Analecta Technica Szegedinensia
Vol. 14, No. 1 ISSN 2064-7964 2020

THE APPLICATION OF BIOGAS FERMENTATION DIGESTATE AS SOIL FERTILIZER

[1]*Klára Czakó-Vér*, [2]*Dávid Somfai*, [2]*Erzsébet Suhajda*, [1]*Márk Strasszer*, [1]*Gyula Árvay*, [2]*Anita Dolgosné Kovács*, [2]*Ernő Dittrich*

[1]Institute of Biology, Faculty of Sciences, University of Pécs, Ifjúság útja 6., H-7624, Pécs, Hungary,
[2]Department of Environmental Engineering, University of Pécs, Boszorkány út 2., H-7624 Pécs, Hungary,
e-mail: klaraczakover@gmail.com

ABSTRACT

As organic manure is becoming less available, using different materials as soil fertilizers and the application of the inorganic fertilizers raises many questions. Therefore, it is increasingly important to use compost and biogas digestate to improve soil quality. The activity of the microbial communities ensures the fertility of the soil. One of the most important enzymes is dehydrogenase. This enzyme group catalyses the hydrogen transfer in the process of biological oxidation. Our aim was to examine the effect of biogas digestate on dehydrogenase enzyme activity (DHA) in 3 different types of soil. Hungarian standard method was used to evaluate DHA. The applied biogas digestate was obtained from the Kaposvár Sugar Factory of Hungarian Sugar Ltd. The dose is equal to 16,7 m3ha-1 and 533 kg organic matterha-1. The treatment was performed in three different groups of soil: brown forest soil, calcereous chernozem and carbonate meadow soil. The results showed an increase in DHA in all types of soil. DHA values were the highest in case of the carbonate meadow soil, specifically 0.337 mg formazan/1 g soil/24 h immediately after the treatment and 0.410 after 28 days. A critical aspect to consider during the construction of biogas plants is the soil protection agency's ban on using soil fertilizers during the winter months. Analysis carried out according to the protocol of sewage sludge examination revealed that biofermentate produced during biogas generation does not contain any environmentally harmful components. After the elaboration of a soil protection plan, the recommended way to apply biogas digestate to arable land is via injectors.

Keywords: biogas, digestate, fertilizer, soil, activity,

1. INTRODUCTION

Arable land can be defined as a complex system of materials and energy in terms of agriculture and forestry. Its physical properties and limitations depend on the soil, the climate and hydrological cycles. The value and quality of arable land is characterized by achievable yield or yields achieved in the past. Extremes in climate (stress resulting from heat and excessive precipitation) highlight the errors of previous soil cultivating practices that included procedures detrimental to soil health. Soil cultivation faces important tasks, involving the realisation of the effects and symptoms of global climate change, reduction of climate risk in terms of summer soil cultivation and developing and applying techniques to prevent draught, water loss and stress from heat and precipitation. [1] The VAHAVA report, that ended the Hungarian National Academy of Sciences' and the Hungarian Ministry of Environmental Protection and Water's joint project titled Effects of global climate change in Hungary and the appropriate answers: Change-Effect-Answer, brought about an important step forward in relation to soil protection. Quality and climate sensitivity of soil were classified as essential factors influencing the future chance of crop growth in agriculture. [2]
Fertilizer demand is 0, if the yield is proportionate to the soil's momentary nutrient providing capability, if we want to maintain or increase the yield, using fertilizer on soil is needed. [2]

