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PRODUCTION OF FERTILIZERS FROM BIOWASTES FOR ORGANIC AGRICULTURE

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ABSTRACT

Biowastes (garden and park wastes, food and kitchen wastes from households and restaurants) are a group of municipal wastes, which mass has recently increased significantly. Currently due to the rapid increase in the mass of municipal solid waste, it must be perceived as a multidimensional global problem. Thus proper waste management must be developed to attain such goals as prevention of waste generation and reduction of its volume, as well as encouraging its reuse and raw material recovery. Biowaste composting is a popular and cheap solution, in line with the circular economy concept and principles of sustainable management of organic mass. Such composts can be important organic fertilizers for use in organic agriculture. However, the quality of composts must be valorized and verified, the more so as they are made of waste of different origins. In this study, the quality of composts and vermicompost prepared from various biowastes was assessed in terms of their use for organic agriculture. In the analyzed materials the content of macro- and micronutrients essential for plants, heavy metal amounts as well as the quantity and quality of humic compounds were determined. On the basis of the obtained results it can be concluded that both vermicompost and composts showed good quality, serving as a valuable source of organic matter and nutrients for plants and thus they can be used for organic agriculture. Moreover, the content of heavy metals in these organic materials did not exceed the permissible standards.

Keywords: *organic wastes, vermicompost, compost, macro- micronutrients, humic compounds*

INTRODUCTION

Maintaining soil fertility and health in organic farming is based on the use of natural fertilizers, which include mainly manure, slurry, green manure and composts. Chemical composition of manure or slurry in the case of animal fertilizers mainly depends on the species, age, sex, breeding direction, feed and fertilizer storage conditions. Composts as fertilizers of plant origin are produced as a result of the composting process, which can take place at different rates and for which various plant raw materials can be used. As a result, composts differ in their chemical composition, and hence in their potential impact on the soil environment and plants. Currently, in many European countries the principles of circular economy are being implemented (Jakubus, 2020), which indicates the legitimacy and necessity of reusing waste as a valuable raw material. Composting of selectively collected biomass waste fits with this type of ideas and principles. Moreover, such a method of recycling biodegradable waste is positively perceived both by the inhabitants and local authorities (Jakubus and Michalak-Oparowska, 2021). Among educational campaigns, home composting of household waste is promoted and the obtained fertilizers are used by residents for their own purposes, mainly fertilizing garden plants or planting potted plants. Additionally, in Poland there is a well-developed network of composting plants producing compost from biowaste for commercial purposes. Composts are an excellent alternative to manure, especially when it is unavailable on the local market. However, as previously mentioned, composts can be of different quality due to the variety of raw materials and composting conditions. Therefore, in this study a qualitative assessment was conducted for 3 composts obtained on the basis of selectively collected biowaste, but composted in a different manner.

MATERIALS AND METHODS

According to the list of waste referred to Article 7 of Directive 2008/98/EC, used wastes belong to the same group of municipal wastes, code 20 (food and kitchen wastes from households and biowastes from the garden). These wastes collected separately by inhabitants were used in the composting process. The detailed information concerning used biowastes and conditions of the composting process are given in Table 1.

Table 1 Raw materials and technology used for individual composts

Organic fertilizer	Raw materials	Technology
VC	Food and kitchen wastes from households	Vermicomposting process was carried out in the household in a vermicomposter. A mixture of apple pomace with earthworms (*Eisenia fetida)* was used as an initial input material for the vermicomposting process. The biowaste for the vermicomposter was delivered with a varying frequency and in different amounts, which depended on the activity of the household.
C1	Mixture of yard trimmings as plant residues except for mowed grass clippings	C1 was prepared by the aerobic method as a fertilizer for their home gardens by private home owners. The composting process was carried out in home composters made of thermoplastic. The temperature of the composting process depended on weather conditions. The organic material was successively collected in containers without

		any mixing of the bulk volume. Under such conditions the organic waste mixture was kept for a year. After this time, the whole mass was mixed to homogenize it and then transferred to dark plastic bags to complete the maturation stage.
C2	Mixed wood, forestry and agricultural residue, garden and park wastes, food and kitchen wastes from households and restaurants	The composting process under controlled bioreactor conditions in a composting plant until the completion of the cooling phase of composting. The maturation stage of compost run in an open shed and lasting 2 months depending on weather conditions.

