INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

No III/1/2019, POLISH ACADEMY OF SCIENCES, Cracow Branch, pp. 279-290
Commission of Technical Rural Infrastructure

DOI: https://doi.org/10.14597/INFRAECO.2019.3.1.020

PHYTOTOXICITY OF VERMIWASH (LEACHATE) FROM HOME VERMIREACTOR – VERIFICATION OF METHODOLOGY

Bohdan Stejskal
Mendel University in Brno

Abstract

Vermicomposting is a completely environmentally friendly technology that converts biodegradable waste into a value-added vermicompost. The vermicomposting technology can also be utilized for generating a bioliquid termed as vermiwash. In case of vermicomposting in vertical continuous feeding vermireactor (VermiHut Worm Bin), the vermiwash can be collected separately in the lowest part of vermireactor. Then the vermiwash can be used as a liquid fertilizer.

The aim of the presented study was to assess the phytotoxicity of vermiwash depending on its concentration. To assess the phytotoxicity levels of the vermiwash, the germination index (GI) was calculated according to the certified methodology (the watercress assay). Within the pilot research, the certified methodology was verified and then optimized.

Key words: vermicomposting, home vermirector, vermiwash phytotoxicity, germination index

INTRODUCTION

Municipal solid waste (MSW) management has become a matter of global concern due to rapid urban population growth and the high costs associated with waste management (Marshall and Farahbakhsh 2013). Studies have

shown that biodegradable materials constitute over half of MSW (Taeporamaysamai and Ratanatamskul 2016), with their results indicating that bioconversion of MSW into soil amendments (compost) is a viable option for sustainable waste management.

In accordance with the framework waste legislation (Directive 2008/98/EC), the European Union's approach to solid waste management is based on an integrated, hierarchical system with waste prevention as the highest priority. In line with this priority, and to comply with the further requirement of the European landfill directive (2018/850/EC) to progressively reduce the amount of municipal biodegradable waste going to landfills, prevention measures and programs are expected and particularly encouraged for the biowaste category, followed by recovery options based on separate collection and biological treatment systems for biowaste that cannot be prevented (European Commission 2010; *Directive number amended by author*). Moreover, the European strategy for waste prevention generally calls for prevention actions to be taken at all geographical scales of governance, including regional and local levels (European Commission 2005). At local territorial levels, the combined option of segregating domestic biodegradable waste at the source and directly destining it to home composting may be seen as a valuable prevention action contributing to reduce the generation of household waste (Onida 2000, Cox *et al.* 2010).

Composting is one of the most environmentally friendly technologies for the management of the organic fraction of municipal solid waste (OFMSW) or biowaste, allowing its material valorisation. At industrial level, composting of OFMSW has been extensively studied and the number of treatment facilities implemented has been increasing in last years. Although less studied, home composting has been proposed as an alternative or a complimentary way to manage household OFMSW (Andersen *et al.,* 2012, Martínez-Blanco *et al.,* 2010).

Recently, home and industrial composting have been studied and compared focusing on their environmental impact, mainly energy consumption and environmental burdens (Colón *et al.,* 2010, Martínez-Blanco *et al.,* 2010, Adhikari *et al.,* 2013). Considering environmental aspects, home composting presents some potential benefits as the avoidance of collection and transportation of biowaste. However, the home composting of the OFMSW also presents some environmental concerns mainly due to the absence of gas treatment systems. In spite of the evident environmental benefits of composting, greenhouse gases (GHG) can be generated and emitted to the atmosphere during the process, thus contributing to global warming (Colón *et al.,* 2012). In fact, biowaste home composting closes the material loop directly at the source place (usually, the owned garden or land) and does not imply any external waste collection, transport, or management actions (with their related costs) nor should any residual waste be generated by the locally performed process (Onida 2000, Zurbrügg *et al.,* 2004, Adhikari *et al.,* 2010).

