way to produce hydrogen from renewable energy without a major technological advance. Glycerol is one illustration of biomass that can be employed for producing hydrogen. The process opens openings to combine biofuel and hydrogen products by using crude glycerol, a by-product, from biodiesel products as feedstock for hydrogen products. The technology is a one-step system for the production of pure hydrogen from biomass by sorption-enhanced brume reforming. This technology is wholly possessed by NTNU and comprises (i) new catalysts, (ii) new sorbents, and also(iii) a system for juvenescence of the sorption material and catalyst, which in all enables nonstop product of CO2-neutral and sustainable hydrogen of veritably high chastity(99% H2 dry base).**

Index Terms – **Biomass, sustainability, hydrogen fuel, renewable energy, glycerol.**

1. INTRODUCTION

1.1 HYDROGEN

The fuel of the future is hydrogen. Our fossil fuel-dependent economy can transition to a hydrogen economy using hydrogen as an energy carrier, which might supply an emissions-free transportation fuel source. Due to the distinctive low density of hydrogen, storage, and transportation of hydrogen are topics of significant investigation. Hydrogen can be burned to create fuel cells or internal combustion engines that emit almost no greenhouse gases when combined with oxygen. Water vapor is the sole important emission. A large portion of the population is becoming increasingly aware of the significant problem of climate change. The phenomena of global warming have been directly attributed to rising CO2 levels. Using hydrogen instead of fossil fuels can reduce greenhouse gas emissions and other issues brought on by the overuse of non-renewable fossil resources. Here are some benefits and drawbacks of using hydrogen as a fuel.

Hydrogen can be created from a variety of domestic resources, including nuclear energy and renewable energy sources like wind, sun, geothermal, and hydroelectric power to split water. Other domestic resources that can produce hydrogen include biomass from renewable non-food crops and fossil fuels like natural gas and coal. Today, fossil fuels are used primarily in the production of hydrogen.

Future decarbonized applications that rely on renewable and carbon-dioxide-neutral hydrogen production could benefit from the gasification of biomass to produce hydrogen. According to Thomas A. Milne et al. [1], the majority of the carbonaceous raw materials used to make hydrogen today are fossil in origin. Most of this hydrogen is used as a chemical feedstock for the petrochemical, culinary, electronics, and metallurgical processing sectors; a small portion is now used for energy purposes. However, the adoption of fuel cell technologies and the rising demand for zero-emission fuels have increased hydrogen's market share in the energy sector. Production of hydrogen must keep up with this expanding industry.

1.2 BIOLOGICAL FEEDSTOCK(BIOMASS)

Humans have used biomass as a source of energy for thousands of years, primarily in the form of wood. Direct combustion has historically been used to utilize biomass, and it is still commonly employed in many parts of the world. Wood, agricultural crops and their waste by-products, municipal solid waste, animal wastes, food processing waste, aquatic plants, and algae are the most significant biomass energy sources.

The electric utility, the timber and wood products, and the pulp and paper industries all use energy derived from biomass fuels. Currently, a lot of research is being done on biomass energy as a sustainable and environmentally acceptable alternative to traditional fossil fuels.

Recently, there has been a lot of focus on the use of renewable biomass as a key feedstock for the production of hydrogen. Biomass can produce hydrogen, but this technology urgently needs to be improved. Biomass-based hydrogen production is currently competitive commercially.

Table 1: List of biomass material used for hydrogen production (Balat & Kırtay, 2010)[11]

Sl no:	Biomass species	Main conversion process
1	Bio-nut shell	Steam gasification
2	Olive husk	Pyrolysis
3	Tea waste	Pyrolysis
4	Crop straw	Pyrolysis
5	Black liquor	Steam gasification
6	Municipal solid waste	Supercritical water extraction
7	Crop grain residue	Supercritical fluid extraction
8	Pulp and paper waste	Microbial fermentation
9	Petroleum basis plastic waste	Supercritical fluid extraction

Fossil fuels are being used to meet everyday energy needs, and as time goes on, more of them are needed. Fossil fuel consumption results in ambient air pollution and greenhouse gas emissions, both of which are currently major worldwide concerns. The development and use of new and renewable energy sources, such as hydrogen energy as an alternative clean fuel, have been supported and promoted by this, combined with the limited fossil fuel reserves (Prof. S. N. Upadhyay et al. [3]).

2. HYDROGEN PRODUCTION METHODS

Several alternative procedures can be used to create hydrogen. Hydrogen is released from organic materials, such as biomass and fossil fuels, or from inorganic materials, such as water, using thermochemical processes. Using electrolysis or solar power, water (H2O) can also be split into hydrogen (H2) and oxygen (O2). Through biological processes, microorganisms like bacteria and algae can create hydrogen.

