

Synergistic effects and mechanisms of ultrasonic, pH, and peracetic acid pretreatment on sludge anaerobic fermentation to stimulate short-chain fatty acid production

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Abstract

Anaerobic fermentation (AF) for short-chain fatty acid (SCFAs) production from waste-activated sludge (WAS) is a sustainable carbon recovery strategy; however, its efficiency is often constrained by inadequate sludge disintegration. To address this challenge, combined pretreatment methods, including ultrasonic-acidic (US-Ac), ultrasonic-alkali (US-Ak), and ultrasonic-alkali/peracetic acid (US-Ak/PAA) have been proposed as effective solutions. The Results revealed that the US-Ak/PAA pretreatment yielded the highest SCFAs accumulation at 370.5 mg/g VSS at day 6 of AF, surpassing the control, sole PAA, sole pH10, and 0.25US30 reactors by 4.27, 2.7, 2.0, and 1.2-fold, respectively. Furthermore, the US-Ak group (0.25US30) significantly enhanced SCFAs yield by 1.46-fold compared to the US-Ac group (US0.5–30). Mechanistic analysis indicated that the US-Ak/PAA pretreatment effectively disrupted extracellular polymeric substances (EPS), lysed microbial cells, and increased the release of soluble organic matter, thereby optimizing metabolic activity and SCFAs accumulation. The enzymatic activities of protease and α -glucosidase were notably enhanced, demonstrating a strong correlation with improved hydrolysis and acidogenesis processes. Microbial community analysis further revealed that the US-Ak/ PAA pretreatment substantially enriched the abundance of hydrolytic and acidogenic bacterial taxa, including *Acinetobacter*, *Petrimonas*, *Macellibacteroides*, *Proteiniphilum*, *Tissierella*, and *unclassified_c_Clostridia*, etc. species. Collectively, the US-Ak/PAA pretreatment strategy not only optimized SCFAs production from WAS but also contributed to mitigating the environmental risks associated with WAS disposal.

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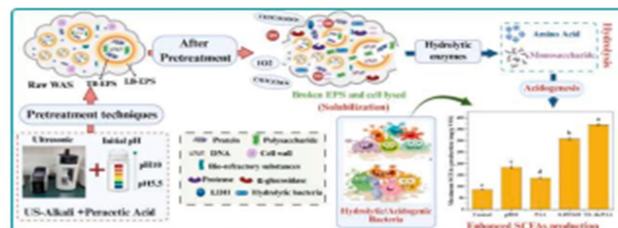
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HIGHLIGHTS

- US-Ak pretreatment significantly boosted the SCFAs yields compared to US-Ac pretreatment.
- US-Ak/PAA pretreatment remarkably improved SCFAs production from WAS (370.5 mg/g VSS).
- US-Ak/PAA pretreatment accelerated sludge disruption and organic matter release.
- Hydrolytic/acidogenic bacteria were significantly enriched with US-Ak/PAA pretreatment.

GRAPHICAL ABSTRACT



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Anaerobic fermentation (AF) for short-chain fatty acid (SCFAs) production from waste-activated sludge (WAS) is a sustainable carbon recovery strategy; however, its efficiency is often constrained by inadequate sludge disintegration. To address this challenge, combined pretreatment methods, including ultrasonic-acidic (US-Ac), ultrasonic-alkali (US-Ak), and ultrasonic-alkali/peracetic acid (US-Ak/PAA) have been proposed as effective solutions. The Results revealed that the US-Ak/PAA pretreatment yielded the highest SCFAs accumulation at 370.5 mg/g VSS at day 6 of AF, surpassing the control, sole PAA, sole pH10, and 0.25US30 reactors by 4.27, 2.7, 2.0, and 1.2-fold, respectively. Furthermore, the US-Ak group (0.25US30) significantly enhanced SCFAs yield by 1.46-fold compared to the US-Ac group (US0.5–30). Mechanistic analysis indicated that the US-Ak/PAA pretreatment effectively disrupted extracellular polymeric substances (EPS), lysed microbial cells, and increased the release of soluble organic matter, thereby optimizing metabolic activity and SCFAs accumulation. The enzymatic activities of protease and α -glucosidase were notably enhanced, demonstrating a strong correlation with

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