Enhancing Anaerobic Digestion of Food Waste: Hyperthermophilic Pretreatment and Zero-Valent Iron addition

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Keywords: food waste, zero-valent iron, pasteurization, biogas.
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In the European Union, over 59 x 10^6 tn of food waste (FW) are generated annually (Eurostat, 2024), causing both environmental and health challenges. Anaerobic digestion (AD) presents a sustainable method for managing organic waste, by converting it into biogas. European regulations require the pasteurization of FW, before or after AD, to ensure biosecurity and prevent disease transmission. One standard method requires heating the material to 70 °C for at least one hour to achieve the necessary pathogen reduction. Moreover, numerous studies have demonstrated that the hyperthermophylic pretreatment at 70 °C of FW facilitates the accumulation of volatile fatty acids (VFAs), which subsequent accelerates methane production (Yin *et al.*, 2020, Liczbiński and Borowski, 2021a).

A review by Ye *et al*. (2021) on the effects and mechanisms of zero-valent iron (ZVI) on AD of solid waste highlighted that ZVI significantly enhances the AD of FW by improving biogas production, methane yield, VFAs balance, and overall process stability. ZVI addition could also balance pH and decrease oxidative-reductive potential, creating a strictly anaerobic condition for the anaerobes' metabolism and methane.

Herein, a two-phase AD system was employed for the treatment of FW. Initially, 2.23 g FW was pretreated at 70 °C using thermophilic anaerobic granular sludge (tAGS) and varying concentrations of ZVI (5,10, 20 g/L), assessing the impact of pasteurization duration (1, 4 and 7 days) and the concentration of ZVI prior to AD. Figure 1 shows the concentration of VFAs produced during the hyperthermophilic pretreatment. Acetic acid was the most dominant organic acid across samples containing FW on day 7, reaching concentrations of 1.5 g/L, 1.4 g/L and 1.6 g/L for samples 5ZVI-FW-tAGS, 10ZVI-FW-tAGS and 20ZVI-FW-tAGS, respectively. Soluble chemical oxygen demand (SCOD) presented in Figure 2 suggests that higher soluble COD concentrations require pretreatment durations exceeding one day. Specifically, on day 4, COD levels ranged between 1.7-2.0 g/L, while on day 7 COD levels increased. Moreover, total sugars content was initially high, (1.0-1.2 g/L) on day 1, but declined by day 4 to approximately 0.1–0.2 g/L, indicating rapid microbial utilization and conversion during the pretreatment phase.

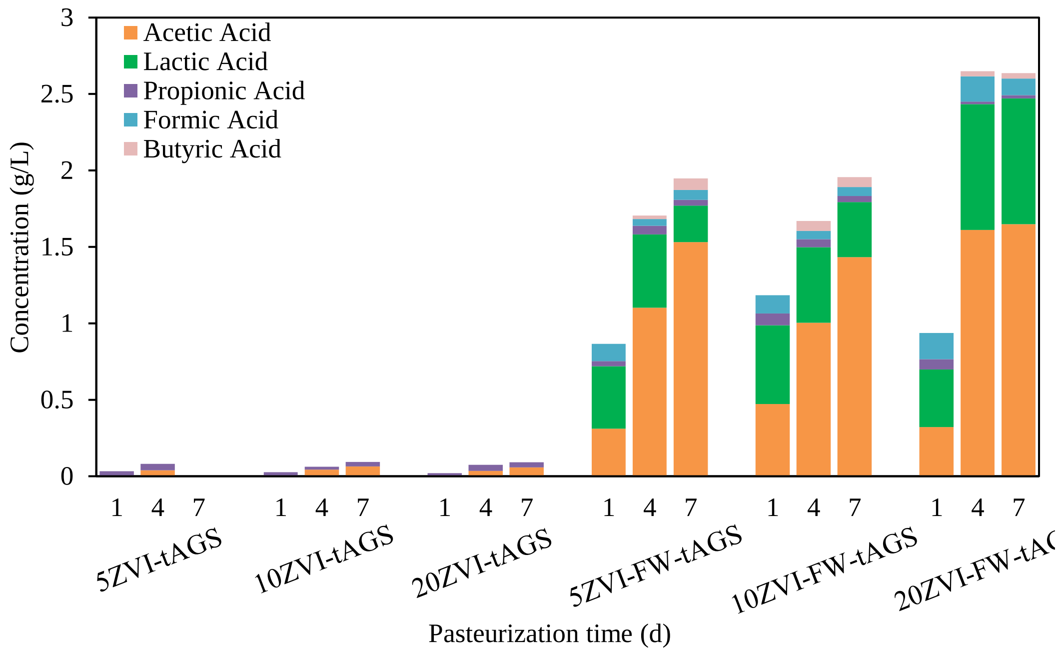

Figure 1. VFAs concentration (g/L) over pasteurization time (d).

