Application of food waste-derived volatile fatty acids as alternative carbon source for post-denitrification process in municipal wastewater treatment

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Introduction

Nutrient pollution is a globally recognized issue that has far-reaching consequences. Nitrogen is a principal nutrient pollutant in municipal wastewater and is also a natural component of ecosystems. However, the unchecked build-up of nitrogen can result in eutrophication of water bodies, a process that stimulates the growth of algae and other aquatic plants. This, in turn, can lead to detrimental effects such as extensive algal blooms and reduced oxygen levels in water bodies. Successful elimination of nutrients in WWTPs is crucial to maintaining the quality of receiving waters, indirectly safeguarding drinking water resources, and promoting the recycling of used water for irrigation.

Various technological approaches can be utilized to achieve nitrogen removal. This can be done via sequential nitrification and denitrification, also known as continuous flow activated sludge system, in wastewater treatment plants (WWTPs) or some other approaches include fixed film, granules, sequencing batch reactors. Nitrification involves the oxidation of nitrite to nitrate, which occurs following the biological oxidation of ammonium to nitrite, facilitated by nitrifiers such as nitrite-oxidizing bacteria and ammonia-oxidizing bacteria. The nitrified wastewater then proceeds to the denitrification stage, where nitrate is utilized as an electron acceptor by heterotrophic denitrifying bacteria, leading to the formation of N_2 via a series of gaseous nitric oxide intermediates (Rahimi et al., 2020). A challenge associated with denitrification is that denitrifying bacteria, unlike nitrifying bacteria that flourish on inorganic carbon sources like CO_2, require organic carbon sources for energy acquisition and growth. Typically, during the early stages of treatment, the majority of the organic carbon sources are consumed, necessitating the provision of external organic carbon to comply with the permissible total nitrogen limits. In many cases, the absence of an easily biodegradable carbon source that can serve as an efficient substrate for heterotrophic denitrifying bacteria is the constraining factor during denitrification (EPA, 2013). The supply, preparation, and addition of ex-situ organic carbon sources introduce external loads to WWTPs, which compromise their ability to be self-sufficient and sustainable. Commercially available and commonly used external carbon sources for denitrification include mainly alcohols (i.e. methanol, ethanol), acetate or glycerine (Playchoom et al., 2011). However, the cost of the WWTP process increases when the carbon source used for treatment must be purchased, transported, and stored. The availability and price of the carbon source can also vary depending on the location and season. The use of fossil-based carbon sources like methanol can be controversial and may challenge the environmental sustainability and circularity of the process. Large volumes of carbon source must be stored on-site to ensure a year-round supply, which increases the process footprint. Although using *in-situ* produced waste streams as a carbon source is a potential alternative.

The strengthening of discharge standards places a considerable burden on existing WWTPs to reduce operating expenses while simultaneously enhancing the quality of their effluent (Palatsi et al., 2021). Consequently, the selection of external carbon sources has become crucial in terms of both environmental and economic considerations (EPA, 2013). Therefore, it is essential to explore novel and sustainable strategies that offer low-cost, renewable carbon sources for WWTPs, while also minimizing energy and capital requirements.

Material and methods

In this study (Figure 1), carbon sources used were heat shock pre-treated food waste through anaerobic digestion effluent (hereinafter referred to as AD-VFA) and one of the conventionally used carbon sources (methanol) (Table 1). Methanol (≥99.8%, Sigma-Aldrich) was used as reference carbon source for the denitrification experiments.

Table 1. Characteristics of carbon sources evaluated

Parameters	AD-VFA	sVFA
pH	5.38 ± 0.02	2.91 ± 0.02
sCOD (g/L)	14.5 ± 0.71	11 ± 0.00
NH_4^+-N (mg/L)	380.0 ± 0.00	-
PO_4-P (mg/L)	99.1 ± 0.42	-
NO_3-N (mg/L)	3.2 ± 0.14	-

