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

STUDIES CONCERNING THE UTILISATION OF DIGESTATE IN BIOGAS PLANTS

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 aims to expose the many possibilities of using digestate in biogas plants and the advantages of its using. In agricultural animal farms is produced a big quantity of animal manure, which must be adequate managed, mainly as fertiliser. The most advantageous solution of using animal manure and slurry is using it in biogas plants, where, due to degradation of organic matter, digestate is easier to pump and easier to apply as fertiliser, with reduced need of stirring, compared to untreated slurry. The researches made showes that digestate has lower C/N ratio, compared to raw manure. This property means that digestate has a better effect in fertilisation with Nitrogen on short term. The paper also shows the effects of digestate application on soil, compared to compost application of digestate as fertiliser, must be done on the basis of a fertiliser plan. The fertiliser plan with digestate is elaborated for each agricultural farm, according to the type of crop.

Key words: *biogas plant, digestate, fertiliser*

INTRODUCTION

In modern EU agriculture, in which we want to be integrated, biogas production is an integrated element of modern, holistic agriculture, which takes into consideration not only economic costs and benefits of agricultural activities, but also socio-economic and environmental benefits, especially in rural areas. Agricultural biogas production provides agricultural, economic and environmental benefits and for this reason, the promoters of the biogas development in Europe, after the oil crisis, were the organic farmers, interested in anaerobe digestion not only for renewable energy generation, but as a way to improve fertiliser quality of their animal manure.

On the other hand, animal production is known also for producing large amounts of animal manure. There are frequent situations where the animal farms do not own enough agricultural land for using optimally the produced manure and slurries as fertiliser. The excess of animal manure requires adequate manure management measures, in order to prevent serious consequences of excessive fertilisation with animal manure in these areas, such as:

- Pollution of ground and surface water through leakage
- Damage of soil structure and soil microbiology
- Damage of specific grassland vegetation populations and formation of typical "slurry vegetation"
- Increased risks of methane and ammonia emissions
- Odour and fly nuisance, from manure storage and application
- Increased risk of contamination and of spreading pathogens

Anaerobe digestion of animal manure and slurries can be the solution to the above situation, allowing environmental friendly agricultural practices.

MATERIALS AND METHODS

Biodegradation of organic matter

Treatment of animal manure and slurries in biogas plants results in biodegradation of organic matter to inorganic compounds and methane. In practice, the anaerobic degradation rate of organic matter from animal manure and slurries is about 40% for cattle slurry and of 65% for pig slurry. The degradation rate depends at large on feedstock type (Table 1) and process temperature. Due to degradation of organic matter, digestate is easier to pump and easier to apply as fertiliser, with reduced need of stirring, compared to untreated slurry.

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]

One of the important 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.

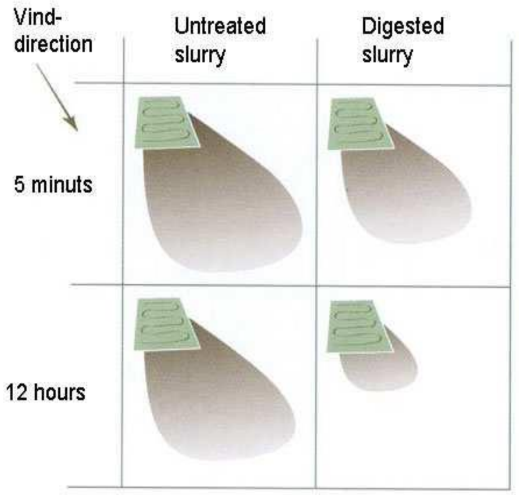

Fig. 1 Area affected and persistence of odour nuisance, after application of digestate and of untreated slurry, on a field with northwest wind (BIRKMOSE 2002)

The best sanitation is obtained at thermophilic temperatures (50-55°C) in 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 anaerobe digestion (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.

RESULTS AND DISCUSSIONS

In this paper we will show the superiority of using digestate over using animal manure or untreated slurry.

Through the anaerobe process, most organically bound nutrients, in particular nitrogen, are mineralised and become easily available to the plants. Figure 2 shows nitrogen utilisation from digested slurry, applied to winter wheat and spring barley, compared to nitrogen utilisation from untreated slurry. Because of the increased availability of nitrogen, digestate can be integrated in the fertilisation plant of the farm, as it is possible to calculate its fertiliser effects in the same way as for mineral fertilisers.

Digestate has lower C/N ratio, compared to raw manure. Lower C/N ratio means that digestate has a better short term N-fertilisation effect. When the value of the C/N ratio is too high, micro-organisms take hold in the soil, as they successfully compete with the plant roots for the available nitrogen.

