Journal of Agriculture and Ecology Research International
8(1): 1-7, 2016; Article no.JAERI.25217
ISSN: 2394-1073

SCIENCEDOMAIN *international*
www.sciencedomain.org

Biobased Fertilizers - Comparison of Nutrient Content of Digestate/Compost

A. Aladjadjiyan[1*], D. Penkov[1], Ann Verspecht[2], A. Zahariev[3] and N. Kakanakov[3]

[1]Agricultural University, "Mendeleev" 12, 4000 Plovdiv, Bulgaria.
[2]Gent University, Gent, Belgium.
[3]National Biomass Association, "Antim I", 22, 4000 Plovdiv, Bulgaria.

Authors' contributions

This work was carried out in collaboration between all authors. Author AZ managed the data about Shishmantsi, collected information about collection, technology and development of compost in the factory. Author DP collected information about waste distribution, collection, storage in Han Bogrov. Author AV managed the analyses of the study. Author AA managed and wrote the last draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2016/25217
Editor(s):
(1) Claudius Marondedze, Biological and Environmental Sciences and Engineering, King Abdullah University of Science and Technology, Kingdom of Saudi Arabia.
Reviewers:
(1) Ade Onanuga, Dalhousie University, Halifax, Canada.
(2) Monica Guadalupe Lozano Contreras, National Institute of Forest Research Agricultural and Livestock (INIFAP), Mexico.
(3) Tunira Bhadauria, Kanpur University, Uttar Pradesh, India.
(4) Raimundo Jimenez Ballesta, Universidad Autonoma Madrid, Spain.
Complete Peer review History: http://sciencedomain.org/review-history/14266

Original Research Article

Received 23rd February 2016
Accepted 12th April 2016
Published 20th April 2016

ABSTRACT

Agriculture is the main source of soil degradation processes in Bulgaria. Therefore, soil improvement is an important task. The possibilities for using composted either municipal waste or residues from biogas production for soil improvement in Bulgaria, suggested by the development of INEMAD (Improvement of Nutrient and Energy Management through Anaerobic Digestion) project, should be assessed and popularized. The advantages and disadvantages should be analysed and discussed. This paper uses the results of two previously published papers by AUP within the framework of INEMAD where the possibilities for production and sale of compost from municipal waste and digestate from biogas by anaerobic digestion of animal manure are discussed.

**Corresponding author: E-mail: anna@au-plovdiv.bg;*

The possibilities for biogas production in Bulgaria as well as the potential for use of digestate as fertilizer are discussed. At present these options are not yet feasible for Bulgaria because of the high prices of anaerobic digestion plant and the insufficient quantities of animal manure. Advantages of waste processing are multiple, on one hand the processing of municipal waste produces compost of organic origin and can be used as a soil improver to recover nutrients and improve structure while at the same time this allows reducing the area of dunghills, unpleasant smell, and Greenhouse Gas emissions.

Keywords: Manure; waste; biogas; digestate; compost; nutrient comparison; Bulgaria.

1. INTRODUCTION

Developing innovative strategies for reconnecting livestock and crop production farming systems is the core idea of the INEMAD project. The acronym INEMAD stands for Improvement of Nutrient and Energy Management through Anaerobic Digestion. Production of biogas from animal manure through anaerobic digestion and further use of digestate as fertilizer is one of the strategies listed in the project. The preconditions for development of bio-based fertilizers are settled in EU and national Laws.

The communication from the European Commission (EC) to the Council and the European parliament in 2010 [1] on future steps in bio-waste management in the European Union (EU) points out that the compost and digestate from bio-waste are under-used materials. The analysis conducted by the Commission confirms that improved management of bio-waste in the EU holds an untapped potential for significant environmental and economic benefits.

In Bulgaria, the legal framework on humus and the use of humus or bio based products is determined by Ordinance No. 26 on reclamation of disturbed areas, improvement of low lands, removal and utilization of the humus layer [2] In performance of the goals set in the law, a “National program for protection, sustainable use and restoration of soil” [3] has been established, and in compliance with this program each of the district governors was assigned to elaborate programs for protection, sustainable use and restoration of soils in their district.

The possibility to use compost as admissible soil fertility product is settled in Ordinance No. 22/2001 of the Ministry of Agriculture and Forestry on organic production of plants.

