

BIOBASED FERTILIZERS - COMPARISON OF NUTRIENT CONTENT OF DIGESTATE/COMPOST

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ABSTRACT

Agriculture is the main source of soil degradation processes in Bulgaria. Therefore, [CM1]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 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.

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 are multiple [CM2], on the 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 [CM3]

Developing innovative strategies for reconnecting livestock and crop production farming systems is the core idea of the INEMAD [CM4]project. 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 Commission [CM5] 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 [CM6] on reclamation of disturbed areas, improvement of low lands, removal and utilization of the humus layer. In performance of the goals set in the law, a “National program for protection, sustainable use and restoration of soil” [2] 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 [CM7] 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. [CM8] 91 of 10 October 1997, amended SG issue 28 of 5 April 2011 [3]. 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 [CM9] RD 09-799/11.08.2010 of the Minister of Agriculture and Food [4].
- Programme of measures to reduce and prevent pollution caused by nitrates from agricultural sources in vulnerable zones, approved by Order No [CM10] RD 141/07.03.2011, and Order No [CM11] RD 09-189/24.03.2011 of the Minister of Agriculture and Food and the Minister of Environment and Water [5].

The Landfill Directive of the European Commission from 1999 [6] 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 [CM12] (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 [7] 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 our colleagues from [CM13] AUP [CM14].

2. DESCRIPTION OF THE PROCESSING PLANTS AND DATA

As a consequence of mentioned EC [CM15] and National Regulations the importance of processing different kind of waste for valuable products is on [CM16] rise.

However [CM17] in contrast with some other countries, the share of animal breeding is decreasing over the last 20 years. As a consequence [CM18], animal manure is not an issue towards environmental contamination and as such no need exists in Bulgaria for anaerobic digestion of animal manure. What become [CM19] more and more important are the raising quantities of municipal organic waste. As stated in *EUROOBSERVER – The state of renewable energies in Europe* [8], in 2011 the total number of biogas installations in Bulgaria was 3, all processing sewage sludge.

85 The composting processes have been reviewed in details [9] as well as various techniques
86 used in compost production, and the methods for determination of compost maturity and
87 quality.

88 There are different ways of treating organic waste, generally subdivided into aerobic and
89 anaerobic processes. Most important limiting parameter in the selection of technologies is
90 the water content in waste, indeed as the water content increases the rate of O₂ diffusion
91 decreases. As O₂ becomes insufficient to meet the metabolic demand, the composting
92 process slows down and becomes anaerobic.

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

96 We will describe two composting plants in Bulgaria. A[CM20] first plant is composting
97 municipal solid waste (MSW) in Plovdiv (Shishmantzi). The second one is a new opened
98 plant for processing food waste “Han Bogrov” in Sofia (Musagenitza).

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

105

106 **2.1 Ecozavod - Plovdiv Plant**

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



117

118 **Figure 1 – Corpus”primary processing” of municipal solid waste in Shishmantzi**

119 Source: <http://ecozavod.com/>

120



Figure 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 [N-P-K]^[CM21], 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 ^[10].

The content of N, P, K and organic C, as well as the pH and the presence of toxic heavy metals [As, Cd, Zn, Pb and Cu]^[CM22] 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.

The ^[experience]^[CM23] 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).

166 The digestate after anaerobic digestion is shown on fig. 3.

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168

169 **Figure 3 – The digestate in “Han Bogrov” – Sofia**

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171 **2.3. Digestate from chicken manure based on Baykov et al. (2005)**

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173 As at this moment anaerobic digestion of manure is not common in Bulgaria, the data for
174 digestate come from the article by Baykov et al. [11] where the researchers analyzed the
175 fermentation of hay-based chicken manure at lab scale. In their experiments the digestate
176 has been prepared from litter from broiler production /LBP/ according to the requirements
177 of Ordinance №22/2001 for the MRL/Maximum Residue Level/ values of toxic elements.
178 The obtained digestate is studied for the content of biogenic and toxic chemical elements
179 by applying the methods described by Jorchem /1993/ with AAS “Perkin-Elmer-4100”
180 (results presented in Table 1 with superscript 2).

181 The digestate obtained after broiler production has been chosen, because according to
182 [CM24] official statistical data of FAOSTAT the distribution in Bulgarian livestock is as follows:
183 poultry - 84,39%; sheep and goats - 9,15%; cattle - 2.94%, swine - 3,25% (fig.4).

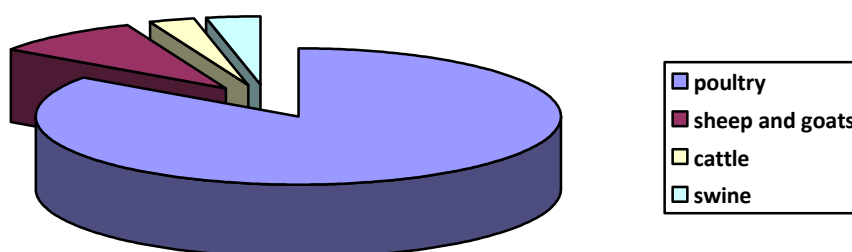


Figure 4 – Distribution of the livestock sectors

3. COMPARISON 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 (2005) 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 [12] with AAS “Perkin-Elmer-4100”.

Table 1 – Comparison of parameters of waste compost and digestate

No.	Parameter	Units	Value (compost ¹) Shishmant si	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: ¹Regional Accredited Laboratory of the Executive Agency of Environment; ²Bayko Baykov et al (2005), ³Accredited Laboratory Complex at AUP

The quality of bio based [CM25] 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 bio based [CM26] 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., 2008 5÷35 g.kg⁻¹ [16], 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 ($1296.7 \text{ mg.kg}^{-1}$ 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} [11] 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 [13]. Possibilities for processing agricultural waste for biogas and bio based fertilisers are discussed too [14].

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 [11] 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 [CM27] there is no manure excess in Bulgaria thus it is easy and cheaper for farmers to dispose their manure.

Therefore [CM28]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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

Author Zahariev managed the data about Shishmantsi, collected information about collection, technology, and development of compost in the factory. Author Penkov collected information about waste distribution, collection, storage in Han Bogrov. Author Verspecht managed the analyses of the study. Author Aladjadjiyan managed and wrote the last draft of the manuscript. All authors read and approved the final manuscript.

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317

318

319 **DEFINITIONS, ACRONYMS, ABBREVIATIONS**

320 Here is the Definitions section. This is an optional section.

321 **Term:** Definition for the term

322

323 **APPEND**

324