MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION
ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE OCHRONY ŚRODOWISKA

Annual Set The Environment Protection
Rocznik Ochrona Środowiska

Volume/Tom 20. Year/Rok 2018 ISSN 1506-218X 358-374

Vermicomposting of Post-harvest Maize Waste

Mariola Garczyńska[*], Grzegorz Pączka[*], Katarzyna Wirkus[*], Agnieszka Podolak[*], Anna Mazur-Pączka[*], Renata Szura[*], Izabela Bartkowska[**], Joanna Kostecka[*]

[*]University of Rzeszow

[**]Bialystok University of Technology

1. Introduction

Irrational soil use and other anthropogenic factors contribute to adverse changes in soil environment. The principal causes of soil degradation are, among others, deforestation, excessive grazing, wrong agricultural economy, industrialization and urbanization as well as biomass combustion. Nowadays, one of the most important challenges is also a problem of proper management of organic waste; if not properly used, it may contribute to environmental degradation (The EU Strategy for Soil Protection (IP/06/1241 of 22 September 2006)). Waste segregation and proper management are an important organizational issue. After the amendment of law in the system of municipal waste management in 2012-2016, an increase in the amount of selectively collected waste was noted, but ecological awareness of the society concerning waste management has been increasing slowly (Kostecka et al. 2016, Krempa et al. 2018). Still too high volume of waste is being landfilled on landfills or illegal rubbish dumps (Municipal infrastructure… 2016).

Post-harvest maize waste cultivated for seeds is a by-product remaining after plant production in agricultural farms. The waste consists of stems with leaves, cob covering leaves, cob cores, uncollected and damaged cobs a well as grain. The average crop of maize cultivated for grain was determined at the level of 14.9 Mg ha^{-1} (Results of plant production of

2016...). In recent years, an increase in farmers' interest in sweet corn cultivation for consumption purposes has been observed. According to Niedziółka and Szymanek (2005), the residues constitute from 72 to 74.8% (depending on a cultivar and the depth of corn kernel cutting) of the total plant mass of sweet corn. In opinion of the same authors, waste parts amount to even from 24 to 31 $Mg \cdot ha^{-1}$ calculated per unit area. Thus, the problem of post-harvest residues management grows together with increasing crop acreage, consumption and especially sweet corn processing. Waste remaining after corn harvest (corn straw) can be used as animal feed in agricultural farms or may be applied for field fertilization, but it is better to compost these residues and other types of organic waste (Szempliński 2012). This results from the fact that without composting, the ploughed corn residues stay in soil for years and are decomposed mainly in anaerobic conditions. The processes of decay that occur there, favour diseases and inhibit normal plant growth (Dubas & Michalski 2005). Moreover, agricultural waste including corn waste is often burnt. Instead of this, in the face of a need for constant supplementation of nutrients and organic matter in soils, the waste should be treated as a raw material for fertilizer production. Restoration of more available nutrients to soils can be also achieved using the vermicomposting process (Kostecka 2000, Villar et al. 2017, Suleiman et al. 2017, Sharma & Garg 2018).

In the present study, possibilities of using vermiculture for processing of corn straw remained after harvesting maize (*Zea mays sp.*) grown for grain were assessed. Vermicomposting of pure maize waste and waste of maize with addition of cellulose and horse manure was investigated. *E. fetida* and *D. veneta* earthworms were used for waste processing.

2. Material and methods

Experiments on vermicomposting waste mass composed of maize *Zea mays* ssp. indurata stems were conducted in the laboratory of the Department of Natural Theories of Agriculture and Environmental Education, University of Rzeszów. The study material consisted of maize *Zea mays* ssp. indurata stems that had been obtained from a field localised in Iwierzyce, in Ropczyce-Sędziszów county located 24 km from Rzeszów. The stems were mechanically ground to particles of 15-20 mm in diameter.

The second factor of the experiment were mature earthworms of species *Eisenia fetida* (Sav.) and *Dendrobaena veneta* (Rosa) with well-developed *clitellum* (Fig. 1). They were adapted to the conditions of climatic chamber for 2 weeks. Afterwards they were introduced to the respective study containers.

Eisenia fetida Sav.