DOI: 10.14232/analecta.2020.1.76-81

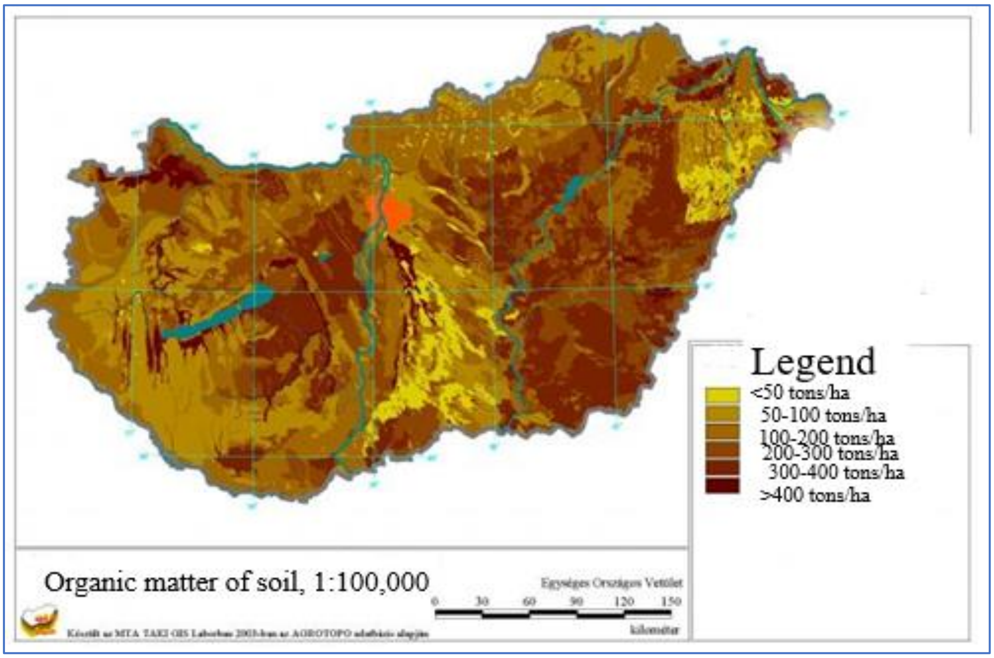

Figure 1.: Organic matter concentration in soil in Hungary [1]

In Hungary, the importance of livestock, including bovine production has been decreasing for the last 50 years. This concluded in the reduction of the amount of organic manure as well. In the last 15 years, livestock in Hungary reduced to its half and one third. Between the years 1983 and 1997 swine population decreased from 11 million to less than 5 million and bovine population lowered from 2 million to 870 thousand. As a result, the amount of organic manure reduced from 17 million of tons to less than 4 million of tons, providing enough fertilizer for only 1,5% of the total arable land.

By-products originating from biogas plants are a rather new way of fertilizing soil. It was established in [3] that their composition varies according to the raw material fed to the biogas process. Although digestates from different types of biogas plants differed in their performance as soil fertilizer, in conclusion they all increased soil microbial activity. [3]

Liquid digestate from biogas plants can serve as a more valuable organic fertilizer than manure or compost, since it has a higher amount of easily absorbable nitrogen, phosphorus, potassium and trace elements.

Furthermore, another benefit of using digestate instead of artificial fertilizers is the fact that it has a lower mobile nitrate to ammoniacal nitrogen ratio, therefore it mitigates the nitrate pollution of surface and subsurface water. The water content of the digestate also has a critical significance, especially in dry years like 2012, when draught could have caused serious damage to farmers had it not been for irrigation.

Another serious advantage is cost effectiveness. Using digestate generates less cost than using artificial fertilizers and it also lowers irrigation costs.

Liquid digestate from biogas plants can prove to be a beneficial nutrient for agricultural lands, providing an accessible supply of soil nutrients for plants. Besides its significant water content, it also possesses a remarkable amount of macronutrients and micronutrients.

