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# Vermicomposting of Sugar Beet Pulps Using *Eisenia fetida* (Sav.) Earthworms

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## 1. Introduction

One-third of the world sugar production is manufactured from sugar beet (Roper 2002). From one ton of this raw material, approximately 150 kg of sugar and 250 kg of sugar beet pulps with the mean dry mass value of 20% are obtained (Spagnuolo et al. 1997). In 2016 in Poland, approximately 2.17 million tons of sugar were produced, and thus over 3.6 million tons of sugar beet pulps (www.stat.gov.pl).

Sugar beet pulps can be used as a feed for farm animals (Journal of Laws No. 16, item 137) on condition that they meet the quality requirements (Regulation EC No. 183/2005). When the standards are not met, in accordance with the regulation of the Minister of Environment of 9 December 2014 on waste catalogue (Journal of Laws of 2014, item 1923), sugar beet pulps are classified as group 02 waste: waste from agriculture, horticulture, aquaculture, fishery, forestry, hunting and food processing, 02 04 subgroups; Waste from sugar industry and 02 04 80 type: sugar beet pulps. The increasing amount of this waste generates a growing problem concerning its management (Bhat et al. 2015).

A large part of postproduction plant waste, such as for example apple pomace from apple processing, rapeseed cake from rape processing, soybean hulls and spelt husks from the processing or olive pomace are designated for energetic purposes (Wojdalski et al. 2016, Kraszkiewicz et al. 2017, Gołofit-Szymczak 2016), whereas some part of them, after neutralization, could be used as plant fertilizer.

Vermicomposting is one of biological methods of organic waste neutralization (Edwards 1995, 1998). It is an efficient process of nutrient recycling for plants, including a synergic action of earthworms and microorganisms. Although the microorganisms are responsible for the biochemical transformations occurring in this process, earthworms are of crucial importance for organic matter processing, because by fragmenting and aerating the substrate, they modify the activity of microorganisms (Aira et al. 2002, Fracchia et al. 2006, Lazcano et al. 2008).

Vermicompost is a material similar to peat, with high porosity, ability to aerate and retain water. It is characterised by the presence of various microorganisms and high content of nutrients for plants, so its use may be very important for sustainable agriculture, as an alternative for mineral fertilizers (Suthar 2012, Lim et al. 2015). However, waste neutralization time and the quality of the final product depend to a large extent on type and quality of the initial substrate (Singh et al. 2010).

The aim of the conducted studies was to assess the possibilities of using *E. fetida* for processing of sugar beet pulps in case of various ways of preparation of initial bedding in vermireactor.

## 2. Material and methods

The experiment was conducted in the Laboratory of the Department of Natural Theories of Agriculture and Environmental Education of the University of Rzeszów. *E. fetida* (Sav.) earthworms derived from the multiannual breeding line maintained at the above-mentioned Department were used in the experiment. Before the start of the experiment, only mature specimens (with well-developed *clitellum*) were selected from the culture and placed in containers filled with garden soil and feed for 7 days, for the acclimation period. It was done in order to eliminate any possible disturbances of the experiment caused by a sudden change in environmental conditions of earthworms.

Sugar beet pulps were obtained from the "Cukrownia Ropczyce" Sugar Plant. They were frozen in order to be stored. Before the onset of the experiment, sugar beet pulps were melted at temperature of 20±1°C and dried until dry mass was obtained, in order to apply the same waste weight to each vermireactor. Prior to placement in vermireactors, thoroughly weighed out waste was soaked in water for 2 hours.

The experiment was conducted in vermireactors of size of 300 x 200 x 200 mm (length x width x height). Vermireactors were constructed from plastic boxes. The bottom of each box was equipped with small holes in order to drain the excess water. Each vermireactor was placed in a slightly bigger box in such a manner, that their bottoms did not touch each other (a distance between the bottoms amounted to 30 mm), to store the excess water. Identical amount of plant waste (200 g of dry mass each) was put into the prepared nets of size of 150 x 200 x 150 mm (length x width x height). Nets with plant waste were placed in vermireactors and the remaining capacity of vermireactors was filled with initial bedding. Vermireactors were divided into two groups; in the first group, biologically active garden soil was used as the initial bedding (BAGS vermireactor), whereas in the second group the same bedding was applied, but it had been sterilised at 105°C (SGS vermireactor) (Fig. 1). The sterilised bedding was used to show the significance of soil microorganisms in the process of vermicomposting and the simulation of using in the vermiculture a soil degraded as a result of anthropopressure.

