Potential for thermophilic digestion of food waste for energy production and resource recovery

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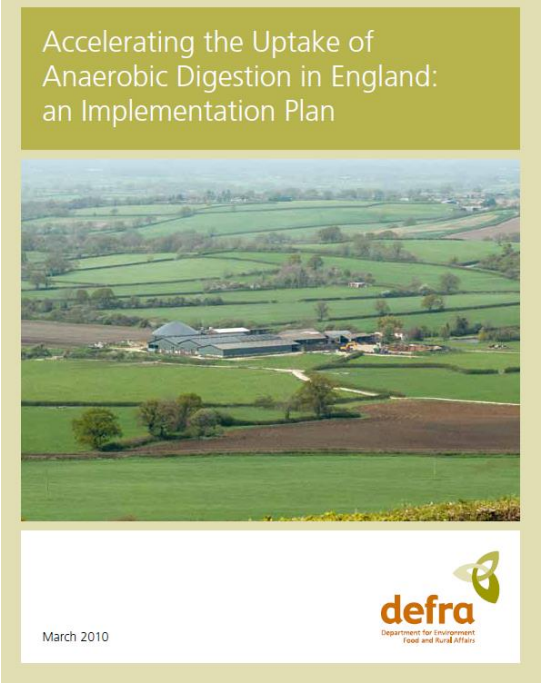
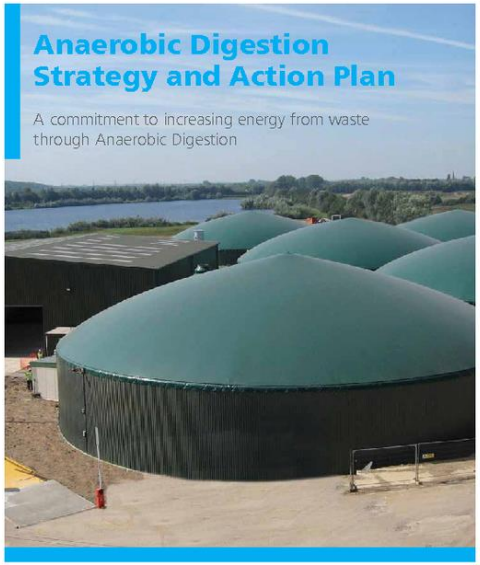
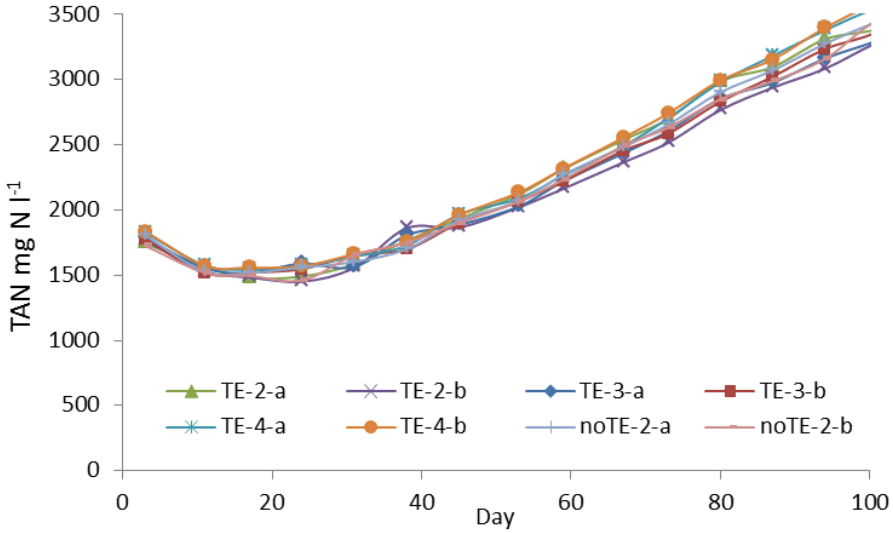


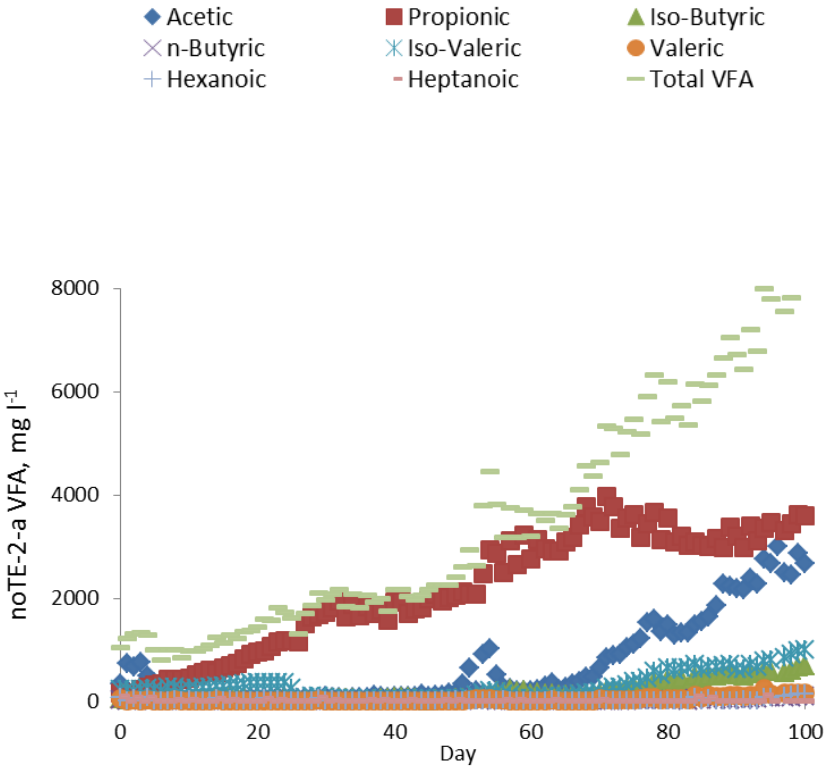
Mesophilic digestion of food waste is already common practice in the UK, following on from the first demonstration-scale digester built in 2006



