Effect of ammonia concentration and pH on anaerobic butyric acid degradation

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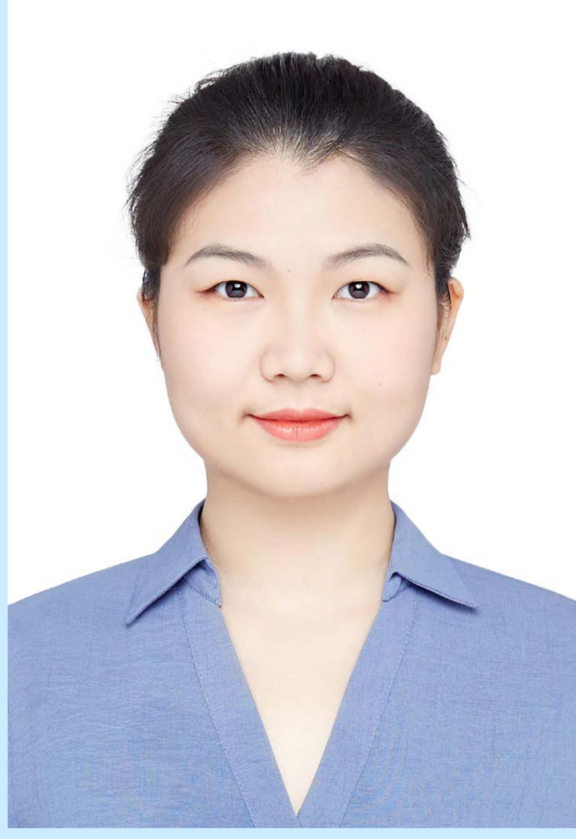

Introduction

The accumulation of butyric acid is a common observation in food waste and animal manure anaerobic co-digestion (Dennehy et al., 2016). However, the factors that affect butyric acid anaerobic degradation have not been well studied. Excess ammonia is generally regarded as a major factor affecting volatile fatty acid degradation (Zhang et al., 2022) but its impact on butyric acid degradation has not been studied. In this study, batch experiments were carried out to investigate the degradation of butyric acid and explore the inhibition degree of different ammonia species (NH_4^+, NH_3) under various total ammonia concentration (TAN, 0.18-20 g N/L) and pH (7.0-8.0) conditions. Then the recoverability of butyric acid degradation after ammonia inhibition was examined.

Objective

(1) the effect of ammonia and pH on butyric acid degradation

(2) the inhibition degree of different ammonia species

(3) butyric acid degradation kinetics

Method

- the experiment was conducted in triplicate in 280 mL serum bottles at 37 ℃.
- Butyric acid (2 g COD/L) was added as the only carbon source, and the inoculum was pre-activated anaerobic sludge.
- The TAN levels used in inhibition experiments were 0.18, 2, 4, 8, 12, 16, 20 g N/L at pH 7.5, respectively, and labeled as R1, R2, R3, R4, R5, R6, and R7.
- Reactors with different pH (7.0, 7.5 and 8.0) was performed with TAN of 4 g N/L, which were labeled as R8, R9, and R10, respectively.
- The recovery experiment was labeled R11 with TAN of 0.18 mg N/L at pH 7.5 and the inoculum was the refreshed sludge from R7.
- Methane, VFAs concentration including aceti, propionic, iso-butyric, butyric, iso-valeric and valeric acid, and ammonia concentration were tested.
- First-order kinetic model and modified Gompertz model were introduction to simulate the reduction of butyric acid.
- Inhibition model was used to evaluate ammonia species inhibition degree.