Restrictions on storage and treatment of fertilizers at national level are imposed by the:

- Law on Protection of plants - promoted State Gazette (SG) No. 91 of 10 October 1997, amended SG issue 28 of 5 April 2011 [4]. Part V is related to organic fertilizers.
- Good Agricultural Practice for the protection of waters against pollution with nitrates from agricultural sources, approved by Order No. RD 09-799/11.08.2010 of the Minister of Agriculture and Food [5].
- Programme of measures to reduce and prevent pollution caused by nitrates from agricultural sources in vulnerable zones, approved by Order No. RD 141/07.03.2011, and Order No. RD 09-189/24.03.2011 of the Minister of Agriculture and Food and the Minister of Environment and Water [6].

The Landfill Directive of the European Commission from 1999 [7] requires Member States to progressively reduce land filling of municipal biodegradable waste to 35% by 2016 (compared to 1995). Member States relying heavily on landfilling in 1995 have a four year extension period and these member states include Bulgaria, Cyprus, Czech Republic, Estonia, Greece, Ireland, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, and United Kingdom. The objective of this Directive is to reduce the production and release of greenhouse gases from landfills.

The National programme for waste management activities for the period 2009–2013 [8] has been published by the Ministry of Environment and Water. The National Programme states that composting will be the basic method for reducing the biodegradable waste while the anaerobic digestion is preferred for co-treatment of agricultural and industrial biodegradable waste (i.e. sewage sludge). In implementation of the programme construction of wastewater treatment plants and construction of sewage networks have been started. The big generators of non-hazardous waste (for big industrial complexes) on regional scale are in process of construction of their own waste disposal facilities.

In this paper we will compare the nutrient content of bio-based fertilizers. We will analyse the composition of compost /digestate from two municipal biological waste plants in Bulgaria and one lab-scale digestate based on chicken manure. The objective is to draw conclusions on the suitability of the use and production processes of green fertilisers in Bulgaria.

Data from Bulgarian governmental documents and EU directives on municipal waste handling and development of animal breeding are analysed as well as useful data on nutrient content from the questionnaires collected by AUP members.

2. DESCRIPTION OF THE PROCESSING PLANTS AND DATA

As a consequence of mentioned EC and National Regulations the importance of processing different kind of wastes for valuable products is on the rise. However, in contrast with some other countries, the share of animal breeding is decreasing over the last 20 years. As a result, animal manure is not an issue towards environmental contamination and as such no need exists in Bulgaria for anaerobic digestion of animal manure. What became more and more important are the raising quantities of municipal organic waste. As stated in *EUROOBSERV'ER – The state of renewable energies in Europe* [9], in 2011 the total number of biogas installations in Bulgaria was 3, all processing sewage sludge.

The composting processes have been reviewed in details [10] as well as various techniques used in compost production, and the methods for determination of compost maturity and quality. There are different ways of treating organic waste, generally subdivided into aerobic and anaerobic processes. Most important limiting parameter in the selection of technologies is the water content in waste, indeed as the water content increases the rate of O_2 diffusion decreases. As O_2 becomes insufficient to meet the metabolic demand, the composting process slows down and becomes anaerobic.

In this paper we consider two techniques for processing municipal waste. Both produce a bio-based fertilizer: The first one is the aerobic treatment of solid waste, resulting in compost, and the second one is the anaerobic digestion of manure, resulting in digestate.

We will describe two composting plants in Bulgaria. The first plant is composting municipal solid waste (MSW) in Plovdiv (Shishmantzi). The second one is a new opened plant for processing food waste "Han Bogrov" in Sofia (Musagenitza).

Most of the organic material, having high dry matter ratio can be treated in aerobic way similar to composting. Treating this substrate in conventional biogas installations is difficult because the high volumes of water required and the by-product of waste water. For composting, energy is needed to turn the substrate periodically and to maintain the optimal temperature. This will accelerate the technological process. The compost as a final product can be used for soil improvement and reduce the risk of soil erosion.

2.1 Ecozavod - Plovdiv Plant

About 85% of the generated municipal solid waste (MSW) in Plovdiv is transported to the depots, and approximately 52% of the total amount of waste is biodegradable. The plant for processing the MSW with a capacity of 125 000 t/yr was built in the village Shishmantsi located 30 km north-west from Plovdiv. It is known as Ecozavod – Plovdiv. The plant accepts only non-hazardous waste. A cell for hazardous waste deposition has been established earlier in Plovdiv accepting certain types of hazardous waste. The installation Ecozavod-Plovdiv is designed for the processing of non-hazardous MSW in Plovdiv and other regional municipalities. After primary separation of the components of municipal waste (Fig. 1) the organic component is used for composting. The full flow-chart of the technological operations in the plant can be illustrated by Fig. 2.

