Scientific Papers Series Management , Economic Engineering in Agriculture and Rural Development
Vol. 14, Issue 1, 2014
PRINT ISSN 2284-7995, E-ISSN 2285-3952

CONSIDERATIONS OVER A BIOGAS PLANT COMPONENTS

Mariana DUMITRU

Lucian Blaga University of Sibiu, 10 Victoriei Boulevard, 550024, Sibiu, Romania, Phone/Fax: +40-(269) 21.60.62, Email: mariana_dumitru2001@yahoo.com

Corresponding author: mariana_dumitru2001@yahoo.com

Abstract

This paper starts from the conviction that one of the main environmental problems of today's society is the continuously increasing production of organic wastes. In many countries, sustainable waste management have become major political priorities in order to reduce pollution and greenhouse gas emissions and to avoid, as much as possible, global climate changes. This problem becomes more and more present in our country too. Production of biogas through anaerobic digestion of animal manure and slurries as well as of a wide range of digestible organic wastes, converts these substrates into renewable energy and offers a natural fertiliser for agriculture. That is why we consider that biogas plants will be more and more used in the future. In this paper we show the different stages which must be operated in a biogas plant and the problems which can be met in each of them.

Key words**:** *biogas plant, digestate, feedstock, fertiliser*

INTRODUCTION

In the recent years, our country begins to use more and more the biogas plants, due the advantages which these plants provides.

A biogas plant is a complex installation, consisting of a variety of elements. The layout of such a plant depends to a large extent on the types and amounts of feedstock supplied. As there are many different feedstock types suitable for digestion in biogas plants, there are, correspondingly, various techniques for treating these feedstock types and different digester constructions and systems of operation. Furthermore, depending on the type, size and operational conditions of each biogas plant, various technologies for conditioning, storage and utilisation of biogas are possible to implement. As for storage and utilisation of digestate, this is primarily oriented towards its utilisation as fertiliser and the necessary environmental protection measures related to it.

MATERIALS AND METHODS

The main process steps in a biogas plant are presented in Figure 1. The differentiation in wet and dry anaerobe digestion is only theoretical, since microbiological processes always take place in fluid media. The limit between wet and dry digestion is determined by the "pumpability" of the feedstock. Direct supply of relatively dry feedstock into the digester increases the DM content of the feedstock mixture.

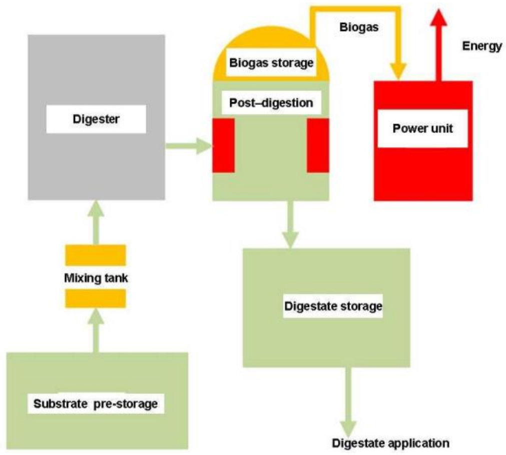

Fig. 1. Main components and general process flow of biogas production (PRAßL 2008)

Agricultural biogas plants operate with four different process stages:

1.Transport, delivery, storage and pre-treatment of feedstock

2. Biogas production
3. Storage of digestate, eventual conditioning and utilisation
4. Storage of biogas, conditioning and utilisation

The process stages shown in Figure 2 are showing a simplified representation of a typical agricultural co-digestion plant.