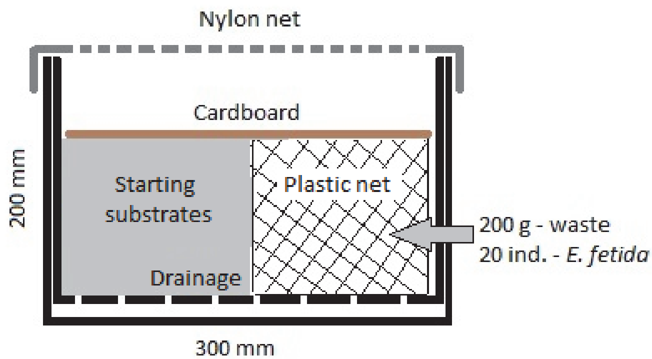


**Fig. 1.** Schematic diagram of vermireactors
**Rys. 2.** Schemat wermireaktorów

Only sexually mature earthworms balanced in terms of number and biomass were introduced to the previously prepared vermireactors. They were protected from the top with a nylon mesh that prevented earthworm escape, and with a paper cardboard that prevented drying out of the soil. Vermireactors were placed in the climatic chamber at constant temperature of 20±0.5°C. In order to maintain the proper humidity of waste, it was moistened every 10 days with the same volume (100 ml) of water (pH – 7.6, conductivity – 542 $\mu S\cdot cm^{-1}$, nitrates V – 8.9 $mg\cdot l^{-1}$, Mg – 15.7 $mg\cdot l^{-1}$, hardness – 257 mg $CaCO_3\cdot l^{-1}$).

The experiment included 5 repetitions in each of the two groups, according to the following outline:

5 BAGS vermireactors (sugarbeet pulps 200 g + 20 mature *E. fetida* specimens 0.347±0.02 g/specimen + biologically active garden soil)

5 SGS vermireactors (sugarbeet pulps 200 g + 20 mature *E. fetida* specimens 0.352±0.01 g/specimen + sterilised garden soil)

Control examinations of the condition of earthworm populations were conducted every 10 days. They consisted in manual segregation of bedding and waste in order to analyse the count and biomass of earthworms and cocoons. After having recorded the above-mentioned characteristics, the cocoons were removed from the experiment. On the $20^{th}$ day of the experiment and after its completion (on the $40^{th}$ day) a control of the level of waste processing was carried out. For this purpose, the sugar beet pulp residues that have not been processed, were removed from the plastic nets, dried until dry mass was obtained and then weighed. Prior to returning them to vermireactors, the residues were soaked in tap water for 2 hours.

Macroelement (N, P, K, Ca, Mg) content was determined both in the waste material and in vermicompost. Nitrogen was assayed by Kjeldahl's method. Phosphorus was assessed by colorimetric vanadium-molybdenum method, potassium, magnesium and calcium were assessed using atomic absorption spectrophotometry after prior sample mineralization in a mixture of concentrated mineral acids ($HNO_3$ : $HCLO_4$ : $H_2SO_4$ in a ratio of 20 : 5.1). Carbon was determined with the use of Vario EL-CUBE elemental analyzer. pH in water was evaluated by potentiometric method and salt concentration was determined by conductometric method.

All statistical analyses were expressed as mean of five replicates using the computer software package Statistica 13.1. Tukey's t test was used as a post hoc analysis to compare the means. One-way analysis of variance (ANOVA) was used to analyze the significant difference between research groups for the observed monitoring parameters and the significance difference between macroelements contents in initial plant waste and vermicomposts.

