Mini Review
Volume 09:02, 2024

Advances in Recycling & Waste Management

ISSN: 2475-7675 **Open Access**

Enhancement of Biogas via CO_2 Sequestration and Concurrent Production of Acetic Acid by Newly Isolated Bacteria

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Abstract

Biogas production from organic waste is a promising renewable energy source. However, the presence of CO_2 in biogas reduces its energy content. This article explores the potential of enhancing biogas quality through CO_2 sequestration using newly isolated bacteria, while concurrently producing valuable acetic acid. The study integrates microbiology, biotechnology, and environmental engineering to optimize biogas production processes. Key aspects such as bacterial isolation, acetic acid yield, CO_2 sequestration efficiency, and overall process economics are discussed. The findings suggest a viable strategy for improving biogas quality and simultaneously obtaining valuable biochemicals.

Keywords: Biogas • CO_2 sequestration • Acetic acid

Introduction

Biogas, primarily composed of methane (CH_4) and Carbon dioxide (CO_2), is a renewable energy source derived from the anaerobic digestion of organic materials such as agricultural waste, sewage sludge, and food waste. It holds significant potential as a sustainable alternative to fossil fuels, offering environmental benefits by reducing greenhouse gas emissions and providing decentralized energy solutions. However, the presence of CO_2 in biogas reduces its energy content and limits its applicability for various energy-intensive applications. The enhancement of biogas quality by reducing CO_2 content has thus become a focal point in biogas research. Various methods such as chemical absorption, membrane separation, and biological processes have been explored for CO_2 removal. Among these, biological CO_2 sequestration using specialized microorganisms offers a promising and environmentally friendly approach. In this context, the concurrent production of value-added products such as organic acids adds economic value to the biogas production process [1].

Literature Review

Biogas production involves the anaerobic degradation of organic materials by a consortium of microorganisms, primarily bacteria and archaea. The main components of biogas are methane (CH_4) and Carbon dioxide (CO_2), along with trace amounts of other gases such as Hydrogen Sulfide (H_2S), Nitrogen (N_2), and water vapor. The composition of biogas can vary depending on the feedstock used and the operating conditions of the anaerobic digester. The presence of CO_2 in biogas decreases its calorific value and limits its use in certain applications such as vehicle fuel and power generation. Various methods have been developed to remove or reduce CO_2 from biogas, including physical and chemical processes. However, these methods often involve high costs, energy consumption, and environmental impacts [2].

Biological CO_2 sequestration presents an attractive alternative, leveraging the metabolic capabilities of microorganisms to convert CO_2 into biomass or other products. Several bacterial strains have been identified for their CO_2 fixation abilities, including acetogenic bacteria that can produce acetic acid through CO_2 reduction. Integrating these bacteria into biogas production systems offers a dual benefit of CO_2 removal and valuable product synthesis. Acetic acid, a key organic acid used in various industries such as food, pharmaceuticals, and chemicals, has garnered significant interest due to its versatile applications. Bacteria capable of producing acetic acid through fermentation or CO_2 reduction pathways have been extensively studied. Acetogenic bacteria, such as Clostridium ljungdahlii and Acetobacterium woodii, are known for their ability to convert CO_2 and H_2 into acetic acid under anaerobic conditions [3].

The production of acetic acid by bacteria involves complex metabolic pathways, including the Wood-Ljungdahl pathway utilized by acetogenic bacteria. Optimization of culture conditions, substrate availability, and reactor design are crucial factors influencing acetic acid yield and productivity. The integration of acetic acid production with biogas upgrading presents a synergistic approach towards sustainable bioprocesses. The isolation and characterization of novel bacterial strains with desirable traits such as CO_2 fixation and acetic acid production are fundamental to this research area. Microbial isolation techniques involve selective enrichment, isolation on specific media, and molecular identification using techniques like 16S rRNA gene sequencing [4].

Discussion

The isolation of bacterial strains with CO_2 fixation and acetic acid production capabilities begins with environmental sampling from diverse sources such as soil, sediments, and wastewater treatment plants. Selective enrichment techniques, coupled with culture on specific media containing CO_2 as a substrate, aid in isolating target bacteria. Screening assays for CO_2 fixation and acetic acid production help identify promising isolates for further characterization. Characterizing isolated bacterial strains involves assessing their growth kinetics, substrate utilization profiles, metabolic pathways, and product formation rates. Molecular techniques such as PCR, sequencing, and genome analysis provide insights into the genetic basis of CO_2 fixation

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Received: 20 March, 2024, Manuscript No. arwm-24-135176; **Editor Assigned**: 22 March, 2024, PreQC No. P-135176; **Reviewed**: 03 April, 2024, QC No. Q-135176; **Revised**: 08 April, 2024, Manuscript No. R-135176; **Published**: 15 April, 2024, DOI: 10.37421/2475-7675.2024.9.335

and acetic acid production. Physiological studies under varying environmental conditions elucidate the optimal parameters for bacterial performance [5].

Once characterized, selected bacterial strains are integrated into biogas production systems for CO_2 sequestration and acetic acid synthesis. Strategies such as co-culturing acetogenic bacteria with methanogenic consortia enhance CO_2 utilization and overall process efficiency. Bioreactor design considerations, nutrient supplementation, and pH control play crucial roles in maximizing CO_2 conversion and acetic acid yield. Optimizing the biogas upgrading process involves fine-tuning operational parameters such as temperature, pressure, retention time, and gas flow rates. Continuous monitoring of bioreactor performance, product concentrations, and microbial activity ensures stable operation and high productivity. Economic assessments, including cost analysis, market demand for acetic acid, and potential carbon credits, determine the overall feasibility and commercial viability of the enhanced biogas production system [6].

Conclusion

Optimizing the biogas upgrading process involves fine-tuning operational parameters such as temperature, pressure, retention time, and gas flow rates. Continuous monitoring of bioreactor performance, product concentrations, and microbial activity ensures stable operation and high productivity. Economic assessments, including cost analysis, market demand for acetic acid, and potential carbon credits, determine the overall feasibility and commercial viability of the enhanced biogas production system.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Nishimu, Sizuki. "Enhancement of Biogas via CO_2 Sequestration and Concurrent Production of Acetic Acid by Newly Isolated Bacteria." *Adv Recycling Waste Manag* 9 (2024): 335.