Home composting has great potential for the sustainable management of organic waste generated in the home, gardens and vegetable plots. The implementation of home composting in recent years has been very intense in many parts of the world (Smith and Jasim 2009, Adhikari *et al.,* 2010, Faverial and Sierra 2014). Adhikari *et al.* (2010) estimated a potential for decentralised composting systems to accommodate up to 50% of generated municipal organic waste in Europe and Canada, thus reducing costs and greenhouse gas emissions by 34–50 and 40%, respectively, as compared to standard landfill disposal. Properly managed, important economic and environmental benefits are obtained by home composting (Andersen *et al.,* 2012, Faverial and Sierra 2014, Vázquez *et al.,* 2015). The combined option of segregating domestic biodegradable waste at the source and directing it to home composting is considered a valuable preventative action which contributes to reducing the generation of household waste (Tatàno *et al.,* 2015). Individuals or family users may benefit from a reduction in the rate of service of waste management, while gaining a fertiliser material (compost) with excellent quality for gardens or vegetable plots. Councils and other entities involved will benefit from a reduction in the costs of collection and waste treatment. This is important from the economic point of view, because waste collection is becoming more common in rural areas of low population density where it is usually accompanied by a revenue deficit. This deficit is caused because the costs of waste collection in rural areas are higher than the service tax applied. From the environmental point of view, the non-necessity of collection, transportation and treatment of this waste implies a clear benefit by reducing all kinds of impacts, in addition to saving fertilisers from other sources (Vásquez and Soto 2017).

Composting using earthworms is known as vermicomposting, and it is considered by some as one of the most advanced composting techniques. The proces involves the bio-oxidation and stabilization of organic materials by the joint action of earthworms and microorganisms. Although it is the microorganisms that biochemically degrade the organic matter, earthworms are the crucial drivers of the process as they aerate and fragment the substrate, and thereby drastically increase the microbial activity (Domínguez *et al,* 1997, Arancon *et al.,* 2004, Edwards 1998, Senesi *et al.,* 2007). Earthworms can consume practically all kinds of organic matter typically that placed in a compost pile, and they can eat wastes typically equal to their own body's weight per day. The castings are rich in nitrate, phosphorus, potassium, calcium and magnesium (Misra *et al.,* 2003).

Thermophilic composting and vermicomposting are effective techniques commonly used to convert biodegradable waste into soil amendments. Thermophilic composting is a composting proces at high temperatures (>45 ^{o}C), but vermicomposting is a mesophilic (<30 ^{o}C) process that involves earthworms and associated microorganisms in decomposing and stabilising organic

materials (Lim *et al.,* 2016). Major similarities and differences between thermophilic composting and vermicomposting are summarised by Lim *et al.* (2016).

Vermicomposting as a completely environmentally friendly technology is a viable method of diverting the organic portion of waste streams, as it avoids the costs of disposal and converts beneficial waste into a value-added vermicompost (Sherman 2011). This product is nutrient rich but also contains high-quality humus, plant growth hormones, enzymes, and substances which are able to protect plants against pests and diseases (Weltzien 1989, Arancon *et al*., 2007). Also abundant presence of beneficial microorganisms has been proved in vermicompost (Pant *et al*., 2009).

Numerous studies have shown the possibility of specific bio-waste vermicomposting processes – such as vermicomposting of cattle manure and sheep bedding Cestonaro *et al.* (2017), banana stem Khatua *et al.* (2018), sewage sludge Zhao *et al.* (2018), paper cups Arumugam *et al.* (2018), manure of animal farms Lalander *et al.* (2015), pig slurry Aira *et al.* (2006), fruit and vegetables Huang *et al.* (2014) and others.

The vermicomposting technology can also be utilized for generating a bioliquid termed as vermiwash. Vermiwash is a liquid leachate collected by allowing excess water to saturate the actively vermicomposting substrate in such a way that the water washes the nutrients from the vermicast excreted by the earthworms feeding on the substrate as well as earthworm's body surface (Ismail 1997). Vermicompost can be used for the preparation of aqueous solutions commonly referred to as vermicompost extracts or teas using steeping and/or brewing (Litterick *et al.*, 2004)

