From waste to table: assessing the biological efficacy of fertilizers derived from anaerobic digestate

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Oral presentation

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Keywords: anaerobic digestion, waste, valorization, agriculture, fertilizer, fertilizer effectiveness

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Food production is closely tied to the global human population, which has grown rapidly in recent years, necessitating increased crop production to meet the needs of people and livestock [1]. This has led to the expansion of cultivated fields and the increased use of fertilizers to enhance crop efficiency. However, the overuse of agrochemicals is considered environmentally unfriendly and is associated with the depletion of natural resources such as natural gas, phosphate, and potassium-bearing rocks [2]. Furthermore, the cost of fertilizers has risen significantly in recent years due to geopolitical conditions and the implementation of new environmental regulations [3].

One solution to these problems may be to utilize waste for fertilizer purposes. By recycling organic waste, which contains many valuable nutrients, it is possible to reduce waste while also reducing greenhouse gas emissions and carbon footprints, thereby promoting sustainable development and aligning with the European Green Deal [4].

Anaerobic digestate is a promising raw material that could be used in fertilizer production. This material is a byproduct of the anaerobic digestion of various organic waste streams, including food waste, agricultural residues, and slaughterhouse waste, and results in the production of biogas. The residue of this process, which exists in solid or liquid form, still contains valuable plant nutrients such as nitrogen, potassium, phosphorus, and organic carbon, and has a low content of toxic metals. As a result, it is suitable for use in crop production as a fertigation fertilizer (liquid fraction) or as a component in the production of liquid or granular organic-mineral fertilizers (liquid and solid fractions), which can replace mineral nitrogen with its organic forms [5].

The purpose of this study was to assess the biological effectiveness of fertilizers made from anaerobic digestate produced from vegetable and food waste. The digestate was sanitized and granulated with sewage sludge incineration ash and urea, with a urease inhibitor added to supplement the nitrogen content, resulting in a multicomponent organic-mineral fertilizer with a high content of micronutrients and amino acids that met the quality requirements set for fertilizers by EU legislation. The fertilizer was then evaluated for its biological efficiency in pot tests, using maize as a model plant. The plants were treated with water (W), liquid anaerobic digestate (AD), granular post-ferment-based fertilizer (GF), and reference fertilizer (RF) at three doses (75%, 100%, and 150% of the standard nitrogen rate of 170 kgN/ha), and the study was conducted under constant soil moisture content (60%) and illumination of 240 lux with a programmed photoperiod of 16:8 day and night, respectively. After 30 days, the plants were subjected to biometric evaluation, including examination of root length, root area, root diameter, chlorophyll content, fresh mass of the plants, and length of the aboveground part of the plants, as well as multi-elemental composition analysis of the dry mass of the plants to assess the content of macro- and micro-nutrients and toxic metals. The obtained results were subjected to statistical analysis.

The pot tests conducted under near-real conditions allowed for the evaluation of plant parameters during the initial stage of growth under the influence of the proposed agrochemicals. The results of the biometric assessment are summarized in Table 1. The study demonstrated that fertilization with the new fertilizer (GF) based on anaerobic digestate, at doses of 75% and 100%, resulted in comparable results to the reference fertilizer (RF) dosed at 100% and 150% N. All biometric evaluation parameters were at the same level, with 100% GF providing a higher chlorophyll content (437 ± 39) and larger root diameter (0.506 ± 0.097), while 100% RF resulted in higher fresh root mass (6.37), fresh stem mass (18.3), and root length (481 ± 187). These results demonstrate that the new fertilizers have a positive effect on the initial stage of plant growth, even with reduced nitrogen dosage, which also has a positive impact on the environment. This may be due to the presence of amino acids in the fertilizer, which are ready-made building blocks for plants and have biostimulatory and metabolic regulatory functions that affect growth parameters [6,7]. The use of AD alone produced less favorable results. At the same dose of nitrogen, the digestate provided decreased amounts of other nutrients, which limited plant growth [8].

Table 1. *Results of biometric assessment of maize seedlings*

Group	N dose	Stem length	Chlorophyll	Root length	Root area	Root diameter	Fresh root mass	Fresh steam mass
	%	cm	mg/m^2	cm	cm^2	mm	g	g
W	-	19.1 ± 4.5^{a,b,c}	347 ± 27^{a,b}	377 ± 56	45.9 ± 9.6	0.387 ± 0.042	3.32	5.90
RF	75	33.9 ± 8.3^{a}	419 ± 39^{a}	387 ± 122	52.6 ± 13.6	0.440 ± 0.042	4.91	21.3
	100	34.0 ± 6.2^{b}	394 ± 3935	481 ± 187	60.6 ± 21.2	0.408 ± 0.039	6.37	18.3
	150	37.0 ± 5.5^{c}	428 ± 21^{b}	326 ± 81	42.7 ± 7.4	0.425 ± 0.048	5.42	20.2
W	-	19.1 ± 4.5^{a,b,c}	347 ± 27^{a,b}	377 ± 56	45.9 ± 9.6	0.387 ± 0.042	3.32	5.90
AD	75	30.2 ± 9.1	405 ± 40	467 ± 117	53.5 ± 15.0	0.362 ± 0.020	3.86	11.4
	100	27.2 ± 9.7	405 ± 40	409 ± 118	54.7 ± 10.8	0.436 ± 0.056	3.37	9.38

