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Two-phase Continuous Digestion of Solid Manure on the Farm

The presented two phase biogas plant digests manure of 65 LU dairy cattle and organic residues from the farm and the surrounding food processing units containing 18.6 ± 1% dry matter. A new technology for continuously filling and discharging the biogas reactor is described. Between November 2003 and May 2004 the biogas plant produced in average 52 m^3 biogas d^{-1}. The maximum yield reached 91 m^3 biogas d^{-1} or 170 l methane kg^{-1} VS. On the average 76.3 % of the methane gas produced was used for process heating. The ultimate energy surplus for heating the farmhouse was 305.5 kWh d^{-1} or 56.2 % of the total energy produced.

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Keywords

Solid manure, biogas, anaerobic digestion

The present commercially available biogas plants digest almost only slurry and co-substrates. Cattle, horse and poultry farms using a solid manure chain are excluded from the prevailing biogas technology. In spite of new research results [1] on-farm dry fermentation biogas plants are not common. The reason for this may be lack of reliable technical solutions, a high work load during filling and discharging and missing technical documentation of on-farm plants. This paper presents a two phase prototype plant of a Demeter-farm developed for continuous digestion of solid manure and organic residues. Based on data recorded between November 2003 and October 2004 we calculated the mass and energy balance of the plant.

Methods

Figure 1 shows the simplified flow chart of the biogas plant. Faeces, straw and oat husks from a dairy stanchion barn of 65 adult bovine units are pushed by a hydraulic powered scraper into the feeder channel of the hydrolysis reactor. From the feeder channel the manure is pressed by another hydraulic powered scraper (180 bars, 2700 mm stroke) via a 400 mm wide PVC pipe to the top of the 30° inclined hydrolysis reactor of 53 m^3 capacity. The bottom of the hydrolysis reactor is provided on both sides of the feeder pipe with hot water channels. The fresh material mixes itself with the substrate sinking down due to gravity force. After a hydraulic retention time of 22 to 25 days at 38°C, the digested substrate is discharged from a bottomless drawer to the lower part of the reactor.

The drawer is guided within a rectangular channel and powered by a hydraulic cylinder (180 bar, 1000 mm stroke). Every drawer cycle removes about 100 l substrate from the hydrolysis reactor to be discharged into the transport screw underneath (Spirac, Ø 260 mm). From the transport screw one part of the substrate drops into a down crossing extruder screw (Spirac, Ø 200 mm), where it is separated into solid and liquid fractions. The other part is conveyed back to the feeder channel and inoculated into the fresh manure. The solid fraction from the extruder screw is stored at the dung yard for composting. The liquid fraction is collected in a 2 m^3 buffer and from there pumped into the methane reactor. Liquid from the buffer and from the methane reactor partly returns into the feeder pipe to improve the flow ability. The methane reactor is 4 m high and filled with about 10,000 filter elements. The effective capacity is 17.6 m^3. After a hydraulic retention time of 15 to 16 days at 38°C the effluent is pumped into a slurry store, covered by a floating canvas. A screw pump controlled by four pressurized air-driven valves, circulates all liquids. The gas generated by both reactors is dried and stored in a sack. A compressor ensures gas supply of 170 mbar pressure to the process heater and the furnace of the farm house for heating purposes.

The urine is separated in the barn via a perforated scraper floor and pumped into a separate store covered by a floating canvas.

The biogas plant is automatically governed by a PLC (Mitsubishi FX 2N 48 MR).

Both reactors are made of CORTEN-steel cylinders of 10 mm wall thickness and 2.85 m inner diameter formerly used as smokestack. They are coated by 20 cm cellulose insulation and covered with corrugated sheet.

We took samples of the input manure from the feeder channel 1, from the solid fraction 6, and from the effluent 11. The gas yield of each reactor was measured by a gas clock (Actaris G6 RF1) and the reading was daily recorded. CO_2-content of the biogas was measured once by falling out soda in soda lye. In autumn 2004 another gas clock (Krom-Schröder BK-G4T) was installed to record gas consumption of the process heater. Further electric power consumption of the whole plant was measured.

Vapour content of the biogas was assumed to be 3 vol % [2].