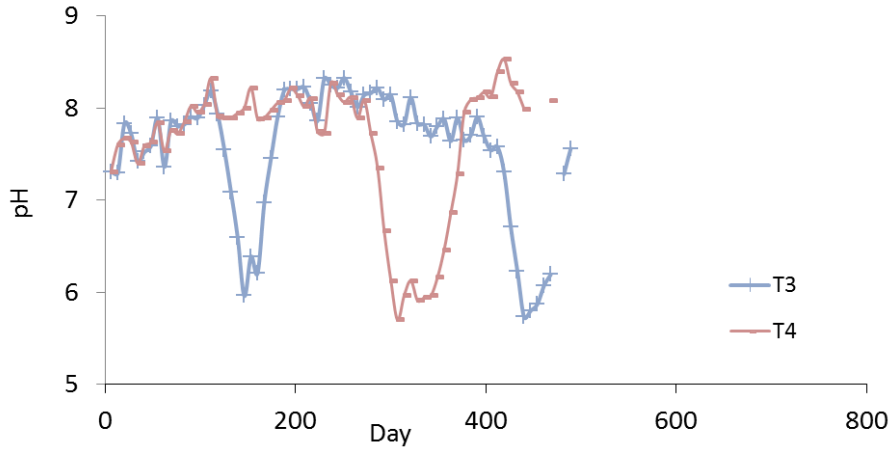
Lab results from thermophilic trials using source separated food waste with and without trace element addition

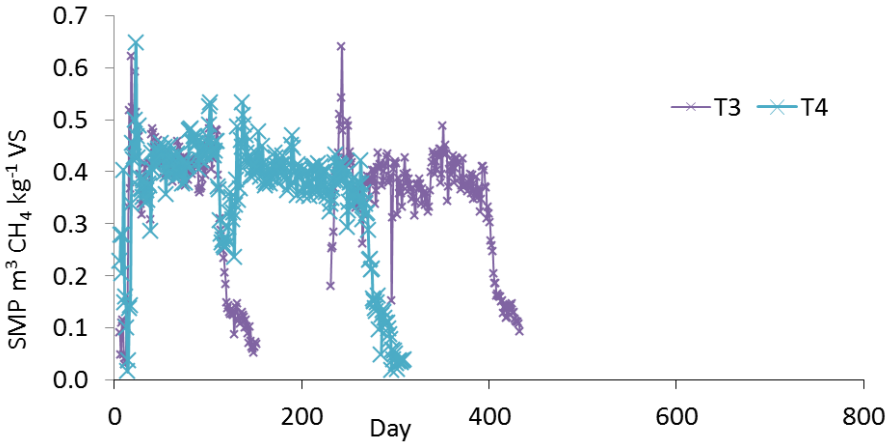
- Typical digester reaction to rising ammonia concentration





Attempts at long-term acclimatisation





- Continued increase in TAN concentration to 5-6 g N L^{-1}
- Continued VFA accumulation which breaks digester alkalinity, leading to severe falls in pH
- Stop-start feeding to recover biogas production following 'crashes' in pH
- Eventually non-recoverable failure

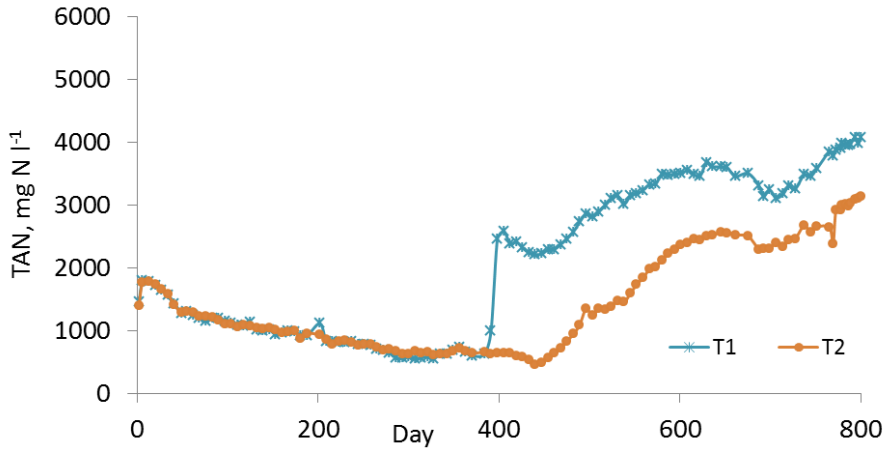
Our estimate of TAN inhibitory concentrations

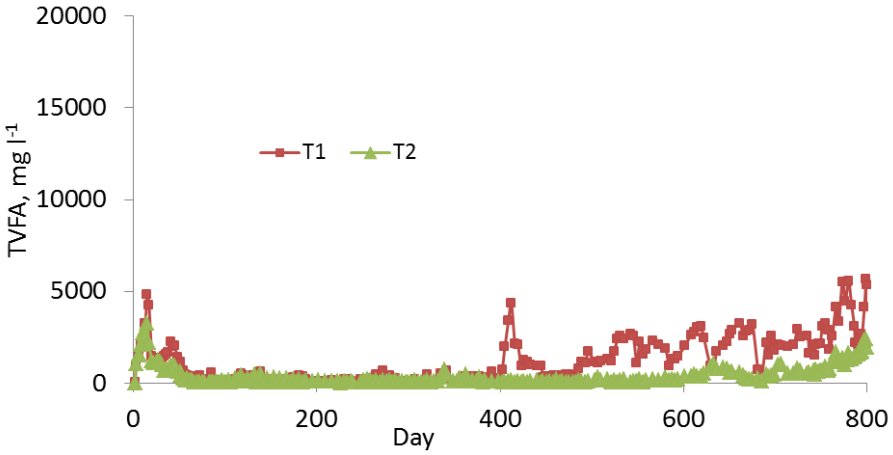
Inhibition Limits	TAN g N L^{-1}	FAN mg N L^{-1}
Mesophilic (35 ^{o}C)	8.0	800
Thermophilic (55 ^{o}C)	2.5-3.5	550-880

- TAN concentration of food waste digestate can be 4-6 g N L^{-1}

Question was asked: were the problems a result of difficulties in transition from a mesophilic to a thermophilic population?