	150	30.2 ± 7.3	401 ± 40	377 ± 129	47.9 ± 17.9	0.437 ± 0.132	3.78	12.3
W	-	19.1 ± 4.5^{a,b,c}	347 ± 27^{a,b}	377 ± 56	45.9 ± 9.6	0.387 ± 0.042	3.32	5.90
GF	75	36.0 ± 7.1^{a,c}	422 ± 24^{a}	376 ± 169	47.9 ± 18.8	0.412 ± 0.056	4.35	14.2
	100	34.6 ± 6.9^{b,d}	437 ± 39^{b}	291 ± 148	43.7 ± 19.0	0.506 ± 0.097	4.39	16.4
	150	19.1 ± 1.8^{c,d}	420 ± 50^{c}	241 ± 106	28.5 ± 8.5	0.413 ± 0.121	2.10	9.21

Table 2 summarizes the results of the multielemental analysis of dry plant biomass. These results make it possible to assess the nutritional status of plants through the application of various fertilizers.

Table 2. *Results of multielemental analysis of dry plant biomass*

Group	N dose	N	P	K	Cu	Mn	Zn	Fe
	%	%	mg/kg d.m.					
W	-	1.26 ± 0.13	$5.18 \cdot 10^3 \pm 7.77 \cdot 10^2$	$3.89 \cdot 10^4 \pm 5.82 \cdot 10^3$	6.74 ± 1.01	35.0 ± 5.3	64.4 ± 9.7	221 ± 33
RF	75	1.89 ± 0.19	$9.13 \cdot 10^3 \pm 1.37 \cdot 10^2$	$5.32 \cdot 10^4 \pm 7.99 \cdot 10^3$	10.9 ± 1.6	45.3 ± 6.8	71.9 ± 10.8	226 ± 34
	100	1.97 ± 0.20	$9.52 \cdot 10^3 \pm 1.43 \cdot 10^2$	$5.21 \cdot 10^4 \pm 7.81 \cdot 10^3$	5.94 ± 0.89	52.2 ± 7.8	70.5 ± 10.6	250 ± 37
	150	2.55 ± 0.25	$1.24 \cdot 10^4 \pm 1.86 \cdot 10^2$	$5.15 \cdot 10^4 \pm 7.72 \cdot 10^3$	6.16 ± 0.93	60.3 ± 9.0	82.3 ± 12.3	217 ± 33
W	-	1.26 ± 0.13	$5.18 \cdot 10^3 \pm 7.77 \cdot 10^2$	$3.89 \cdot 10^4 \pm 5.82 \cdot 10^3$	6.74 ± 1.01	35.0 ± 5.3	64.4 ± 9.7	221 ± 33
AD	75	2.84 ± 0.28	$3.77 \cdot 10^3 \pm 566$	$4.53 \cdot 10^4 \pm 6.79 \cdot 10^3$	8.00 ± 1.20	35.6 ± 5.3	152 ± 23	250 ± 37
	100	3.01 ± 0.30	$3.60 \cdot 10^3 \pm 539$	$4.45 \cdot 10^4 \pm 6.67 \cdot 10^3$	4.84 ± 0.73	42.9 ± 6.4	58.3 ± 8.7	462 ± 69
	150	3.86 ± 0.39	$3.91 \cdot 10^3 \pm 587$	$5.34 \cdot 10^4 \pm 7.99 \cdot 10^3$	4.85 ± 0.73	43.6 ± 6.5	65.3 ± 9.8	356 ± 53
W	-	1.26 ± 0.13	$5.18 \cdot 10^3 \pm 7.77 \cdot 10^2$	$3.89 \cdot 10^4 \pm 5.82 \cdot 10^3$	6.74 ± 1.01	35.0 ± 5.3	64.4 ± 9.7	221 ± 33
GF	75	2.52 ± 0.25	$4.36 \cdot 10^3 \pm 654$	$4.78 \cdot 10^4 \pm 7.17 \cdot 10^3$	5.62 ± 0.84	36.5 ± 5.5	60.0 ± 9.0	519 ± 78
	100	3.26 ± 0.33	$5.11 \cdot 10^3 \pm 767$	$4.90 \cdot 10^4 \pm 7.35 \cdot 10^3$	8.60 ± 1.28	41.9 ± 6.3	78.2 ± 11.7	424 ± 64
	150	3.84 ± 0.38	$6.17 \cdot 10^3 \pm 925$	$5.09 \cdot 10^4 \pm 7.64 \cdot 10^3$	10.8 ± 1.63	40.0 ± 6.0	86.8 ± 13.0	708 ± 106

The fertilization with product based on anaerobic digestate (GF) resulted in better plant nutrition in terms of nitrogen and iron, while the fertilization with reference fertilizer (RF) resulted in better nutrition in terms of potassium and manganese. The higher uptake of nitrogen by plants from the GF fertilizer is attributed to the presence of amino acid nitrogen [9], while the presence of iron is attributed to its presence in the ash from sewage sludge combustion [10]. Additionally, a correlation was observed between the increase in nitrogen content in plant biomass and the increasing dosage. Specifically, the nitrogen contents for doses of 75%, 100%, and 150% were 2.52, 3.26, and 3.84 for GF, and 1.89, 1.97, and 2.55 for RF, respectively.

Acknowledgments

This work was financed by European Union's Horizon2020 Research & Innovation Programme under grant agreement No 696356 and from the Executive Agency for Higher Education, Research, Development and Innovation Funding - UEFISCDI (Romania), the National Centre for Research and Development – NCBR (Poland), Agenda Estatal de Im/estigación - AEI (Spain), and the Ministry of Agriculture and Forestry- MMM (Finland).

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