It has been demonstrated that decentralized solid waste management is capable of preventing mixture and inter-contamination of wastes, reducing the costs of transportation, enhancing subsequent treatments, and resulting in the production of compost with organic waste (Zurbrugg *et al.,* 2004, Colon and Fawcett 2006). It has also been mentioned that one of the options of decentralized waste management is home composting. In addition to the traditional home composting in the garden, flat composting is slowly expanding, using vertical continuous feeding worm reactor/vermireactor (VermiHut Worm Bin). In this case it is necessary to continuously remove the leachate/vermiwash from the vermireactor. Popular articles mention the possibility to use vermiwash as a fertilizer when potting potted plants but the dosage data and the effect of vermiwash on plants are missing. The scientific literature dealing with the research of the vermiwash and its properties can not be found.

Keeping the above fact in mind, the aim of this work was to verify the applicability of the certified methodology (Watercress assay) and to determine the vermiwash phytotoxicity of home vermireactor as its basic property.

MATERIALS AND METHODS

Raw materials

The input material for composting in home vermireactor was formed of OFMSW. Household OFMSW was collected at a flat household in Brno (the Czech Republic). Composted bio-waste contained a mixture of food waste (as it was produced) and waste from maintenance of indoor plants but it did not contain any baked goods, animal residues (like bones, meat cuts or rests of meal) or faeces of domestic flat animals (guinea pig, dwarf rabbit).

Vermicomposting process

The vermicomposting process was carried out in vertical continuous feeding vermireactor (VermiHut Worm Bin). This vermireactor contains four boxes placed above each other; the capacity of each box was 15 dm^3. Only once a box has been filled, the waste was inserted into the following box. This construction allows continuous addition of biowaste and gradual removing of the compost without the need of mutual mixing. 2.5 kg of apple pomace vermicompost with earthworms *Eisenia foetida andredi* was used as an initial input material to vermicomposter. Apple pomace vermicompost and earthworms *E. andrei* were provided by Jakub Filip, Luzice u Hodonina (the Czech Republic). Bio-waste for composting was filled in the vermicomposter irregularly, in varying amounts, just as it was produced in the household. In the case of the completely filled vermicomposter box (the vermicomposter box was full at the moment of bio-waste filling), the empty box was added and then was filled with bio-waste.

The vermiwash (the leachate of composted OFMSW) was collected in the lowest part of vermireactor and subsequently it was discharged via a drain valve. As mentioned above, the vermiwash can be used as a liquid fertilizer.

Sample processing procedure

Since the certified methodology (see chapter 2.4) is used to determine the phyotoxicity of compost aquous extract, it has been simply adapted to vermiwash assay. Instead of compost aquous extracts there were prepared aquous solutions of vermiwash in concentrations 20 %, 40 %, 60 %, 80 % and 100 % (own idea). Control (zero) sample consisted just of a pure demineralized water.

Phytotoxicity assay (Watercress assay)

To assess the phytotoxicity levels of the vermiwash, the germination index (GI) was calculated according to the certified methodology by Plíva (Plíva *et al.,* 2006).

Filter papers are placed into Petri dishes of 5 cm diameter to cover the bottom of the dish. Then the paper is moistened with 1 mL (= 1 cm^3) of prepared

aquous solutions of vermiwash. Eight seeds of watercress (*Lepidium sativum L.*) are regularly distributed on the moistened filter paper. For each sample, 10 Petri dishes with 8 seeds (i.e. 80 seeds) are used. The prepared and closed Petri dishes are placed in a thermostat where the seeds germinate at 28 °C for 24 hours in the darkness (Plíva *et al.,* 2006). In addition to the test aquous solutions, a control sample with demineralized water is also placed in the thermostat.