The chemical analyses were conducted on dried samples. Organic matter (OM) in composts (C1, C2) and vermicompost (VC) was determined by the loss-on-ignition test (dry combustion for 6 hours at a temperature of 550^{o}C). The obtained ashes of composts were used to assess the amounts of macronutrients (K, Mg), micronutrients (Mn, Zn, Cu) and heavy metals (Pb, Cr) after extraction in 6 mol·dm^{3} HCl (Ostrowska *et al.*, 1991) using atomic absorption spectrophotometry in a Varian Spectra AA 220 FS apparatus. In the same extracts phosphorus (P) content was measured colorimetrically by the vanadium–molybdenum method. Total organic carbon (TOC), nitrogen (N) and sulphur (S) contents were determined using Vario Max CNS. Humus fractionation was determined according to the method proposed by Kononova and Bielczikova (Dziadowiec and Gonet, 1999), in which humic substances were determined in a mixture of 0.1 mol·dm^{-3} $Na_4P_2O_7$ + 0.1 mol·dm^{-3} NaOH solution. Optical density ($Q_{4/6}$) of the obtained fractions was determined at 465 nm and 665 nm. The fulvic acid fraction (FA) was separated after precipitation of humic acids at pH 1.5 (HA). Carbon in the obtained fractions (C_{HS} and C_{FA}) was oxidized by 0.1 mol·dm^{-3} $KMnO_4$ in the H_2SO_4 medium. Humic acid carbon (C_{HA}) was calculated by subtracting C_{FA} from C_{HS}. On the basis of C_{HA} and C_{FA} degree of polymerisation (DP), was calculated for VC and C1 and C2 according to equation: DP = C_{HA}:C_{FA} The labile carbon (LC) was assessed by $KMnO_4$ oxidation (Łoginow *et al.*, 1987). All the assays determining the amounts of individual elements in the tested samples were performed in six replications and the presented results are their mean values. The obtained results were subjected to formal evaluation by the analysis of variance using the F test at the significance level p≤ 0.95. The least significant differences were calculated using the Tukey test at the significance level α≤ 0.05 and then uniform groups within the factor level were established.