- Natural gas reforming (also called steam methane reforming or SMR).
- Biomass gasification.
- Biomass-derived liquid reforming.
- Solar thermochemical hydrogen (STCH)

2.1 STEAM REFORMING OF METHANE

Although this method can support an initial foray into the hydrogen economy, it only represents a modest reduction in vehicle emissions when compared to emissions from current hybrid vehicles and ultimately only substitutes natural gas imports for oil imports. Today, hydrogen is primarily produced from natural gas via steam methane reforming. It is obviously unsustainable. It is ideal to gradually replace fossil fuels with hydrogen generated from a variety of renewable primary energy sources. In recent years, the utilization of renewable biomass as a significant feedstock for the production of hydrogen has drawn a lot of interest (Balat & Kırtay, 2010)[11].

Here are some methods to produce hydrogen from biomass and how hydrogen is produced by those methods.

Table 2: Some methods to produce hydrogen (Rachel Chamousis [6]).

Methods	Process	Implementation
Steam reforming of methane gas	In presence of nickel catalyst & at 700 – 1100 °C: CH4(g) + H2O(g) CO(g) + 3H2(g) Next reaction at lower temperature: CO(g) + H2O(g) CO2(g) + H2(g)	Current major source of hydrogen.
Hydrogen from coal (Gasification)	At high temperature and pressure: Coal + H2O(g) + O2(g) syngas Syngas = H2 + CO + CO2 + CH4	Current method of mass hydrogen production.
Electrolysis of water	Electric current passed through water: 2H2O(l) 2H2(g) + O2(g)	Not in widespread use due to cost of electricity.
Solar – Hydrogen system	Electric current passed through water: 2H2O(l) 2H2(g) + O2(g)	Not in widespread use due to cost of renewable energy sources.

2.2 GASIFICATION

Without using combustion, biomass is converted to hydrogen and other products by a controlled process that uses heat, steam, and oxygen. This process is known as "biomass gasification." The net carbon emissions of this technology may be low due to the removal of carbon dioxide from the atmosphere during biomass growth, especially if carbon capture, utilization, and storage are used in the long run. Building and running gasification plants for biofuels can teach us best practices and valuable lessons for producing hydrogen. The United States Department of Energy believes that biomass gasification could be put into use soon.

Three different sorts of products can be made from biomass: chemical feedstock, electrical/heat energy, and transportation fuel.

The cellulose, hemicelluloses, and lignin components undergo a thermochemical degradation in the initial step of the gasification process when using biomass as a feedstock, producing char and volatiles. Additionally, char gasifies, and a few additional equilibrium reactions take place. According to (Balat & Kırtay, 2010)[11], possible products obtained during the gasification process are: Hydrogen, Carbon monoxide, Carbon dioxide, Methane etc.

Numerous gasification processes are available for biomass, and gasification of biomass offers a large potential for potential product gas applications. The primary distinction is in the gasification agent employed and how heat is supplied in relation to this, both of which are required due to the overall endothermic gasification reactions. This heat can either be produced internally by the complete combustion of some biomass, known as the auto-thermal gasification process, or it can be added outside through the so called allo-thermal gasification process. The reactor architecture, which differentiates between fixed bed, fluidized bed, and entrained flow reactors, as well as the gasification agent utilized, is another key element of various gasification processes. Gasification often involves a number of processes (Balat & Kırtay, 2010)[11]

· Evaporation of moisture at temperatures up to 150 °C

· Pyrolysis, therefore releasing of volatiles (H2, CO, CO2, CH4, tar, etc.) xiv between 200 and 650 °C

· Reaction of volatiles in the gas phase between 700 and 1000 °C

· Heterogeneous reaction of char between 700 and 1000 °C ((Balat & Kırtay, 2010)[11]

Production from whole Biomass by Gasification

- Thermal/Steam/Partial Oxidation
- Direct Solar Gasification
- Miscellaneous Gasification Processes

2.2.1 Thermal/Steam/Partial Oxidation

The technique of catalytic steam gasifying biomass while simultaneously separating the hydrogen in a membrane reactor using a perm-selective membrane is known as thermochemical gasification of biomass to hydrogen. The procedure can be carried out at temperatures as low as 300°C and is especially well suited for wet biomass. While most studies were conducted within 1-5-30 psi, one was done at 4000 pressure and 450°C. SepRx was the procedure's name. It was discovered that 500°C, atmospheric pressure and a steam-to-biomass ratio of 10/1 were the ideal gasification conditions. Under these circumstances, hydrogen was generated at 65% (volume) in the presence of a nickel catalyst (Thomas A. Milne et al. [1]).

According to research on almond shell steam gasification in a fluidized bed, at temperatures between 500 and 800 °C, smaller particles produced more hydrogen than larger ones. Later, a bench-scale system with a secondary fixed-bed catalytic reactor and a fluidized-bed gasifier was used to study the catalytic steam gasification of biomass.

The catalytic converter was tested across a temperature range of 660-830°C utilizing various steam-reforming nickel catalysts and dolomite. According to Thomas A. Milne et al. [1], fresh catalyst produced 60% by volume of hydrogen at the maximum temperature.

