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NEW SYSTEMS FOR THE DIGESTION OF SOLID WASTES

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ABSTRACT

Two new systems for the digestion of solid wastes at thermophilic temperatures were developped and are currently being investigated at our research institute.

The first system (ANCOM) was designed to process straw-rich cattle manure with a natural dry matter content of 18% to 22%. First results demonstrated a good specific gas production of 1.2 m^3 biogas per m^3 digester volume and day (54% methane) corresponding to a gas yield of 400 l per kg VS.

A second digester system was developed to treat fruit, garden and vegetable (FGV-) waste. Because FGV-waste tends to float, a stirred tank reactor was designed in cooperation with an engineering firm. The reactor includes a distinguished new stirring system taking up strong shear forces and a hydraulic feeding system which guarantees that even during recirculation of the material, the hygenized digested substrate leaving the digester is not brought in contact with the fresh incoming material. First results measured at an HRT of 40 days demonstrated a specific gas production of 2.7 m^3 per m^3 fermenter and day.

KEYWORDS

Anaerobic digestion; solid waste; cattle manure; municipal solid waste; pilot plant.

INTRODUCTION

The tremendous increase of municipal wastes in the form of sewage and trash as well as animal wastes has raised serious logistical and environmental problems in recent years. The steady land spreading of liquid manure with its high loads of nitrogen resulted in an accumulation of nitrate in the ground water. In addition soils were poisoned by heavy metals deriving from sewage sludge of industrialized areas. Another problem is created by the increase of municipal solid waste. The space for new landfill sites becomes scarce and incineration plants with their problematic flue gases are contested by environmental pressure groups. In consequence, new strategies were developed to recycle part of the material, preferentially in its solid state, in order to reduce the volume. Possible steps within new procedures of solid waste treatment include the anaerobic treatment of organic fractions.

The physical and chemical composition of the organic fraction of source-separated waste differs considerably from solid animal manure. Two different fermenter systems were therefore developed for the anaerobic treatment of the respective substrates. However, both have in common that they are operated in a continuous mode which is less labour intensive than a batch system.

THE ANCOM SYSTEM FOR THE DIGESTION OF FARM MANURE

Currently over 500 biogas plants are in operation on agricultural farms in Europe (Pauss et al., 1991; Wellinger, 1988). All except a few are operated with liquid manure despite the fact that more than 80% of the farms are producing solid waste. This might be explained in part by the fact that the batch technique utilized to treat the solid wastes, which was originally introduced by Isman and Ducellier in the late forties, was not further developed after the seventies (Theoleyre,1986). Their practical application is limited due to the relatively high costs of batch systems as well as their intensive labour for filling and emptying.

We have set the goal to develop a continuous-flow digester called ANCOM (ANaerobic COmposting of Manure) which should fulfil the following premises. First, the digester should handle the manure without pretreatment,i.e. the straw should not be chopped either before or after bedding. Second, the consistency of the digested manure should still allow its field application by a conventional manure spreader, i.e. the total solids should be around 15% or higher.

Laboratory Experiments

Influence of dry matter content. In preliminary laboratory experiments at 30°C the optimal dry matter content with respect to gas formation was determined. The manure utilized was collected manually in a milk cow barn. It contained mainly feces and only small amounts of urine as well as full-length wheat straw from bedding (3 to 4 kg per animal and day), previously stored in bales. The manure of 18% to 22% total solids (TS) was filled into 30 plastic vessels and the desired TS adjusted by addition of water.

The experiments demonstrated that the gas yield increased with increasing quantities of free liquids. Best results were achieved with TS-values equivalent to 13% or lower (Table 1). With increasing TS an increasing inhibition was expressed, a result which confirms earlier findings (Jewell et al.,1981; Schulte & Luis,1983). The ultimate gas yield of all solids concentrations tested,however, was equally high at approximately 500 l per kg volatile solids (VS).

Comparable gas yields were achieved in experiments where the liquid phase (20% w/w of the manure), which was separated in the digester from the manure by a perforated plate, was recycled periodically (15 minutes every two hours) in a closed circuit to moisten the manure (Hall et al.,1985). The idea of the setup was to recycle the liquid of a full-size plant through an external heat exchanger in order to moisten and heat up the digester contents at the same time. The heat transfer through solid substrates is relatively poor (Rathbun and Shuler,1983). However, the scale-up of the system led to unsolvable problems of floating, bridge formation, etc., so it had to be abandoned.

