Ammonia removal in food waste anaerobic digestion using a side-stream process

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Introduction

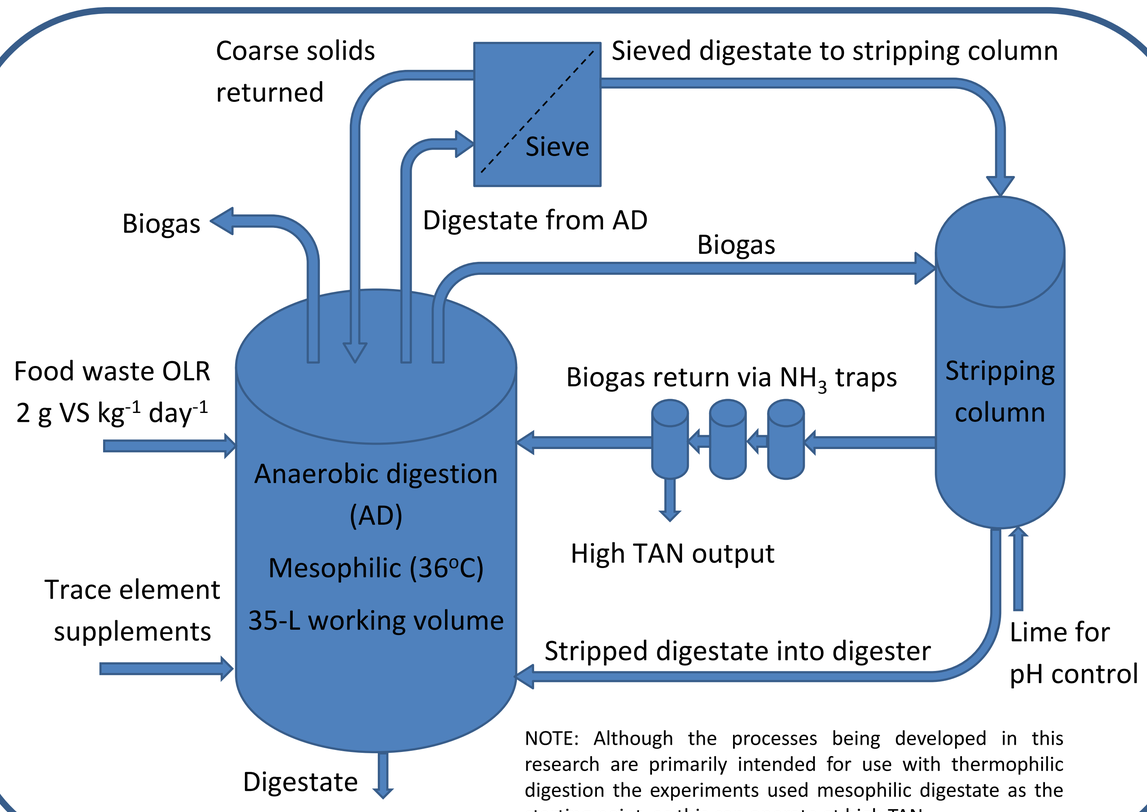
High ammonia concentrations are a known cause of problems in food waste digestion[1]. Although these can be overcome in mesophilic conditions[2], the lower threshold for toxicity in thermophilic systems may require ammonia removal to achieve effective operation. The current experiments were conducted with a mesophilic digester with a high initial ammonia concentration as a model system to show how ammonia can be removed by a high-temperature sidestream stripping process.

Objectives

1)To establish a performance baseline for digestion at high ammonia concentration without side-stream stripping. 2) To test the stripping process at different temperatures, pH values and volume ratios.

Methodology

4 no. 35-L digesters were used with 4 no. 2-litre stripping columns. 3% of the digester volume was removed every 3-5 days and added to a stripping column. This was operated with our without pH adjustment (Table 1) at temperatures from 55-85 ^{o}C. A mixture of methane and CO_2 was used as the stripping gas and initially this was supplied in a continuous loop by taking it from a common reservoir at 0.150 L L^{-1} min^{-1} and passing the gas through each column individually. Ammonia was removed by traps before the gas was returned. In later experiments (day 250 on) each tower operated with an independent reservoir and recirculation loop.



NOTE: Although the processes being developed in this research are primarily intended for use with thermophilic digestion the experiments used mesophilic digestate as the starting point, as this can operate at high TAN.