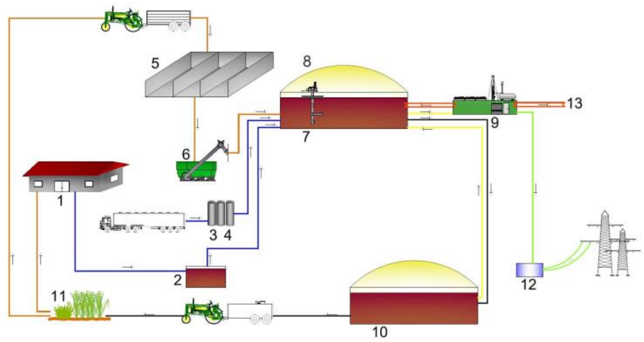

Fig. 2. Agricultural co-digestion biogas plant using manure and maize silage (LORENZ, 2008)

1 Stalls
2 Liquid manure tanks
3 Collection bins for biowaste (co-substrate)
4 Sanitation tank
5 Drive-in storage tanks
6 Solid feedstock feed-in system
7 Digester (Biogas reactor)
8 Biogas storage tank
9 CHP plant
10 Digestate storage
11 Agricultural fields
12 Transformer/ Power to greed

1.The first process stage (storage, conditioning, transport and insertion of feedstock) includes the storage tank for manure (2), the collection bins (3), the sanitation tank (4), the drive-in storage tanks (5) and the solid feedstock feeding system (6).

2.The second process stage includes the biogas production in the biogas reactor (7), also referred to as the digester.

3.The third process stage is represented by the storage tank for digestate (10) and the utilisation of digestate as fertiliser on the fields (11).

4.The fourth process stage (biogas storage, conditioning and utilisation) consists of the gas storage tank (8) and the CHP- unit (9).

These four process stages are closely linked to each other.

When building a biogas plant, the choice of type and the design of the plant are mainly determined by the amount and type of available feedstock. The amount of feedstock determines the dimensioning of the digester size, storage capacities and CHP unit. The feedstock types and quality determines the process technology.

Depending on the composition of the feedstock, it may be necessary to separate problematic materials, to mash the feedstock or even to add water, in order to convert it into a pumpable mixture. If the supplied feedstock is prone to contamination it is necessary to include a pre-sanitation step in the overall design of the future plant.

In the case of wet digestion, single-stage anaerobe digestion (AD) plants, operating with flow-through process are usually used. In the two-stage process, apre-digester is placed before the main digester.The pre-digester creates the optimal conditions for the first two process steps of the AD process (hydrolysis and acid formation). After pre-digester, the feedstock enters the main digester, where the subsequent AD steps take place.

The digested substrate (digestate) is pumped out of the digester and stored in storage tanks.

These storage tanks should be provided with covers of gas proof membranes, to facilitate collection of the biogas production which can take place inside these tanks, at ambient temperature (post-digestion). Alternatively, digestate can be stored in open digestate containers, with natural or artificial floating layer, aimed to minimise surface emissions.

The produced biogas is stored, conditioned and used for energy generation.

Feedstock receiving unit

Transport and supply of feedstock plays an important role in the operation of a biogas plant. It is thus important to ensure a stable and continuous supply of feedstock, of suitable quality and quantities. If the biogas plant operator is at the same time the feedstock producer, then the high quality feedstock supply can be easily guaranteed. In many cases, the biogas plants receive additional feedstock (co-substrates), produced by neighbouring farms, industries or households. In these cases, management of feedstock quality is necessary, in order to check, account and verify the supplied material. In a first step, it is absolutely necessary to make visual control of each feedstock load. Then, the delivery weight and all feedstock data (supplier, date, quantity, type of feedstock, processes of origin and quality) should be recorded. Particular attention is needed for feedstock types classified as wastes, for which it may be necessary to fulfil regulatory obligations (depending on the waste category), as well as legal and administrative conditions.

Feedstock storage and conditioning

Feedstock storage serves primarily to compensate the seasonal fluctuations of feedstock supply. It also facilitates mixing different co-substrates for continuous feeding of the digester.

