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Janusz Ryszard MROCZEK[1*] and Joanna KOSTECKA[1]

EFFECT OF SAPONIN EXTRACT ON VERMICOMPOSTING OF SELECTED ORGANIC WASTE

WPŁYW EKSTRAKTU SAPONINOWEGO NA WERMIKOMPOSTOWANIE WYBRANYCH ODPADÓW ORGANICZNYCH

Abstract: Vermicomposting of livestock manure and organic kitchen refuse is a possible way of utilizing this type of waste. The study was designed to assess the impact of saponin extract on the characteristics of the earthworm *Eisenia fetida* used for vermicomposting of swine manure with added organic kitchen refuse and cellulose, as well as its effect on the chemical composition of the produced vermicomposts. During the study, extract of *Quillaja saponaria* added to the waste did not affect the size and mass of the population or reproduction of the earthworms, yet it adversely modified the mass of adult specimens. The vermicomposts obtained had varied composition. Significant differences were shown in the contents of sodium, calcium, copper and zinc.

Keywords: swine manure, organic kitchen refuse, cellulose, *Eisenia fetida* (Sav.), saponins, vermicompost

Introduction

An increasing volume of municipal waste, including organic kitchen refuse, generated in rural areas is not utilized or processed, which is directly linked with a change in lifestyle leading to greater consumption of goods. In addition to organic kitchen waste, the volume and quality of biomass wastes produced in rural areas are connected with crop and animal production. At present, livestock farming is a particularly expansive type of agricultural operation leading to production of such waste as farmyard manure, slurry, urine manure, and poultry droppings. All these types of waste inadequately utilized can pose hazards for the environment; alternatively they are a valuable source of nutrients for crops.

Highly concentrated pig farming leads to excessive size of stock in relation to the area designated for plant production and is the reason why animal manure is

[1] Department of Natural Theories of Agriculture and Environmental Education, Faculty of Agriculture and Biology, University of Rzeszów, ul. M. Ćwiklińskiej 2/D3, 35-601 Rzeszów, Poland, email: jmrok@univ.rzeszow.pl; jkosteck@univ.rzeszow.pl

* Corresponding author: jmrok@univ.rzeszow.pl

increasingly burdensome for the surroundings [1]. This is caused by ammonia, which is produced during decomposition of nitrogen compounds contained in excrements, and is harmful for people, animals and the natural environment. It is estimated that livestock farming is responsible for approximately 50 % of global ammonia emissions. Penetrating the soil along with rainwater, ammonia adversely affects the nitrogen balance leading to changes in natural ecosystems and agrocoenoses. Excessive amounts of ammonia derivatives causes deactivation of biological life in specific components of the environment, which then leads to a loss in its capacity for self-purification and gradual degradation [2–6].

Methods of reducing ammonia emissions from animal excrements, which have been used for years, include the use of deodorizing agents (*eg* microbiological, humic and chemical). Due to the fact that synthetic agents frequently cause allergic reactions in animals, increasingly popular are formulas containing saponin substances obtained from extract of such plants as *Yucca schidigera* and *Quillaja saponaria*.

Most saponin substances show strong biotic activity. For instance saponins promote growth of beneficial microflora in the digestive system of animals and hinder activity of urease, the enzyme which is responsible for disintegration of urea into ammonia [7–9].

Supplementing livestock fodder with saponin agents contributes to reduced ammonia emission in the animals' immediate surroundings, and as a result improves their productivity and health [10]. Because of their natural origin, saponin agents secreted into the environment with excrements should biodegrade. Yet, no research has been conducted to investigate their impact on biological diversity, including soil macrofauna and earthworms, as significant elements of trophic chains.

Earthworms, commonly occurring in various types of soil, are not only good bioindicators showing the state of the environment (they are used in monitoring of the soil environment because they come into contact with soil *via* their skin and, internally, through their digestive system) [11], but they are also used in organic waste utilization and vermicompost production [12, 13].