Dendrobena veneta Rosa

Fig. 1. Earthworm species used in vermicomposting of maize waste
Rys. 1. Gatunki dżdżownic wykorzystywanych do wermikompostowania odpadów kukurydzy

Studies were conducted in three experimental variants. The experiments were carried out in the climatic chamber at temperature of 20±0.5° in containers of size 21 x 15 x 10 cm (Fig. 2, Table 1). In all the study variants the containers were filled with garden soil and in variant I – with fragmented maize stem residues, in variant II – with this organic waste added with cellulose (in the ratio of 2:1). Variant III included vermicomposting of the same maize waste with addition of horse manure (2:1). The waste (always at the amount of 300 g each) was introduced to the containers in a nylon large-mesh net and placed next to a stratification layer that was composed of garden soil. All was covered with a layer of the same soil, cardboard and nylon material, that reduced water evaporation and prevented from earthworm migrations (Fig. 2 a,b, Table 1). The experiments were run for 5 months.

Fig. 2. Containers used in the experiment
Rys. 2. Pojemniki wykorzystywane w doświadczeniu
a – single container filled with maize residues and the stratification layer,
b – experimental series
a – pojedynczy pojemnik wypełniony resztami kukurydzy
i warstwą stratyfikacyjną, b – seria doświadczalna

Content of all the containers was regularly sprinkled (once a week) with tap water with the above characteristics. Acting in accordance with the standard (PN-ISO 2001), a constant humidity – of approximately 70% was maintained inside them.

The condition of earthworm populations in the neutralized waste was checked by the method of manual segregation of the entire volume of beddings. Biomass of the found specimens and the number of cocoons laid by them were assessed.

Maize waste and vermicompost were subjected to chemical analysis. The following were determined: C/N ratio (organic carbon using Turin's method; N- by Kjeldahl's method PN-Z (2001), pH in H_2O – by potentiometric method ISO (2005), salinity – by conductometric method, nitrate nitrogen content – using ionometer and ion-selective electrode, available phosphorus – by vanadium-molybdenum method PN-Z (2001), available potassium and calcium – using flame photometer, magnesium – on atomic absorption spectrophotometer.

Table 1. Schematic diagram of the experiment
Tabela 1. Schemat prowadzonego doświadczenia

Study containers	Bedding – stratification layer	Earthworms	Balanced biomass of the introduced specimens	Organic waste
Experiment I – post-harvest maize residues				
1-4	garden soil ($2dm^3$)*	*E. fetida*	14.316±0.187 g (31±1 specimens)	300 g of fragmented maize stems
5-8		*D. veneta*	14.534±0.146 g (12±1 specimens)	
Experiment II – post-harvest maize residues with cellulose (2:1)				
1-4	garden soil ($2dm^3$)*	*E. fetida*	14.573±0.464 g (31±1 specimens)	200 g of fragmented maize stems + 100 g of cellulose
5-8		*D. veneta*	14.537±0.085 g (11±1 specimens)	
Experiment III – post-harvest maize residues with horse manure (2:1)				
1-4	garden soil ($2dm^3$)*	*E. fetida*	15.053±0.241 g (29±2 specimens)	200 g of fragmented maize stems + 100 g of horse manure
5-8		*D. veneta*	15.158±0.131 g (12±1 specimens)	
tap water**				

*universal substrate for decorative plants Fluro – hum with pH 5.5-6.5.
Composition: high-moor peat, low-moor peat, perlite, sand, microelements, NPK mineral fertilizer.
** tap water: pH 7.5 (min: 6.5; max: 9.5), nitrates 7.0 mg/l, nitrites 0.01 mg/l, total organic carbon 2.31 mg/l).
*uniwersalne podłoże do roślin ozdobnych Fluro – hum o pH 5,5-6,5.
Skład: torf wysoki, torf niski, perlit, piasek, mikroelementy, nawóz mineralny NPK.
** woda wodociągowa: pH 7,5 (min: 6,5; Max: 9,5), azotany V 7,0 mg/l, azotany III 0,01 mg/l, ogólny węgiel organiczny 2,31 mg/l).

The obtained results were presented as arithmetic means ($\bar{x}$) and standard deviations (SD). STATISTICA software v. 13.1 (*StatSoft*) was used for statistical calculations. Normal distribution was checked using *Shapiro-Wilk W test* and *Brown-Forsythe test* was used to confirm the homogeneity of variance. Statistically significant differences were assessed by *Student's t-test* and by variance method, using Tukey's test on Statistica PL software (Łomnicki 2014). Differences at the significance level $\alpha = 0.05$ were considered statistically significant.