On the other hand, it also contains materials that has not been digested entirely, for example organic matter and remains of bacteria and different enzymes. These by-products increase the growth of microbes and plants and boost the microbial activity of soil, thus enhancing the amount of absorbable nutrients in the soil. Therefore, it has a positive effect on crop growth. [3]

DOI: 10.14232/analecta.2020.1.76-81

Although other countries, for example Sweden, elaborated a separate certification system for biogas residues [3], in Hungary the application of digestate to arable lands faces serious legal barriers to this day. [4] The main complication is the fact that digestate does not constitute an independent legal category, therefore it is treated as sewage sludge in official procedures. [4]
However, as opposed to sewage sludge, digestate does not contain harmful industrial waste. Besides, the exact composition of materials entering the biogas plant is known.
Currently there are several regulations regarding soil fertilizers and yield enhancers, nevertheless liquid digestate from biogas plants does not play a role in any of them.

Ecological demands of biogas production
Its advantages compared to fossil fuels are that no excess CO_2 enters the atmosphere, and that during fermentation emission of CH_4, a gas with high greenhouse gas potential, is prohibited.
The anaerobic digestion of organic manure provides an end-product characterized by reduced smell intensity and high fertilization potential thanks to its optimal C:N ratio and the mineralization of nitrogen and phosphorus. This can lead to decreased artificial fertilizer usage.
Most pathogen microorganisms found in manure decease during fermentation and preparation, diminishing the amount of substances harmful to human health applied to arable land.
Regulation 90/2008. (VII.18.) of the Ministry of Agriculture imposes the creation of a soil protection plan to permit the use of manure and waste on arable lands. [4] Organic manure is excepted from this rule.
A simplified soil protection plan is necessary in case of the use of sewage sludge compost or non-hazardous agricultural waste. Liquid digestate from biogas plant classifies as, non-agricultural, non-hazardous waste. This means that in order to get a permission to use it on arable land, the elaboration of a detailed and more expensive soil protection plan is needed. In order to fully map the potential of digestate in agriculture, further experiments are required, involving different types of soils and biogas plants.
Use of liquid digestate from biogas plants is economical and the significance of this can grow in the future. Therefore, the construction and development of biogas plants are beneficial, because they do not only produce biogas, but also provide a valuable nutrient supply for crop growth.
During the anaerobic fermentation of biogas production, the original material's composition undergoes significant changes (for example in ammonium content, pH, C:N ratio) until it reaches its final state. This possesses a great significance in its later use on arable land regarding the macronutrients and micronutrients available for plants [3].
Digestate can be applied directly as fertilizer or it can be divided into liquid and solid phase before its utilization. The solid phase can be composted, dried or incinerated. The liquid phase can be diluted to later use as a nutrient solution, or it can be concentrated by applying filter or membrane technologies.
After fermentation, the end product has a higher ammoniacal nitrogen to total nitrogen ratio and a higher pH value than the original material. However, it experiences a decrease in total organic matter, total and organic carbon, biological oxygen demand (BOD), C:N ratio and viscosity. The fermented material's ammoniacal nitrogen has a direct link to the original matter's total nitrogen content. Easily degradable materials, like wheat or chicken and swine manure have a high ammoniacal nitrogen to total nitrogen ratio and low C:N ratio. Nevertheless, bovine manure or materials low in nitrogen (for example maize silage) have a low ammoniacal nitrogen to total nitrogen ratio.

In the biogas plant of Nyírbátor, agricultural plant wastes, animal by-products (primarily manure) and the waste of a poultry slaughterhouse are utilized.
Pot experiments, small parcel experiments and industrial experiments were carried out to determine the green mass and yield enhancing capacity of digestate. Its effect on soil, specifically biological activity and nutrient content of soil were also assessed.
As a control group, untreated control samples and samples irrigated with water instead of digestate were used. Moreover, the effects of several different types of nutrient replacing methods were compared, including using digestate, bentonite, sewage sludge compost and Phylazonit MC bacterial manure.

