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Research Article

THE INFLUENCE OF RED WORMS (*E. FOETIDA*) ON COMPOST'S FERTILIZING PROPERTIES

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ABSTRACT

Composting is becoming a more and more common way of biodegradable waste disposal. Composts should be characterized by high content of nutrients and low amount of pollutants. Vermicompost is a compost produced by overpopulated culture of earthworm *Eisenia foetida* (Savigny 1826). World scientific literature states that vermicompost has a high fertilizing value which often exceeds such value of conventional composts. The results showed that vermicompost has a much higher fertilizing value than the compost produced by the traditional pile method. However, prism vermicompost created with the participation of a less concentrated population of earthworms has an intermediate value as a fertilizer (nitrogen and heavy metals), it could be assessed as a lower value product due to the lower content of potassium and phosphorus than the material obtained without earthworms.

Keywords: vermicompost, earthworm compost, *Eisenia foetida*, fertilizing properties

INTRODUCTION

Vermicompost (earthworm compost) is the final product of organic matter after being broken down by earthworms in a mesophilic composting process called vermicomposting. The red worm Eisenia foetida is widely considered as the best species at converting organic matter into compost, what is more, it feeds intensively and breeds most quickly. Composting is a biochemical process that uses microorganisms to aerobic organic matter decomposition. In the vermicompost method microorganisms begin the process, but it is the red worm that plays the largest role in converting organic matter subjected to preliminary decomposition processes (e.g. hydrolysis or fermentation). Composting by those organisms are the most effective between 15 and 25 °C, and with humidity between 60 and 70%. If the conditions are beyond the optimum scope, the effectiveness declines [Edwards 1995, Suthar 2009]. During the typical composting process a high temperature (55–65 °C) guarantees composted hygienic organic waste but also significantly eliminates earthworms' activeness. Possible waste that can be utilized by vermicomposting is mainly kitchen waste, green waste, farm animals' excrement, and selectively gathered municipal waste's organic fraction and sewage residue.

Vermicompost method can be effectively used to utilize homogeneous waste that traditional composting could not handle, e.g. paper production waste or textiles [Kostecka 1999, Suthar 2009]. Nevertheless, it is important to add structural material that is rich in coal. The best conditions for breeding and generating active earthworms, are foods which contain 60% cellulose and 10 to 20% protein. Earthworms do not tolerate spicy or acidic food waste such as: onion, garlic, or citrus fruits. Furthermore, fats, bones, and animal waste have a negative effect to the composting process [Kostecka 1999, Munroe 2009, Songin 1994, Suthar 2009].

The main aim and advantage of the vermicompost method is a quick neutralization of organic matter along with generation of organic fertilizer which is a valuable source of organic coal for soil [Evanylo et al. 2008]. The two main advantages of vermicomposting are: creating a compost which is a valuable fertilizer and earthworm biomass, which can be used as fish bait or substrate to production of protein flour.

The compost, highly contained with macro- and microelements, not only enriches soil but can also be used as a bed for flowers or perfect matter for soil and soil-less beds, and finally as a sorbent of oil derivatives and heavy metals in low polluted soils [Olszewska 2001, Rosik-Dulewska and Ciesielczuk 2010, Wróbel and Nowak 2005]. Some researchers suggest to use vermicompost only as an additive to flower beds because of its salinity [Kostecka 1998]. However, its diluting reduces the salt to the levels that are harmless for plants. Other positive effects of vermicompost on plants include: increased sprouting, the limiting of fungi occurrence and limited stress while replanting [Edwards 1995, Olszewska 2001, Tripathi 2004].

LEGAL FRAMEWORK

Legal framework regulating waste management in Poland is the Act on waste of 21 April 2001 [Journal of Laws of the Republic of Poland 2010 No. 28 pos. 145 with further changes]. Among others, it regulates time horizons and sets the time when biodegradable waste mass should be reduced from 50 to 35% respectively in 2013 and 2010 in comparison to the base year: 1995. It means that more and more professional composting plants are founded, as well as composting in households is becoming a way to reduce the cost of mixed waste. The act from 10th July 2007 [Journal of Laws of the Republic of Poland No. 147 pos. 1033] on fertilizers and fertilizing regulates the conditions and the way of marketing fertilizers, additives encouraging plant growth and their usage in agriculture. The Act of Ministry of Agriculture and Rural Development of 18th June 2008 (Journal of Laws of the Republic of Poland No. 119 pos. 765], in respect to putting into effect several acts considering fertilizers and fertilizing, sets minimal quality requirements and permissible heavy metals concentrations in fertilizers. Using (mainly in reclamation process) low quality compost (not suitable for fertilizing) is allowed by Act 10 from 22nd April 2011 [Journal of Laws of the Republic of Poland No. 86 476].