3. Results and discussion

Maize waste is the type of waste that can be used for biogas production (Wiater & Horysz 2017). According to the data by Fugol and Szlachta (2010) biogas with average methane content of approximately 50-55% can be obtained from maize silage. However, aiming at such way of maize waste treatment is not entirely correct. Biomass processing for energetic purposes is not only associated with many risks (Gołofit-Szymczak et al. 2016), but also causes loss of potentially useful nutrients, including nitrogen, sulphur and carbon. Therefore, using this waste for vermicomposting is an alternative. Post-harvest maize waste is a valuable material that is a source of carbon (Table 2).

Table 2. Chemical analysis of maize stem (according to Arvanitoyannis and Tserkezou 2008) (%)
Tabela 2. Analiza chemiczna łodygi kukurydzy (za Arvanitoyannis i Tserkezou 2008) (%)

Feature	Carbon	Hydrogen	Oxygen	Nitrogen	Cellulose	Lignin	Ash	C/N
maize stem	43.6 ± 0.5	5.4 ± 0.2	42.3 ± 0.9	0.6 ± 0.1	50.4 ± 7.0	13.7 ± 1.1	0.9 ± 0.1	40-60

In the conducted experiment, a possibility of vermicomposting maize stems was demonstrated (Fig. 3). Valuable organic fertilizers were produced in all the variants of the experiment (Table 3).

(post-harvest maize residues) (resztki pożniwne kukurydzy)

(after 3 months of vermicomposting) (po 3 miesiącach wermikompostowania)

(after 5 months of vermicomposting) (po 5 miesiącach wermikompostowania)

Fig. 3. Gradual changes in the structure of bedding during vermicomposting of pure maize stems
Rys. 3. Stopniowe zmiany w strukturze podłoża podczas wermikompostowania czystych łodyg kukurydzy

Table 3. Features of vermicomposts obtained during the experiments
Tabela 3. Cechy wermikompostów uzyskanych w trakcie prowadzenia badań

Variants / Features		*Eisenia fetida*			*Dendrobena veneta*			Optimal level for plants*
		Waste composed of			Waste composed of			
		maize stems	maize stems with cellulose	maize stems with horse manure	maize stems	maize stems with cellulose	maize stems with horse manure	
		min-max	min-max	min-max	min-max	min-max	min-max	min-max
pH in H_2O		5.8-6.1	5.9-6.1	5.8-6.1	5.6-5.9	5.9-6.1	5.8-6.1	6.0-7.5
(NaCl $g \cdot dm^{-3}$)		0.5-1	1-1.5	1-1.5	0.5-1	1-1.5	1-1.5	about 1.0
NO_3	($mg\ kg^{-1}$ d.m.)	70-72	74-88	76-97	66-68	74-79	69-88	50-120
P	($mg\ kg^{-1}$ d.m.)	67-77	79-91	89-102	66-74	81-88	91-98	40-80
K	($mg\ kg^{-1}$ d.m.)	239-252	258-268	272-289	232-247	237-255	247-263	125-250
Ca	($mg\ kg^{-1}$ d.m.)	679-704	675-726	757-780	659-688	677-707	690-730	1,000-2,000
Mg	($mg\ kg^{-1}$ d.m.)	96-122	119-146	131-156	88-118	98-127	117-136	60-120
C/N (%)		19-23	18-21	19-21	18-23	17-22	19-21	20

