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Productivity Analysis of Single Phase and the Dual Phase Biogas Reactors

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Abstract

Biogas is a renewable and clean energy source produced through anaerobic digestion (AD), a process in which microorganisms decompose organic matter in the absence of oxygen. It provides a sustainable solution for energy generation and organic waste management while reducing greenhouse gas emissions. The single-phase biogas system is the most common method of biogas generation. However, dual-phase biogas reactor systems are increasingly adopted in advanced applications because they offer higher productivity and improved process stability. In dual-phase reactors, the hydrolysis and acidogenesis stages are separated from the acetogenesis and methanogenesis stages. This separation allows optimization of operating conditions for the specific anaerobic microorganisms involved in each stage, thereby enhancing overall digestion efficiency and increasing biogas production. This study was conducted at the Sisili Hanaro Encare facility to research on productivity comparison of single-phase and dual-phase biogas reactors. The dual-phase reactor system consists of two plastic shell tanks: T1 (2 m^3) and T2 (10 m^3). Tank T1 is used for the hydrolysis and acidogenesis stages, while Tank T2 is used for the acetogenesis and methanogenesis stages. The single-phase reactor consists of a single 10 m^3 tank in which all four stages of anaerobic digestion occur within the same reactor. Biogas is collected using HDPE polyethylene bags. Stainless-steel agitators are installed to ensure uniform mixing, temperature regulation, and improved reactor productivity. A 3 HP industrial blender is used to reduce the particle size of kitchen waste. Each system is fed daily with 25 kg of blended kitchen waste mixed with water at a 90:10 ratio (water: solids). In the single-phase reactor, the blended kitchen waste is directly transferred into the 10 m^3 tank. In the dual-phase system, the blended kitchen waste is first fed into the 2 m^3 tank (T1). Once the pH in T1 reaches 4.0-4.5, the slurry is transferred to the 10 m^3 tank (T2) for the acetogenesis and methanogenesis stages. After statistical evaluation of the results, it was found that the dual-phase reactor achieved a higher average biogas yield (2.20 m^3/day) compared to the single-phase reactor (1.58 m^3/day), along with improved total volatile solids removal efficiency (79.52% vs. 74.05%) and productivity (1.4 vs. 1.1). These findings indicate that dual-phase reactors offer higher performance in biogas production, waste stabilization, and overall process efficiency, making them a promising option for sustainable energy generation from organic waste. Further development is in progress to implement automated effluent transfer system within the dual-phase system, from the 2 m^3 (T1) tank to the 10 m^3 (T2) tank, based on VFA (volatile fatty acid) concentration focusing commercial bio gas plants development in future.

Keywords: *Biogas, Anaerobic digestion, Single-phase reactor, Dual-phase reactor, Volatile fatty acid*