EXPERIMENTAL MATERIAL AND STUDY DESIGN

The studied area included composts generated in individual households. Compost samples were taken from kitchen and garden waste (KO) made by a prism method and two types of vermicompost: the first one was made of kitchen and garden waste (WK), and the second one from kitchen and garden waste (KM) that was created by vermicomposting using a condensed red worm *E.foetida* population. This sample was the only one from the tested samples that originated from Upper Silesia; the following two samples (WK and KM) were created in a rural area near Opole. All tested composts were made in sheltered composting plants that allowed rainwater to seep into the compost mass, while in the case of WK vermicompost, seeping rainwater was completely eliminated. For the sake of the experiment the KM composting plant used 500 adult red worms (*E. foetida*). In the examined composts the humidity, organic matter, nitrogen, phosphorus, acidity and the proper electric conduction (according to Polish Norms) were determined. Quantification of sodium, potassium, and calcium was determined by FES methods. Heavy metals were determined by an atomic absorption spectroscopy using the iCE-Thermo 3500 after previous wet microwave mineralization in aqua regia in MARS-X apparatus.

RESULTS AND DISCUSSION

Applying compost causes multiple, positive changes in the physicochemical properties of soil fertilized by the compost [van der Gaag et al. 2007]. A crucial direction of those changes shows a significant increase, stabilized reaction and, subsequently, limitation of soils susceptibility to acidification. Those changes are particularly crucial in cases of rehabilitation process of soilless and saline areas [Lakhdar et al 2009]. Nevertheless, composts' reaction and organic matter content depend not only on the content of waste being composted but also on the effectiveness of waste selecting system [Lopez et al 2010 Montemurro et al 2010]. In Table 1 basic characteristics of the examined composts is presented.

Table 1. Characteristics of main investigated composts properties

Typ kompostu	WK	KO	KM	Dz.U. 2008 no 119, pos. 765
pH	6.83 (0.11)	6.84 (0.08)	7.00 (0.03)	nl
EC [mS/cm]	3.63 (1.07)	1.23 (0.15)	1.26 (0.07)	nl
Organic matter [%]	71.92 (5.36)	37.58 (1.13)	30.68 (8.46)	30
Nitrogen Kiejdahl $N_{(Kiejd)}$ [%]	2.97 (0.28)	1.10 (0.90)	1.49 (0.13)	0.3
Phosphorus P_2O_5 [%]	1.37 (0.04)	1.33 (0.16)	1.25 (0.09)	nl
Potassium K_2O [%]	2.34 (2.11)	0.80 (0.71)	0.67 (0.06)	0.2
Sodium Na_2O [%]	0.22 (0.01)	0.09 (0.00)	0.09 (0.00)	0.2
Calcium CaO [%]	1.29 (1.30)	0.90 (1.00)	0.25 (0.11)	nl
TOC [%]	34.48 (1.92)	16.07 (0.62)	13.01 (0.83)	nl

n = 3 (SD value in brackets).
nl – no limitated.

All tested samples are characterized by a neutral reaction and are nearly similar; nevertheless, in comparison to the scientific research data, the observed pH levels are slightly lower [Ciesielczuk et al. 2011].

The salinity of the tested composts (expressed with EC value) is low, only the WK samples are characterized by a slightly higher concentration of soluble salt which is 3.63 mS/cm, what is confirmed by other authors [Pączka and Kostecka 2013]. It is the effect of limited or no access of rainwater and, consequently, the leaching soil from compost which is proven by a nearly two times higher content of sodium and potassium ions in comparison to KO and KM composts. The conductivity values of KO and KM composts are typical for composts made by a prism method and not sheltered against precipitation, especially since the composting took place during heavy rain. However, the compost produced from municipal solid waste reached even higher EC values, exceeding even 7–8 mS/cm [Hargreaves et al. 2008, Saha et al. 2010]. A particularly important fertilizer's parameter is the content of organic matter. The vermicompost (WK) was characterized by the highest content of organic matter, while in composts KO and HP (produced in composts plants which allowed access of rain water) the value of this parameter was approximately two times lower. This may partly result from DOC losses resulting from the leaching by rainfall and a slightly different composition of the composted material.

WK compost is very rich in nitrogen, only vermicompost from municipal sewage sludge may contain more of it – up to 3.2% [Khwairakpam and Bhargava 2009]. Lower content of this element (0.8–1.5%) was observed in samples PS and KO made by the traditional prism method [Nagavallemma et al. 2004]. Despite significant nitrogen content (especially in samples WK) all tested composts were mature, characterized by the C / N ratio within 8.7–11.6.

The potassium content in the tested vermicompost WK (2.3%) far exceeds the amount of this element in other vermicomposts [Fernández-Gómez, 2009]. This is probably the result of waste composition being composted (kitchen waste) and the lack of leaching this element by rainfall. Potassium content in the samples of KM and KO (Table 1) are typical for the composts produced by the prism method [Evanylo et al. 2008].

The highest phosphorus content was determined in samples of WK compost, slightly less in the samples of composts KO and KM. These values are close but other organic fertilizers, such as manure is richer in this element [Bansal and Kapoor, 2000]. It is believed, however, that the enzymes in the digestive tract of earthworms (and remaining coprolites) convert phosphorus compounds to form what is available to plants – as a result, vermicomposts have a higher content of available phosphorus forms in comparison to the material formed without their participation [Suthar, 2009]. All the tested composts comply with the minimum nitrogen content (0.3%), potassium oxide and phosphorus oxide (0.2%) in organic fertilizer as defined in the Regulation of Ministry of Agriculture and Rural Development on the implementation of certain provisions of the Act on fertilizers and fertilization of 18 June 2008, including later amendments.

