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Production of Biofuel from Algal Biomass by Aqueous Phase Reforming

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Abstract- With the growth of the human population, the need for sustainable resources of energy has increased a lot. Large scale utilisation of fossil fuels would lead to absence of viable energy resources for our future progeny, so, for that we need renewable and clean sources of energy which are called Green Energy Resources. Biological hydrogen (H2) production (BHP) enhancement through the use of nanoparticle (NPs) supplements in the media is being recognized in recent times as an encouraging approach. The NPs, including those of metal and metal oxides, have shown a significant improvement in the BHP. Therefore, Suitable bacteria like C. butyricum as inoculum and AuNPs provided a suitable approach for efficient H2 production from sucrose. Also, Kappaphycus alvarezii and sludge was processed for bio-hydrogen production. As a result,Reforming of aqueous phase with 7.5 wt% Au It is found that, with synthetic wastewater containing sucrose as a feed, anaerobic culture resulted in 62.3% higher yield than those to the control applying the minimum amount of AuNPs, remarkably, the H2 production, overall catalyst showed 61.25% of bio-hydrogen.Maximum bio-hydrogen yield was 36.1% for 2:1 (sludge: algae) at 360°C.The high ratio of acetate to butyrate and low production of ethanol in the presence of AuNPs is associated with a significant increase in H2 production. Kappaphycus alvarezii toWith the purpose of expanding applications in the field of production of Hydrogen with the help of Bionanotechnology, the Biosynthesis of AuNps by aqueous reforming of a synthetic compound (brewery wastewater) is supported on activated Carbon. It is observed that AuNPs has the catalytic performance for the degradation of pollutants at the industrial level. Therefore, Gold nanoparticles exhibit excellent catalytic degradation and decomposition of pollutants making the environment cleaner and sustainable. Thus, Hydrothermal gasification(APR) resulted in syngas, biochar and higher H2 production by liquid phase formation and Anaerobic Digestion of cyanobacterium lead to the breakdown of complex Inorganic and organic compounds in the Industrial Wastewater that led to easy Reforming process.

Keywords - Hydrothermal Gasification, Macroalgae, Microbial Sludge, Bio-Hydrogen Production (BHP), Aqueous Phase Reforming (APR), Gold Nanoparticles (AuNPs), Anaerobic Digestion

I. INTRODUCTION

The depletion of fossil fuel reserves and growing concerns regarding greenhouse gas emissions have intensified the search for renewable energy sources. Hydrogen is widely recognized as a clean energy carrier because its combustion produces only water as a by-product. However, conventional hydrogen production methods rely heavily on fossil fuels, contributing significantly to carbon emissions.

Algal biomass has gained considerable attention as a renewable feedstock for biofuel production due to its high growth rate, ability to grow in wastewater environments, and minimal competition with agricultural land. Unlike terrestrial biomass, algae possess high carbohydrate and lipid contents, making them ideal candidates for bioenergy applications.

Aqueous Phase Reforming (APR) is an emerging thermochemical conversion technology capable of converting biomass-derived oxygenates into hydrogen-rich gas at relatively low temperatures (200–300°C) and elevated pressures. APR provides advantages such as reduced energy requirements, high hydrogen selectivity, and the ability to process wet biomass without extensive drying.

Recent developments in nanotechnology have introduced advanced catalysts such as gold nanoparticles (AuNPs), which exhibit exceptional catalytic activity and selectivity. The integration of AuNPs into APR systems has demonstrated significant improvements in hydrogen yield and process efficiency.

This study explores the potential of APR combined with AuNP-based catalysis for sustainable hydrogen production from algal biomass and wastewater-derived feedstocks.

II. LITERATURE REVIEW

Several studies have investigated hydrogen production from biomass using thermochemical and biological processes.

Huber et al. demonstrated that APR effectively converts biomass-derived oxygenated compounds into hydrogen under moderate reaction conditions. Cortright et al. reported enhanced hydrogen selectivity using noble metal catalysts, particularly platinum and gold-supported catalysts.

Research on macroalgae such as Kappaphycus alvarezii has shown significant potential for bioenergy generation due to high carbohydrate content and rapid biomass accumulation. Furthermore, wastewater-derived microbial sludge provides an inexpensive substrate while simultaneously addressing waste management concerns.

Recent studies have highlighted the role of gold nanoparticles in enhancing catalytic reforming reactions. AuNPs exhibit high surface area, excellent electron transfer properties, and superior resistance to catalyst deactivation, resulting in increased hydrogen productivity.

III. MATERIALS AND METHODS

3.1 Feedstock Preparation

Fresh algal biomass (Kappaphycus alvarezii) and microbial sludge were collected and pretreated to remove impurities. The biomass was washed, dried, and mechanically ground to obtain a homogeneous feedstock.