# 3. Results and discussion

## 3.1. Changes in *E. fetida* populations and waste treatment rate

As it results from the conducted experiments, the count of mature *E. fetida* specimens was slightly decreasing in both groups of vermireactors (BAGS and SGS vermireactors) during the entire experiment (Fig. 2), that might have resulted from, among others, the stress associated with a change in habitat conditions or frequent controlling of the condition of earthworm population (Garczyńska & Kostecka 2012), but the differences between the groups were not statistically significant ($p > 0.05$) and, most probably, it did not have the effect on the plant waste treatment rate. Similar results were obtained by Bhat et al. (2016) who vermicomposted sugarcane waste. They demonstrated a decrease in count of *E. fetida* neutralizing exclusively sugarcane waste, with concurrent increase in the count of earthworms raised on the same waste with addition of cattle manure.

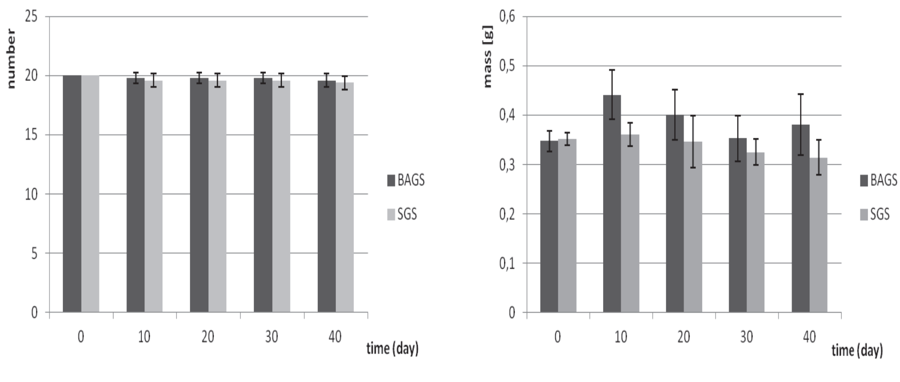


**Fig. 2.** The average number and mean weight of *E. fetida* specimens depending on the group of vermireactors
**Rys. 2.** Średnia liczebność oraz średnia masa osobników *E. fetida* w zależności od grupy wermireaktorów

However, pronounced differences were observed in the mean weight of E. *fetida* specimens (Fig. 2). Weight of specimens from the BAGS was higher (on average by 14%) compared to the earthworms from the SGS group. The greatest differences were showed on the 10th (18.2%) ($p < 0.05$) and on the 40th day of the experiment (17.6%) ($p < 0.05$), that might have affected the rate of vermicomposting of sugar beet pulps at that time. Bhat et al. (2015) demonstrated a positive effect of the addition of cattle manure to the neutralized sugar beet pulps on growth of *E. fetida*.

The applied vermicomposting technology affected the number of produced cocoons. The greatest and significant differences ($p < 0.05$) between BAGS and SGS groups were observed between the 10th and the 30th day of the experiment (Fig. 3). However, no differences were noted in the mean cocoon weight (except the 10th day of the experiment – when significant differences were observed ($p < 0.05$) (Fig. 3). Bhat et al. (2015) noticed that a higher ratio of sugar beet pulps to cattle manure delays sexual maturity of *E. fetida* earthworms and has a negative effect on their reproduction.

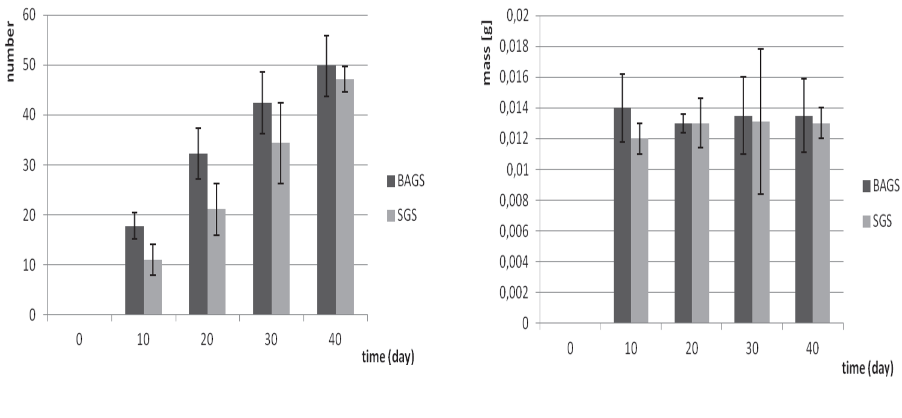


**Fig. 3.** The average number and mean weight of *E. fetida* cocoons depending on the group of vermireactors
**Rys. 3.** Średnia liczebność oraz średnia masa kokonów *E. fetida* w zależności od grupy wermireaktorów