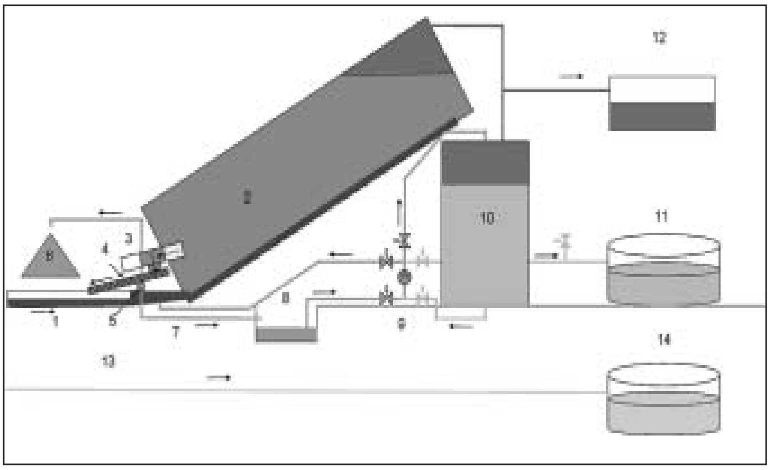

Fig. 1: Material flow of the biogas plant at the Yttereneby farm in Järna, Sweden. 1 feeder; 2 hydrolysis reactor; 3 drawer; 4 transport screw; 5 extruder screw; 6 solid fraction; 7 drain pipe for liquid fraction; 8 buffer store; 9 screw pump and valves; 10 methane reactor; 11 effluent store; 12 gas sack; 13 urine drain pipe; 14 urine store

Gas yield

The plant produced first time biogas on 15. 11. 2003. The biogas yield from start to begin of pasture season is shown in *Figure 2*. In the beginning of January a frozen gas pipe and in April a corroded gas pipe biased the records. In average we measured 52 m^3 biogas d^{-1} or 31 m^3 methane d^{-1}. On 29. 3. 2004 the plant reached a maximum of 91.5 m^3 biogas d^{-1}.

Mass balance

Daily input was 2 to 2.5 Mg manure. After anaerobic digestion, 0.9 to 1.5 Mg of the solid fraction for compost and about 1 Mg effluent remained. 52 to 70% of the VS-input came from straw and oat husks. 15% of the VS input was degraded to biogas, 71 to 75% of the VS input are fixed in the solid fraction digested output of the hydrolysis reactor.

Energy balance

The mean energy production was about 300 kWh d^{-1}. During the measuring period the mean daily air temperature was 0.4°C. Heat losses by heat transfer of the reactors as well as heat energy required for heating the daily input mass were calculated. From the difference between gas consumption and heat demand of the biogas plant we calculated a thermal efficiency of 80.6% for the process heater. The overall heat energy demand was 206 kWh d^{-1}. Additionally the plant consumed 32 kWh d^{-1} resulting in an overall energy efficiency of about 24% in terms of the produced energy.

Conclusions

The new technical design of the prototype biogas plant in Järna allows continuous automatic digestion of solid manure and organic residues. However, the measured biogas yield does not reach the level of the potential biogas yield reported in recent research papers [3, 4, 5]. The optimisation of the plant in terms of hydraulic retention time and load rate may lead to higher gas generation. This requires an improved material flow management and improved measuring technique. The two phase plant offers on one side a high methane production level, on the other side the double heating of the substrate requires more process energy compared to one phase plants. After process optimisation an economic evaluation is necessary to assess the competitiveness of the new technology.

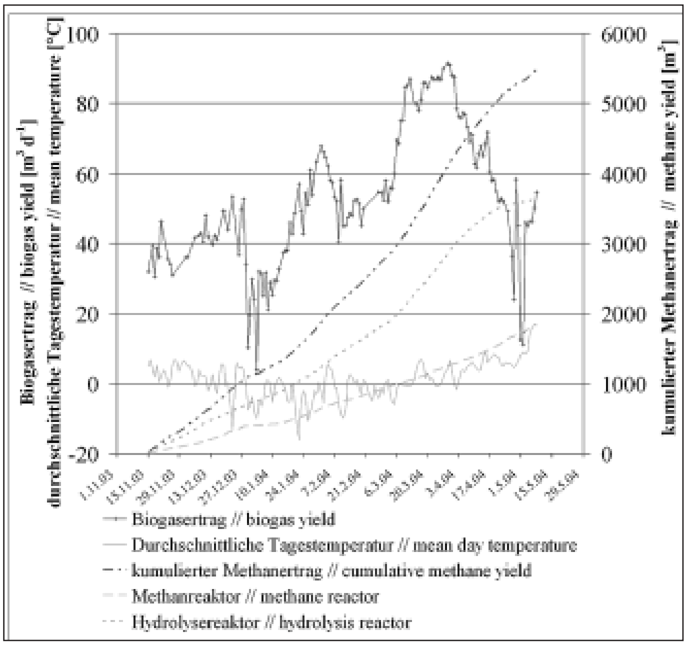

Fig 2: Biogas yield, cumulative methane yield, and daily mean temperature between 15.11.2003 and 8.5.2004

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