Fig. 1. Corpus"primary processing'' of municipal solid waste in Shishmantsi
Source: http://ecozavod.com/

Fig. 2. Technological chart of production of municipal waste compost

The final product is compost, an organic fertilizer of about 36% water, and 30-38% organic substance in dry mass. Its quality depends on its nutrient contents nitrogen (N) - phosphorus (P) - potassium (K), as well as the content of metals and organic toxic substances. When organic compost is added to the soil, this will improve the soil quality and structure and will finally result in higher yield. Composting of municipal solid waste can recycle nutrients. Its safe use in agriculture, however, depends on the production of good quality compost, specifically, compost that is mature and sufficiently low in metals and salt content [11].

The content of N, P, K and organic C, as well as the pH and the presence of toxic heavy metals arsenic (As), cadmium (Cd), zinc Zn, lead (Pb) and cuprum (Cu) are analysed in the accredited Laboratory for analysis of the components of the environment, part of the Executive Agency on Environment. These parameters are important for determination of the quality of compost and the composting installations are regularly subjected to analyses of these components. Results in Table 1 present average values of control measurements performed in 2010 and 2011 (with superscript 1). International Standard Methods (ISO) for the tests of parameters 1 to 8 is used, and internally validated laboratory methods for the rest. Standard values for investigated parameters are presented in last column of the Table.

2.2 Han Bogrov plant in Sofia

Recently, the municipal waste processing company “Han Bogrov” in Sofia with capacity 44 000 t/y has been built in frame of an EU project. It has been put into service in April 2014. Food waste from restaurants and other food processing industries in Sofia (capacity 20 000 t/year) are collected and processed through anaerobic digestion for biogas production. Produced biogas is used for electricity generation and maybe in the future for cogeneration.

To complete the process of obtaining a final marketable product, partially dehydrated digestate should be subjected to additional aerobic fermentation, dried and proposed as a fertilizer in the market. Due to still insufficient production, these additional processing steps are not carried out, although the enterprise has the necessary technology and facilities.

Our experience shows that even in this state the digestate can be used as fertilizer. The additional treatments would increase its cost and at this stage there is no evidence of how the costs will raise the Bulgarian practices and what strategies should be implemented to increase the market attractiveness, profitability and competitiveness of the final product.

Besides the digestate from anaerobic digestion, Han Bogrov prepares entirely plant-based and dried compost that is ready as fertilizer. The input material for this aerobic composting plant with capacity 20 000 t/y is mostly plant residues from parks in Sofia: about 50% of grasses, 40% clipped trees branches and extra 10% of agricultural plant waste from neighbouring farms.

Samples of digestate and green compost produced in the enterprise Han Bogrov in Sofia have been analysed in the Accredited Laboratory Complex at AUP with standards methods for determining the content of N, P, K and organic C, as well as the pH and the presence of heavy metals As, Cd, Zn, Pb and Cu. Results from the analysis of green compost and digestate are presented in Table 1 (with superscript 3).

The digestate after anaerobic digestion is shown on Fig. 3.

2.3 Digestate from chicken manure based on Baykov et al. [12]

As at this moment anaerobic digestion of manure is not common in Bulgaria, the data for digestate come from the article by Baykov et al. [12] where the researchers analyzed the fermentation of hay-based chicken manure at lab scale. In their experiments the digestate has been prepared from litter from broiler production /LBP/ according to the requirements of Ordinance №22/2001 for the MRL/Maximum Residue Level/ values of toxic elements. The obtained digestate is studied for the content of biogenic and toxic chemical elements by applying the methods described by Jorchem /1993/ with AAS "Perkin-Elmer-4100" (results presented in Table 1 with superscript 2).

Fig. 3. The digestate in "Han Bogrov" – Sofia

The digestate obtained after broiler production has been chosen, because the part of poultry production in Bulgarian animal breeding prevails. The distribution in Bulgarian livestock according to official statistical data of FAOSTAT is as follows: poultry - 84.39%; sheep and goats - 9.15%; cattle - 2.94%, swine - 3.25% (Fig. 4).

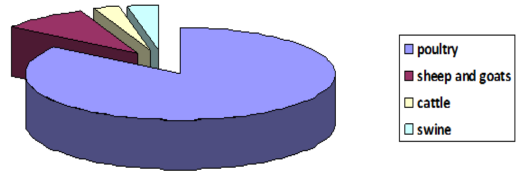

Fig. 4. Distribution of the livestock sectors

3. COMPARISION OF THREE CASES

Values for compost from the plant in Shishmantsi, Plovdiv (1), presented in Table 1, have been compared with those obtained in Han Bogrov, Sofia (3). To compare the nutrients content in bio-based fertilizers from compost and digestate the laboratory results of Baykov et al. [12] were used (2). Digestate in this publication has been obtained only from litter from broiler production /LBP/ on an experimental Bulgarian farm according to the requirements of Ordinance №22/2001 for the MRL/Maximum Residue Level/ values of toxic elements. The obtained compost is studied for the content of biogenic and toxic chemical elements by applying the methods described by Jorchem [13] with AAS "Perkin-Elmer-4100".