*according to Kończak-Konarkowska 2009

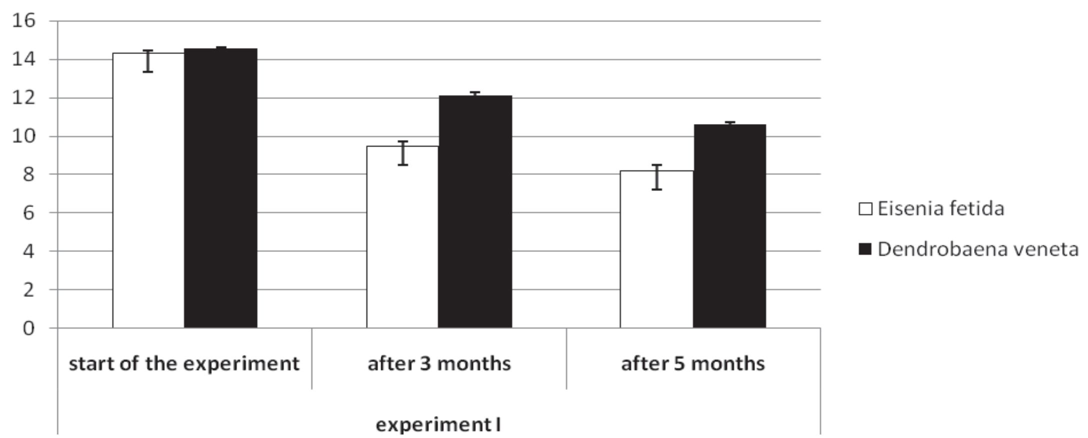
Vermicomposting of post-harvest maize stem residues in all the variants of the experiment resulted in their odourless transformation. During vermicomposting, earthworms permanently loosen organic waste. Organic and mineral aggregates of lumpy structure and increased water resistance are formed in their digestive tracts. Thus, the obtained fertilizers were characterised by lumpy structure and were rich in plant nutrients.

C:N ratio indicates the quality and maturity of vermicompost, so it is commonly used for the assessment of its quality. In vermicomposting process, C:N ratio can be regulated, for example, by increasing carbon content adding cardboard or straw. Therefore, variant II – post-harvest maize residues with cellulose was analysed in the present experiment. Kostecka (2000) proved that the addition of cellulose to the vermicomposted waste accelerates its processing. A decrease in C:N ratio below 20 indicates an advanced degree of organic matter stabilization (Lim et al. 2011) and expresses a satisfactory degree of organic waste maturity (Sharma & Garg 2018). On the other hand, nitrogen substances in vermicomposting process accelerate microbiological and enzymatic activity in earthworm gut, that has the effect on quicker rate of bedding mineralisation (Alidadi et al. 2016). A decrease in C:N ratio is also observed in the increased rate of humification of organic matter (Parthasarathi et al. 2016). Vermicomposts described by Sharm and Garg (2018), produced from a mixture of cattle manure, rice straw and paper, were characterised by C:N ratio fluctuating from 12.23% to 38.85%. These authors observed that when vermicomposting the above-mentioned mixtures, they obtained fertilizers characterised by various degrees of maturity: (12.23% C:N– mixture of 3:1:1) < (14.20% C:N – mixture of 9:0:1) < (14.53% C:N – waste mixture of 8:1:1). C:N ratio in maize vermicomposts amounted to 17-23%, that indicates a very high degree of maturity and stabilization of the produced fertilizer.

The obtained vermicomposts were characterised by similar features ($p > 0.05$). They did not differ in pH in water (min 5.6; max 6.1). This pH reaction was close to the neutral one, but lower compared to pH in kitchen waste vermicomposts observed by Kostecka (2000), where it amounted to between 6.5 and 7.5. Salinity in the produced fertilizer was close to the optimal level for plants (min 0.5; max 1.0). Meanwhile, Kostecka (2000) described that salinity of vermicomposts produced by earthworms from kitchen organic waste rapidly increased throughout the year from 3.9 g $NaCl·dm^{-3}$ to 12.6 g $NaCl·dm^{-3}$.

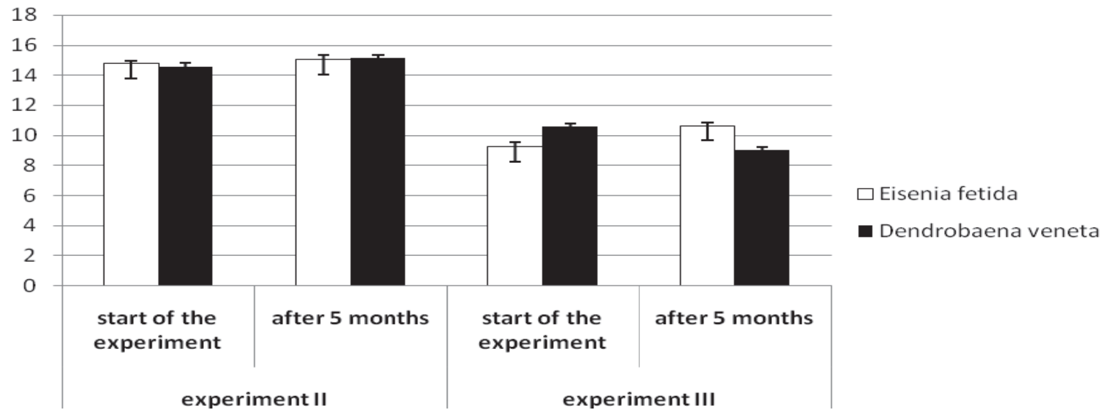
Vermicomposts produced in all three variants using maize stem residues did not differ in the content of nitrate nitrogen (min 66; max 88 $mg·kg^{-1}$), available phosphorus (min 66; max 102 $mg·kg^{-1}$), potassium (min 232; max 289 $mg·kg^{-1}$), calcium (min 675; max 780 $mg·kg^{-1}$) and magnesium (min 88; max 156 $mg·kg^{-1}$) ($p > 0.05$). The obtained fertilizers are a source of available nutrients for plants (table 3).