After 24 hours, the lengths of all roots are measured. The resulting germination index, which is an indicator of toxicity, is obtained by the formula

$$GI = 100 * \frac{g_s * l_s}{g_c * l_c} [\%] \quad (1)$$

g_s germination of sample [%]
g_c germination of control [%]
l_s average length of the sample roots [mm]
l_c average length of the control roots [mm] (Plíva et al., 2006)

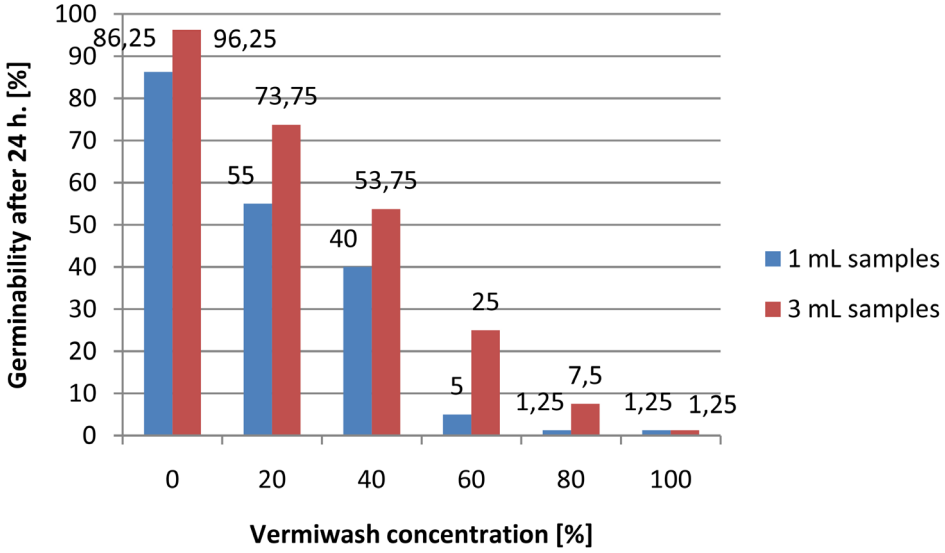
Since the diameter of used Petri dishes was 9 cm (instead of 5 cm Petri dishes asked for the certified methodology), it was compared the phytotoxicity assay using 1 mL samples with phytotoxicity assay using 3 mL samples (which is adequate to the ratio of Petri dishes dimensions).

Due to very short sample roots after 24-hours long experiment and consequent inability of germination index determination, the third experiment of phytotoxicity assay was extended to 4-day long staying in the thermostat.

RESULTS, COMMENTS AND DISCUSSION

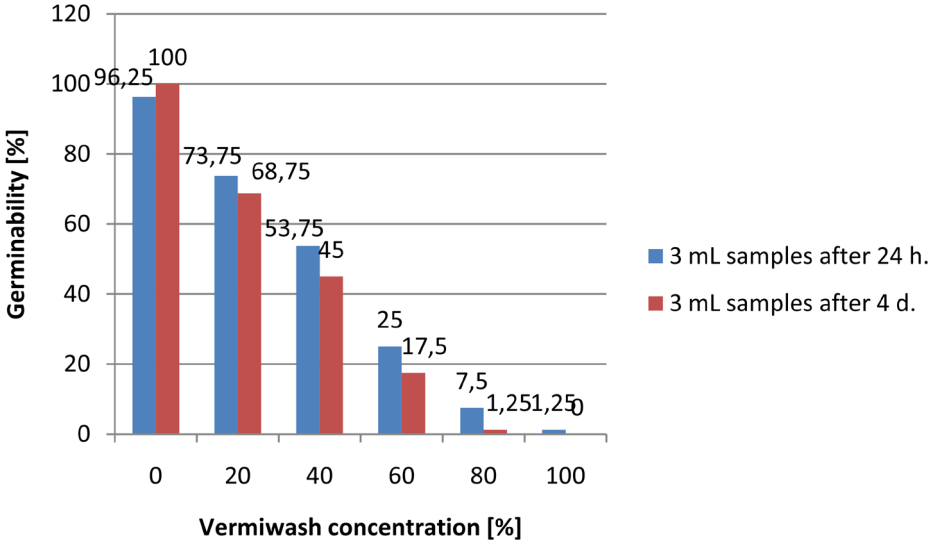
Germinability resulsts of both samples 1 mL and 3 mL after 24-hours long experiment of phytotoxicity assay are shown in Fig. 1. Due to request of verification of applicability of the cetrified methodology, it can be seen that samples of 3 mL achieve significantly higher germination. Visual evaluation of the samples during preparation also showed that the 1ml samples were too small because a part of the filter paper in the Petri dish may have remained almost dry. For these reasons, there should be used samples of 3 mL when using Petri dishes of 9 cm diameter.