RESULTS AND DISCUSSION

In general, VC was characterized by statistically higher amounts of OM, CHS and $Q_{4/6}$ (Table 2) as well as macronutrient contents (N, P, K, S, Mg) (Figure 1) with the lowest amounts of micronutrients (Cu, Zn, Mn) (Table 3). Compost No. 2 was characterized by significantly higher contents of LC (Table 2) as well as higher amounts of micronutrients (Mn, Zn, Cu) and Pb content (Table 3). Generally, for C1 the smallest amounts of macronutrients (Figure 1), OM, CHS, LC (Table 2) were determined. The contents of Mn, Zn and Cu in C1 did not differ significantly from those determined for VC (Table 3). The amounts of Cr were the same for C1 and C2. The mentioned composts had the same $Q_{4/6}$ values (Table 2). Compost No. 1 characterized by the lowest Pb amount (Table 3). In Poland VC and Cs dedicated to agricultural use have to meet specific threshold amounts of N, P, K, organic matter and heavy metals given in the Regulation of the Minister of Agriculture and Rural Development (2008). According to this the content of OM must be at least 30% d.m., the amount of potassium (K_2O) and phosphorus (P_2O_5) should be more than 0.2% d.m., while the total N value should be min. 0.3% d.m. The tested fertilizers met the criteria for N, P, K, but the one required OM content was not found only for C1. At this point, it should be emphasized that the raw materials used and the composting technology applied had a major impact on the abundance in nutrients of composts and vermicompost. In literature one can find various contents of macro- and micronutrients, both similar, lower and higher than in this study (Sciubba *et al*., 2015, Ibrahim *et al*., 2019, Jakubus, 2020, Singh *et al*., 2020, Jakubus and Michalak-Opraowska, 2022). According to the above-mentioned Regulation vermicompost or compost cannot exceed, among other things, 100 $mg \cdot kg^{-1}$ Cr and 140 $mg \cdot kg^{-1}$ Pb. The EU guidelines (Commission Regulation 2008) in this regard are more restrictive, because the amount of Pb in composts cannot be higher than 45 $mg \cdot kg^{-1}$, and Cr greater than 70 $mg \cdot kg^{-1}$ d.m. Nevertheless, the tested fertilizers were characterized by much smaller amounts of heavy metals. It is worth emphasizing this fact because many authors (Jakubus, 2020, Ibrahim *et al*., 2019, Rodrigues *et al*., 2020) gave significantly higher amounts of Cr and Pb for composts. It should be noticed that composts are a significant source of organic matter, including carbon compounds, especially humic substances. Humic substances mainly consist of fulvic and humic acids. Fulvic acids are compounds weakly polymerized and relatively readily undergoing chemical and microbiological changes, which results in their considerable solubility and mobility. In turn, HAs are generally recognized as being non-degradable or sparsely degradable compounds with a strongly polymerized structure (Yu *et al*. 2019). Generally immature composts contain a high FA content, while HA dominates in mature composts. According to this the obtained data indicate that the maturation degree was favorable in the case of C2. Although the amounts of SH for CV and C2 did not differ statistically, the proportion of FAs and HAs was different as shown in Figure 2 and FAs (57%) predominated in the HS of CV, while the HAs (65%) predominated in HS of C2. The percentage share of FAs and HAs for C1 was comparable, accounting for 49.5% and 50.5%, respectively. When assessing the quality of vermicompost and composts the evaluation of their stability and maturity is also essential. It is an extremely important element of composting, because an unstable and immature organic material may have adverse effects on plant growth and the environment. The assessment of composts in this respect can be made based not only on the HS composition, but also on the value of C:N. In these studies, the values of C:N were the same regardless of the tested fertilizer (Table 2). Jakubus and Michalak–Oparowska (2022) cited various authors indicating that the C:N ratio for the matured compost should range at 9-20:1. Taking this criterion into account, the tested composts can be considered mature and usable for soil fertilization. The $Q_{4/6}$ ratio is negatively related to the aromatic polycondensation degree and molecular weight of humic substances. High $Q_{4/6}$ values imply the presence of low molecular weight aromatic molecules, which in contrast to $Q_{4/6}$ low values indicate high contents of large molecular weight molecules, such as humic–like compounds, usually present in well-matured organic materials (Alvarenga *et al*., 2016). In the present study the analyzed vermicompost and composts also showed comparable values of optical density expressed as $Q_{4/6}$; however, slightly lower values were found for C1 and C2. Compost maturation can be also assessed on the basis of C_{HA}:C_{FA} (DP). Azim *et al*. (2018) based on a literature review stated that the correct threshold value of the polymerization degree needs to be greater than 1. Taking into account that threshold it may be assumed that all analyzed organic fertilizer meet this criterion, because the values were 1.0, 1.1 and 1.2 for C1, VC and C2, respectively (Table 2). In terms of the quality of carbon connections, one should also interpret the amounts of labile carbon (LC), which were the highest for C2 (1.18 $g \cdot kg^{-1}$) and the smaller for C1 (0.38 $g \cdot kg^{-1}$) (Table 2). Labile carbon represents the most active pool of organic carbon that is susceptible to microbial degradation. Taking into account the fact that the LC is more susceptible to decomposition it can theoretically be assumed that they may play an important role in the transformation of VC and Cs in the soil. The rapid degradation of easily mineralizable LC can contribute to enhancing the microbial activity of the soil, as well as releasing N and S from easily mineralizable combinations.