NO_2-N (mg/L)	0.01 ± 0.00	-
AA (g/L)	0.71 ± 0.01	0.7 ± 0.1
PA (g/L)	0.29 ± 0.04	0.3 ± 0.1
Ibu (g/L)	0.21 ± 0.00	0.2 ± 0.05
BA (g/L)	0.79 ± 0.19	0.8 ± 0.1
Iva (g/L)	0.07 ± 0.10	0.1 ± 0.1
VA (g/L)	0.21 ± 0.00	0.2 ± 0.05
CA (g/L)	2.09 ± 0.29	2.1 ± 0.1
tVFA (g/L)	4.37 ± 0.11	4.4 ± 0.2

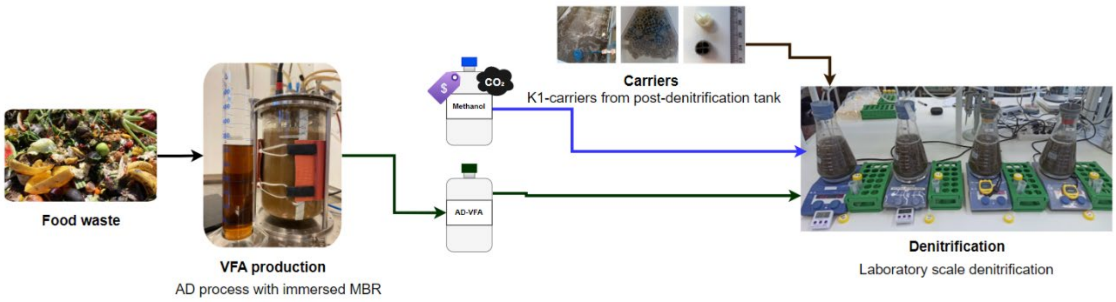

Figure 1. Schematic diagram of denitrification study

Results and discussion

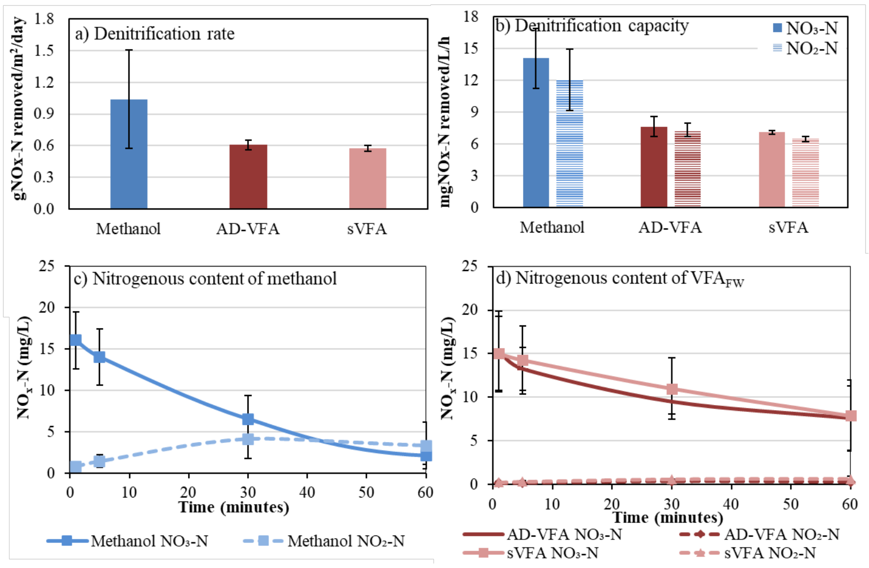

Figure 2. a) Denitrification rate and b) denitrification capacity using AD-VFA, and sVFA, and methanol, c), and d), shows NO_3-N (solid line), and NO_2-N (dashed line) concentrations

This study demonstrates that AD-VFA are promising carbon source that has the potential to replace methanol in denitrification. VFAs in WWTPs have been shown potentially to reduce carbon footprints and enhance sustainability. VFAs outperformed methanol in the removal of nitrite. With C/N ratio of 9.5 and denitrification rates of 0.61±0.04 and 0.57±0.03 g NO_x-$N_{removed}$/m^2/day, respectively, AD-VFA and sVFA performed nearly as well as methanol (1.04±0.46 g NO_x-$N_{removed}$/m^2/day) (Figure 2).

Conclusions

AD-VFA proved to be promising carbon source alternative for denitrification in wastewater treatment plants. To demonstrate the viability of conventional application, the potential of using different VFAs, concentrating VFAs, and combining carbon sources must be researched further.

References

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