TABLE 1 Gas Yield of Wheat Straw containing Cow Manure in Batch Experiments (30 L Digester)

Total Solids	Gas Yield [Liter/kg VS] After 30 days	After 50 Days
9.7%	295	371
11.5%	273	358
13.0%	279	380
16.0%	222	329
21.3%	100	160

Influence of density of the manure. Since increasing TS effected a reduction of the gas yield, at least during the first 50 days of batch digestion at dry matter contents of more than 13%, it might be anticipated that the densitiy of the manure could play a role as well. The density of manure with unchopped straw is primarily defined by the manure removal system. Average values range from 500 kg per m^3 for hand removed waste, over 900 kg/m^3 for waste removed by pushing bars with flaps to 950 kg/m^3 for open housing with deep straw bedding and 1000 kg/m^3 for mole dung systems.

A batch experiment demonstrated, however, that the influence of the removal systems is negligible (Fig.1). The gas yields are rather consistent except from the waste of the two deep straw beds where the larger amount of straw added (5 to 6 kg/animal*d vs. 3 to 4 kg/animal*d) reduces the amount of gas produced.

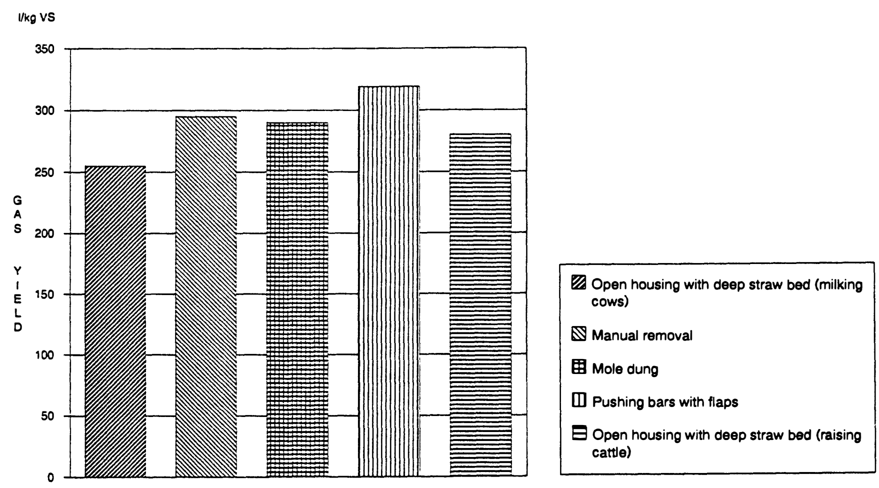

Fig.1. Gas yields after 30 days of manures removed from the barns by different systems. TS 10 - 12%.

Pilot Plant Experiments

Since continuous-flow experiments with solid wastes are difficult to accomplish in bench-scale reactors of 30 litres, a pilot plant unit of rectangular form was constructed with a total volume of 10 m^3 and a net volume of 6 m^3. The system is operated at 50°C with fattening cattle manure from an experimental farm with deep straw bedding on a sloped floor.

