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Editorial: The role of biochar in enhancing biogas productivity and bio-fertilizer quality

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Editorial on the Research Topic
The role of biochar in enhancing biogas productivity and bio-fertilizer quality

Rapidly increasing population, urbanization, and fossil-based industrial development and the resultant adverse climate change impacts have renewed the focus on bioenergy technologies and systems. Bioenergy can cater to a whole spectrum of energy demand, including power generation, heating and cooking applications, and transportation, to achieve clean energy transition and ultimately carbon neutrality (Aravind et al., 2022). Simultaneously, biomass-based systems and products can also help strengthen the organic and natural farming practices, which is an urgent need of the hour considering the severely depleting soil health and high GHG emissions. Therefore, a deep focus is being given to the biogas sector for supporting energy production, waste minimization, and bio-fertilizer production along with its eco-friendly and carbon-capturing characteristics. For instance, India has a huge biogas generation potential of 74.79 billion m^3/year (Singh and Kalamdhad, 2023). Another report estimates the feedstock and CBG potential of India as indicated in Table 1 (Jain, 2023).

Biochar is emerging as an attractive biomaterial having diverse applications, including carbon sequestration, soil conditioning, and energy generation (Vijay et al., 2021). In the last couple of years, there has been a developing research interest in the applications of biochar in the biogas sector to tackle the challenges around biogas production, biomethane enrichment, and bio-fertilizer quality enhancement.

This Frontiers Research Topic was designed to collect articles to explore the use of biochar in biogas production with individual feedstocks or in co-digestion, understand how different biochar properties alleviate challenges in biogas production, engineer biochar to meet specific goals in the biogas sector, and elucidate the role of biomass feedstocks, biochar production parameters, and biochar properties in enhanced biogas production and enrichment.

The Research Topic of published articles includes two reviews, one original research article and one brief research report, which are summarized below.

Premalatha et al. (2023) summarized the effects of biochar application on the physical, chemical, and biological soil properties, remediation potential of biochar in soils contaminated with heavy metals, and biochar's impact on crop productivity. Their

TABLE 1 BioCNG/CBG potential in India from different feedstocks.

Categories of organic waste annual feedstock	Annual feedstock potential (MT)	Estimated potential of BioCNG/CBG (MT)
Animal and poultry waste	190	25
Surplus agro-residues	150	20
Municipal solid waste (MSW): organic fraction	62	5
Sewage treatment plants	50	10
Spent wash/pressmud	20	2

analysis indicates that biochar properties like greater surface area, cation exchange capacity, pH, and the nutrient content positively impact the soil properties, leading to improved soil fertility. They also observed from the literature that the efficacy of biochar depends on its type, dosage, and soil type. General trends from this review showed that biochar can positively amend acidic soils compared to the alkaline or calcareous soils. Furthermore, the authors suggested that the long-term effects of biochar under field conditions need to be extensively studied to develop useful recommendations for biochar application for different soil types and climatic conditions.

Through their experimental investigations, Hu et al. (2023) analyzed the impact of the application of different biochar dosages in an anaerobic digester setup under normal and high substrate loadings. They considered three inoculum-to-substrate ratios (ISRs) for the investigation: one ratio for demonstrating a normal substrate loading (ISR 2) and two other ratios for demonstrating substrate overloading of ISRs 1 and 0.5, respectively. They tested each substrate loading with a biochar dose of 0% (i.e., control), 10%, and 25% based on substrate volatile solid content. Their work revealed that biochar positively impacted the AD process only under severe conditions with the highest biochar dosage. They found that biochar application did not affect AD processes at various biochar dosages, which could be attributed to different substrates, biochar types, and experimental conditions. Based on their observations, they recommended that future research should explore optimization of substrate loadings and biochar dosages under real conditions to understand the impact on AD process.

Świechowski et al. (2023) produced biochar from brewer's spent grain at different temperatures of 300, 450, and 600°C and used these for anaerobic digestion of brewer's spent grain in a circular approach. They tested biochar dosages of 2, 5, 10, and 50% in total solid content of the substrate at three substrate-to-inoculum ratios (SIRs) of 0.5, 1.0, and 2.0, respectively. The AD process was undertaken at 37°C for 30 days to analyze the biomethane production, determine kinetic parameters according to the first-order model, and to discriminate the fertilizing potential of digestates. Their findings revealed that SIRs and BC dosages were the major factors affecting biomethane production along with the AD process parameters, and the quality of the used inoculum and quantity of the used substrate mainly affected the digestate quality. The research highlights the need for the study of biochar addition to the AD process in a continuous mode over time to check its practical and realistic impact while considering the feedstock properties and operational conditions.

Through their review, Wolski et al. (2023) examined the factors that impact the activity of biomass-degrading enzymes in the presence of ionic liquids as an eco-friendly solution. The review consolidated data from available research in this area and analyzed them for the application of this knowledge for developing innovations and techniques that could result in improvement in processing biomass to biofuels and bio-products.

Overall, the Research Topic highlights the integration potential of biochar and AD process, the role of biochar in soil amendment, and the role of ionic liquids in enzymatic activity as sustainable solutions to treat waste. The editorial team of the Research Topic is thankful to the authors for their valuable contributions.

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VV: conceptualization, writing–original draft, and writing–review and editing. RC: writing–review and editing. VV: writing–review and editing. AC: writing–review and editing.

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Conflict of interest

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