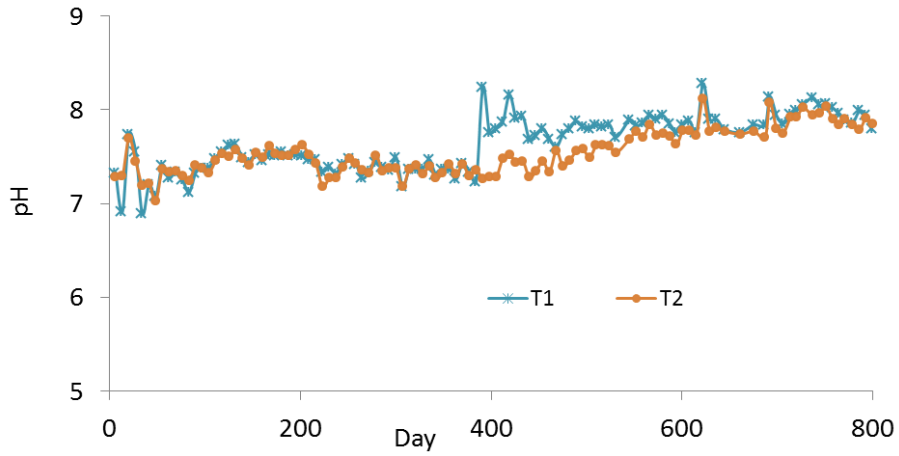
Thermophilic acclimatisation with ‘low’ N input

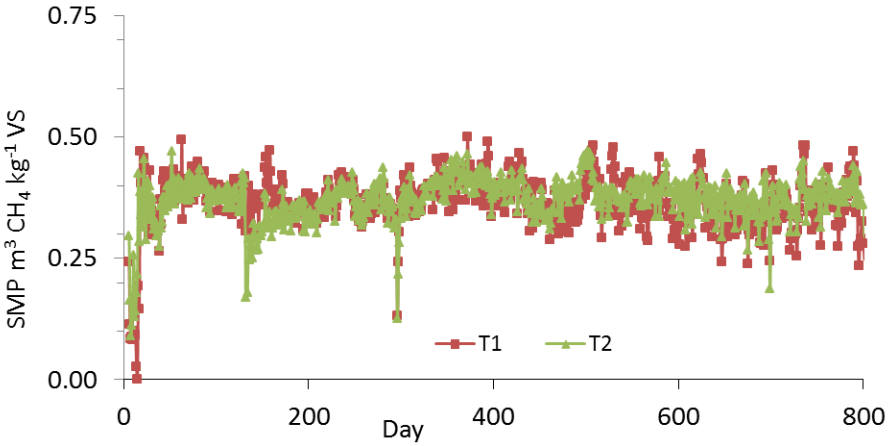




- Low N food waste prepared mainly from fruit and vegetables
  - TE supplemented
  - 1 year to acclimate to thermo conditions before urea addition to raise TAN concentration
- VFA start to accumulate as TAN reaches critical threshold

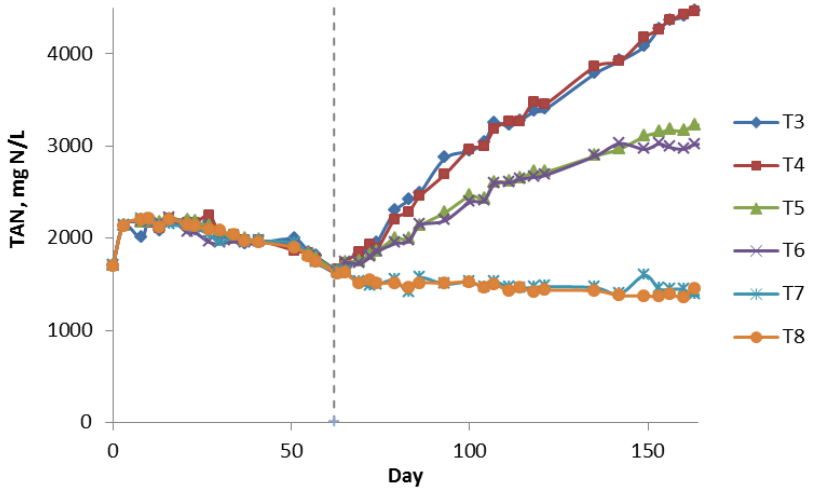
Thermophilic acclimatisation with ‘low’ N input