The type of storage facilities depends on the feedstock used. Storage facilities can be mainly classified into bunker silos for solid feedstock (e.g. maize silage) and storage tanks for liquid feedstock (e.g. liquid manure and slurries). Usually, bunker silos have the capacity to store feedstock more than one year and storage tanks for manure have the capacity to store feedstock several days. In some cases, also vertical cylinder silos can be used as well. The dimensioning of the storage facilities is determined by the quantities to be stored, delivery intervals and the daily amounts fed into the digester.

Bunker silos for energy crops

Bunker silos were originally developed to store silage as animal fodder and thus to balance its seasonal availability. Nowadays this type of storage is frequently used for storing the energy crops used as feedstock for biogas production.

Silage must be made from plant material with suitable moisture content (55-70%, depending on the means of storage, degree of compression and water content that will be lost during storage).

In the case of bunker silos, it must always be considered that the fermentation process of the silage releases liquids which can contaminate water courses, unless precautions are taken.

The high nutrient content can lead to eutrophication of surface waters (growth of algaeblooms). Silo effluent contains nitric acid (HNO), which is a corrosive compound.

Storage tanks for pumpable feedstock

Pumpable feedstock is generally stored in sealed, water-tight and reinforced concrete tanks in or above the ground. These tanks, similar to the ones used in agriculture, for storage of liquid manure, usually have a storage capacity sufficient for one to two days. To prevent emissions,all storage tanks should be covered. The chosen solution for cover must ensure easy opening and removal of settled sediments. If storage tanks are placed on a higher level compared to the digester (sloping topography), the hydraulic incline eliminates the need for transport equipment (pumps) and saves energy.

Storage tanks for pumpable feedstock require limited maintenance, this including removal of sediment layers of sand and stones, which reduce the storage capacity of the tanks. Sediments are removed using scrape floors, conveyor screws, sump pumps, collection tanks or countersink aggregates.

Feedstock types of industrial origin can require sanitation measures and must therefore always be handled and stored strictly separated from the delivery station for agricultural feedstock, in order to prevent mixing critical feedstock with non-critical feedstock, before processing in the sanitation equipment.

Feeding system

After storage and pre-treatment, AD feedstock is fed into the digester. The feeding technique depends on the feedstock type and its pumpability. Pumpable feedstock is transferred from storage tanks to the digester by pumps. The pumpable feedstock category includes animal slurries and a large number of liquid organic wastes (e.g. flotation sludge, dairy wastes, fish oil). Feedstock types which are non-pumpable (fibrous materials, grass, maize silage, manure with high straw content) can be tipped/ poured by a loader into the feeding system and then fed into the digester (e.g. by a screw pipe system). Both feedstock types (pumpable and non-pumpable) can be simultaneously fed into the digester. In this case it is preferable to feed the non-pumpable feedstock through by-passes.

From a microbiological point of view, the ideal situation for a stable AD process is a continuous flow of feedstock through the digester. In practice, the feedstock is added quasi-continuously to the digester, in several batches during the day. This saves energy as feeding aggregates are not in continuous operation. There are various feeding systems and their selection depends again on feedstock quality, herewith their pumpability and on feeding intervals.

RESULTS AND DISCUSSIONS

Special attention must be paid to the temperature of the feedstock which is fed into the digester. Large differences between the temperature of the new feedstock and the operation temperature of the digester can occur if the feedstock has been sanitised (up to 130°C) or during winter season (below 0°C). Temperature differences disturb the process microbiology, causing losses of gas yield and must therefore be avoided. There are several technical solutions to this problem, such as using heat pumps or heat exchangers to pre-heat /cool the feedstock before insertion in the digester.

Table 1. Nutrient distribution in digestate, compared to cattle and pig slurry

	Dry matter %	**Total N Kg /ton**	**NH_4 - N kg/ ton**	**P Kg /ton**	**K kg/ ton**	**pH**
Cattle slurry	6,0	5,0	2,8	0,8	3,5	6,5
Pig slurry	4,0	5,0	3,8	1,0	2,0	7,0
Digested slurry	2,8	5,0	4,0	0,9	2,8	7,5

Source: [1]

In Table 1 it is shown the superiority of using digested slurry over other organic slurry, concerning the content of n, P and K. One of the noticeable positive changes which take place through anaerobe digestion of manure is the significant reduction of odoriferous substances (volatile acids, phenol and phenol derivatives).

