

Comparative Evaluation of Digestate Solubilization by Thermal Hydrolysis and Ultrasonication for Anaerobic Digestion

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Background and objectives

Biological wastewater treatment produces large amounts of sludge, posing serious environmental challenges due to rising disposal expenses and the risk of secondary pollution from traditional methods such as incineration and landfilling. Anaerobic digestion (AD) is commonly employed to stabilize sludge and recover methane; however, its performance is often hindered by slow hydrolysis rates and the requirement for extended retention periods. One proposed method to improve this is recycling digested sludge back into the reactor to increase microbial residence time without altering the reactor's physical size, though this has shown limited effectiveness in reducing overall sludge volume (Yang et al., 2017). To improve the degradability of recycled digestate, this study explores solubilization techniques, specifically thermal hydrolysis and ultrasonication, and examines their influence on digestate characteristics, methane production efficiency, and the formation of inhibitory substances, aiming to determine the most effective approach for digestate recycling within AD systems.

Solubilization methods and BMP test

To investigate the effects of solubilization on anaerobic digestion, sludge samples obtained from the Jungnang Water Reclamation Center in Seoul, Korea, were treated using two solubilization techniques: thermal hydrolysis (TH) and ultrasonication (US). For TH, the digestate was heated for 30 minutes at four different temperatures ranging from 160°C to 280°C. For US, the digestate was exposed to a 20 kHz ultrasonic processor across a range of durations from 2.5 to 10 hours.

Following treatment, the solubilized digestate was analyzed for its chemical properties and used in biochemical methane potential (BMP) tests to evaluate methane yield and potential microbial inhibition. BMP assays were conducted using 800 mL serum bottles containing 60 mL of inoculum, 80 mL of substrate, and a buffered anaerobic mineral medium. Anaerobic conditions were established by nitrogen flushing prior to sealing, and samples were incubated at $35 \pm 1^\circ\text{C}$ with agitation at 120 rpm. Methane generation was continuously measured over a 28 day period using an automated monitoring system equipped to eliminate CO_2 for precise methane quantification (Lee et al., 2024).

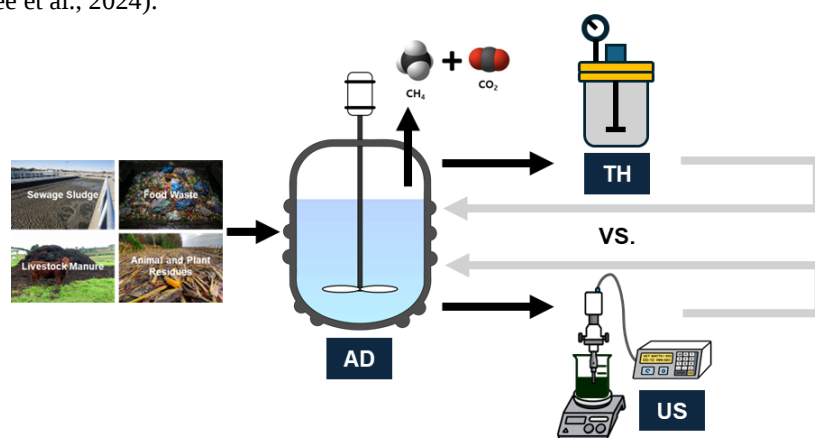


Figure 1. Schematic diagram of this study

Solubilization characteristics and methane production

The solubilization performance of thermal hydrolysis (TH) and ultrasonication (US) showed clear methodological contrasts in terms of both SCOD release and volatile solids (VS) reduction. As shown in Fig. 2(a) and (b), TH led to a sharp increase in SCOD, with the highest value observed at 200°C, while also causing a progressive decrease in VS at higher temperatures. This indicates effective breakdown of organic matter but also suggests thermal degradation of solids. In contrast, US treatments resulted in a gradual enhancement of SCOD with minimal loss in VS, reflecting a more conservative solubilization process that preserved the particulate phase while promoting

solubility. These trends confirm that TH is a more aggressive and rapid solubilization strategy, whereas US enables more controlled organic matter release.

Fluorescence excitation-emission matrix (EEM) analysis (Fig. 2(c)) showed that solubilization caused distinct compositional changes in dissolved organic matter. Thermal hydrolysis led to a substantial increase in fluorescence intensity at Peaks C and D, corresponding to humic and fulvic acid-like substances, respectively. In contrast, ultrasonication mainly intensified protein-like fluorescence, particularly at Peaks A and B, associated with tryptophan and aromatic protein-like compounds. These differences suggest that thermal treatment promotes humification and the formation of more complex refractory compounds, whereas ultrasonic treatment primarily affects proteinaceous components.