After 3 or 5 months of vermicomposting of the given waste mass, the mean earthworm biomass in all the variants of bedding was decreasing (in case of *E. fetida* in variant I it decreased by 50%, in variant II – by 30% and in variant III – by 25% ($p > 0.05$)); in case of *D. veneta* in variant I it decreased by 40%, in variant II – by 28% and in variant III – by 49% ($p > 0.05$)). The above-mentioned decreases were not statistically significant. Fig. 4 and 5 show that at the end of all the experiments the mean biomass of *E. fetida* earthworms is lower than the biomass of *D. veneta* on pure maize stem bedding, whereas the situation is opposite in case of maize stems mixed with horse manure. On maize stem bedding with cellulose, the mean biomass of both species was similar. Although the described differences between the studied species were not statistically confirmed ($p > 0.05$), they can indicate different food adaptations of the studied species. It seems that variant I of bedding – maize waste was preferred by *D. veneta* (according to Chachina et al. (2015) occurring in forests), whereas the variant with maize waste + horse manure was better for *E. fetida* species that naturally occurs in manure heap (Neuhauser 1980, Guandi et al. 2003).



(start of the experiment – mature specimens; after 3 months – mature and immature specimens; after 5 months of the experiment – mature and immature specimens)
(początek doświadczenia – osobniki dojrzałe; po 3 miesiącach – osobniki dojrzałe i niedojrzałe; po 5 miesiącach doświadczenia – osobniki dojrzałe i niedojrzałe)

Fig. 4. Changes in the biomass of *E. fetida* and *D. veneta* earthworm populations in variant I of the experiment on pure maize stem bedding [$g \cdot container^{-1}$]
Rys. 4. Zmiany biomasy populacji dżdżownic *E. fetida* i *D. veneta* w doświadczeniu I na podłożu z czystych łodyg kukurydzy [$g \cdot pojemnik^{-1}$]



(start of the experiment – mature specimens; after 5 months of the experiment – mature and immature specimens)
(początek doświadczenia – osobniki dojrzałe; po 5 miesiącach doświadczenia – osobniki dojrzałe i niedojrzałe)

Fig. 5. Changes in the biomass of *E. fetida* and *D. veneta* earthworm populations in variant II (maize stems + cellulose) and variant III (maize stems + horse manure) of the experiment [g · container^{-1}]
Rys. 5. Zmiany biomasy populacji dżdżownic *E. fetida* i *D. veneta* w doświadczeniu II (łodygi kukurydzy +celuloza) i III (łodygi kukurydzy + obornik koński) [g · pojemnik^{-1}]

Most probably, a decrease in biomass of the mean earthworm populations was a result of depletion of nutrients in the beddings, whereas a decrease in body weight of the mature specimens could be additionally conditioned by cocoon production (Kostecka 2000) (Fig. 6 a, b).