Numerous studies [14–18] have shown evidence that vermicomposting can be applied to kitchen refuse, as well as waste generated by paper plants, distilleries and other types of industry.

The purpose of the study was to assess the impact of saponin extract on the characteristics of earthworms used in the vermicomposting process, based on swine manure with added organic kitchen waste and cellulose as well as the effect on chemical composition of the vermicompost obtained.

Materials and methods

The experiment was conducted in plastic containers with the capacity of 3 dm^3, filled with selected organic waste (swine manure, kitchen refuse and cellulose, in the proportion of 1:1:1 calculated per dry mass). The process of vermicomposting was conducted with earthworms of the species *Eisenia fetida* (Sav.) following the pattern shown in Table 1.

Table 1

Pattern of the experiment

Specification	Container no. (replication)	Waste used in vermicomposting process	Initial number and total mass of the earthworm population per container
Control group (C)	1–3	250 g of swine manure + 250 g* organic kitchen refuse + 250 g of cellulose**	20 sexually mature specimens of *E. fetida* with the assessed total biomass of 9.279 ± 0.110 g
Experimental group (E)	4–6	250 g of swine manure + 250 g* organic kitchen refuse + 250 g of cellulose** + saponin extract	20 sexually mature specimens of *E. fetida* with the assessed total biomass of 9.304 ± 0.208 g

* Pasta leftovers, apple and potato peelings, at the ratio of 1:1:1; ** waste cardboard egg box.

The substrate used in the vermicomposting process in the experimental group (D) was supplemented with saponin extract from *Quillaja saponaria* amounting to 0.125 mg per container. The amount of saponin extract used as a supplement was similar to the extract dosage administered with fodder in pig farming.

The experiment was conducted in laboratory conditions, during March–April 2012 (air temperature 20 ± 5 ^{o}C). Changes in the characteristics of the study populations of earthworms (number, and body mass in specimens of specific age groups and cocoons) were checked every three weeks. The earthworms were detected by means of manual segregation of the substrates subjected to the process of vermicomposting. The detected specimens and cocoons produced by them were counted and weighed.

The contents of selected elements (C, N, P, K, Ca, Na, Mg, Fe, Mn, Zn, Cu and Pb) in the vermicompost were determined in the Faculty Laboratory for the Analysis of Environment Health and Materials of Agricultural Origin, at the University of Rzeszow. The contents of C and N were identified by means of Vario El-Cube elemental analyzer manufactured by Elementar. Samples of vermicomposts were digested in *aqua regia* using Berghof Speed Wave Four microwave digestion system. The contents of macro- and microelements were identified using a Hitachi Z-2000 series atomic absorption spectrophotometer. The total phosphorus contents were measured by means of vanadium-molybdenum method using Jasco V-530.

The findings of the experiment were analyzed using Microsoft Office Excel 2007 spreadsheet and presented as mean values ($\bar{x}$) for experiments replicated three times and as standard deviation (*SD*). The results were tested using one-way analysis of variance, and the significance of differences between arithmetic means was estimated with Tukey's test (α = 0.05); for this purpose Statistica PL software was used.

Results and discussion

Authors' own findings suggest that saponin extract of *Quillaja saponaria* added to organic waste used in the vermicomposting process did not affect the size and mass of the earthworm (*E. fetida*) population participating in this biotechnology (Table 2, Fig. 1).

Table 2

Characteristics of earthworm *E. fetida* populations used in the vermicomposting process utilizing the prepared mixtures

Group	Total population		Mature individuals		Immature individuals		Cocoons	
	number [ind. ± SD]	total biomass [g ± SD]	number [ind. ± SD]	total biomass [g ± SD]	number [ind. ± SD]	total biomass [g ± SD]	number [ind. ± SD]	total biomass [g ± SD]
Control (C)	72 ±36	18.339 ±9.361	28 ±12	14.506 ±6.363	44 ±14	5.117 ±4.185	58 ±32	0.689 ±0.333
Experi-mental (E)	70 ±31	14.678 ±5.785	24 ±9	11.005 ±4.403	47 ±18	4.927 ±2.881	61 ±31	0.737 ±0.339