Table 1. Comparison of parameters of waste compost and digestate

No.	Parameter	Units	Value (compost[1]) Shishmantsi	Value (digestat[2]) Broiler	Value (compost[3]) Han Bogrov	Value (digestat[3]) Han Bogrov	Standard or maximum allowed
1	pH	-	7.49±0.05		8.41	7.45	6÷7.4
2	As	$mg.kg^{-1}$	<1.5	0.5±0.1	-	-	25÷35
3	Cd	$mg.kg^{-1}$	0.55±0.03	0.5±0.2	<2.0	<2.0	2.0÷3.0
4	Zn	$mg.kg^{-1}$	29±3	80.1±9	86.87	784.5	250÷300
5	Pb	$mg.kg^{-1}$	67±6	45.0±4.6	39.79	45.26	80÷100
6	Cu	$mg.kg^{-1}$	<2.5	65.0±4.1	33.60	172	100÷140
7	Dry matter	%	93.5±6.5	7	61.7	28.97	-
8	Water content	%	6.4±0.7				-
9	Cr	$mg.kg^{-1}$	15±2	60.0±4.6	15.65	56.10	200÷200
10	Ni	$mg.kg^{-1}$	<10	2.4±1.2	-	-	60÷75
11	Hg	$mg.kg^{-1}$	<0.01	0.4±0.1	-	-	1÷1
12	C (organic, soluble)	$mg.kg^{-1}$	8790				-
13	Ratio C/N	-	0.6÷0.8				17
14	N (total, soluble)	$mg.kg^{-1}$	13150	28472±400	13710	32910	-
15	P	$mg.kg^{-1}$	38.5	-	1296.7	20287	-
16	K	$mg.kg^{-1}$	1932	34560±1450			-

Source: [1]Regional Accredited Laboratory of the Executive Agency of Environment; [2]Bayko Baykov et al. [12], [3]Accredited Laboratory Complex at AUP

The quality of biobased fertilizers depends on the content of N, P, K and organic C, as well as the pH. The presence of heavy metals As, Cd, Zn, Pb and Cu is harmful and worsens the quality of biobased fertilizer. These parameters are important for determination of the quality of compost.

The data in Table 1 show that the controlled parameters of toxic components as heavy metals are below the standard values where these exist, so the produced compost or digestate can be evaluated as not-harmful and be used for soil improvement. One exception is the surprisingly higher levels of Zn and Cu in the digestate from "Han Bogrov, compared with the standard ones. This must be further investigated.

The content of macronutrients also lies between limits found in literature: N - approximately 13 $g.kg^{-1}$ compared to those obtained by Hargreaves et al. [11] 5÷35 $g.kg^{-1}$, P - 38.5 $mg.kg^{-1}$ compared to 0÷15 $g.kg^{-1}$, and K – 1.93 $g.kg^{-1}$ compared to 0÷35 $g.kg^{-1}$ respectively.

Higher content of N in digestate makes it preferable for fertilizer. The content of N in waste compost (about 13500 $mg.kg^{-1}$) for both investigated cases (Shishmantsi - Plovdiv and Han Bogrov – Sofia) is less than the half of the measured in digestate samples (32910 $mg.kg^{-1}$ for the samples from Han Bogrov – Sofia).

The content of P in investigated samples of digestate is also higher than in those of compost. In the green compost from Han Bogrov – Sofia it is higher than in the municipal waste compost from Shishmantsi – Plovdiv (1296.7 $mg.kg^{-1}$ against 38.9 $mg.kg^{-1}$). The highest value of P content is in the digestate from Han Bogrov – Sofia - 20287 $mg.kg^{-1}$.

PH in all measured results is higher than standard, especially in the case of compost from Han Bogrov. The reason for this result should be investigated further.

Potassium content in the investigated samples is also higher in digestate: about 34 $g.kg^{-1}$ [12] compared to 1.93 $g.kg^{-1}$ (compost from Shishmantsi – Plovdiv).

The composting of municipal waste for soil re-cultivation in Shishmantsi has been described in more details previously [14]. Possibilities for processing agricultural waste for biogas and bio based fertilisers are discussed too [15].