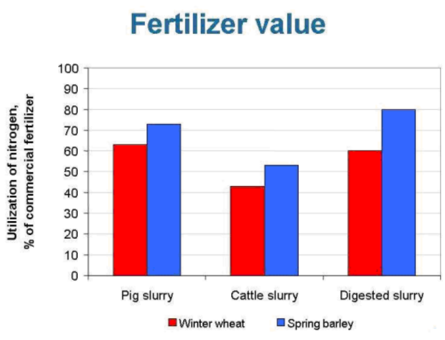

Fig. 2. Application of digestate as fertiliser

Digestate is more homogenous, compared to raw slurry, with an improved N-P balance. It has a declared content of plant nutrients, allowing accurate dosage and integration in fertilisation plans of farms. Digestate contains more inorganic nitrogen, easier accessible to the plants, than untreated slurry. N-efficiency will increase considerably and nutrient losses by leaching and evaporation will be minimised if digestate is used as fertiliser in conformity with good agricultural practice. Due to its higher homogeneity and flow properties, digestate penetrates in soil faster than raw slurry. Nevertheless, application of digestate as fertiliser involves risks of nitrogen losses through ammonia emissions and nitrate leaking. In order to minimise these risks, some simple rules of good agricultural practice must be respected:

- Avoid too much stirring of digestate before application
- Application of cooled digestate, from the post storage tank
- Application with dragging pipes, dragging hoses, direct injection in soil or disk injectors
- Immediate incorporation in soil, if applied on the surface of soil
- Application at the start of the growing season or during vegetative growth
- Application to winter crops should be started with 1/3 of the total N requirement
- Optimum weather conditions for application of digestate are: rainy, high humidity and no wind. Dry, sunny and windy weather reduces the N-efficiency considerably.

Depending on the crop, experience shows that, in Europe, the best time for digestate application is during vigorous vegetative growth. Application as top-fertiliser on crops in full vegetation offers little concern about loss of e.g. nitrogen as nitrate into ground water, since the main part is absorbed immediately by the plants.

Effects of digestate application on soil

Degradation of organic matter, which occurs through AD process, includes degradation of carbon bounds, organic acids as well as odoriferous and caustic substances. For this reason, when applied on soil, digestate creates less stress and more suitable environment for soil organisms, compared to application of raw slurry. Direct measurements of biological oxygen demand of digested cattle and pig slurry showed ten times less oxygen demand than in the case of undigested slurry. As oxygen consumption is reduced, so is the tendency to form anoxic soil areas, such as oxygen free, nitrogen containing zones. The capability to build up new soil and the humus reproduction through supplied organic matter is also higher, when compared to fertilisation with raw slurry. In Figure 3 it is shown an example of vehicle used for digestate application.

Fig. 3. Vehicles for application of digestate as fertiliser, using dragging hoses (AGRINZ 2008)

Compared to compost and to untreated slurry application, digestate supplies larger portions of carbon, available for the reproduction of organic substances in soils. During anaerobe digestion, decomposable organic bounds such as cellulose and fatty acids are broken down. The lignin bounds, valuable for formation of humus, remain. Methane bacteria themselves produce a whole series of amino acids, which are available for plants and other living organisms in the soil. German studies made with digested pig slurry showed an increase in humus production efficiency index from 0,82 to 1,04.

Table 2. Separated fractions by decanter centrifuge (AL SEADI and MOELLER, 2003)

	Amounts %	DM %	N %	NH4-N %	P %	K %
Raw slurry	100	100 (6,4%)	100 (5,7%)	100 (4,2%)	100 (1,6%)	100 (2,6%)
Solid fraction	14	65 (30%)	25 (10,1%)	15 (4,5%)	75 (8,7%)	17 (3,1%)
Liquid fraction	86	35 (2,6%)	75 (4,9%)	65 (4,2%)	25 (0,5%)	83 (2,5%)

Source: [1]

In Table 2 is presented a comparison between the separation fractions of solid fraction, liquid fraction and raw slurry, showing their superiority over raw slurry.

Complete conditioning separates digestate in three refined end products: pure water, concentrated nutrients and organic fibres. All nutrients (nitrogen, phosphorus, and potassium) and organic bounds are separated from the main stream in a low volume, concentrated form.

The remaining purified water can be disposed into the surface water system or used as process water. The complete conditioning is particularly suitable for agricultural areas containing nitrogen in excess.

In both cases (partial or complete conditioning), the first step is the separation of liquid and fibre fractions, which divides the digestate into a concentrated carbon and phosphorus enriched solid fraction and a nitrogen rich, fluid fraction. Depending on the plant configuration and the type of conditioning, the complete conditioning further concentrates or separates the NPK nutrients. The most used processes include membrane separation technologies, sorption or stripping of ammonia and evaporation or biological treatment.

The fibre separation is done by separators or spiral sieves, decanters and occasionally by ribbon-sieve presses (Figure 4). 15-20% of the solids are separated by spiral sieves and more than 60% by decanter centrifuges. Most of nitrogen (up to 90%) is separated with the liquid fraction, while phosphorus is only partially removed, as bonded to the fibre fraction/particles of solid matter.

Fig. 4. Fibers collection wagon with distribution screw (ANGELIDAKI, 2004)

Membrane Separation Technology

A membrane is a filter with very fine pores, which can separate particles and solutes from most of the liquids on a molecular scale. The decision to use micro-, ultra-, or nano-filtration or soluble reverse osmosis depends on the size of the particles to be separated. The process is based on the difference of pressure between the two sides of the membrane, i.e. water, as well as minute particles, passing the membrane under pressure. Several conditioning steps are often connected, in successive series, in order to achieve the desired separation. For example, larger particles are removed from a decanter filtrate, through a first step of ultra-filtration and then the solubles are removed in a second step by reverse osmosis. Besides purified water, the membrane separation produces a nutrient rich concentrate, which can be sold either directly as liquid fertiliser, or further processed for volume reduction through evaporation.