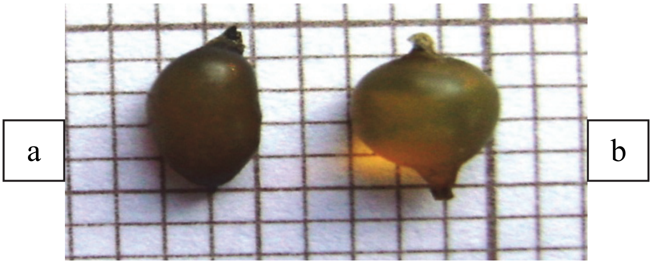


Fig. 6. Cocoons laid by *E. fetida* (a) and *D. veneta* (b) earthworms in the experiment III
Rys. 6. Kokony złożone przez dżdżownice *E. fetida* (a) i *D. veneta* (b) w doświadczeniu III

The mean count of cocoons produced by *D. veneta* was lower compared to the cocoons of *E. fetida* earthworms in all the experimental variants (Table 4). The addition of cellulose and horse manure to post-harvest maize residues had a positive effect on reproduction of *E. fetida* earthworms ($p < 0.05$) compared to the variant with maize stems only. As it was demonstrated in the studies by other authors, cocoon production in earthworms depends on many biotic (e.g. crowding in the population) and abiotic (temperature, humidity, type of food) factors (Dominguez & Edwards 2004, Monroy et al. 2006).

Table 4. The mean count of cocoons laid by one mature specimen depending on the species and variant of vermicomposted beddings
Tabela 4. Średnia liczebność kokonów złożonych przez jednego dojrzałego osobnika w zależności od gatunku i wariantu wermikompostowanych podłoży

Variant of the experiment	Mean number of cocoons / per one mature specimen	
	E. fetida	*D. veneta*
I – (maize)	1.60 ± 0.01^{a}	1.08 ± 0.00^{a}
II – (maize + cellulose)	3.87 ± 0.01^{b}	2.30 ± 0.001^{a}
III – (maize + horse manure)	4.30 ± 0.001^{b}	2.70 ± 0.003^{a}

ab – statistically significant differences, aa – no statistically significant differences
ab – różnice istotne statystycznie, aa – brak różnic istotnych statystycznie

A positive effect of cellulose on earthworm biomass growth and their reproduction was demonstrated by Kostecka & Surmiak (1999) and Kostecka (2004) as well as Kostecka and co-authors (2010). Guandi et al. (2003), analysing the changes in *E. fetida* population and the advancement of the degree of vermicomposting of cattle and pig manure, observed that the higher the growth in count and reproduction of compost earthworms, the lower the C:N ratio. In contrast, Ndegawa and Thompson (2000) noticed that during vermicomposting of paper waste mixed with oak bark, the slower the development of earthworm populations, the higher the C:N ratio.

4. Conclusions

1. Vermicomposting of maize residues is effective and the produced compost has valuable parameters. The conducted studies demonstrated that maize stems (*Zea mays*) can be processed by both *E. fetida* and *D. veneta* earthworms. Vermicomposting of this type of waste enable to provide plants with valuable nutrients in the available form.
2. The addition of cellulose and horse manure to maize stem waste did not significantly differentiate the content of principal nutrients ($p > 0.05$) in the produced vermicomposts.
3. Differences in biomass growth of both earthworm species in the studied waste and the number of cocoons laid by them indicate that *E. fetida* preferred the most maize waste with horse manure. *D. veneta* preferred pure maize waste.
4. Differences in the composition of waste vermicomposted by earthworms had a significant effect on the number of cocoons laid by *E. fetida species.*

References

Alidadi, H., Hosseinzadeh, A., Najafpoor, A.A., Esmaili, H., Zanganeh, J., Takabi, M.D., Piranloo, F.G. (2016). Waste recycling by vermicomposting: maturity and quality assessment via dehydrogenase enzyme activity, lignin, water soluble carbon, nitrogen, phosphorous and other indicators. *Journal of Environmental Management*, *182,* 134-140. DOI. 10.1016/j.jenvman.2016.07.025.

Arvanitoyannis, I. S., Tserkezou, P. (2008). Corn and rice waste: a comparative and critical presentation of methods and current and potential uses of treated waste. *International Journal of Food Science and Technology, 43,* 958-988. DOI. 10. 1111/j. 1365-2621. 2007.015445.

Chachina, S.B., Voronkova, N.A., Baklanova, O.N. (2015). Biological remediation of engine lubricant oil-contaminated soil with three kinds of earthworms, *Eisenia fetida*, *Eisenia andrei*, *Dendrobena veneta*, and a mixture of microorganisms. *Procedia Engineering, 113,* 113-123.

Dominguez, J., Edwards, C.A. (2004). Vermicomposting organic wastes: A review. In; Soil Zoology for Sustain Development in the 21st Century. S.H. Shakir Hanna and W.Z.A. Mikhall (eds). Cairo. 369-395.