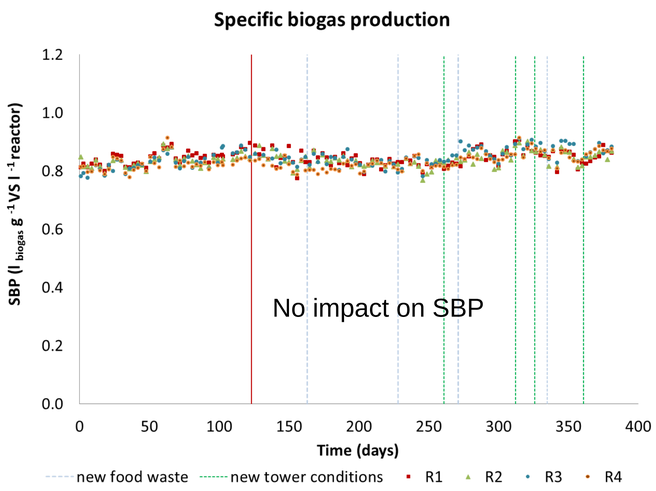
Digesters and stripping columns

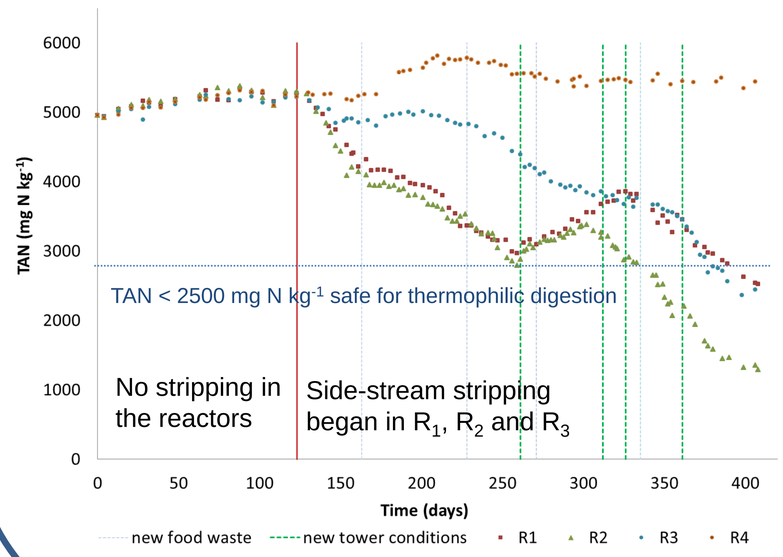
Results

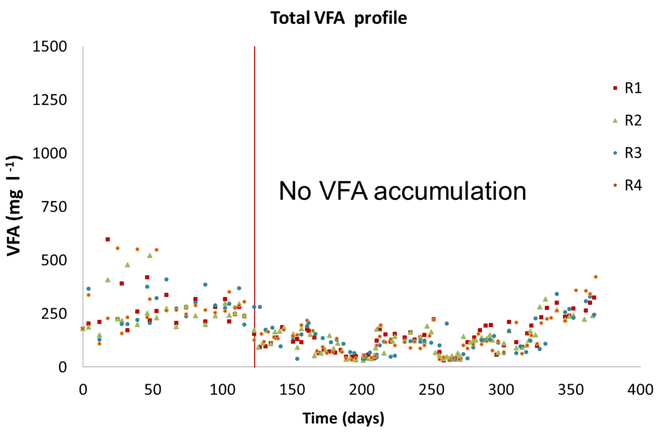
- Stable operation was maintained for the first 120 days without stripping, despite high TAN levels of 5.1 g N kg^{-1} (free ammonia 500 mg N kg^{-1})
- In R3 stripping at 55 ^{o}C and pH 10 only gave a low removal rate of 6.8% per day
- In R2 and R3 stripping at 70 ^{o}C with and without pH control gave 15.3% and 20.6% removal at 3 and 4 day RT respectively, indicating that temperature was a more important factor than pH
- On day 250 the gas stripping streams were separated, the temperature of R3 was increased to 85 ^{o}C and pH adjustment ceased in all reactors. This led to a rise in ammonia in R1 and R2, and only a moderate increase in removal rate in R3. The only explanation was that previously there had been a transfer of alkalinity between reactors via the common gas supply
- When alkalinity was added to R2 on day 311 this resulted in an immediate reversal of the trend, with ammonia again being removed. The same effect was noted in R1 after addition of alkalinity on day 328. Rates of ammonia removal were restored to >20% per day
- When the pH was increased at 85 ^{o}C the removal rate was 30% per day

Table 1: Stripping column conditions

Reactor	Stripping condition 1	Stripping condition 2	Stripping condition 3
1	(day 123-326) 70^{o}C, unadjusted pH, 1 tower, 4 days RT	(from day 326 onwards) 70^{o}C, pH 10, 1 column, 3 days RT	-
2	(day 123-261) 70^{o}C, pH 10, 1 column, 3 days RT	(day 261-312) 70^{o}C, unadjusted pH, 2 columns, 4 days RT	(from day 312 onwards) T1:70^{o}C, pH 10, 3 days T2:70^{o}C, unadjusted pH, 4 days RT
3	(day 123-261) 55^{o}C, pH 10, 1 column, 5 days RT	(day 261-361) 85^{o}C, unadjusted pH, 1 column, 3 days RT	(from day 361 onwards) 85^{o}C, pH 10, 1 column, 2 days RT
4	Control, no stripping column		







Conclusions

- The sidestream process requires high temperature and pH to achieve high removal rates
- Despite the harsh conditions in the stripping column there was no negative impact on digestion performance
- The results showed that ammonia could be reduced from over 5 g N l^{-1} to < 1.5 g N l^{-1}, a safe operating concentration even in thermophilic conditions
- To achieve the highest stripping rate of ~30% per day the daily volume of digestate removed for stripping could be as low as 1%
- The stripping process could potentially be combined with final pasteurisation in a single reactor
- Sidestream stripping can control ammonia in the reactor in a flexible mode by modifying the conditions in the stripping tower → 'designer' digestates, fulfill land application requirements

References

1 Banks C. J., Chesshire M, Stringfellow A., (2008) A pilot-scale comparison of mesophilic and thermophilic digestion of source segregated domestic food waste. Wat Sci Technol 58(7) 1475-1480

2 Banks, C.J., Y. Zhang, Y. Jiang, S. Heaven, (2012) Trace element requirements for stable food waste digestion at elevated ammonia concentrations. Biores Technol, 104, 127-135