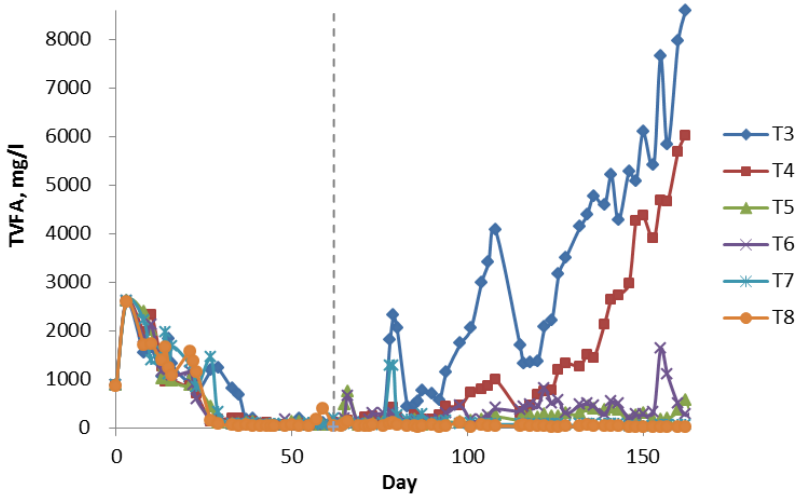




- Addition of urea shown by pH change
- Stable gas production

Thermo AD of 'high' N food waste with dilution

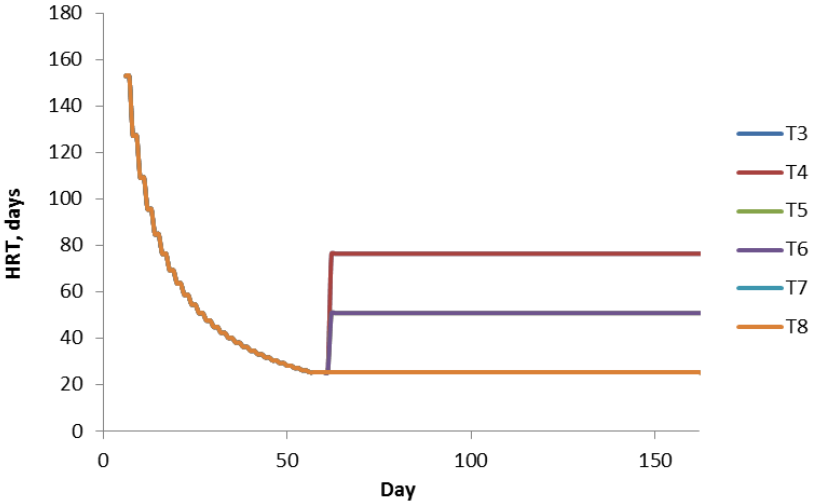


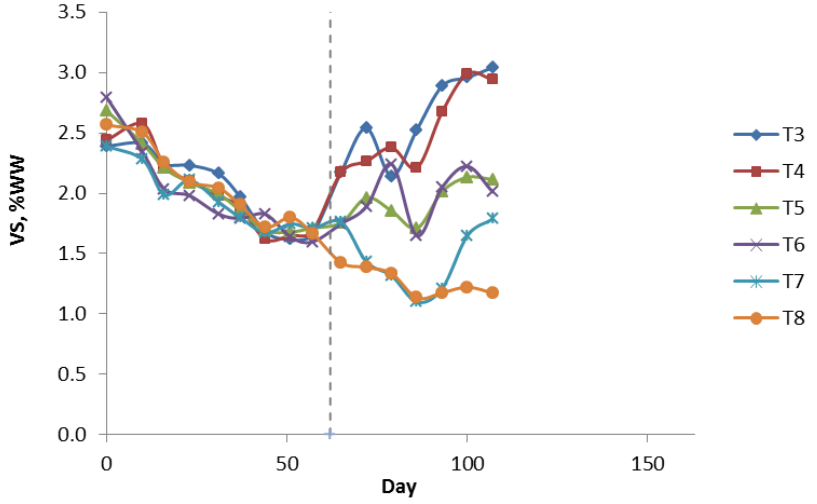


- Started with dilution 2 parts water to 1 part FW
- Changed dilution on day 60 in 2 sets of digesters
  - 1:1 in T5 and T6
  - No dilution in T3 and T4

- VFA start to accumulate in T3 and T4 when TAN > 2.5 g N L^{-1}

Thermo AD of 'high' N food waste with dilution





- Dilution also reduces HRT and VS concentration
- Dilution of ≥ 1:1 is necessary for stable digestion

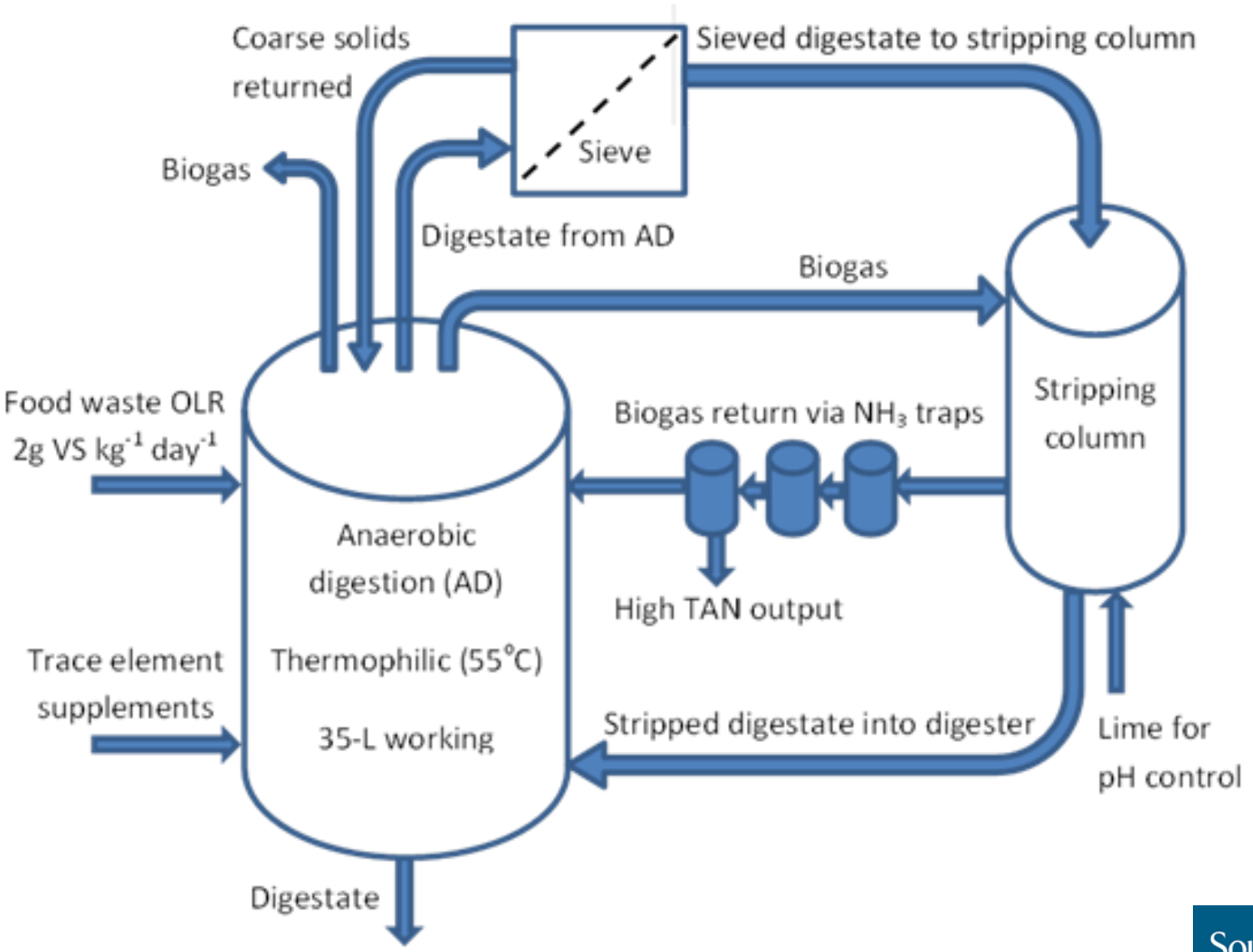
Conclusions from early thermophilic digestion studies