Analysing the mean waste treatment rate, it was observed that in vermireactors with sterilised garden soil (SGS) this process occurred significantly slower compared to the group in which biologically active soil was used (BAGS). Both on the 20th and on the 40th day of the experiment, the earthworms from SGS group processed 44% ($p < 0.05$) and 27% ($p < 0.05$) of plant waste less compared to BAGS group (fig. 4). This could have been a result of lower biodiversity of microorganisms that play a crucial role in vermicomposting process, in the sterilised soil (Aira et al. 2002).

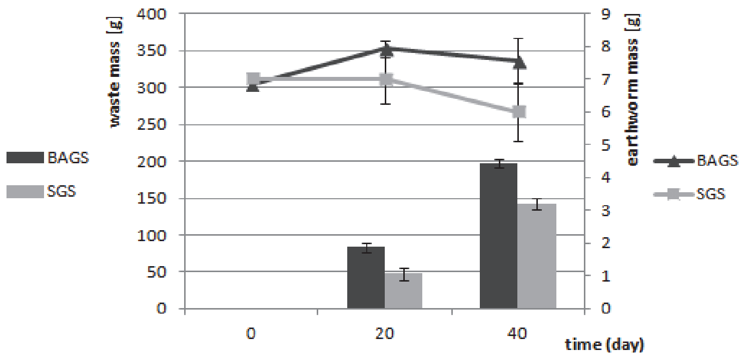


**Fig. 4.** Waste treatment rate and changes in the weight of *E. fetida* population depending on the type of used vermireactor
**Rys. 4.** Tempo przetwarzania odpadów i zmiany masy populacji *E. fetida* w zależności od rodzaju zastosowanego wermireaktora

### 3.2. Content of macroelements

As it was demonstrated in the studies by Dominguez et al. (2010), in the process of vermicomposting earthworms modify physical, chemical and biological properties of organic waste. Value of the obtained vermicompost depends on many factors, such as type and origin of organic waste, temperature, humidity and aeration of vermiculture, earthworm species and other elements. Thus, before starting the process of vermicomposting it is important to determine the physicochemical properties of waste, and after the completion of vermicomposting – to analyse these properties in vermicompost with regard to its usefulness as a fertilizer. Physicochemical properties of plant waste and vermicomposts are presented in Table 1.

**Table 1.** Macroelement content in sugar beet pulps and the obtained vermicomposts
**Tabela 1.** Zawartość makroelementów w wysłodkach buraczanych oraz otrzymanych wermikompostach

| Parameter | Units | | BAGS | SGS |
|---|---|---|---|---|
| N | $mg\ kg^{-1}$(d.m.) | *Initial* | 1413.7 ± 23.4*a* | |
| | | *Final* | 1785.3 ± 26.1*b* | 1604.9 ± 28.5*c* |
| | | *% of change* | 26.3 | 13.5 |
| P | | *Initial* | 119.2 ± 11.8*a* | |
| | | *Final* | 285.2 ± 30.2*b* | 227.1 ± 26.8*c* |
| | | *% of change* | 139.3 | 90.5 |
| K | | *Initial* | 2842.8 ± 21.1*a* | |
| | | *Final* | 3516.7 ± 36.5*b* | 3309.1 ± 30.4*c* |
| | | *% of change* | 23.7 | 16.4 |
| Ca | | *Initial* | 1514.4 ± 27.3*a* | |
| | | *Final* | 1891.8 ± 11.3*b* | 1711.2 ± 23.4*c* |
| | | *% of change* | 24.9 | 12.9 |
| Mg | | *Initial* | 179.6 ± 9.7*a* | |
| | | *Final* | 263.4 ± 10.8*b* | 212.1 ± 14.2*c* |
| | | *% of change* | 46.6 | 18.1 |
| C/N ratio | - | *Initial* | 53.11 ± 3.16*a* | |
| | | *Final* | 19.72 ± 0.35*b* | 28.41 ± 1.09*c* |
| | | *% of change* | -62.9 | -46.6 |
| pH in $H_20$ | - | *Initial* | 7.05 ± 0.04*a* | |
| | | *Final* | 6.28 ± 0.14*b* | 6.01 ± 0.23*b* |
| | | *% of change* | 10.9 | 14.8 |
| Electrical conductivity | $mS \cdot cm^{-1}$ | *Initial* | 1.74 ± 0.02*a* | |
| | | *Final* | 2.13 ± 0.04*b* | 2.01 ± 0.08*b* |
| | | *% of change* | 22.4 | 15.5 |