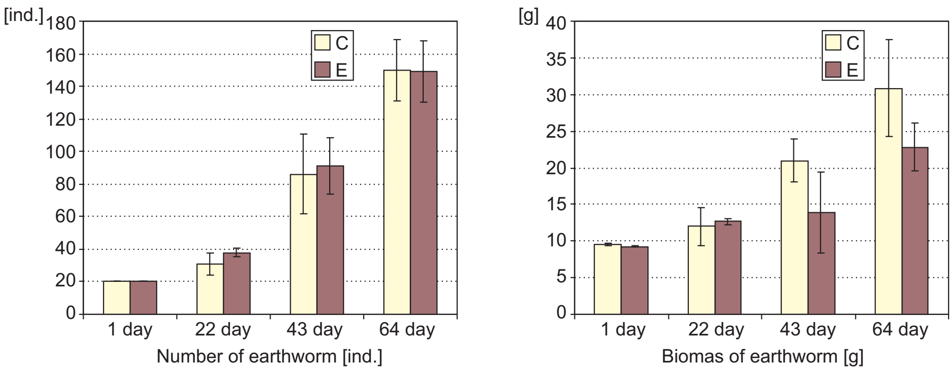

Fig. 1. Dynamics of the changing number and biomass of earthworm in the populations during the period of the experiment (ind. ± SD); C – control; E – experimental group

Although the size and mass of earthworm populations were slightly higher in the control group, the identified differences were not significantly statistically different. Statistically significant differences were found when mean masses of mature specimens were compared throughout the entire duration of the experiment (Table 3). The experimental specimens were smaller than the controls.

Table 3

Individual mass of *E. fetida* in age groups and mass of cocoons – mean values for all measurements (mean ± SD)

Group	Mature specimens	Immature specimens	Cocoons
	[g]		
Control (C)	0.516* ± 0.041	0.086 ± 0.035	0.012 ± 0.001
Experimental (E)	0.485* ± 0.077	0.083 ± 0.036	0.013 ± 0.002

* Differences statistically significant at $\alpha = 0.05$.

During the time of experiment, the presence of saponin extract in the mixed waste participating in the vermicomposting process did not significantly alter reproduction of the populations (Tables 2 and 3), although the number and mass of cocoons produced in the substrate supplemented with saponins were slightly higher. This may have been caused by a modified life strategy adopted by the more actively reproducing population staying in the substrates with saponins and the resulting greater loss of mass in the earthworms multiplying in slightly higher numbers in the experimental containers.

The experiment made it possible to successfully utilize biodegradable waste mixed at the ratio of 1:1:1, *ie*: swine manure (code 02 01 06), selected organic kitchen refuse (20 01 08) and waste cellulose (03 03 08), whose improper storage and utilization may lead not only to loss of fertilizing components but also to hazards such as spreading diseases and pollution of ground water and air.

According to projections included in the National Waste Management Plan 2014 (KPGO) [19], the amount of waste generated by agriculture, fruit farming and hydroponic crops and other biodegradable waste other than municipal waste classified in group 02, will increase from 6,052 thousand Mg in 2011 to 6900 thousand Mg in 2022. In the case of municipal organic waste KPGO predicts an increase from 6,088 thousand Mg in 2011 to 7,761 thousand Mg in 2022. An equally significant increase is expected for cellulose pulp, as a component of the group of waste with 03 code, which will grow from 3,028 thousand Mg to 3,444 thousand Mg in the period from 2011 to 2022.

Monitoring of existing waste management in rural areas, particularly related to municipal waste, including biodegradable waste (code 20 01), shows that the situation is becoming similar to that existing in urban areas.

In accordance with the objectives envisaged by KPGO (2014) (* provide organized municipal waste collection schemes for 100 % of the population by 2015, at the latest; ** ensure that services under selective waste collection schemes are provided to all inhabitants by 2015, at the latest; *** reduce quantities of municipal biodegradable waste deposited at landfills, so that by 2013 the amount of waste deposited at landfills does not exceed 50 % and by 2020 it is no more than 35 % of the volume of waste generated this way in 1995), the long-term road towards the strategy for building a national waste management system is equivalent to achieving compliance with the principles of sustainability.