Dubas, A., Michalski, T. (2005). Kukurydza.Corn. [in]: Chotkowski J. Markets and technologies of production of agricultural plants. *Wieś Jutra,* Publishing House, 224.

Fugol, M., Szlachta J. 2010. The reason for using corn and fermented liquid manure ensilage for biogas production. *Agricultural Engineering, 1(119),* 169-174.

Gołofit-Szymczak, M., Ławniczek-Wałczyk, A., Górny, R.L., Cyprowski, M., Stobnicka, A.A. (2016). Characteristics of biological hazards associated with processing of biomass for energy purposes. *Annual Set The Environment Protection, 18,* 193-204.

Guandi, B., Edwards, C.A., Blount, C. (2003). The influence of different moisture levels on the growth, fecundity and survival of *Eisenia foetida* (Savigny) in cattle and pig manure solids. *European Journal of Soil Biology, 39,* 19-24. https://doi.org/10.1078/0031-4056-00109

ISO (2005). Soil quality. Determination of pH. 10390. https://www.iso.org/standard/40879.html

Kończak-Konarkowska, B. (2009). The principles of fertilizer recommendations in horticulture. Manual for horticulture laboratories in Chemical and Agricultural Research Laboratories. *National Chemical and Agricultural Research Laboratory in Warsaw. Regional Chemical and Agricultural Research Laboratory in Gorzów Wielkopolski*, 69.

Kostecka, J. (2000). Badania nad wermikompostowaniem odpadów organicznych. *Zesz. Nauk. AR w Krakowie. Rozprawy, 268,* 88.

Kostecka, J. (2004). Changes in the selected features of *Eisenia fetida* (Sav.) earthworms in cellulose waste. *Zesz. Probl. Post. Nauk Rol, 498,* 119-125.

Kostecka, J., Koc-Jurczyk, J., Garczyńska, M. (2016). Considerations on sustainable waste management. *Polish Journal for Sustainable Development, 20,* 105-117. DOI: 10.15584/pjsd.2016.20.12.

Kostecka, J., Mazur, A., Górecki, W. (2010). Vermicomposting of cellulose waste using *Eisenia fetida* (Sav.) and *Dendrobaena veneta* (Rosa) earthworms. *Zesz. Nauk. PTIE i PTG Odział w Rzeszowie, 12,* 35-40.

Kostecka, J., Surmiak, J. (1999). Observations of office-type waste in the annual cycle. *Zesz. Nauk. PTE I PTG, 2,* 61-66.

Krempa, M., Miazga, N., Garczyńska, M., Pączka, G. (2018). Waste management and biodiversity. *Polish Journal for Sustainable Development, 22(1),* 47-55. DOI: 10.15584/pjsd.2018.22.1.6

Lim, SS., Jung, J.W., Choi, W.J., Ro, HM. (2011). Substrate quality effects on decompostion of Tyree livestock manure composts with similar stability degree in an acid loamy soil. *Korean. Journal of Science Fertility, 44,* 527-533.

Łomnicki, A. (2014). Introduction to statistics for naturalists. *Wyd. Nauk. PWN publishing house*, 207-214.

Monroy, F., Aira, M., Dominguez, J., Velando, A. (2006). Seasonal population dynamics of *Eisenia fetida* (Savigny, 1826) (Oligochaeta, Lumbricidae) in the field. *Population Biology, 32,* 912-915. DOI: 10.15584/pjsd. 2016.20.12.

Municipal infrastructure, 2016a, Municipal waste management. 2016, Warsaw, www.stat.gov.pl (12.02.2018)

Ndegwa, P.M., Thompson, S.A. (2000). Effects of C-to-N ratio on vermicomposting of biosolids. *Bioresource Technology,75,*7-12.

Neuhauser, E. F., Kaplan, D. L., Malecki, M. R., Hartenstein, R. (1980). Material supporting weight gain by the earthworm *Eisenia fetida* in waste conversion systems. *Agricultural Wastes, 2,* 43-60.

Niedziółka, I., Szymanek, M. (2005). Problems of the plant mass utilization in process of harvesting and processing of sweet corn cobs. *Agricultural Engineering, 7,* 207-214.