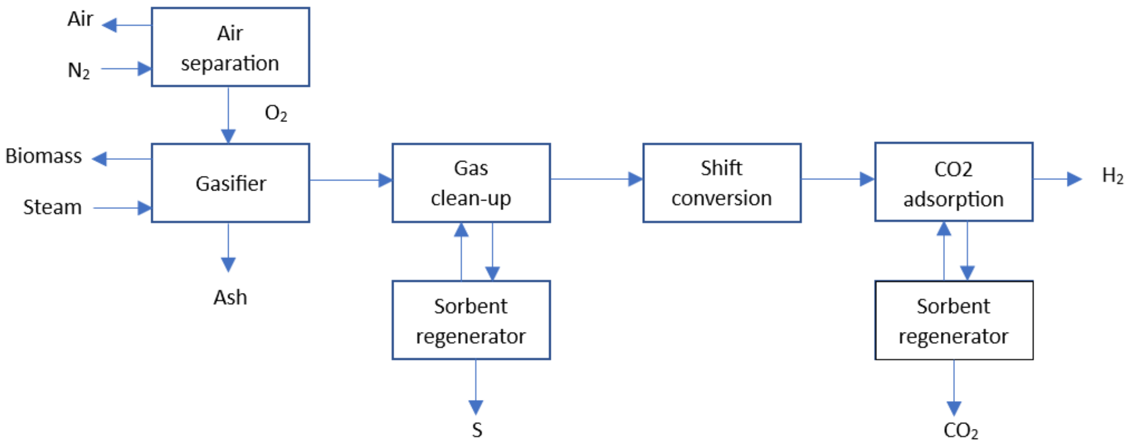

Figure : flow diagram for the process of hydrogen from biomass (Pavlos Nikolaidis et.al, [10]).

3. ADVANTAGES AND DISADVANTAGES

There are numerous benefits to utilizing hydrogen fuel as a source of energy. One of the greatest advantages of hydrogen fuel is that it is a renewable resource, meaning that it can be produced indefinitely. Hydrogen fuel is also an incredibly clean source of energy, producing minimal pollution in comparison to other fossil fuels. Moreover, hydrogen fuel can be produced from a variety of sources, including water and biomass, making it an extremely versatile source of energy. Overall, the use of hydrogen fuel is a fantastic way to reduce our reliance on fossil fuels and move towards a more sustainable future (Dash et al., 2022).

While there are numerous benefits to utilizing hydrogen fuel as a source of energy, there is one notable disadvantage to consider. The production of hydrogen fuel can require a significant amount of energy, which can ultimately offset the environmental benefits of using this renewable resource. Additionally, the infrastructure for producing and distributing hydrogen fuel is not yet as widespread as that for traditional fossil fuels, which can make it less accessible and more expensive for consumers. Despite these drawbacks, hydrogen fuel remains an important and promising option for transitioning towards a more sustainable future (Tarhan & Çil, 2021).

Table 3: Use of hydrogen as a fuel (Rachel Chamousis [6]).

Advantage	Disadvantage
High energy yield (122 kJ/g)	Low-density (large storage areas)
Most abundant element	Not found free in nature
Produced from many primary energy sources	Low ignition energy (similar to gasoline)
Wide flammability range (hydrogen engines operated on lean mixtures)	It is difficult to store because it is highly flammable and dangerous
High diffusivity	Currently expensive
Water vapour is major oxidation product	
Most versatile fuel	

Advantages of using biomass for the production of hydrogen
- Independence from oil imports
- Net product remains within the country
- Stable pricing level
- The CO2 balance can be improved by around 30%.
- Sustainable, CO2 neutral hydrogen production.
- Production of relatively pure hydrogen (99 % dry basis).
- Higher hydrogen yields in one single step.

Four major industries absorb the majority of the hydrogen produced worldwide: ammonia manufacturing (which uses 50% of it), refinery applications (22%), methanol synthesis (14%), and different reduction processes (7%). The remaining 7% is distributed to other customers. Future hydrogen demand will be high due to the rising global need for hydrogen as well as the growing interest in using hydrogen as an energy source. The aforementioned facts raise the issue of how future hydrogen generation will differ from the non-renewable sources used in the present (Matthias Binder et al. [2]).

4. CONCLUSION

Biomass can produce hydrogen, but this technology urgently needs to be improved. Biomass-based hydrogen production is currently economically viable. Major obstacles must be overcome for biomass to produce hydrogen. It is anticipated that biomass will one day play a significant role as a sustainable source of hydrogen. The market share of hydrogen from biomass for vehicle fuel will increase quickly over the next ten years due to its environmental benefits.

The gasification of biomass has been found as a potential method for creating renewable hydrogen. This method is advantageous for using biomass resources, developing a highly effective clean method for producing hydrogen on a large scale and relying less on unstable fossil fuel sources. By the end of the twenty-first century, biomass gasification and steam reforming of natural gas will be the two most prevalent technologies.

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