Values designate mean ± standard deviation based on 5 samples
Mean value followed by different letters is statistically different ($p < 0.05$)

As a result of using various vermicomposting technologies, no significant differences in pH of vermicomposts from BAGS group and SGS group were found. However, significant ($p < 0.05$) changes in pH value between waste biomass of sugar beet pulps and the obtained fertilizers were noted (Table 1). Similar observations were obtained by Sangwan et al. (2008), by vermicomposting sugar beet waste mixed with biogas plant waste with the use of *E. fetida* earthworms. These authors demonstrated a decrease in pH value of the obtained vermicomposts. On the other hand, Bhat et al. (2014), in studies on vermicomposting of press-mud sludge sediment with cattle manure using *E. fetida*, showed a pronounced increase in pH value of the obtained vermicompost. These discrepancies in the obtained results may be explained by the use of different additives to the treated sugar beet pulp waste.

After 40 days of vermicomposting process a significant decrease in C/N ratio in the obtained vermicomposts was observed, compared to the initial waste biomass (in BAGS and SGS vermireactors - a decrease by 62.9% ($p < 0.05$) and 46.6% ($p < 0.05$), respectively. Significant differences in C/N ratio between the vermicomposts obtained using different technologies were noted as well (BAGS 19.72±0.35, SGS 28.41±1.09) ($p < 0.05$) (Table 1). C/N ratio is the most often used indicator of vermicompost maturity that implies the degree of waste mineralisation and stability. Depending on the degree of advancement of vermicomposting process, loss of carbon in the form of $CO_{2\ occurs}$ as a result of respiration of microorganisms, with concurrent increase in nitrogen content resulting from, among others, physiological processes of earthworms (Suthar 2008).

Electrical conductivity (EC) of vermicomposts did not differ significantly between the groups but was significantly higher ($p < 0.05$) in comparison to the initial biomass (table 1). The increase in EC value was a result of release of various mineral ions, such as phosphates, ammonium ions, potassium ions and others, from the organic matter (Kaviraj & Sharma 2003).

A significantly increased macroelement content compared to the utilized waste biomass was also observed in the obtained vermicomposts (Table 1).

Nitrogen content in vermicompost obtained in BAGS group increased significantly by 26.3% (from 1413.7±23.4 to 1785.3±26.1 mg $kg^{-1}$; $p < 0.05$), whereas in SGS group the content of this element increased nearly by less than a half – by 13.5% ($p < 0.05$). As reported by Plaza et al. (2011) decreasing pH may lead to retaining nitrogen in vermicompost, whereas in increasing pH this element may be lost in the form of ammonia.

A similar situation was observed in case of phosphorus P, which content in the obtained vermicomposts was significantly higher in relation to plant waste (in BAGS group it increased by 139.3%, whereas in SGS group by 90.5%) ($p < 0.05$) (Table 1). Prakash & Karmegam (2010) claim that, among others, microorganisms dwelling in coprolites of earthworms are responsible for increasing phosphorus content in vermicompost.

Potassium content in vermicomposts in groups BAGS and SGS also significantly increased compared to the initial waste biomass (Table 1). Higher increase in the content of this element was also observed in BAGS group (from 2842.8±21.1 to 3516.7±36.5 mg $kg^{-1}$, (23.7%) ($p < 0.05$), whereas in SGS group the mentioned increase amounted to 16.4% ($p < 0.05$). Potassium content in vermicomposts obtained with the use of both technologies differed significantly (Table 1).