DOI: 10.14232/analecta.2020.1.76-81

Makádi et al. [5] stated that as a result of applying digestate to agricultural parcels and especially due to the water contribution aspect of digestate treatment, maize (Zea mays var. saccharata) grew bigger, more robust and healthier ears. Administering digestate lead to an increase in the mass of corn ears. Furthermore, plants treated with digestate suffered less damage from environmental and climatic fluctuations than plants in control pot experiments.
Digestate treatment on sandy soil resulted in a significant change of yield. However, it had no statistically significant effect on pasture soil characterized by greater nutrient content and better water retention ability.
A critical aspect to consider during the construction of biogas plants is the soil protection agency’s ban on using yield enhancing materials during winter months. Hence biogas plants must have enough storage capacity to be able to store 4 months’ worth of digestate. [6]

2. MATERIALS AND METHODS

For our *in vitro* model experiment, we chose 3 types of soil, all three characteristic to the Southern part of Transdanubia. These significantly differ in their components and chemical parameters, like pH, CaCO3 and humus content and KA.
The most frequent physical and chemical parameters of the soil types are shown in Table 1.
The activity of the microbial communities ensure the fertility of the soil. One of the most important enzyme is dehydrogenase. This enzyme group catalyses the hydrogen transfer in the metabolism of biological oxidation [7]. For the determination of the dehydrogenase enzyme activity (DHA) Hungarian standard method was used [8]. The DHAs were measured 0, 7, 14 and 28 days following treatment in samples and controls.
The applied biogas digestate derived from Kaposvár Sugar Factory of Hungarian Sugar Ltd. The dose is equal to 16,7 m^3ha^{-1} and 533 kg organic matter ha^{-1}. The chemical parameters of the digestate are shown in Table 2.

Table 1. Main soil physical and chemical properties of the characteristic types of soil from Hungary (Data of the Plant Health and Soil Conservation Service, Fejér county.)

Genetic soiltype	*pH H_2O*	*$CaCO_3$ ($mg.kg^{-1}$)*	*Humus (%)*	*K_A*	*Loam (%)*	*Mud (%)*	*Sand (%)*
Brown forest soil	5.65	0.00	0.88	28	15.30	25.5	59.30
Pseudomycelliar chernozem	8.29	16.0	2.29	37	22.2	63.1	14.7
Meadow soil	7.49	1.9	3.56	71	35.9	61.7	2.5

DOI: 10.14232/analecta.2020.1.76-81

Table 2. Main chemical parameters of the biogas digestate

OTS %	***3.2***
TS %	***5.25***
pH	***7.1-7.4***
NH_4 mg dm^{-3}	***200-1500***
Total N mg dm^{-3}	***300-1600***
O-phosphate mg dm^{-3}	***10-40***

3. RESULTS AND DISCUSSION

After the measurement, results were calculated to mg formazan /1 g soil /24 hours. (Table 3.)

Table 3. DHA data in the different types of soil after treatment with biogas digestate on the 0, 7, 14 and 28 days.

	Brown forest soil			Calcereous chernozem			Meadow soil		
	control	treated	treated (in % of control)	control	treated	treated (in % of control)	control	treated	treated (in % of control)
0.day	0.0263	0.0379	144%	0.0991	0.1115	113%	0.2856	0.3374	118%
7. day	0.0306	0.0413	135%	0.1013	0.1365	135%	0.3583	0.3972	111%
14. day	0.0324	0.051	157%	0.1206	0.1532	127%	0.3396	0.3694	109%
28. day	0.0404	0.0584	145%	0.1383	0.1789	129%	0.3747	0.4102	109%

The three different types of soil showed a significant difference in biological activity, even in the beginning of the experiment. Compared to brown forest soil, calcerous chernozem and meadow soil had a 4- and 10-times higher dehydrogenase activity, respectively.

Brown forest soil is characterized by low humus content (0.88%) and a significant sand content (59.30%). This type of soil showed a maximum in DHA on the 14^{th} day following digestate treatment and reached 157% of the enzyme activity of the untreated control group.

Pseudomycelliar chernozem has better humus content (2.29%) and a significantly lower sand content (14.7%). In this case, biogas digestate only increased DHA by 13% immediately after treatment and even on the 28^{th} day after treatment, enyzme activity was only 130% of the control group's value.

