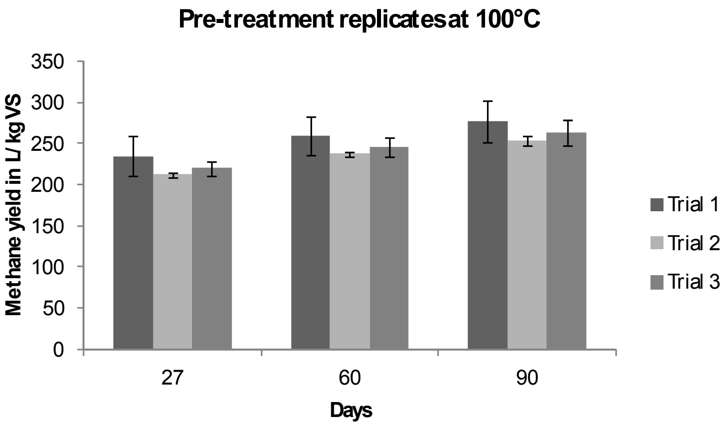
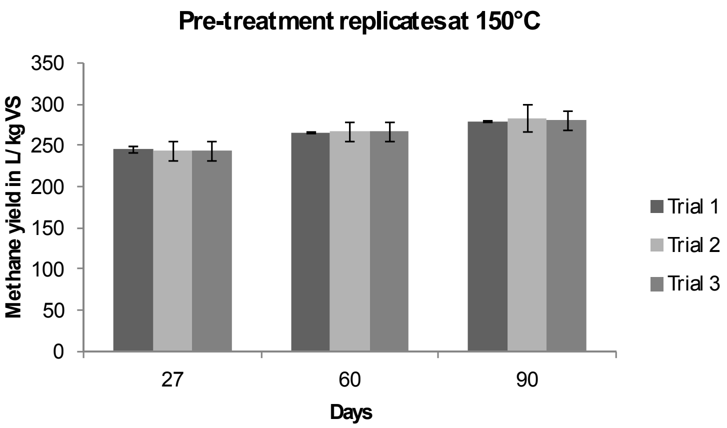
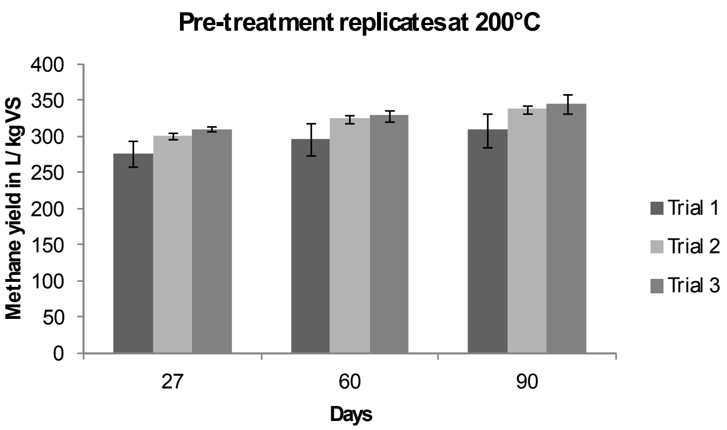
Supplementary material

1. Pre-treatment replicates:







Pre-treatment temperatures ; 100°C, 150°C, 200°C, were selected to test the repeatability of the pre-treatment process itself. Three pre-treatment trials were performed on cattle manure at each temperature. At a = 0.05, there was no significant difference between the three trials at each temperature. The error bars in the figure represent the standard deviations.

2. **Energy input required for the pre-treatments (column II in Table 3)**

Required energy input:

Basis of the calculation is 1 tonne of manure

The energy required; Q is calculated using the equation

$Q = mC_p \Delta T$

where

m is the mass of the material in kg,

Cp is the specific heat capacity of the material in kj/kgK, and assuming that the Cp does not change with temperature

$\Delta T = T2 - T1$, is the temperature difference (here, it is the difference between the temperature of the incoming manure to the required pre-treatment temperature)

Assuming T1= 10 degree centigrade (average ambient temp, since the manure is assumed to be stored in tanks before being used)

T2 = Pre-treatment temp

m = 1000 kg

The Cp of cattle and pig manure were calculated based on the equation

$Cp = 4.19 - 0.00275(DM)$ [1,2]