Germinability results of both samples 3 mL after 24-hours and 4-days long experiment of phytotoxicity assay are shown in Fig. 2. As can be seen, in a four-day experiment, 100% of the seeds germinated in the zero sample. In contrast, the germination of all other samples was lower compared to the 24-hour experiment. Probably prolonged exposure time of the solutions to the seeds results in a more significant impact.



Source: Own elaboration

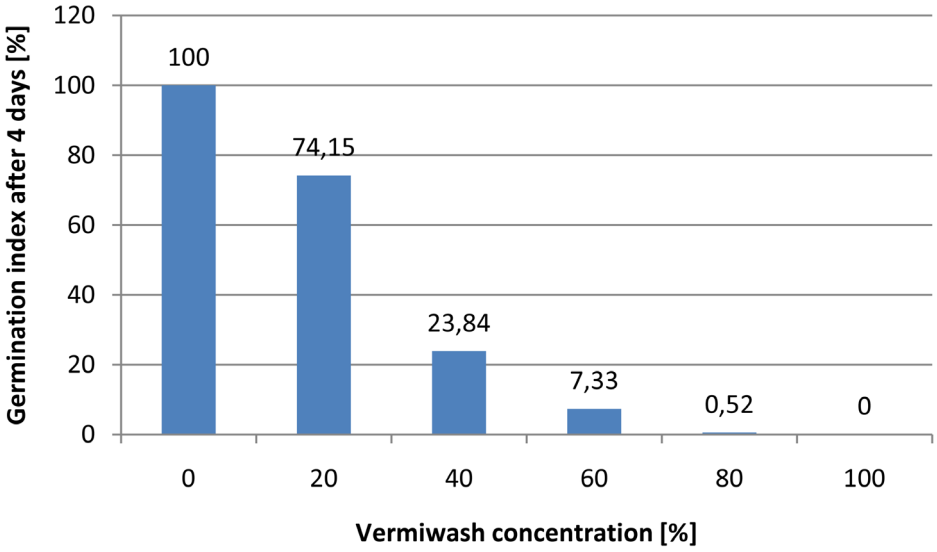
Figure 1. Germinability of 1mL and 3 mL samples after 24 hours.



Source: Own elaboration

Figure 2. Germinability of 3 mL samples after 24 hours and 4 days.

Finally, it was possible to determine the germination index just for samples of 4-days long experiment. In order to determine the germination index, the duration of the experiment must be at least 3 days because after the 24-hour experiment the plant roots were not measurable. Results are shown in Fig. 3.



Source: Own elaboration

Figure 3. Germination index of 3 mL samples after 4 days.

Germination index at values up to 50% represents unusable compost for direct application, from 60 to 80% gives the possibility of application with a certain risk of damage to sensitive plants (Plíva *et al.,* 2006). Using the same criteria for vermiwash evaluation, it can be seen that even 20 % solution of vermiwash indicates a risk of damage to sensitive plants while higher concetrations of vermiwash are phytotoxic.

CONCLUSIONS

The experiments that have been proved imply the applicability of the certified methodology for the determination of vermiwash phytotoxicity assay. However, the sample size must be adequate to the size of the Petri dish. Experiments also imply that vermiwash concentrations above 20% are phytotoxic and thus pose a significant risk to plants. Thus, when using vermiwash as a fertilizer for plants, it is necessary to dilute the vermiwash.

REFERENCES

Adhikari, B.K., Trémier, A., Barrington, S., Martinez, J., Daumoin, M. (2013). Gas emissions as influenced by home composting system configuration. J. Environ. Manage. 116, 163–171.

Adhikari, B.K., Trémier, A., Martinez, J., Barrington, S. (2010). Home and community composting for on-site treatment of urban organic waste: perspective for Europe and Canada. Waste Management. 28, 1039–1053.