Experience shows that up to 80% of odours in feedstock substrates can be reduced by anaerobe digestion. It is not only a reduction of the intensity and persistence of odours (Figure 1), but also a positive change in the composition of odours, as digestate no longer has the unpleasant slurry smell, but smells more like ammonia. Even if stored for longer periods of time, digestate shows no increase in emission of odours. Figure 1 shows that, 12 hours after the application of digestate, the odour has almost disappeared.

The anaerobe digestion process is able to inactivate viruses, bacteria and parasites in the treated feedstock substrates, an effect which is usually called sanitation.

The sanitation efficiency of anaerobe digestion depends on the actual retention time of the feedstock inside the digester, the process temperature, the stirring technique and digester type.

The best sanitation is obtained at thermophilic temperatures (50-55°C) in e.g. an elongated plug flow reactor, with the appropriate retention time. In this digester type no mixing of digestate with fresh feedstock occurs, allowing up to 99% of all pathogens to be destroyed.

In order to ensure veterinary safe recycling of digestate as fertiliser, European legislation requires specific sanitation measures in the case of feedstock types of animal origin. Depending on the type of feedstock pre-sanitation by pasteurisation or by pressure sterilisation is required before supplying the substrate to digester. A considerable reduction of germination capacity of weed seeds occurs throughout the AD process. This way, biogas production contributes to ecological weed reduction.

Application of raw slurry as fertiliser can cause burning of plant leaves, which is the effect of low-density fatty acids, such as acetic acid. When fertilising with digestate, plant burns are avoided, as most fatty acids have been broken down by the AD process. Digestate flows more easily off the plants vegetable parts compared to raw slurry, which reduces the time of direct contact between digestate and the aerial parts of the plants, reducing the risk of leaf damage.

Pumps for transport of pumpable feedstock

The transfer of pumpable feedstock substrate from the storage tank into the digester is done by pumps. Two types of pumps are frequently used: the centrifugal and the displacement pumps. Centrifugal (rotating) pumps are often submerged, but they can also be positioned in a dry shaft, next to the digester. For special applications, cutting pumps are available, which are used for materials with long fibres (straw, feed leftovers, grass cuttings). Displacement pumps (turning piston pumps, eccentric screw pumps) are more resistant to pressure than rotating pumps. They are self-sucking, work in two directions and reach relatively high pressures, with a diminished conveying capacity. However through their lower price, rotating pumps are more frequently chosen than displacement pumps.

Centrifugal pumps

A centrifugal pump is a roto-dynamic pump, using a rotating impeller to increase the velocity of a fluid. The fluid enters the pump impeller along or near the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber, from where it exits into the downstream piping system. Centrifugal pumps are commonly used to move liquids through a piping system and are therefore frequently used for handling liquid manure and slurries.

Pressure displacement pumps

For the transport of thick liquid feedstock, with high dry matter content, pressure displacement pumps (which are rotary piston and eccentric screw pumps) are often used. The quantity of transported material depends on the rotation speed, which enables better control of the pump and precise dosing of the pumped feedstock. Displacement pumps are self-sucking and more pressure stable than centrifugal pumps. For this reason, the piping performance is less dependent on difference in height. As pressure displacement pumps are relatively prone to problems caused by high fibre content in pumped materials, it makes sense to equip them with cutters and separators, to protect them from large particle size and fibrous materials.

The function of pumps, and by this the transport of pumpable substrate, is controlled automatically, using process computers and timers. In many cases the entire feedstock transport within the biogas plant is realised by one or two pumps, located in a pumping station, as it is shown in figure 3.

