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EVALUATION OF USE OF BIOGAS PLANT DIGESTATE AS FERTILIZER IN ALFALFA AND WINTER WHEAT

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Abstract. Anaerobic decomposition of plant residues from which biogas is produced, generates very large amounts of digestate. Due to its physicochemical properties post-digestion liquid can be used as a fertilizer. Post-digestion liquid was used in the field cultivation of fodder alfalfa and winter wheat. The content of macroelements and the content of protein in the grains of winter wheat fertilized with digestate were on the same levels as in the grains of wheat fertilized with mineral fertilizers. The analysis showed a similar content of macroelements in alfalfa leaves fertilized both with post-digestion liquid and mineral fertilizers as well. Fertilizing fields with digestate brings destruction of possible pathogens. Digestate utilization as a fertilizer brings tangible benefits in agricultural production, but it is also a product, the application of which can reduce the negative effects of mineral fertilization and contribute to development of sustainable agriculture. The study has shown that digestate can be used as a fertilizer.

Keywords: digestate, fertilizer, alfalfa, winter wheat.

Introduction

Reduction of the amount of waste can be achieved by means of fermentation processes. Especially the process of anaerobic fermentation has enormous potential for the production of biofuels and bioproducts. Creating added value of bioproducts together with bioenergy opens up a number of opportunities of economic potential growth [1]. Anaerobic digestion of heterogenous waste, such as organic waste and other types of municipal waste, is a promising development of energy bioproduction from organic waste in the world [2] that could be used in several agricultural processes such as olive oil extraction [3-5], almonds postharvest process [6], packaging process [7].

Energy can be obtained in several sustainable ways, such as hydrogen systems coupled with renewable sources[8], geothermal energy, photovoltaic and solar thermal systems [9-11], boilers [12], microturbines [13] or from organic or municipal waste through the process of fermentation. This is a universally popular utilization method. During anaerobic digestion biogas and post-digestion liquid are produced, which can be used instead of mineral fertilizers [14-18]. Methane fermentation is a natural process – it is conducted in anaerobic conditions with the participation of microorganisms: acidogenic, acetogenic and methanogenic bacteria. In the process of methanogenesis most frequently there is decomposed approximately 30-60 % of organic matter introduced into the chamber together with the substrates [19]. Anaerobic digestion has long been used to produce biogas from organic residues, such as sewage sludge, agricultural and industrial by-products. Anaerobic decomposition converts organic waste into two products: biogas and fermented biomass (digestate). This biological process does not only produce renewable energy (biogas), but it also reduces the emission of greenhouse gasses [20-22]. Particular care has to be taken in this biological process because of its intrinsic environmental and safety dangerousness like in other agricultural processes [23-25]. Anaerobic decomposition is a proven technology of biological waste processing; it entails degradation and stabilization of organic materials in anaerobic conditions by bacteria and leads to the production of biogas. The process is becoming a popular technology because of its ability to produce renewable energy from a wide variety of organic wastes from municipal, agricultural and industrial sources, while allowing nutrient recovery through application of the digestate to land. Post-digestion liquid is produced as well, which can be used as a fertilizer in agriculture. It should not be discharged into sewers due to the hazard of bacterial infestation [26].

Fermented biomass has the same or higher agricultural value than liquid manure since it contains more mineral components (including nitrogen) and less organic matter [20; 27; 28]. Digestate also has undesirable properties, such as: smell, viscosity, considerable humidity and high content of fatty acids, which are phytotoxic, this is why digestate can be pathogenic [20; 29].

The use of post-digestion liquid as a fertilizer brings substantial benefits for agriculture; the possibility of using fermented biomass as a fertilizer contributes to improved soil fertility and higher crop yields. The utilization of post-digestion liquid as a fertilizer leads to the reduction of the use of mineral fertilizers [19; 30]. In literature [31-36] it is reported that digestate does not contain any heavy metals, and consequently can be used as a mineral fertilizer, which is an important step towards better environmental protection [37-40].

The aim of the work is to present the possibility of using a post-digestion liquid instead of a mineral fertilizer in field cultivation.

Materials and methods

Digestate obtained from the biogas plant in Piaski (Lubelskie Province) was applied on experimental fields for alfalfa and winter wheat. There were fodder alfalfa of Kometa variety and winter wheat of Zyta variety sown. For the sake of comparison, all the plants mentioned above were sown and fertilized with mineral fertilizers as well. Cultivation fields are located in the experimental farm of the University of Life Sciences in Lublin, in Czesławice Commune, Lubelskie Province. The area of each field was 75 m^2: winter wheat in the first decade of September, 2016 and alfalfa, a perennial, in April, 2015 [41]. In the third year of harvesting (2017) alfalfa was harvested one time. The harvested plants were examined to determine the content of macroelements. Post-digestion liquid was used in the amount of 270 l per 75 m^2. On the field fertilized with mineral fertilizers, for alfalfa sowing, there were used: nitrogen – 20 $kg \cdot ha^{-1}$, phosphorus – 60 $kg \cdot ha^{-1}$, potassium – 80 $kg \cdot ha^{-1}$ [41]. Then, on the field fertilized with mineral fertilizers, for winter wheat sowing, there were used: nitrogen – 140 $kg \cdot ha^{-1}$ (first dose: pre-sowing and for spring pre-sowing cultivation, second dose in the period of shooting, third dose during earing), phosphorus – 62 $kg \cdot ha^{-1}$, potassium – 81 $kg \cdot ha^{-1}$.

Laboratory tests were performed at the District Chemical-Agricultural Station in Lublin and in the Central Agro-ecological Laboratory at the University of Life Sciences in Lublin.