Similar objectives are imposed on decision makers and citizens by the current Act on waste, which strictly implements the EU directive 2008/98/EC on waste. The Act of 14 December 2012 on waste [20] replaces the previously binding Act of 27 April 2001 on waste (consolidated text: Journal of Laws, 2010, No 185, item 1243, as amended) and became effective on 23 January 2013.

Recycling and organic recycling are very significant components of sustainable waste management systems. Organic recycling is understood as treatment of biodegradable waste by means of aerobic (*eg* composting) or anaerobic (fermentation) processes conducted in controlled conditions using microorganisms. As a result of composting one can obtain fertilizers which have significant content of crop nutrients and are currently in high demand. Approval of composts for commercial use is strictly regulated by applicable laws.

Trends and perspectives for municipal waste composting systems have been discussed *eg* by Goscinski [21], who described both simple compost heaps located on the ground and complex bioreactors utilizing municipal waste in large cities. Potential applications and the importance of vermicomposting to be used for biodegradable waste treatment under community waste management programmes have been outlined by Kasprzak [22] and Bozym [23] while other studies have demonstrated that vermicomposting is an effective method of neutralizing both farmyard manure [24–26], organic kitchen refuse [27, 28] and cellulose [13, 15].

It should be emphasized that the process of neutralization carried out for 64 days using quantities described in the methodology, where swine manure was supplemented with kitchen refuse and cellulose, was successful both in the control group and in the containers with added contents of saponin extract. The vermicomposts produced had visibly different organoleptic properties; unlike the input material they had uniform crumb structure, dark colour, and had no unpleasant smell.

Chemical composition of vermicomposts based on mixtures of selected organic materials with and without saponin extract is shown in Table 4.

Table 4

The content of selected elements in vermicomposts produced (mean ± SD)

Specification		Vermicomposts	
		Control (C)	With saponin extract (E)
Carbon	$[g \cdot kg^{-1}]$	241.9 ± 30.1	279.7 ± 22.8
Nitrogen		71.524 ± 14.322	75.322 ± 15.834
Phosphorus		2.150 ± 0.487	2.151 ± 0.850
Potassium	$[mg \cdot g^{-1}]$	3.107 ± 0.517	3.707 ± 0.323
Sodium		0.384* ± 0.094	0.220* ± 0.085
Calcium		47.214* ± 2.899	38.783* ± 2.608
Magnesium		1.669 ± 0.181	1.471 ± 0.117
Iron		13.526 ± 1.692	13.770 ± 1.411
Copper		0.025* ± 0.004	0.015* ± 0.001
Zinc		0.036* ± 0.004	0.028* ± 0.002
Manganese		0.263 ± 0.020	0.266 ± 0.015
Lead		0.018 ± 0.002	0.016 ± 0.008

* Differences statistically significant at $\alpha = 0.05$.

The most pronounced differences between these vermicomposts were found in the content of calcium ($8.43\ mg \cdot g^{-1} \pm 5.57$), sodium ($0.16\ mg \cdot g^{-1} \pm 0.04$), copper ($0.01\ mg \cdot g^{-1} \pm 0.004$) and zinc ($0.008\ mg \cdot g^{-1} \pm 0.005$). They were confirmed statistically ($p \le 0.05$). In the case of the remaining mineral elements the differences between the experimental and control group were much smaller and statistically insignificant.

Kostecka and Paczka [29] conducted another experiment in which the same mixture of organic kitchen refuse was used and the chemical composition of the vermicomposts differed depending on the applied technology of vermicomposting. Significantly higher contents of nitrate nitrogen NO_3-N (differences of value 558 g · dm^{-3}), assimilable phosphorus (of 195 g · dm^{-3}), potassium (of 710 g · dm^{-3}), magnesium (of 170 g · dm^{-3}) and calcium (of 166 g · dm^{-3}) were found when, in accordance with the applied technology, the substrate and the earthworm populations were not frequently divided. On the other hand the method based on frequent division of the substrate and earthworm populations promoted reduction of NaCl contents in vermicompost.