Fig. 3. Pumping systems (AGRINZ 2008)

In figure 4 it is shown that feeding solids to the digester through wash-in shafts or sluices is made by using front or wheel loaders, which allows large quantities of solids to be delivered any time, directly to the digester.

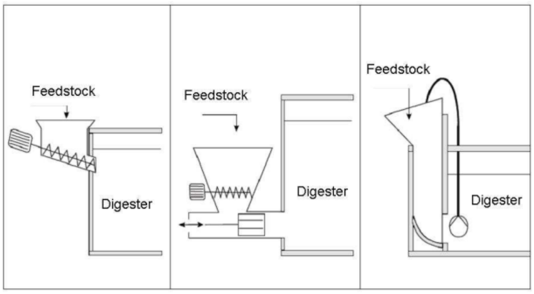

Fig. 4 Wash-in shaft, feed pistons and feed conveyors system for feedstock insertion into the digester (FAL 2006)

Heating system - digester heating

Constant process temperature inside the digester is one of the most important conditions for stable operation and high biogas yield. Temperature fluctuations, including fluctuations determined by season and weather conditions as well as local fluctuations, in different areas of the digester, must be kept as low as possible. Large fluctuations of temperature lead to imbalance of the AD process, and in worst cases to complete process failure.

CONCLUSIONS

Through this paper, we wanted to show that biogas plants represent a viable alternative for energy in agricultural farms, considering our apartenance to EU. That is why we considered usefull to present the necessary steps which must be done in order to make a biogas plant. Thus, the first process stage is storage, conditioning, transport and insertion of feedstock, followed by biogas production in the biogas reactor. The third stage consists of storage of digestate, and, finally,the last stage is the storage of biogas.

The first thing to consider when we want to start a biogas plant is mainly determined by the amount and type of available feedstock. depending on the type, size and operational conditions of each biogas plant, various technologies for conditioning, storage and utilisation of biogas are possible to implement. As for storage and utilisation of digestate, this is primarily oriented towards its utilisation as fertiliser and the necessary environmental protection measures related to it.

Every stage presented in the paper has its particularities and things which must be considered. For example, constant process temperature inside the digester is one of the most important conditions for stable operation and high biogas yield.

It is a fact that a biogas plant is a complex enterprise, but it is worthy, in the conditions of a large agricultural farm.

REFERENCES

[1] Teodorita Al Seadi, Dominik Rutz, Heinz Prassl, Michael Köttner, Tobias Finsterwalder, Silke Volk, Rainer Janssen, 2008, Biogas handbook, University of Southern Denmark Esbjerg, Denmark

[2]Al Seadi,T., 2001, Good practice in quality management of AD residues from biogas production. Report made for the International Energy Agency, Task 24- Energy from Biological Conversion of Organic Waste. Published by IEA Bioenergy and AEA Technology Environment, Oxfordshire, United Kingdom

[3]Meynell, P.J., 1976, Methane, Planning a Digester, Prism Press, Dorset, England

[4]Moller, H. *et al*., 2004, Methane productivity of manure, straw and solid fractions of manure, Biomass & Bioenergy 26, pp 485-495

[5]Persson, M., 2007, Biogas-a renewable fuel for the transport sector for the present and the future, SGC, www.sgc.se

[6]Preißler, D., 2007, Anaerobic digestition of energy crops without manure addition, 35.Symposium "Actual Tasks of Agricultural Engineering", Opatija, Croatia, S. 363-370.

[7]Boukis I., Sioulas, K.,. Chatziathanassiou, A., Kakaniaris, A., Mavrogiorgos, D., 2002, Development of networking and synergies for Anaerobic Digestion energy schemes based on agro-industrial wastes in Southern Europe, The citrus-processing industries case study. "Energy Efficiency and Agricultural Engineering" Proceedings of the Union of Scientists, Rousse-Bulgaria Volume I, 255-263