- Threshold inhibition concentration for total ammonia nitrogen (TAN) is ~2.5 g N L^{-1}
- Failure of digester occurs at ≥ 3.5 g N L^{-1}
- Trace element supplementation is not effective in controlling VFA accumulation in thermophilic digesters
- Food waste can be digested thermophilically by dilution with water, but the ratio must be such as to reduce TAN ≤ 2.5 g N L^{-1} which is greater than a 1:1 dilution

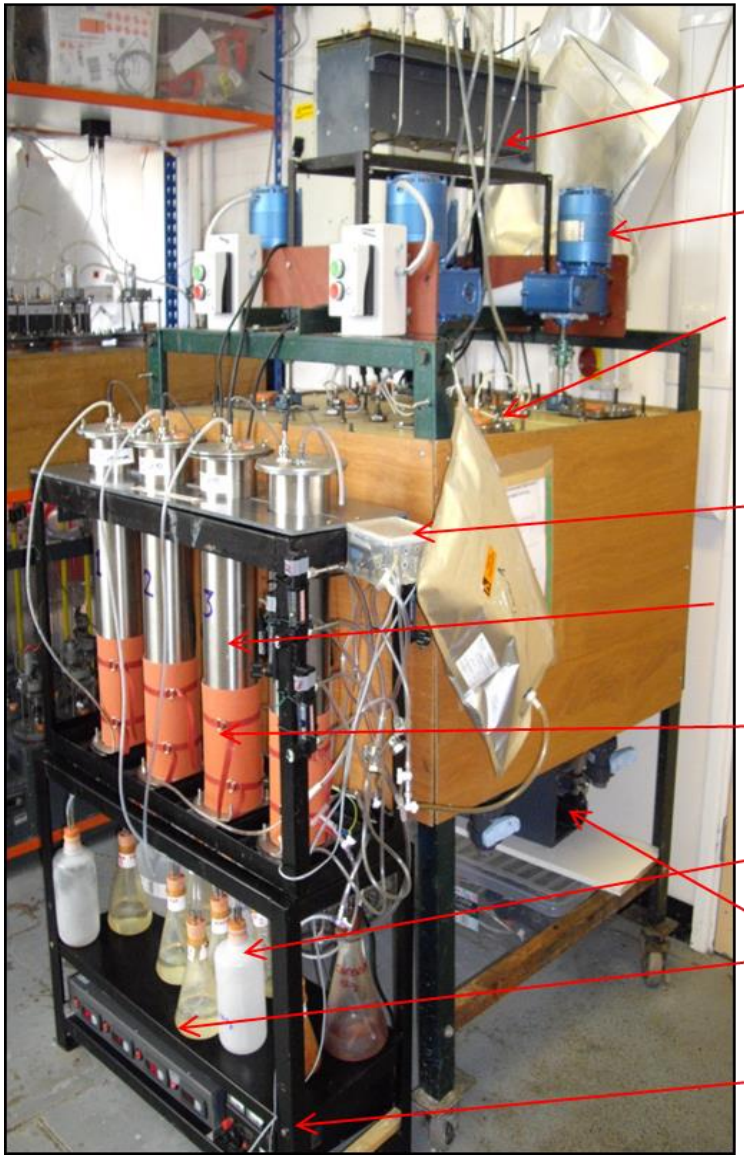
Alternative – ammonia removal by side-stream stripping

- We can control TAN concentration by biogas stripping – shown this in mesophilic digesters
  - Serna-Maza A, Heaven S, Banks CJ (2014) Ammonia removal in food waste anaerobic digestion using a side-stream stripping process. *Bioresource technology*, *152*, 307-315.
- Is this possible over a longer period in thermophilic conditions, and are the severe conditions of temperature and pH associated with a side-stream process likely to affect digester performance?