Aira, M., Monroy, F., Dominguez, J. (2006). Changes in microbial biomass and microbial activity of pig slurry after the transit through the gut of the earthworm Eudrilus eugeniae (Kinberg, 1897). Biol. Fert. Soils 42, 371–376.

Andersen, J.K., Boldrin, A., Christensen, T.H., Scheutz, C. (2012). Home composting as an alternative treatment option for organic household waste in Denmark: An environmental assessment using life cycle assessment-modelling. Waste Management 32, 31–40.

Arancon, N.Q., Edwards, C.A., Bierman, P., Welch, C., Metzger, J.D. (2004). Influences of vermicomposts on field strawberries-1. Effects on growth and yields. Bioresource Technology 93 (2), 145–153.

Arancon, N.Q., Edwards, C.A., Dick, R.(2007). Vermicompost tea production and plant growth impacts. BioCycle 48, 51–52.

Arumugam, K., Renganathan, S., Babalola, O.O., Muthunarayanan, V. (2018). Investigation on paper cup waste degradation by bacterial consortium and Eudrillus eugeinea through vermicomposting. Waste Management 74, 185–193.

Cestonaro, T., de Mendonça Costa M.S.S., de Mendonça Costa,L.A., Pereira, D.C., Rozatti, M.A.T., Martins, M.F.L. (2017). Addition of cattle manure to sheep bedding allows vermicomposting process and improves vermicompost quality. Waste Management 61, 165–170.

Colón, J., Martínez-Blanco, J., Gabarrell, X., Artola, A., Sánchez, A., Rieradevall, J., Font, X., 2010. Environmental assessment of home composting. Resour. Conserv. Recycl. 54, 893–904.

Colón, J., Cadena, E., Pognani, M., Barrena, R., Sánchez, A., Font, X. (2012). Determination of the energy and environmental burdens associated with the biological treatment of source-separated Municipal Solid Wastes. Energy Environ. Sci. 5, 5731–5741.

Colon, M., Fawcett, B., 2006. Community-based household waste management: lessons learnt from EXNORA's zero waste management' scheme in two South Indian cities. Habitat International 30, 916–931.

Cox, J., Giorgi, S., Sharp, V., Strange, K., Wilson, D.C., Blakey, N., 2010. Household waste prevention – a review of evidence. Waste Manage. Res. 28, 193–219.
Directive 2008/98/EC on waste and repealing certain directives. Official Journal of the European Union, L 312/3-30, 22.11.2008.

Domínguez, J., Edwards, C.A., Subler, S. (1997). Comparison of vermicomposting and composting. BioCycle 38, 57–59.

Edwards, C.A., 1998. The use of earthworms in the breakdown and management of organic wastes. In: Edwards, C.A. (Ed.), Earthworm Ecology. CRC Press, Boca Raton, FL, USA, pp. 327–354.

European Commission, 2005. Taking Sustainable Use of Resources Forward: A Thematic Strategy on the Prevention and Recycling of Waste. COM(2005) 666 final, Brussels, Belgium.

European Commission, 2010. Communication from the Commission to the Council and the European Parliament on Future Steps in Bio-waste Management in the European Union. COM(2010) 235 final, Brussels, Belgium.

Faverial, J., Sierra, J., 2014. Home composting of household biodegradable wastes under the tropical conditions of Guadeloupe (French Antilles). J. Clean. Prod. 83, 238–244.

Huang, K., Li, F., Wei, Y., Fu, X., Chen, X. (2014). Effects of earthworms on physicochemical properties and microbial profiles during vermicomposting of fresh fruit and vegetable wastes. Bioresource Technology 170, 45-52.

Ismail, S.A. (1997) Vermicology: the biology of earthworms. Hyderabad: Orient Longman Press.

Khatua, C., Sengupta, S., Balla, V.K., Kundu, B., Chakraborti, A., Tripathi, S. (2018). Dynamics of organic matter decomposition during vermicomposting of banana stem waste using Eisenia fetida. Waste Management 79, 287–295.

Lalander, C.H., Komakech, A.J., Vinnerås, B. (2015). Vermicomposting as manure management strategy for urban small-holder animal farms – Kampala case study. Waste Management 39, 96-103.

