IOCEN 2026 Conference

The 3rd International Online Conference on Energies

12–15 May 2026 | Online

MDPI

Process Stability and Biomethane Production in Food Waste Anaerobic Digestion with Functional Compost-Based Additives

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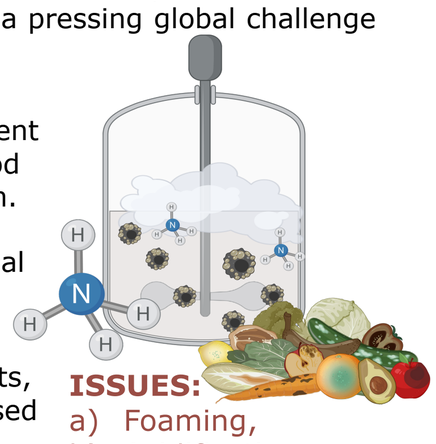
INTRODUCTION & AIM

Environmental impacts accumulate across the entire life cycle of food products, with consumer-level food waste representing a major contributor to this burden (Huang et al., 2022; UNEP, 2021). Nearly one-third of all food produced for human consumption worldwide is wasted annually (UNEP, 2024). Food waste contains rich organic matter, which, if unmanaged, can cause serious environmental and public health concerns due to the release of greenhouse gases (Badsha et al., 2025; Sun et al., 2018), contamination of water resources (Thakali et al., 2022), and proliferation of disease vectors (Liu et al., 2023). As such, the effective management and valorization of food waste has become a pressing global challenge (Roy et al., 2023).

The adoption of anaerobic digestion (AD) has expanded across sectors, contributing to improved waste management and renewable energy generation. However, the AD of food waste remains challenging due to its complex composition. High moisture content, fats, salts, and nitrogen-rich compounds often lead to process instability and operational limitations (He et al., 2024).



To address these challenges, additives can be used to enhance buffering capacity, supply essential trace nutrients, and support microbial activity. Among these, compost-based materials are promising due to their availability, low cost, and rich mineral content.

ISSUES:

a) Foaming,
b) Acidification,
c) Ammonia inhibition

METHOD

Material

Bio-Plus Activator (ELR Family Trading Co. Inc.) or CBE (Table 1-2) is a commercial product containing 25 functional compound agents (FCA), including **7 bacteria** for decomposition, enzyme production, and nutrient transformation; **3 bacteria** for polysaccharide decomposition and enzyme production; **3 bacteria** that enhance decomposition, produce compost "sweetening," and generate probiotics; **5 nitrogen-fixing bacteria**; **7 fungi** involved in composting; and aerobic and anaerobic methane-producing bacteria, along with sulphate- and ammonia-consuming, heavy metal-binding bacteria and emulsifiers.

Table 1. Composition of Bio-plus Activator according to material safety and data sheet

Composition	Percentage share (%)
Cane bagasse	20
Sawdust	20
Filter cake or mud press	20
Carbonized rice husk	10
Soya meal	10
Coco peat	10
Molasses	5
Chelated trace minerals	2.5
Growth promoting substances	1.5
Functional compounds	1.5

Experimental Setup

The biochemical methane potential (BMP) assay experiment (Figure 1) was performed with the Automatic Methane Potential Test System (AMPTS II). For the experiment, **82.4 mg** of CBE samples were utilized with a representative dosage according to industrial application. The artificial **food waste** mixture was prepared with the following composition: **55.9% fruits and vegetables, 2.1% pasta, 4% rice, 23% bread, and 15% meat.**

The BMP test was conducted in a batch experiment using serum bottles with a working volume of 400 mL, under mesophilic conditions (37 ± 1 °C), over a period of 20 days.