Methane production trends supported these observations. Although not presented graphically, BMP test results revealed that both TH and US enhanced methane yield relative to untreated digestate. TH at 200°C achieved the highest methane production, exceeding 250 NmL/gVS, while US at 10 hours reached approximately 150 NmL/gVS. When normalized against SCOD increases, TH demonstrated superior conversion efficiency, implying more biodegradable solubilized fractions. Importantly, even under high-temperature conditions no apparent inhibition of methane production was observed, indicating process stability despite the potential formation of inhibitory compounds.

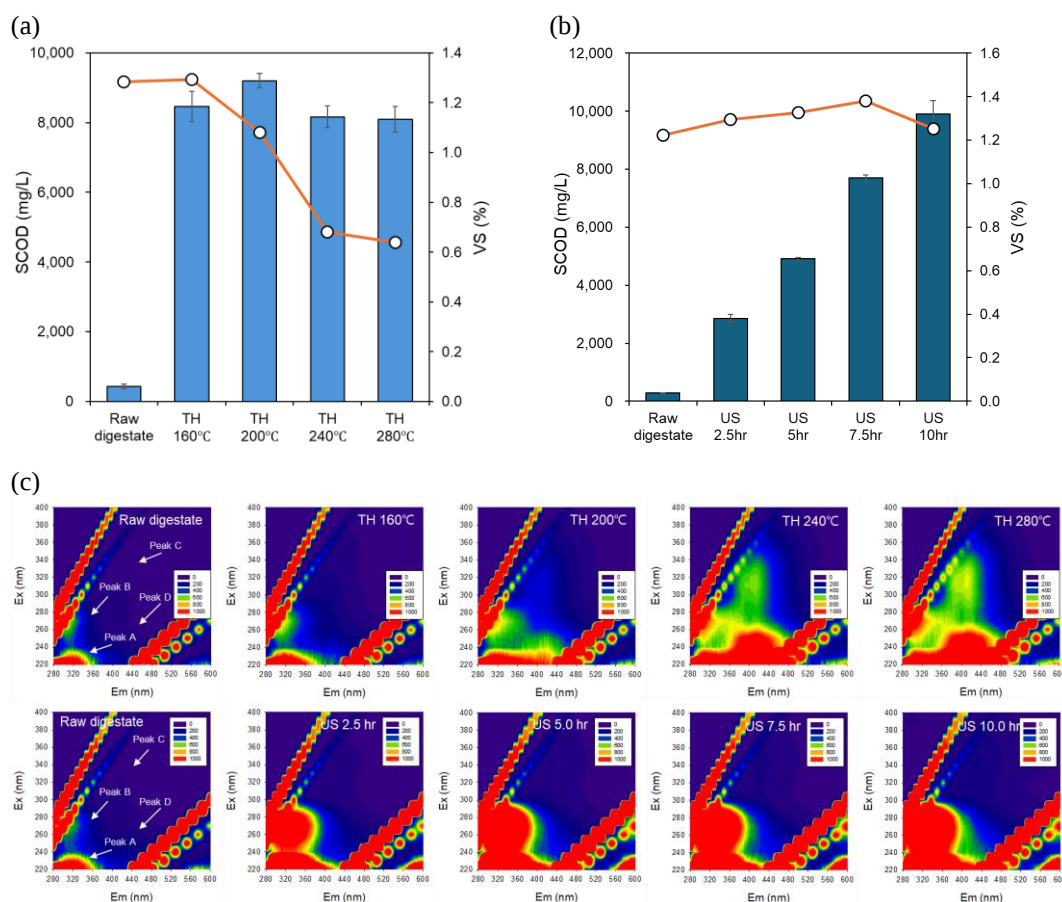


Figure 2. SCOD, VS, and EEM responses of digestate after thermal and ultrasonic solubilization

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References

- Lee E, Min KJ, Choi H, Park KY (2024). Impact of dewatering inorganic coagulants on anaerobic digestion treating food waste leachate. *Bioresour. Technol.* 393:130136.
- Yang S, McDonald J, Hai FI, Price WE, Khan SJ, Nghiem LD (2017). The fate of trace organic contaminants in sewage sludge during recuperative thickening anaerobic digestion. *Bioresour. Technol.* 240:197–206.