Sustainable Utilization of Pig Slurry During Anaerobic Digestion on Struvite Crystallization - Abstract

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Summary

High ammonia concentrations (>3 g $NH4^{+}$-N L^{-1}) released from the degradation of nitrogen-rich organic waste could lead to suboptimal biogas production during anaerobic digestion (AD) due to toxicity events. These toxic events are very common and can yield significant economic losses in full scale AD plants. In addition, globally, nutrient-rich (e.g., nitrogen (N) and phosphorus (P)) digestate effluents are still discarded in agricultural land, releasing nutrients into the environment with adverse effects including the pollution of surface (eutrophication) and ground waters, emissions of greenhouse gases, and soil erosion, that in return impact human health. This study aimed to assess and advance the integrated scheme of nutrient recovery in the form of struvite, and of energy formation as biogas from livestock waste. Struvite is a crystalline mineral, which constitutes a slow-release high-value fertilizer, containing equal molar concentrations (1:1:1) of magnesium, ammonium, and phosphate ($MgNH_4PO_4 \cdot 6H_2O$), that can be recovered from nutrient-rich wastewater. The methane in biogas is a renewable fuel, that can be produced by the biodegradation of organic matter. The effect of a specific feeding strategy during AD on the crystallization of struvite from pig slurry at pilot scale was first investigated, while a microbial tracking study was also conducted on this experiment. The results showed that the stepwise feeding of the substrate to the digester alleviated ammonia inhibition. Experimentally measured methane production efficiency reached approximately 90% of the theoretical production, thus indicating an efficient anaerobic digestion process. The produced struvite was of very high purity (> 95 w/w) (X-ray crystallography (XRF) using reference intensity ratio method). Scanning electron microscope analysis revealed the production of typical struvite crystals e.g., orthorhombic. The obtained XRF spectra indicated that heavy metals were within the acceptable regulatory limits. No carcinogens were detected (polycyclic aromatic hydrocarbons and Cr6+). Finally, pathogens such as Salmonella spp. and Escherichia coli, were absent (Regulation (EU) 2019/1009). In this study, the production of a high purity product, safe to use in agriculture and horticulture. To conclude, this integrated innovative process for recovering energy and nutrients from pig slurry can lead to high biogas yield and the production of high-purity struvite organo-mineral fertilizer, thus minimizing nutrient losses, safeguarding the declining phosphate rock, and making this process energy independent.

Keywords

Anaerobic Digestion, Biogas, Nutrients, Pilot Scale, Struvite

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