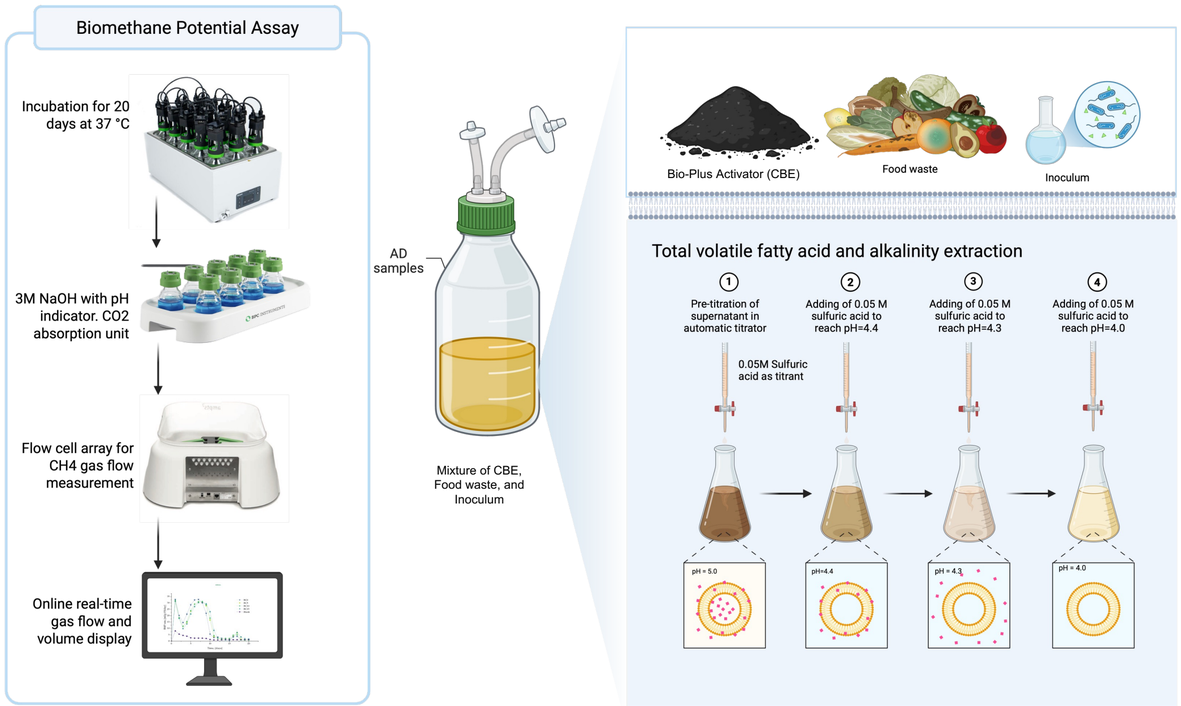


Figure 1. Schematic diagram of the biochemical methane potential (BMP) assay and the extraction method for total volatile fatty acids (as CH_3COOH) and alkalinity (as $CaCO_3$) used to assess AD process stability.

RESULTS & DISCUSSION

Process Stability

TVFA degradation: CBE significantly enhanced TVFA removal (78.6%) compared to the control (36.1%) (Tukey, $p<0.01$), indicating improved organic matter breakdown. This aligns with findings that compost-like materials buffer pH and reduce TVFA accumulation (Shyan et al., 2023).

pH: The control showed a higher pH increase (7.79 → 8.27; $p<0.001$) than the CBE reactor, suggesting that CBE did not strongly mitigate acidic inhibition during AD.

Total Alkalinity: CBE improved buffering capacity, with a 16.19% increase in ALK. Although not statistically significant, this likely helped prevent acidification toward the end of digestion.

FOS/TAC: The FOS/TAC ratio, which is an indicator of system stability, revealed that both systems remained stable (FOS/TAC < 0.4). Early-stage values (0.35 ± 0.07 for CBE; 0.29 ± 0.01 for control) indicate balanced acid production and buffering, especially within the first 24 h.

Electrical conductivity: CBE increased initial EC (7.17 ± 0.01 mS/cm), potentially enhancing microbial activity. However, EC declined significantly during digestion (28.4 → 22.8 mS/cm; $p<0.001$), suggesting reduced availability of trace metals over time (Zhang et al., 2015).