Parthasarathi, K., Balamurugan, M., Prashija, K.V., Jayanthi, L., Basha, S.A. (2016). Potential of *Perionyx excavatus* (Perrier) in lignocellulosic solid waste management and quality vermifertilizer production for soil health. *International Journal of Recycling of Organic Waste in Agriculture, 5,* 65–86. DOI: 10.1007/s 40093-016-0118-6.

PN – ISO (2001). Soil quality. Effects of pollutants on earthworms *(Eisenia fetida).* Determination of effect on reproduction. 11268-2. DOI://pzn. pkn.pl/info/published/9000128854.

PN-Z (2001). Determination: pH, organic content, organic carbon, nitrogen, phosphorus and potassium. 15011-3. pkn.pl/pn-z-15011-3-2001p.html

Results of plant production in 2016. Central Statistical Office. [results_of_plant_production_in_2016.]

Sharma, K., Garg, V.K. (2018). Comparative analysis of vermicompost quality produced from rice straw and paper waste employing earthworm *Eisenia fetida* (Sav.) *Bioresource Technology, 250,* 708-715. DOI: 10.1016/j.biortech.2017.11.101.

Suleiman, H., Rorat, A., Grobelak, A., Grosser, A., Milczarek, M., Płytycz, B., Kacprzak, M., Vandenbulcke, F. (2017). Determination of the performance of vermicomposting process applied to sewage sludge by monitoring of the compost quality and immune responses in three earthworm species: *Eisenia fetida*, *Eisenia andrei* and *Dendrobena veneta*. *Bioresource Technology, 241,* 103-112. DOI: http:// dx.doi.org/10.1016/j.biortech. 2017.05.104.

Szempliński W. 2012. Agricultural plants. *Wydawnictwo UWM*, Olsztyn.

The EU Strategy for Soil Protection (IP / 06/1241 of 22 September 2006. http:// eur-lex.europa.eu/legal-content=52006DC0231.

Villar, I., Alves, D., Mato, S. (2017). Product quality and microbal dynamics during vermicomposting and maturation of compost from pig manure. *Waste Management, 69,* 498-507.

Wiater, J., Horysz, M. (2017). Organic waste as a substrat in biogas production. *Journal of Ecological Engineering, 18(5),* 226-234.

Wermikompostowanie odpadów pożniwnych kukurydzy

Streszczenie

W artykule przedstawiono wyniki badań nad wykorzystaniem zagęszczonych populacji dżdżownic z gatunku *Eisenia fetida* (Sav. 1826) i *Dendrobena veneta* (Rosa 1893), do unieszkodliwiania resztek pożniwnych kukurydzy zwyczajnej (*Zea mays ssp. indurata*). Doświadczenie prowadzono w warunkach komory klimatyzacyjnej w różnych wariantach (podłoże I – łodygi kukurydzy, podłoże II – łodygi kukurydzy z dodatkiem celulozy (2:1), podłoże III – łodygi kukurydzy z dodatkiem obornika końskiego (2:1)). W chowie dżdżownic na wskazanych podłożach analizowano zmiany w ich populacjach, określając biomasę oraz liczbę składanych kokonów. Otrzymane nawozy organiczne poddano analizie chemicznej. Wykazano, że odpady były utylizowane przez oba gatunki dżdżownic, a otrzymane wermikomposty posiadały korzystne właściwości jako podłoża do uprawy roślin.

Abstract

The article presents results of studies on using dense populations of *Eisenia fetida* (Sav. 1826) and *Dendrobena veneta* (Rosa 1893) earthworms for neutralization of post-harvest maize (*Zea mays ssp. Indurata)*) waste. The experiment was conducted in climatic chamber conditions in various variants (bedding I – maize stems, bedding II – maize stems with cellulose (2:1), bedding III – maize stems with horse manure (2:1)). In earthworm cultures on the above-mentioned beddings, changes in their populations were analysed, assessing biomass and the number of laid cocoons. The obtained organic fertilizers were subjected to chemical analysis. It has been demonstrated that waste was neutralized by both earthworm species and the obtained vermicomposts had beneficial properties as beddings for plant cultivation.

Słowa kluczowe:
wermikultura, *Eisenia fetida* (Sav. 1826), *Dendrobena veneta* (Rosa 1893), odpady pożniwne kukurydzy

Keywords:
vermiculture, *Eisenia fetida* (Sav. 1826), *Dendrobena veneta* (Rosa 1893), post-harvest maize waste