Vermicomposts obtained by Kostecka and Kolodziej [25], based on cattle manure had extremely high contents of nutrients. In that case the vermicomposting process contributed to increased contents of nitrogen and total phosphorus, in comparison with their average contents observed in cattle manure. By contrast, Gasior et al [24] reported that the contents of most elements in vermicompost based on swine manure was similar to those found in cattle and sheep manure vermicomposts.

As a conclusion, taking into account other studies [30–32], it can be assumed that products of vermicomposting process are characterized by high contents of nitrogen and other nutrient elements used by plants, therefore they can be applied for purposes related to crop cultivation. The speed of producing vermicompost from waste depends on the nature of waste materials, and their fraction in addition to the earthworm species and concentration [33].

Conclusion

1. The study has shown that addition of saponin extract to waste participating in the vermicomposting process did not impact the size and mass of earthworm (*E. fetida*) populations, yet it negatively modified mature specimens in terms of their mass. Their reproduction was not affected for the duration of the experiment.

2. Addition of saponin extract to the mixture of waste used for vermicomposting process did not impact the contents of nitrogen, phosphorus, potassium, iron, and manganese, but it promoted reduced contents of sodium, calcium, copper and zinc in the fertilizers obtained.

References

[1] Mroczek JR. Inż Ekol. 2010;22:63-70.

[2] Bartecki P, Tymczyna L. Przegl Hodowl. 2005;3:27-31.

[3] Mroczek JR. Hazards for the Natural Environment Originating from Intensive Animal Production. In: Practical applications of environmental research. Kostecka J, Kaniuczak J, editors. Nauka dla Gospodarki. 2012;3:115-124, http://www.univ.rzeszow.pl/wydzialy/biologiczno-rolniczy/monografie-wydzialowe.

[4] Pawlak J. Probl Inż Roln. 2008;4:85-91.

[5] Szymańska E. Zesz Nauk AR we Wrocławiu LXXXVII, Rolnictwo. 2006;540:531-535.

[6] Vidal C. A high-performance pigment industry with an environmental impact. Statistics in focus. European Communities. 2002;5:1-7.

[7] Cheeke PR. J Animal Sci. 2000;77:1-10.

[8] Lessire M, Etienne M. Biul Pol Związku Producent Pasz. 2007;1:19-24.

[9] Stefanowicz-Hajduk JR. Ochocka R. Post Fitoterapii. 2006;1:36-40.

[10] Mroczek JR. Życie Weterynaryjne. 2011;1:47-48.

[11] Kostecka J, Płytycz B, Mazur-Pączka A, Podolak-Machowska A. Soil Fauna in Biomonitoring of the Environment. In: Practical applications of environmental research. Nauka dla gospodarki. Kostecka J,