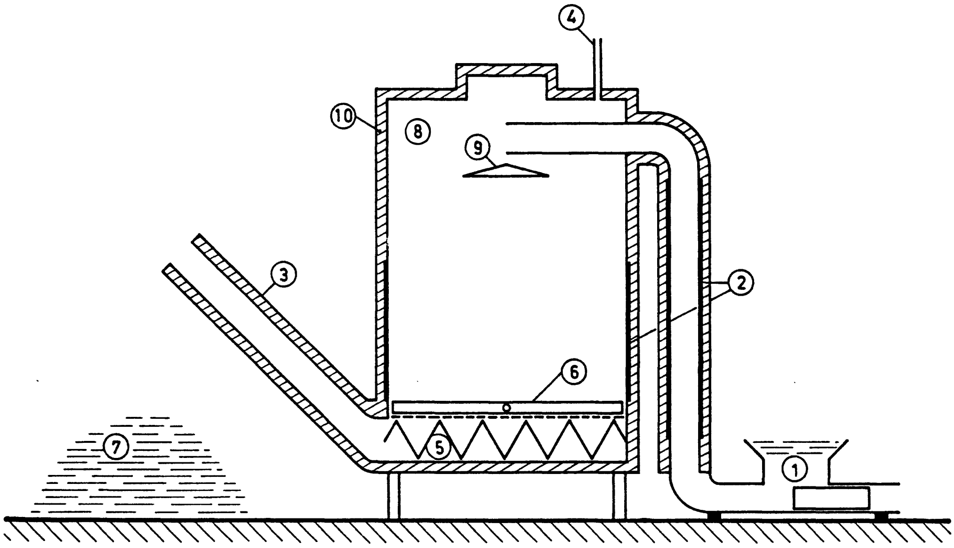

Fig. 2. Scheme of the ANCOM pilot plant
Explanation of the numbers see text

The manure is removed from the barn manually and after weighing is shovelled into the so called mole dung system (Fig.2 (1)). It pushes the manure with a piston to the top of the fermenter, passing through an external heat exchanger (2). Depending on the daily load, the mean residence time in the heat exchanger varies from 9.5 hours to 17 hours. A cone assures an equal distribution of the manure in the digester (9). To balance the heat losses during digestion, the fermenter is equipped with a second heat exchanger around the lower half of the digester walls (2). A 12 cm thick layer of mineral wool reduces the heat losses (10). The digested manure is removed at the bottom by a combination of scraping floor and a screw (5,6). The entire equipment is driven by a single hydraulic system.

The digester was first started more than three years ago. After various improvements of the mechanical components, the system demonstrates now a good mechanical and biological performance. Some of the first results are compiled in Table 2.

Table 2. Performance of the ANCOM digester

Net capacity	6000 kg
Daily feed	170 kg
Calculated HRT	35 d
Measured HRT	26 d
Daily gas production	8.0 m^3/d
Gas yield	344 l/kg VS
Specif. gas production	1.33 m^3/m^3*d

DIGESTION OF MUNICIPAL SOLID WASTES

Treatment of Raw Wastes

During traditional land filling, biogas is produced at high dry matter contents. However, degradation is a slow process lasting some 15 to 20 years. Controlled anaerobic digestion of refuse can significantly speed up the degradation process to treatment periods of less than 30 days.

A first full-scale plant was operated in the late seventies in Pompano Beach, Florida, treating diluted waste (3% to 5% TS). However, the plant could never be operated correctly due to problems of upstream waste separation as well as mixing problems and scum formation (Walter, 1982).

An improved system, where undiluted waste was digested in two phases, was first introduced by Ghosh (1984). In the first phase the substrate is degraded mainly to short-chain fatty acids (acidification), whereas in the second phase the biogas is formed (methanogenesis). Another leachbed reactor combined with an upflow anaerobic sludge blanket (UASB) digester was introduced by Van Rijkens (1981). The system is actually marketed by a company (AN) from Bremen. The struggle of the system is the often incomplete leaching procedure. As a result, the waste is only partially stabilized and requires a secondary aerobic treatment by windrow composting. A somewhat similar system was recently introduced by a company from Munich (BTA). However, the solid material is almost completely solubilized. The highly loaded liquid is then treated in a hybrid reactor before it is recycled.

Recent improvements in dry anaerobic digestion were brought by the procedures of DRANCO (De Wilde, Six, und De Baer, 1989) and VALORGA (Cayrol, 1989). Both procedures treat the organic fraction of separated raw refuse. Only little water has to be added. The digesters are operated at 50° to 55°C with dry matter contents of the substrate of 30 to 35%.

Source Separated Wastes

The techniques for municipal solid waste collection are actually changing, at least in European countries. Source separation starts to become the standard technique yielding among others the so called fruit, garden and vegetable (FGV) waste. Typical total solid values of FGV-wastes vary from 18 to 30%. During digestion, considerable amounts of water are liberated. Hence, FGV-wastes tend to float. Downflow systems such as ANCOM or DRANCO, where the material is removed at the bottom, are therefore not well suited for this type of material except if it is concentrated before digestion. A new system specifically designed for the digestion of FGV-wastes was therefore developed.

The KOMPOGAS Procedure

Preliminary lab-experiments. A series of lab experiments in 30 litre batch digesters was set up to optimize the start-up and to determine gas yield at 30°C of a material deriving from a composting experiment of the city of Zürich, where the source-separated organic fraction of waste from a quarter with 17,000 inhabitants was collected in green plastic bags (green bag experiment). The waste was chopped with a snail mill and fractioned by a drum sieve with 6 cm pore size before fermentation.

Among others, the start-up procedure of ten Brummeler (1988) was followed with addition of compost and sodium bicarbonate. Best results however, were achieved with a 50% mixture (w/w) of fresh FGV-waste and cow manure (8% TS) from a psychrophilically operated biogas digester (Sutter and Wellinger, 1987). Successful starting was also possible with a half/half mixture of FGV-waste and solid manure from the ANCOM pilot plant. At lower inocula (30%) some souring occurred which had to be corrected by addition of sodium bicarbonate.