Lim, S.L., Lee, L.H., Wu, T.Y., 2016. Sustainability of using composting and vermicomposting technologies for organic solid waste biotransformation: recent overview, greenhouse gases emissions and economic analysis. J. Clean. Prod. 111, 262-278.

Litterick, A.M., Harrier, L., Wallace, P. (2004). The role of uncomposted materials, composts, manures, and compost extracts in reducing pest and disease incidence and severity in sustainable temperate agricultural and horticultural crop production – a review. Crit Rev Plant Sci.4/23, 453–479.

Marshall, R., Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. Waste Management 33, 988-1003.

Martínez-Blanco, J., Colón, J., Gabarrell, X., Font, X., Sánchez, A., Artola, A., Rieradevall, J. (2010). The use of life cycle assessment for the comparison of biowaste composting at home and full scale. Waste Management 30, 983–994.

Misra, R.V., Roy, R.N., Hiraoka, H., 2003. On-farm Composting Methods. Food and Agriculture Organization of the United Nations (FAO), Rome, pp. 1–35.

Onida, M., 2000. Innovation in prevention of quantitative and qualitative waste production. In: Innovation in Waste Management, Proceedings of the IV European Waste Forum organized by EWC (European Waste Club), Environmental Series, vol. 23/a. CIPA Publisher, Milan, Italy, pp. 91–105.

Pant, A.P., Radovich, T.J.K., Hue, N.V. (2009). Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activity in Pak choi (Brassica rapa cv. Bonsai Chinensis group) grown under vermicompost and chemical fertilizer. J Sci Food Agric.89, 2383–2392.

Plíva, P. (2006). Zakládání, průběh a řízení kompostovacího procesu. Výzkumný ústav zemědělské techniky, Praha. ISBN 80-86884-11-2

Senesi, N., Plaza, C., Brunetti, G., Polo, A., 2007. A comparative survey of recent results on humic-like fractions in organic amendments and effects on native soil humic substances. Soil Biol. Biochem. 39, 1244–1262.

Sherman, R.L. (2011). Vermicomposting for businesses and institutions. In: Vermiculture technology. Boca Raton, FL: CRC Press; p. 391–408.

Smith, S.R., Jasim, S., 2009. Small-scale home composting of biodegradable household waste: overview of key results from a 3-year research programme in West London. Waste Management 27, 941–950.

Taeporamaysamai, O., Ratanatamskul, C. (2016). Co-composting of various organic substrates from municipal solid waste using an on-site prototype vermicomposting reactor. Int. Biodeter. Biodegr. 113, 357-366.

Tatàno, F., Pagliaro, G., Di Giovanni, P., Floriani, E., Mangani, F. (2015). Biowaste home composting: experimental process monitoring and quality control. Waste Management 38, 72–85.

Vázquez, M.A., Sen, R., Soto, M. (2015). Physico-chemical and biological characteristics of compost from decentralised composting programmes. Bioresource Technology 198, 520–532.

Vázquez, M.A., Soto, M. (2015). The efficiency of home composting programmes and compost quality. Waste Management 64, 39-50.

Weltzien, H.C. (1989) Some effects of composted organic materials on plant health. Agric. Ecosyst. Environ.27, 439–446.

Zhao, C. Wang, Yo., Wang, Yu., Wu, F., Zhang, J., Cui, R., Wang, L., Mu, H. (2018). Insights into the role of earthworms on the optimization of microbial community structure during vermicomposting of sewage sludge by PLFA analysis. Waste Management 79, 700–708.

Zurbrügg, C., Drescher, S., Patel, A., Sharatchandra, H.C. (2004). Decentralized composting of urban waste – an overview of community and private initiatives in Indian cities. Waste Management 24, 655–662.

Ing. Bohdan Stejskal, Ph.D.
bohdan.stejskal@mendelu.cz
Mendel University in Brno
Faculty of Agronomy
Department of Applied and Landscape Ecology
Zemedelska 1/1665
613 00 Brno
The Czech Republic

Received: 04.11.2019
Accepted: 20.11.2019