Results and discussion

The post-digestion liquid was tested for the content of macroelements and heavy metals (Table 1). The pH of the digestate used for alfalfa and winter wheat cultivation was 8.39. The digestate sample contained no heavy metals. Moreover, the digestate contains substantial amounts of macroelements, therefore it can be used as a fertilizer. This is confirmed by the investigation conducted last year [30].

Soil samples were tested before and after the use of digestate and after the harvests of alfalfa and winter wheat. The results of the analyses are presented in Tables 2 and 3. The tests of the soil for alfalfa cultivation showed a very slight increase in pH reaction, from 7.46 to 7.50, then it dropped to 7.34 after the wheat harvest. A similar tendency was observed while testing the soil for winter wheat cultivation. The pH reaction increased from 7.59 to 7.60, and after the harvest its value dropped to 7.49. After winter wheat harvest the value of pH reaction was observed to fall to 7.49, which is a basic reaction. After the harvest of winter rape pH reaction value fell to 7.34, which is a neutral reaction.

Table 1

Comparison of macroelements and heavy metals in the digestate used for the field crops

Examined feature	Content in digestate
Phosphorus, $g \cdot l^{-1}$	0.18
Potassium, $g \cdot l^{-1}$	6.12
Calcium, $g \cdot l^{-1}$	0.45
Magnesium, $g \cdot l^{-1}$	0.18
Cadmium, $mg \cdot l^{-1}$	0.40
Lead, $mg \cdot l^{-1}$	0.41
Nickel, $mg \cdot l^{-1}$	0.39
Chromium, $mg \cdot l^{-1}$	0.42
Copper, $mg \cdot l^{-1}$	0.52
Zink, $mg \cdot l^{-1}$	2.08
Manganese, $mg \cdot l^{-1}$	2.39
Iron, $mg \cdot l^{-1}$	74.66

Table 2

Tests for pH and macroelement content in the soil for alfalfa cultivation

Examined feature	Before digestate application	After digestate application	After harvest
Reaction, pH	7.46	7.50	7.34
Phosphorus, mg per 100 g of soil	34.19	45.02	40.58
Potassium, mg per 100 g of soil	8.30	13.89	10.55
Magnesium, mg per 100g of soil	14.49	18.23	15.01

Table 3

Tests for pH and macroelement content in the soil for winter wheat cultivation

Examined feature	Before digestate application	After digestate application	After harvest
Reaction, pH	7.59	7.60	7.49
Phosphorus, mg per 100 g of soil	49.48	55.87	52.41
Potassium, mg per 100 g of soil	16.01	17.93	16.78
Magnesium, mg per 100g of soil	13.28	18.68	17.05

In alfalfa cultivation, after digestate application, the content of phosphorus rose by 10.83 mg per 100 g of soil, potassium by 5.59 mg per 100 g of soil, and magnesium by 3.74 mg per 100 g of soil. As it was in the case of wheat cultivation, also in after alfalfa harvest there was observed decrease in the content of macroelements. In winter wheat cultivation the content of phosphorus rose by 6.39 mg per 100 g of soil, potassium by 1.92 mg per 100 g of soil and magnesium by 5.4 mg per 100 g of soil. After winter wheat harvest there was observed decrease in the content of macroelements. The decrease in the macroelement content after the harvests is connected with good absorption of macroelements by plants.

Table 4 shows changes in the content of macroelements in alfalfa leaves from the sixth harvest.

The highest rise was observed in the content of nitrogen, 0.11 p.p. The relative percent differences were: nitrogen – 3.15 %, phosphorus – 11.76 %, potassium – 1.00 %, calcium – 7.74 %, magnesium – 23.53 %.

Table 4

Content of macroelements in alfalfa leaves from the sixth harvest

Examined feature	Alfalfa sown on the soil fertilized with mineral fertilizers	Alfalfa sown on the soil fertilized with digestate
Nitrogen, %	3.49	3.60
Phosphorus, %	0.17	0.19
Potassium, %	1.99	2.01
Calcium, %	1.46	1.50
Magnesium, %	0.17	0.21

Winter wheat grains were collected from the fields fertilized with mineral fertilizers and digestate. The moisture of the grains collected from the field fertilized with mineral fertilizers was 12.9 %, and from the field fertilized with digestate – 13.4 %.

The elementary feature of wheat grains, which determines their value in use, is protein content. The protein content in the winter wheat grains collected from the field fertilized with mineral fertilizers was 10.84 %, and from the field fertilized with digestate 11.01 %. The relative percent difference for the protein content in the wheat grains is 1.56 %. The changes in the content of macroelements in winter wheat grains are presented in Table 5.

There was a slight percentage increase in the content of macroelements. The relative percent differences were: nitrogen – 3.93 %, phosphorus – 13.33 %, potassium – 9.26 %, calcium – 15.38 %, magnesium – 9.52 %.

Table 5

Content of macroelements in winter wheat grains.

Examined feature	Winter wheat sown on the soil fertilized with mineral fertilizers	Winter wheat sown on the soil fertilized with digestate
Nitrogen, %	1.78	1.85
Phosphorus, %	0.45	0.51
Potassium, %	0.54	0.59
Calcium, %	0.13	0.15
Magnesium, %	0.21	0.23

Conclusions

The examination of soil samples before and after digestate application showed increase in the content of macroelements in the soil, which implies a good fertilizing value of digestate. The analysis of the test results revealed a slight percentage increase in the content of particular macroelements in alfalfa and winter wheat. The examination of winter wheat grains from the soil fertilized with digestate also revealed a rise in the protein content as compared to the winter wheat grains from the field fertilized with mineral fertilizers. Fertilizing fields with digestate brings destruction of possible pathogens. Digestate utilization as a fertilizer brings tangible benefits in agricultural production, but it is also a product, the application of which can reduce the negative effects of mineral fertilization and contribute to development of sustainable agriculture.

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