The gas yield was measured at two instances from material collected in Fall 89 and Spring 90. The former contained visually more garden refuse rich in branches and leaves. As a result the gas yield of the spring material was far better (Table 3).

TABLE 3 Batch Digestion of FGV-Waste in 30l Vats at 30°C

		Sept. 1989	May 1990
Fresh Substrate	TS	28%	28%
	VS	65%	75%
Digested Substrate	TS	22%	19%
	VS	58%	
Degradation	TS	20%	33%
	VS	29%	
Gas Yield		297 l/kgVS	380 l/kg VS
		54 m^3/t waste	80 m^3/t waste

Gas yield defined 60 days after inoculation with 50% cow manure from a low temperature biogas plant

Pilot plant experiments. A horizontally positioned digester of cylindrical form with a net volume of 15 m^3 was designed in cooperation with an engineering firm (Schmid/AFAG). The CSTR is equipped with a hydrauli-

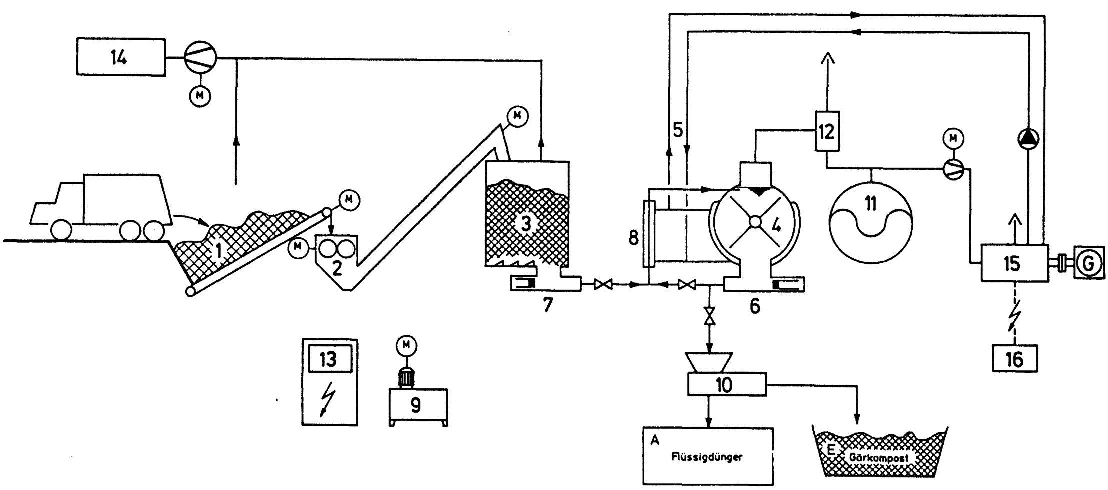

Fig. 3. Flow sheet of the KOMPOGAS system
Explanation of the numbers see text

cally driven stirrer which takes up strong shear forces. Also, the system includes a shredder to reduce the size of the material to less than 5 cm (Fig.3 (2)). From a holding tank (3) the fresh material is fed to the digester (4) through an external heat exchanger (8) with a combined scraping floor/piston (7) similar to the one used in the ANCOM digester. The digested material is removed by a second piston (6) into a screw filter press (10) where it is separated into humus-like substrate of about 45 to 50% TS and a liquid fertilizer of about 20 to 24% TS. A part of the digested material is recycled as inoculum. The produced biogas drives a cogenerator (15). The electricity is introduced into the grid. The hot water is utilized to heat the digester which is operated at approx. 55°C. During a first run the digester was operated at a HRT of 40 days. The start-up substrate was a mixture of 3.2 tonnes of fresh FGV (1.3 t TS), 5.1 t of compost (2.3 t TS) and 4 t of sewage sludge (160 kg TS). The pH was kept beyond 7.2 by additions of $Ca(OH)_2$ (totally 70 kg). The feeding of fresh waste was started after about one week when the CO_2 concentration dropped below 50%.

TABLE 4 Performance of the KOMPOGAS Pilot Plant at 40d HRT

Fresh Waste	TS	42%
	VS	76%
Digested Waste	TS	27%
	VS	40%
	VFA	350 ppm Acetic
		48 ppm Propionic
		37 ppm Butyric
Gas Production		40 m^3/d
Specific Gas Production		2.7 m^3/m^3*d
Gas Yield		370 Litre/kg VS
Methane Content		63%

The gas production showed considerable variation which was in part due to the changing composition of the fresh waste which was collected once a week. The major reason however, was the poor temperature control during this first phase. Overall the process demonstrated an excellent performance (Table 4). Actually the HRT was reduced to 20 days.

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