$$\mu = \mu_m \cdot I_{NH_4^+} \cdot I_{NH_3}$$

$$I_X = \frac{K_X{}^n}{K_X{}^n + C_X{}^n}$$

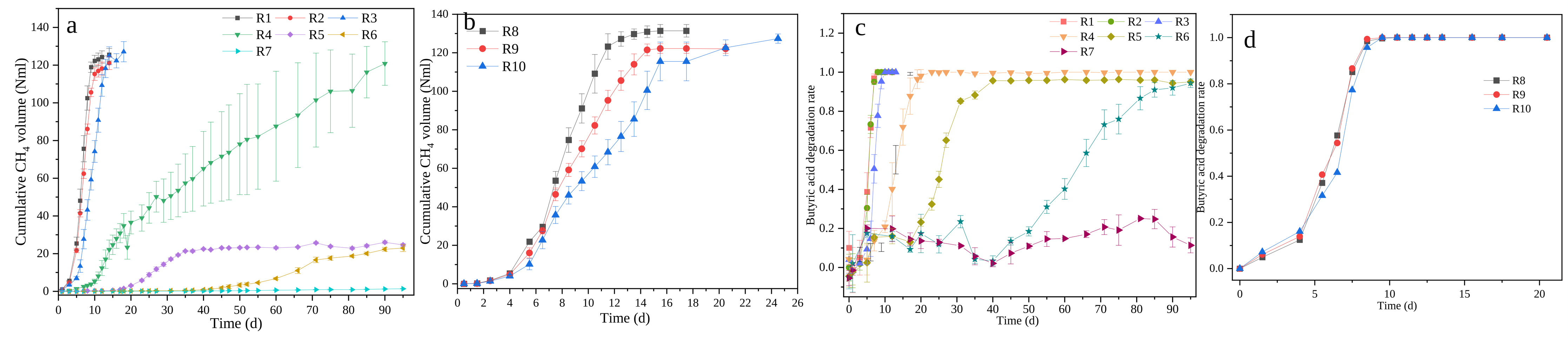

Fig.1. Methane production and butyrate degradation rate in different ammonia concentration: (a) (b) cumulative methane volume; (c)(d) butyrate degradation rate.

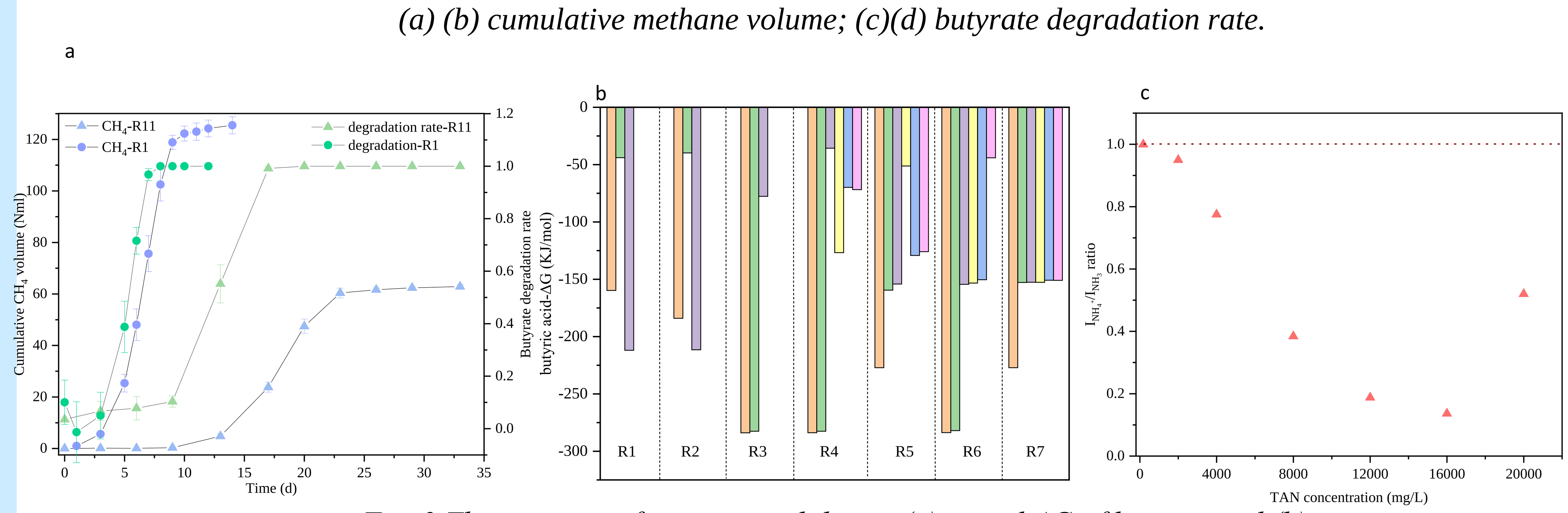

Fig. 2 The recovery of ammonia inhibition (a) actual ΔG of butyric acid (b) and the ration of $I_{NH_4^+} / I_{NH_3}$ (c)under different ammonia concentration