3.2 Catalyst Synthesis

Gold nanoparticles were synthesized using a green biosynthesis approach and subsequently deposited onto activated carbon supports. The catalyst was dried and characterized using standard analytical techniques.

3.3 Aqueous Phase Reforming Process

The APR experiments were conducted in a high-pressure stainless-steel batch reactor. Operating Conditions:
Temperature: 220–360°C Pressure: 20–50 bar
Catalyst Loading: 7.5 wt% Au Reaction Time: 1–4 h
Feedstock: Synthetic wastewater containing sucrose and algal slurry

3.4 Hydrothermal Gasification

Hydrothermal gasification was performed to enhance biomass decomposition and syngas generation. Various sludge-to-algae ratios were investigated to determine optimal hydrogen production.

3.5 Analytical Techniques

The gaseous products were analyzed using Gas Chromatography (GC), while catalyst morphology and particle size were characterized using:
Scanning Electron Microscopy (SEM) Transmission Electron Microscopy (TEM) X-Ray Diffraction (XRD)
Fourier Transform Infrared Spectroscopy (FTIR)

IV. REACTION MECHANISM

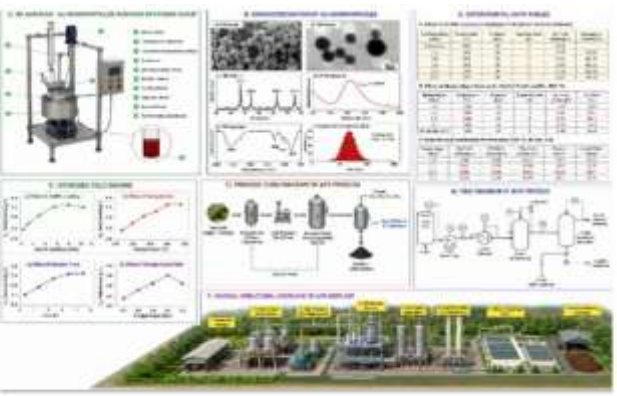
The APR process involves the catalytic reforming of oxygenated organic compounds present in algal biomass according to the following simplified reactions:

Reforming Reaction
$C_6H_{12}O_6 + 6H_2O \rightarrow 12H_2 + 6CO_2$
Water-Gas Shift Reaction $CO + H_2O \rightarrow CO_2 + H_2$

Methanation Reaction
$CO + 3H_2 \rightarrow CH_4 + H_2O$

Gold nanoparticles facilitate the cleavage of C–C and C–H bonds, thereby improving hydrogen selectivity and suppressing undesirable side reactions.

Overview Model



V. RESULTS AND DISCUSSION

5.1 Effect of Gold Nanoparticles

The addition of AuNPs significantly enhanced hydrogen production compared to the control system. The catalyst improved electron transfer and promoted reforming reactions, resulting in approximately 61.25% higher hydrogen generation.

5.2 Influence of Feedstock Composition

Experiments involving varying sludge-to-algae ratios revealed that a 2:1 ratio produced the highest bio-hydrogen yield of approximately 36.1% at 360°C.

5.3 Hydrothermal Gasification Performance

Hydrothermal gasification converts wet biomass into syngas, biochar, and liquid intermediates suitable for further reforming. The process effectively reduced organic pollutants while increasing hydrogen productivity.

5.4 Environmental Benefits

The combined APR and hydrothermal gasification system demonstrated substantial environmental advantages:

Reduction of industrial wastewater pollutants
Carbon-neutral hydrogen production Valorization of waste biomass
Reduced dependence on fossil fuels

5.5 Economic Feasibility

Although noble metal catalysts increase initial investment costs, improved hydrogen yield and catalyst longevity can offset operational expenses. The utilization of wastewater-derived feedstocks further enhances economic viability.

VI. FUTURE PERSPECTIVES

Future research should focus on:

- Development of low-cost nanocatalysts
- Continuous APR reactor design
- Integration with wastewater treatment plants
- Scale-up studies for industrial hydrogen production
- Life-cycle assessment and techno-economic analysis
- Advances in nanotechnology and biomass conversion technologies are expected to make APR-based hydrogen production commercially feasible in the near future.

VII. CONCLUSION

This study demonstrates the potential of aqueous phase reforming as an efficient and sustainable technology for hydrogen production from algal biomass. The incorporation of gold nanoparticles significantly enhanced catalytic performance and hydrogen yield. Hydrothermal gasification and anaerobic digestion further improved biomass conversion efficiency, leading to increased syngas and bio-hydrogen generation.

The findings confirm that algal biomass, coupled with nanocatalyst-assisted APR, represents a promising pathway toward sustainable energy production, environmental remediation, and circular bioeconomy development. Continued research and technological advancements are expected to facilitate large-scale implementation of this renewable hydrogen production strategy.

Environmental monitoring sustainability strategy model ESG and an accountability plan for the production

VIII. ACKNOWLEDGEMENTS

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