Cp in kJ/kg Centigrade is the same as kj/kg K

DM is the dry matter content of the manure

Thus the Cp values are:

Manure	DM (%)	Cp
Cattle	11.6	3.87
Pig	20	3.64

3. **Heat loss calculations (column III in Table 3)**

To pre-treat 1 tonne of manure, the dimensions of the pre-treatment tank could be as follows:

Volume of pre-treatment tank, V = 1.25 m^3 (assumed volume required for 1 tonne + 25% extra space)

For a cylindrical pre-treatment unit if :

the radius of pre-treatment tank =0.5 m and

height = 1.6 m

then, surface area =6.6 m^2

Considering a pre-treatment unit with the aforementioned dimensions and neglecting the heat losses via the fittings on the reactor:

The losses from the pre-treatment unit can be calculated as follows:

The heat transfer coefficient is taken to be, k= 0.20 W/m^2K [3]

Heat loss from the surface of the reactor is given by:

surface area* (temperature inside the reactor - ambient temperature)* k *time of operation

Temperature inside the reactor = Pre-treatment temperature

Assumed average ambient temperature = 10°C

Time of operation = time taken for the material to reach the pre-treatment temperature + 15 minutes of actual pre-treatment time

Assuming time taken for the material to reach the pre-treatment temperature =15 min

Time of operation = 0.5 hour

Taking the pre-treatment temperature of 175°C as example,

The heat losses for pre-treating material at 175°C would be

6.6 *(175-10)*0.20*0.5 = 108.9 Wh = 0.11 kWh

4. **Sample calculations for energy gain obtained from pre-treated manure (column IV in Table 3):**

The values for cattle manure that was pre-treated at 175 is used as an example for the following calculations:

The BMP was calculated based on the amount of volatile solids in the manure

But the amount of energy obtained will be calculated based on the wet material which is more relevant to an actual biogas plant.

After pre-treatment at 175°C the BMP of cattle manure gives on an average 275 L of methane/kg of VS while the untreated manure gives 244 L of methane/kg of VS

The cattle manure had 9.4% VS wet weight basis. In other words, 1 kg of wet material contained 0.094 Kg of VS

Thus 1 kg of pre-treated wet material would give 275*0.094 = 26 L of methane/kg wet material = 26 m^3 of methane/ tonne of wet material

Similarly the untreated cattle manure would give 23 m^3 of methane/tonne of wet material

1 m^3 of methane = 36 MJ of energy

and 1 MJ = 3.6 kWh

The extra energy obtained from the pre-treated material when compared to the untreated will be:

26*36 – 23*36 = 108 MJ

108MJ = 108/3.6 = 30 kWh of energy/tonne of wet material

5. **Energy requirement for dewatering the pig manure**

2.9 kWh of energy was required to de-water 1 tonne of fresh pig manure from an initial dry matter (DM) content of 5.7% to solids with 30% DM [4]

Thus 1000 kg of wet manure after separation gives 300 kg of solids

Thus to get 1000kg of solids, we should separate 3333 kg of wet material that is approximately 3.3 tonnes of wet material

To separate 1 tonne of material 2.9 kWh of energy is required

Thus 3.3 tonnes will require 2.9 * 3.3 = 9.57 kWh energy, which will produce 1 tonne of material at 30% DM

6. **Net energy gain (column V in Table 3) without including the energy required to raise the temperature of the material to the pre-treatment temperature.**

For cattle manure:

Net energy = Energy gain – heat losses from the pre-treatment unit

For Pig manure:

Net energy = Energy gain – heat losses from the pre-treatment unit – energy for dewatering

Reference List

[1] Y.R. Chen, *Thermal properties of beef cattle manure*, Agricultural Wastes, 6 (1983), pp. 13-29.

[2] Y.R. Chen, *Kinetic analysis of anaerobic digestion of pig manure and its design implications*, Agricultural Wastes, 8 (1983), pp. 65-81.

[3] H.B. Møller, A.M. Nielsen, M. Murto, K. Christensson, J. Rintala, M. Svensson, M. Seppälä, T. Paavola, I. Angelidaki, and P.L. Kaparaju, *Manure and energy crops for biogas production - Status and barriers*. 2008. Nordic Council of Ministers.

[4] H.B. Møller, I. Lund, and S.G. Sommer, *Solid-liquid separation of livestock slurry: efficiency and cost*, Bioresour. Technol., 74 (2000), pp. 223-229.