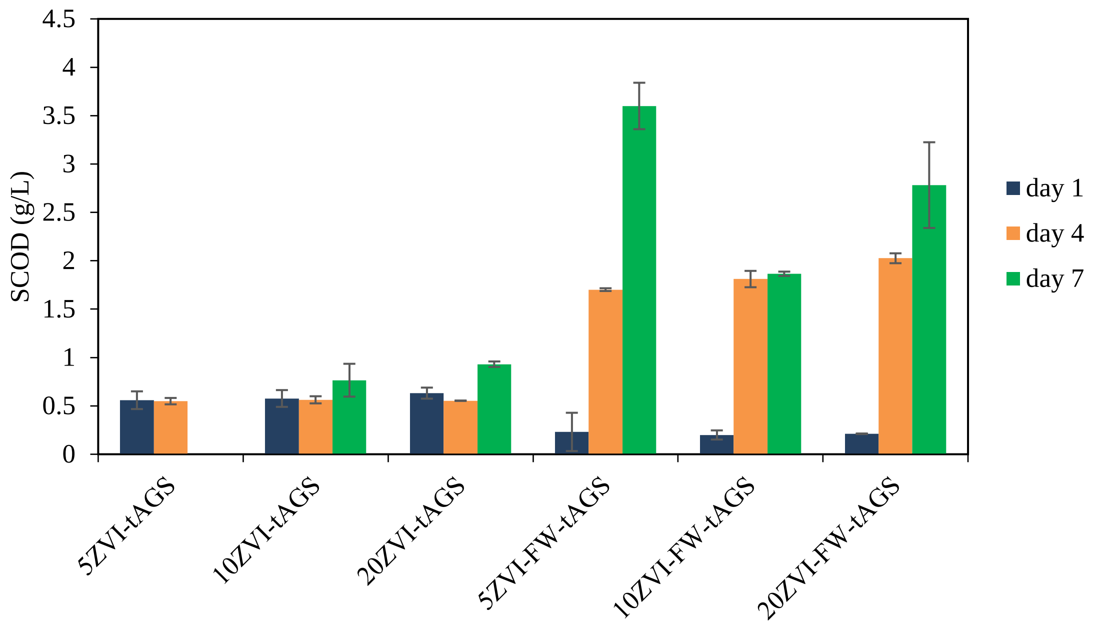

Figure 2. SCOD (g/L) over pasteurization time (1, 4, and 7 days).

During the two-phase AD treatment, FW was first subjected to a 4-day pretreatment at 70 °C (1st phase) before introduced to mesophilic anaerobic granular sludge (mAGS) (2nd phase). Figure 3 indicates that ZVI enhances cumulative methane production during the 2nd phase, since samples FW-ZVI-tAGS(+mAGS), FW-ZVI(+mAGS) and FW-tAGS(+ZVI+mAGS) exhibit the highest cumulative methane production on day 53, reaching 235.4, 239.5, 212.2 ml, respectively, while sample FW-tAGS(+mAGS) without the addition of ZVI, produced 187.7 ml methane. In contrast, untreated samples (rawFW-mAGS and rawFW-ZVI-mAGS) exhibited the lowest cumulative methane production, highlighting the positive impact of both the pretreatment and ZVI addition. Notably, biogas upgrading was achieved (>95% CH_4) in sample FW-ZVI-tAGS(+mAGS).

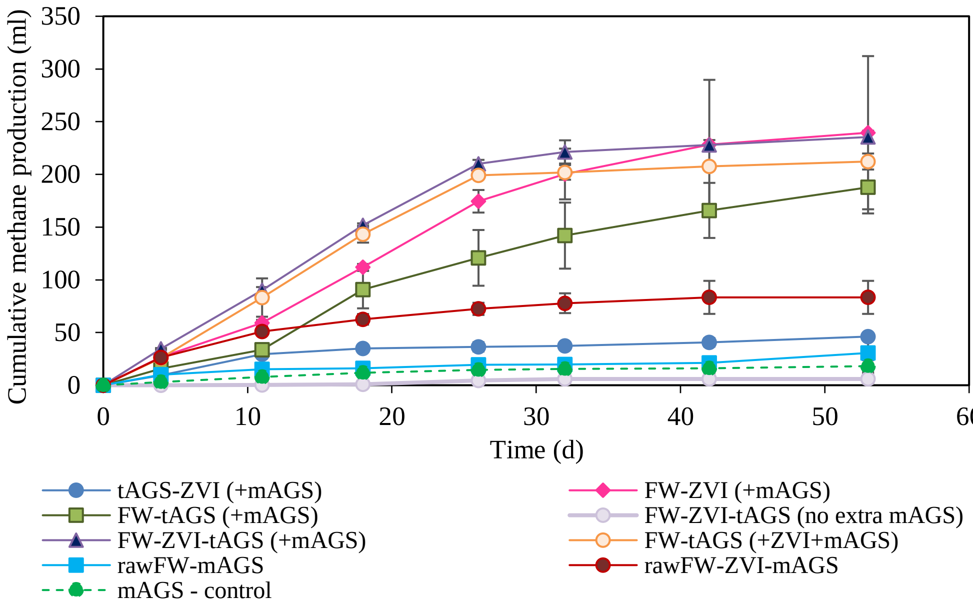

Figure 3. Cumulative methane production (ml) over time during the 2nd phase – AD. Parenthesis represents the addition of mAGS or ZVI after the pretreatment.

Acknowledgments: This work is supported by the CARING NATURE project that has received funding from the European Union's Horizon Europe research and innovation programme under the Grant Agreement No. 101101322.

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