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BIOGAS PRODUCTION FROM AGRICULTURAL WASTE IN CROP FARMS

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ABSTRACT

Agricultural waste, including crop residues like straw, stalks, and leaves, presents a significant opportunity for sustainable energy production through anaerobic digestion. This process converts organic matter into biogas, primarily methane, which can serve as a renewable energy source. This paper explores the potential of agricultural waste for biogas production, examining pretreatment methods, co-digestion strategies, and the integration of biogas systems into crop farming operations. Additionally, it discusses the environmental and economic benefits, challenges, and policy frameworks supporting the adoption of biogas technologies in agriculture.

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1. Introduction

The global agricultural sector generates vast quantities of organic waste annually, such as straw, leaves, and stalks. Traditional disposal practices like burning contribute significantly to air pollution and greenhouse gas emissions. Anaerobic digestion provides a sustainable method to convert these residues into biogas, which is primarily composed of methane (CH) and carbon dioxide (CO). This paper explores the utilization of agricultural waste for biogas production in crop farming and assesses its environmental, economic, and policy dimensions.

2. Anaerobic Digestion of Agricultural Waste

Anaerobic digestion (AD) is a biological process involving microorganisms breaking down organic matter in the absence of oxygen. Crop residues, which are rich in lignocellulosic materials, can be challenging to digest, but pretreatment methods such as enzymatic hydrolysis or biological treatment with fungi (e.g., *Trichoderma* spp.) have been shown to enhance biogas yield (Alengebawy et al., 2024).

Co-digestion, combining crop waste with other organic materials like livestock manure, balances carbon-to-nitrogen (C:N) ratios, improving microbial activity and overall methane production (Sharma et al., 2023).

3. Environmental and Economic Benefits

Utilizing crop waste for biogas production reduces dependency on fossil fuels and mitigates methane emissions from unmanaged agricultural residues. The digestate, a by-product of AD, serves as a nutrient-rich organic fertilizer, reducing the need for synthetic alternatives and promoting soil health (Singh, Singh, & Yadav, 2022).

Economically, on-farm biogas systems can decrease energy expenditures and provide income from surplus energy sales, particularly when upgraded to biomethane for grid injection or vehicle fuel (Zhang & Zhang, 2023).

4. Challenges in Implementation

Despite its benefits, several barriers impede the widespread use of biogas in crop farms:

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- **Feedstock Logistics**: Crop residues are spatially dispersed, making collection and transport logistically and economically challenging.
- **High Initial Investment**: The capital cost for anaerobic digesters, gas storage, and purification systems remains high.
- **Lack of Technical Expertise**: Farmers often lack training in the design, operation, and maintenance of biogas systems.
- **Policy Inconsistencies**: Inadequate policy support and fragmented incentives deter adoption in many regions (Charan, 2025).

5. Policy Support and Future Outlook

Governments across the globe, including India and the EU, have initiated programs to promote bioenergy. India's National Bio-Energy Mission and PM-KUSUM scheme aim to support decentralized energy generation from agricultural sources (Charan, 2025). There is also growing interest in state-level schemes promoting residue management to combat stubble burning.

Future directions should focus on:

- Cost reduction through local manufacturing of digesters
- R&D on lignocellulose degradation
- Farmer education and technical support

6. Conclusion

Biogas production from agricultural waste is a promising approach for enhancing energy security and environmental sustainability in crop farming. By addressing logistical, economic, and technical challenges through coordinated policy efforts and innovations, this green energy pathway can be successfully integrated into modern agricultural practices.

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