BIOGAS PRODUCTION TECHNOLOGY

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Abstract: Biogas, a versatile fuel derived from organic waste, presents a promising solution to mitigate greenhouse gas emissions while generating clean energy. To harness its full potential, here are five innovative technologies driving the evolution of biogas extraction:

Key words: Biogas texnology, anearobic, gas, rotted, Algal Bioreactors, reactor.

Advanced Anaerobic Digestion Systems:

- High-Rate Digesters: These systems employ advanced microbial consortia to accelerate the breakdown of organic matter, significantly increasing biogas production rates.

- Two-Stage Digestion: By separating acidogenesis and methanogenesis phases, two-stage digestion systems optimize biogas yield and allow for the treatment of diverse feedstocks, including complex waste streams.

Next-Generation Gas Upgrading Techniques:

- Membrane Separation: Utilizing selective permeable membranes, this method efficiently removes impurities such as carbon dioxide and hydrogen sulfide from biogas, enhancing its purity and energy content.

- Pressure Swing Adsorption (PSA): PSA systems employ adsorbent materials to selectively capture contaminants from biogas under alternating pressure conditions, resulting in purified methane suitable for injection into natural gas pipelines or use as vehicle fuel.

Smart Monitoring and Control Systems:

- IoT Integration: Internet of Things (IoT) devices enable real-time monitoring of biogas production parameters such as temperature, pH, and gas composition, facilitating proactive management and optimization of anaerobic digestion processes.

- Predictive Analytics: By leveraging machine learning algorithms, predictive analytics platforms analyze historical data to forecast biogas production trends, anticipate operational inefficiencies, and optimize system performance.

Biogas Utilization Innovations:

- Combined Heat and Power (CHP) Systems: Integrated CHP units utilize biogas to generate both electricity and heat, maximizing energy efficiency and providing decentralized power generation solutions for remote or off-grid areas.

- Biomethane Injection Infrastructure: Development of infrastructure for injecting biomethane into existing natural gas grids enables seamless integration of renewable biogas into the mainstream energy supply, reducing reliance on fossil fuels.

Emerging Biogas Production Pathways:

- Algal Bioreactors: Algae-based bioreactors harness photosynthetic organisms to convert carbon dioxide into biomass, which can be subsequently digested to produce biogas, offering a sustainable approach to carbon capture and renewable energy generation.

- Microbial Electrolysis Cells (MECs): MECs utilize microbial communities to catalyze the electrolysis of organic compounds in wastewater, generating hydrogen that can be utilized directly or further metabolized to produce biogas, expanding the range of feedstocks suitable for anaerobic digestion. In conclusion, the ongoing advancements in biogaz extraction technology hold tremendous potential to revolutionize the renewable energy landscape. By embracing innovation and integrating cutting-edge solutions, we can accelerate the transition towards a sustainable energy future while addressing pressing environmental challenges. Anaerobic digestion (AD) is one of the most popular renewable energy technologies. The AD process produces sustainable energy using various low-cost wastes. Although AD technology is widely used, its low biodegradation efficiency and poor stability limit its commercial application. The use of additives has been shown to offer marked improvements in AD performance. However, in practice, the use of additives in AD is not fully understood. In this review, the principles and achievements of additives (including metal elements, carbon-based accelerants, biological additives, and alkali addition) promoting AD performance are summarized. The review also discusses the issues and development trend of each additive. There are still many challenges associated with using additives in AD systems owing to significant variations in digestion substrates and AD operational procedures. The dosage and types of additives have a great influence on the efficiency of AD, which mainly depend on the substrate. Moreover, the implementation process of each additive is not perfect. Therefore, it is essential to better utilize additives to promote AD performance according to the merits of each material. The application of composite additives requires further exploration to optimize the implementation process. This paper deepens our understanding of flexible additives in the AD process and provides comprehensive information that can be used to promote renewable clean energy.

Microorganism attachment and fast growth, thereby resulting in reduced microbial lag phase and increased biogas production (Li et al., 2019a). Some additives (e.g., biochar, activated carbon) can remove gaseous impurities from biogas to help mitigate environment pollution (Choudhury and Lansing, 2020). The addition of additives in AD not only increases biogas production but also reduces air pollution during the production. Same/different additives have significant variations in the digestion of the various feedstocks. For example, addition of biochar (10 g/L) to AD with glucose or dairy manure as substrates increases the CH4 production rate by 21.4% or 37.35%, respectively; CH4 yield is increased by 13.1% or 7.3% in an AD system fed with sewage sludge when activated carbon (27 g/L) or Fe3O4 (27 g/L) is added, respectively (Peng et al., 2018).

Each additive offers unique advantages for promoting biogas production in AD. Information on additives for improving the performance of the AD process is urgently required. Although many additives have been shown to increase biogas production during the AD process, there are few comprehensive reviews on the use of additives to promote clean bioenergy efficiency. Many reviews only focused on a certain kind of additive (such as zero-valent iron, biochar, carbon-based accelerants) for improving the AD performance of specific substrates, such as food waste, solid waste, or waste water (Shen et al., 2021; Velimirovic et al., 2016; Ye et al., 2021). At present, a comprehensive understanding of the different kinds of additives to promote clean bioenergy efficiency is lacking. In particular, the dosages, effects, and applications of each additive need to be discussed. Therefore, summarizing the effects of different additives on the performance of anaerobic digesters has been an important topic of research in recent years (Habagil et al., 2020). The present paper reviews the use of additives (metal compounds, carbon-based functional materials, fungi, enzymes, etc.) for improving the performance of AD systems. The mechanisms and current state research progress for these additives are summarized. Recommendations for improvements and future research challenges are also presented for consideration. This review is expected to provide a reference for further research on the application of additives in AD.

Alkali addition to AD systems can improve CH_4 yield and rate. NaOH efficiently removes lignin and hemicellulose. Other caustic salts (e.g., lime, KOH) could be more advantageous because they are easily recovered and can be used as fertilizer. However, NaOH is more environmentally friendly and cheaper than KOH. The addition of 2% NaOH in briquetted wheat straw increased net energy production by 38.3%, whereas 4% NaOH increased it by 36.1% (Moset et al., 2018). AD batch experiments showed that 2%

Perspectives and prospects

Additives are shown to be beneficial for improving the performance and efficiency of AD systems. Certain trends have been summarized herein to facilitate appropriate additive application and selection. The combined addition of the different kinds of metals resulted in a high biogas yield in AD. In contrast, a high concentration of metals may inhibit the methanogens, thereby causing low methane production. Carbon-based materials accelerate the DIET behaviors and help in microbial immobilization

Conclusions

Biogas is one of the most popular sustainable clean energy sources. Additive provides a valuable method for efficient increase in biogas production. Metal elements (0.01–1000 mg/L) in AD process always as enzyme cofactors can increase CH_4 yield by 7.0%–120%. Carbon-based accelerants (1–50 g/L) stimulated 13.1%–121.97% CH_4 production by facilitating DIET and the enrichment of microorganisms during methanogenesis. Biological additives, including microorganisms and enzyme, accelerated CH_4 yield by

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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