Table 2. Physicochemical properties of CBE

Properties	Values
Moisture content, %	15.23 ± 1.21
Total Solid, %	84.77 ± 1.21
Volatile solid, %	70.99 ± 0.94
High heating value, MJ/kg	4.51
Carbon, %	13.55 ± 0.52
Hydrogen, %	1.83 ± 0.06
Nitrogen, %	4.37 ± 0.29
Sulfur, %	1.22 ± 0.12
C:N	3.6

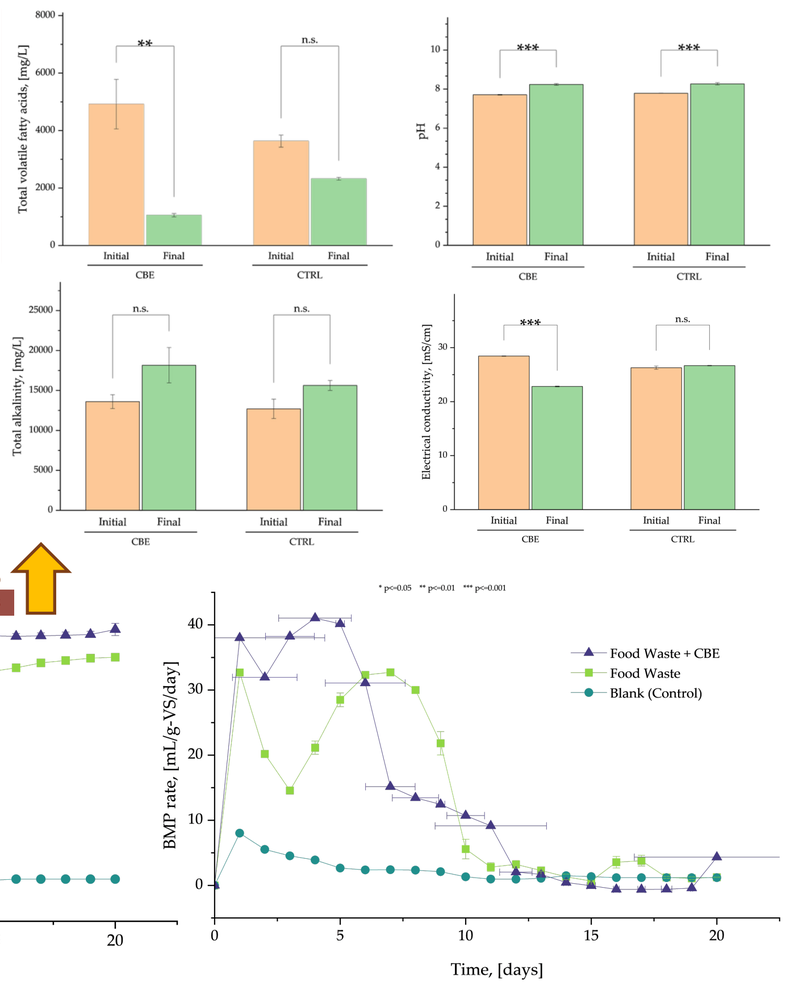


Figure 2. Process stability parameters and biochemical methane potential (BMP) of FWAD with CBE

Biochemical methane potential

CBE supplementation significantly increased methane yield to 291.8 ± 6.09 mL/gVS, compared to 264.06 ± 1.17 mL/gVS in the control ($p<0.05$), representing a 10.51% improvement (Figure 2).

The CBE-amended reactor also showed a higher daily peak methane production, increasing from 38.01 ± 3.39 mL/gVS (Day 1) to 41.04 ± 1.44 mL/gVS (Day 4). This early surge is linked to rapid degradation of readily biodegradable organics (Zeng et al., 2022). Overall, results indicate that the enhanced methane production suggests that CBE may have stimulated microbial consortia involved in organic matter breakdown and methanogenesis.

CONCLUSION

- Supplementation of unstabilized properties further indicates that the remaining organic fraction is susceptible to microbial degradation, contributing to additional biomethane yield.
- The CBE in the reactor increased alkalinity, improving the buffering capacity with enhanced TVFA degradation. These highlight the potential of CBE as an additive in AD systems, contributing to improved waste valorization and renewable energy generation.
- Further investigations into the microbial dynamics and long-term system behavior associated with CBE use are recommended to fully elucidate its mechanisms and scalability.

REFERENCES