Through evaporation, the liquid is further refined and separated into nutrients and purified water. Evaporation units require high energy consumption.

Conditioning technologies (especially the complete conditioning) require high energy consumption in order to create the pressure used in membrane technologies, or for the production of heat, used in evaporation processes. Up to 50% of the biogas produced electricity is necessary for the complete conditioning of the produced digestate, using membrane technology. Partial conditioning is less energy demanding, cheaper and, in regions where there is a surplus of phosphorus, it is the most economical conditioning technology.

In all the cases, the conditioning technology is chosen according to the chemical and physical characteristics of digestate, herewith the tendency of the digestate to layer formation. If complete conditioning is aimed, it is important that most of the digestible dry matter is removed through complete separation of liquid and fibres, followed by ultra filtration (< 0,2 mm), so that the remaining liquid fraction has almost the quality of pure water. If the separated fractions do not reach the necessary level of purity, or if the chosen membranes and processes are not suitable for digestate, the expenditures for energy, labour, maintenance and cleaning of the system can increase considerably.

Nutrient management in digestate

One of the important aspects regarding recycling of digestate is the load of nutrients on farmland. Nitrate leaching or phosphorus overloading can occur due to inappropriate handling, storage and application of digestate as fertiliser.

In Europe, the Nitrate Directive (91/676/EEC) restricts the input of nitrogen on farmland, aiming to protect the ground and surface water from nitrate pollution and allows maximum 170 kg N/ha/year. Nutrient loading on farmland is regulated by national legislation in most European countries (Table 3).

Table 3. Example of national regulations of the nutrient loading on farmland (NORDBERG, 1999)

	Maximum nutrient load	**Required storage capacity**	**Compulsory season for spreading**
Austria	170 kg N/ha/year	6 months	28/2-25/10
Denmark	170 kg N/ha /year (cattle) 140 kg N/ha/year (pig)	9 months	1/2-harvest
Italy	170-500 kg N/ha /year	90-180 days	1/2- 1/12
Sweden	Based on livestock units	6-10 months	1/2- 1/12

Source: [1]

Application of digestate as fertiliser must be done on the basis of a fertiliser plan. The fertiliser plan is elaborated for each agricultural field, according to the type of crop, the planned crop yield, the anticipated utilisation percentage of nutrients in digestate, the type of soil (texture, structure, quality, pH), the existing reserve of macro and micro nutrients in the soil, the pre-crop and the irrigation conditions and the geographic area.

Experience from Denmark indicates that the most economic and environmental friendly strategy of application of digestate as fertiliser is by fulfilling the phosphorus requirement of the crops with phosphorus from digestate. Application of digestate to fulfil the phosphorus requirement implies also a partial fulfilment of nitrogen requirement of the crops. The remaining nitrogen requirement can thus be completed by application of mineral fertiliser.

CONCLUSIONS

Using digestate in biogas plant is very usefull from many points of views.

Compared to compost and to untreated slurry application, digestate supplies larger portions of carbon, available for the reproduction of organic substances in soils. During anaerobe digestion, decomposable organic bounds such as cellulose and fatty acids are broken down.

Methane bacteria produce a whole series of amino acids, which are available for plants and other living organisms in the soil.

On the other hand, complete conditioning separates digestate in three refined end products: pure water, concentrated nutrients and organic fibres.

This paper also emphasizes the importance of nutrient management in digestate.

In EU there are directives that restricts the input of nitrogen on farmland, aiming to protect the ground and surface water from nitrate pollution. Application of digestate as fertiliser must be done on the basis of a fertiliser plan.

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]Dumitru, M., 2012, The advantages of using biogas as an alternative fuel in rural areas, Bulletin UASVM Agriculture, 69(1)/2012, Print ISSN 1843-5246; Electronic ISSN 1843-5386

[4]Dumitru, M., Moise, G., Bibu, M., 2013, Obtaining bioethanol used as biofuel for auto-vehicles using a self pressured bioreactor**,** Simpozionul ştiinţific internaţional „Managementul dezvoltării rurale durabile, Timisoara "Lucrări Ştiinţifice Management AGRICOL" Seria I, vol. XV - ISSN:1453-1410, E-ISSN: 2069-2307

[5]Jönsson, O. *et al.*, 2001, Adding gas from biomass to the gas grid, Swedish Gas Center Report, SGC 118.ISSN 1102-7371

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

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

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

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

[10]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

[11]Chatziathanassiou, A., Sioulas, K., Mavrogiorgos, D., Veneti, A., Boukis, I., 2002, Stakeholders' perceptions for Anaerobic Digestion Energy Schemes in Greece, 12th European Conference and Technology Exhibition on biomass for Energy, Industry and Climate Protection, Amsterdam, The Netherlands