Calcium content in these vermicomposts was also different. A different between the technologies was 12% ($p < 0.05$), whereas the difference between the initial biomass and fertilizers obtained using BAGS and SGS technologies amounted to 24.9% ($p < 0.05$) and 12.9% ($p < 0.05$), respectively. Similar observations were presented by Yadav and Garg (2011) in the studies on vermicomposting of various types of organic waste, but in their results Ca in vermicompost increased 1.15-3.57-fold.

A significant increase in Mg content in vermicomposts compared to the biomass of sugar beet pulps was also noted. In BAGS and SGS groups the content of this element increased by 46.6 and 18.1% ($p < 0.05$), respectively. Significant differences in Mg content between the vermicomposts obtained using different technologies were observed.

## 4. Conclusions

1. A possibility of using *E. fetida* earthworms in the treatment of sugar beet pulps in vermireactors with different characteristics of initial beddings (BAGS and SGS) was confirmed.
2. In both technologies of running vermireactors, vermicomposts with high nutrient content for plants were obtained. The collected vermicomposts were characterised by higher N, P, K, Ca and Mg content

compared to the initial waste biomass. The mean rate of waste treatment in vermireactors with biologically active soil (BAGS) was significantly higher compared to the group in which sterilised garden soil (SGS) was used.

3. During waste treatment in vermireactors, insignificant decreases in earthworm count were noted as well as significant differences in mean weight of specimens used in different technologies (BAGS and SGS). Earthworms reproduced that has been proved by the mean number of laid cocoons which was significantly increasing during the experiment conducted using both technologies.

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# Wermikompostowanie wysłodków buraczanych z wykorzystaniem dżdżownic *Eisenia fetida* (Sav.)

## Streszczenie

W artykule przedstawiono wyniki zastosowania różnych technologii procesu wermikompostowania odpadowej biomasy wysłodków buraczanych przy użyciu dżdżownic *E. fetida*. Stwierdzono możliwość wykorzystania *E. fetida* do szybkiego unieszkodliwiania wysłodków w wermireaktorach o odmiennej charakterystyce podłoży startowych. Otrzymane wermikomposty charakteryzowały się wyższą zawartością N, P, K, Ca i Mg w porównaniu z inicjalną biomasą odpadową. Podczas unieszkodliwiania odpadu w wermireaktorach (BAGS i SGS) stwierdzano utrzymywanie się populacji dżdżownic przy nieistotnych spadkach ich liczebności. Zaobserwowano istotne różnice w średniej biomasie osobników z grup BAGS i SGS. Największe różnice (22 i 21%, $p < 0.05$) zaobserwowano w 10 i 40 dniu doświadczenia. Dżdżownice rozmnażały się, o czym świadczy średnia liczba składanych kokonów, która rosła istotnie w trakcie trwania doświadczenia w obu technologiach (średnio 36%; $p < 0,05$). Istotne różnice w średniej masie kokonów w zastosowanych technologiach stwierdzono jedynie w 10 dniu doświadczenia.

## Abstract

The article presents results of application of various technologies of the process of vermicomposting of waste biomass of sugar beet pulps using earthworms *E. fetida*. A possibility of using *E. fetida* for quick utilization of sugar beet pulp in vermireactors with different characteristics of initial beddings was observed. The obtained vermicomposts were characterised by higher N, P, K, Ca and Mg content compared to the initial waste biomass. During waste utilization in vermireactors (BAGS and SGS) it was noted that the population of earthworms persisted, but earthworm count insignificantly decreased. Significant differences in the mean biomass of specimens from BAGS and SGS groups were also observed. The greatest differences (22 and 21%, $p < 0.05$) were observed on the 10th and 40th day of the experiment. Earthworms multiplied that has been proved by the mean number of laid cocoons which was significantly increasing during the experiment conducted using both technologies (on average by 36%; $p < 0.05$). Significant differences in the mean cocoon weight between the used technologies were noted only on the 10th day of the experiment.

**Słowa kluczowe:**
wysłodki buraczane, wermireaktor, technologia, *E. fetida*, makroelementy

**Keywords:**
sugar beet pulps, vermireactor, technology, *E. fetida*, macroelements