Results

- Butyric acid degradation was inhibited with TAN over 8 g N/L. Besides, when TAN concentration was at 20 g N/L, the degradation rate of butyric acid was severely inhibited and decreased to 18% from 100% (Fig.1 (c)).
- The inhibition on butyric acid degradation with TAN of 20 g N/L was reversible, whereas butyric acid degradation can't be fully recovered (Fig.2 (a)).
- The actual ΔG of butyric acid oxidation was in the range of -50 ~ -250 KJ/mol, indicating that the butyrate degradation was thermodynamically spontaneous in different ammonia concentration.
- The ratio of $I_{NH_4^+} / I_{NH_3}$ was to evaluate individual contributions of NH_4^+ and NH_3 to the ammonia inhibition.
- NH4+ made more contributions to the ammonia inhibition with TAN ≥ 2 g N/L.
- Modified Gompertz modelling results better matched the measured results with Adj.R^2 > 0.9 (Fig.3).

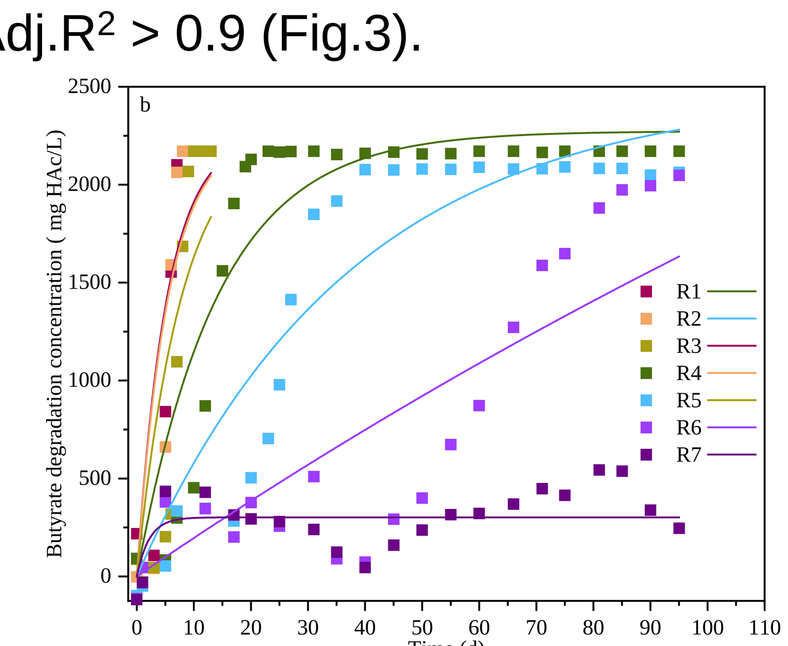

Fig.3 Butyrate degradation concentration under different ammonia concentration with modified Gompertz model

Conclusion

Butyric acid degradation rate was inhibited with TAN ≥ 8 g N/L. NH_4^+ made more contribution to the inhibition than NH_3 at TAN 2- 20 g N/L. Butyric acid degradation was thermodynamically spontaneous in different ammonia concentration. Lower pH can't relive ammonia inbition. A long HRT strategy is suggested to reduce butyric acid accumulation when treating food waste and animal manure via anaerobic digestion.

Reference

Dennehy, C., Lawlor, P. G., et al., 2016. Synergism and effect of high initial volatile fatty acid concentrations during food waste and pig manure anaerobic co-digestion. Waste management, 56, 173-180.

Zhang, H., Yuan, W., Dong, Q., et al., 2022. Integrated multi-omics analyses reveal the key microbial phylotypes affecting anaerobic digestion performance under ammonia stress. Water Research, 213, 118152.

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