Flow diagram



In practice



Gas counter

Motor

Continuous stirred-tank reactors (mesophilic) 35-l volume

Gas pump

Ammonia stripping towers

Heating mat

Ammonia traps

Temperature control

Pump power supply

Operation

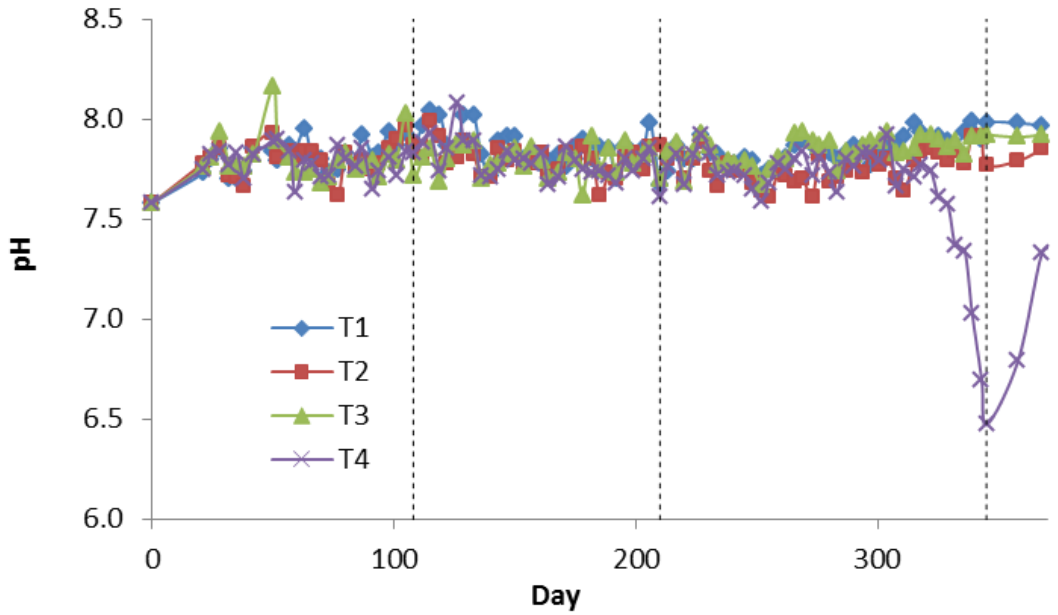
- Digesters seeded with mesophilic wastewater biosolids digestate
- Transformation to thermophilic conditions by 'one step' temperature shift
- Gradual increase in OLR from 0.5 to 2.0 kg VS m^{-3} day^{-1} using low N food waste (days 0 - 21)
- Day 21 feed switched to normal source segregated domestic food waste (SS-DFW), stripping began

Operational stages

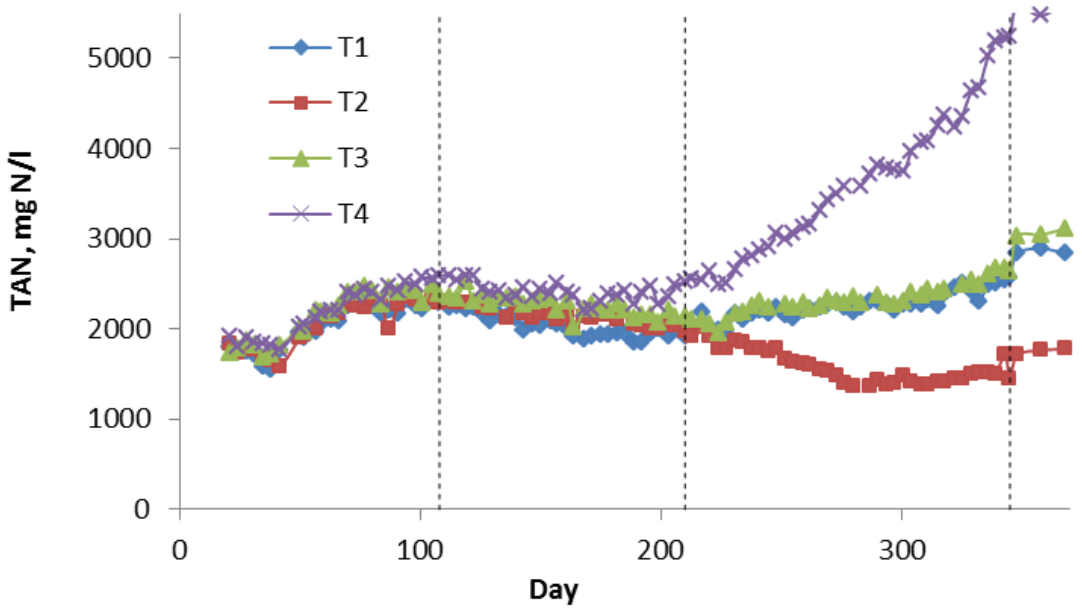
- Stage 1 (day 0-107): all digesters operated under the same conditions
  - ammonia stripped from digestate equal to 6% of digester volume, twice a week from day 21
- Stage 2 (day 108-209): mass of digestate stripped from T1 and T2 increased to 7.1% twice per week
- Stage 3 (day 210-345): mass of digestate stripped from T2 doubled to 14.3% twice per week, and stripping stopped for T4
- Stage 4 (day 345 onward): feeding and stripping stopped, monitoring of digesters continued