4. CONCLUSION

On one hand the higher values of N, P and K in the digestate indicate the more suitable use for digestate as fertiliser and on the other hand, the digestate from "Han Bogrov contained higher levels of Zn and Cu than maximum allowed. Further analysis is needed to find the source of these higher levels and to find a solution. The digestion of manure has only been tested on lab scale and results should be compared with care.

Due to the high water content in digestate from both poultry litter [12] and food waste (Han Bogrov) additional technological operations are necessary before their final preparation as fertilizers. This means also additional costs. This indicates that there is no added value of digestion of poultry because of the higher cost. Furthermore, there is no manure excess in Bulgaria thus it is easy and cheaper for farmers to dispose their manure.

Therefore, composing plants seem to economically have the most perspective in Bulgaria. The experience gained in the municipality of Plovdiv can be multiplied when planning waste processing plants in other big cities. Creation of waste processing plants in at least the regional cities with a capacity satisfying the needs of the region is highly recommendable in view of the Landfill Directive of the European Commission.

When finding a solution for the high heavy metal concentration, the digestion of OBW presents good perspectives. In the future, the plant in Han Bogrov, Sofia, will also use the produced biogas for cogeneration.

ACKNOWLEDGEMENTS

Present work has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 289712 as a part of project INEMAD.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anonymous. Communication from the commission to the council and the

European parliament on future steps in bio-waste management in the European Union (SEC 577); 2010.
Available:http://ec.europa.eu/environment/waste/compost/pdf/sec_biowaste.pdf
2. Anonymous. National programme for waste management activities 2009 – 2013 Available:http://www.moew.government.bg/?show=19
3. Anonymus. Ministry of environment and water. Decision on environmental impact Available:http://www.moew.government.bg/files/file/Industry/EIA/2014/Transboundary_2014/1-1-2013-en.pdf
4. Anonymous. Law on protection of plants - promoted SG. 91 of 10 October 1997, amended SG. 2011;28. Available:http://www.babh.government.bg/bg/legislation-bg-laws.html
5. Anonymous. Order No. RD 09-799/11.08.2010 of the Minister of Agriculture and Food. Available:http://www.mzh.government.bg/MZH/bg/ShortLinks/DobraZemedelskaPraktika.aspx
6. Anonymous. Order No. RD 141/07.03.2011, and Order № RD 09-189/24.03.2011 of the minister of agriculture and food and the minister of environment and water. Available:http://www.mzh.government.bg/MZH/bg/ShortLinks/DobraZemedelskaPraktika.aspx
7. Anonymous. Landfill of waste - Landfill Directive of European Commission (1999/31/EC). Available:http://ec.europa.eu/environment/waste/landfill_index.htm
8. Anonymous. National programme for waste management activities 2009 – 2013 Available:http://www.moew.government.bg/?show=19
9. Anonymous. EUROOBSERV'ER – The state of renewable energies in Europe; 2013.
Available:http://www.energies-renouvelables.org/observ-er/stat_baro/barobilan/barobilan13-gb.pdf
10. Kuo S, Ortiz-Escobar ME, Hue NV, Hummel RL. Composting and compost utilization for agronomic and container crops. Recent Res. Dev. Environ. Biol. 2004;1:451-513.
11. Hargreaves JC, Adl MS, Warman PR. A review of the use of composted municipal solid waste in agriculture, Agriculture. Ecosystems & Environment. 2008;123(1–3):1-14.
ISSN 0167-8809
Available:http://dx.doi.org/10.1016/j.agee.2007.07.004
12. Bayko Baykov, Irina Popova, Botyo Zaharinov, Kiril Kirov, Ivan Simeonov. Assessment of the compost from the methane fermentation of litter from broiler production with a view to its utilization in organic plant production. ISAH 2005 - Warsaw, Poland. 2005;2:65-72.
13. Jorhem L. Determination of metals in foodstuffs by atomic absorption spectrophotometry after dry ashing. J. of AOAC International. 1993;76/4/:798-813,
14. Zahariev A, Sv. Kostadinova, Aladjadjiyan A. Composting municipal waste for soil recultivation in Bulgaria. International Journal of Plant & Soil Science. 2014;3(2).
ISSN: 2320-7035,
DOI: 10.9734/IJPSS/2014/6919)
15. Zahariev Aleksandar, Dimo Penkov, Anna Aladjadjiyan. Biogas from animal manure – perspectives and barriers in Bulgaria. Annual Research & Review in Biology. 2014;4(5).
ISSN: 2347-565X
DOI: 10.9734/ARRB/2014/6505

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14266