Table 2. The amounts of organic matter (OM), humic substances (CHS), labile carbon (LC) as well as values of degree of polymerisation (DP) and optical density ($Q_{4/6}$) obtained for analysed organic fertilizers

Organic fertilizer	OM	CHS	LC	C:N	DP	$Q_{4/6}$
	$g \cdot kg^{-1}$					
VC	494.9a	34.4a	0.97b	10:1	1.1	8.12
C1	192.9b	23.9b	0.38c	10:1	1.0	6.92
C2	357.9b	31.3a	1.18a	10:1	1.2	6.92

Table 3. The mean content of metals in analysed organic fertilizers ($mg \cdot kg^{-1}$)

Organic fertilizer	Mn	Zn	Cu	Pb	Cr
VC	90.9b	5.1b	16.5b	11.5b	7.6a
C1	103.4b	7.5b	18.7b	2.7c	4.4b
C2	182.4a	22.6a	36.1a	22.4a	4.4b

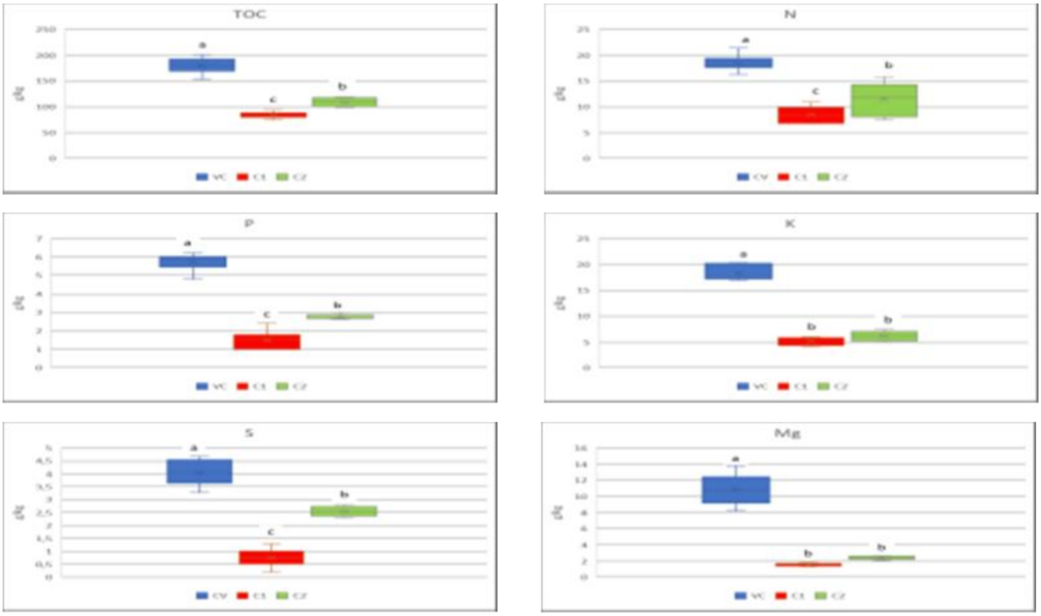

Fig.1 The mean macronutrient contents in organic fertilizers

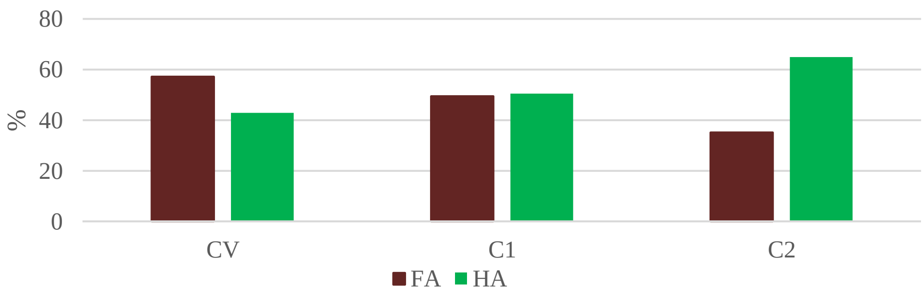

Fig.2 The percentage share of FA and HA in humic substances of organic fertilizers