Kaniuczak J, editors. 2012;3:303-322, http://www.univ.rzeszow.pl/wydzialy/biologiczno-rolniczy/monografie-wydzialowe.
[12] Kostecka J. Selected aspects of the significance of earthworms in the context of sustainable waste management. In: Contemporary problems of management and environmental protection. Sądej W, editor. Sevages and waste materials in environment, Olsztyn. 2009:153-170.
[13] Kostecka J, Mazur A, Górecki W. Zesz Nauk PTIE i PTG Oddz w Rzeszowie. 2010;12:35-40, http://www2.univ.rzeszow.pl/wbr/zeszyty/pl/index.html.
[14] Adi AJ, Noor ZM. Bioresource Technol. 2009;100:1027-1030.
[15] Butt KR. Bioresource Technol. 1993;44:105-107.
[16] Ceccanti B, Masciandaro G. BioCycle. 1999;40(6):71-72.
[17] Nair J, Okamitsu K. Waste Manage. 2010;30:977-982.
[18] Seenappa SN, Rao J, Kale R. Journal of IAEM. 1995;22(1):244-246.
[19] Krajowy plan gospodarki odpadami 2014. Monitor Polski, 2010, nr 101, poz 1183, http://dokumenty.rcl.gov.pl/M2010101118301.pdf.
[20] Ustawa z dnia 14 grudnia 2012 roku o odpadach. DzU 2013, nr 0, poz 21.
[21] Gościński J. Przegl Komunalny. 2007;1:58-60.
[22] Kasprzak K. Kompostowanie w programach gospodarki odpadami w gminie – potencjalny udział i znaczenie wermikultur. In: Mat konf nauk „Ekologiczne i gospodarcze znaczenie dżdżownic", Rzeszów. Zesz Nauk AR w Krakowie. 2001;75:13-22.
[23] Bożym M. Prace Instytutu Ceramiki i Materiałów Budowlanych. 2012;10:335-349.
[24] Gąsior J, Kaniuczak J, Kostecka J. Skład chemiczny wermikompostów z obornika bydlęcego, owczego i trzody chlewnej. In: Mat konf nauk „Ekologiczne i gospodarcze znaczenie dżdżownic", Rzeszów. Zesz Nauk AR w Krakowie. 1998;58:143-148.
[25] Kostecka J, Kołodziej M. Post Nauk Roln. 1995;2:35-45.
[26] Zając J. Roczn Nauk Zootechniki. 2002;2:161-173.
[27] Kostecka J, Pączka G. Ecol Chem Eng A. 2011;18(12):1683-1689.
[28] Kostecka J, Garczyńska M. Ecol Chem Eng A. 2011;18(19-10):1263-1270.
[29] Kostecka J, Garczyńska M, Paczka G, Mroczek JR. Contemporary Problems of Management and Environmental Protection "Some Aspects of Environmental Impact of Waste Dumps". 2011;9(ch 10):143-156.
[30] Boruszko D. Roczniki Ochr Środow. 2001;13:1417-1428.
[31] Pączka G, Kostecka J. J Ecol Eng. 2013;14(2):49-53. DOI:10.5604/2081139X.1043183.
[32] Wacłowicz R, Zimny L, Kuc P. Post Ochr Roślin. 2011;51(4):1716-1719.
[33] Dominguez J, Aira M, Gomez-Brandon M. Vermicomposting: earthworms enhance the work of microbes. In: Microbes at work: from wastes to resources. Insam H, Franke-Whittle I, Goberna M, editors. Berlin, Heildelberg: Springer-Verlag; 2010:93-114. DOI: 10.1371/journal.pone.0016354.

WPŁYW EKSTRAKTU SAPONINOWEGO NA WERMIKOMPOSTOWANIE WYBRANYCH ODPADÓW ORGANICZNYCH

Katedra Biologicznych Podstaw Rolnictwa i Edukacji Środowiskowej
Uniwersytet Rzeszowski

Abstrakt: Wermikompostowanie odchodów zwierzęcych i organicznych odpadów kuchennych stanowi jeden ze sposobów ich utylizacji. Celem badań było określenie wpływu ekstraktu saponinowego na cechy dżdżownic *E. fetida* użytych do wermikompostowania obornika od trzody chlewnej z dodatkiem organicznych odpadów kuchennych i celulozy oraz na skład chemiczny wyprodukowanych wermikompostów. W okresie prowadzonych badań, ekstrakt z *Quillaja saponaria* dodany do odpadów nie wpłynął na liczebność, masę populacji i rozmnażanie dżdżownic, ale modyfikował niekorzystnie masę osobników dojrzałych. Skład uzyskanych wermikompostów był zróżnicowany. Istotne różnice wykazano w zawartości sodu, wapnia, miedzi i cynku.

Słowa kluczowe: obornik od trzody chlewnej, organiczne odpady kuchenne, celuloza, *Eisenia fetida* (Sav.), saponiny, wermikompost