Performance indicators

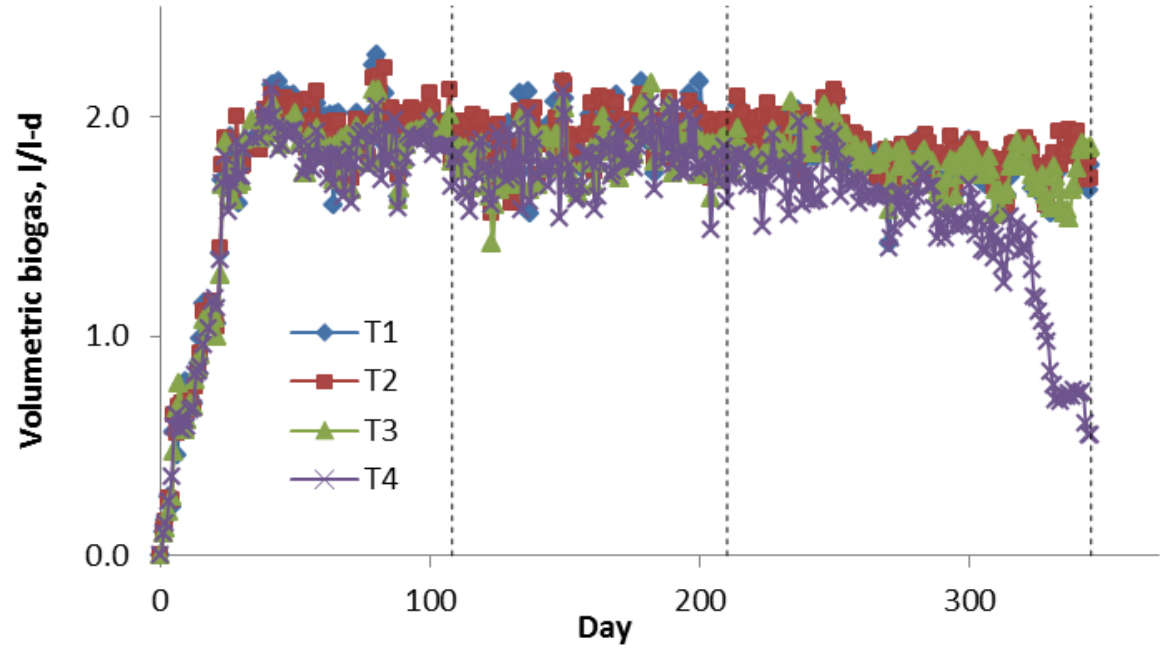
pH



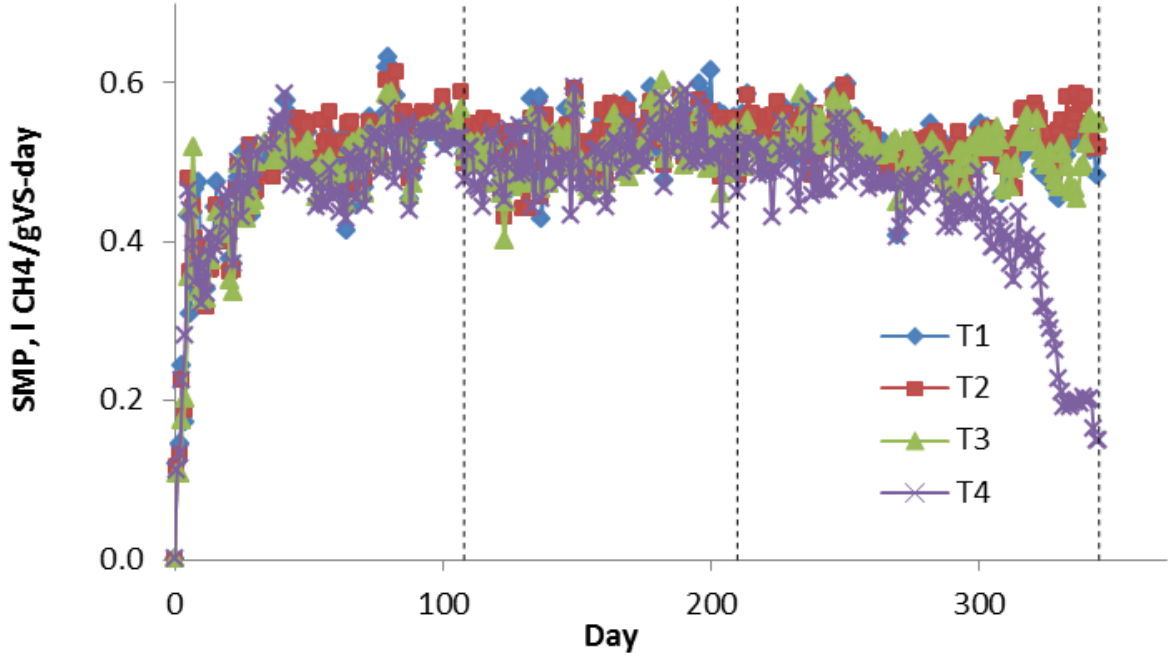
TAN



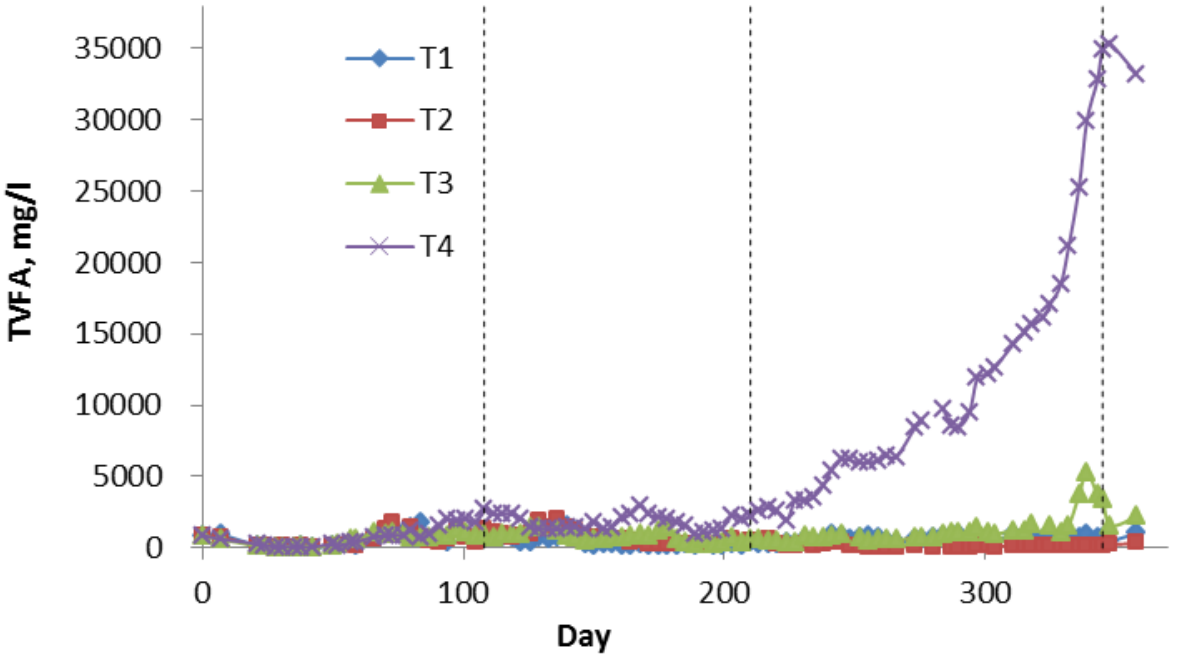
Volumetric Biogas



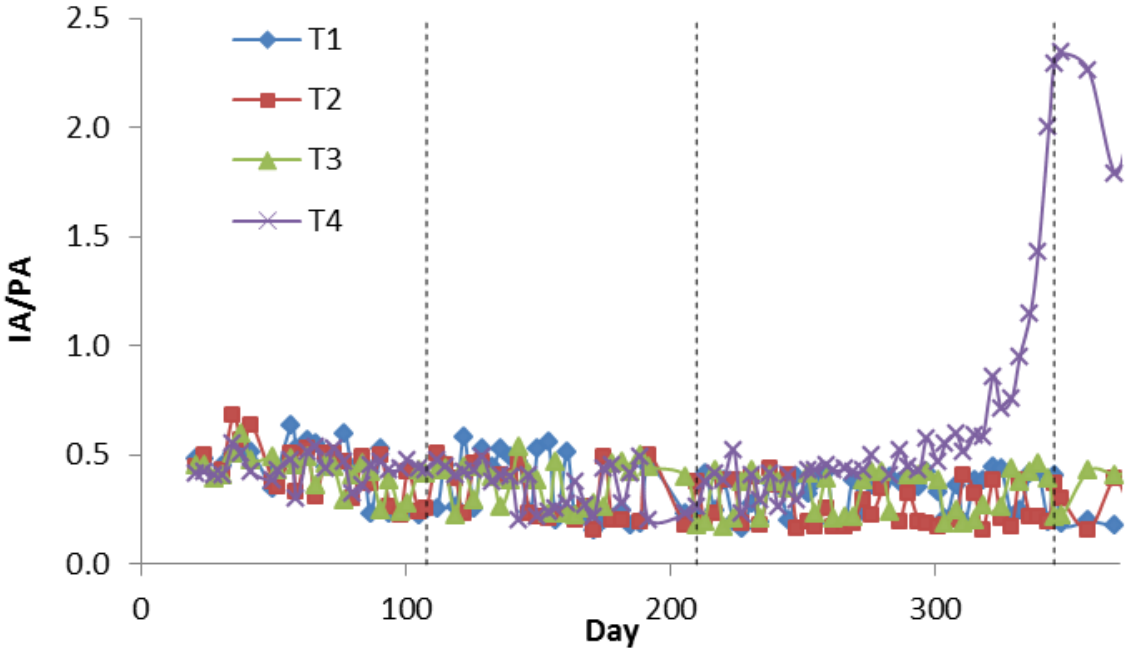
Specific methane



VFA



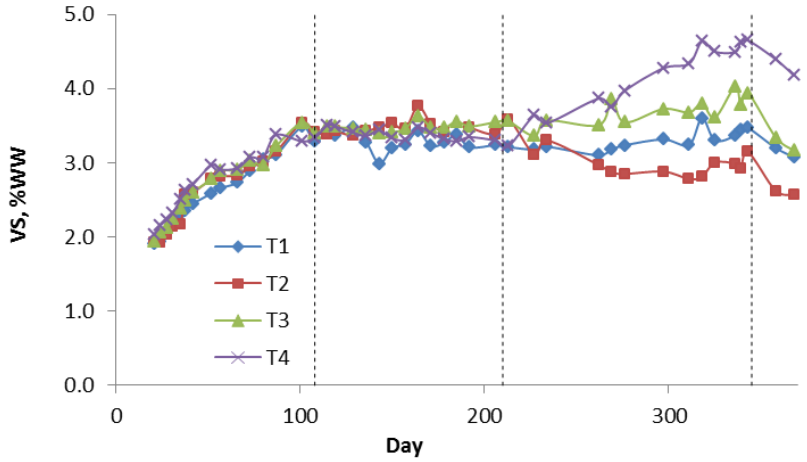
IA:PA ratio

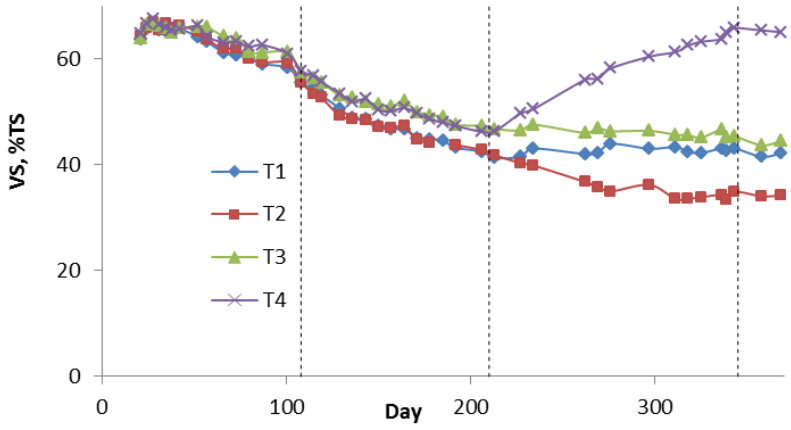


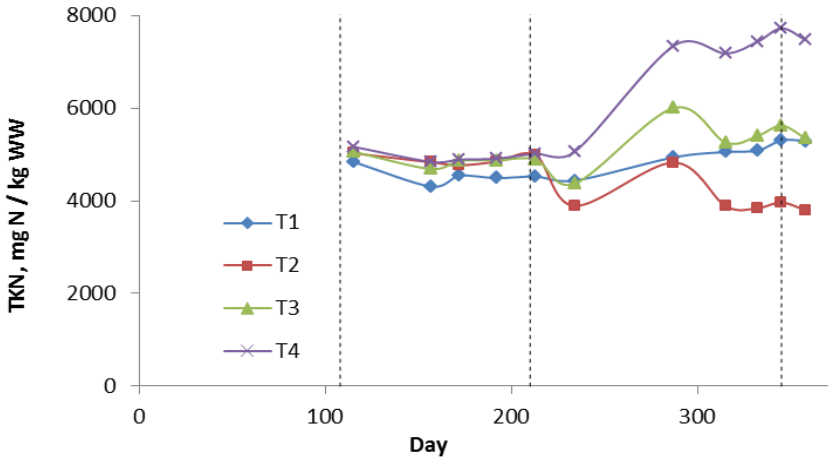
Volatile solids (VS)

VS %TS

Biomass TKN







Conclusions

- Stable digestion could be achieved by side-stream stripping of 12% of the reactor volume per week
- No detriment to overall biogas production
- May have been a small increase in Specific methane yield (but needs to be confirmed)
- Ammonia recovered could be considered as a secondary value-added product

Our thanks to:

TAN and VFA profiles