CONCLUSION

The conducted research has shown that the quality of composts is the result of both different raw materials and the composting processes carried out. The assessed parameters allowed to evaluate the fertilising value of composts. The worst quality was found for compost No. 1 prepared using a backyard composting method only from green waste. Vermicomposting of kitchen waste resulted in favorable amounts of OM, CHS and macronutrients. On the other hand, compost No. 2 produced in professional installations was characterized by higher amounts of micronutrients and favorable values of humification parameters. Since the content of heavy metals in VC and Cs did not exceed the permissible standards, high safety of their soil application should be underlined. Regardless of the differences shown, the tested organic fertilizers can be used by individual households for their own purposes, including gardening and agricultural purposes, for soil fertilization, which clearly underlines the importance of recycling biowaste both at the household level and on an industrial scale. At the same time, it should be remembered that when using composts in organic agriculture, they should undergo a certification process based on applicable standards.

REFERENCES

Alvarenga, P., Mourinha, C., Farto, M., Santos, T., Palma, P., Sengo, J.M.C., Morais, M.C., Cunha-Queda, C. (2016). Quality assessment of a battery of organic wastes and composts

using maturity, stability and enzymatic parameters. Waste Biomass Valorisation, 7, 455 – 465.

Azim, K., Soudi, B., Boukhari, S., Perissol, C., Roussos, S., Alami, T. (2018). Composting parameters and compost quality: a literature review. Organic Agriculture, 8, 141-158.

Commission Regulation (EC) No 889/2008.

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives OJ L 312, 22.11.2008, p. 3.

Dziadowiec, H., Gonet, S. (1999). A methodological guide to soil organic matter research. 1st ed. Publisher: PTG Warszawa, Poland, 120, 43-51 (In Polish).

Ibrahim, M.I.M., Awad, E.A.M., Dahdouh, S.M.M., El-Etr, W.M.T., Ibrahim, A.S.M. (2019). Characterisations of some organic materials sources and analysis of the humic acids extracted from them. *Zagazig Journal of Agricultural Research* 46(3), 685 – 698.

Jakubus, M. (2020). A comparative study of composts prepared from various organic waste based on biological and chemical parameters. Agronomy, *10*(6), 869.

Jakubus, M.; Michalak-Oparowska, W. (2021). Social participation in the biowaste disposal system before and during the COVID -19 pandemic. A case study for Poznań**.** Environment Protection Engineering, 47, 2, 109-123.

Jakubus M., W. Michalak – Oparowska (2022). Valorisation of vermicomposts and composts quality using various parameters. *Agriculture, 12,* 293.

Łoginov, W., Wisniewski, W., Gonet, S.S., Cieścinska, B. (1987). Fractionation of organic carbon based on susceptibility to oxidation. Polish Journal of *Soil Science*, 20, 47-52.

Ostrowska, A., Gawliński, S., Szczubialka, Z. (1991). Methods for analysis and evaluation of soil and plant properties, 1st ed. Publisher: IOŚ Warszawa, Poland, 158-167 (in Polish).

Regulation of the Minister of Agriculture and Rural Development of 18 June 2008. Journal of Laws 2008, 119, item 765 (in Polish).

Rodrigues, L.C., Puig-Ventosa, I., López, M., Martínez, F.X., Ruiz, A.G., Bertrán, T.G. (2020). The impact of improper materials in biowaste on the quality of compost. Journal of Cleaner Production, 251.

Sciubba, L., Cavani, L., Grigatti, M., Ciavatta, C., Marzadori, C. (2015). Relationships between stability, maturity, water-extractable organic matter of municipal sewage sludge composts and soil functionality. *Environmental Science* and *Pollution Research,* 22, 13393–13403.

Singh, S., Singh, J., Kandoria, A., Quadar, J., Bhat, S.A., Chowdhary, A.B., Vig, A.P. (2020). Bioconversion of different organic wastes into fortified vermicompost with the help of earthworms: A comprehensive review. *International Journal of Recycling of Organic Waste in Agriculture,* 9, 432-439.

Yu, H.; Xie, B.; Khan, R.; Shen, G. (2019). The changes in carbon, nitrogen components and humic substances during organic-inorganic aerobic co-composting. Bioresource Technology, 271, 228-235.