The highest calcium content was also determined in the compost WK (1.29%). This is, however, due to the addition of calcium carbonate to vermicompost, which was used to prevent pH lowering below the optimum value for earthworms and bacteria (including endosymbiotic). The recorded calcium content values in composts KO (0.90%) and KM (0.25%) are lower than in comparison to composts produced by the prism method. An over normative heavy metal content in compost is one of the reasons disqualifying compost from applying it as a fertilizer. Comparison of the results for the six heavy metals to the current standards is shown in Table 2. Segregation of municipal solid waste „at source", results in lowering the amount of heavy metals, even up to the level normally recorded in the soils [Rosik-Dulewska 2003, Smith 2009].

Among the tested samples, compost WK contains the lowest amounts of heavy metals, significantly below the maximum amounts allowed by the regulation of the Minister of Agriculture and Rural Development dated 18 June 2008 No 119 pos. 765. The content of chromium and zinc is the lowest of the compared data: two composts produced in households in Opole (GU) and Opole Voievodeship (KS), where chromium content was respectively (in mg / kg dm), 79.78 and 15.07, and zinc content 276.90 and 167.61 [Ciesielczuk and Kusza 2009]. It is expected that after the implementation of the act on fertilizers and fertilization, the major factor eliminating the use of compost as a fertilizer is going to be the zinc content. In the studied vermicompost only cadmium content is increased, but does not exceed the legally permitted limits. The reason for such a low content of heavy metals in vermicomposts seems to be the ability of cumulating metals in earthworms' tissues which argues for the popularization of this composting method [Edwards 1995].

This phenomenon is confirmed by the results obtained for composts KO and KM. The heavy metal content in compost KO is relatively high. Quantities of lead and cadmium content are higher than allowed by Polish as well as Canadian legislation, and thus compost KO can not be used as a fertilizer, but it is possible to use it for rehabilitation purposes [Journal of Laws of the Republic of Poland No. 86 pos. 476]. The content of zinc and chromium are also the highest among the compared composts. Copper and nickel content is quite high, but does not exceed the permissible limits in Poland [Journal of Laws of the Republic of Poland No. 86 pos. 476 and Journal of Laws of the Republic of Poland from 2008 No 119 pos. 765]. The high content of heavy metals, especially cadmium and lead may appear due to the location where the composting process took place, which was in urban areas, near highly concentrated industrial zones (Upper Silesia), and a large part of the mass was biodegradable garden waste.

Compost KM which was made by red worms E. foetida contains small amounts of heavy metals, considerably below the maximum permitted by the law. Cadmium content is low and comparable for compost produced from biodegradable waste selected at the source [Ciesielczuk and Kusza 2009]. Nickel and chromium contents are very low – only compost WK contains fewer of them. The quantities of zinc and lead stays at an average level of the three compared to paper composts.

CONCLUSION

On the basis of the obtained results it was found that only two composts analyzed in this study (WK and KM) meet the requirements for organic fertilizers regarding the minimum content of nitrogen (0.3%), phosphorus and potassium in the oxide form (0.2%) and organic matter (30%) specified in the aforementioned regulation on the implementation of certain provisions of the act on fertilizers and fertilization. Vermicompost WK is a fertilizer particularly rich in nutrients, which is also confirmed by scientific data. This is due

Table 2. Heavy metals content in investigated composts and law concentrations limits (mg/kg d.w.)

Compost type	WK	KO	KM	Dz.U. 119, pos. 765	Dz.U. 86, pos. 476	CCME 2005 limits
Zinc (Zn)	154.35	1122.84	219.10	nl	2500	nl
Copper (Cu)	16.30	52.81	22.49	nl	800	< 400
Nickel (Ni)	6.98	15.70	7.51	< 60	< 200	< 62
Chromium (Cr)	5.16	39.72	6.30	< 100	< 800	< 210
Lead (Pb)	4.91	145.54	22.75	< 140	< 800	< 150
Cadmium (Cd)	1.52	5.46	0.53	< 5	< 25	< 3

nl – no limitated; CCME – Canadian Council of Ministers of the Environment, PIN 1340.

to the presence and activity of earthworms and, indirectly, their symbiotic bacteria. High salinity of vermicompost, which results not only from the composition of the composted waste, but also from a lack of salt leached by precipitation, which forces the use of this fertilizer in small doses, precisely targeted not only to the type of soil but also to its salinity. Among the tested materials, compost KO can not be classified as organic fertilizer, due to noted excess amounts of heavy metals such as cadmium and lead, but still can be used in accordance with the provisions of the regulation on the recovery of R10 22.4.2011 [Journal of Laws of the Republic of Poland No. 86 pos. 476]. Compost KM, despite the participation of a condensed earthworm population in the process of composting, is less rich in phosphorus, potassium and calcium. This may result from heavy rainfall and leaching of these elements from the compost. All in all, using E foetida earthworms favors rapid production of high quality compost, which can successfully be used as organic fertilizer.

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