The meadow soil contains a remarkable amount of humus (3.56%), paired with 2.5% sand content and 61.7% mud. The digestate treatment increased biological activity by 18%, however this value decreased during the 28-day experiment, ending with a value equivalent to 110% of the control group's DHA.

Considering the measured results as a percentage of the control group's DHA activity, brown forest soil experienced the highest increase during the whole experiment. Maximal DHA activities in function of the control group were measured in the first 14 days in all three cases (14^{th} day in case of brown forest soil, 7^{th} day in case of calcereous chernozem and immediately after treatment in case of meadow soil). These results can help in establishing the recommended frequency of applying biogas digestate for different kinds of soil.

Using injectors for the distribution of biogas digestate facilitates the precise control of application frequency and minimizes ammonia volatilisation. It was established in [9] that the most suitable methods for digestate application combine close contact with top-soil and minimal surface area exposed to air.

DOI: 10.14232/analecta.2020.1.76-81

4. CONCLUSIONS

Our measurements revealed that the highest increase in biological activity by biogas digestate treatment can be achieved in soil characterized by low humus content and high sand content.
Since the examined biogas plant uses sugar beet press pulp as its substrate, and this raw material does not contain any environmentally harmful components, the application of the plant's biogas digestate as a soil fertilizer can be recommended, especially in case of brown forest soil. If the digestate's solid and liquid phase is separated, the solid phase can be applied to the land by manure spreading spray tables. The liquid component of the digestate can be administered by injectors.
Using liquid biogas digestate also implies applying extra moisture to the soil, contributing to the advantages of using biogas digestate as soil fertilizer.

ACKNOWLEDGEMENT

Our work was created as part of the project "Sustainable Raw Material Management Thematic Network— RING 2017" EFOP-3.6.2-16-2017-00010 within the Programme SZECHENYI2020, supported by the European Union, co-financed by the European Social Fund.

REFERENCES

[1] Várallyai,G., Szabóné Kele,G., Berényi Üveges,J., Marth, P., Karkalik,A., Thury,I., 2006. (Szerk.: Juhász,I.) Magyarország talajainak állapota. FVM, Budapest.
[2] Bíró, B., A talaj mint a mikroorganizmusok élettere. In: A talajok jelentősége a 21. században. (Szerk.:Stefanovits,P., Micheli,E.) 2005. MTA TKI, Budapest. pp.141-1658.
[3] Adubaker et al., 2012. Biogas residues as fertilisers. Effect on wheat growth and soil microbial activities. Appl. Energy 99. 126-134.
[4] Barczi,A., Szalai,D., Nagy, V. 2017. The legislative background of the application of fermentation residues to agricultural lands in Hungary. Analecta Techn. Szegedinensia 11. 26-35.
[5] Makádi,M., Tomócsik,A., Orosz,V., Lengyel,J., Bíró,B., Márton,Á. 2007. Effect of digestate and Phylazonit MC on the yield of silage maize and the biological acivity of the soil. (In Hungarian) Agrokémia és Talajtan, 56. 367-378.
[6] Kátai,J., Vágó,I., Tállai, M., Makádi,M. 2009. A biogáz gyártás melléktermékének hatása a talaj néhány mikrobiológiai tulajdonságára. Talajvédelem (S) 417-422.
[7] Kiss, I. 2004. A mikroorganizmusokkal beoltott talajok enzimológiája. Scientia Kiadó, Kolozsvár pp.
[8] MSZ-08-1721/3-86: Soil analysis of agricultural treated with sewage and sludge. Analysis of soil biológia activity by method of dehydrogenase enzyme activity.
[9] Lukehurst C. T., Frost P., Al Seadi T. 2010 Utilisation of digestate from biogas plants as biofertiliser. IEA Bioenergy.

DOI: 10.14232/analecta.2020.1.76-81